Second Edition

SUSTAINABLE HEALTHCARE ARCHITECTURE

ROBIN GUENTHER, FAIA, LEED AP
GAIL VITTORI, LEED Fellow

WILEY

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Cover image: Michael Rutkowski

Cover design: Courtesy of the author

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

Library of Congress Cataloging-in-Publication Data:

Guenther, Robin.
Sustainable healthcare architecture / Robin Guenther, Gail Vittori.—Second edition.
pages cm
Includes bibliographical references and index.
ISBN 978-1-118-08682-7 (hardback : alk. paper); 978-1-118-41611-2 (ebk.); 978-1-118-41865-9 (ebk.); 1. Hospital architecture—Environmental aspects. 2. Health facilities—Design and construction—Environmental aspects. 3. Sustainable architecture. I. Vittori, Gail. II. Title.
RA967.G827 2013
725'.51—dc23

2013004583

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

"Our lives are touched by those who lived centuries ago, and we hope that our lives will mean something to those who will live centuries from now. It's a great 'chain of being,' someone once told me, and I think our job is to hope, to dream and to do the best we can to hold up our small segment of that chain."

Dorothy Day

For Perry Gunther and Pliny Fisk III

CONTENTS

PART 2 ACTUALIZING THE VISION 81

THE GREEN BUILDING MOVEMENT is guided by a simple, yet revolutionary, idea: that the buildings in which we live our lives can nurture instead of harm, can restore instead of consume, and can inspire instead of constrain. The business case for green building is highly compelling, and it is a large part of the reason that we have made such great strides in the last fifteen years. But it is important for us to remember that at its core, green building is about making the world a better place for people to live. In the second edition of *Sustainable Healthcare Architecture,* Robin Guenther and Gail Vittori present their essential guide to sustainable design and environmental stewardship for the healthcare industry. The second edition builds upon the groundbreaking first volume, detailing how resilient and regenerative design is transforming the sterile, imposing facilities of the past—replacing them with buildings that are filled with daylight, connected to nature, and, above all, designed to promote health and well-being and combat climate change.

The way we design, construct, and operate buildings has a profound impact on our health and the health of our environment. For too many years, the impact has been negative, from carbon dioxide emissions and construction waste to the wanton use of energy, water, and natural resources. Often, indoor air is more polluted than the air outside and has been linked to illnesses ranging from asthma to cancer.

That's the bad news. But the positive corollary is that changing the way we build offers unprecedented opportunities to have a positive impact on human and environmental health. Green buildings consume fewer resources, generate less waste, and dramatically curb emissions. The people who live, work, learn, and heal in green buildings are healthier, happier, and more productive. And the communities we build with green homes, offices, schools, and hospitals are the foundation of a healthy, prosperous future for generations to come.

The convergence of these opportunities in the healthcare sector has brought us to a watershed moment for both the green building movement and the healthcare industry. Healthcare has a huge influence on our nation's economy and politics, and in no other sector are the human health impacts of buildings more explicit or more important. With the healthcare industry's leadership, we can dramatically advance green building throughout the marketplace, while increasing our focus on critical public and human health issues.

Meeting patient needs is a hospital's top priority. Through what some experts are now terming "healing architecture,"[1] several studies have shown that elements of green building can positively influence patient health, leading to faster healing times and shorter hospital stays. One study found that more than 60 percent of patients in rooms with high levels of indoor daylight were hospitalized for a shorter period of time than those with less daylight exposure.[2]

Compared to other building types, healthcare facilities have an especially large impact on the environment. Operating those buildings to meet patient needs consumes tremendous energy and resources; hospitals use twice as much energy per square foot as office buildings and spend nearly $3 billion each year on electricity alone.[3]

Protecting the environment is a natural and necessary extension of this mission—as this book makes clear, you can't have healthy people on a sick planet. In the last decade, healthcare has made remarkable changes in its operations, such as creating safer, "no-burn" waste management practices and eliminating the use of mercury-based products. But the fact is that the healthcare sector can—and must—do more. Climate change is a ticking clock, a threat to the very systems on which we depend for life. Transforming the design, construction, and operations of our buildings is our best chance to stop time.

The U.S. Green Building Council (USGBC) was founded in 1993 with a mission that was at once wildly ambitious and terribly urgent: to transform the building industry to sustainable practices. The origins of this mission can

1 Aripin, S. Healing Architecture: Daylight in Hospital Design. Conference on Sustainable Building, South East Asia, November 5–7, 2007. Retrieved from http://mrt.academia.edu/RafidRifaadh/Papers/711511/HEALING_ARCHITECTURE_DAYLIGHT_IN_HOSPITAL_DESIGN.

2 Choi, Joonho and Liliana Beltran. Study of the Relationship between Patients' Recover and Indoor Daylight Environment of Patient Rooms in Healthcare Facilities. Proceedings of the 2004 ISES Asia-Pacific Conference. Retrieved from http://faculty.arch.tamu.edu/lbeltran/Pubs/Choi_Beltran_AsiaPacific_2004.pdf.

be traced to the energy crisis of the early 1970s, which prompted the architectural community to focus on energy efficiency in buildings. But recognizing that sustainability is about more than energy, architect Bob Berkebile asked a question that would fundamentally change the way we think about our built environment: "Are our designs improving quality of life, health, and well-being, and the quality of the neighborhood, community, and planet?"

USGBC was conceived as a coalition comprising every sector of the building industry, working together to transform the marketplace. Guided by the passion, vision, and commitment of early leaders like Berkebile, Bill Browning, and countless others (many of whose names you will find in this book's table of contents), we developed the LEED Green Building Rating System, a holistic framework for sustainable building design, construction, and operations.

Since its launch in 2000, LEED has been the catalyst for the explosive growth of the green building movement. Currently, nearly two billion square feet of building space has been built to LEED standards, with another 6.4 billion awaiting LEED certification. Organizations ranging from rural school districts to Fortune 100 companies have embraced LEED and green building as an immediate, measurable solution to the critical challenges ahead of us. More than 1,400 healthcare facilities have already embraced LEED.

To better support the healthcare sector's transformation to sustainability, USGBC developed LEED for Healthcare. Recognizing the unique challenges of hospital buildings, LEED for Healthcare affirms that a hospital's fundamental mission is to heal—placing emphasis on issues such as increased sensitivity to chemicals and pollutants; acoustical design; and access to daylight, nature, and the outdoors. Drawing upon the work of the environmental health advocates and healthcare industry leaders chronicled in these pages, LEED for Healthcare demonstrates that meeting patient and staff needs does not preclude meeting environmental needs. Instead, the goals are complementary, so interwoven as to be inseparable.

The current interest in green building results from the coincidence of our growing awareness about climate change with an ever-more-impressive business case. But there is another, equally important reason for building green: the direct impact building design has on human health and well-being. It doesn't make the *Wall Street Journal* as often as statistics about ROI and lease rates, but the way buildings make people feel is an essential part of the story. In the case of hospitals, we have ample evidence that design, construction, and operations are key determinants of patient health and staff well-being and productivity. Embracing green building is not just an opportunity to do what's right for the environment; it is also an opportunity for the healthcare industry to help us broaden and refine the definitions of green building to include human health and vitality.

In fact, the opportunities are endless. Sustainable design is bridging the traditional boundaries of building type, linking our homes and our schools and our hospitals with the common language of green building. By articulating green building in the context of health, the healthcare industry can help us to define the architecture of the twenty-first century. Together, the green building movement and the healthcare industry can enter a new era, one that is connected to the global imperatives of climate change, global toxification, freshwater shortages, and resource depletion—and one that recognizes how these imperatives are interconnected.

So how do we get there? In the end, green building comes down to people. Every green building, every LEED rating system, every new technology, happens because a passionate, committed person makes it happen. We see it in the projects and people described in this book, and we see it in the leadership of Robin Guenther and Gail Vittori. It has been my great privilege to know and work with both Robin and Gail for many years and to be part of a movement that has benefited so greatly from their vision. With this book, Robin and Gail show us how critical our green building mission is to the future of human health and secure a lasting legacy that will continue to challenge and focus the green building movement, the healthcare industry, and the world for years to come.

RICK FEDRIZZI
President, CEO, and Founding Chairman,
U.S. Green Building Council
Washington, D.C.

3 Choi, Joonho and Liliana Beltran. Study of the Relationship between Patients' Recover and Indoor Daylight Environment of Patient Rooms in Healthcare Facilities. Proceedings of the 2004 ISES Asia-Pacific Conference. Retrieved from http://faculty.arch.tamu.edu/lbeltran/Pubs/Choi_Beltran_AsiaPacific_2004.pdf.

ACKNOWLEDGMENTS

SINCE BEGINNING THE FIRST EDITION of this book in early 2005, we have shared this journey with so many others. In 2010, Stephen Verderber published *Innovations in Healthcare Architecture*, citing our first edition as a major influence. This second edition of our book owes him a similar debt of gratitude—we are incredibly grateful for both his cogent thinking and intelligent framing of ecological design. Likewise, Thomas Fisher's writing on designing to avoid disaster is a critical and timely critique of building design. Ironically, it was Hurricane Katrina that catalyzed Stephen's idea set; the 2011 Fukushima nuclear power plant disaster that catalyzed Thomas Fisher's; we can describe the recent extreme drought in Texas and Hurricane Sandy as having a similar impact on us. We live in strange and interesting times, when weather events define both our psyche and our approach to scholarship.

This edition would not have come to completion without the amazing skills of our team—Patrick J. Roche, Himadri Sinha, Lindsay Franta, and Michelle DeForrest—who worked with the case study teams and tracked the images, and particularly Patrick, who designed the graphics and icons. Breeze Glazer, Perkins+Will, took the lead in organizing our updated research on the business case and researched a number of case studies. Special thanks to an impromptu focus group of our colleagues at Perkins+Will New York, who reviewed the drafts of the Global Survey projects and offered sage observations and advice. Blair McCarry, Perkins+Will, coached us through the metric conversions. Matt Kania and John Cotter assisted with organizing the maps. Marc Sansom, from the International Academy of Design and Health, introduced us to a number of the project teams. And thanks again to John Czarnecki, formerly with Wiley, who set us on this journey by posing the simple question about writing this book, and to Kathryn Bourgoine and Danielle Giordano, who picked up where he left off and gracefully and patiently stewarded us through this process. We also acknowledge the contributions of Maya Sheppard and Dylan Siegler on the first edition, whose work carries forward in this second edition.

We owe special thanks to the U.S. Green Building Council: Rick Fedrizzi, who generously offered once again to author our Foreword; Lonny Blumenthal, Mira Panek, and Chris Pyke, who assisted with accessing LEED data. Romilly Madew, from the Green Building Council of Australia, provided information on Greenstar for Health. Our essayists—many of them authors in their own right who have influenced our professional development—inspired us through their collective contributions (they are listed individually in the contributor list). We continue to marvel at our first edition essayists' wisdom and foresight: we hope the excerpts we have retained in this edition inspire many of our readers to seek out their work.

There are a few special individuals in our journey that deserve mention, including Jamie Harvie for his inspiring work on the Commons, Janet Brown for her enthusiasm for greening healthcare, and some of our other colleagues from the Green Guide for Health Care and LEED for Healthcare work, including Steve Guttmann, Jean Hansen, Adele Houghton, Tom Lent, Clark Reed, Kim Shinn, Jerry Smith, Scott Slotterback, and Walt Vernon—who are tireless in pushing the boundaries.

U.S. healthcare systems, collectively, are doing amazing work around sustainable design and operation. It was difficult to select a representative group! For their leadership and inspiration (as well as their thoughtful graphics and work products), we thank Sonia Roschnik (NHS); John Messervy and Hubert Murray (Partners HealthCare); Richard Beam and Geoffrey Glass (Providence Health & Services); Jeff Rich, Janelle Roghair, Tom Thompson, Corey Zarecki (Gundersen Health System) with Lin Hill (Practice Greenhealth); and John Kouletsis, Jeff Keyak, and Susan Saito (Kaiser Permanente).

The fifty-five case study teams, collectively, are actualizing extraordinary and innovative healthcare projects—breaking new ground every day in the service of a socially just and ecologically informed vision of healthcare. Over eighteen months, they tolerated our multiple requests for information, reviewed drafts of text, and assisted us while continuing to advance the industry. Teams include: Julian Weyer, CF Moller (Akershus); Sheri Besford, BDP (All Ukranian Health); Denis Bouvier, groupe-6 (Arras Hospital); Camila Morley, David Morley Architects (Bluestone Unit);

Michael Murphy and Holly Jacobson, MASS Design Group (Butaro); Phil Risner and Alan Bell, Dell Children's (Seton Family of Hospitals); Henk deJong, Pat Quintelier, deJong Gortemaker Algra (Deventer); Holly Mansergh, Feilden Clegg Bradley (Dyson Centre); Alejandro Branger, Jason Flores, Breeze Glazer, Rick Hintz, George Miu, Deborah Rivers, Jessica Stebbins, Peter Syrett, Perkins+Will (Discovery, Embassy, Hospital San Vincente de Paul, Lucile Packard, Kenya Wellness Center, Spaulding Rehabilitation); Raymond Pan, HMC Architects (First People's Shunde); Sarah Crouch and Andy Marolt, AECOM (Gundersen LaCrosse); Daria Pahhota, BIG-Bjarke Ingels Group and Poul Henning Hansen, Moe & Brodsgaard (Helsingør); Sunand Prasad and Sarah Drake, Penoyre & Prasad (Jubilee Gardens, Guys Tower); John Kouletsis and Susan Saito, Kaiser Permanente, Michael Bardin, Perkins+Will and Walt Vernon, MNLB, Felicia Borkovi and Agnessa Todorova, Aditazz, Bill Scrantom, Arup (Kaiser Permanente SHBI); Jerry Ong Chin-Po, CPG (Khoo Teck Puat); Tim Dudte and Rick Wilson, Health Facilities Group and Robin Sweet, KCMH (Kiowa County); Sandeep Shikre, SSA Architects and Kath Williams, Kath Williams Associates (Kohinoor); Carl Yost, Sonya Poland, and Daniel Skiffington, NBBJ (MGH Lunder Building and Seattle Children's Bellevue); Arnold Burger, SEED Architects and Alex Jansen, Deerns (Martini Hospital); Ann F. Clark, Ann Clark Architects (Mirebalais); Mark Gage, Llewelyn Davies Yeang (Mittal Children's); Ray Pradinuk and Jonathan Wilson, Stantec (Nanaimo and New South West Acute); Veronika Sundberg and Maria Nordberg, Skanska (New Karolinska Solna); Jerry Ong Chin-Po, CPG and Mara Baum, HOK (Ng Teng Fong); Clark Brockman, Lisa Petterson, Kristy Edmark, and Paul Jeffreys, SERA Architects (Old Town Recovery Center); Kyle Andersen, GBD Architects (OHSU Center for Health and Healing); Erica Hildebrand, Mahlum Architects (Peace Island Health); Hans Nickl and Christine Nickl-Weller, Nickl & Partner (Pediatric and Cardiac Center Innsbruck); Richard Kroeker, Piskwepaq Design (Pictou Landing); Andrew McKeown and Samantha Grant, Avanti Architects (Portadown Health); Lauren Dando, Farrow Partnership (Protea Health); Richard Beam, Providence (Providence Newberg); Geoffrey Glass and Keith Edgerton (Providence St. Peter); Ines Vischer, REHAB Basel (REHAB Basel); Irene Cassinello, Estudio Lamela Arquitectos (Reina Sofia Alzheimer); Mara Baum, Chuck Siconolfi, and Patsy Trine, HOK (Rhine Ordinance Barracks, St. Barts/Royal London, Ng Teng Fong, Eskenazi Health); Sheree Proposch, Bates Smart and Keith Davis, Norman Disney and Young (Royal Children's); Laura Candelpergher, Tamassociati (Salam Centre); Francesc Pernas and Roger Pernas, CASA Sólo Arquitectos (Santa Lucia University Hospital); Sean Stanwick, Farrow Partnership and Breeze Glazer, Perkins+Will (St. Mary's Sechelt); Lee Brei and Jeff Grinzel, Swedish Issaquah and Phil Giuntoli, Collins Woerman (Swedish Issaquah); Punit Jain and Danielle Forsyth, Cannon Design (Tata Cancer Centre); Jess Field, Field Architecture (Ubuntu Centre); Tyler Krehlik, Stantec/Anshen & Allen (UCSF Mission Bay); Rhiannon Sutton, Henley Halebrown Rorrison (Waldron Health); Erika Trabucco, FARE Studio (CBF Women's Health); Mike Nightingale, Natalie Fisher, and Lindsay Gibbon, Nightingale Associates (Ysbyty Aneurin Bevan).

The early genesis of this work was made possible through the generosity of Jenny Russell of the Merck Family Fund, Diane Ives of the Kendeda Fund, Gary Cohen at Health Care Without Harm, and Bill Walsh of the Healthy Building Network. For supporting us throughout this remarkable journey, tolerating our absences, and continuing to deliver work on time, we owe thanks to the staffs of Perkins+Will New York and the Center for Maximum Potential Building Systems and their Board of Directors.

And most importantly, thank you to Perry Gunther and Pliny Fisk III, who once again experienced what it means to have life partners buried in books (this time for even longer than before) with a shared aspiration that all of this is contributing to healthcare's transformation. Perry, thank you for your inspiring photos and good spirit through a whirlwind tour of European hospitals. Pliny, thank you for your relentless encouragement to learn from the edge. A special thanks to our parents, who instilled in us a sense of purpose and possibility; Robert Guenther, Eleanor Guenther Wells; Francis Charles Vittori and Doreen Dorothy Vittori. During our journey toward this edition, our first grandchild arrived to remind us of "the great chain of being"—Mela, the first of a new generation that will inherit the consequences of our collective actions. And finally, thank you all for your love, support, and encouragement through a seemingly endless process; and thank you to our children, Jyllian, Nicole, Ariel, Carson, Adam, and Noah, whom we know understand that this crazy life we lead is, after all, dedicated to their future. Imagine if we just tended the garden!

KEY SUSTAINABILITY INDICATORS

WHAT MAKES A BUILDING GREEN? Sustainable Healthcare Architecture defines thirty-one key sustainability indicators organized in six categories to measure performance: site planning; form + facade; water; energy; materials + construction practices; community. While not exhaustive, these indicators address a range of performance-based strategies that align with resilient, regenerative, and healthy buildings. Definitions of indicators are below, each with a unique icon. For some, specific benchmark performance thresholds establish a basis for recognition. For example, Low-EUI is highlighted if the project's modeled or actual energy use intensity is ≤120 kBtu/sf/yr (335 kWh/sm/yr). For others, multiple project-specific qualitative strategies aggregate to qualify for recognition. Each case study includes the collection of icons that characterize its sustainability profile; 21 of these indicators are compared on the infographic that follows.

Site Planning

Connection to nature

The building design prioritizes views of nature, incorporates biophilic design elements or therapeutic landscape, with the express intent of connecting building occupants to the natural world to promote healing

Habitat restoration

The landscape design contains specific elements that foster natural habitat restoration; restoration of native landscape species, natural hydrology, enhancement of wildlife corridors or specific restoration of degraded ecosystem services

Innovative stormwater management

Stormwater runoff is mitigated through absorptive site 'green infrastructure' elements such as swales, permeable surfaces and catchment systems

Brownfield site

A site whose use has been compromised by the presence of a hazardous substance or pollutant, and that, through remediation, can be safely redeveloped with appropriate cleanup of contaminants

Transit access

Provision of on- or near-site transit stop, extension of mass transit system or shuttle systems that connect building occupants to systems that offer alternative transportation options to single-occupancy vehicles

Innovative parking

Includes alternative to surface paved parking lots; permeable paving, significantly reduced parking quantity, structured/tuck-under parking are all examples of innovative parking solutions. Projects that have no additional parking qualify

Form and Facade

Climatic/bioregional design

Building form, orientation and construction designed to collect, store, and distribute solar energy and daylight; design that highlights the unique ecology of the bioregion, emphasizes local knowledge, customs, and solutions

Narrow floor plate

Planning that prioritizes access to light and air through either narrow building footprint (i.e., less than 78 feet (24 meters)) or larger floorplates that introduce interior courtyard(s) to provide an increased number of occupied spaces with daylight and views

Energy Responsive Facade

Envelope and fenestration strategies that modulate thermal performance through facade-specific exterior or building-integrated shading devices and high performance glazing, double-skin construction, or building-integrated photovoltaic facade systems

Green Roof

A vegetated roof using intensive or extensive planting methods to provide habitat, sound attenuation, thermal performance, roof longevity, and a visually stimulating roofscape

Water

Water Use Reduction

Reduction of potable water use resulting from the use of low flow indoor plumbing fixtures, water-conserving landscapes and irrigation equipment, and water-recirculating mechanical equipment

Rainwater Harvesting

The collection of rainwater from roofs, walls, and hardscapes in tanks or water bodies that reduces stormwater runoff and can be reused, with appropriate filtration, for potable and non-potable uses

Reclaimed Water Reuse

Collected condensate or other gray or black wastewater that is distributed for reuse after secondary or tertiary treatment, or utilization of large municipal-scale “purple pipe” systems; in this assessment, irrigation as a singular reuse strategy does not qualify.

Onsite Wastewater Treatment

The onsite treatment of gray- or blackwater using biological or chemical methods that results in water quality suitable for potable or nonpotable reuse, or to enable safe discharge into aquatic ecosystems

Energy

Low Energy Use Intensity (EUI)

Low EUI hospitals are defined as those with energy demand ≤120 kBtu/sf/yr (335 kWh/sm/yr); low EUI ambulatory facilities with energy demand ≤80 kBtu/sf/yr (252 kBtu/sf/yr), inclusive of plug load

Innovative Source Energy Systems

Innovative source energy systems include ground-coupled thermal energy systems, combined heat and power (CHP), tri-gen, fuel cell, or biomass- or landfill gas–fired condensing boilers and/or heat recovery chillers

Innovative Energy Distribution Systems

Innovative ventilation systems include displacement, underfloor air, low-velocity fan-wall technology, and mixed-mode systems; innovative conditioning systems include passive strategies such as thermal mass (i.e., night flush cooling systems) and thermal labyrinths; active strategies such as chilled beams and radiant/hydronic distribution systems

Natural Ventilation

Projects may incorporate mixed-mode ventilation systems or rely on natural ventilation in all or part of the program area. The presence of operable windows alone does not meet this intent; operable windows must be part of a natural ventilation strategy

Onsite Renewable Energy Systems

Inclusion of onsite renewable systems such as wind turbines, solar, thermal, or photovoltaics (PV) that directly meet energy needs or are grid-connected to offset fossil fuel use; biomass or landfill gas–fired boiler/turbine or fuel cell systems, if located onsite, are also included

Heat Recovery

Projects that incorporate heat recovery technologies to utilize waste heat from plant elements or building exhaust streams

Occupant Control

Thermal, lighting, and window blind controls that can be accessed and used by occupants of single- and multi-occupant spaces

Energy Display

Inclusion of public display for energy performance or integration of building performance with occupant behaviors

Materials + Construction Practices

Low Embodied Energy Materials

Encompasses local and natural materials that reduce extraction and transportation impacts, indigenous or minimally processed materials

Healthy Materials

Construction and interior finish materials and furnishings manufactured without added carcinogens, mutagens, teratogens, reproductive or other persistent bioaccumulative toxicants, and are protective of human health through the life cycle

Prefabrication/Modularity/Adaptability

Projects that include on- or offsite prefabrication of systems and building components, focus on modular components to decrease waste, and buildings that focus on long-term programmatic adaptability to completely different uses

Recycled Content Material

Materials and products manufactured with pre- or postconsumer recycled content

Acoustics

Sound attenuation strategies that locate and orient patient care and staff work areas to minimize externally and mechanically generated noise, and that employ products, materials, and design strategies that limit noise and diminish sound transmission

Safe Construction Practices

Adherence to protocols implemented on the construction site that are protective of worker health and safety, and of the broader public health, including use of low- and non-emitting construction equipment, noise reduction, and proper use of personal protection equipment

Community

Civic Function

Provide community benefit including free and reduced-fee patient services, space for community meetings, new community-based economic development and employment opportunities; program uses beyond healthcare services such as retail, transit stations, health clubs, daycare, schools, or libraries that foster community connectivity

Resilience

Incorporate explicit provisions for passive survivability and/or resilience in the face of health pandemics or extreme weather events; strategies include dedicated pandemic management facilities, "safe haven" provisions, locating critical infrastructure above floodplains, onsite renewable energy infrastructure for disaster management

Food Production

Onsite food production located on rooftops, in greenhouses, or on land used by the facility's food services department for patient, staff, and visitor meal preparation

INFOGRAPHIC '13

The Sustainable Healthcare Architecture (SHA) Infographic '13 aggregates twenty-one of the thirty-one key sustainability indicators for the fifty-five case studies in the book, color-coded by category. On the individual project scale, each "wedge" serves as an at-a-glance summary of its indicators, and the circle provides an opportunity to compare projects. The fifty-five case studies, which vary in scale, typology, and location, were each selected based upon a demonstrated level of innovation that sets them apart from the general field of sustainable healthcare.

On the aggregate scale, the intensity of implementation, as represented by the circular pattern of highlighted cells associated with a specific sustainability indicator, is a representation of cumulative achievement across the global sustainable healthcare marketplace—for the fifty-five case studies, what strategies, for example, are widely implemented (such as potable water reduction) and which are only sparsely implemented (such as on-site reclaimed water reuse). This "window" into the state of the marketplace is a powerful indicator of the effectiveness of public and institutional policy and practice. It also serves as a basis to gauge the maturity of market uptake along the innovation cycle, differentiating strategies employed by innovators and early adopters from those by early and late majorities.

The SHA Infographic '13 is an invaluable decision support tool to guide bases of design in sustainable healthcare projects around the world; over time, updates will provide a visual tracking of the evolution of key sustainability indicators and reveal market trends associated with each metric.

CASE STUDY KEY

Chapter 5

1 Dell Children's Medical Center of Central Texas
2 OHSU Center for Health and Healing
3 Peace Island Medical Center
4 Sherman Hospital
5 Kiowa County Memorial Hospital
6 Kohinoor Hospital
7 The Dyson Centre for Neonatal Care, Royal United Hospital,
8 St. Mary's Hospital Sechelt Addition
9 New Karolinska Solna University Hospital
10 UCSF Medical Center at Mission Bay
11 Lucile Packard Children's Hospital at Stanford

Chapter 7

12 Mittal Children's Medical Centre
13 The Bluestone Unit, Craigavon Area Hospital
14 New South West Acute Hospital
15 The Lunder Building, Massachusetts General Hospital
16 Spaulding Rehabilitation Hospital
17 Providence Newberg Medical Center
18 Providence St. Peter Hospital
19 Gundersen LaCrosse Hospital Addition
20 Kaiser Small Hospital Big Idea Competition

Chapter 8

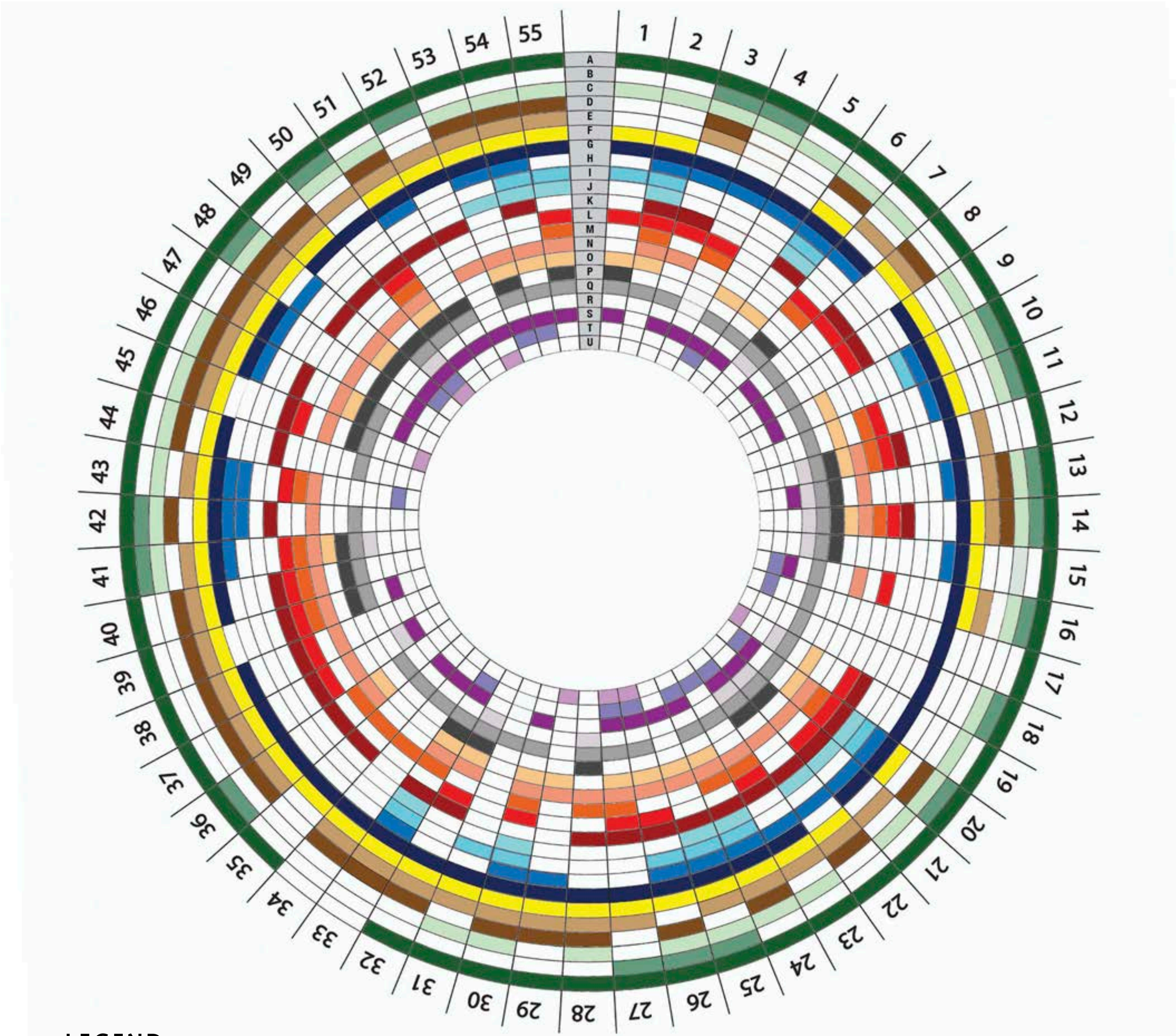
21 Akershus University Hospital
22 Butaro Hospital
23 Deventer Ziekenhuis
24 First People's Hospital
25 Hospital Universitario San Vincente de Paul
26 Khoo Teck Puat Hospital
27 Portadown Health and Care Centre
28 REHAB Centre for Spinal Cord and Brain Injuries
29 Reina Sofia Foundation Alzheimer Centre
30 The new Royal Children's Hospital
31 Rush University Medical Center
32 Salam Centre for Cardiac Surgery
33 Santa Lucia University General Hospital
34 St. Bartholomew's and The Royal London Hospitals
35 Swedish Medical Center
36 Ysbyty Aneurin Bevan (Aneurin Bevan Hospital)

Chapter 9

37 Martini Hospital
38 Arras Hospital Centre
39 Pediatric and Cardiac Center of the Innsbruck University Clinic
40 Helsingør Psychiatric Clinic
41 Rhine Ordinance Barracks Medical Center Replacement
42 Ng Teng Fong General Hospital and Jurong Community Hospital
43 Nanaimo Regional General Hospital Emergency Department
44 Seattle Children's Bellevue Clinic
45 Pictou Landing Mi'Kmaq Community Health Centre
46 Kenya Women's and Children's Wellness Centre
47 Tata Medical Centre Cancer Hospital
48 CBF [Centre pour le Bien-etre des Femmes] Women's Health Centre

Chapter 10

49 The Ubuntu Centre
50 Jubilee Gardens Health Centre and Library
51 Old Town Recovery Center
52 Waldron Health Centre
53 Mirebalais National Teaching Hospital
54 Embassy Medical Center
55 All Ukrainian Health Protection Centre for Mothers and Children



LEGEND

A – Connection to nature/biophilia
B – Habitat restoration
C – Innovative stormwater management

D – Climatic/bioregional design
E – Narrow floor plate
F – Energy-responsive facade

G – Water use reduction
H – Rainwater harvesting
I – Reclaimed water reuse
J – Onsite wastewater treatment

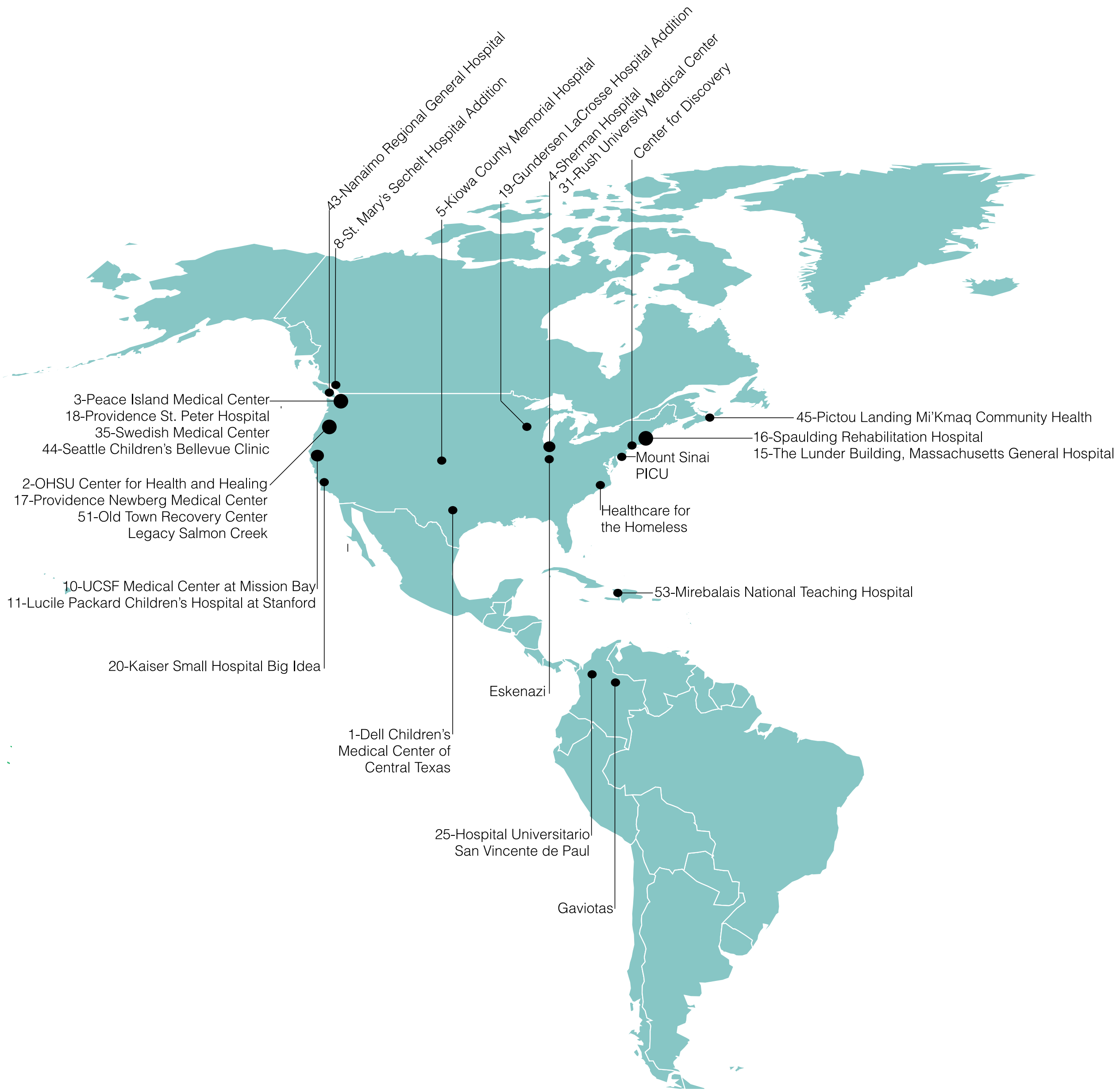
K – Low energy use index (EUI)
L – Innovative source energy
M – Innovative energy distribution
N – Natural ventilation
O – Onsite renewable energy

P – Low embodied energy materials
Q – Healthy materials
R – Prefabrication/modularity/adaptability

S – Civic function
T – Resilience
U – Food production

LOCATION MAPS

The 55 case studies in the book are located on a series of location, biome and climate zone maps.



LOCATION MAPS

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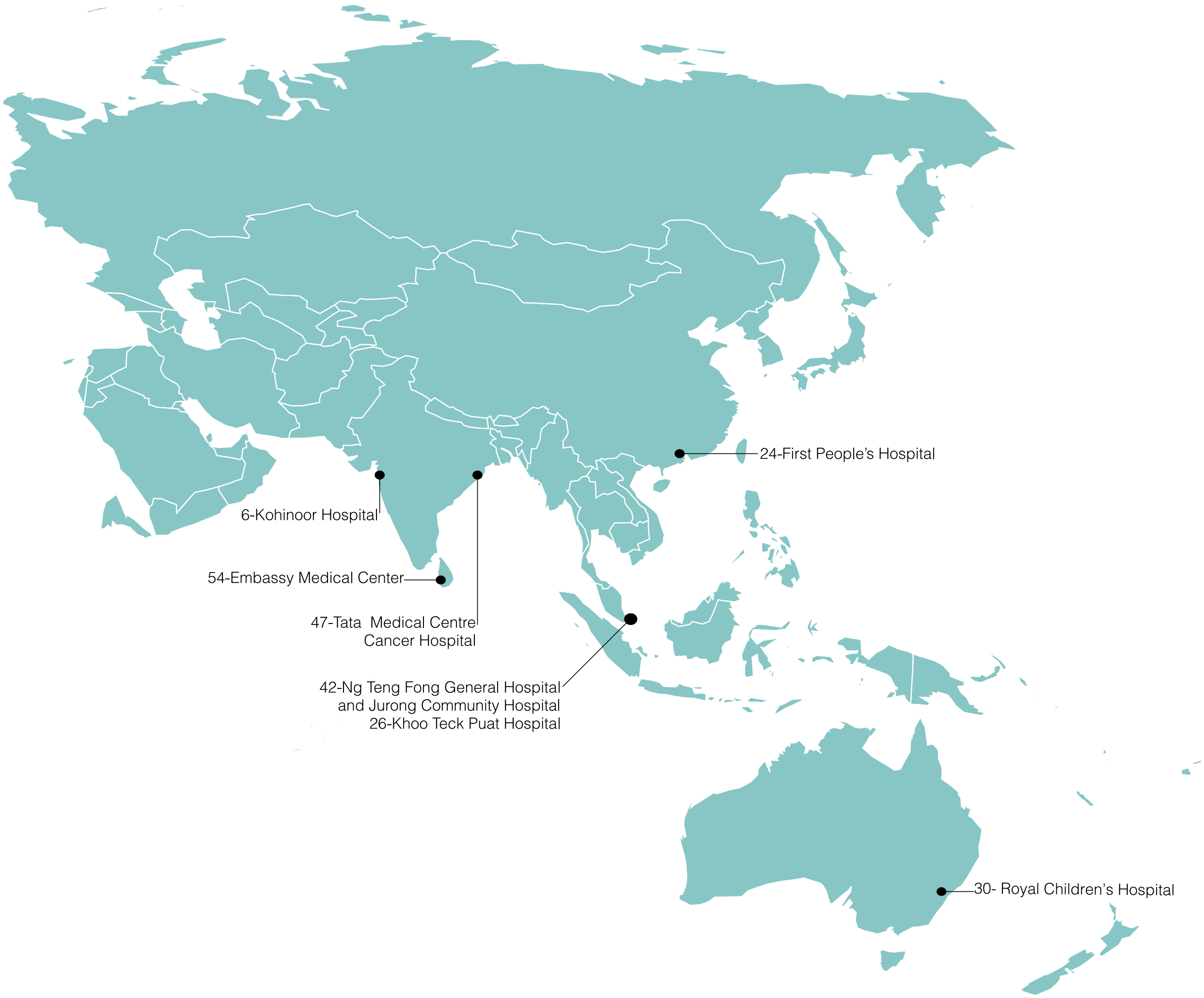
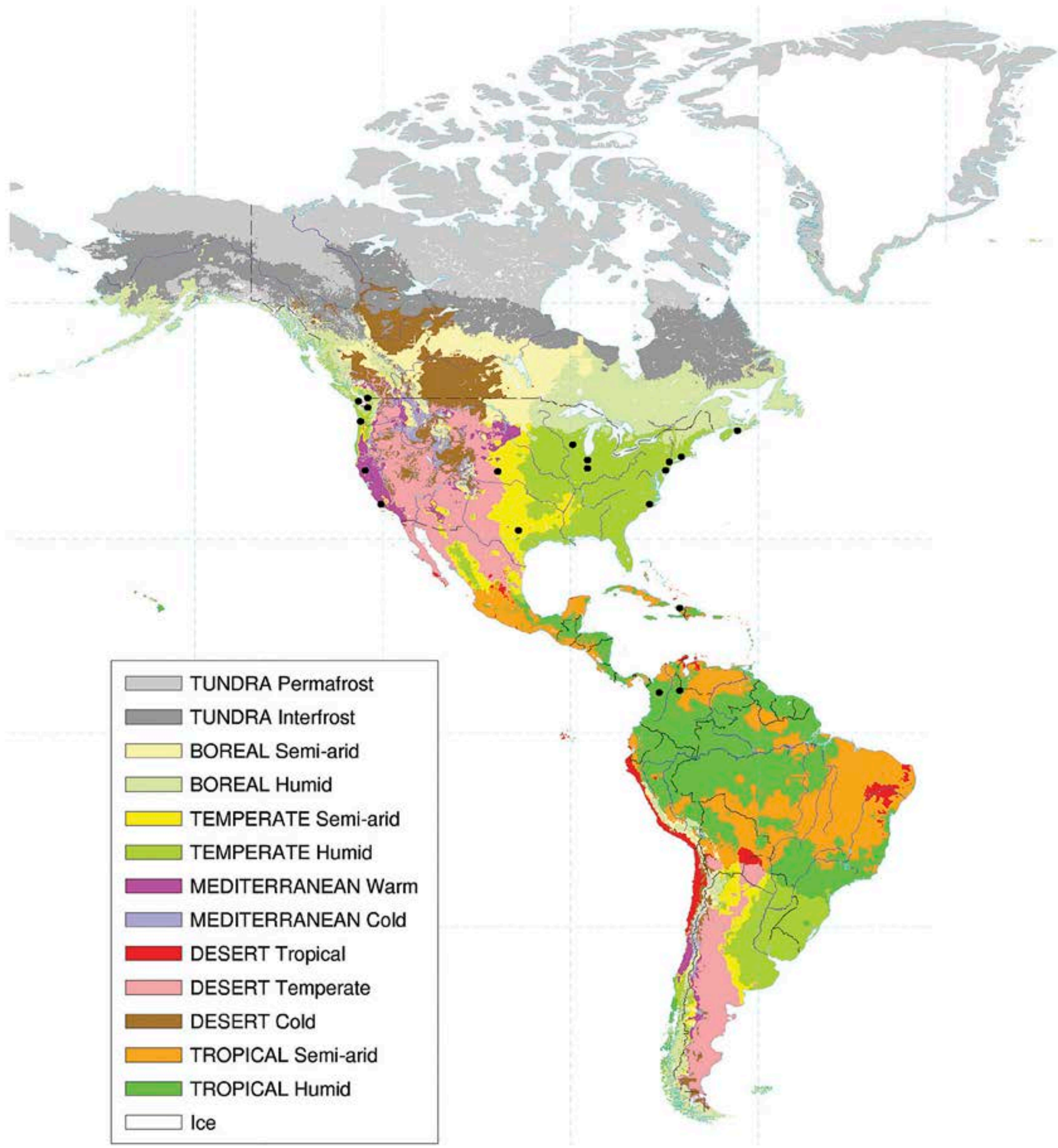
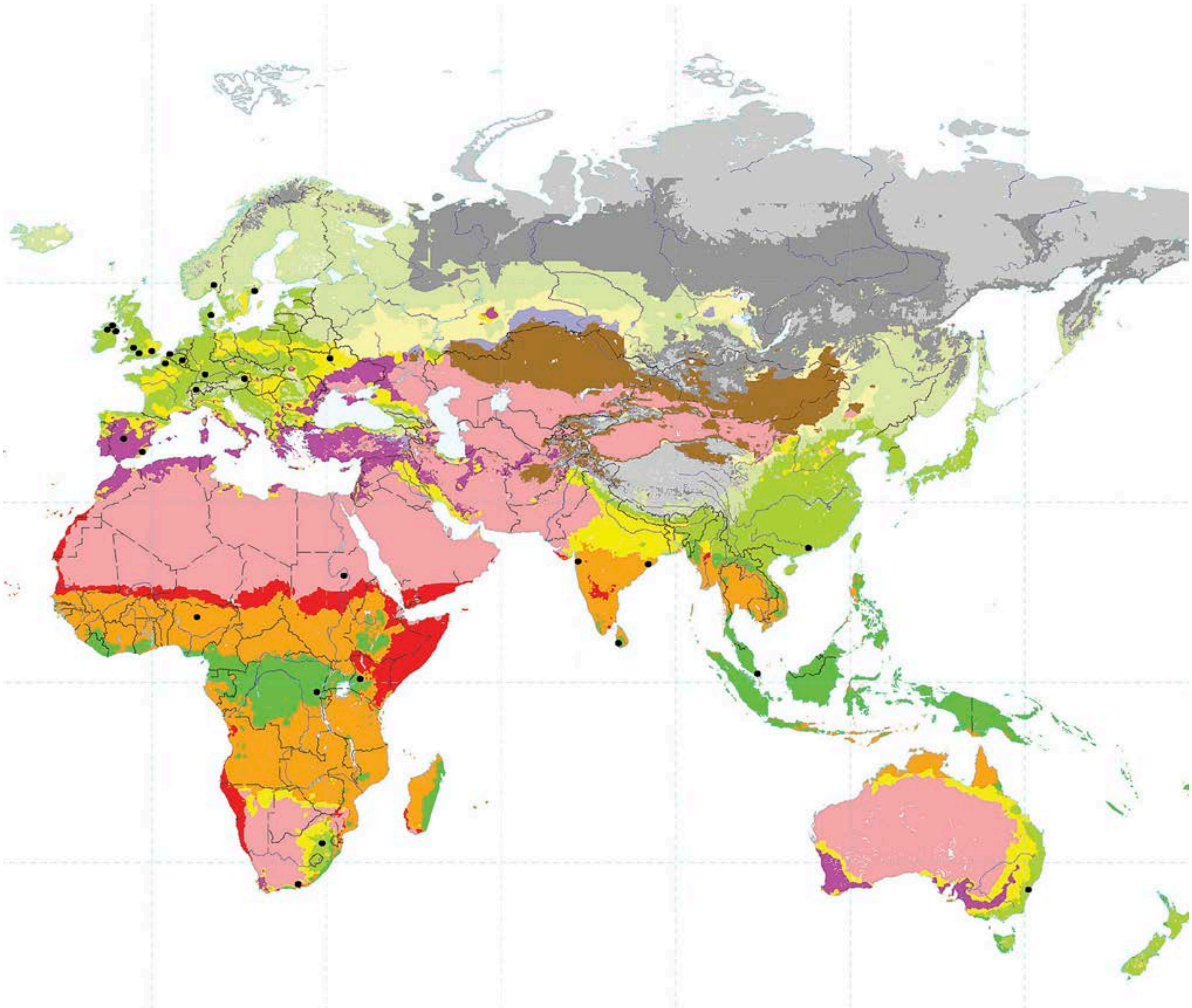


BIOME MAPS

Biomes are distinctive regions around the world that share similar patterns of flora and fauna; they also correlate with similar climate and soil types. Biomes provide a nature-based context to understand the relationship between building, site, and the stock of regional indigenous materials. Moreover, given their similar patterns, biomes provide a basis for robust global information sharing about appropriate approaches to climatic design strategies and material use.

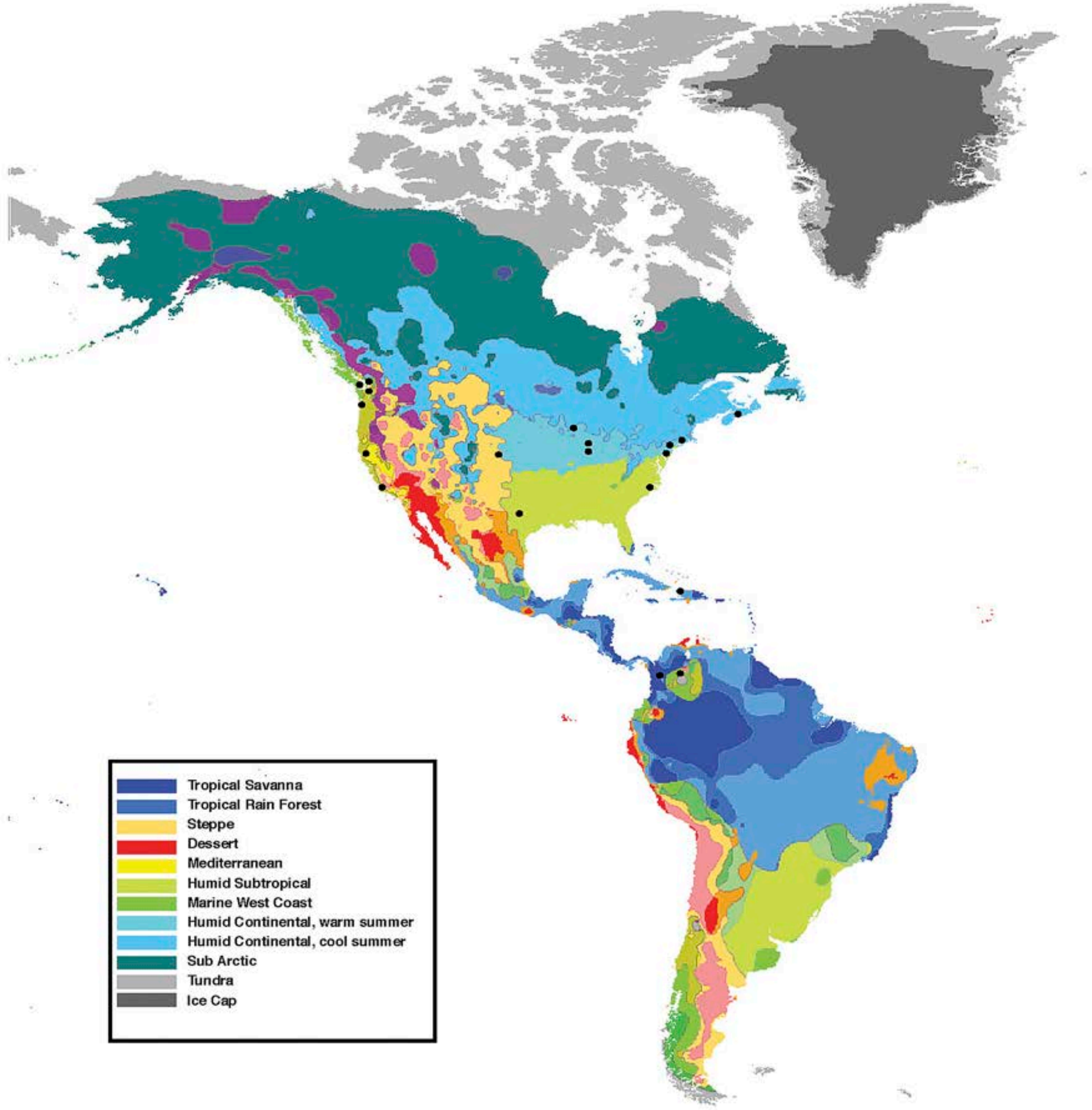


BIOME MAPS

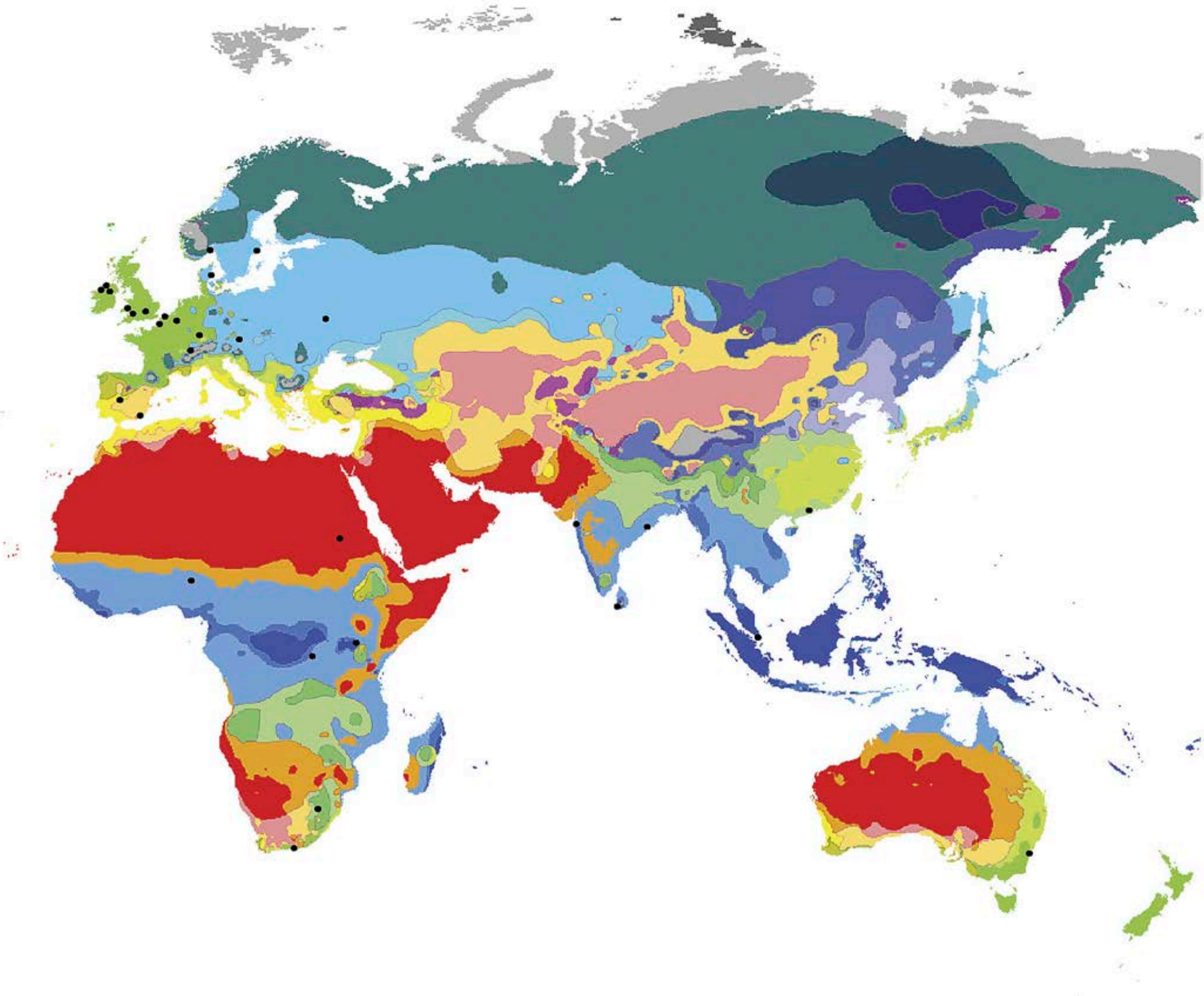


CLIMATE ZONE MAPS

Climate zones represent distinctive areas around the world, derived from the seminal climate classification work of the Russian German climatologist Wladimir Koppen initially released in 1884. Climate zones reflect native vegetation patterns, considered to be the best indicator of climate, along with annual and monthly temperatures and precipitation, and seasonal precipitation patterns. Recognizing the dynamic nature of these patterns, climatologists revise climate zone boundaries to reflect a changing climate.



CLIMATE ZONE MAPS



PART 1
CONTEXT

CHAPTER 1

DESIGN AND STEWARDSHIP

> The standard for ecological design is neither efficiency nor productivity but health, beginning with that of the soil and extending upward through plants, animals, and people. It is impossible to impair health at any level without affecting it at other levels. The etymology of the word "health" reveals its connection to other words such as healing, wholeness, and holy. Ecological design is an art by which we aim to restore and maintain the wholeness of the entire fabric of life increasingly fragmented by specialization, scientific reductionism, and bureaucratic division.
>
> David Orr

INTRODUCTION

What does stewardship mean, and what is the role of the design disciplines in furthering and developing this idea? The stewardship model of responsibility has its foundation in theological writings on the relationship between humans and the natural world—hence its prominent position in many of the mission statements of faith-based healthcare organizations. At many such organizations, stewardship of God-given natural resources has been reinterpreted in the modern era to include promotion of human health. Such an expanded view leaves the design industries a correspondingly broad role in terms of stewardship.

The concept of resource stewardship is pivotal in sustainable, or "green," design as it is currently defined and practiced throughout the design disciplines. The design of hospital buildings (as cultural artifacts) can be viewed as an important component of the larger practice of the design of habitats for humans—in this case, healing habitats. For the last half-century, however, the design of hospital buildings has been remarkably independent of the broader trends in architectural design. As a particular typology, healthcare architecture has evolved in a world apart, responding, for the most part, to industry trends in technology and ever-more complex life-safety regulations. Until recently, healthcare owners, architects, and engineers have been unaware of the impact that sustainable design concerns have had on the larger design industry.

Environmental stewardship is a defining principle of sustainable architecture, as the essayist and commentators in this chapter eloquently state. Architect Bill Valentine, FAIA, postulates below that "less is better" and challenges design professionals to reconsider scale and deliver better, healthier buildings using less. Designer and educator Pliny Fisk III presents an expanded definition of lifecycle design, one that postulates a "new ecology of mind," which joins together architecture and neuroscience. In his essay, designer Jason F. McLennan challenges design to redefine itself as no less than "living" for our buildings, our health, and the planet. Finally, architect Bob Berkebile, FAIA, challenges us to imagine a "restorative" and "regenerative" future, a concept further explored in the final chapter.

The sustainable design movement, through such leaders as Paul Hawken, Amory Lovins, and L. Hunter Lovins, has given us new lenses for viewing the economy: Natural Capitalism: Creating the Next Industrial Revolution (2000) and The Ecology of Commerce (1993). The parallel ideologies of "clean production" and William McDonough and Michael Braungart's "cradle to cradle" are having significant impacts on building materials science, from revolutions in the petrochemical components of our material economy to end-of-life ideas such as "waste equals food." Science writer Janine Benyus, in *Biomimicry: Innovation Inspired by Nature* (1997), points to a future when science will look to nature for inspiration and technology—and an impressive roster of corporations and designers who have adopted biomimicry principles in their research and applied them to products is testament to that future becoming reality (Biomimicry 3.8, 2012). Just outside the silo that defines the current practice of healthcare architecture, notions of planetary stewardship linked to health are fundamentally redefining the design and production of the built environment.

THE CASE FOR STEWARDSHIP

The scientific community is in general agreement that human activity now exceeds the global carrying capacity of the Earth's ecosystems, and that those ecosystems are rapidly degrading. The United Nations' Millennium Ecosystem Assessment, released in 2005, chronicles the continued degradation of the natural environment, amplifying the growing awareness that healthy people cannot live on a sick planet. The Ecological Footprint Atlas (Ewing et al. 2010) and the World Wildlife Fund's Living Planet Report (2010) estimate the world's economies are overshooting their capacity for natural resource regeneration by 50 percent (see Figure 1.1). While much of the discussion on finite global resources has focused on the depletion of nonrenewable resources, such as petroleum, it is increasingly evident that renewable resources, and the ecosystem services they provide, are also at great or even greater risk (Ewing et al. 2010).

Environmentalist and writer Bill McKibben (1989) contends that there are no longer any ecosystems on Earth uninfluenced by humans. "Anthropocene," a term introduced in 2000 by Nobel Prize laureate Paul Crutzen and ecologist Eugene Stoermer, describes our current geological epoch as fundamentally defined by the influence of human activities (Crutzen and Stoermer 2000). The Living Planet Report (2010) reports general decline in global biodiversity from 1970 to 2007 as follows:

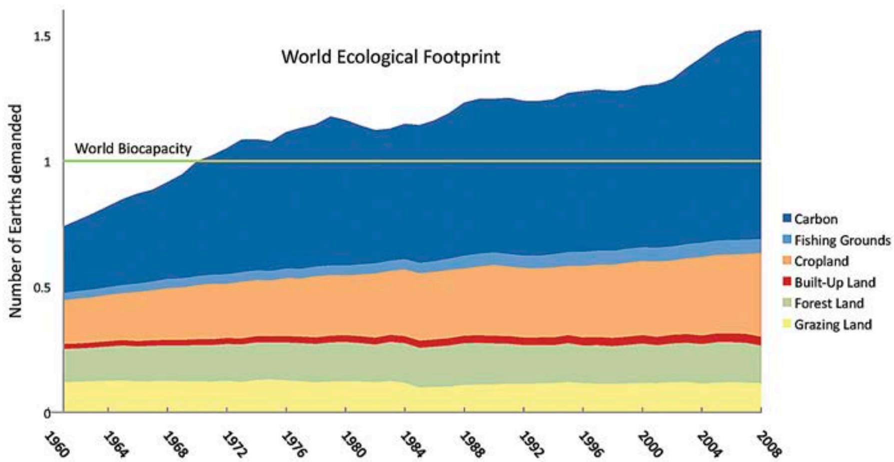


Figure 1.1 In 2007, humanity's total ecological footprint worldwide was 18.0 billion global hectares (gha); with world population at 6.7 billion people, the average person's footprint was 2.7 gha. But there were only 11.9 billion gha of biocapacity available that year, or 1.8 gha per person. This overshoot of approximately 50 percent means that in 2007 humanity used the equivalent of 1.5 Earths to support its consumption. *Source: Global Footprint Network and UNDP, 2010*

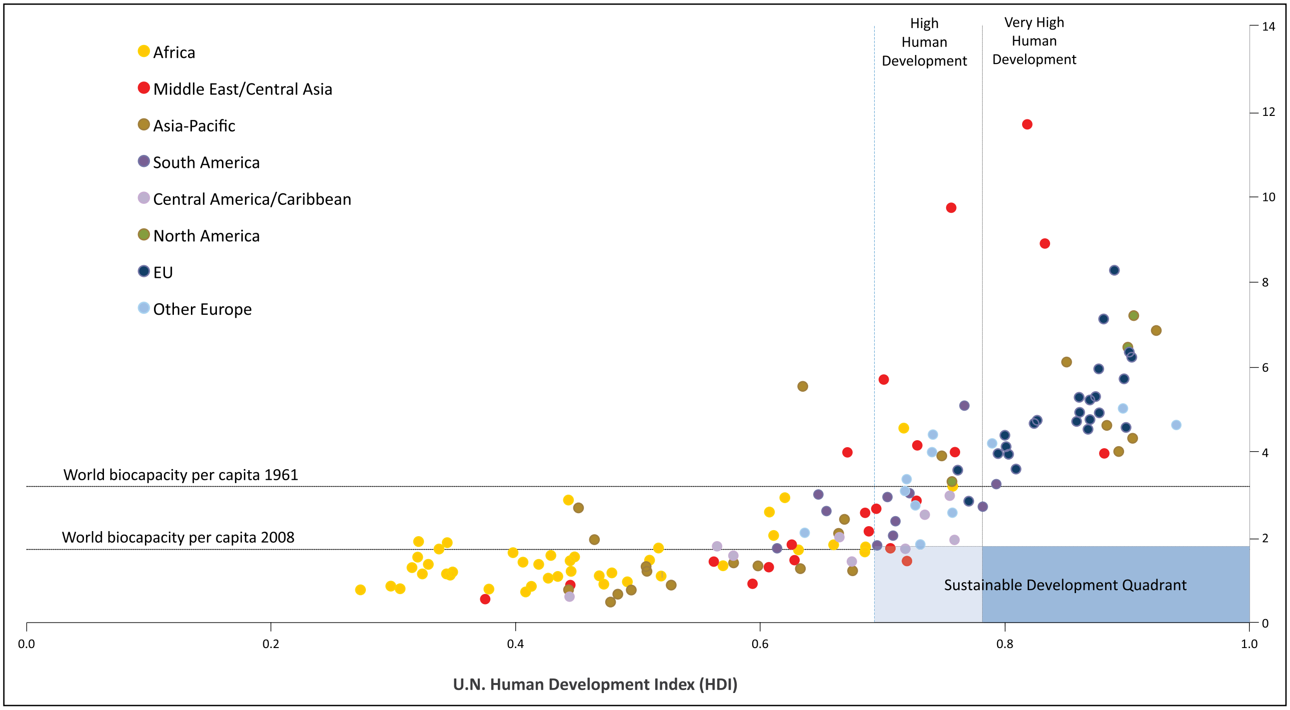


Figure 1.2 The Ecological Footprint of consumption for 2008 and Human Development Index by region. The HD values are linear interpolations between the 2005 and 2009 values from the Human Development Report 2011. Countries with an HDI score of 0.8 or higher and a footprint of 1.8 global hectares per person or lower meet two minimum criteria for global sustainable development. The graph indicates that countries consume vastly differing global resources to attain high human development. Countries living within planetary means also achieve radically different levels of human development. *Source: Global Footprint Network and UNDP, 2013*

- 37 percent decline in temperate and topical freshwater ecosystems
- 24 percent decline of marine life
- percent decline in terrestrial plant and animal species

From 10 to 15 percent of the Earth's land surface is dominated by agriculture and urban development. Close to 50 percent of the Earth's land mass has been transformed by humans. Humans consume more than 40 to 50 percent of all available freshwater (in the Middle East, consumption is estimated to be 120 percent); 25 percent of the Earth's land surface is cultivated. Furthermore, the globalization of nature—that is, the introduction of nonnative species in unfamiliar ecoregions—has disastrously weakened functioning ecosystems (Millenium Ecosystem Assessment 2005).

A key question is whether this increased resource consumption is required to meet basic human development needs. Given increasing global population, reliance on a growing level of consumption to attain sustainable well-being for all is unrealistic. The challenge of reaching a high level of human well-being while ensuring long-term resource availability is illustrated in Figure 1.2. High levels of human development, as measured by United Nations Development Programme (UNDP), are an HDI score of 0.8 or greater. The Global Footprint Network defines the average productive area available for each person on the planet as 1.8 global hectares.

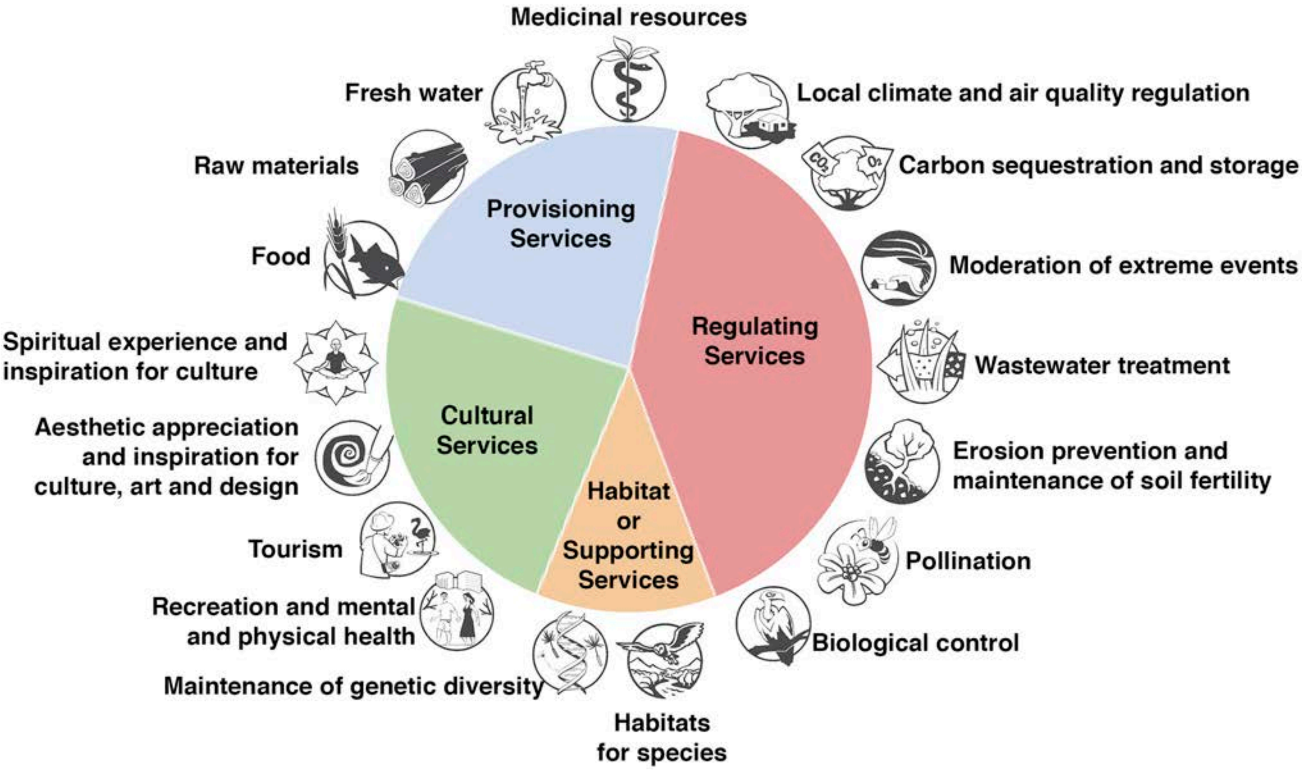


Figure 1.3 Ecosystem Services. These four types of ecosystem services are essential to support human life. *Source: TEEB, redrawn by the authors*

The concept of assigning monetary value to ecosystem services—i.e., the value of clean drinking water or pollinating insects—was first postulated by Vitousek and others (1997); at that time, they assigned a conservative value of approximately $33 trillion to these services. The Economics of Ecosystems and Biodiversity (TEEB 2010) is an ongoing project that reviews the science and economics of ecosystems and biodiversity and includes a valuation framework to improve policy decision-making. It defines four basic types of ecosystem services: provisioning services, regulating services, habitat services, and cultural services, as described in Figure 1.3.

In 1992, the Union of Concerned Scientists, on behalf of 1,600 scientists (including the majority of living Nobel laureates) issued the World Scientists' Warning to Humanity. It outlined the case for stewardship as essential to survival:

> We, the undersigned senior members of the world's scientific community, hereby warn humanity of what lies ahead. A great change in our *stewardship of the earth* [emphasis added] and the life of it is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated (Union of Concerned Scientists 1992).

The principle of stewardship is intrinsic to the idea of sustainable development. This movement, global in scope while locally implemented, has broad implications for both medicine and the environments that support it.

> *The resilience of the community of life and the well-being of humanity depend upon preserving a healthy biosphere with all its ecological systems, a rich variety of plants and animals, fertile soils, pure waters, and clean air. The global environment with its finite resources is a common concern of all peoples. The protection of the Earth's vitality, diversity, and beauty is a sacred trust.*
>
> —Earth Charter (2000)

SUSTAINABLE DEVELOPMENT

Sustainable development was defined for the first time in the United Nations'1987 Brundtland Commission Report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." It quickly gained stature in the public lexicon. This definition both inserted an explicit value proposition into the international development domain and gave "green building" a broad conceptual foundation on which to grow.

In 1992, the first United Nations' Conference on Environment and Development (commonly referred to as the Earth Summit), convened in Rio de Janeiro, and resulted in Agenda 21, a blueprint for achieving global sustainability, and the Rio Declaration on Environment and Development. The Earth Summit produced some of the earliest statements on climate change and biodiversity. Adopted by more than 178 participating governments (including the United States) (UN 2004), its visionary declarations and action plans recognized the interconnections among all living systems on Earth.

Two of these declarations would prove to be pivotal for sustainable building in healthcare. Principle 1 of the Rio Declaration states: "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature." Principle 15 advances the principle of precaution, an important construct in medicine:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

As global resources become less available, this precautionary approach becomes both more important but equally more challenging to actualize. At Rio+20, convened in 2012, Principle 15 was extensively debated. A diminishing resource base presents both unique opportunities and constraints in the development of design and stewardship. But one thing is clear: A diminishing resource base has profound consequences for the built environment and the profession of architecture.

THE PROFESSION OF ARCHITECTURE

Early environmental design initiatives were disparate, focusing primarily on the reduction of energy demands. In response to the energy crisis of the early 1970s, the American Institute of Architects (AIA) established the Committee on Energy to develop tools and policies to address mounting public concern about the building industry's reliance on fossil fuels. Parallel federal initiatives included the creation of the Solar Energy Research Institute (now the National Renewable Energy Laboratory) and the cabinet-level Department of Energy. Absent a larger framework for sustainable design, these departments focused on energy technologies and conservation.

In 1989, the AIA Committee on Energy transformed itself into the Committee on the Environment (AIA/COTE), reflecting a broader view of sustainability. In 1998, AIA/COTE announced the Top Ten Green Projects annual award program to recognize design excellence in sustainable architecture.

Inspired by the Earth Summit, the UIA/AIA World Congress of Architects (UIA stands for "International Union of Architects" in French) issued its Declaration of Interdependence for a Sustainable Future in 1993. Signed by more than three thousand participants, it states: "Buildings and the built environment play a major role in the human impact on the natural environment and on the quality of life"—a bold challenge to the profession at large to put a broader sustainability agenda into practice (UIA 1993).

In 2005, the AIA issued this position statement on the responsibility of design professionals (AIA 2005):

> The AIA recognizes a growing body of evidence that demonstrates current planning, design, construction and real estate practices contribute to patterns of resource consumption that seriously jeopardize the future of the Earth's population. Architects need to accept responsibility for their role in creating the built environment and, consequently, believe we must alter our profession's actions and join our clients and the entire design and construction industry to change the course of the planet's future.

The statement continues with a commitment to achieve a 50 percent reduction in fossil fuel consumption for new and renovated buildings by 2010 and target continuing reduction thereafter, a commitment to integrate sustainable design education into the curricula of architecture schools (and ultimately into the licensing process), and a commitment to promote research into lifecycle assessment methodologies.

In January 2006, architect Edward Mazria, FAIA, launched the 2030 Challenge: to achieve zero emissions and carbon neutrality for all building operations by 2030, beginning with an initial 60 percent reduction of fossil fuel consumption by 2010, and continuing with an additional 10 percent incremental reduction in every subsequent five-year period (Architecture 2030 2012) (see Figure 1.4). Many U.S. organizations have adopted this bold initiative, including the American Institute of Architects (AIA); American Society of Interior Designers (ASID); the U.S. Green Building Council (USGBC); the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE); and the U.S. Conference of Mayors.

In addition, major firms such as Perkins+Will, HOK, and HKS have also endorsed its principles. The Oregon State Hospital Replacement, Salem, Oregon, completed in 2011 by HOK and SRG, was designed to achieve an Energy Use Index of 114.5 kBtu/sf/yr to comply with the 2010 energy target of 60 percent below regional average baseline; in operation, it is tracking just below 100 kBtu/sf/yr (see Figure 1.5). For the new Oregon State psychiatric hospital in Junction City, HOK projects an EUI of just below 100 (see Figure 1.6).

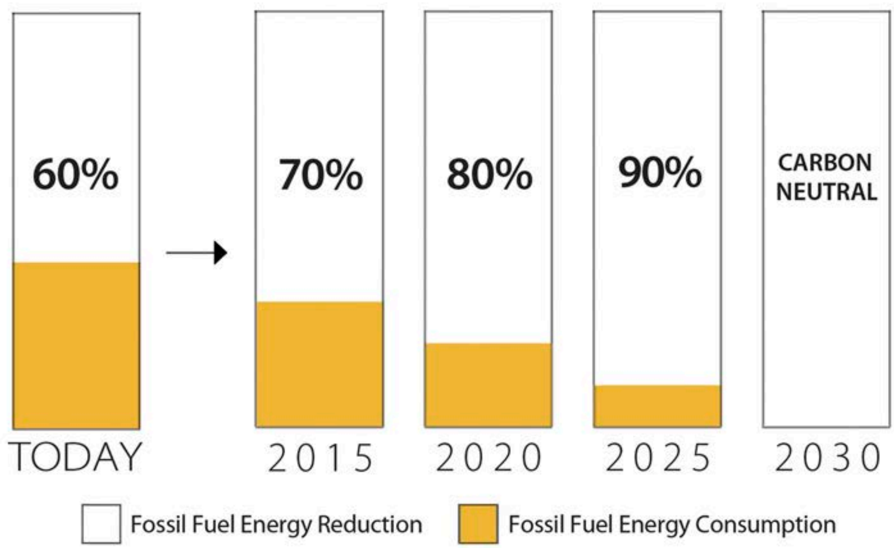


Figure 1.4 The 2030 Challenge goals. All new buildings, developments, and major renovations by 2015 shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 70 percent below the regional (or country) average for that building type, increasing by 10 percent each five years. By 2030, all buildings will be designed to be carbon-neutral, operated with 100 percent renewable energy.

Figure 1.5 Oregon State Hospital at Salem, Oregon, is designed to meet the 2030 Challenge 2010 goal. *Source: HOK with SRG Architects*

Figure 1.6 Oregon State Hospital at Junction City is designed to meet the 2030 Challenge 2015 goal. *Source: HOK*

THE ETHICAL CHALLENGE FOR DESIGNERS

Ultimately, the built environment is the product of intentional design decisions, and waste signifies failure. *Metropolis* magazine editor Susan Szenasy (2004) sums up the challenge this way: "Designers today stand on the brink of being seen by society as essential contributors to its health, safety, and welfare. If you—together with the other design professions—decide to examine the materials and processes endemic to your work, as well as demand that these materials and processes become environmentally safe, you will be the heroes of the twenty-first century." Or, as David Orr (2004) sees it, "The larger challenge is to transform a wasteful society into one that meets human needs with elegant simplicity." As this change occurs, labels like "biomimicry" or "sustainable design" attempt to describe the efforts. The ethical challenge is, however, broad in scope. It is not simply about designing environmentally benign hospital buildings for an ever-expanding industrial-medical complex, but about formulating a system of healthcare that supports vital communities that nurture health and whole people "who do not confuse what they have with who they are" (Orr 2004). This broader vision of design can best be termed "ecological design."

ECOLOGICAL DESIGN

Ecological design, Orr continues, "requires a revolution in our thinking." He suggests changing the kinds of questions we ask about a design, from, "How can we do the same old things more efficiently?" to ones such as:

- Do we need it?
- Is it ethical?
- What impact does it have on the economy?
- Is it safe to make and use?
- Is it fair?
- Can it be repaired or reused?
- What is the full cost over its expected lifetime?
- Is there a better way to do it?

> *Architects have wonderful opportunities to make things better by enthusiastically promoting "less" in the buildings we design. This doesn't mean stripping away the elements that make our buildings beautiful. But we can design structures in simpler, more thoughtful ways that work with, instead of against, nature. And by doing so we can prove to people that less can be better in many aspects of their lives. Though we can't legislate less in our culture, we're at a potential tipping point—that dramatic time popularized by Malcolm Gladwell's* Tipping Point *(2000) when something that had once been unique becomes common. Using less can become the norm.*
>
> *My message actually goes far beyond buildings and, I hope, straight to the heart of our culture. I'd like to trigger a move toward less in the building industry that also spreads across our society and catalyzes a profound cultural shift toward simplicity. Let's show people that all this stuff isn't required to live "the good life." Let's change our habits and reclaim our culture by making less a virtue. If we can make the idea of using less fashionable and chic in the U.S., our success could send ripples all over the world.*
>
> —Bill Valentine, Chairman, HOK (2008)

Orr conceives of ecological design not so much as an individual art practiced by individual designers but as an ongoing negotiation between a community and the ecology of particular places. Ecologically designed buildings "grow" from the long-term knowledge that derives from intimate experience of a place over time; they "live" within a biotic framework established by an understanding of natural principles and man-made policies standing together.

At the Patrick H. Dollard Discovery Health Center (see sidebar), the first LEED-certified ambulatory building, the decision to construct a sustainable building was informed by an ecological viewpoint—the belief that the health vulnerabilities of developmentally disabled children are influenced by the health of the ecosystems and built environments within which they live and learn. Completed in 2004, this building demonstrates the power of stewardship in healthcare settings. It is as relevant today as the day it opened.

CLEANER PRODUCTION

The concept of stewardship requires a reexamination of materials, the units of production from which the built environment is created. Materials extraction and production processes as they evolved during the Industrial Revolution have come to be categorized as "beat, heat, and treat" methodologies. Industry thrived in an era of inexpensive energy, using industrial processes to replace human labor in an ever-expanding era of raw material usage. Waste was seen as an inconvenience rather than a measure of inefficient production. In the early 1990s, in response to growing recognition of environmental degradation and resource depletion, the United Nations Environment Programme (UNEP 1989) defined "cleaner production":

> Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products and services to increase overall efficiency, and reduce risks to humans and the environment...
>
> For production processes, Cleaner Production results from... conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production process.
>
> For products, Cleaner Production aims to reduce environmental, health and safety impacts over their entire life cycles, from raw materials extraction, through manufacturing and use, to the "ultimate" disposal of the product.

Advocates of cleaner production have developed "tool kits" for reducing pollution by substituting safer, more benign materials for hazardous materials; by optimizing production technologies; and by closing loops in manufacturing processes to recycle and reuse what had been waste materials. Tools such as the Green Screen, Pharos, and the Health Product Declaration are being developed to assist designers and specifiers in accessing information and understanding the complex chemical components of building materials (see Chapter 5).

Pollution prevention programs, as defined by the healthcare industry, are examples of cleaner production initiatives in action. In some states, "toxic use reduction plans" are manifestations of cleaner production initiatives. Cleaner production demonstration programs have been launched all over the world and are now common not only in industrialized nations, but also in developing nations. Generally speaking, cleaner production "design" activities achieve both environmental benefits and economic returns—and demonstrate improved stewardship of both resources through the lifecycle.

The Patrick H. Dollard Discovery Health Center

Harris, New York

Architect: Guenther 5 Architects/Perkins+Will

This 28,000 sq. ft. (2,601 sq. m) project seeks to evolve a noninstitutional ambulatory medical facility nested within a rural, residential campus. It is the new front door for the Center for Discovery, a 350-acre residential facility that houses more than 250 developmentally disabled adults and children in a decentralized group home model.

The center emphasizes a nature-based program that includes community-supported agriculture manifested in its organic farm. Goats and horses pasture in the fields adjacent to the clinic building. The project site, a 9-acre (3.6-ha) former "industrial" egg farm, created significant pollution runoff to the adjacent organic farm. Although it might have been less expensive to develop on a greenfield parcel, the Center for Discovery realized that the ecological remediation of the project site would improve irrigation water quality on the farm and safeguard against future potential contamination. The plan prioritizes daylight and views, with a focus on visual connection to the adjacent farm (Figures 1.7–1.10).

Linking hydronic heating to ground-source heat pumps eliminated all onsite combustion, contributing to reduced airborne emissions (Figure 1.8). The center utilizes radiant heating systems in residential buildings because they provide superior thermal comfort, reduce maintenance, and improve resident safety, leaving no exposed heating equipment in the wheelchair zone. The project predates the 2030 Challenge but met the 2010 goal for 60% energy use reduction. It also captures and stores rainwater for irrigation, fire tank reserves, and ground source makeup. Excess rainwater is released to the farm irrigation system.

Source: Guenther 5/Perkins+Will

Figure 1.7 The Patrick H. Dollard Discovery Health Center. *Source: David Allee*

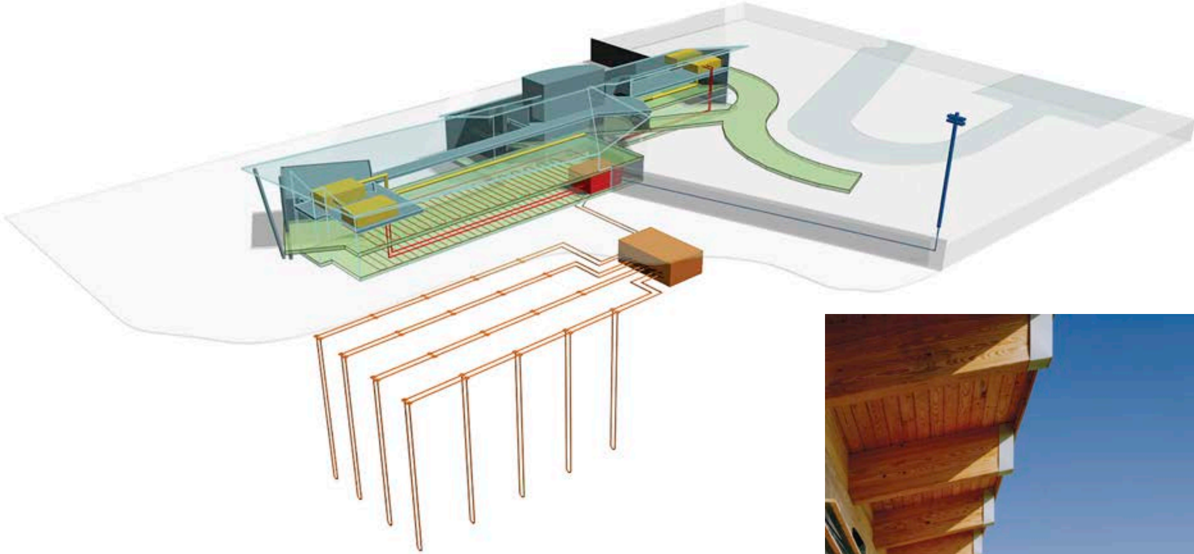


Figure 1.8 Ground source heat pump systems link to hydronic distribution. *Source: Guenther 5/Perkins+Will*

Figure 1.9 The deck overlooking the adjacent farm. *Source: David Allee*

Figure 1.10 The shallow floor plate ensures deep daylight penetration into waiting areas and exam spaces. *Source: Guenther 5/Perkins+Will*

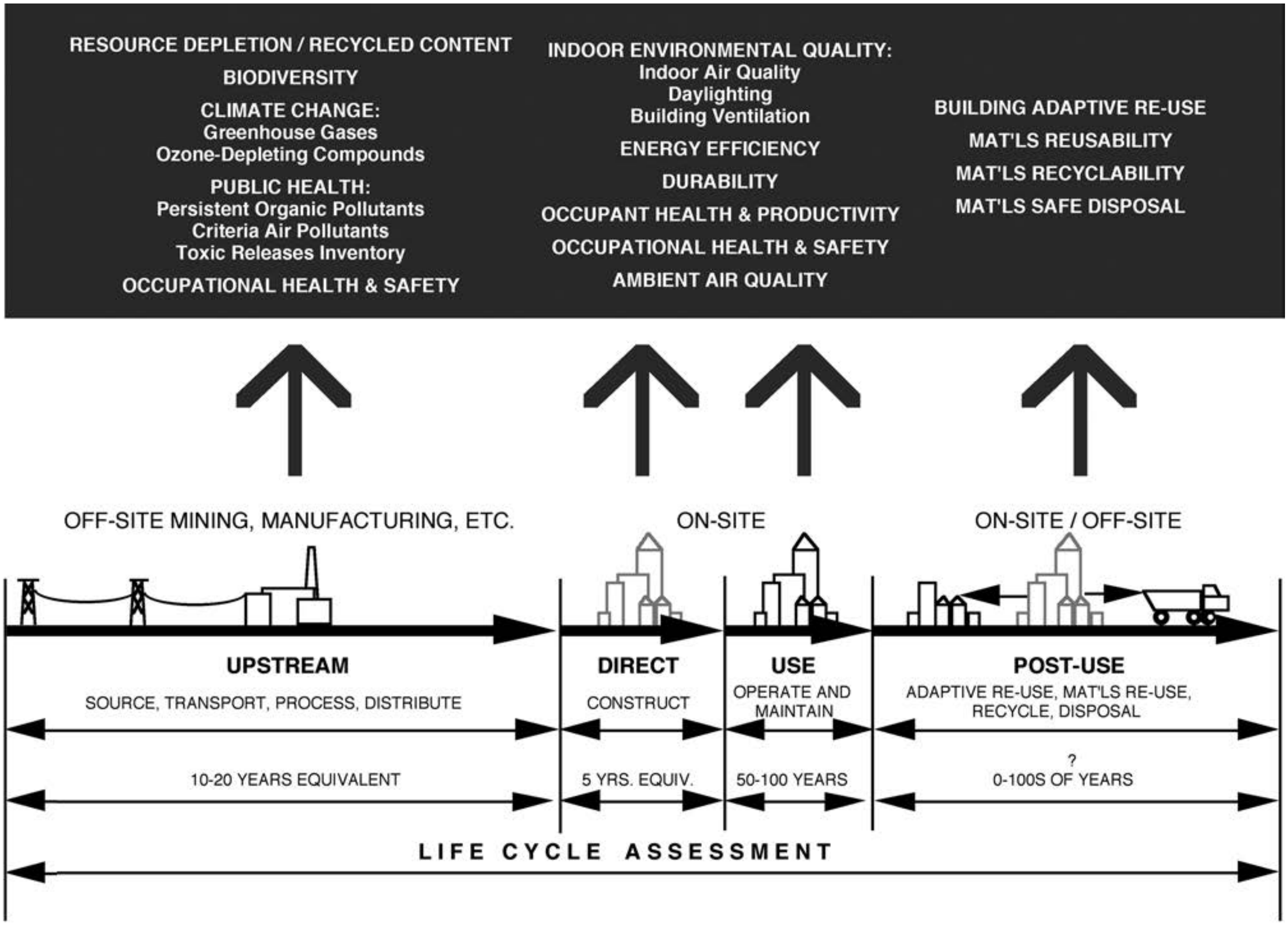


Figure 1.11 Life cycle diagram. Each building life cycle phase results in a range of environmental and health consequences—some of these are constants and some more variable based on building type, location, and programmatic focus. Using these indicators as evaluative criteria to compare material choices and design features leads to robust material specification and design decisions. *Source: Center for Maximum Potential Building Systems*

LIFE CYCLE THINKING

Healthcare building design and construction processes have usually been cradle to grave, with ever-shorter use life spans. While many late-nineteenth-century healthcare buildings remain in use, they have often been downgraded from acute care to ancillary facilities as the technology and the associated space requirements of acute-care buildings have escalated. After sixty years in service, the post–World War II Hill-Burton buildings throughout the United States are presently the target of replacement. At the same time, mid- to late-1970s facilities are being downgraded after barely thirty years in service. Because the vast resource base that supported the expansion of the built environment in the nineteenth and twentieth centuries is diminished, the processes associated with buildings at every stage of their life cycle are being fundamentally reconsidered (see Figure 1.11).

Broadly termed Life Cycle Design (LCD) thinking, the production cycle for building design and construction is expanded to include the extraction, production, and transportation consequences to ecosystems and human health that often, collectively, exceed the use-phase impacts of a building material. Within the discipline of sustainable design, the advantages of LCD have thus far been evaluated on a tangible level; for instance, reducing the distance a material must be transported to a building site creates quantifiable reductions in fuel, emissions, and economic cost. Incrementally more sophisticated effects of LCD might include the development of regionalized economic loops incorporating virgin and byproduct materials, local producers, and locally appropriate resources, or the advancement of a building vernacular based on such a regional network.

Architectural designer and educator Pliny Fisk III provides a brief introduction to both the principles that underlie current life cycle design concepts (see Life Cycle Design Principles) as well as a set of concepts that extend the reach of LCD into a behavioral realm (see Elements of an Ecology of Mind) and suggests that LCD has the potential to engage our perceptions and alter our behaviors related to the resources we use, reconnecting humans to nature and its processes.

> The hypothesis is based on an understanding of how humans engage with their environments through life cycle events—when we directly encounter the life cycles of water, energy, food, air, and materials often remote from our everyday experience. This reflects our lack of knowingly playing a role with life cycle "events," such as how oxygen is produced or carbon is absorbed by a certain quantity of vegetation and soil systems. The fact is that approximately 5000 sq. ft. (465 sq. m) of temperate forest is needed to support an individual's oxygen needed for breathing, and 7500 sq. ft. (697 sq. m) is needed for carbon sequestering—these essential life-giving threads have not been part of our "event" vocabulary, but should be. In the model outlined here, buildings are designed to mimic and illuminate the life cycle events around us, causing humans to experience resource flows and cycles, understand resource dependencies, and adapt their behavior accordingly (Fisk 2008).

Life Cycle Design Principles

- Recognize the resource flows on which a building depends, and identify them and their multiple boundaries, from the building scale through to neighborhood, city, regional, and global scales.
- Evaluate and apply the source, transport, process, use, and re-source life cycle sequence in all resource-flow areas when considering the scales above, including energy, materials, water, and air. (In healthcare projects, food and medical waste are examples of operational resource flows that might be considered as well.)
- Increase resource-flow efficiency by basing decisions first on the scale of the building and site, progressing upward to tap into larger life cycle scales only as necessary.
- Support regionalized economic loops by respecting tight-knit regional integration. Each stage of the building life cycle supply chain should become a part of a regional economy.
- Plan for the extended use of a building through the separation of utilities, structure, and shell. Designing for flexibility extends the use phase of the building's life cycle.
- Create regionally relevant benchmarks throughout the world through comparisons with similar industrial bases, climates, and material conditions, as well as similar flora and fauna, using patterns supplied by the internationally accepted biome system.
- Reduce the size and complexity of the life cycle to enable it to relate more directly to people, involving the user with the resources associated with their everyday activities.
- If possible, incorporate both an input-output life cycle assessment and a process life cycle assessment, one supplying the perspective using national data, the other homing in on the low-hanging fruit identified.

Source: Pliny Fisk III (2008)

Elements of an Ecology of Mind

- Consider life cycle events in a building—direct interactions with the natural life cycles of water, air, energy, and materials—as microcosms of the life cycle events around us, and treat them with the same awe and respect as natural life cycle events, eliciting engagement with and response to these cycles through design.
- Identify the full range of ecosystem life cycles and life cycle events in and around our buildings, and consciously cover all environmental life cycle phases (or in behavioral terms, "events") from source (e.g., rain) to re-source (e.g., drinking water).
- Conceive of the life cycle as successions of resource events that can be balanced and the user part of the balancing act, so that people understand both the parts (i.e., the individual events) and the whole.
- When designing, differentiate between building elements that stimulate human brain activity at the circadian and interval scales, so that life cycle involvement can occur at both levels.
- Go beyond circadian brain rhythms by engaging the interval time function of the brain's neocortex through the miniaturization of the life cycle.
- Synchronize the scale of everyday life cycle events with the interval time of the neocortex through two- and three-dimensional means and miniaturization.
- Project from past to future and from locus to region the effects of our actions, not just at the individual scale but also at the community, regional, and global scales. Consider simulation and gaming environments so the neocortex is enticed to participate with the life cycles that support us.

Source: Pliny Fisk III (2008)

According to Fisk, this represents a new LCD framework not driven solely by the physical and engineering manipulation of resources and analyses of building phases, but instead by the idea that our relationship with life cycle events might be related to behaviors based on the evolution of the brain itself. In this new conception of LCD, miniaturizing the life cycle—for example, bringing the cycle of water (from capture to use to waste treatment) within the site boundary so that the processes are no longer removed and abstracted—is recognized to trigger brain functions that may better connect us to these significant environmental sequences. Buildings, then, extend our perceptions and connect us to the resources we use on a deeper level than previously imagined.

CRADLE TO CRADLE DESIGN

Informed by ecological design approaches, industrial designers are beginning to use an alternative framework for reengineering both products and processes as a response to the limits of "cradle to grave" ideology. Architect William McDonough and chemist Michael Braungart (2002) developed the cradle to cradle (C2C) design paradigm based on three key principles (see sidebar).

CRADLE TO CRADLE PRINCIPLES

- ***Waste equals food.*** In nature, one organism's waste is food for another.
- ***Use current solar income.*** Plants use sunlight to manufacture food. In fact, fossil fuels are "ancient sunlight"—past solar income. Both energy and material inputs are renewable rather than depleting.
- ***Celebrate diversity.*** Nature's diversity provides many models to imitate in the design of systems and processes: biomimicry.

Source: McDonough and Braungart, Cradle to Cradle 2002

Biologist Janine Benyus (1997) suggests nine principles that define natural systems (see sidebar). These design axioms provide a roadmap for how we might further broaden and re-vision an approach to Life Cycle Design, an idea that is explored in Fisk's work. As industry redesigns material production in accordance with C2C and biomimicry principles, it remains the task of designers to reimagine buildings based on similar tenets.

NATURAL SYSTEMS

Nature runs on sunlight.

Nature uses only the energy it needs.

Nature fits form to function.

Nature recycles everything.

Nature rewards cooperation.

Nature banks on diversity.

Nature demands local expertise.

Nature curbs excesses from within.

Nature taps the power of limits.

Source: Janine Benyus, Biomimicry (1997)

LIVING BUILDINGS

What would ecological design mean for the typology of healthcare buildings? "In the century ahead we must chart a course that leads to restoration, healing, and wholeness" (Orr 2004). Architect Bob Berkebile and designer Jason F. McLennan (1999) define the future of architecture as a future of living buildings, operating on the following six principles. This is not a future predicated on less, but rather one inspired by doing more—and doing better—with less. Living buildings will:

1. Harvest water and energy needs onsite.
2. Be adapted specifically to site and climate and evolve as conditions change.
3. Operate pollution free and generate no wastes that aren't useful for some other process in the building or immediate environment.
4. Promote the health and well-being of all the inhabitants, as a healthy ecosystem does.
5. Comprise integrated systems that maximize efficiency and comfort.
6. Be beautiful and inspire us to dream.

In 2006, the Cascadia Region Green Building Council, led by Jason F. McLennan, launched the Living Building Challenge, a "global vision for lasting sustainability" that embodies these six principles in a third-party certified green building rating system. Now held by the independent nonprofit International Living Future Institute, the Living Building Challenge, comprised of seven performance areas, Site, Water, Energy, Health, Materials, Equity, and Beauty, defines priorities on both a technical level and as a set of core values. The performance areas are subdivided into a total of twenty Imperatives, each of which focuses on a specific sphere of influence (ILFI 2012). In the following essay, Jason F. McLennan expands upon his aspirations for the system.

LIVING BUILDINGS AND A RESTORATIVE FUTURE

Jason F. McLennan LEED Fellow

> Do not follow where the path may lead. Go Instead where there is no path and leave a trail.
>
> —Harold R. McAlindon

Back in the nineties, before LEED was even released, Bob Berkebile and I began to work on an idea called "the Living Building." The idea was based on a simple premise—that nature was the ultimate measuring stick for success for our buildings and other built infrastructure. Why couldn't we build things that were as elegant and efficient as nature's architecture? Buildings that generated their own energy collected and treated their own water and waste and did so without the use of toxic products. It was an idea a bit early for a market that still viewed "green" as a fad. LEED changed all that by introducing structure and requirements to define sustainable design in the early part of the last decade—and launched a movement that grew from fringe to mainstream in a few short years. Suddenly LEED Gold and Platinum was a widely achievable goal.

In 2005, emboldened by the success of LEED and urged on by the increasing evidence of the effects of climate change, I worked to translate our early vision of Living Buildings into a pragmatic, yet aspirational tool—the Living Building Challenge, the world's most stringent, yet progressive green certification program. It was decidedly simple and focused on ultimate proven performance rather than predicted modeled outcomes. It embraced the measurable like net zero energy and water—and the hard to measure—things like beauty, inspiration, and issues of equity. It worked not on a model of incremental improvements, but rather on defining the "end game" and urging people to move as quickly as possible to this ideal state.

We launched the first version at the end of 2006 and weren't sure what to expect. Would anyone be crazy enough to push building performance this far? It was a challenge to the industry, and the industry responded. Fast-forward a few short years and the Living Building Challenge has become a "meme": a powerful idea with a life of its own beyond what we could have predicted. Dozens of projects have sprung up in countries around the world. Thousands of people share the tool, our research and our case studies, and we now have the world's first fully certified Living Buildings up and operating—proving that this level of performance is possible already, with today's technology and know-how. Each project is a beacon of hope—buildings that will never have an energy or water bill again and where nearly all the specifications have been scrubbed of red list chemicals. Healthier buildings that outperform any other structures built today.

A powerful example is the new Hawaii Preparatory Academy on the Big Island (see Figure 1.12). This beautiful school building exemplifies the power of the Living Building Challenge to create a new kind of academic infrastructure. The building is a powerful pedagogical tool where students are immersed in an experience and learn the connections between the built and natural environments. It feels better than a conventional building somehow, and we know it performs better in multiple ways environmentally.

Living Buildings are now emerging in every market sector and in all shapes and sizes. Projects range

Figure 1.12 Hawaii Preparatory Academy on the Big Island is a certified Living Building. *Source: Matthew Millman Photography courtesy of Flansburgh Architects*

from 200,000 sq. ft. (18,581 sq. m) to 2,000 sq. ft. (186 sq. m)—new buildings and retrofitted existing buildings. It's a quiet revolution. Jumping scales is next as we ask what's possible at the neighborhood and campus level. Along the way we've revealed systemic regulatory hurdles that need to change, especially around water. We've helped encourage the reformulation of new products to be nontoxic yet high performing. We've looked how to change economic and institutional barriers that are essential to tackle. The positive impacts are creating ripple effects everywhere.

The healthcare industry is an exciting next place for this level of paradigm shift. It should be obvious that places of healing should be our healthiest buildings—both directly to occupants through improved air quality and nontoxic materials and also indirectly through reduced energy and resource use that has been proven to have significant health impacts as well. This directly aligns with the goals of the Challenge.

We define healthy building both very broadly and deeply within the Living Building standard. We focus on physical health directly through ensuring great indoor air quality. We focus on the elimination of the sources of indoor contaminants rather than merely minimizing them. We don't allow combustion energy sources and require IAQ testing prior to occupancy and throughout construction. Our materials red

Figure 1.13 Omega Center for Sustainable Living. *Source: Copyright ©2009 Farshid Assassi; courtesy of BNIM Architects*

list for all building materials within a structure ensures the elimination of the most toxic substances in our buildings with only a few exceptions. Zero carcinogens is a better goal than 10% less carcinogens!

The Challenge also focuses on psychological well-being through its emphasis on access to natural systems and biophilia, with strict standards for access to operable windows, natural systems, and beauty. These elements benefit patients and staff alike. Given the strong focus on transportation, habitat preservation, and zero emissions, indirect adverse upstream and downstream health impacts are also reduced or eliminated. We believe that a Living Building is currently the healthiest building you could possibly build today.

Hospitals and clinics should also be places of refuge for the public—part of a resilient system of decentralized infrastructure that is immune to most natural disasters and other infrastructure challenges. A "Living Hospital" will have its own energy and water infrastructure—where quantity and quality are controllable and systems are flexible to operate with or without municipal energy or water grids that may become unreliable.

Ultimately the Living Building Challenge is about promoting life and reconnecting people to natural systems in a world that has lost touch with the things that keep us healthy long-term. Healthcare institutions should lead the way in adopting restorative and regenerative structures that manifest through the Living Building Challenge.

CONCLUSION—THE NEXT GENERATION

Physical manifestations of this expanded vision of design are already being realized. Peace Island Health Center (Case Study 3, Chapter 5) is the first hospital project to attempt to meet the Living Building Challenge. The Omega Center for Sustainable Living (see Figure 1.13), the first certified project, is an example of living building principles applied to a wellness/health management typology. While we have not yet seen the first generation of climate-neutral healthcare buildings, the projects in this book suggest a radical reconsideration of energy use as well as new approaches to bioregionalism and specific adaptations to location and site context. They embrace the goals of promoting the health and well-being of all inhabitants. These buildings are integrating systems in innovative ways. Many are beautiful and inspire us to dream.

CONTRIBUTOR

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Jason F. McLennan serves as the CEO of the International Living Future Institute—a leading NGO that focuses on the transformation to a world that is socially just, culturally rich, and ecologically restorative. McLennan is the founder and creator of the Living Building Challenge, widely considered the world's most progressive and stringent green building program and the winner of the 2012 Buckminster Fuller Challenge Award. McLennan is the author of four books, and is an Ashoka Fellow.

BIBLIOGRAPHY

American Institute of Architects [AIA]. (2005). High-Performance Building Position Statements. AIA: Washington, DC.

Architecture 2030 (2012); www.architecture2030.org.

Benyus, J. (1997). *Biomimicry: Innovations Inspired by Nature.* New York: William Morrow.

Berkebile, R. J., and J. McLennan. (1999). The Living Building. *The World & I* (October): 160–168.

Biomimicry 3.8. (2012). http://biomimicry.net.

Brundtland, G., Ed. (1987). *Our Common Future: The World Commission on Environment and Development.* Oxford: Oxford University Press.

Cascadia Region Green Building Council. (2006). *The Living Building Challenge v1.0: In Pursuit of True Sustainability in the Built Environment.* Portland, OR: Cascadia Region Green Building Council.

Crutzen, P. J., and E. F. Stoermer. (2000). The "Anthropocene." *Global Change Newsletter*, 41:17–18.

Earth Charter Initiative. (2000). The Earth Charter; www.earthcharter.org/files/charter/charter.pdf.

Ewing, B., D. Moore, S. Goldfinger, A. Oursler, A. Reed, and M. Wackernagel. (2010). *The Ecological Footprint Atlas 2010.* Oakland: Global Footprint Network; www.footprintnetwork.org/images/uploads/Ecological_Footprint_Atlas_2010.pdf. (Accessed March 2012).

Fisk III, P. (2008). Life Cycle Thinking. In *Sustainable Healthcare Architecture*, R. Guenther and G. Vittori. New York: John Wiley & Sons, Inc.

Gladwell, M. (2000). *The Tipping Point: How Little Things Can Make a Big Difference.* New York: Little, Brown.

Global Footprint Network (2013). www.footprintnetwork.org/en/index.php/GFN/blog/human_development_and_the_ecological_footprint

Hawken, P. (1993). *The Ecology of Commerce: A Declaration of Sustainability.* New York: Harper Business.

Hawken, P., A. Lovins, and L. H. Lovins. (2000). *Natural Capitalism: Creating the Next Industrial Revolution.* Back Bay Books.

International Living Future Institute [ILFI]. (2012). The Living Building Challenge; https://ilbi.org/lbc/standard (Accessed October 28, 2012).

International Union of Architects [UIA] and American Institute of Architects [AIA]. (1993). *Declaration of Interdependence for a Sustainable Future.* Authored at the World Congress of Architects, Chicago, June 18–21; www.uia-architectes.org/texte/england/2aaf1.html.

McDonough, W., and M. Braungart. (2002). *Cradle to Cradle: Remaking the Way We Make Things.* New York: North Point Press/Farrar Strauss and Giroux.

McKibben, B. (1989). *The End of Nature.* New York: Anchor Books.

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-Being: Current State and Trends: Findings of the Condition and Trends Working Group.* New York: Island Press.

Orr, D. W. (2004). *The Nature of Design: Ecology, Culture, and Human Intention.* Oxford: Oxford University Press.

Szenasy, S. (2004). "Ethics and Sustainability: Graphic Designers' Role." Speech given at the annual American Institute of Graphic Arts National Design Conference, Vancouver, BC, October 23–26; http://powerofdesign.aiga.org/content.cfm/szenasy.

TEEB (2010). *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB.* ISBN 978–3–9813410–3–4.

Union of Concerned Scientists. (1992). World Scientists' Warning to Humanity; www.ucsusa.org/ucs/about/1992-world-scientists-warning-to-humanity.html.

United Nations Department of Economic and Social Affairs. Division for Sustainable Development. (2004). Documents; www.un.org/esa/sustdev/documents/agenda21/index.htm.

United Nations Environment Programme [UNEP]. (1989). Cleaner Production—Key Elements; www.uneptie.org/pc/cp/understanding_cp/home.htm.

Valentine, B. (2008). Less Is Better. In *Sustainable Healthcare Architecture*, R. Guenther and G. Vittori. New York: John Wiley & Sons, Inc.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. (1997). Human Domination of Earth's Ecosystems. *Science* 277: 494–499.

World Wildlife Fund International, Zoology Society of London, and Global Footprint Network. (2010). *Living Planet Report 2010.* http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/2010_lpr/.

CHAPTER 2

THE BUILT ENVIRONMENT AND HUMAN HEALTH

> Can we move nations and people in the direction of sustainability? Such a move would be a modification of society comparable in scale to only two other changes: the Agricultural Revolution of the late Neolithic and the Industrial Revolution of the past two centuries. These revolutions were gradual, spontaneous, and largely unconscious. This one will have to be a fully conscious operation, guided by the best foresight that science can provide . . . . If we actually do it, the undertaking will be absolutely unique in humanity's stay on Earth.
>
> WILLIAM RUCKELSHAUS

INTRODUCTION

The built environment influences health. As a species, humans need structures for physical shelter as manifestations of social and cultural values and as embodiments of spiritual and emotional needs. As population growth accelerates, the production of the built environment becomes more resource intensive, stressing both renewable and nonrenewable building material stocks and methods beyond their sustainable capacities. Resource depletion, in turn, adversely affects human health.

Clinical medicine and public health professionals define health differently than the mere absence of disease. The World Health Organization, for example, defines health as a state of physical, mental, and social well-being. Architecture and planning can and should promote this broader conception of human health and well-being.

In the nineteenth century, infectious diseases such as smallpox, tuberculosis, typhoid, pneumonia, and rubella were responsible for the majority of deaths. To a large degree, these could be, and eventually were, controlled through environmental and clinical public health interventions—sanitation and inoculation (Turner 1995). Many of these health improvements were achieved through urban planning and zoning mechanisms, reflecting a close partnership among urban planning, architecture, public health, and allopathic medicine professions.

Moving into the twenty-first century, long-term chronic illnesses such as cancer, heart disease, and strokes claim the most lives—more than from infectious diseases. In their recent book *Sick Societies* (2011), sociologist and epidemiologist David Stuckler, MPH, PhD and Karen Siegel, MPH present critical data showing that the majority of chronic disease burden is related to tobacco use, diet, increased physical inactivity, and alcohol. They also postulate that this is not, in fact, a "transition" from infectious to chronic disease: Many of the same households are continuing to face infectious disease while simultaneously having family members with diabetes and heart disease—"a double burden."

In the last twenty-five years, chronic respiratory afflictions such as asthma and sick building syndrome have emerged as widespread threats to public health. While we have created a large allopathic medical structure to address these issues, growing evidence suggests that a renewed partnership among urban planning, architecture, public health, and medicine is necessary to prevent these illnesses before they occur.

Public health concerns of the late nineteenth century and those of the twenty-first century are starkly different. Today's public health challenges of asthma, developmental disabilities, diabetes, obesity, reduced fertility, and cancer have causal relationships to the technological and environmental changes that characterized the twentieth century. Climate change, manifested by increasingly severe and frequent calamitous events transforming our sense of place before our eyes, is also rooted in twentieth-century technologies. While adaptive strategies may result in easing some of the physical harm resulting from these storms, the psychological effects can endure, as we learn from the environmental refugees of Hurricane Katrina in 2005 and of Hurricane Sandy in 2012. Describing this phenomenon of loss of place, Professor of Sustainability Glenn Albrecht of Murdoch University in Perth, Western Australia, coined the term "solastalgia" derived from the words "solace" and "nostalgia," which he describes as "... the pain or sickness caused by the loss of, or inability to derive, solace connected to the present state of one's home environment," and that exists when "... the place where one resides and that one loves is under assault (physical desolation)" (Albrecht 2007). Paradoxically, the built environment is and has been a significant contributor to these technological and environmental changes through its prodigious resource use.

What does all this mean for the healthcare industry? As long as human health continues to be adversely affected by environmental stress, the healthcare industry will build larger, more resource-intensive structures to respond to the downstream health consequences of environmental degradation. In so doing, it will unwittingly contribute to the very problem it is trying to solve. Moreover, beyond the production and operation of its own buildings, the culture of automobile dependence and suburban sprawl further challenges the medical-care infrastructure.

This chapter examines the global-, community-, and occupant-level health impacts associated with the built environment. Insofar as healthcare construction is both a major player in the construction economy and a resource consumer, its contributions to environmental stress are significant.

THE GLOBAL IMPACTS OF THE BUILT ENVIRONMENT

As the condition of the natural environment deteriorates, we face an increasingly complex and difficult global public health crisis. The World Health Organization (WHO) estimates that 25 percent of the global disease burden, measured in disability-adjusted life years (DALYs), is influenced by modifiable environmental factors such as unsafe drinking water, poor sanitation and hygiene, indoor and outdoor air pollution, and inadequate pedestrian and cycling infrastructures. Children bear an even higher incidence of environmentally influenced disease burden, estimated at one-third of total diseases and more than four million deaths each year (WHO 2006). As environmental quality declines, environmental health issues such as nutrition, clean water, and hygiene become more complex.

A host of contemporary environmental problems—climate change, ozone depletion, acid rain, toxic pollution, decline in biodiversity—can be linked to the production, operations, and maintenance of the built environment. Buildings are resource intensive in both their construction and ongoing operation. According to the U.S. Energy Information Administration, residential and commercial buildings in the United States are responsible for 39 percent of atmospheric carbon dioxide (CO_2) releases, a precursor to global warming (USEIA 2012). These buildings are also responsible for 73.5 percent of electricity use (USEIA 2012). Even more startling, while CO_2 emissions are leveling off in the industrial sector, they are significantly rising in the building and transportation sectors, where they have increased from 300 million metric tons (mmt) in 1960 to 700 mmt in 2000 to 2900 mmt in 2010 (Mazria 2010). Building construction activities account for 60 percent of the raw materials, with the exception of food and fuel, and 25 percent of the world's virgin lumber (Roodman and Lenssen 1995). Building construction and demolition generates almost 60 percent of nonindustrial, nonhazardous municipal solid waste (EPA 2010). Buildings contribute to stratospheric ozone layer depletion by using refrigerants and products manufactured with ozone-depleting compounds, including some insulation materials. Buildings use over 75 percent of the polyvinyl chloride (PVC) produced; chlorine production, one of the world's most energy intensive industrial processes, consumes approximately 1 percent of the world's total electricity output—47 billion kWh per year—equivalent to the annual output of eight medium-sized nuclear power plants (Thornton 2003). Polyvinyl chloride production represents the largest use of chlorine in the world (World Chlorine Council 2012).

Material production also has public health consequences. "A focus on improving public health or protecting ecological systems without addressing the production, use, and disposal of industrial materials will prove inadequate and ineffective," writes Dr. Kenneth Geiser, co-director of the Lowell Center for Sustainable Production. "Depletion of the resources of the environment and impairment of human health are the symptoms of a poorly designed and functionally flawed industrial production and consumption economy, not of an unprotected environment" (Geiser 2001). As resources are depleted, materials must be shipped longer distances in response to growing worldwide demand. Because built environments are now produced in a global materials marketplace, cleaner production and life cycle assessment methodologies can positively influence that marketplace.

CLIMATE CHANGE AND PUBLIC HEALTH

Climate change is projected to continue to impose unprecedented health threats on populations worldwide. In 2000, the U.S. Global Change Research Program released an assessment of the potential consequences of global warming on the United States that included an analysis of its health impacts (Figure 2.1). As Aaron Bernstein, MD, MPH submits in his essay "Where We Heal: The Importance of Healthcare Buildings to Our Health and the Planet's," certain health outcomes are known to be associated with weather, including illnesses resulting from extreme temperature and precipitation events, air pollution, water contamination, and diseases carried by ticks, mosquitoes, and rodents. While the causes of climate change are global, the health impacts manifest at the community level.

Although the precise health impacts associated with global climate change are unknown, political pressure to reduce CO_2 emissions is mounting. The Kyoto Protocol (1997) called for the reduction of greenhouse gas emissions 5 percent below 1990 levels by 2012. While the United States is not a signatory, as of January 2013 mayors of 1054 U.S. cities representing more than 88 million citizens—from the Northwest to the Deep South and every state in between in addition to the District of Columbia and Puerto Rico—have signed on through the 2005 U.S. Mayors Climate Protection Agreement (U.S. Conference of Mayors 2013). This Agreement is precautionary in nature; by taking steps now, its signatories hope to avoid or reduce future adverse impacts through "...bold action to significantly reduce carbon emissions in cities" (U.S. Conference of Mayors 2009). Ultimately, greenhouse gas reductions can only be achieved through strategies that target both the transportation and building sectors and development and urban planning philosophies that underlie twentieth-century suburban development patterns.

Physicians and public health professionals are connecting the dots between climate change and public health. Recognizing that "no scientific doubt remains about the causes of climate change," Aaron Bernstein, MD, MPH challenges us to provide a resilient healthcare infrastructure: one that functions in the face of natural calamities and serves as an example of twenty-first-century design strategies for patients and communities, reinforcing the potential for mutually beneficial connections between technology, our planet, and people.

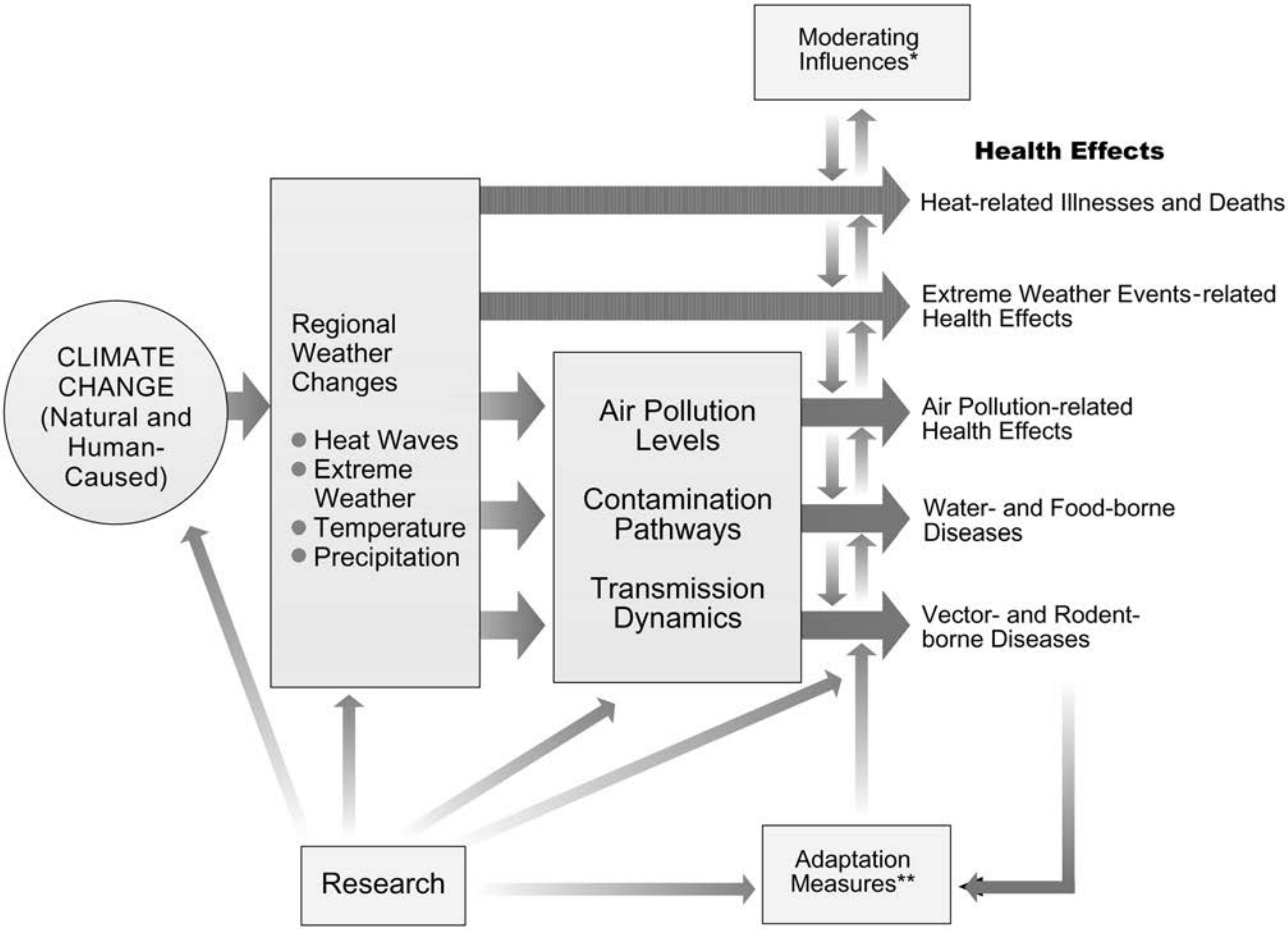


Figure 2.1 Potential health effects of climate variability and change.

*Moderating influences include nonclimate factors that affect climate-related health outcomes, such as population growth and demographic change, standards of living, access to healthcare, improvements in healthcare, and public health infrastructure.

**Adaptation measures include actions to reduce the risks of adverse health outcomes, such as vaccination programs, disease surveillance, monitoring, use of protective technologies (e.g., air-conditioning, pesticides, water filtration/treatment), use of climate forecasts and development of weather warning systems, emergency management and disaster preparedness programs, and public education. *Source: United States Global Change Research Program (USGCRP) 2001*

WHERE WE HEAL: THE IMPORTANCE OF HEALTHCARE BUILDINGS TO OUR HEALTH AND THE PLANET'S

By Aaron Bernstein, MD, MPH

Dark, drab, and impersonal, too many healthcare buildings have stood in opposition to the wellness of their occupants. Their existence belies the seemingly obvious premise that our physical surroundings matter to healing. This disconnect between people and place emerged as medicine itself ceaselessly reached for new scientific and technologic heights over the past century. As medicines grew more effective, diagnostic tests more abundant, and surgeons more skillful, credence in the relevance of the environment in which these advances were realized to health faded, unwittingly, from attention.

In the same way that technology fostered an inadvertent distraction as to how a building's design may influence the health of its occupants, it has likewise enabled a striking detachment between people and their surroundings more broadly, and especially with nature. Not more than 150 years ago did nearly all of us farm or gather our own food. Technology released most us from the land, and most of us have since moved to cities. As urbanites we largely have no idea where our food and water comes from or where our wastes go, and weather has become increasingly irrelevant to what we may do from day to day. In short, our technological success has opacified the influence of nature upon our lives.

With the consequences of our actions inapparent to us, indifference to redressing global environmental changes, even when those changes—such as climate change—bespeak calamity for our species and countless others upon which our health depends, becomes easier to understand.

Our lack of action does not stem from a lack of knowledge. Scientists, starting with the Nobel Prize–winning physicist Svante Arrhenius in 1896, have predicted that the addition of so-called greenhouse gases into Earth's atmosphere, primarily from the burning of fossil fuels such as coal, oil and natural gas, would have an overall warming effect upon the planet. Today, no scientific doubt remains about the causes of climate change, and the untoward health effects of climate change are becoming clearer with each passing year.

Extra heat trapped in Earth's atmosphere has fueled more frequent and intense heat waves and more severe floods and droughts, all of which directly endanger, among other essential items for our health, the crops and animals we rely upon for food. Warming swells the oceans and melts sea ice bringing about rising seas that imperil the livelihoods of millions of coastal dwellers as coastal groundwater stores turn brackish or higher seas inundate homes and agricultural lands.

Floods, droughts, and heat waves, in addition to their potential to exact a health toll directly, also test the resiliency of the healthcare infrastructure itself. In the wake of Hurricane Katrina, for instance, 900,000 people were displaced as large swaths of New Orleans were inundated, and most of the city's hospitals were rendered useless. Nearly 1,500 people died. During heat waves, such as those of Chicago in 1995, Europe in 2003, and Russia in 2010, victims of the heat flocked to hospitals and clinics in search of care and comfort, often overwhelming their capacities to do so. All too often during such extreme weather, power sources fail and hospitals rely on an electricity stopgap from diesel fuel generators that churn out air pollutants. This is a particularly unwelcome turn of events during heat waves when air quality is often already poor, in no small part owing to the ability of heat to spur the production of ground level ozone, a potent lung irritant that triggers breathing troubles for those with chronic lung diseases, including asthma.

Fortunately, architects and engineers have been on the leading edge of needed reforms in light of what climate change portends. They have led quests to find new and more effective ways to reduce the consumption of energy and other resources of buildings. The U.S. Green Building Council has in part catalyzed this reformation through establishing and refining LEED criteria, and their success reflects a wider, and encouraging, trend in how we think about the energy use of our built environments. Buildings consume the lion's share of energy in developed countries. In the U.S., nearly 40 percent of greenhouse gas emissions derive from buildings, and on a per square foot basis, healthcare buildings, especially hospitals, which are roughly 3 times as energy intensive as outpatient buildings, are some of the most energy intensive in the world.

Starting with cost savings, hospitals and other healthcare facilities have many reasons to conserve energy. Less power consumption also means healthier people through reduced pollutant emissions. For most of us, our electricity largely originates from burning fossil fuels, especially coal, which in addition to producing carbon dioxide (the most influential greenhouse gas), releases a host of noisome pollutants, from air particulates (microscopic bits of organic matter suspended in the air) to mercury, which are well known to damage hearts, lungs, and developing minds.

Fewer greenhouse gas emissions from healthcare facilities will not, in and of themselves, markedly slow the warming of the planet or cure the chronic health issues related to air quality. But actions to this end can and do set a powerful example to demonstrate that acting to protect the climate, and hence our health, can be done without fiscal pain. In terms of financial performance, payback for energy efficiency measures often comes within a few years. Switching to LED lighting, for instance, can dramatically reduce the roughly 10 percent of hospital energy budgets that goes into lighting and often pays for itself within 5 years.

More influential than energy savings themselves, however, may be the example these buildings set for patients and communities. If we are to bridge the disconnect between our technology, our planet and ourselves, we must do more to showcase the instances when all three stand to mutually benefit. The ever-growing number of hospitals and clinics that have markedly lowered their energy use serve as potentially superb examples to this end. Beyond energy savings, sustainable features can be put on display for people seeking care or convalescing. Green roofs can at once save energy, capture carbon dioxide, reduce runoff after heavy storms that can lead to waterborne disease outbreaks, and, preliminary evidence suggests, make people healthier, faster. Choices about what food is served to patients likewise can have multiple benefits. More fruits and vegetables, particularly if locally grown, and less meat promote health and lowers greenhouse gas emissions.

In short, as healthcare architecture hews a truer line to the purpose of healing, it holds the tantalizing potential to do much more to help ensure the healthiest possible future for all.

URBAN PLANNING AND PUBLIC HEALTH

By the middle of the nineteenth century, business leaders, physicians, planners, and architects throughout the industrialized world saw daily the effects of unhealthy urban environments. Most evident were communicable diseases—cholera and tuberculosis, for example—associated with poor housing conditions, overcrowding, limited access to light and air, unfit drinking water, mosquitoes, and uncarted waste. Virtually every family had lost a loved one to an infectious disease of environmental origin. Controlling these diseases required improved sanitation, urban planning, and building regulations.

In the United States, more than just engineers and doctors pressed for the funding for large urban improvements and public sanitation efforts. In 1890, Jacob Riis, a newspaperman, published his book *How the Other Half Lives;* in it he described the appalling conditions in which immigrants in New York City lived (Riis 1890). The book strengthened the anti-tuberculosis movement's arguments for improved housing and led to the enactment of zoning and building regulations that provided for increased ventilation and access to light and air (Crisci 1990).

Such infrastructure improvements could not have occurred if each of the professions had remained isolated within its specialty. According to physician and public health advocate Richard Jackson, MD, MPH, "Doctors had to care about sewers, architects about sunlight, and politicians about public health accountability." The success of these efforts has been magnificent. Average American life spans have doubled since that time—from forty to eighty years—and only a small part of those added years have come from medical care. Most of the decreased mortality can be attributed to better housing, nutrition, water, workplaces, and immunizations (Preston 1996).

This public health approach to design extended to hospital environments as well. In the nineteenth century, the view that the circulation of fresh air was the primary requirement for institutional health was unchallenged. Medical historian Charles Rosenberg (1987) observes:

> Hospital planners, including Florence Nightingale, were quick to invoke arbitrary but seductively precise formulae for the numbers of cubic feet each hospital patient (or schoolchild or tenement dweller) required to avoid infection. The maintenance of health reduced itself to the placement of beds and windows, the arrangement of flues and ventilators, and the proper design of heating systems.

Sociologist Paul Starr (1949) observed that ideas about dirt have serious political implications, as is evidenced by today's environmental struggles. "A broad conception of dirt," he noted, "may imply a need for a correspondingly large investment in cleaning things up. A more narrow conception may be much cheaper." Despite the major health advances, the turn of the twentieth century brought forward the idea that dirt, per se, did not cause infectious disease. By 1910, a reconsideration of public health advocacy initiated a "new public health," with two defining characteristics: an emphasis on education in personal hygiene, and the role of the physician to examine and diagnose.

The separation of diagnosis from treatment, of public health from allopathic medicine (and more generally preventive medicine from curative medicine), was the beginning of the fragmentation of the medical system—a fragmentation that remains with us today. Likewise, the separation of public health from urban planning—resulting in the rise of the suburb and automobile-oriented land use and development patterns in the United States—has engendered a set of emergent chronic health issues. Ranging from the increase in asthma among children in urban populations to obesity and diabetes in the general population, these chronic diseases, many of epidemic proportion, are challenging the delivery of healthcare in terms of both cost and scale of services.

In response, public health practitioners are reinvigorating the relationship between urban planning and public health. The American Public Health Association's 140th Annual Meeting in 2012 had as its theme, Prevention and Wellness Across the Life Span, with several sessions focused on environmental, social, and behavioral issues that influence health across the life span, including sustainable communities that promote healthier lifestyles, physical fitness, and environmental exposures. Physicians and public health advocates Richard Jackson, MD, MPH and Marlon Maus, MD, MPH (2008), argue that the U.S. healthcare system, already the largest and most resource-intensive in the world, will be unable to provide the clinical services required to "clinically solve" the twenty-first century's chronic disease challenges of obesity, diabetes, depression, and asthma, and offer a vision of prevention through design that designers and healthcare executives alike should heed (see sidebar and Figures 2.2 and 2.3).

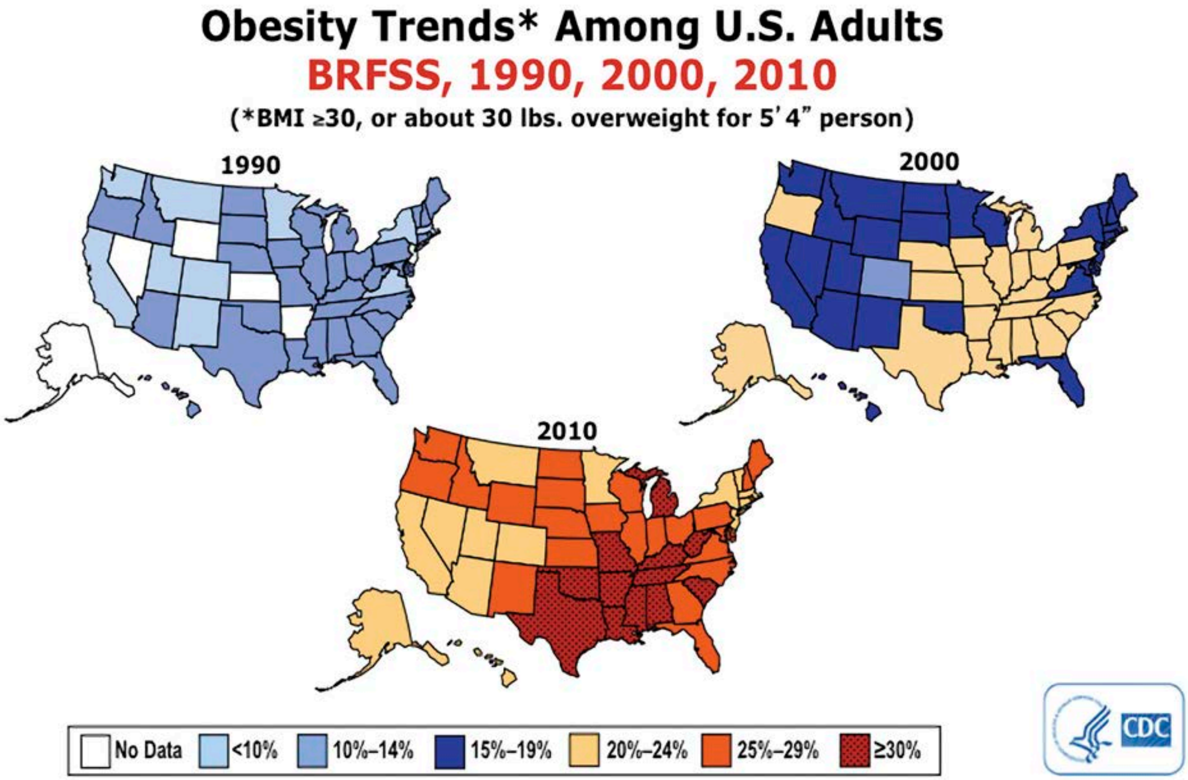
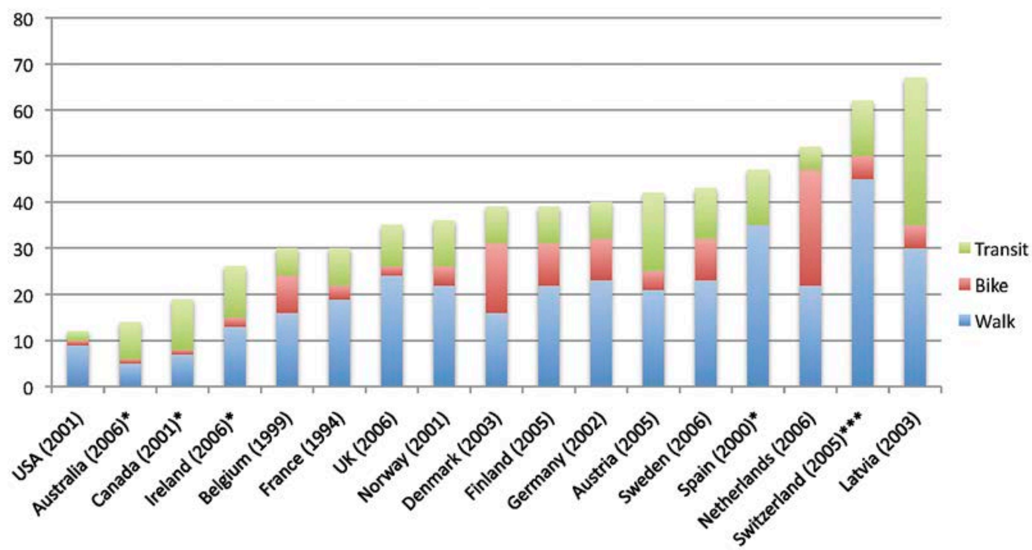


Figure 2.2 Obesity among adults by state. Obesity is defined as a body mass index of greater than 30, corresponding to a weight of about 185 pounds for a height of 5′ 6″, 210 pounds for a height of 5′ 10″, and 230 pounds for a height of 6′ 1″. The states in white (in the 1991 map) are missing data. The shades of gray correspond to the obesity prevalence percentage shown in the legend. *Source: CDC 2012*

Figure 2.3 Proportion of trips in urban areas made by walking, bicycling, and transit (2008). A combination of more walkable built environments and different social attitudes results in a dramatic increase in walking in other countries. *Source: D. R. Bassett et al. 2008*



We need to belong to a community—one that is the hub and support for the important tasks of life: working, playing, learning, shopping, socializing, rejoicing, and mourning. Well-designed communities make this much easier. To accommodate the growing population and at the same time increase social capital we must re-create denser communities that have privacy, safety, beauty, tranquility, and culture. Such communities need to cluster near mass transit; people who use mass transit walk more and pollute less. Well-designed communities can also be safe havens during the weather disasters that climate change will bring us. Green and sustainable building and community design must advance past sustainability and become restorative.

The biggest challenge is not knowledge (though plenty more research is needed) and it is not good will (we all want to give our children a planet as healthful, diverse, and beautiful as the one we were given). The biggest challenge is one of leadership. We need to articulate and take ownership of a vision of healthy communities that provide optimal support for families, children, old people, workers, and parents, as well as the natural world around us. The importance of the healthcare industry's leadership in advocating for this vision cannot be underestimated. Much more can be accomplished to improve health when communities are well designed—when they are a place of the heart, as well as the wallet.

SOURCE: JACKSON AND MAUS (2008)

SPRAWL AND AIR QUALITY

Smart Growth Vermont (2012) defines sprawl as "dispersed, automobile-dependent development outside of compact urban and village centers, along highways, and in the rural countryside." Sprawl is associated with increased vehicle miles traveled. In spread-out cities like Atlanta and Houston, there is as much as 50 percent more vehicle miles traveled per capita than more-compact cities with similar populations. This assessment comes from T. Keith Lawton (2001), transportation planner in Portland, Oregon, who comments, "When looking at the amount of travel in U.S. cities, it is clear that those cities with lower densities and a larger road supply consume significantly more vehicle miles of travel." Likewise, Australian transportation scholars Peter Newman and Jeff Kenworthy (1998, 1993) have revealed the same relationship on a global scale—comparing decreased urban density with increased vehicle miles traveled. More vehicle miles generate more vehicle exhaust, which in turn results in reduced air quality. Exposure to air pollution has public health consequences. Ground-level ozone can exacerbate respiratory illness and reduce lung function. Exposure to carbon monoxide, sulfur dioxide, and nitrogen dioxide can cause respiratory illnesses and alter the lungs' defense systems (USGCRP 2001). Figure 2.4 provides a model for the health linkages between these factors.

Numerous studies link increases in emergency department visits with increases in community ozone levels. One study links these increases to motor vehicles. During the Atlanta Olympic Games in 1996, morning peak traffic flow decreased by 22 percent, one-hour peak ozone levels decreased by 28 percent, and various measures of acute asthma decreased between 11 percent (for emergency hospital admissions) and 44 percent (for urgent care through health maintenance organizations) (Friedman et al. 2001; Frumkin, Frank, and Jackson 2004).

Increasing temperatures in urban areas are another manifestation of global warming. In heat-sensitive regions, populations in urban areas are most vulnerable to adverse heat-related health outcomes. Heat indices and heat-related mortality rates are higher in the urban core than in surrounding areas, a situation exacerbated by air conditioners, which transfer heat from building interiors to the outdoors. For urban residents, the absence of nighttime relief from heat is a factor in heat-related deaths.

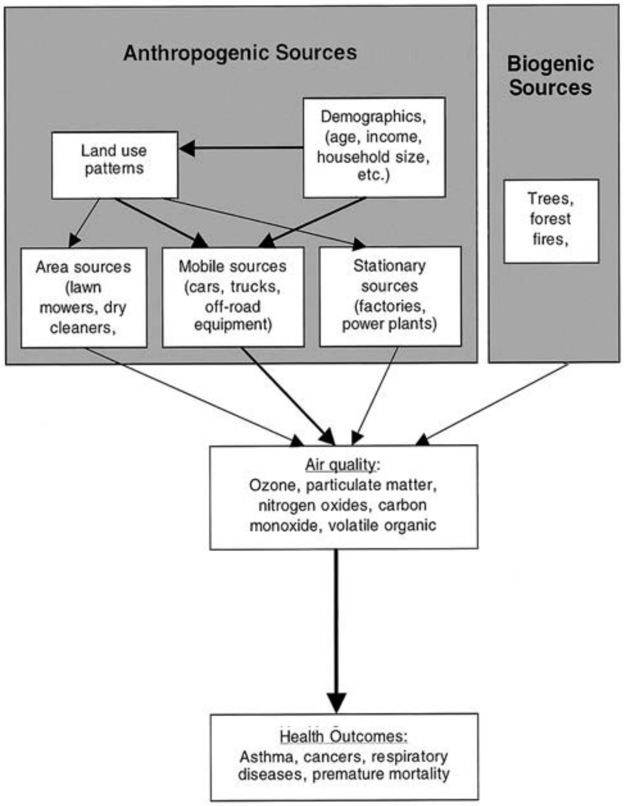


Figure 2.4 A conceptual model links sprawl, travel, air pollution, and health. Two types of pollutants—anthropogenic (man-made) and biogenic (natural)—are depicted. Anthropogenic sources come from mobile, stationary (point), and area sources, which combine to release a variety of air pollutants. Air quality, in turn, has a causal effect on human health. *(Frumkin, Frank, and Jackson 2004)*

In 1995 during a five-day heat wave in Chicago, maximum temperatures ranged up to 104°F. The number of deaths increased 85 percent over the number recorded during the same time period the preceding year. At least seven hundred excess deaths were recorded, most directly attributable to the heat. The elderly, young children, the poor, and people who had underlying medical conditions were at particular risk (USGCRP 2001). The 2011 heat wave spread across the Midwest, Great Plains, and Southern regions of the United States, resulting in heat advisories and warnings affecting approximately 141 million people and heat index values approaching 131°F (Park 2011).

SMART GROWTH AND HEALTHY CITIES

It is a cruel irony that the development of low-density suburban neighborhoods that many critique from a public health perspective was in some respects a public health response to the overcrowded urban experience. Just as the public health infrastructure advanced through zoning and building regulations, improving urban health, the invention of the automobile fed the growing belief that suburban living was healthier. As the results of this belief contribute to a new age of chronic health diseases, organizations dedicated to reinvigorating a healthy, higher-density, development model have emerged.

In 1987, the World Health Organization initiated its Healthy Cities Project. Representing about ninety member cities of the WHO European Healthy Cities Network, and thirty national networks in Europe, North America, and Australia, its members are "conscious of health and striving to improve it" through a portfolio of activities. The program's major focus is health promotion; more than six thousand cities around the world have undertaken many of its missions (WHO/Europe). Corresponding initiatives such as the California-based Healthy Communities Institute are leveraging the global momentum with the development of a data and decision support information system to improve indicator tracking, best practice sharing, and community development (www.healthycommunitiesinstitute.com).

In 1996, the U.S. Environmental Protection Agency (EPA) and several nonprofit organizations formed the Smart Growth Network (www.smartgrowth.org) to assist communities in boosting their economies, protecting their environment, and enhancing their vitality. Smart Growth Network strategies include mixed land use, decreased automobile dependence balanced by transportation alternatives, and increased density balanced by the preservation of undeveloped green space. Related initiatives include the Congress for the New Urbanism

Smart Growth Principles

- Mix land uses
- Take advantage of compact building design
- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Strengthen and direct development toward existing communities
- Provide a variety of transportation choices
- Make development decisions predictable, fair, and cost effective
- Encourage community and stakeholder collaboration in development decisions

Source: Smart Growth Network 2006

(www.cnu.org), a planning and architecture movement with similar goals. New Urbanism argues for a return to traditional neighborhood development—the compact, higher density, mixed-use, transit-oriented, walkable developments that were the norm prior to the 1950s. All of these initiatives aim to mitigate the health and social consequences of sprawl.

A final related initiative is the Community Indicators Movement. More than 250 communities in the United States—from Missoula, Montana, to Jacksonville, Florida—have developed alternative approaches to measure progress and engage community members in a dialogue about health, the future, and changing community outcomes (Community Indicators Consortium 2012). Some use a healthy communities framework, while others focus on sustainability. The common goal is to bring diverse community sectors together, foster new alliances and relationships, provide citizens with the tools to understand problems and opportunities, and foster healthy change. These initiatives provide the healthcare sector—a major employer and service provider within local economies—increasing opportunities to advocate for healthy planning and design innovation.

With obesity now a reality for more than one-third of the U.S. adult population and about 17 percent of children aged two to nineteen years, where we locate buildings and how they are designed and operated has emerged as a critical causal link to this alarming contemporary public health crisis (CDC 2012). These trends are not limited to the United States. Indeed, the World Health Organization estimates that worldwide obesity has more than doubled since 1980; in 2010, more than 40 million children under the age of five were overweight. Overweight and obesity rank as the fifth leading cause of death worldwide (second in the United States). Somewhat counterintuitively, overweight and obesity represent more annual deaths globally than underweight. As in the United States, causal factors include high fat and caloric diet and lack of physical activity. Both are preventable with lifestyle changes that lead to healthier diet and increased physical activity (WHO 2012).

ACTIVE DESIGN

The built environment has a particularly consequential role to positively influence physical activity. As physician Karen Lee and architect Joyce Lee persuasively express in their essay that follows, *Active Design: Converging Design Efforts to Promote Environmental Sustainability and Address Today's Leading Causes of Death,* tangible solutions to this challenging public health reality are emerging. Lee and Lee describe their groundbreaking effort in developing New York City's *Active Design Guidelines.* The *Guidelines,* released in 2010, serve as a primer to planners, designers, building owners and managers, and policymakers on a new decision-making framework to encourage high levels of physical activity associated with the buildings we occupy.

ACTIVE DESIGN: CONVERGING DESIGN EFFORTS TO PROMOTE ENVIRONMENTAL SUSTAINABILITY AND ADDRESS TODAY'S LEADING CAUSES OF DEATH

Karen K. Lee, MD, MHSc, FRCPC
Joyce S. Lee, FAIA, LEED AP

Non-communicable diseases (NCDs), such as heart disease and stroke, chronic lung diseases, cancers and diabetes, have overtaken infectious diseases as the leading causes of death, accounting for over 36 million deaths annually around the world. The situation is considered so urgent that a UN General Assembly Summit in September 2011 focused on NCDs as its key theme, identifying four leading risk factors: tobacco use, physical inactivity, harmful use of alcohol and poor diets (WHO 2011). Lessons from the history of public health and the control of infectious diseases demonstrate the need for design and environmental interventions in the control of diseases and epidemics.

In the United States, obesity is the second leading cause of death (after tobacco), and physical inactivity is the fifth leading cause. Physical inactivity also contributes to the second, third and fourth leading causes of death—obesity, high blood pressure and high blood glucose, respectively (Danaei, Ding and others 2009). Obesity, and with it, type 2 diabetes, are epidemic and have been rising rapidly. In the U.S., obesity has doubled in adults and tripled in children since 1980 (USCDC 2011). If current trends continue, 51% of adults and 30% of youth are projected to be obese by 2030 (with another 35% of adults overweight but not obese). By 2030 obesity-related costs will have doubled every decade, to equal nearly one trillion dollars annually (Sturm and others 2007).

The scientific evidence for the important role that our daily environment plays in supporting regular physical activity, better dietary behaviors and healthier weights, and protecting the environment is mounting. Environmental design solutions, such as those offered in New York City's *Active Design Guidelines,* employ a variety of building, street and neighborhood design strategies to improve both health and the environment.

Active Design

"Active Design" refers to design strategies for creating buildings, streets and neighborhoods that promote physical activity and health. The term is derived from New York City's *Active Design Guidelines* (2010) (www.nyc.gov/adg), a manual of environmental design strategies intended for design, planning, policy, and real estate professionals. Wherever possible, Active Design strategies also seek to promote environmental sustainability and universal accessibility. Key components of the *Active Design Guidelines* are:

1. *Active Transportation, rather than automobile use, in streets and neighborhoods.* Walking, bicycling and use of mass transit for public transportation, and environments supportive of these modes, rather than automobile use, have been associated with increased physical activity (Frank and others 2004, Wener and Evans 2007, Rundle and others 2009), as well as improved air quality (Goldberg and others 2007) and reduced oil consumption.
2. *Active Vertical Circulation within buildings, promoting the use of stairs and ramps, rather than elevator and escalator use.* Buildings constitute an opportunity for daily "active living"—a way of life that integrates physical activity into the daily routine. Based on strong evidence, the U.S. Centers for Disease Control and Prevention's (CDC's) Guide to Community Preventive Services recommends the use of stair prompts, signs prompting stair use for health benefits, at elevators and escalators (TFCPS 2002, Lee and others 2012). Research has shown that stair and

elevator spatial and operational design strategies, such as improving stair visibility, convenience, width (Nicoll 2007) and aesthetics (Boutelle 2001, Kerr 2004), and decreasing elevator visibility, convenience, (Nicoll 2007), speed (Van Houton and others 1981), and stops (Nicoll and Zimring 2009) for those who are able to use the stairs can also promote stair use. Just two minutes of stair climbing daily could burn enough calories to prevent the average annual weight gain seen in U.S. adults (Zimring and others 2005). In one study, even less than that—just 20–34 floors of stair climbing per week (or ~3–5 floors per day)—was shown to be associated with a 29 percent decreased risk of stroke among men (Lee and Paffenbarger 1998). Since elevators routinely account for 3–5% of a commercial building's energy use (USDOE 2001), and an escalator running 24 hours a day 7 days a week can use enough electricity to generate about 4 car-loads of CO_2 per year (Toledo 2007), promoting routine stair use among those who are able also has the potential to reduce electrical energy and carbon emissions.

3. *Active Recreation, rather than television viewing and sedentary electronic recreation.* Television viewing has been associated with increased overweight and obesity, especially in children (Parsons and others 2008, Kaur and others 2003). Enhancing access to spaces for physical activity, such as parks and playgrounds, is associated with increased physical activity in children and adults (Potwarka and others 2008, Sallis and Glanz 2009) and decreased television viewing among children (Farley and others 2007). Thus, designing active recreation spaces has the potential to shift recreation time away from television viewing and electronically-based sedentary activities, increasing physical activity and contributing to energy savings and reduction in building-related carbon emissions.
4. *Tap water consumption, rather than consumption of bottled and canned caloric beverages.* In the U.S., per capita consumption of sugary drinks among adults is 200 calories per day (Bleich and others 2009), while consumption of sugary drinks and 100 percent fruit juice accounts for 10–15 percent of a child's caloric intake (Wang, Bleich, and Gortmaker 2008). Since these beverages are bottled and transported, their consumption also contributes to resources needed to make the cans and bottles (Gleick and Cooley 2009), to transportation-related environmental burdens, and waste generation. Thus, providing and enhancing access to tap water facilities can assist in achieving both health and environmental sustainability goals.
5. *Consumption of locally grown fruits and vegetables, rather than highly caloric, highly processed foods.* Many highly caloric foods are also processed foods that have high environmental burdens related to ingredient and product manufacturing, packaging and transportation, and waste generation. Providing healthy food options onsite and/or promoting nearby farmers' markets are examples of strategies for promoting both health and environmental sustainability.

Emerging Practices

LEED® Innovation Design Credit for Physical Activity

In 2007, the New York City Health Department and the New York City Department of Design + Construction teamed up with LEED consultants from 1100 Architects and Atelier Ten to create a new LEED Innovation Design Credit titled "Design for

Health through Increased Physical Activity" for the New York City Riverside Health Center, a Health Department clinic. The Active Design Innovation Credit was created to promote and protect health through physical activity. Since its approval by the U.S. Green Building Council in 2011, the Active Design Credit has successfully been incorporated into numerous project types in New York City and nationally, including the Lucile Packard Children's Hospital at Stanford (Case Study 11, Chapter 5).

Active Design Index

In 2011, based on the market's positive reception to and interest in the LEED Active Design Innovation Credit, the U.S. Green Building Council invited the New York City Health Department and Department of Design + Construction to assist in the development of an Active Design Index. This Index will assess all LEED projects on their potential to increase physical activity. A Health Advisory Committee of national physical activity, and built environment and health experts has been assembled to participate in the development process; it has rated existing LEED Credits and their various credit options in the Commercial Interiors, New Construction, and Neighborhood Development LEED Rating Systems for their potential to impact physical activity through the 10 following parameters:

1. Active Transport/Circulation Within Buildings: Adult (Incidental)
2. Active Transport/Circulation Within Buildings: Children (Incidental)
3. Active Transport Between Buildings: Adult (Incidental)
4. Active Transport Between Buildings: Child (Incidental)
5. Active Recreation Within Buildings: Adult
6. Active Recreation Within Buildings: Child
7. Active Recreation Between Buildings: Adult
8. Active Recreation Between Buildings: Child
9. Crime Safety (known to be associated with physical activity)
10. Traffic Safety (known to be associated with physical activity)

AIR POLLUTION

In addition to the individual-scale health issues that arise from community planning decisions, a range of community-scale health issues are associated with local point sources of chemical contamination, most of which affect either air or water. Many of these stressors are related to commonly manufactured materials and products. In fact, most of what we know about the impacts of exposures to industrial pollutants—silica, asbestos, tobacco, and other materials—has been learned through studies of industrial workers since the Industrial Revolution (Christiani 1993).

Since the advent of the twentieth century, whole communities have been engulfed by air pollution, resulting in serious illness and death from cardiopulmonary disease. In her book *When Smoke Ran Like Water* (2002), environmental health expert Devra Davis recounts the story of Donora, Pennsylvania, in 1948. In the worst of such episodes, in London in 1952, the death toll exceeded four thousand. Based on these incidents, individual governments moved to enact laws aimed at improving air quality. But pollution knows no boundaries or national borders. With continued population growth and worldwide industrial expansion, worldwide air quality, including indoor air quality, continues to decline.

In fact, indoor air pollutants remain a leading factor in the high mortality rates for acute respiratory disease, causing about 2 million premature deaths primarily in developing countries; almost half of these deaths are attributed to pneumonia in children under five (WHO 2011). In the United States, air pollution is among the leading causes of increased asthma rates in children, affecting one in twenty children (Figure 2.5).

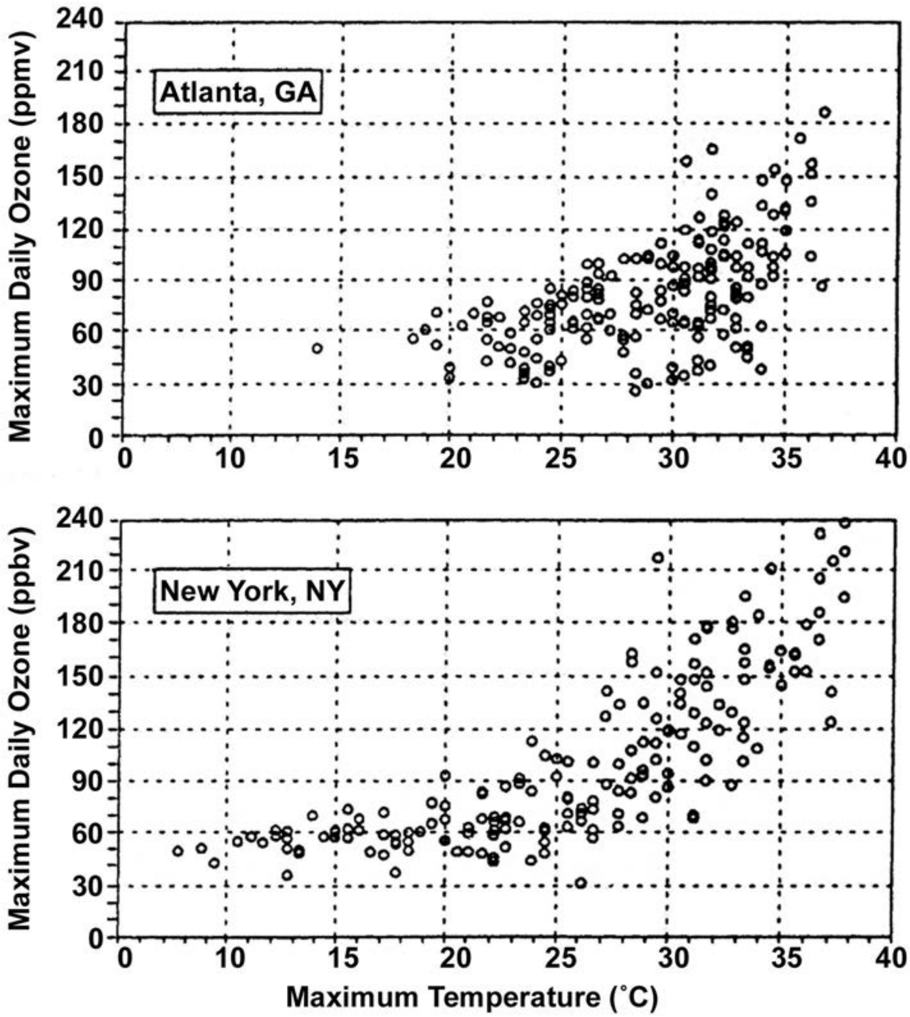


Figure 2.5 Ground-level ozone concentration and temperature. These graphs illustrate the observed association between ground-level ozone concentrations and temperature in Atlanta and New York City (May to October 1988–1990). Projected higher temperatures across the U.S. in the twenty-first century are likely to increase the occurrence of high ozone concentrations. Ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function. *(USGCRP 2001)*

WATER POLLUTION AND SCARCITY

John Snow's 1854 discovery that cholera was being spread from a water pump in London energized the efforts to improve the infrastructure of cities worldwide. It was not until the 1970s, however, that the hazards associated with industrial and agricultural activity were deemed a major threat to water supplies—including for potable water. Despite the major improvements, the threat to human health posed by both potable water contamination and scarcity remain high. As of 2012, the World Health Organization/UNICEF estimated that while more than 2 billion people around the world have benefited from access to improved drinking water, about 780 million people still lack access to it (World Health Organization/UNICEF 2012). Water contamination is often difficult to detect, and many chemicals once thought to be safe are now believed to be hazardous (Hu and Kim 1993).

According to the EPA (2000), the contamination of groundwater with relatively new contaminants (i.e., methyl tertiary butyl ether, or MTBE) is increasing. Groundwater remains the source of drinking water for almost half the nation's population. The built environment is directly responsible for ten of the top twenty sources of its contamination. The most prevalent contaminants are heavy metals (lead, arsenic, cadmium, and mercury) and volatile organic chemicals (gasoline and the halogenated solvent trichloroethylene) (see Figure 2.6). In addition, water contamination affects the food chain, hence the widespread health advisories against consuming fish or shellfish products.

The story of the Gaviotas Hospital in Colombia, South America, offers an inspiring example of a fundamental shift away from treating disease to promoting health, through their effective appropriate technology approach to water treatment (see sidebar). Visionary developer Paolo Lugari, founder, noted that social exper-

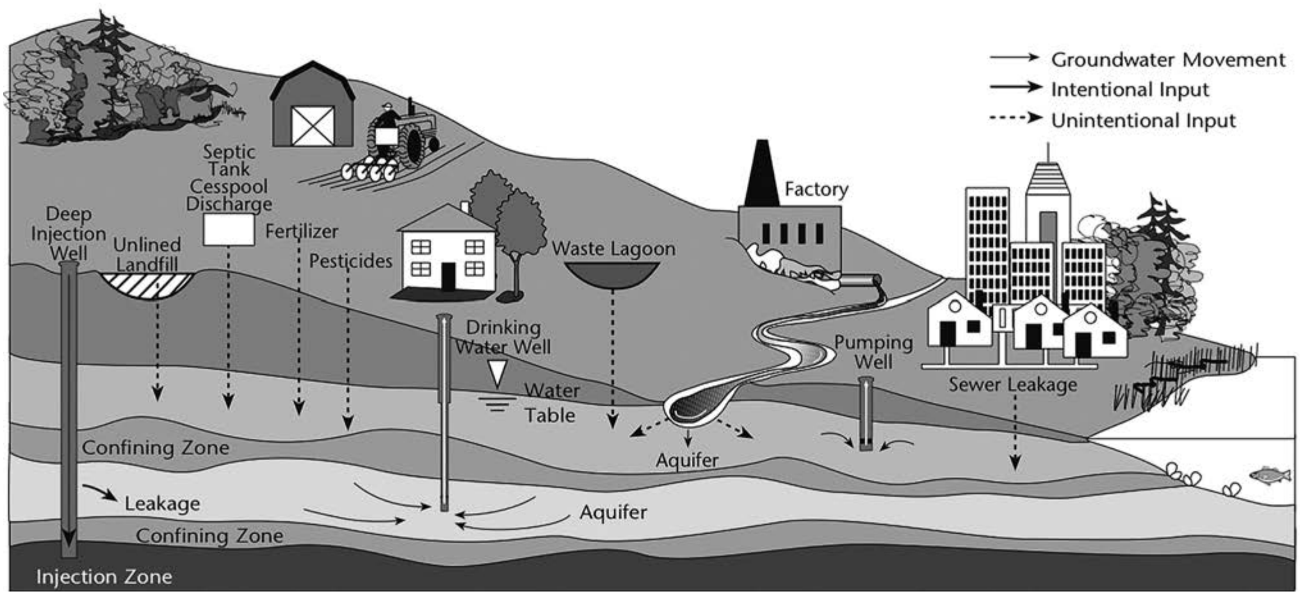


Figure 2.6 Sources of groundwater contamination. Groundwater contamination can occur from point sources such as leaking underground storage tanks, spills, landfills, waste lagoons, and industrial facilities. Groundwater quality degradation can also occur over a wide area due to diffuse nonpoint sources such as agricultural fertilizer and pesticide application. In some cases, contaminants introduced into the subsurface decades ago are only now being discovered. *Source: EPA 2000*

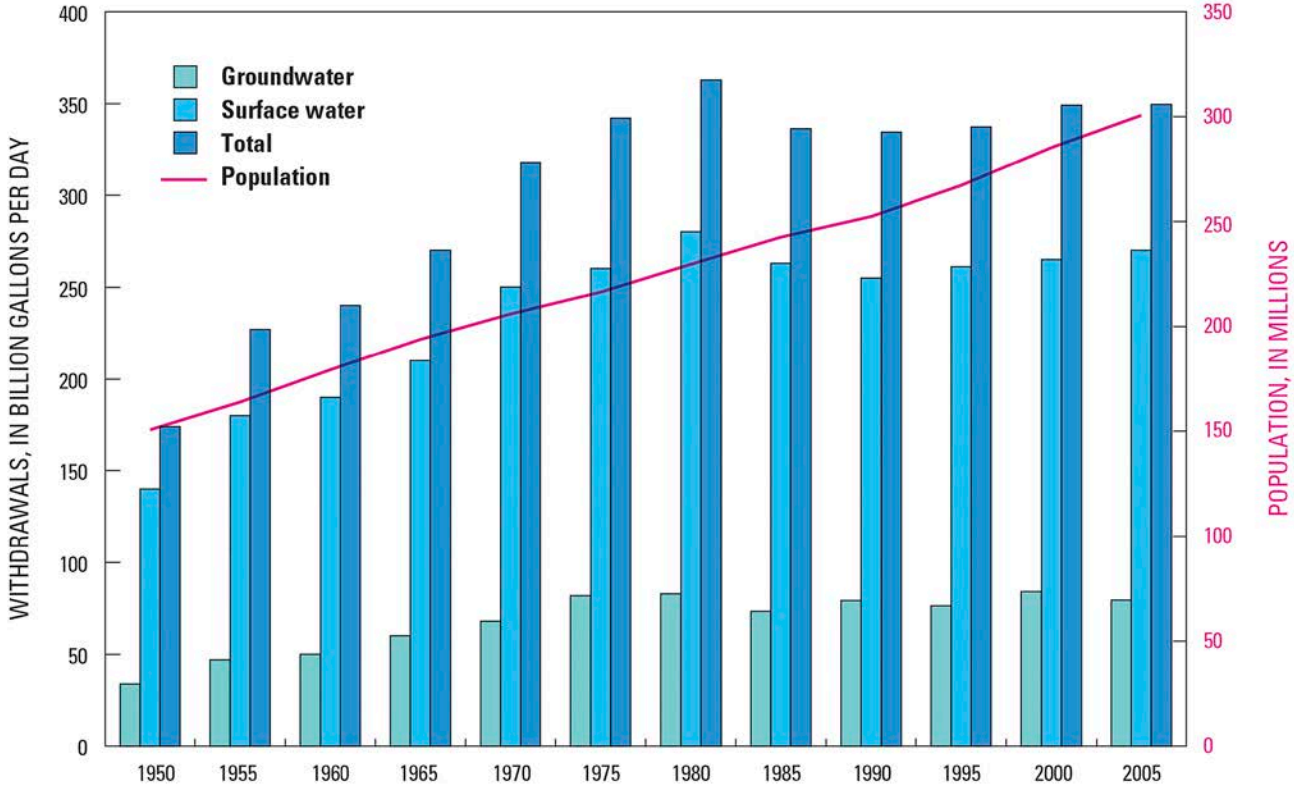


Figure 2.7 Water withdrawals and population trends in the United States. Although U.S. population has continued to increase, water withdrawals have declined on a per capita basis. Reductions are due to increased efficiency and recycling in some sectors, and a reduction in acreage of irrigated agriculture. *Source: USGS (2011)*

iments cannot simply import solutions from temperate climates, and sought a unique bioregional solution for delivering much-needed healthcare services.

Overall U.S. trends in water withdrawal are encouraging. While the population continues to increase, Figure 2.7 suggests that total water withdrawals are leveling (USGS 2011). Industries that consume large amounts of water have been actively engaged in curbing their water usage, while improvements in irrigation methods have also contributed to this leveling trend.

These trends, however, can be misleading. Water availability is not uniform across the United States. Arid regions of the Southwest, for example, struggle with chronic potable water shortages. Areas in the Midwest, dependent on the Ogallala Aquifer, are withdrawing potable water far faster than the natural recharge rate. In 2012, more than 64 percent of the contiguous United States experienced moderate to exceptional drought (NCDC 2012) rivaling the historic droughts of the "dustbowl" of the 1930s, and coincided with the hottest July on record. Municipalities in drought-prone areas are installing recycled water infrastructure (Austin, Texas, calls its reclaimed water system the "purple pipe" because of its distinctive color to differentiate it from potable water supply). These systems reduce the use of potable water for irrigation and process uses. Likewise, many cities also require stormwater management design strategies to maximize groundwater recharge in an effort to sustain potable water sources.

Gaviotas Hospital

Vichada, Colombia

Gaviotas is a self-sufficient community of about 200 people, founded in 1971 in the remote savannas of eastern Colombia. The sixteen-bed 7,266 sq. ft. (674 sq. m) solar-powered hospital was designed and built between 1982 and 1986. Heralded by a Japanese architectural journal in 1995 as "one of the thirty most important buildings in the world," the hospital—elegant in its pragmatic functionality—manifests humanistic core values that underscore Gaviotas's self-declared identity as "an oasis of imagination and sustainability" (Friends of Gaviotas 2007).

When the Gaviotas community began, many people were suffering from gastrointestinal disorders attributable to unclean drinking water. Adhering to the Gaviotas way of life, villagers created the hospital in a participatory, experimental, socially conscious, and environmentally sound manner. The hospital's provision of purified water using simple solar distillation technology immediately reduced deaths and illnesses previously plaguing villagers.

As with all Gaviotas's buildings, the hospital functioned off-the-grid, relying on solar and wind power for its modest energy demands made possible, in part, by passive cooling design strategies (Figure 2.8). Underground ducts enabled the building's interior to maintain cool temperatures by creating a convective loop: cool underground air entering the building, and warmer air escaping through honeycombed-shaped air channels in the double-layered corrugated roof. Despite frequent 100 percent humidity, a passive dehumidification system inspired by the workings of a termite mound contributed to comfortable indoor conditions—the surgical room maintained 17 percent humidity year-round.

The Gaviotas hospital was forced to close between 1997 and 1998 due to the Colombian government's prohibition of hospital operations lacking a minimum level of equipment, staff, and insured patients and now operates as a purified water-bottling plant. The hospital—reborn as a water purification plant—services the community through prevention rather than treatment providing clean drinking water that offsets the need for acute medical care (Figure 2.9).

Sources: Friends of Gaviotas 2007; Weisman 1995, 1999)

▲ **Figure 2.8** The Gaviotas hospital. *Source: ZERI Foundation*

► **Figure 2.9** The water purification plant relies on simple, appropriate technology and addresses an urgent public health need for clean water. *Source: ZERI Foundation*

INDOOR AIR QUALITY

No discussion of the impacts of the built environment on human health can be complete without acknowledging the health impacts of indoor air quality. The EPA estimates that people spend 89 percent of their time indoors, with the balance split between automobiles (6 percent) and outdoors (5 percent). Further estimates suggest that the level of pollutants indoors is up to five times greater than outdoor levels. Extensive driving not only impacts pollution levels within the air shed, but also creates particular problems for those people who spend much of their time in cars (Frumkin, Frank, and Jackson 2004).

Asthma affects almost 25 million people in the United States, including almost 7 million children (EPA 2011). Since 1980, the largest increase in asthma cases has been in children under five. In 2011, there were nearly 2 million emergency room visits and over 15 million physician office and hospital outpatient visits due to asthma, at a cost of almost $20 billion and 10.5 million missed school days (EPA 2011). In addition to concerns about outdoor air pollution, increasing scrutiny of indoor pollutant sources, ranging from dust to formaldehyde, and from phthalate plasticizers to pesticides to cleaning products, is yielding new data about the importance of source control as in the example of the Atlanta Olympics.

According to the National Institute for Occupational Safety and Health (NIOSH), occupational lung disease, including occupational asthma, is the leading work-related disease (NIOSH 1988). As a group, healthcare workers account for more than 40 percent of occupationally related adult-onset asthma with exposures tied to cleaning products (Rosenman et al. 2003). Because of concerns for worker safety, a new generation of "greener cleaners" is being introduced in healthcare settings.

CONCLUSION—THE FUTURE

According to the U.S. Census Bureau, the population is projected to increase to 571 million—nearly double today's population—by 2100 (U.S. Census Bureau 2000). Metropolitan areas will continue to grow at rates faster than other areas. The challenge is not to marshal the resources to construct ever-larger emergency departments to service ever-expanding populations with asthma related to air pollution or intestinal disorders from contaminated water. Rather, it is to make compelling arguments within communities that these problems are increasingly overburdening our healthcare system and consuming an ever-greater percentage of our paychecks and gross domestic product.

A larger healthcare infrastructure will mean more energy, more materials, and more development. The opportunity before us, and the healthcare industry, is to support and advocate community growth that is healthy, socially just, and environmentally sustainable. Redefining and redesigning healthcare's built environment—including its infrastructure—will relieve the ecological resource burdens within communities associated with an expanding healthcare sector. Indeed, the healthcare sector can use its prominence and scale to transform the built environment, rather than be victimized by this vicious cycle. As is increasingly made clear by public health practitioners and others, there is no basis for the belief that we can improve health without a public health approach to chronic disease issues: We never have.

Transforming the materials marketplace and its mechanical systems—the buildings' lungs—in the service of indoor air quality will be challenging; however, the journey is underway. The healthcare industry's enormous purchasing power, advocating for standards such as California's Section 01350 and the emerging Health Production Declaration, greener cleaning products, and improved indoor air quality, can have a positive impact on moving toward cleaner production.

For those who believe that this upstream, precautionary approach is outside the realm of the healthcare industry, the projects in this book demonstrate that such advocacy fits within their mission. Their stories of leadership inspire us to recognize and act on the good work that the myriad of research studies cited here give us the background to understand.

CONTRIBUTORS

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Joyce Lee served New York City as Chief Architect at the Office of Management and Budget during the Giuliani and Bloomberg administrations. In 2008, the AIA NY Public Architect Award cited her "extraordinary ability to bring sustainability theory and practice to the public realm." In 2010, she became the City's first Active Design director at the Department of Design and Construction. She currently serves as the international LEED advisor for Environetics, a design firm with offices on both coasts and Asia.

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Karen K. Lee directs the Built Environment and Active Design Program at the NYC Department of Health and Mental Hygiene, leading their work on the *Active Design Guidelines.* She also works closely with the New York AIA Chapter on the annual Fit City Conferences. The *Guidelines* have received awards from the U.S. EPA, the Sustainable Buildings Industry Council, the AIA, and the Robert Wood Johnson Active Living Research Program. Prior to coming to NYC, Dr. Lee was with the Epidemic Intelligence Service at the U.S. Centers for Disease Control and Prevention.

BIBLIOGRAPHY

Albrecht, Glenn. (2007). Solastalgia: A new psychoterratic illness; http://healthearth.blogspot.com/2007/03/solastalgia-new-concept-in-human.html.

Bassett, David R. Jr., J. Pucher, R. Buehler et al. (2008). Walking, Cycling, and Obesity Rates in Europe, North America and Australia. *Journal of Physical Activity and Health*, 2008, 5, 795–814. Human Kinetics, Inc.

Centers for Disease Control and Prevention [CDC]. (2012). Overweight and Obesity Facts, www.cdc.gov/obesity/data/facts.html.

Christiani, D. (1993). Urban and transboundary air pollution: Human health consequences. In Chivian, McCally, Hu et al., *Community Indicators Consortium* (2012). www.communityindicators.net/projects.

Congress for the New Urbanism. (2007). www.cnu.org.

Crisci, M. (1990). Public health in New York City in the late nineteenth century. In Services UDoHaH, ed. National Library of Medicine, History of Medicine Division. New York: National Library of Medicine.

Davis, D. (2002). *When Smoke Ran Like Water: Tales of Environmental Deception and the Battle Against Pollution.* New York: Basic Books.

Environmental Protection Agency [EPA]. (2000). National Water Quality Inventory, Ch. 6: "Ground Water." www.epa.gov/305b/2000report/.

———. (2010). Choosing Green Materials and Products, www.epa.gov/greenhomes/SmarterMaterialChoices.htm.

———. Indoor Environments Division Office of Air and Radiation. (2011). Asthma Facts. EPA-402-F-04–019. March 2011, www.epa.gov/asthma/pdfs/asthma_fact_sheet_en.pdf.

Friedman, M. S., K. E. Powell, L. Hutwagner, L. M. Graham, and W. G. Teague. (2001). Impact of changes in transportation and commuting behaviors during the 1996 summer Olympic Games in Atlanta. *Journal of the American Medical Association* 285(7):897–905. Quoted in Frumkin, Frank, and Jackson (2004).

Friends of Gaviotas. (2007). www.friendsofgaviotas.org.

Frumkin, H., L. Frank, and R. Jackson. (2004). *Urban Sprawl and Public Health.* Washington, DC: Island Press.

Geiser, K. (2001). *Materials Matter.* Boston: MIT Press.

Hu, H., and N. Kim. (1993). Drinking-Water Pollution and Human Health. In Chivian, McCally, Hu et al.

Jackson, Richard, and M. Maus. (2008). Good Places—Good Health. In *Sustainable Healthcare Architecture,* R. Guenther and G. Vittori. Hoboken, NJ: John Wiley & Sons, Inc., pp. 29–33.

Kyoto Protocol. (1997). United Nations Framework Convention on Climate Change; http://unfccc.int/resource/docs/convkp/kpeng.html.

Lawton, T. K. (2001). The Urban Structure and Personal Travel: An Analysis of Portland, or Data and Some National and International Data. Rand Infrastructure, Safety and Environment; www.rand.org/scitech/stpi/Evision/Supplement/lawton.pdf.

Mazria, E. (2010). Architecture 2030. http://architecture2030.org/files/2010_handout.pdf.

National Climate Data Center [NCDC]. (2012). State of the Climate Drought, September 2012. www.ncdc.noaa.gov/sotc/drought/#national-overview.

National Institute for Occupational Safety and Health [NIOSH]. (1988). Proposed National Strategies for the Prevention of Leading Work-Related Diseases and Injuries, Part 1. Washington, DC: Association of Schools of Public Health.

Newman, P., and J. Kenworthy. (1993). Automobile Dependence: "The Irresistible Force." Murdoch, Australia: Institute for Sustainability and Technology Policy.

Newman, P., J. Kenworthy, F. Laube, and P. Barter. (1998). Indicators of Transport Efficiency in 37 Global Cities: A Report to the World Bank. Murdoch, Australia: Institute for Sustainability and Technology Policy.

Park, M. (2011). Heat wave drives up emergency calls, possible deaths, July 20, 2011, www.cnn.com/2011/HEALTH/07/20/heat.wave.states/index.html.

Preston, S. (1996). American longevity: past, present, and future. Syracuse University Policy Brief No. 7.

Riis, J. A. (1890). *How the Other Half Lives: Studies Among the Tenements of New York.* New York: Charles Scribner's Sons.

Roodman, D. M., and N. Lenssen (1995). A Building Revolution: How Ecology and Health Concerns are Transforming Construction. (Worldwatch Institute Paper #124). Washington, DC: Worldwatch Institute.

Rosenberg, C. E. (1987). *The Care of Strangers: The Rise of America's Hospital System.* New York: Basic Books.

Rosenman, K. D., M. J. Reilly, D. P. Schill et al. (2003). Cleaning products and work related asthma. *Journal of Occupational and Environmental Medicine* 45 (5):557–563.

Smart Growth Network. (2006). Getting to Smart Growth: 100 Policies for Implementation. Washington, DC: International City/County Management Association. www.smartgrowth.org/pdf/gettosg.pdf.

Smart Growth Vermont. (2012). What Is Sprawl? www.smartgrowthvermont.org/learn/sprawl/.

Starr, P. (1949). *The Social Transformation of American Medicine.* New York: Basic Books.

Stuckler, D., and K. Siegel (2011). *Sick Societies: Responding to the Global Challenge of Chronic Disease.* New York: Oxford University Press.

Thornton, J. (2003). The Environmental Impacts of Polyvinyl Chloride (PVC) Building Materials. Washington, DC: Healthy Building Network. www.healthybuilding.net/pvc/ThorntonPVCSummary.html.

Turner, B. (1995). *Medical Power and Social Knowledge*, 2nd ed. London: Sage. Quoted in C. Samson, ed. *Health Studies: A Critical and Cross-Cultural Reader.* Oxford: Blackwell Publishers.

U.S. Census Bureau. (2000). Annual Projections of the Total Resident Population as of July 1: Middle, Lowest, and Highest Series, 1999 to 2000. Population Division, Population Estimates and Population Projections Programs. Released January 13, 2000.

U.S. Conference of Mayors. (2013). List of Participating Mayors. www.usmayors.org/climateprotection/list.asp.

———. (2009). Press Release "1000th Mayor—Mesa, AZ Mayor Scott Smith Signs the U.S. Conference of Mayors Climate Protection Agreement." October 2, 2009.

U.S. Energy Information Administration (2012). *Monthly Energy Review,* Tables 2.1, 12.2–12.5 (May 2012), preliminary 2011 data.

U.S. Geological Survey. (2011). Trends in Water Use in the United States, 1950 to 2005. http://ga.water.usgs.gov/edu/wateruse-trends.html (Downloaded January 24, 2012).

U.S. Global Change Research Program [USGCRP] National Assessment Synthesis Team. (2001). Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change. Washington, DC: USGCRP.

Weisman, A. (1995). Colombia's Model City. Context 42 (Fall).

———. (1999). Gaviotas: A Village to Reinvent the World. White River Junction, Vermont: Chelsea Green.

World Chlorine Council. (2012). Chlorine Products & Benefits: 2005 Global Chlorine Capacity, www.worldchlorine.org/products/index.html.

World Health Organization [WHO]. (2012). Obesity and Overweight, Fact Sheet No. 311, May 2012; www.who.int/mediacentre/factsheets/fs311/en/.

———. (2011). Air Quality and Health, Fact Sheet No. 313, Updated September 2011: www.who.int/mediacentre/factsheets/fs313/en/index.html.

———. (2006). Preventing Disease through Healthy Environments: Towards an estimate of the environmental burden of disease; http://www.who.int/quantifying_ehimpacts/publications/preventingdisease/en/index.html.

World Health Organization [WHO]/Europe. (2012). Healthy Cities; www.euro.who.int/en/what-we-do/health-topics/environment-and-health/urban-health/activities/healthy-cities.

World Health Organization [WHO]/UNICEF. Joint Monitoring Programme. (2012). Progress on Drinking Water and Sanitation—2012 Update; www.unicef.org/media/files/JMPreport2012.pdf.

Bibliography for Lee and Lee Essay

Active Design Guidelines: Promoting Physical Activity and Health in Design. The City of New York. January 2010. Available from: www.nyc.gov/adg.

Bleich, S.N. et al. (2009). Increasing consumption of sugar-sweetened beverages among U.S. adults: 1988–1994 to 1999–2004. *American Journal of Clinical Nutrition*, 89(1):372–381.

Boutelle, K.N. et al. (2001). Using signs, artwork, and music to promote stair use in a public building. *American Journal of Public Health*, 91(12):2004–2006.

Danaei, G., E. L. Ding, D. Mozaffarian et al. (2009). The preventable causes of death in the United States: Comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *Public Library of Science: PLoS Med 2009*; 6(4).

Farley, T., R. Meriwether et al. Safe play spaces to promote physical activity in inner-city children: Results from a pilot study of an environmental intervention. *Am J Public Health.* 2007; 97(9):1625–1631.

Frank, L.D., M.A. Andresen, and T.L. Schmid (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine*, 2004. 27(2):87–96.

Gleick, P.H. and H.S. Cooley (2009). Energy implications of bottled water. *Environmental Research Letters*, Vol. 4.

Goldberg, D. et al. (2007). New Data for a New Era, A Summary of the SMARTRAQ Findings: Linking Land Use, Transportation, Air Quality and Health in the Atlanta Region.

Kaur, H. et al. (2003). Duration of television watching is associated with increased body mass index. *Journal of Pediatrics,* 143(4):506–511.

Kerr, N.A. et al. (2004). Increasing stair use in a worksite through environmental changes. *American Journal of Health Promotion*, 18(4):312–315.

Lee, I.M. and R.S. Paffenbarger, Jr. Physical activity and stroke incidence: The Harvard alumni health study. *Stroke.* 1998:29:2049–2054.

Lee, K. K., A. S. Perry, S. A. Wolf, R. Agarwal, R. Rosenblum, S. Fischer, V. E. Grimshaw, R. E. Wener, and L. D. Silver. Promoting Routine Stair Use: Evaluating the Impact of a Stair Prompt Across Buildings. *American Journal of Preventive Medicine*, February 2012, 42(2):136–141.

Nicoll, G. (2007). Spatial measures associated with stair use. *American Journal of Health Promotion*, 21(4 Suppl):346–352.

Nicoll, G., and C. Zimring (2009). Effect of Innovative Building Design on Physical Activity. *Journal of Public Health Policy*, 30:S111–S123.

Parsons, T.J., O. Manor, and C. Power (2008). Television viewing and obesity: A prospective study in the 1958 British birth cohort. *European Journal of Clinical Nutrition.* 62(12):1355–1363.

Potwarka, L.R., A.T. Kaczynski, and A.L. Flack (2008). Places to play: Association of park space and facilities with healthy weight status among children. *Journal of Community Health,* 33(5):344–350.

Rundle, A. et al. (2009). Neighborhood food environment and walkability predict obesity in New York City. *Environmental Health Perspectives*, 117(3):442–447.

Sallis, J. F., and K. Glanz (2009). *Physical Activity and Food Environments: Solutions to the Obesity Epidemic.* Milbank Quarterly, 87(1): p. 123–154.

Sturm, R. et al. (2007). Obesity and Disability: The Shape of Things to Come. RAND Health; Available from: www.rand.org/pubs/research_briefs/RB9043/.

Task Force on Community Preventive Services [TFCPS]. (2002). The Effectiveness of Interventions to Increase Physical Activity, *American Journal of Preventive Medicine*, 22:67–72.

Toledo, C. (2007). Reduce Greenhouse-Gas Emissions with Vertical Transportation Equipment. Available from: http://buildings.com/articles/detail.aspx?contentID=4823.

U.S. Centers for Disease Control and Prevention [USCDC]. (2011). Obesity: Halting the Epidemic by Making Health Easier. At a Glance 2011. www.cdc.gov/chronicdisease/resources/publications/aag/obesity.htm.

U.S. Department of Energy [USDOE]. (2001). *Greening Federal Facilities: An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers.* Section 5.7.4 Energy-Efficient Elevators. 2nd Edition: Available from: www1.eere.energy.gov/femp/pdfs/29267–5.7.4.pdf.

Van Houten, R., P. A. Nau, M. Merrigan (1981). Reducing energy elevator use: A comparison of posted feedback and reduced elevator convenience. *Journal of Applied Behavior Analytics*, 14(4):377–387.

Wang, Y. C., S. N. Bleich, and S. L. Gortmaker (2008). Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among U.S. children and adolescents, 1988–2004. *Pediatrics*, 121(6):e1604–e1614.

Wener, R. E., and G. W. Evans (2007). A Morning Stroll: Levels of Physical Activity in Car and Mass Transit Commuting, *Environment and Behavior*, 39(1):62–74.

World Health Organization (2011). Global Status Report on Non-Communicable Diseases 2010. April, 2011. Available from: www.who.int/nmh/publications/ncd_report2010/en/.

Zimring, C., A. Joseph, G. L. Nicoll, and S.Tsepas. (2005). Influences of building design and site design on physical activity: Research and intervention opportunities. *Am J Prev Med.*28:186–193.

CHAPTER 3

ENVIRONMENT AND MEDICINE

> The mirage of modern medicine (to use René Dubos's image) is one facet of the dream of progress as increasing material comfort and mastery over nature, a dream that is drifting into nightmare. The expansionist mindset strives for the gradual and eventually perfect victory over disease, disability, and perhaps even over aging and death. While in this dream state, medicine remains oddly oblivious to the large-scale constraints of ecosystems.
>
> JESSICA PIERCE AND ANDREW JAMETON

INTRODUCTION

The twentieth-century divergence between public health and medicine signaled the shift in medicine's focus from prevention to cure and, with it, the centralization of medicine and medical education on the acute-care medical center campus. For the last sixty years, the United States has invested in an ever-expanding system of acute-care hospitals to "cure" sickness. However, the late-twentieth-century emergence of chronic disease, with its complex mix of environmental, social, and medical factors, has resisted purely medical cures. Cancer, heart disease, and obesity are seen as the emergent disease burdens globally in both the developed and developing world. Medical professionals and the general public alike increasingly view these chronic conditions as linked to lifestyle (diet, reduced physical activity, tobacco, and alcohol) and environmental and industrial causes (industrial chemicals).

The study of the relationship between ecological and human health encompasses the disciplines of environmental health and ecological medicine. Through these emerging disciplines and the treatment of chronic diseases, public health and medicine are once again finding common ground—linked through prevention, lifestyle, and policy.

What is healthcare for? Can the healthcare industry become a model for the larger world in developing an ecological approach to these environmental and health challenges? Central to these approaches to medicine is the axiom, "First, do no harm." This seminal principle forms the basis of a medicine that embraces a broad definition of health and recognizes the primacy of prevention and restoration as preferable to treatment on a planet with a finite carrying capacity.

What is health in a world dominated by degraded ecosystems? What will a healthcare system that values restoration look like? The work of educators Jessica Pierce and Andrew Jameton (2004), excerpted here, represents the beginning of an answer. Inevitably, a discussion of medicine and ecology raises the question of scale—scale of the industry, resource use, and the buildings that support medical care. In his essay, environmental activist Gary Cohen discusses the healthcare industry's recognition that healthy people cannot exist on a sick planet.

> *Can our present medical industry produce an adequate definition of health? My own guess is that it cannot do so. Like industrial agriculture, industrial medicine has depended increasingly on specialist methodology, mechanical technology, and chemicals; thus, its point of reference has become more and more its own technical prowess and less and less the health of creatures and habitats. I don't expect this problem to be solved in the universities, which have never addressed, much less solved, the problem of health in agriculture. And I don't expect it to be solved by the government.*
>
> —Wendell Berry (1995)

THE STATE OF HEALTH IN THE WORLD

In the fourth century BCE, Hippocrates, the father of Western medicine, prophetically wrote: "Human health cannot be treated separately from the natural environment." As outlined in Chapter 2, through the end of the nineteenth century, medicine and public health were linked; urban planning, architecture, and healthcare improved the health of increasing urban populations through such seemingly unrelated initiatives as zoning, sanitation systems, and the construction of hospitals.

By the end of the nineteenth century, however, scientific and technical advances created a divergence in these previously linked fields. Medical practice evolved toward education and training based on the recognition and treatment of disease. Medicine became increasingly specialized toward the goal of individual patient outcomes, leading to the emergence of a wide range of medical specialties. Despite tremendous advances in the field of public health, including the eradication of numerous infectious diseases, the attention focused on clinical medicine has increasingly dissociated our health from environmental issues.

The World Bank (1993) reports that global health conditions improved more between 1940 and 1990 than in all of the years before: Life expectancy increased to an average of 65 years, and death rates declined. In the United States, life expectancy climbed from 69.8 years in 1960 to 78 years in 2010. Monaco, Macau, and Japan lead the world with average life expectancy of 89.7, 84.3, and 83.9 years, respectively; by contrast, average life expectancy in sub-Saharan Africa can be as low as 38 years (CIA 2012). Variations in life expectancy are attributed to differences in public health measures, access to medical care, and diet. In poorer nations industrial working conditions, war, violence, starvation, and communicable diseases (AIDS, malaria, etc.) increase mortality rates.

Climate may also affect life expectancy. In 2001 nearly 40 percent of American children lived in counties that exceeded the eight-hour ozone standard at least one day (U.S. EPA 2003). In the United States, the rates of asthma increased 73.9 percent during 1980 through 1996 (Mannino et al. 2002). The total costs of environmentally attributable diseases in American children are estimated at $54.9 billion annually (Landrigan and others 2002).

Poor environmental quality is estimated to be directly responsible for approximately 25 percent of all preventable ill health in the world (WHO 1997). Globally, 19 percent of all cancers are attributable to the environment, including work setting, resulting in 1.3

> *The burgeoning number and complexity of known or suspected environmental carcinogens compel us to act to protect public health, even though we may lack irrefutable proof of harm. Action is possible at several levels: conducting scientific research to enhance our understanding and by extension, our ability to prevent and respond to environmental carcinogens; enforcing existing policies and regulations that protect workers and the public; implementing policy and regulatory changes that support public health and reduce the burden of cancer; and taking personal action.*
>
> —Source: The President's Cancer Panel 2009 Annual Report (NCI 2010)

million deaths each year (WHO 2011). In 2010, the President's Cancer Panel (NCI 2010) released its 2009 Annual Report titled *Reducing Environmental Cancer Risks.* In a cover letter, it made this plea:

> Environmental exposures that increase the national cancer burden do not represent a new front in the ongoing war on cancer. The American people—even before they are born—are bombarded continually with myriad combinations of these dangerous exposures. The Panel urges you most strongly to use the power of your office to remove the carcinogens and other toxins from our food, water, and air that needlessly increase health care costs, cripple our Nation's productivity, and devastate American lives.

Finally, the reality is that enormous health disparities remain between the richest and poorest countries, contributing to a wide range of life expectancy. At the close of the twentieth century, nearly 20 percent of all people in developing nations were not expected to survive to age 40 (UNDP 1997). Add to this the background of unsustainable resource extraction and continued population growth, and the picture becomes even more disturbing.

With life expectancy increases come epidemiological transitions: changes in the types of diseases and illnesses a society experiences. In *The Nature and Etiology of Disease,* Gaydos and Veney (2002) describe three such transitions. The first was associated with the development of urban centers and resulted in communicable diseases (such as cholera) due to contaminated water and viral diseases (like measles and smallpox) associated with density. Tuberculosis and respiratory diseases were even more serious problems, with social and cultural overlays related to harsh working conditions and overcrowding. The second transition, experienced by industrialized nations in the second half of the twentieth century, was the shift from acute infectious disease to chronic, noninfectious, degenerative diseases, their prevalence related to increases in longevity. Finally, Gaydos and Veney identify a third epidemiological transition—the reemergence of infectious diseases with antibiotic resistance. The result of the interaction of social and environmental changes resulting in the adaptation of the microbe, it has the potential to be global in scope.

Ironically, they point out, "the technological advances that have allowed for increased longevity can also cause an increase in environmental degradation, and these advances arguably lead to new chronic diagnoses . . . . Many of the diseases of the second transition share common factors related to human adaptation, including diet, activity level, mental stress, behavioral practice, and environmental pollution." Global warming, ozone depletion, habitat destruction, and toxic chemicals are major global environmental concerns with defined human and ecosystem health impacts. Over the last twenty-five years, the study of these issues and their complex impacts on ecosystem health has evolved into the fields of environmental health and ecological medicine.

> *Nature's goods and services are the ultimate foundations of life and health, even though in modern societies this fundamental dependency may be indirect, displaced in space and time, and therefore poorly recognized. This [is] a call to the health sector, not only to cure the diseases that result from environmental degradation, but also to ensure that the benefits that the natural environment provides to human health and well-being are preserved for future generations.*
>
> —Lee Jong-wook, MD, former Director General, World Health Organization
>
> Source: Corvalan, Hales, and McMichael 2005

ENVIRONMENTAL HEALTH

The natural, social, and built environments, and their complex interrelationships, affect human health. Together, they comprise environmental health. According to the World Health Organization (WHO), environmental health is "the study of the direct pathological effects on health of chemical, physical and biological agents . . .

We have, over the past decade, seen dramatic growth in the environmental health movement. It has driven the issue of climate change to the top of the global agenda. Awareness of the threat of destruction of the ozone layer resulted in the Montreal Protocol on Substances That Deplete the Ozone Layer in the hopes of reducing the use of the chemicals destroying this fragile layer protecting life on earth. More recently, the Stockholm Convention on Persistent Organic Pollutants became the first global treaty to ban the use of a dozen of the most toxic chemicals. Likewise, efforts to protect and restore the habitats of endangered species have gathered strength around the world, preserving imperiled lands and oceans on an unprecedented scale.

—Michael Lerner, Executive Director, Commonweal (2008)

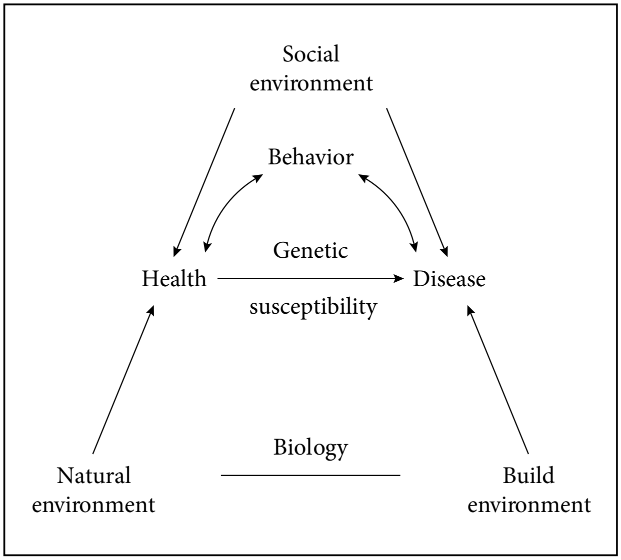


Figure 3.1 Environmental health is the study of the complex interrelationship between the natural, built, and social environments and how they create the conditions for health and disease. *Source: Samuel H. Wilson MD 2004*

and the effects of the broad physical and social environment on human health." The direct health impacts of degraded ecosystems—air and water—have historically been documented in the public health literature. The asthma epidemic (annual self-reported asthma prevalence increased 73 percent between 1980 and 1996) (Mannino et al. 2002) may be attributable to increased exposure to indoor allergens and poor indoor air quality (the built environment), combined with more time spent indoors (90 percent on average), and decreased physical activity (behavior). As chronic diseases like asthma are linked to this complex set of factors, studying these interrelationships propels environmental medicine from the fringes of medical discourse into the mainstream (Figure 3.1).

Bioethics

In the late 1960s, Van Rensselaer Potter coined the term "bioethics" to join environmental and medical concerns with the goal of the "long-term acceptable survival of the human species" (Potter 1971). However, just as medicine and public health diverged in an era of major technological advances, a similar bifurcation in bioethics has suppressed global environmental concerns in favor of debate over clinical technologies and patient care. Environmental medicine is just beginning the integrative work of defining environmental bioethics, drawing on the work of philosopher Herschel Elliot (1997): "An acceptable system of ethics is contingent on its ability to preserve the ecosystems which sustain it."

In formulating environmental health ethics, Andrew Jameton (2005), who sits on the faculty of health promotion, social and behavioral health at the University of Nebraska Medical Center's College of Public Health, outlines three compelling implications:

1. Methods of accounting that discount future health risks must be reconsidered. The notion that diminished human and ecosystem health is "the price we pay" for technological or economic progress is unacceptable.

2. The full life cycle cost of environmental health measures must be considered in development decisions. Whether a sewage treatment plant, a nuclear power plant, or a new hospital campus, the local health benefits must be weighed against the life cycle impacts of the construction and operation of the facility.
3. While there is an observed correspondence between the wealth of a nation and the average health of its citizens (World Bank 1993), if a nation overburdens its environment in pursuit of wealth, that nation will undermine everyone's health in the long run.

> *Humans cannot have a moral duty to deliver the impossible, or to supply something if the act of supplying it harms the ecosystem to the point where life on earth becomes unsustainable. Moral codes, no matter how logical and well-reasoned, and human rights, no matter how compassionate, must make sense within the limitations of the ecosystem; we cannot disregard the factual consequences of our ethics. If acting morally compromises the ecosystem, then moral behavior must be rethought. Ethics cannot demand a level of resource use that the ecosystem cannot tolerate.*
>
> —Herschel Elliott and Richard Lamm (2002)

ECOLOGICAL MEDICINE

More recently, a global movement of concerned scientists, doctors, and environmentalists began "a field of inquiry and action to reconcile the care and health of ecosystems, populations, communities and individuals" (Myers et al. 2002). Ecological medicine draws on public health, ecology, conventional medicine, complementary and alternative medicine, conservation medicine, and conservation biology in framing the following basic tenets (Ausubel 2004):

- The first goal of medicine is to establish the conditions for health and wholeness, thus preventing disease and illness. The second goal is to cure.
- The Earth is also the physician's client. The patient under the physician's care is one part of the Earth.
- Humans are part of a local ecosystem. Following the ecopsychological insight that a disturbed ecosystem can make people mentally ill, a disturbed ecosystem can surely make people physically ill.

Medicine should not add to the illnesses of humans or the planet. Medical practices themselves should not damage other species or the ecosystem. In a call to reconcile the care and health of ecosystems, populations, communities, and individuals, ecological medicine integrates the concepts and values enumerated in Figure 3.2.

How might these concepts and values manifest in the healthcare delivery system and the buildings that define it? It is not so simple to make the conceptual leap from these visionary statements to the reality of healthcare delivery in the industrialized world. In the first example, Pierce and Jameton (2004) led a group of inspired medical professionals and students in strategizing a set of principles they bundled into the definition of a "green health center." These thirteen core principles, viewed in Figure 3.2 alongside the precepts of ecological medicine, are an initial attempt at mapping the edges of this brave new world.

In 2011, the United Kingdom's National Health Service (NHS) released their Route Map for Sustainable Health (see profile in Chapter 7). Growing from the policy realization that the current care model is both economically and environmentally unsustainable, the Route Map depicts a sustainable NHS where more care and support is offered closer to home, there is increased use of telemedicine, and the focus is on prevention rather than acute care (see Figure 7.4). More fundamentally, the Route Map imagines the fundamental

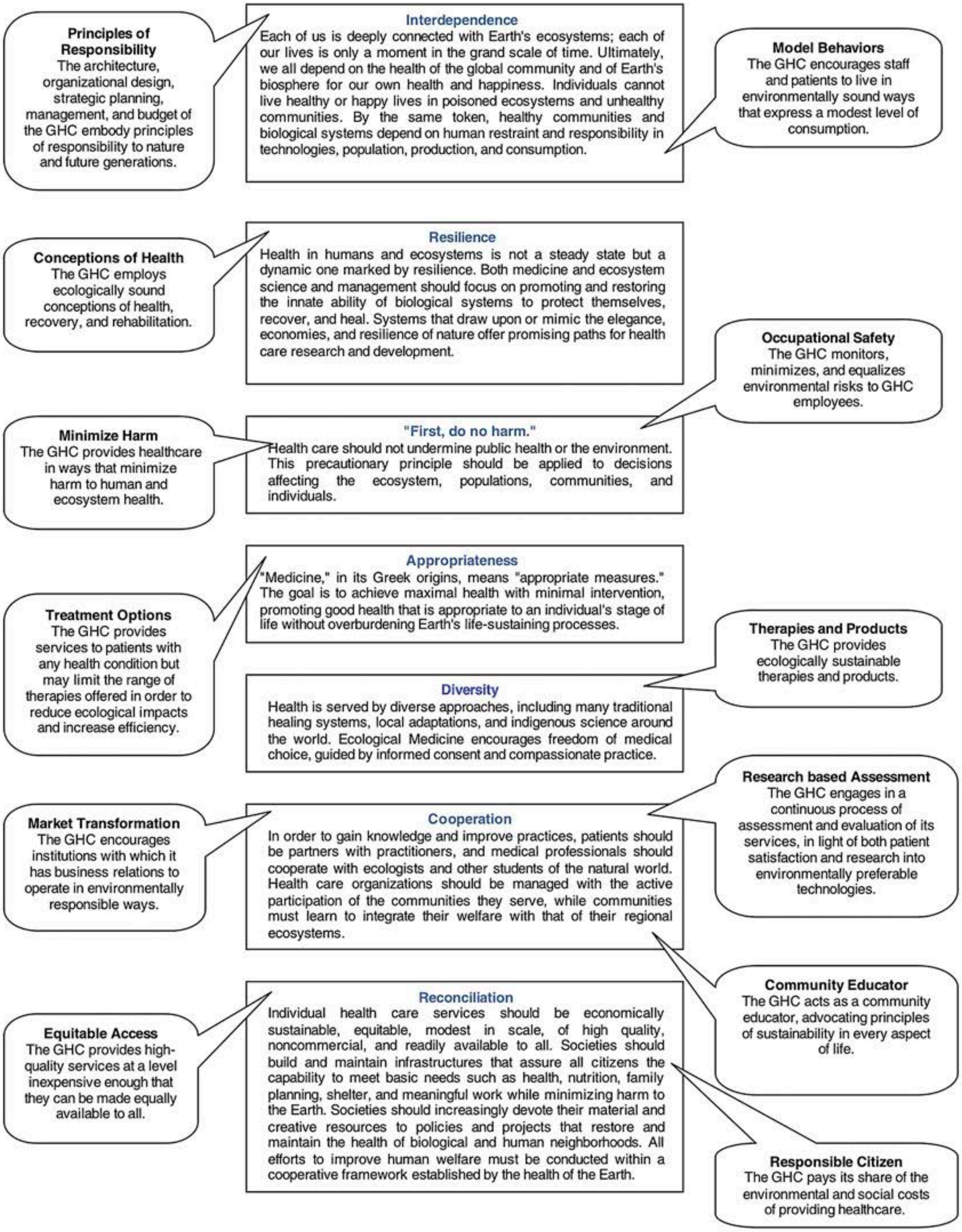


Figure 3.2 The concepts and values of ecological medicine inform the development of core principles of a green health center (GHC) as articulated by Jessica Pierce and Andrew Jameton (2004). *(Ecological medicine principles reprinted with permission from the Science and Environmental Health Network.)*

Imagine a time when going to hospital is seen as a failing of the health and social care system. Where most of the care and support you need can be offered at home. Where you can get instant medical help online, by phone or at a local health center. Where health inequalities are low and well-being is key.

Imagine a place where the few buildings that support the health system are in tune with the environment. They use almost no carbon and are integrated into the community and with nature. They are inviting for patients and a pleasure to work in.

Imagine a world where friends, family and society help promote healthy living. Where we all support the local health and social care system to recycle, re-use and minimize waste. Where we know that delivery of services takes the long-term financial, social and environmental costs into account.

Imagine knowing that we have done our best to improve health and minimize our impact on the environment.

SOURCE: THE NHS ROUTE MAP FOR SUSTAINABLE HEALTH (NHS SDU 2011)

transformation of the care system (see Figure 7.6 and sidebar).

Built examples of this ecological view of medicine are beginning to appear. Many of the projects included in this book also embody aspects of these principles; hopefully, this dialogue will inform the transformation ahead. First, the NHS projects exemplify a new focus on community integration, health management, and prevention: Portadown Health and Care Centre (Case Study 27, Chapter 8), Jubilee Gardens (Case Study 50, Chapter 10), and Waldron Health Centre (Case Study 52, Chapter 10). In addition, Healthcare for the Homeless (Chapter 5), Pictou Landing (Case Study 45, Chapter 9), Women's Health, Burkina Faso (Case Study 48, Chapter 9), Ubuntu Health Centre (Case Study 49, Chapter 10), and Old Town Recovery Center (Case Study 51, Chapter 10) offer glimpses into a more proactive, ecological health delivery model and its impact on the built structures that house it.

Finally, Protea Health is featured as a new model of "salutogenic" design for health (see sidebar). In describing the prototype, architect Tye Farrow articulates a new design imperative: "Now that the cost of coping with chronic diseases has become unsustainable, we must design our way to health. All around us we see opportunities to promote health rather than cope with illness."

Protea Health

Prototype, South Africa

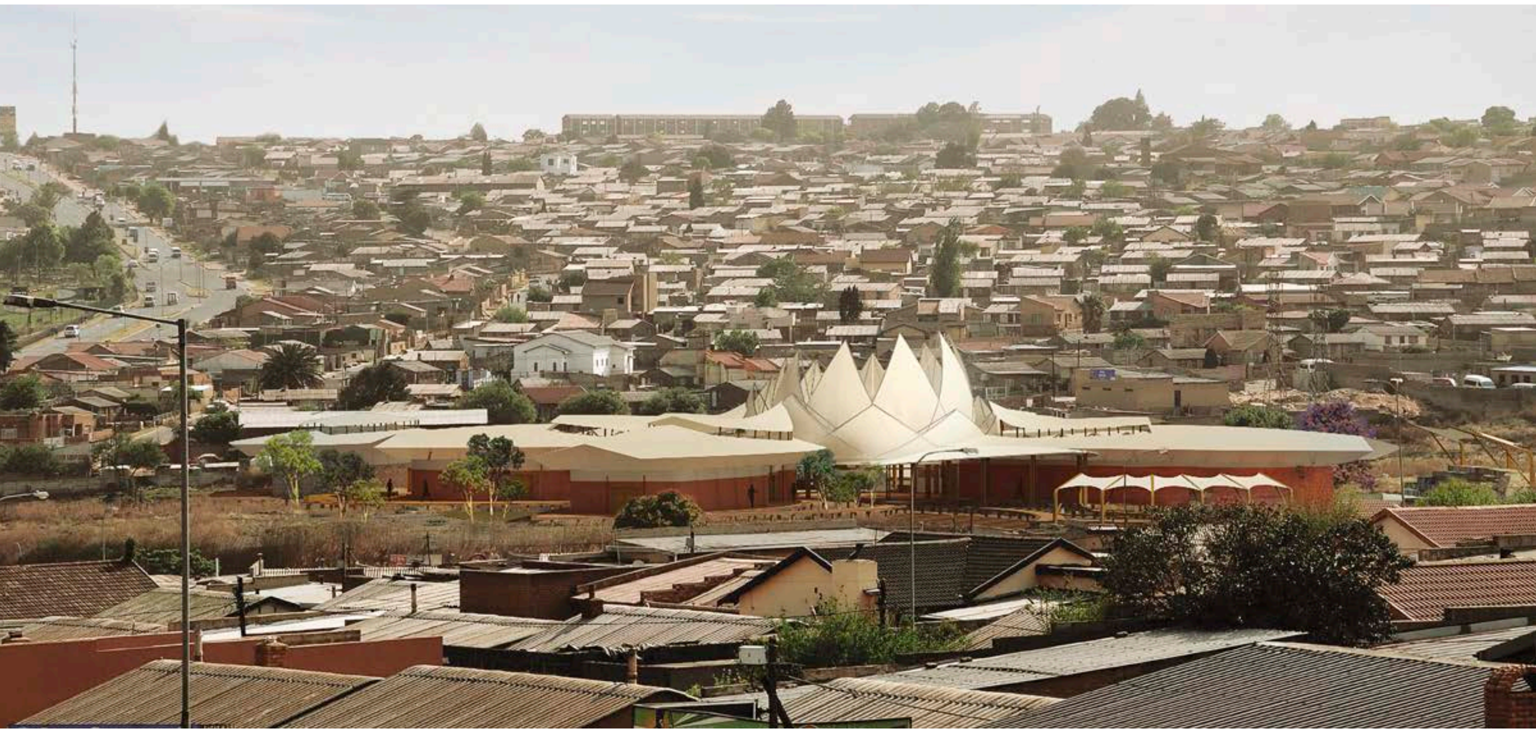
Design Team: Farrow Partnership, Ngonyama Okpanum & Associates and Clark Nexsen

This inspiring winning submission to the South African Ministry of Health's Health Promoting Lifestyle Centre (HPLC) international design competition uses the national flower of South Africa—the Protea—as the symbolic metaphor for hope, healing and renewal, and for a safe and healthy gathering place. The Protea also inspires the building form, with the roof designed to mimic the flower's petals (Figures 3.3, 3.5). The team's bold vision underscores its design approach: "A new world must shift attention beyond the causes of diseases to the causes of health."

Designed as a prototype for construction in rural settings, townships, and cities throughout South Africa's nine provinces, the HPLC is a multifaceted health clinic integrating functional outdoor spaces into its program. Services include antenatal, dental, TB/HIV/AIDS treatment and traditional healing, a pharmacy and optician, educational space for family planning and counseling, a library and theater (Figure 3.4). It emphasizes education and training of community members and health workers in disease prevention and health promotion, with classes spanning diverse topics from malaria net installation to sustainable farming.

The HPLC supports these activities in the context of a poetic building that visibly advances sustainable features integrating natural ventilation, with a convective loop circulating air from below the floor through

Figure 3.3 Protea Health. *Source: Farrow Partnership*



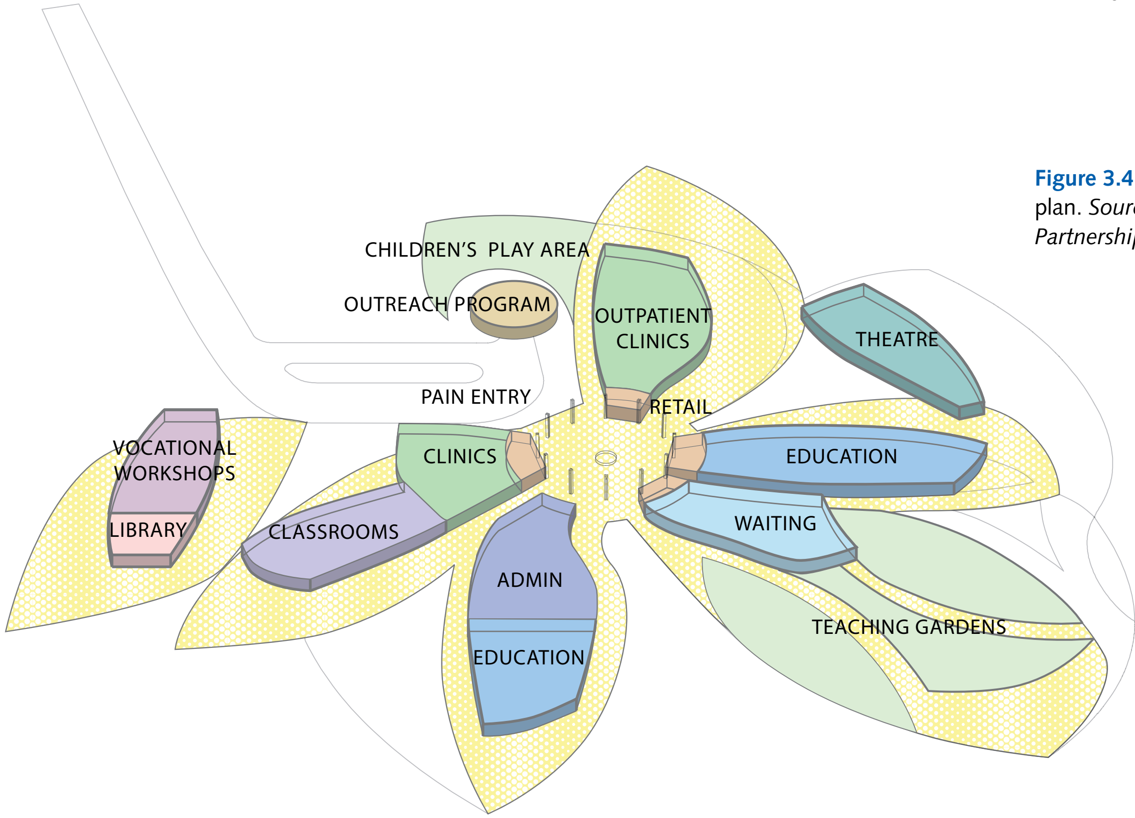


Figure 3.4 Diagrammatic plan. *Source: Farrow Partnership*

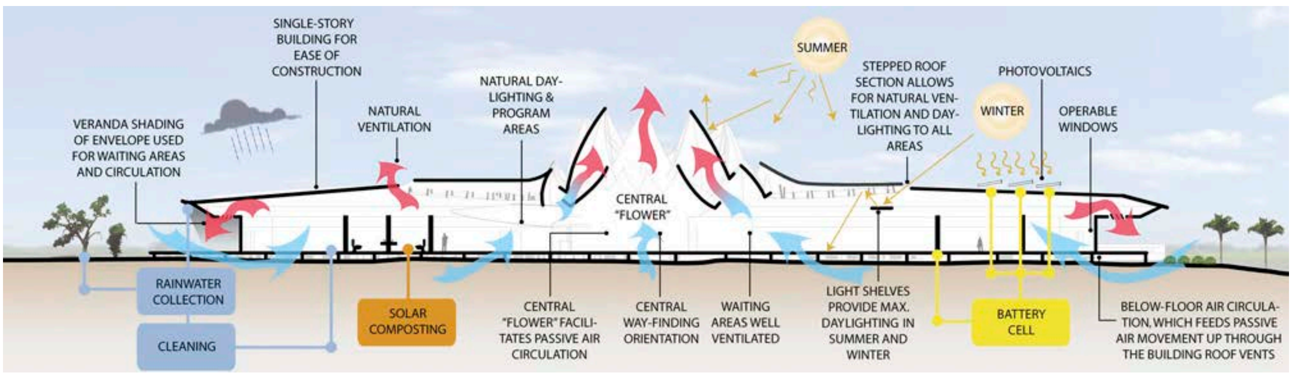


Figure 3.5 Section illustrating passive design principles. *Source: Farrow Partnership*

the roof vents, solar photovoltaics, composting, and rainwater harvesting; its single-story form was intentionally selected to facilitate construction. By integrating the services of healing, education, training and salutogenic design principles, the HPLC puts forward a bold aspiration to "…set an international standard for promoting the full range of upstream causes of health, which will be seen as appealing, understandable and accessible to everyone."

Source: Farrow Partnership

HEALTHCARE AND THE ENVIRONMENT

In stark contrast to the preceding goals, the existing healthcare industry is increasingly environmentally paradoxical. Pierce and Jameton (2004) summarize the dilemma:

> The materials and methods of healthcare contribute to pollution, add to global warming and ozone depletion, and rely on an extensive natural resource base—the extraction, manufacturing, and use of which incurs a significant environmental burden both locally and globally. This is partly a problem of scale. The United States maintains the world's largest healthcare system, spending close to half of all the money spent in the world on healthcare. Maintaining such a large healthcare system requires a large economy. That economy, however, is making a substantial contribution to the decline in the state of the world's environment. And environmental decline is in turn harming human health and creating more illnesses in need of treatment. As the need for healthcare increases, this already oversized healthcare system, caught in the vicious positive feedback cycle, is likely to respond by growing and thereby continuing to further compound health problems. As such, healthcare frustrates its own practical and moral commitment to promote and maintain human health.

In 2010, the United States spent $2.6 trillion on healthcare—just over 17 percent of the gross domestic product, while the average health status of its citizens has begun to decline. Despite having the highest per capita expenditure on healthcare per year (just under $8,000), the U.S. global ranking based on a spectrum of health indicators has been in decline for the past twenty-five years. To put these numbers in perspective, the United States spends on healthcare alone more than the entire GDP of France, the fifth largest economy in the world—that is, what the 65 million people of France spend on everything: education, defense, the environment, scientific research, vacations, food, housing, cars, clothes, and healthcare. The United States spends 50 percent more per person than the next highest spending countries, Switzerland and Norway (Emanuel 2011).

The irony of healthcare's role in environmental degradation provides compelling insight into what is wrong with the delivery of healthcare and foreshadows a path to the future that recognizes the ethical, economic, and environmental dimensions of service delivery and the construction and operation of buildings. The nonprofit Health Care Without Harm is transforming the industry on both policy and operational levels. Environmental health issues are increasingly appearing in mainstream medical literature. Essayist Gary Cohen, president and co-founder of Health Care Without Harm, provides a blueprint for medical service delivery in the twenty-first century that recognizes that healthy people cannot exist on a sick planet.

TRANSFORMING HEALTHCARE

Gary Cohen

What is the role of medicine in a world where new diseases are emerging due to global climate change and where toxic chemicals have trespassed not only into our food and consumer products and buildings but also into the womb? What does the Hippocratic oath mean in a healthcare sector addicted to petrochemicals in its products and operations? What does "the environment of care" signify in a society in which close to 40 percent of adult work-related asthma is triggered in hospital environments? How will healthcare be resilient in a world in which climate change impacts may be the greatest threat to public health in the 21st century?

Our Rising Disease Burden

In 2005, 133 million Americans—almost 1 out of every 2 adults—had at least one chronic illness (CDC 2012). In addition to increases in diabetes, asthma, cancer, and chronic heart disease, the best available data show increasing incidence of autism, birth defects, childhood brain cancer, acute lymphocytic leukemia, endometriosis, Parkinson's disease, and infertility (Trasande and Landrigan 2004, Jahnke et al. 2005).

The picture is profoundly troubling. The human toll on families and communities is immense, particularly on those already disadvantaged by persistent economic disparities and other social stressors. In 2007, the diabetes-related total cost was $174 billion in the United States, including $116 billion in direct healthcare expense and $58 billion in indirect cost for loss of work productivity (ADA 2008). By 2050, healthcare and lost productivity costs for these diseases may exceed $6 trillion globally (DeVol and Bedroussian 2007).

Environmental health is linking each of these diseases and disorders to exposure to toxic chemicals (CHE 2006, Heindel 2003). In the past decade, the Centers for Disease Control and Prevention (CDC) have released four biomonitoring studies detailing toxic chemical loads among the American population. The CDC's cumulative Fourth National Report on Human Exposure to Environmental Chemicals (CDC 2011b) provides an ongoing assessment of human exposure to 148 environmental chemicals—including lead, mercury, cadmium; dioxin, furans, and polychlorinated biphenyls or PCBs; and 42 pesticides—in the bodies of thousands of participants. The fourth report includes data on 75 additional common industrial chemicals never before systematically measured in the U.S. population—

Highlights of Americans' Disease Burden

- The lifetime risk of getting cancer is 1 in 2 for men, and 1 in 3 for women; 1 in 12 men and 1 in 11 women will develop invasive cancer before the age of sixty (ACS 2005a).
- The risk of breast cancer has almost tripled from more than 1 in 20 to 1 in 8 in the last forty years (ACS 2005b).
- Annual self-reported asthma prevalence increased 73 percent between 1980 and 1996 (Mannino et al. 2002). In 2009, asthma prevalence was 8.2 percent of the U.S. population (24.6 million). In 2007, there were 1.75 million asthma-related emergency department visits and 456,000 asthma hospitalizations (Akinbami et al. 2011).
- In America, in 2009–2010, more than one-third of adults and almost 17 percent of children and adolescents were obese (CDC 2011a).
- Between 1997 and 2004, the incidence of diabetes increased 45 percent among eighteen- to forty-four-year-olds (CDC 2005).
- Endometriosis, which has been linked to dioxin exposure, now affects 10 percent to 20 percent of American women of childbearing age (Suchy and Stepan 2004; Endometriosis Association 2009).

Highlights of Chemical Exposures

Findings in the CDC's Fourth National Report on Human Exposure to Environmental Chemicals indicate widespread exposure to some commonly used industrial chemicals:

- Polybrominated diphenyl ethers are used as fire retardants in certain manufactured products. These chemicals accumulate in the environment and in human fat tissue. One type, BDE-47, was found in the serum of nearly all participants.
- Bisphenol-A (BPA), a component of epoxy resins and polycarbonates and a reproductive toxicant, was found in more than 90 percent of the urine samples representative of the U.S. population.
- Perfluorooctanoic acid (PFOA) is a byproduct of the synthesis of other perfluorinated chemicals and a synthesis aid in the manufacture of a commonly used polymer used to create heat-resistant nonstick coatings in cookware and textile stain and moisture repellant treatments. Most participants had measurable levels of this environmental contaminant.

Source: CDC Fourth Report (2011)

including environmental phenols (Bisphenol-A, triclosan), 12 perfluorinated compounds (PFOA, PFOS), and a range of volatile organic compounds (VOCs). The startling conclusions indicate widespread exposure to some common industrial chemicals among the U.S. population.

Without our knowledge or informed consent, all of us carry the products and byproducts of the chemical industry in our bodies—carcinogens, reproductive toxicants, neurotoxicants, mutagens, and chemicals that impact a broad set of bodily systems. Our exposures come from food, building materials, cleaning and disinfection products, personal-care products, pesticide and herbicide applications, emissions from chemical manufacturing and disposal sites, pharmaceuticals, and a multitude of other sources, some known and some unknown. Since 1976, only five chemicals or chemical classes have been restricted by the Toxic Substances Control Act of 1976 due to their impact on public health, yet thousands of new chemicals have entered the marketplace without comprehensive toxicity testing (Wilson 2006). Essentially, the chemical industry is conducting an uncontrolled experiment on us and on our children. The overall social, public health, and environmental costs of toxic chemical poisoning are borne by society instead of the companies that are trespassing into our bodies.

Healthcare's Contribution to Chemical Contamination

Dioxin is one of the most infamous of the persistent bioaccumulative toxicants (PBTs), one of the most potent carcinogens known to science, and one of the few targeted for elimination by international treaty. Health effects linked to dioxin exposure in humans and/or animals include cancer, endometriosis, testicular atrophy, immune and neurological system damage, increased miscarriages and birth defects, and alterations in hormone function. Intimately linked to dioxin is polyvinyl chloride (PVC), used widely in the production of IV and blood bags, plastic tubing, and an array of other hospital products. Because of PVC's high chlorine content, its manufacture and its intentional (as with incineration) or unintentional (as with fires) combustion contributes to dioxin formation and release into the ambient environment.

The U.S. Environmental Protection Agency (EPA) estimates that humans receive most of their dioxin intake through food (EPA

2011); the dioxin in dairy products, meat, and fish is ingested and stored in fatty tissue for years, building up over time. Dioxin's global distribution means that every member of the human population is exposed. This is especially problematic for childbearing women, who pass dioxin to an embryo or fetus in utero, and to a child through breast-feeding. In its reassessment of dioxin-related science, the EPA (2001) also estimated that the average amount of dioxin in all Americans' bodies is "at or approaching levels" that will begin to cause a variety of adverse health effects. Globally, food recalls for dioxin contamination continue to occur (WHO 2010).

Another chemical, di(2-ethylhexyl) phthalate, or DEHP, is a plasticizer used to make flexible PVC-based products such as IV tubes and blood bags. DEHP can leach out of these products and enter patients' bodies. In 2005, the National Toxicology Program (NTP) updated its year 2000 conclusions that DEHP is a reproductive toxicant and that infants in hospitals are at risk from exposure to it (NTP 2005). Following the 2000 NTP findings, the U.S. EPA classified DEHP as a Class B2, probable human carcinogen (EPA 2007). The Food and Drug Administration (FDA) followed with a health advisory to hospitals, urging healthcare facilities to seek safer alternatives, especially for vulnerable patient populations (FDA 2002).

Pharmaceutical discharges are also emerging as a major environmental and public health threat. Many pharmaceuticals contain hormone-disrupting chemicals that migrate from people, hospitals and homes to bodies of water, where they negatively impact aquatic life. They also wind up in our drinking water (Fox 2005; Heinzmann 2005). As patients consume more drugs, these biologically active agents persist in the environment and/or bioaccumulate in the food chain—more than one hundred pharmaceuticals or their metabolites have been found in bodies of water in Europe and the United States (Hemminger 2005; Heberer et al. 1997).

Healthcare, Climate Change, and Health

More than any other issue on the public health agenda, climate change forces us to recognize that the public health is dependent upon the planet's sustained provision of healthy soils, clean water, and habitable weather patterns. Greenhouse gas emissions are resulting in increasingly dangerous climate events and public health threats. According to the World Health Organization (WHO 2012), climate change causes a wide range of complex health impacts, including temperature-related illness and death, injuries and illnesses due to extreme weather events, the spread of infectious disease vectors, increases in water borne illnesses, and wide-ranging impacts from air pollution.

The WHO (2009) estimated that climate change that has occurred since the 1970s is already contributing, worldwide, to 150,000 deaths per year; in 2012, the nonprofit DARA Group and Climate Vulnerable Forum released the Climate Vulnerability Monitor, which increased the annual death toll estimate to 400,000 (DARA 2012), with annual economic losses estimated at $1.2 trillion, or 1.6 percent of global GDP. A 2009 article in *The Lancet* medical journal concluded, "Health impacts will be disproportionately greater in vulnerable populations"—including the very young, the elderly and the medically infirm. The article goes on to state, ". . . the health sector can play a key role in helping societies adapt to the effects of climate change and the risk it poses to human health" (Costello et al. 2009).

> *Climate change could be the biggest global health threat of the 21st century. Effects on health of climate change will be felt by most populations in the next decades and put the lives and well-being of billions of people at increased risk.*
>
> —*The Lancet* (Costello et al. 2009)

In fact, the provision of medical services itself contributes to climate and health impacts. A study by Abt Associates (2000) in Massachusetts found that in terms of respiratory problems alone, coal- and oil-fired power plants in Massachusetts are responsible for contributing to 441 premature deaths, 313 hospitalizations, 8,880 asthma attacks, and approximately 78,000 lost work days annually. Health Care Without Harm's preliminary assessment of energy use in Boston's healthcare facilities shows that the direct medical expense associated with health facility emissions is more than $2.4 million annually, in addition to $23 million in indirect societal costs for premature deaths, chronic bronchitis, asthma, and more.

Innovative building examples spanning the globe, profiled in this book, demonstrate that this doesn't need to be the case. The U.S. EPA estimates that 30 percent of the sector's current energy use—or $2.9 billion—could be reduced without sacrificing quality of care through a shift toward energy efficiency and renewable energy sources. International studies echo this conclusion.

Healthcare's Path to Ecological Medicine

Once the link between healthy people and a healthy environment is made, new opportunities emerge for healthcare organizations to model environmental responsibility; as 'anchor institutions' they can extend their upstream leverage to economically benefit surrounding communities. The Healthy Hospitals Initiative's six challenge areas provide a roadmap (see www.healthierhospitals.org).

Resilient and Restorative Healthcare

In this century, we will be severely challenged to provide affordable and appropriate healthcare to more than 10 billion people on an ecologically stressed planet. At present, the healthcare sector is ill equipped to handle the scale of this challenge, as evidenced by the failures of healthcare's response to Hurricane Sandy in 2012, with many of New York City's hospitals forced to close down and evacuate, threatening the lives of scores of vulnerable patients; Hurricane Katrina in 2005, claiming more than 1,800 deaths; and the European heat wave of 2003, where more than 50,000 people died.

As the human health impacts of climate change and chemical contamination unfold, healthcare needs to move upstream to help prevent a cascade of chronic diseases, disaster-related illness, and death, rather than simply treating people once they get sick. It will need to redefine itself to provide essential services to the communities it serves in the aftermath of increasing extreme weather events. And, hospitals and clinics will need to help restore degraded environments and unhealthy communities and educate people how to stay healthy and adapt to changing social and environmental stressors. This is the promise of restorative healthcare.

Conclusion

As the full dimensions of the planet's environmental crisis become apparent, healthcare is in a unique position to provide leadership at many levels, to firmly embrace the essential link between healthy people and a healthy environment, and to build a new vision of ecological medicine and resilient and restorative healthcare. Healthcare leaders must understand that it is difficult to have healthy people on a sick planet. The twenty-first-century healthcare organization can promote the health of its patients, staff, the general public, and the environment in its design and operations; it can support the local economy through purchasing an array of safe products and technologies and healthy food; it can model the kind of environmentally responsible institutions every community should have. The hospital, in essence, can situate itself within the broader ecology of its community and region and act as a healing force.

THE PRECAUTIONARY PRINCIPLE

Of paramount importance to this dialogue is the acknowledgment of prevention and precaution as bases for decision-making. As articulated by physician Ted Schettler, environmental attorney Carolyn Raffensperger, and others, science and industry must first assess the health and environmental impacts of their activities before they act, and in the face of uncertainty, precautionary action is an appropriate basis for preventing harm (Schettler 2001; Tickner and Raffensperger 1999). Author and social entrepreneur Kenny Ausubel (2004) sums it up as follows: for generations, the "risk paradigm" has allowed us to accept the inevitability that a "certain amount of pollution and disease is the price we have to pay for modern life." This presumes there are acceptable levels of contamination that our bodies, and the Earth, can tolerate, and leaves the burden of proof of harm to society at large. "The risk paradigm is at best a high-stakes game of biological roulette with all the chambers loaded." In contrast is the precautionary principle:

- Recommends the study of industrial innovations' risks before they are accepted
- Shifts the burden of proof so that proponents must demonstrate that a practice is sustainable
- Assumes it is preferable to avoid harm than to incur benefits
- Takes a long-term view

The precautionary principle is emerging globally, fostered by the recognition that science cannot reliably predict consequences and possible harm, and our rapidly acquired "fast knowledge" is often repudiated over time. The precautionary approach is not a new idea in medicine—the pharmaceutical industry, for example, has operated according to a form of precaution for a generation or more. Ecological medicine and environmental health practitioners, joined by organizations such as the American Nurses Association, the American Public Health Association, and Physicians for Social Responsibility, are actively promoting the expansion of precaution in the choices surrounding matters of health and the environment.

MEDICINE'S ROLE IN ENVIRONMENTAL IMPROVEMENT

Increasingly, major academic medical centers and universities are recognizing environmental medicine and reinvigorating the dialogue between allopathic medicine and public health. Curricula in medical schools are responding not only to "mind-body" medicine, but also to the growing awareness of environmental issues that compromise health.

The fact that so many of these chronic diseases and environmental threats affect children first is a key motivator for both pediatricians and educators. The American Academy of Pediatrics encourages pediatricians to become informed about air pollution problems in the community and published a book on the identification, prevention, and treatment of childhood environmental health problems (AAP 2003). More broadly, the Institute of Medicine recommends the integration of environmental health concepts into all levels of nursing and medical education (Pope and Rall 1995). The American Medical Association encourages physician educators in medical schools, residency programs, and continuing medical education sessions to devote more attention to environmental health issues and encourages physicians to educate themselves about pesticide-related illnesses (AMA 1994).

In 2010, the U.S. Department of Health and Human Services launched the Healthy People 2020 campaign to address the broad range of environmental health issues, with a particular emphasis on health equity and the social determinants of health (www.healthypeople.gov). It emphasizes an ecological approach to disease prevention and health promotion. The rise of chronic health conditions that require a public health solution, like obesity, is signaling "a new era of cooperation" between medicine and public health, one that is likely to impact the physical structure of healthcare delivery.

Physician Ted Schettler presents a new vision of public health and medicine predicated on an ecological view of human health, one nested within both ecological and public health in the missions and goals of healthcare institutions. He recognizes that the ethical challenges raised by this definition represent new territory—a territory that is beginning to open for debate.

If medicine and public health incorporate a view of human health as nested within a broader concept of ecological health and adopt an expanded scope of bioethics that incorporates medical and public health ethics, what is likely to follow?

- Among their basic responsibilities, medical and public health institutions will commit to appropriately promoting, restoring, and fostering the health of individuals, communities, and ecological systems of which we are members and that the institutions serve and/or impact. Appropriateness implies wisdom in knowing why, where, how, and on what scale to intervene.
- Medical and public health institutions will explicitly commit to promoting the health and restoration of the natural, social, and built environments. These commitments will extend to the soil, water, landscapes, and other features that contribute to the integrity, beauty, and resilience of the entire biotic community. They will extend to the social determinants of health and disease. Institutions will demonstrate their commitments through community actions, advocacy, and education.
- Medical and public health institutions will also translate these commitments into a variety of operational initiatives—reduced resource consumption, green building, environmentally preferable purchasing, recycling, disposing of waste materials in ways that substantively reduce their ecological footprint, and purchasing and serving nutritious food produced in respectful, just, and sustainable ways, among many others.

Ted Schettler, MD, MPH (2008)

CONCLUSION

Finding common ground between public health and medicine, and acknowledging the profound health consequences of an environment in distress, provide the ethical groundwork for challenging healthcare sector's relationship with environment, and an imperative to proactively create the conditions for health; moving from a position of "do no harm" to a vision of "health promotion." Grounded by the concepts of prevention and the precautionary principle, emergent trends reveal that healthcare is beginning to transform its practice and embrace a broader ecological framework.

> Preventive, precautionary action—action with foresight—aimed at increasing the resilience and well-being of the whole biotic community and having salutary effects on individual community members necessitates an expanded ethical framework. As a practical undertaking in institutions with ecologically framed missions, bioethics will embrace its original intent as a guide toward a science for survival and an aid in securing lives of quality. Instead of focusing solely on individual rights and responsibilities, bioethics adds individual membership in larger ecological communities and their health to its frame of reference. Anything less perpetuates a worldview belonging to a story that should no longer be told as the way things are.
>
> SOURCE: PIERCE + JAMETON (2004)

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BIBLIOGRAPHY

American Academy of Pediatrics Committee on Environmental Health. Pediatric Environmental Health. 2nd ed. R. A. Etzel, Ed. [AAP 2003]. Elk Grove Village, IL: American Academy of Pediatrics.

American Medical Association [AMA] (1994). Report 4 of the council on scientific affairs, educational and informational strategies for reducing pesticide risks (resolutions 403 and 404).

Ausubel, K., ed. (2004). *Ecological Medicine: Healing the Earth, Healing Ourselves.* San Francisco: Sierra Club Books.

Berry, W. (1995). Health Is Membership. In *Another Turn of the Crank.* Washington, DC: Counterpoint.

_______ (1983). Solving for Pattern. In *The Gift of the Good Land.* New York: North Point Press.

Central Intelligence Agency [CIA] (2012). Country Comparison: Life Expectancy at Birth. www.cia.gov/library/publications/the-world-factbook/rankorder/2102rank.html.

Corvalan, C., S. Hales, and A. McMichael (2005). Health Synthesis Report of the Millennium Ecosystem Assessment. Geneva: World Health Organization.

Elliott, H. (1997). A General Statement of Hardin's Tragedy of the Commons. *Population & Environment*, 18 (6): 515–531.

Elliott, H., and R. Lam (2002). A moral code for a finite world. *Chronicle of Higher Education*, November 15. www.cairco.org/ethics/elliott_lamm_ethics.html.

Emanuel, E. (2011). Opinionator: How Much Does Health Cost? *The New York Times*, October 30, 2011.

EPA (2003). U.S. Environmental Protection Agency. America's Children and the Environment: Measures of Contaminants, Body Burdens, and Illnesses. 2nd ed. February 2003. Publication EPA 240-R-03–001.

Gaydos, L. M., and J. E. Veney (2002). The nature and etiology of disease. In *World Health Systems: Challenges and Perspectives,* eds. B. J. Fried and L. M. Gaydos. Chicago: Health Administration Press.

Jameton, A. (2005). Environmental health ethics. In *Environmental Health: From Global to Local*, ed. H. Frumkin. San Francisco: Jossey-Bass.

Landrigan, P. J., C. B. Schechter, J. M. Lipton, M. C. Fahs, and J. Schwartz. (2002). Environmental Pollutants and Disease in American Children: Estimates of Morbidity, Mortality, and Costs for Lead Poisoning, Asthma, Cancer, and Developmental Disabilities. *Environmental Health Perspectives*; 110(7):721–728.

Lerner, M. (2008). The Recovery of the Sacred in Healthcare in the Ecological Renaissance. In *Sustainable Healthcare Architecture*, R. Guenther and G. Vittori. New York: John Wiley & Sons, Inc., pp. 51–56.

Mannino, D. M., D. M. Homa, L. J. Akinbami, J. E. Moorman, C. Gwynn, and S. C. Redd (2002). Surveillance for asthma—U.S. 1980–1999. In *Surveillance Summaries, Morbidity and Mortality Weekly Report.* Atlanta: Centers for Disease Control and Prevention.

Myers, N., A. Jameton, C. Raffensperger et al. (2002). *What Is Ecological Medicine?* Bolinas, California: Commonweal Foundation.

National Cancer Institute [NCI] (2010). The President's Cancer Panel Report: "Reducing Environmental Cancer Risk: What We Can Do Now." http://deainfo.nci.nih.gov/advisory/pcp/annualreports/pcp08–09rpt/PCP_Report_08–09_508.pdf.

National Health Service [NHS] (2011). Route Map for Sustainable Health. Sustainable Development Unit. February. www.sdu.nhs.uk/documents/resources/Route_Map_Main_Document_no_timeline.pdf.

The Paris Appeal (2004). www.artac.info/static/telechargement/PARISAPPEAL_SIGNATR.pdf.

Pierce, J., and A. Jameton (2004). *The Ethics of Environmentally Responsible Health Care.* Oxford: Oxford University Press.

Pope, A.M., and D. P. Rall, eds. (1995). *Environmental Medicine: Integrating a Missing Element into Medical Education, Institute of Medicine Report.* Washington, DC: National Academy Press; 1995.

Potter, V. R. (1971). *Bioethics: Bridge to the Future.* Englewood Cliffs, NJ: Prentice-Hall.

Schettler, T. (2008). From Medicine to Ecological Health. In *Sustainable Healthcare Architecture*, R. Guenther and G. Vittori. New York: John Wiley & Sons, Inc., pp. 68–70.

______ (2001). Environmental challenges and visions of sustainable health care. Presented at CleanMed Conference, Boston, May 4. www.cleanmed.org/2002/documents/schettler.pdf.

Tickner, J. A., and C. Raffensperger (1999). *Protecting Public Health and the Environment: Implementing the Precautionary Principle.* Washington, DC: Island Press.

United Nations Development Programme [UNDP] (1997). *Human Development Report 1997.* New York: United Nations Development Programme.

Wilson, S. (2004). Design for Health: Summit for Massachusetts Health Care Decision Makers, September 28. PowerPoint slides.

World Bank (1993). *World Development Report, 1993: Investing in Health.* Washington, DC: World Bank.

World Health Organization [WHO] (2011). Fact Sheet 350. Geneva, Switzerland: WHO. March, 2011.

——— (1997). Fact Sheet 170. Geneva, Switzerland: WHO: 1997.

Transforming Healthcare—Gary Cohen

Abt Associates (2000). The Particulate-Related Health Benefits of Reducing Power Plant Emissions, prepared for the Clean Air Task Force, Boston, MA. October 2000; www.abtassociates.com/reports/particulate-related.pdf.

Akinbami, L. MD, J. E. Moorman, and X. Liu (2011). Asthma Prevalence, Health Care Use, and Mortality: United States, 2005–2009. Centers for Disease Control and Prevention, National Health Statistics Reports. No. 32: January 2011; www.cdc.gov/nchs/data/nhsr/nhsr032.pdf.

American Cancer Society [ACS] (2005a). Probability of Developing Invasive Cancers over Selected Age Intervals, by Sex, U.S. 1999–2001. www.cancer.org/docroot/MED/content/downloads/MED_1_1x_CFF2005_Probability_of_Developing_Invasive_Cancers_Selected_Age_Intervals_by_Sex_1999–2001.asp.

——— (2005b). Detailed Guide: Breast Cancer. What Are the Key Statistics for Breast Cancer? www.cancer.org/docroot/STT/content/STT_1x_Breast_Cancer_Facts__Figures_2003–2004.asp.

American Diabetes Association [ADA] (2008). Economic costs of diabetes in the U.S. in 2007. *Diabetes Care 2008*; 31:596–615.

American Obesity Association [AOA] (2006). AOA Fact Sheets: Obesity in the U.S. www.obesity.org/subs/fastfacts/obesity_US.shtml.

Catholic Healthcare West [CHW] (2006). CHW Food & Nutrition Services Vision Statement. www.noharm.org/details.cfm?ID=1298&type=document.

Centers for Disease Control and Prevention [CDC] (2012). Chronic Disease Overview. www.cdc.gov/chronicdisease/overview/index.htm

——— (2011a). Prevalence of Obesity in the United States, 2009–2010. NCHS Data Brief, No. 82. January. www.cdc.gov/nchs/data/databriefs/db82.pdf.

——— (2011b). Fourth National Report on Human Exposure to Environmental Chemicals, with Updated Tables (February 2011). Atlanta: National Center for Environmental Health, Division of Laboratory Sciences.

——— (2005). National Health Interview Survey. Incidence of Diagnosed Diabetes per 1,000 Population Aged 18–79 Years, by Sex and Age, United States, 1997–2004. Atlanta: National Center for Health Statistics, Division of Health Interview Statistics.

Collaborative on Health and the Environment [CHE] (2006). CHE Toxicant and Disease Database. http://database.healthandenvironment.org/.

Costello, A., M. Abbas, A. Allen, S. Ball, S. Bell, and others (2009). Managing the health effects of climate change. *The Lancet*, Vol. 373, Issue 9676, pp. 1693–1733, May 16, 2009. www.thelancet.com/climate-change.

DARA Internacional [DARA] (2012). Climate Vulnerability Monitor 2nd Edition. *A Guide to the Cold Calculus of a Hot Planet.* http://daraint.org/wp-content/uploads/2012/09/CVM2ndEd-FrontMatter.pdf.

DeVol, Ross, and Bedroussian, Armen (2007). An Unhealthy America: The Economic Burden of Chronic Disease. October. www.milkeninstitute.org/healthreform/pdf/AnUnhealthyAmericaExecSumm.pdf.

Environmental Protection Agency [EPA] 2011. Dioxins and Furans. www.epa.gov/pbt/pubs/dioxins.htm.

——— 2007. Phthalates. TEACH Chemical Summary. www.epa.gov/teach/chem_summ/phthalates_summary.pdf.

——— (2001). Information Sheet 1 / Dioxin: Summary of the Dioxin Reassessment Science. www.epa.gov/ncea/pdfs/dioxin/factsheets/dioxin_short2.pdf.

Electronic Industries Alliance Regularly Tracking Tool [EIA] (2005). Matrix of Enacted Mercury-Containing Product State Laws in the USA. www.eiatrack.org/p/219.

Endometriosis Association (2009). Endometriosis and Dioxins: Information for physicians, nurses and other healthcare professionals. Milwaukee, WI, 2009. www.endometriosisassn.org/pdfs/Endo-and-Dioxins.pdf.

Food and Drug Administration [FDA] (2002). Public Health Notification: FDA Public Health Notification: PVC Devices Containing the Plasticizer DEHP. www.fda.gov/cdrh/safety/dehp.html.

——— (2006). Questions and Answers about Dioxins. www.cfsan.fda.gov/–lrd/dioxinqa.html.

Fox, J. E. (2005). Non-traditional targets of endocrine disrupting chemicals: The roots of hormone signaling. *Integrative and Comparative Biology* 45 (1):179–188. http://icb.oxfordjournals.org/cgi/content/abstract/45/1/179.

Goldman, L. (2001). Environmental contamination and chronic diseases/disease clusters. Testimony before the Senate Committee on Environment and Public Works. 107th Congress. 1st sess. June 11.

Green Guide for Health Care [GGHC] (2007). Best Practices for Creating High Performance Healing Environments, Version 2.2. www.gghc.org/about.cfm.

Heberer, T., U. Duennbier, C. Reilich, and H. J. Stan (1997). Detection of drugs and drug metabolites in ground water samples of a drinking water treatment plant. *Fresenius Environmental Bulletin*, 6 (7–8): 438–443.

Heindel, J. J. (2003). Endocrine disruptors and the obesity epidemic. *Toxicological Sciences*, 76:247–249.

Heinzmann, B. (2005). Occurrence and behavior of trace substances in the partly closed water cycles of Berlin and its relevance to drinking water. Paper presented at the International Workshop on Rainwater and Reclaimed Water for Urban Sustainable Water Use, Tokyo, June 9–10. http://env.t.u-tokyo.ac.jp/furumailab/j/crest/workshop05/
june10pm_1.pdf.

Hemminger, P. (2005). Damming the flow of drugs into drinking water. *Environmental Health Perspectives*, 113 (10):A678–A681.

Holloway, M. (1994). An epidemic ignored: Endometriosis linked to dioxin and immunologic dysfunction. *Scientific American* 270 (4):24–26.

Hospitals for a Healthy Environment [H2E] (2005). Making Medicine Mercury Free: A 2005 Report on the Status of Virtual Mercury Elimination in the Health Care Sector. www.h2e-online.org/pubs/mercuryreport.pdf.

Huffling, K. (2006). Effects of environmental contaminants in food on women's health. *Journal of Midwifery & Women's Health* 51 (1):19–25.

Jahnke, G. D., A. R. Iannucci, A. R. Scialli, and M. D. Shelby (2005). Center for the evaluation of risks to human reproduction—the first five years. *Birth Defects Research Part B: Developmental and Reproductive Toxicology*, 74 (1):1–8.

Kaiser Permanente (2005). Kaiser Permanente Comprehensive Chemicals Policy. www.sehn.org/rtfdocs/Chemicals_Policy_3.23.05.doc.

——— (2006). Medical Center and . . . Grocery Store? Find a Farmer's Market near You. http://members.kaiserpermanente.org/redirects/farmersmarkets/.

KnowledgeSource (2006). Group Purchasing Organizations Market Overview. http://knowsource.ecnext.com/coms2/summary_0233–3641_ITM.

Mannino, D. M., D. M. Homa, L. J. Akinbami, J. E. Moorman, C. Gwynn, and S. C. Redd (2002). Surveillance for asthma—U.S. 1980–1999. In Surveillance Summaries, Morbidity and Mortality Weekly Report. Atlanta: Centers for Disease Control and Prevention.

National Toxicology Program [NTP]. Center for the Evaluation of Risk to Human Reproduction [CERHR] (2005). NTP-CERHR Expert Panel Update on the Reproductive and Developmental Toxicity of Di-2-Ethylhexyl) Phthalate. Washington, DC: Department of Health and Human Services. http://ntp.niehs.nih.gov/ntp/ohat/phthalates/dehp/DEHP__Report_final.pdf.

Shea, K. M. (2004). Nontherapeutic use of antimicrobial agents in animal agriculture: Implications for pediatrics. *Pediatrics*, 114 (3):862–868.

Suchy, T., and J. Stepan (2004). Extragenital endometriosis as a subject of interest for the surgeon. *Rozhl Chir.*, 83 (5):239–241.

Trasande, L., and P. J. Landrigan (2004). The National Children's Study: a critical national investment. Environmental Health Perspectives. October. 112(14): A789–90.

Wilson, M. P. (2006). *Green Chemistry in California: A Framework for Leadership in Chemicals Policy and Innovation.* Berkeley: Northern California Center for Occupational and Environmental Health, School of Public Health, University of California.

World Health Organization [WHO] (2012). Climate change and health. Fact Sheet No. 266, October 2012. www.who.int/mediacentre/factsheets/fs266/en/. Accessed November 1, 2012.

——— (2010). Dioxins and their effects on human health. Fact Sheet No. 225, May 2010. www.who.int/mediacentre/factsheets/fs225/en/. Accessed October 12, 2012.

——— (2009). Global Health Risks: Mortality and burden of disease attributable to selected major risks. Geneva, Switzerland. www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf.

CHAPTER 4

NATURE AND HEALING

> We cannot win this battle to save species and environments without forging an emotional bond between ourselves and nature as well—for we will not fight to save what we do not love.
>
> STEPHEN JAY GOULD
>
> Through its infinite complexity, nature is an instructive and inspirational influence that can expand the aesthetic horizons of the building arts and confirm the inalienable right of humanity to try to salvage a place on this planet before it's too late. The mission now in architecture, as in all human endeavors, is to recover those fragile threads of connectedness with nature that have been lost for most of this century.
>
> JAMES WINES
>
> The "control of nature" is a phrase conceived in arrogance, born of the Neanderthal age of biology and the convenience of Man.
>
> RACHEL CARSON

INTRODUCTION

Medicine has long-standing ties with the natural world. Whether through the harvesting of willow bark in the early formulation of salicylate (aspirin), the public health work of Florence Nightingale that noted the benefits of daylight and fresh air for patients, or Thomas Mann's description of nineteenth-century tuberculosis sanatoriums in The Magic Mountain (Mann 1996) where people huddled under blankets to "take the cure," the interrelationships between nature and healing have been a part of the slow knowledge universally acquired and understood across diverse cultures and traditions. As the Industrial Revolution progressed, the medical profession distanced itself from this partnership with nature. The pharmaceutical industry, as it increased in scale, converted from natural to synthetic petrochemical derivatives; North American healthcare buildings became sealed, totally artificial environments with severely limited access to natural light and ventilation. Today, allopathic medicine rarely acknowledges that healing is, fundamentally, a natural process.

Just as twentieth-century industrial processes are out of sync with biological systems, medical technology has become ever more aggressive in battling disease. The common refrain, "If the disease doesn't kill you, the treatment will," accompanies many of our more advanced medical interventions. We describe our medical research as "wars" on disease. Since the early twentieth century, metaphors of nature have given way to those of machines to describe our approach to medicine and medical buildings. Designer Jason F. McLennan (2000) observed that the machine metaphor "implies a relationship with nature that is exploitative and relies on brute force combined with great amounts of energy to solve problems."

When was it determined that nature is somehow in opposition to healing, a precept reflected in hospital architecture today, particularly evident throughout

North America? As the twenty-first century emerges, can medicine, and the buildings that clothe it, be reimagined in partnership with natural processes and flows? Can medicine and hospital architecture restore and regenerate both social and natural systems? What form might such a partnership take? How might this relate to the bioethical constructs in medicine outlined in Chapter 3?

Chapter 4 explores new ways to integrate nature and healing in the service of ecological design. First, biophilic design elements reconnect building occupants to nature. Then, an ethic of conservation as a component of an expanded view of bioethics leads to a fundamental reexamination of the hospital's place in the landscape—an intervention of restorative land planning. Finally, the idea of landscapes that heal is introduced through an exploration of therapeutic and restorative landscape design.

THE TRADITION OF NATURE AND HEALING

Nature has been recognized as a source for healing throughout history. In ancient times, healing rituals were conducted in sacred spaces defined by the presence of awe-inspiring nature. Among the earliest surviving Western manifestations of architecture for health are the open halls of Asclepieia in ancient Greece, where in the fourth century BCE priests converted patients' dreams into therapeutic regimens. Such early places of healing included patient beds, treatments, medication, and diet and exercise regimens, taking their architectural placement from nature: the sun and prevailing breezes.

Since that early vision, advancements in medical education, care, and technology have defined the hospital as the primary typology of healing architecture. Until the late nineteenth century, courtyards, daylight, and natural ventilation produced hospital buildings that focused on convalescence, as interventional treatment modalities were limited. Clean air and water were seen as essential in hospital settings. Florence Nightingale, in *Notes on Hospitals* (1859), reinforced prescriptive design measures, including ward dimensions and window sizes, for providing abundant daylight and fresh air. "To deprive the sick of pure air," she wrote, "is nothing but manslaughter under the garb of benevolence."

The nineteenth-century pavilion hospitals were often remotely situated from the dense urban environment, where access to light and air was still achievable. As cities expanded, hospitals eagerly sought sites at their edge, alongside rivers or at high elevations, to ensure access to water, fresh air, and light. Continued urbanization throughout the nineteenth and twentieth centuries eventually engulfed many of them in the cities they had initially hoped to stay clear of.

The development of anesthesia, surgical techniques, and medical treatment modalities further separated the late-nineteenth-century hospital from its beginnings in convalescence. Resort spas, tuberculosis sanatoriums, residential psychiatric facilities, and other specialty-care settings maintained a focus on the restorative aspects of landscape, while the twentieth-century hospital followed the broader pursuit of mastery over nature.

THE THERAPEUTIC SPA MOVEMENT

As hospitals focused on medical education and technology, the resort spa movement in Europe and the United States continued to focus on nature as a therapeutic modality. Dedicated to the notion of reconnecting highly stressed individuals in the industrial economy to their bodies and health, these typologies emerged in the private sector as the most powerful and potent connection to disease prevention. During urban epidemics, the wealthy routinely retreated to the resort spa as refuge.

As the Industrial Revolution progressed, an anti-urban commune movement endured, offering an alternative view of people's inherent humanism and need to connect with authentic nature. Initially, these buildings included tuberculosis sanatoriums. Alvar Aalto's sanatorium in Paimio, Finland (1929–1933), a surviving example of the early-twentieth-century hospital building, retains a strong connection between nature and healing that postwar twentieth-century North American hospitals, with their focus on technology, left behind.

NATURE RECONSIDERED

By the mid-1980s, a body of research began to emerge indicating that a connection to nature positively influences medical outcomes and staff performance. The studies on the therapeutic importance of views supported reconnecting nature with the healthcare environment (Ulrich 1984). In 1993, the nonprofit Center for Health Design (www.healthdesign.org) began advocating for a critical reexamination of the hospital building. Recognizing that the built environment impacts both the patient experience and medical outcomes, the Center gathered a coalition of environmental design researchers to define evidence-based design in support of life-enhancing environments that promote health and healing.

The influence of this work in the healthcare industry is compelling. New hospitals routinely emphasize improved access to nature, interpreted to mean windows at the ends of corridors, "healing gardens," and a new focus on patient and staff amenity areas. In *The Business Case for Better Buildings*, Leonard Berry, Derek Parker, and others (2004) define a better building as one that reduces stress, improves safety, and contributes to ecological health. Nature, they contend, has an important role in defining this "better building." Those findings were corroborated in *Fable Hospital 2.0: The Business Case for Building Better Health Care Facilities*, which establishes a series of evidence-based design features—including those connecting patients and staff to nature—that benefit patient outcomes with an estimated three-year payback (Sadler et al. 2011).

At the same time, there is no definitive pattern language or tool kit to assist in the reintegration of nature in hospitals, though elements of this are beginning to emerge, initially in the *Green Guide for Health Care* and later in *LEED for Healthcare*. Outdoor places of respite, therapeutic landscaping, daylighting, and views of nature are all increasingly appearing in hospitals. Sustainable design considerations extend the vocabulary further, by introducing another set of prescriptive design strategies—restorative habitat, for example, or green roofs. What are the emergent ideas that can catalyze a new approach to healthcare's integration of nature? Thunder Bay Regional Health Sciences Centre, located in Thunder Bay, Ontario, uses its landscape design to support onsite stormwater retention and filtration while also providing patients, staff, and visitors with an evocative visual connection to nature (see Figure 4.1). Becoming part of the site's ecosystem, the ponds are designed as coldwater fish breeding areas to help repopulate the adjacent river with native species.

Figure 4.1 Thunder Bay uses its landscape design to support onsite stormwater retention and filtration. *Source: Peter Sellar, Klik Photography*

BIOPHILIA

Increasing evidence suggests that contact with nature can foster human health, productivity, and well-being, and that humans possess a basic need for contact with natural systems and processes (Kellert 2005). The entomologist E. O. Wilson (1984) coined the term "biophilia" to describe humans' inherent inclination to affiliate with nature, most particularly with life and ecosystem features of the natural environment. More recently, Wilson collaborator and social ecologist Stephen Kellert has extended the definition of biophilic design to include buildings and constructed landscapes that foster a positive connection between people and nature in places of cultural and ecological significance. In the biophilic principles that follow, Kellert and environmental psychologist Judith Heerwagen offer an overview of design strategies that integrate nature references at all levels of building design—from organization to materials—and this aspiration for their application:

Effectively incorporating these biophilic design elements in constructed buildings and landscapes to varying degrees and in various combinations can enhance human health and well-being. This list of biophilic design elements can guide healthcare designers and hospital developers in addressing the inherent human affinity for nature. Yet the effectiveness of the design always depends on the creativity and integrative talent of the development more than on following a prescribed list. A checklist can never assure that even a well-intentioned project will produce a harmonious and beneficial design. Like all great constructions, the whole always remains more than the simple sum of its parts.

Two basic dimensions distinguish biophilic design: the human experience of nature—organic or naturalistic design—and the context where this experience occurs—vernacular or place-based design. Both low-environmental and biophilic design must work in complementary relation to achieve a true and lasting sustainability. This broader approach to sustainability seeks to avoid and minimize harmful impacts on the natural environment and human health as well as provide and restore beneficial contact between people and nature in the built environment.

—Kellert and Heerwagen (2008)

Figure 4.2 This eighth-floor healing garden overlooks the Charles River and an adjacent historic prison cupola, which has been converted to hospital use. The use of a glass rail system expands the boundaries of the urban setting, and its height allows viewers to lose the middle landscape in favor of the distant river view. *Source: Ben Watkins, Halvorson Design Partnership, Inc.*

BIOPHILIC DESIGN PRINCIPLES

1. Environmental features:
   - Natural materials
   - Natural colors
   - Sunlight
   - Water
   - Natural ventilation
   - Plants and animals
   - Natural views and vistas
   - Facade greening
   - Geological and landscape forms
   - Habitats and ecosystems
   - Fire
2. Natural shapes and forms:
   - Botanical motifs
   - Animal motifs
   - Shell and spiral forms
   - Egg, ovular, and tubular forms
   - Arches, vaults, domes
   - Columns and treelike supports
   - Shapes that resist right angles
   - Simulation of natural features
   - Biomorphism (resemblance to organic forms)
   - Natural morphology (e.g., stratified surfaces and rooted relationships)
   - Biomimicry (mimicry of organic structures and functions)
3. Natural patterns and processes:
   - Sensory variability
   - Information richness
   - Time, aging, and change
   - Growth and efflorescence
   - Central focal point
   - Patterned whole
   - Bounded spaces (e.g., borders, territories)
   - Transitional spaces (e.g., gateways, thresholds)
   - Complementary contrasts (e.g., light/dark, high/low)
   - Dynamic balance and tension
   - Similar forms at different scales (e.g., fractals)
   - Hierarchically organized scales
   - Ordered complexity
   - Relation and integration of parts to whole
   - Linked series and chains
4. Light and space:
   - Natural light
   - Filtered and diffused light
   - Light and shadow
   - Reflected light
   - Light pools
   - Warm light
   - Light as shape and form
   - Spatial variability
   - Spaciousness
   - Space as shape and form
   - Spatial harmony (the integration of light, mass, and scale)
   - Inside/outside spaces (e.g., atria, colonnades)
5. Place-based relationships:
   - Historical connection to place
   - Cultural connection to place
   - Geographical connection to place
   - Ecological connection to place
   - Use of indigenous materials
   - Compatible orientation to land-scape
   - Landscape features that define building form
   - Landscape ecology (connections, corridors, biodiversity)
   - Integrating culture and ecology
   - Sense or spirit of place
   - Avoiding placelessness
6. Evolved human relations to nature:
   - Prospect and refuge
   - Exploration and discovery
   - Mystery and enticement
   - Order and complexity
   - Change and metamorphosis
   - Information and cognition
   - Attraction and beauty
   - Mastery and control
   - Security and protection
   - Affection and attachment
   - Fear and awe
   - Reverence and spirituality

Source: Kellert and Heerwagen (2008)

According to Wilson (1984), given free choice, people will move to open, tree-studded land on promontories overlooking water. The compelling healing garden atop the Yawkey Center for Outpatient Care illustrates Wilson's principles in action (see Figure 4.2). A candid journal entry by a twelve-year-old child, reproduced at the garden entrance, reads: "Coming here is the best medicine" (Ravanesi 2006).

URBANIZATION AND NATURE

Likewise, there is emerging evidence that urbanization, with limited nature contact, creates a unique set of social and mental health stressors that can negatively impact health. Urbanization, a process that started in North America and Western Europe but is now mainly occurring in developing nations, is a major socioecological change confronting mankind. By 2050, 69 percent of humans are projected to live in urban areas. In the first large-scale behavioral study of its kind, Florian Lederbogen and a team of researchers isolated particular brain activity in urban dwellers correlated with increased stress-related activations (Lederbogen et al. 2011). While it is possible that any of the multiple factors related to urban living—pollution, noise, crowding—might be responsible for these associations, the postulate is that differences in natural and social support structures are a major environmental determinant separating urban dwellers from their rural counterparts. Hence, the research suggests that cities need to support both nature contact and provide a rich variety of social support structures in order to support physical and mental health.

LANDSCAPE PERCEPTION

Related to environmental psychology, the field of environmental aesthetics encompasses the question: What is the nature of nature? How do we perceive landscape and nature settings, and what does this mean for reconnecting nature and healing? Landscape, as a concept, derives from the seventeenth century Dutch landschap, referring to the background of a painting. Geographer J. Douglas Porteous (1996) notes that the British expanded the concept to include "a visually pleasing prospect whether on the ground or on canvas." It delighted all the senses and was best appreciated kinesthetically, by moving through it, rather than simply gazing upon it. Porteous observes that in the United States, landscape has always been seen as reflecting the dominant value system that lauds freedom, individualism, power, and progress. In fact, the United States has long defined landscape as a commodity, or a means of wealth-production—the waterfront view, the mountain vista property.

As long ago as the eighteenth century, we developed our sense of the beautiful in landscape design. Aristocrats reshaped the countryside to fit contemporary theories of how landscapes should look. The pastoral/beautiful was seen as the antidote to the Industrial Revolution's urban landscape—a manifestation of the tranquility of nature. In the nineteenth century, the writers Ralph Waldo Emerson and Henry David Thoreau argued for a return to an authentic, emotional contact with wilderness and nature—the development of the system of the country's national parks was partially inspired by this challenge. In addition to developing a model for humankind's intangible relationship with the environment (Figure 4.3), Porteous (1996) observed that rapid population growth and urban development won out: "As Western societies developed the tools for making over the earth, the 'feel' for harmony between humankind and nature was lost in the frantic exploitation of 'resources.'"

HEALING LANDSCAPE

Healing, for the purposes of this discussion, embodies the three ideas articulated by landscape architect Clare Cooper Marcus (1999): relief from symptoms

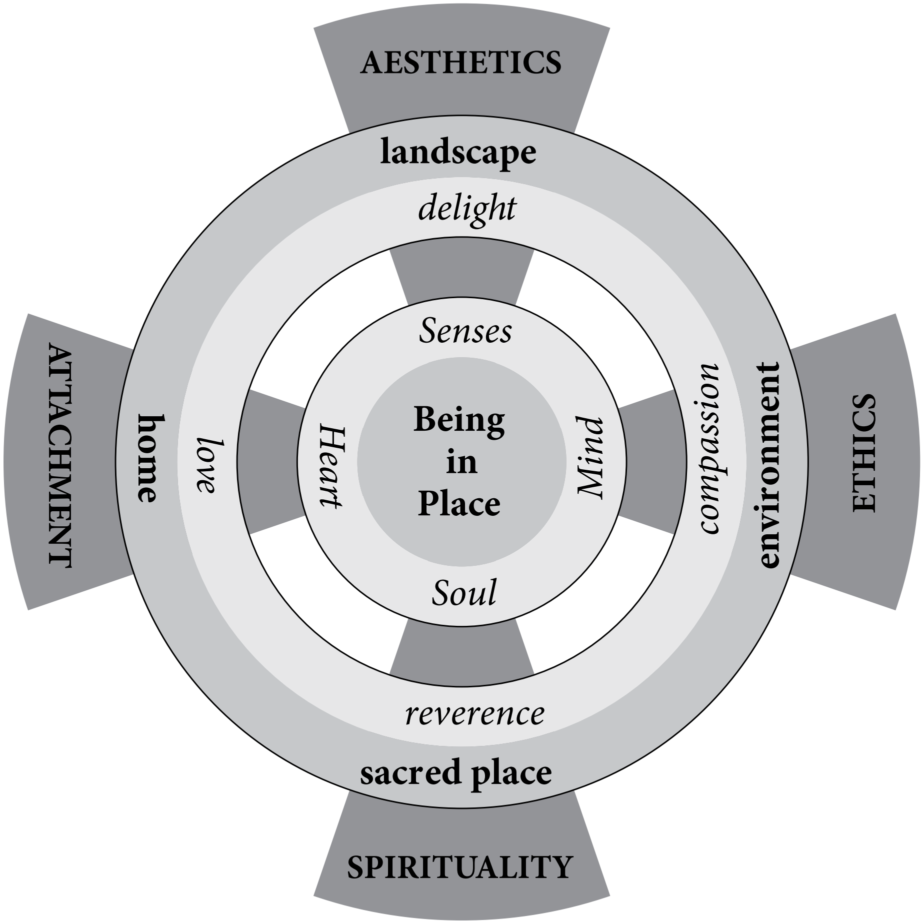


Figure 4.3 Humankind's intangible relationships with the environment directly inform the consideration of therapeutic or healing landscape in healthcare settings by recognizing the complex attributes of well-being—thought (mind), feeling (heart), intuition (soul), and sensation (senses). *Source: Porteous (1996). Redrawn with permission from Routledge Taylor.*

of illness, stress reduction, and improvement in the sense of overall well-being. In fact, she maintains, the healing garden is emerging as a supplement to drug- or technology-based treatments. Marcus has led a lifelong exploration of the principles that inform healing landscapes in healthcare settings and underlie the worldwide therapeutic landscape movement.

The Sidney and Lois Eskenazi Hospital and Health Campus in Indianapolis, Indiana, scheduled to open in 2014, is designed by HOK. This 1.4 million sq. ft. (130,064 sq. m) building on a 34 acre (13 ha) site, introduces a series of accessible gardens and a large food producing green roof "sky farm" that brings nature's therapeutic values to patients and staff through visual, physical, and nutritional connections.

Sidney and Lois Eskenazi Hospital and Health Campus

Indianapolis, Indiana

Architects: HOK

The Eskenazi Health Campus, a public hospital located in Indianapolis on the Indiana University campus, scheduled to open in 2014, moves beyond conventional healthcare building design by creating a calm, relaxing and healthy environment for patients, staff, and the surrounding community. This is achieved in the context of serving 20 percent more patients in one-third less space compared to the original facility, reducing total square footage by 300,000 sq. ft. (27,871 sq. m). The hospital's 35,000 sq. ft. (3,252 sq. m) green roof, installed during initial construction, can be expanded up to an additional 46,000 sq. ft. (4,274 sq. m) at the Owner's discretion. The green roof will contribute to energy savings and also function as an on-site food producing "farm" for the hospital itself, with a yield estimated to be about 10,000 pounds of produce per year. This will augment the hospital's commitment to procure locally sourced food from nearby farms (see Figure 4.4).

Also noteworthy is the hospital's capacity to collect 40,000 gallons (151,416 L) of rainwater used to irrigate the hospital's extensive landscaped gardens. Along with rainwater collection, the hospital also has an aggressive approach to stormwater management to protect adjacent rivers. The hospital site is designed to be porous, allowing water to enter the aquifer. Stormwater runoff is captured in bio-filtration swales before being released back into the environment.

Figure 4.4 The green roof will function as an onsite food producing "farm." *Source: H2 Studios*

Figure 4.5 Building section. *Source: HOK*

Eskenazi will feature a series of therapeutic gardens for different populations on the campus (e.g., staff, patients, visitors, and researchers). For example, the Women's Garden is located near Women's Services and the Burn Unit; the Research Garden is primarily used by Eskenazi's Researchers; the Slip Garden serves as a walkway between the Parking Garage and Ambulatory Clinic Building; the Well of Wishes is a garden associated with the emergency waiting room; the Secret Garden is a place of respite for the hospital staff. The numerous gardens are emblematic of the desire to create an enhanced healing environment for everyone at the hospital. In addition to the Commons and the Sky Farm—the two most prominent outdoor spaces on campus—the gardens provide peace and comfort for smaller, specific groups.

As a public hospital, the Eskenazi Health Campus has significant connections with the broader community. The outside trellis area, farmers market, and Health and Wellness Trail engage the public with a particular emphasis on supporting healthy living. And, in a spirit of moving beyond compliance, Eskenazi provides a fully accessible campus, with all spaces and paths of travel meeting Title 1, 2, and 3 requirements of the Americans with Disabilities Act.

Departing from its antecedents, decisions about hospital siting have devolved to no longer be based on affinity for view or natural and cyclical properties of sites, but rather by commercial real estate interests. The hospital landscape, for the most part, has been obliterated by surface parking requirements, helipads, and service and emergency vehicle access. While a patient room window may frame a natural vista of distant views, the view across the intermediate landscape is rarely satisfactory. Often, the middle ground is dominated by vehicle access or urban structures. In what was less common even five years ago, many of the projects featured in this book's case studies foreshadow an emergent twenty-first-century pattern language for both urban and rural hospitals that instantly and profoundly connects occupants to the landscape. In so doing, they demonstrate the challenges inherent in reconsidering the fundamental relationship of the building to its site, and the power of doing so.

Landscape architects Jody Rosenblatt-Naderi and Jerry Smith present this challenge in the design of therapeutic landscapes:

> Healing gardens, or therapeutic landscapes, are by definition places of renewal. Therapeutic benefits derive from contact with nature because the spatial experience encourages people to connect with a deeper part of themselves and with their natural surroundings. These deep connections, in turn, renew the spirit and help people find a strength that is a crucial part of healing.
>
> Gardens designed to heal should themselves be in a healthy relationship with their biophysical and cultural contexts. Successful gardens tend to transport people away from the intensity of healthcare through contrasts and distractions. But, in doing so, they may, ironically, inadvertently displace nature with generic healing gardens. Tucked into the harsh landscapes of courtyards and hospital rooftops, these gardens can be an oasis, but are at risk of failing by being out of step with the ecology of the ambient landscape.
>
> Taking cues from the history of ecological and sustainable design literature, evidence favors survival based on the diversity of the indigenous palette (Ndubisi 2002). However, behavioral and landscape-preference research suggests that most people prefer a more controlled, familiar, or even domestic landscape (Marcus 1997). How can a Disneyesque, domesticated landscape impart the healing force of nature honestly and sustainably? Given the constraints and environmental boundaries that are often imposed on outdoor places of respite within todays built environments of care, is the designed landscape able to impart that same sense of healing that nature provides?

For new hospital campuses on urban sites, ideas of therapeutic landscape merge with sustainable site planning principles in developing healing gardens, green roofs, and native plantings. The Lunder Building at Massachusetts General Hospital (Case Study 15, Chapter 7) demonstrates how a massive building on a tight urban site can creatively extend available perimeter and integrate nature through the introduction of atria open to the perimeter. The work of Walker Macy at Legacy Salmon Creek Hospital illustrates how developing structured parking and orienting patient room vistas toward adjacent wooded areas achieved a profound healthcare experience (Figures 4.6 through 4.8). At Lucile Packard Children's Hospital (Case Study 11, Chapter 5), the 9-acre (3.6-ha) suburban grayfield (former predominantly surface parking) site actually increases habitat by close to 4 acres (1.6 ha) while accommodating an increase of 500,000 sq. ft. (46,400 sq. m) in built area.

Figure 4.6 The Legacy Salmon Creek forecourt garden juxtaposes geometric and organic forms as it terraces from the entrance road beyond to the hospital entrance. Paving blocks and porous paving recharge groundwater; the water feature provides the sound of water in the court. *Source: Walker Macy*

Figure 4.7 Native perennials and grasses provide both visual stimulation and scent in the therapeutic healing garden.
Source: Walker Macy

Key to plant names:

1. Golden Glory euphorbia *Euphorbia amygdaloides* "Golden Glory"
2. Jerusalem sage *Phlomis russelliana*
3. Feather reed grass *Calamagrostis x acutiflora* "Karl Forester"
4. Golden bamboo *Phyllostachys aurea*
5. Purple smoke bush *Cotinus coggygria* "Royal Robe"
6. Black Flower fountain grass *Pennisetum alopecuroides* "Moudry"
7. Sweet variegated iris *Iris pallida* "Variegata"
8. Camas *Camassia quamash*
9. Purple silver grass *Miscanthus "Purpurascens"*
10. Dark Horse weigelia *Weigelia florida* "Dark Horse"
11. Adjective Hybrid Daylily *Hemerocallis x* "Adjective"
12. Otto Quast Spanish lavender *Lavandula stoechas* "Otto Quast"
13. Ice Dance Japanese sedge *Carex morrowii* "Ice Dance"
14. Superbum sea holly *Eryngium alpinum* "superbum"
15. Russian sage *Perovskia atriplicifolia*

Figure 4.8 The meditation room floats in the healing garden, a landscaped roof space between the two inpatient tower wings. The garden was designed as an integral component of a horticulture therapy program. *Source: Copyright © Eckert & Eckert*

Summary of Landscape Design Principles for Healing

- Celebrate the rhythm and cycles of nature through design by acknowledging seasonal change, natural patterns, and the movement of sun, water, terrain, and natural materials.
- Connect to the sacred dimensions of the subculture and biophysical setting unique to each hospital community.
- Present seasonal experiences with views of infinity aligned with contextual celestial movements of the sun, moon, and stars.
- Engage all the senses with plants, wind, water, earth, movement, and music.
- Utilize horizontal and vertical dynamics that draw the visitor into the garden and provide visual focus beyond it.
- Evoke memory and familiarity.
- Contrast with the intensity of the healthcare experience through changing scale, materials (nature over man-made), microclimate (e.g., fresh air, dew, breeze, and sunlight), sound levels (in contrast with the public address system) and views (e.g., infinity at the micro and macro scale, reflections, from windows).
- Employ ergonometric and spatially comfortable details for patients, visitors, and staff.

Suggested Design Methods for Enabling Healing

- Provide places for pause along paths that are comfortable, semiprivate, sited in response to microclimate, and present natural elements through interesting views, smells, textures, and sounds.
- Provide paths connecting transitional spaces to facilitate chance encounters.
- Maximize the number of paths and intersections to facilitate informal walking circuits, path choice, and contemplative walking.
- Plant trees along paths, around seating, and within view of windows.
- Increase the variety of social spaces and seating groups.
- Engage the site's natural preconstruction condition to celebrate the genius loci of the hospital location.
- Provide signage and accessibility to the garden for all mobility types.

—Jody Rosenblatt-Naderi, RLA and Jerry Smith, FASLA (Rosenblatt-Naderi 2008)

SUSTAINABLE LANDSCAPE

Landscape architect and professor Ian McHarg, the pioneer of ecological land planning, devoted his life to revealing the complexity of contemporary site planning hubris—the widespread belief that nothing in nature should constrain what humans do to the land they own. Most importantly, McHarg advocated for three important principles of sustainable site planning (Sorvig 2006):

1. Sustainable site planning depends on proactive advocacy for the land itself.
2. Landscape architecture is equal in importance to architecture and civil engineering.
3. It is both possible and essential to recognize and map sites for their inherent natural, cyclical patterns and flows.

> *Our eyes do not divide us from the world, but unite us with it. . . . Let us abandon the self-mutilation which has been our way and give expression to the potential harmony of man-nature. The world is abundant; we require only a deference born of understanding to fulfill man's promise. Man is that uniquely conscious creature who can perceive and express. He must become the steward of the biosphere. To do this he must design with nature.*
>
> —Ian McHarg (1969)

As research on the therapeutic benefits of a connection with nature and sustainable healthcare emerges, the critical significance of McHarg's work becomes more evident. Compelling evidence associated with hospital patient outcomes and staff well-being affirms the fundamental relationship between healing and nature. As a result, situating hospital buildings in seas of parking, devoid of any direct connection to the landscape, is becoming unacceptable, as the case studies throughout this book foreshadow.

The antithesis of locating a hospital in a parking lot is nestling it in a natural forest. The design of the All Ukrainian Health Protection Centre for Mothers and Children, located in Kiev, Ukraine (Case Study 55, Chapter 10) is inspired by the power of their natural context: "Developed on a stunning site, the design aims to respect and work with the forest to preserve its unique atmosphere, rather than destroy it. By seeking to destroy as few trees as possible and develop a landscape design that uses the natural forest floor rather than grass as its base. . .the natural habitat is maintained and a more powerful cultivation of the healing environment is made possible" (Cadenhead 2012).

CONCLUSION

More than 100 years of the systematic decoupling of nature, healing, and healthcare buildings will not be overcome easily. No longer are sacred natural sites reserved for buildings for healing, thanks to the simultaneous commoditization of health and the landscape; nor are healthcare buildings intentionally sited alongside hot springs, or on promontories with water views that resonate with humans in times of stress—places of strong biophilic content for humans in their greatest hours of need.

The dictates of technology and fear of contamination and infection have eliminated most traces of nature from hospital buildings, particularly in North America: the lack of natural ventilation and operable windows, the dependence on electrical lighting over natural daylight, the deep floor plate building, the rejection of courtyards and other nature-inclusive spaces for patient use. Sustainable healthcare architecture challenges this typology; the projects in this book, at this moment of transformation, demonstrate a renewed partnership between buildings and nature. The creative re-introduction of healing landscapes can assist in developing and strengthening the biophilic connections to nature and further reconnection to the therapeutic powers of nature.

Sustainable design calls the question of whether buildings that purport to heal and restore people can also be a force to restore the natural surroundings they are sited within. We see in the projects featured in this book that the disciplines of land planning and landscape design bring coherence to the relationship between healing people and healing the Earth. A healthcare campus offers the quintessential opportunity of a place where people can and should experience a positive, restorative natural setting.

BIBLIOGRAPHY

Berry, L., D. Parker, R. C. Coile, Jr. et al. (2004). The business case for better buildings. *Frontiers of Health Service Management,* 21 (1):3–24.

Cadenhead, N. (2012). Children's Health: The Enchanted Hospital. World Health Design. www.worldhealthdesign.com/The-Enchanted-Hospital.aspx.

Carson, Rachel (1962). *Silent Spring.* Houghton Mifflin.

Gould, S. J. (1991). Enchanted evening. *Natural History*, September 14.

Kellert, S. (2005). *Building for Life: Designing and Understanding the Human–Nature Connection.* Washington, DC: Island Press.

Kellert, S., and J. Heerwagen (2008). Nature and Healing: The Science, Theory, and Promise of Biophilic Design. In *Sustainable Healthcare Architecture.* R. Guenther and G. Vittori. Hoboken, NJ: John Wiley & Sons, Inc. p. 89.

Lederbogen, F., P. Kirsch, L. Haddad, F. Streit, H. Tost, P. Schuch, and others (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature*: Vol. 474, June 23, 2011: pp. 498–501.

Leopold, A. (1966). *A Sand County Almanac, with Other Essays on Conservation from Round River.* New York: Oxford University Press.

Mann, Thomas. (1996). *The Magic Mountain.* New York: 1st Vintage Int'l. ed.

Marcus, C. C. (1999). *Healing Gardens: Therapeutic Benefits and Design Recommendations.* Hoboken, NJ: John Wiley & Sons, Inc.

Marcus, C. C. and C. Francis, eds. (1997). *People Places: Design Guidelines for Urban Open Space.* 2nd ed. Hoboken, NJ: John Wiley & Sons.

McHarg, I. (1969). *Design with Nature.* Garden City, NY: Natural History Press.

McLennan, J. F. (2000). Living buildings. In Sustainable Architecture White Papers. New York: Earth Pledge Foundation.

National Cancer Institute (2002). Taxanes in Cancer Treatment. http://cancerweb.ncl.ac.uk/cancernet/600715.html.

Ndubisi, F. (2002). *Ecological Planning: A Historic and Comparative Synthesis.* Baltimore: Johns Hopkins University.

Nightingale, F. (1859). *Notes on Hospitals.* London: John W. Parker.

Orians, G., and J. Heerwagen (1992). Evolved responses to landscapes. In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, eds. J. H. Barkow, L. Cosmides, and J. Tooby. New York: Oxford University Press, p. 558.

Porteous, J. D. (1996). *Environmental Aesthetics: Ideas, Politics and Planning.* London: Routledge.

Ravanesi, B. (2006). Personal communication with Robin Guenther.

Rosenblatt-Naderi, J., and J. Smith (2008). Design with Rhythm. In *Sustainable Healthcare Architecture*, R. Guenther and G. Vittori. Hoboken: John Wiley & Sons, Inc., pp. 94–95.

Sadler, B., L. Berry et al. (2011). Fable Hospital 2.0: The Business Case for Building Better Health Care Facilities. *The Hastings Center Report*, Vol. 41, No. 1.

Stephenson, F. (2002). A tale of taxol. Research in Review (Florida State University), Fall. www.rinr.fsu.edu/fall2002/taxol.html.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224:420–421.

Wilson, E. O. (1984). *Biophilia: The Human Bond with Other Species.* Cambridge: Harvard University Press.

Wines, J. (1998). *The Art of Architecture in the Age of Ecology.* New York: Taschen. Quoted in Sustainable Architecture White Papers, eds. D. Brown, M. Fox, and M. R. Pelletier. New York: Earth Pledge Foundation.

PART 2

ACTUALIZING THE VISION

CHAPTER 5

IMPROVING PERFORMANCE

> If you can't measure it, you can't manage it.
>
> PETER DRUCKER

> Global warming isn't a prediction. It is happening. . . .The cost of acting goes far higher the longer we wait—we can't wait any longer to avoid the worst and be judged immoral by coming generations.
>
> JAMES HANSEN

> In healthcare, sustainable building represents a bold move toward precaution and prevention. The building stands for health. In creating it, the organization is essentially saying, "We're investing in keeping people healthier." But it's consistent with a physician's value system. It represents a mindset and a culture of health as opposed to sickness treatment. Healing is an intangible concept. Creating the right environment for people mentally, physically, and spiritually is so important. Being attentive to sustainability, wellness, and resource stewardship presents a holistic view of healthcare that has an impact. We may not be able to measure or test it, but I'm convinced it has a tremendous impact on a person's ability to attain health. Not just to be not sick, but to be in health.
>
> JOHN KOSTER, MD

INTRODUCTION

Charting the course toward sustainable healthcare design and construction requires perspective and tools: a conceptual framework, metrics (i.e., what we measure), and the basis for measurement—or how we measure it. The choice of tool implies a definition of the measures of success. Just what defines a high-performance healing environment? Is it a carbon neutral, water-balanced, zero-waste hospital, free of persistent bioaccumulative toxic chemicals? Is it also a building intrinsically connected to health, well-being, and the healing process? If so, how is that performance defined and measured?

This chapter proposes an expanded view of measuring performance, responding to the layered ecological urgencies and opportunities of our time: climate change, global toxification, water balance, and zero waste. The parallels between these seemingly disparate ecological markers are striking: they each have global reach independent of political boundaries, geography, and generation.

Healthcare has deep roots and successes in both the policy and implementation arenas associated with toxic chemical avoidance and waste reduction. On the other hand, reducing climate change impacts, while grabbing headlines in the first decade of the twenty-first century, is just beginning to emerge among healthcare's priorities; similarly, a full view of healthcare's water dependencies—from source, to use and re-source—is nascent. An integrated health-based ecological framework—with carbon neutrality, persistent bioaccumulative toxic chemical (PBT) elimination, water balance, and zero waste as the measures of success—builds on healthcare's pioneering leadership and provides sharp focus to global ecological stewardship efforts.

TOOLS AND METRICS

Having established a broad, multifaceted value proposition for green healthcare facilities, what tools guide and measure the sector's progress? The prospect of establishing green building protocols for healthcare facilities is challenging, given their technical sophistication and complex programs. The promise of quantifying performance benefits makes such tools essential. What defines a high-performance healing environment, and how do we measure it? Attributes that make healthcare settings unique—from 24/7 operations, infection-control concerns, construction amid ongoing occupancy, and hazardous chemical use to creating physical environments conducive to healing patients and optimizing work conditions for staff—are precisely those that make them challenging.

As the healthcare sector aligns a health promotion and disease prevention mission with its built environment approaches, the metric tools specifically structured to reinforce that design and operational intention also evolve. This journey to develop an appropriate set of measures began years ago, undertaken by individuals and organizations, influenced by international policy and courageous individual hospital initiatives, informed by green building tools, and inspired by a vision of healing and health for all. With each successive policy and development tool, the journey moves the industry closer to actualizing this unique vision for healthcare in the twenty-first century.

In the Beginning: Sustainable Design Tools, Principles, and Policies

Beginning in the 1990s and through the first decade of the twenty-first century a proliferation of tools, best-practice procedures, and policy frameworks structured to promote and support sustainable planning, development, design, and construction emerged. Ranging from international policies to local sustainability guidelines, building industry leaders recognized the importance of green buildings and began moving the agenda into practice. From these early U.S.-based efforts, such as the City of Austin's Green Building Program, the American Institute of Architects' *Environmental Resource Guide,* and the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) emerged a powerful definition of sustainability and the first comprehensive tools for rating green buildings. While the healthcare industry was largely untouched by these early developments, this first generation of green building rating systems ultimately provided the framework for healthcare's green building tools.

From 2002 through 2011, the Green Guide for Health Care (Green Guide), a project of the Center for Maximum Potential Building Systems and Health Care Without Harm, developed and pilot tested a range of sustainable building strategies unique to healthcare, including places of respite, acoustics, daylighting, and a customized prescriptive path for hospitals greater than 70,000 sq. ft. (6,503 sq. m) to achieve 14 percent energy reduction across U.S. climate zones (GGHC 2007). The Green Guide was the first self-certification tool to place sustainable building strategies within a broader health framework, and featured the first credits on material health, including persistent bioaccumulative toxic chemical avoidance.

Somewhat inevitably, the North American market shifts toward green building have resonated globally, echoing the pattern of tool development that occurred in the United States. The Green Building Council of Australia, for example, launched its own green building tool, Green Star, and has gone on to modify it for several sector-specific applications, including healthcare.

Market Transformation

Now in the second decade of the new millennium, sustainable design has achieved broad recognition and acceptance—in the United States and internationally—distinguishing it from earlier dispersed, more singularly focused efforts. The evolution of green building tools continues, focused both on measuring performance and market transformation. Today, multiple tools and rating systems are continuing to both measure performance improvements and catalyze market transformation in the healthcare sector, including LEED for Healthcare, BREEAM Healthcare and Green Star–Healthcare. Concurrently, a next generation of rating tools, such as the International Living Future Institute's Living Building Challenge—a tool with no credits, only "imperatives"—continues to raise the bar for building performance.

Both the China Hospital Association and the Chinese Construction Ministry have developed green guidelines for hospitals and other healthcare facilities, recognizing the significant opportunity to influence the 20,000 new county and township hospitals projected to be constructed in China between 2011 and 2015 per its twelfth five-year plan (China Trend Building Press Ltd. 2011). And Passivhaus, a standard developed in Germany in the early 1990s based on the definition of ". . .a building, for which thermal comfort can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions—without the need for additional recirculation of air" is being applied to hospitals and clinics in Europe (Passivhaus Trust 2012). This complement of standards, while not exhaustive, provides a clear indication of a marketplace increasingly defined by rigorous performance bars that recognize a carbon-challenged era and the opportunity for standards to usher in dramatically improved energy performance, deliver excellent air quality, and healthy materials.

LEED Rating Systems

By December 2012, almost two decades after its founding, the U.S. Green Building Council (USGBC) has grown to represent more than 13,000 member organizations, with more than 15,400 LEED-certified and 50,000 LEED-registered commercial projects (GBCI 2012); 1.7 million sq. ft. of building area are certified each day (USGBC 2013). Fueling this expansion is the growing suite of LEED rating systems, customized for specific sectors and building phases. In 2011, following a seven-year development including three public comment periods, the USGBC released the first LEED for Healthcare rating system, combining LEED NC 2009 with many of the unique and customized strategies piloted through the Green Guide for Health Care. Viewed as USGBC's first health-based rating system, LEED for Healthcare introduced an explicit focus on the human health dimensions of green building, and a vocabulary and framework about chemicals of concern that has evolved to influence LEED Pilot Credits and new credit content anticipated in LEED version 4.

> LEED for Health Care supports sustainable planning, design, and construction of healthcare facilities by adapting the U.S. Green Building Council's LEED to respond to the unique set of opportunities and challenges presented by the healthcare sector. By affirming healthcare's fundamental mission of '. . . first, do no harm,' LEED for Health Care recognizes the profound and impact of the built environment on the health of occupants, local communities, and global ecology and encourages design strategies that enhance the healing environment for patients, healthy and productive work environments for staff, and responsible ecological stewardship.
>
> —LEED for Health Care Core Committee (2004)

> Being a 'green' hospital has a profound, measureable effect on healing. What's good for the environment and good for our . . . neighbors is also good for our patients.
>
> —Robert Bonar, President and CEO
> *Dell Children's Medical Center of Central Texas*

As the first LEED Platinum–certified hospital in the world, Dell Children's Medical Center of Central Texas, Austin, Texas (Case Study 1, this chapter) raised the bar for a healthy, environmentally conscious approach to large-scale hospital design. Key innovations included its site selection on a remediated brownfield, district-level combined heat and power, and enhanced connection to nature through a series of seven interior courtyards, dubbed "the lungs of the building." Since the completion of the base building in 2007, it has continued to value a leadership position in sustainable design. A new neurological surgery suite and third bed tower have been added, providing opportunities to expand the breadth of sustainability features. The new Bed Tower 3 features significant investments in solar technology: solar thermal (for water heating) and solar photovoltaic (for electrical generation). In addition, as part of its expanded scope of healthy materials it pursued LEED Pilot Credits to avoid halogenated organic compounds, including halogenated flame retardants, and phthalates. The new bed tower addition is anticipated to be among the first LEED for Healthcare Platinum–certified projects.

> As an organization that seeks to improve the health of all Oregonians, we also believe we have a responsibility to protect the health of our environment.
>
> —Joe Robertson, MD, President of OHSU (2011)

The first LEED Platinum–certified ambulatory building in the world, Oregon Health and Sciences University (OHSU) Center for Health and Healing, Portland, Oregon (Case Study 2, this chapter) includes a number of innovative sustainable features that continue to be a model in the United States and globally. It features an on-site membrane bioreactor for sewage treatment, and recycles conveyance water for toilet flushing. Innovative ventilation systems include chilled beams and displacement ventilation. On-site renewable energy includes both building-integrated solar photovoltaics and a site-built solar thermal system for domestic water heating. Continuing on the LEED journey, OHSU achieved LEED EBOM (Existing Building Operation and Maintenance) Platinum certification in 2011.

In addition to these pioneers, LEED Platinum certifications have been awarded to two hospitals: Kiowa County Memorial Hospital, Greensburg, Kansas (Case Study 5, this chapter), and the first LEED Platinum hospital certified under the LEED India rating system, Kohinoor Hospital, Mumbai, India (Case Study 6, this chapter). Together with a series of smaller Platinum-certified ambulatory facilities, these projects form the "leading edge" of sustainable healthcare facilities utilizing LEED rating systems.

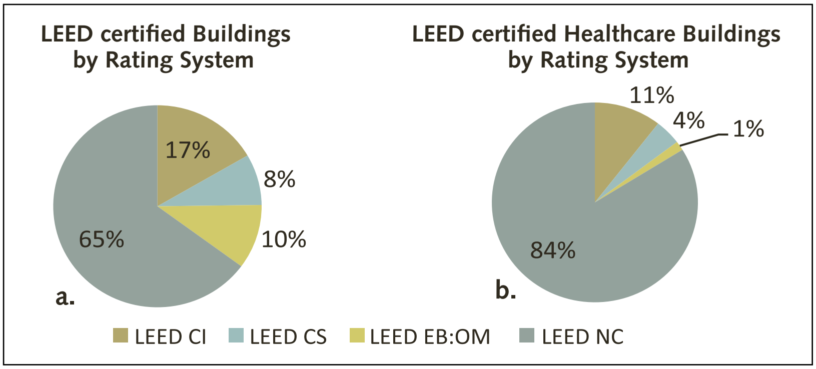
The growth of LEED certifications, both in the United States and abroad, is impressive. While more than 15,400 projects have certified through 2012, healthcare accounts for a mere 2.3 percent of certifications. Other rating systems, such as the Green Building Council of Australia's Green Star–Healthcare, mirror this pattern, and could be an indication that healthcare's adoption of formal certification is still dominated by the relatively small percentage of innovators and early adopters, while other market sectors have bridged into the early majority. Figures 5.1 through 5.3 represent a current snapshot of LEED achievements, comparing the rating system uptake and achievements of the total certified projects to healthcare.

With LEED viewed as a journey, not a destination, and with an increasing focus on building performance, USGBC leadership has cultivated an entrepreneurial approach to its evolution. The next generation of LEED, LEEDv4 (anticipated November 2013), is elevating performance thresholds and introducing greater emphasis on human health. LEED continues to be the U.S. market leader in third-party certification tools for green building: 14 federal agencies or departments, 34 state governments, more than 450 city and county governments, in addition to public school jurisdictions and institutions of higher education have adopted various forms of legislation, policies, and incentives associated with LEED (USGBC 2013).

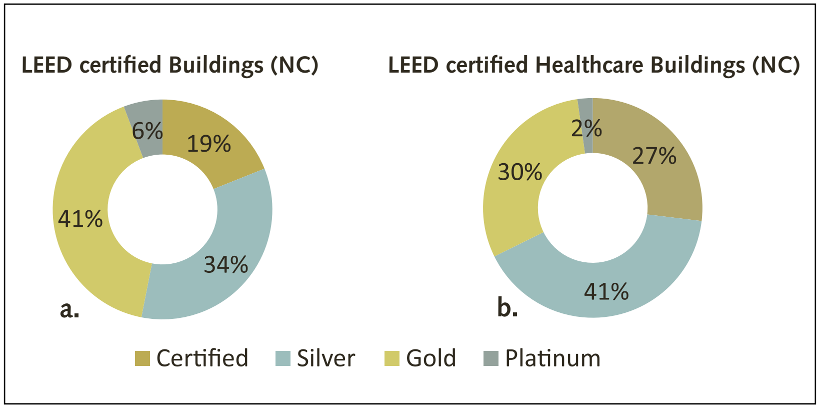
Living Building Challenge

The Living Building Challenge is a philosophy, advocacy tool, and certification program that addresses development at all scales (see sidebar). It elevates aspirational goals and advances the measurement of building performance. While not specifically tailored for unique building types, it nonetheless serves as an inspirational rubric for office buildings, schools, and hospitals (see Chapter 1). It encourages the achievement of buildings with "net-zero" resource impacts, particularly with regard to energy (and by extension carbon) and water. It prioritizes human health as a specific consideration, and includes a Material "Red List" as the basis for one of the twenty imperatives—all mandatory. The first projects were certified in 2010; as of December 2012, six projects have certified as "living," "net-zero energy," or "petal recognition."

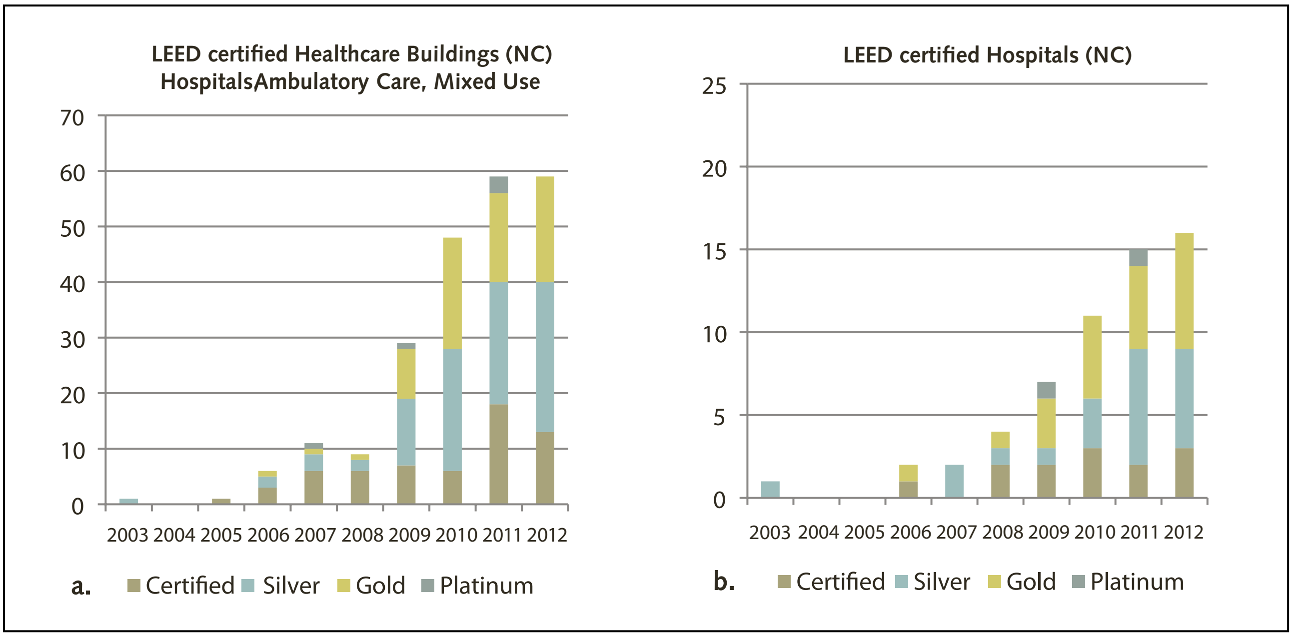
▶ **Figure 5.1a, b** a. More than 10,000 commercial and institutional buildings have achieved LEED certification using LEED for New Construction (NC), LEED for Commercial Interiors (CI), LEED for Existing Buildings, Operations and Maintenance (EB:OM) or LEED for Core and Shell (CS). b. More than 200 healthcare buildings have achieved LEED certification; the vast majority has used LEED for New Construction; as of December 2012 no projects have been certified using LEED for Healthcare. *Source: USGBC*



▶ **Figure 5.2a, b** a. Achievement levels of the LEED-NC certified commercial and institutional buildings. Gold and Platinum account for 47% of certifications. b. Gold and Platinum certifications account for 32% of the LEED-NC healthcare certifications. *Source: USGBC*



▼ **Figure 5.3a, b** a. Total number of LEED-NC certified healthcare projects are increasing over time, and projects are achieving higher certification levels. b. Total number of LEED-NC certified hospitals are also increasing, and are achieving higher certification levels. *Source: USGBC*



Living Building Challenge

The Living Building Challenge is a program of the International Living Future Institute (ILFI) intended to "raise the bar and define a closer measure of true sustainability in the built environment. Projects that achieve this level of performance can claim to be among the 'greenest' and as close to true sustainability as currently possible." By structuring the Living Building Challenge around only performance-based imperatives—comparable to prerequisites in LEED—rather than credits, the ILFI's intention is to achieve a balanced state between the built and natural environments while encouraging diverse solutions reflecting building type and bioregion. The Living Building Challenge places these twenty imperatives within a framework of seven performance areas, referred to as "petals."

1. *Site*: Restoring a healthy coexistence with nature
2. *Water:* Creating water-independent sites, buildings, and communities
3. *Energy:* Relying only on current solar income
4. *Health:* Maximizing physical and psychological health and well being
5. *Materials:* Endorsing products and processes that are safe for all species through time
6. *Equity:* Supporting a just, equitable world
7. *Beauty:* Celebrating design that creates transformative change

Source: International Living Future Institute (2012)

Peace Island Medical Center in Friday Harbor, Washington (Case Study 3, this chapter), is the first hospital project to pursue the Living Building Challenge. While the project fell short of achieving Living Building Challenge certification, its journey presents an innovative framework for contextualizing sustainable design strategies in the context of living systems.

In 2009, the Cascadia Green Building Council commissioned "The Living Building Financial Study" to compare the capital cost differential of applying the Living Building Challenge to nine LEED Gold–certified buildings, each representing a distinct market sector, including hospitals. To do this, each base building was conceptually re-designed to meet the Living Building Challenge requirements, and further modified for four U.S. cities representing unique climate zones (see Chapter 6).

BREEAM for Healthcare

BREEAM (UK Building Research Establishment's Environmental Assessment Method) is the world's leading and most widely used environmental assessment method for buildings, with 200,000 buildings certified and over one million registered since it was first launched in 1990 (BRE 2012). BREEAM Healthcare was commissioned by the Department of Health and Welsh Health Estates, replacing NEAT (NHS Environmental Assessment Tool) in 2008 as the preferred environmental assessment method and certification scheme for healthcare buildings in the United Kingdom.

The Department of Health requires, as part of the Outline of Business Case approval, that all new builds achieve an Excellent rating and all refurbishments achieve a Very Good rating under BREEAM Healthcare. Many of the NHS case studies in this book, including the Dyson Center for Neonatal Care (Case Study 7, this chapter), New South West Acute Hospital (Case Study 14, Chapter 7), Portadown Health Centre and Ysbyty Aneurin Bevan (Case Studies 27 and 36, both in Chapter 8), used the self-assessment tool NEAT, while St. Barts and The Royal London (Case Study 34, Chapter 8), was a pilot site for BREEAM Healthcare. As of June 2012, there were 737 registered and 119 certified healthcare projects—only 23 that are fully assessed postconstruction/occupancy (Northumbria University 2012).

BREEAM ranks achievement in ten categories of green building on a 100-point scale, with an Excellent rating based on a score of 70 or more, and Outstanding for a score of 85 or more, in addition to fulfilling mandatory credit requirements. Categories are weighted; an accredited BREEAM Assessor reviews projects and scores achievements.

Green Building Council of Australia—Green Star–Healthcare v1

The Green Building Council of Australia (GBCA), founded in 2002, initiated the development of its Green Star rating system in 2003. Building on the precedents of BREEAM in the United Kingdom and LEED in the United States, along with data and surveys developed in Australia, Green Star crafted a system based on environmental measurement criteria relevant to the Australian marketplace and ecological context. As with BREEAM and LEED, Green Star has expanded into a "portfolio of products." Green Star–Healthcare was initially released as a Pilot in 2006, with the *Green Guide for Health Care* serving as a substantive reference document and providing technical support during the development phase. Designed for buildings that provide healthcare services such as hospitals, medical centers, ambulatory clinics, and healthcare facilities for the aged, the balloted Green Star–Healthcare v1, encompassing Design and As-Built sections, was released in June 2009 and updated in November 2012. Its intention is to support healthcare facility owners and operators to "minimize the environmental impact of their buildings; improve patient health outcomes and staff productivity; receive recognition for green leadership; and achieve real cost savings" (GBCA 2012).

To ensure appropriate accommodation of healthcare facilities' unique development requirements, environmental, and health considerations, credits are organized in nine categories and are customized to ensure appropriateness, such as "Places of Respite," IEQ-19 inspired by the seminal *Green Guide* credit. Two credits, referred to as "Conditional Requirements," must be achieved to qualify for Green Star–Healthcare certification: in the Energy category, a requirement that the project's predicted greenhouse gas emissions must be equal to, or show an improvement over, the predicted greenhouse gas emissions of the "benchmark building" as determined by the Green Star–Healthcare v1 Greenhouse Gas Emissions Calculator; in the Land Use and Ecology category, a requirement that projects avoid development on prime agricultural land containing old-growth forest, and within 100 meters of a wetland. Green Star–Healthcare also offers a Commuting Mass Transport and Material Calculator Guide.

As of December 2012, of 478 total Green Star–Registered projects, there are three Healthcare Design v1 and four Healthcare Design v1 As-Built; of 540 total Green Star–Certified projects, there is one certified healthcare pilot, one Healthcare v1 Design, and one Healthcare v1 As-Built, in each case representing less than 1 percent of total Green Star projects.

Comparative Analysis of Healthcare Rating Systems

A comparison of three healthcare rating systems—LEED 2009 for Healthcare, Green Star–Healthcare v1, BREEAM for Health, and the human health focused Living Building Challenge, shown in Tables 5.2 through 5.4—provides useful perspective on how these tools are collectively building momentum on specific natural resource and human health performance strategies: carbon neutral, water balance, zero waste, and toxic free. While not a comprehensive review of healthcare rating systems in use around the world, these four provide a broader global influence than their origins suggest.

On the most general level, two of the rating systems—BREEAM Healthcare and Living Building Challenge—have credit categories that explicitly address health: "Health + Wellbeing" and "Health," respectively. This could imply that only credits in the health-specific categories influence health outcomes. In fact, health outcomes underscore credits in multiple categories, such as addressing alternative modes of transportation and "places of respite" in Site/Transport categories; control of outdoor pollutants in the Energy category; and low-emitting materials in the Indoor Environment category. A human health benefits assessment linked to credits in healthcare-specific rating systems, or more generally, reveal many with a positive causal relationship: applying strategies across credit categories can yield measurable, positive human health benefits. A more visible expression of human health benefits associated with credit compliance is an important dimension to consider as these rating systems evolve.

As shown in Table 5.3, while there is general consistency in categories there is significant variation in the credits and, specifically, the *minimum requirements* for

Table 5.2 Comparative Categories

	LEED 2009 for Healthcare	Green Star-Healthcare	BREEAM for Health	Living Building Challenge
Management		Management	Management	
Site	Sustainable Sites	Land Use + Ecology	Land Use + Ecology	Site
Transport		Transport	Transport	
Health			Health + Well being	Health
Water	Water Efficiency	Water	Water	Water
Energy	Energy + Atmosphere	Energy	Energy	Energy
Materials	Materials + Resources	Materials	Materials	Materials
Waste			Waste	
Indoor Environmental Quality	Indoor Environmental Quality	Indoor Environment Quality		
Emissions		Emissions	Pollution	
Innovation	Innovation + Design	Innovation	Innovation	
Equity				Equity
Beauty				Beauty

certification, from the Living Building Challenge with twenty "imperatives" to Green Star–Healthcare with only two requirements. Do the requirements associated with these rating systems represent strategic market signaling and effective leveraging of strategic market transformation priorities?

As the most aggressive of the four, the Living Building Challenge requires net-zero energy and water, minimum 80 percent diversion of construction debris (with percentages as high as 100 percent depending on material), and adherence to the LBC's materials Red List; LBC is the only system that requires a full year of performance before awarding certification. LEED for Healthcare, with thirteen prerequisites including four unique to LEED-HC, requires a minimum 20 percent reduced potable water use, energy systems commissioning, minimum 10 percent improved energy performance, strict limits on mercury content in lamps (representing the first PBT-related prerequisite in the LEED family of products), and adherence to an integrated design process.

Table 5.3 Comparison of Prerequisites*

	LEED 2009 for Healthcare 13 requirements	Green Star–Healthcare v1 2 requirements	BREEAM for Health (for excellent rating as req'd by NHS for new-builds) 12 requirements	Living Building Challenge 20 requirements
Management			Man 2 Considerate Constructors Man 4 Building User Guide	
Site-Transport-Habitat-Land Use-Ecology	SSp1-Construction Activity Pollution Prevention	Eco-Conditional Requirement (site requirements)	LE 4-Mitigating Ecological Impact	01-Limits to Growth
	SSp2-Environmental Site Assessment			02-Urban Agriculture 03-Habitat Exchange 04-Car-Free Living
Water	WEp1-Water Use Reduction- 20% reduction		Wat 1-Water Consumption (WCs @ ≤4.5 L/flush	05-Net-Zero Water
	WEp2-Minimize Potable Water Use for Medical Equipment Cooling		Wat 2-Water meter	06-Ecological Water Flow
Energy	EAp1-Fundamental Commissioning of Building Energy Systems		Man 1-Commissioning	
	EAp2-Minimum Energy Performance (≥10% improved energy performance)	Ene-Conditional Requirement (≤ GHG emissions compared to 'benchmark building')	Ene 1-Reduction of CO2 emissions (≥40% GHG reduction)	07-Net Zero Energy
	EAp3-Fundamental Refrigerant Management			
			Ene 2-Sub-metering of Substantial Energy Uses Ene 5-Low or zero carbon technologies	
Health			Hea 4-High Frequency Lighting	08-Civilized Environment
			Hea 12-Microbial Contamination	09-Healthy Air
				10-Biophilia
Materials-Waste	MRp1-Storage + Collecon of Recyclables		Wst 3-Storage of recyclable waste	
	MRp2-PBT Source Reduction-Mercury			11-Red List 12-Embodied Carbon Footprint 13-Responsible Industry 14-Appropriate Sourcing 15-Conservation + Reuse
Equity				16-Human Scale + Humane Places 17-Democracy + Social Justice 18-Rights to Nature
Indoor Environmental Quality	EQp1-Minimum Indoor Air Quality Performance			
	EQp2-Environmental Tobacco Smoke Control			
	EQp3-Hazardous Materials Removal or Encapsulation			
Beauty				19-Beauty + Spirit
				20-Inspiration + Education
Innovation in Design	IDp1-Integrative Project Planning + Design			

*Blue text indicates prerequisites unique to LEED for Healthcare

Table 5.4 Comparative Rating System Comparison by Category*

	LEED 2009 for Healthcare 13 requirements	Green Star–Healthcare v1 2 requirements	BREEAM for Healthcare 2008 12 requirements	Living Building Challenge 20 requirements
Management		Commissioning±Clauses, Building Tuning, Independent CX Agent; Building Guides (Mgmt)	Commissioning; Building User Guide (Mgmt)	
			Considerate Constructors	
			Shared Facilities	
			Security	
		Maintainability	Ease of Maintenance	
		Sustainable Procurement Guide	Provision of Energy Efficient Equipment	
			Life Cycle Costing	
			Good Corporate Citizen (Man 13)	
Sites - Transport - Habitat	Construction Activity Pollution Prevention		Construction site impacts (Management); Topsoil (Eco)	
	Environmental Site Assessment	Reclaimed Contaminated Land		
	Site Selection	Conditional Requirement (site restrictions); Change of Ecological Value (Eco)	Flood Risk (Pol)	Limits to Growth
	Development Density + Community Connectivity	Reuse of Land (Eco)	Proximity to Amenities; Reuse of Land (LE)	Limits to Growth
	Brownfield Redevelopment	Reclaimed Contaminated Land	Contaminated Land (LE)	Limits to Growth
	Alternative Transportation: Public Transportation Access; Bicycle Storage + Changing Rooms; Low-Emitting + Fuel Efficient Vehicles; Parking Capacity	Provision of Car Parking; Cyclist Facilities; Fuel-Efficient Transport; Commuting Mass Transport; Transport Design + Planning (All in Transport)	Provision of Public Transport; Cyclist Facilities; Pedestrial + Cyclist Safety; Maximum Car Parking Capacity (All in Transport)	Car-Free Living
	Site Development—Protect/Restore Habitat; Maximize Open Space	Change of Ecological Value	Ecological Value of Site + Protection of Ecological Features; Mitigating Ecological Impact; Enhancing Site Ecology; Long Term Impact on Biodiversity (LE)	Habitat Exchange
	Stormwater Design—Quantity + Quality Control	Watercourse Pollution; Discharge to Sewer (Emi)	Minimizing Water Course Pollution (Pol)	Ecological Water Flow (Water)
	Light Pollution Reduction	Light Pollution (Emissions); Efficient External Lighting (energy)	Internal + External Lighting Levels (Hea); External Lighting (Ene); Reduction of Night Time Light Pollution (Pol)	
	Connection to the Natural World—Places of Respite + Direct Exterior Access for Patients	Places of Respite (IEQ)	Outdoor Space (Hea)	
			Travel Plan	
			Travel Information Point	
			Deliveries + Maneuvering	
				Urban Agriculture
				Human Scale + Humane Places (Equity)
				Rights to Nature (Equity)

***Prerequisites represented in blue font**

Table 5.4 Credit Comparison

	LEED 2009 for Healthcare 13 requirements	Green Star–Healthcare v1 2 requirements	BREEAM for Healthcare 2008 12 requirement	Living Building Challenge 20 requirements
Water	Water Use Reduction—fixtures + process water uses (each ≥20% reduction)	Occupant Amenity Water; Heat Rejection Water	Water Consumption (≤4.5 L/flush); Water Recycling	Net Zero Water
	Minimize Potable Water Use for Medical Equipment Cooling (prereq	Potable Water Use for Equipment		Net Zero Water
	Water Efficient Landscaping	Landscape Irrigation	Irrigation Systems	Net Zero Water
	Water Use Reduction: Measurement + Verification	Water Meters	Water Meter	
	Water Use Reduction: Building Equipment, Cooling Towers, Food Waste		Major Leak Detection	
			Sanitary Supply Shut Off	
		Fire System Water		
		Trade Waste Pollution (Emi)		
Energy	Commissioning - Fundamental + Enhanced (E+A)			
	Energy Performance—Minimum (≥10%) + Optimize	Conditional Requirement (≤ GHG emissions compared to 'benchmark building'); Greenhouse Gas Emissions;	Reduction of CO2 Emissions (≥40%); Lifts; CHP Community Energy	Net Zero Energy
	Refrigerant Management—Fundamental + Enhanced	Refrigerant ODP; Refrigerant GWP; Refrigerant Leaks (Emissions)	Refrigerant GWP; Preventing Refrigerant Leaks (All Pol)	
	On-site Renewable Energy		Low- or Zero Carbon Technologies	
	Measurement + Verification	Energy Sub-Metering; Building Management System (Mgmt)	Sub-Metering of Substantial Energy Uses; Sub -metering of High Energy Load + Tenancy Uses	
	Green Power			
	Community Contaminant Prevention—airborne releases	Outdoor Pollutant Control (IEQ)	NOx emissions from heating source (Pol)	
		Sustainable Procurement Guide	Provision of Energy Efficient Equipment	
		Peak Energy Demand Reduction		
		Insulant ODP (Emi)		
Materials - Waste	Storage + Collection of Recyclables	Recycling Waste Storage	Recyclable Waste Storage; Compactor/Baler; Composting (All Wst)	Conservation + Reuse
	PBT Source Reduction—mercury			
	Building Reuse	Building Reuse	Reuse of Façade; Reuse of Structure	
	Construction Waste Management	Waste Management (Mgmt)	Construction Site Waste Mgmt	Conservation + Reuse
	Sustainably Sourced Materials + Products	Recycled Content + Reused Products & Materials; Concrete; Steel; Sustainable Timber; Ceilings, Walls + Partitions	Materials Specification; Materials Reuse; Recycled Aggregates; Hard Landscaping + Boundary Protection; Responsible Sourcing; Robustness	Responsible Industry; Appropriate Sourcing
	PBT Source Reduction—mercury, lead, cadmium, copper			Red List
	Furniture + Medical Furnishings	Loose Furniture		Red List
	Resource Use—Design for Flexibility	Design for Disassembly	Ceilings, Walls + Partitions	Conservation + Reuse
		Flooring	Embodied Life Cycle Impact of Materials (Insulation)	Embodied Carbon Footprint
		PVC Minimization		Red List
		Dematerialization		
		Joinery		

(Continued)

Table 5.4 Credit Comparison

	LEED 2009 for Healthcare 13 requirements	Green Star–Healthcare v1 2 requirement	BREEAM for Healthcare 2008 12 requirements	Living Building Challenge 20 requirements
Indoor Environmental Quality—Health—Well being	Minimum Indoor Air Quality Performance	Ventilation Rates; Air Change Effectiveness; Air Distribution System; Mould Prevention	Potential for Natural Ventilation; Indoor Air Quality (Hea)	Healthy Air (Hea)
	Environmental Tobacco Smoke Control			Healthy Air (Hea)
	Hazardous Material Removal or Encapsulation (prereq)	Hazardous Materials		
	Outdoor Air Delivery Monitoring	Carbon Dioxide Monitoring + Control	Indoor Air Quality (Hea)	
	Acoustic Environment	Internal Noise Levels	Acoustic Performance (Hea); Noise Attenuation (Pol)	
	Construction IAQ Management Plan - during construction, before occupancy	Environmental Management; Construction Indoor Air Quality Plan (Mgmt); VOC Monitoring (IEQ-3)		Healthy Air (Hea)
	Low-Emitting Materials	Volatile Organic Compounds; Formaldehyde Minimization; Flooring; Joinery; Ceilings, Walls + Partitions	Volatile Organic Compounds (Hea)	Red List (Mtls)
	Controllability of Systems—lighting + thermal control	Individual Thermal Comfort Control; Lighting Zoning (Energy)	Thermal Zoning; Lighting Zones + Controls (Hea)	Civilized Environment (Hea)
	Thermal Comfort—design + verification	Thermal Comfort	Thermal Comfort (Hea)	
	Daylight + Views	Daylight; Daylight Glare Control; External Views	Daylighting; View Out; Glare Control; Internal + External Lighting Levels (Hea)	Civilized Environment (Hea)
		High Frequency Ballasts	High Frequency Lighting (Hea)	
		Electric Lighting Levels		
		Legionalla (Emi)	Microbial Contamination (Hea)	
			Arts in Health (Hea)	Biophilia (Hea)
		Car Park Ventilation		
Innovation + Design	Integrated Project Planning + Design		Consultation (Mgmt)	
	Innovation in Design	Innovative Strategies + Technologies; Exceeding Green Star Benchmarks; Environmental Design Initiatives	Innovation	
	LEED Accredited Professional	Green Star Accredited Professional (Management)		
Equity				Democracy + Social Justice (Equity)
Beauty				Beauty + Spirit; Inspiration + Education

BREEAM Healthcare has twelve requirements (based on the "Excellent" rating required for all NHS "new-build" projects) including prescriptive limits on potable water used for toilet flushing, water metering, commissioning, an impressive minimum 40 percent reduction in greenhouse gas emissions along with low- or zero carbon technologies and submetering of substantial energy uses that align with the broader UK carbon reduction strategy, storage for recyclable wastes, and control of microbial contamination (Legionella). Finally, Green Star–Healthcare is the most flexible with only two requirements: avoiding development on prime agricultural land, old-growth forest, or in proximity to a wetland and greenhouse gas emissions not exceeding the benchmarked building.

While the requirements collectively map to the strategic priorities of carbon neutral, water balance, zero waste, and toxic free, the individual system variability signals a cautious marketplace, balancing options and rewards associated with higher certification levels with stringent baseline requirements. Tracking building performance based on meeting aggressive requirements reveals a measurable pattern of what is possible today; going forward, it will also be an indicator of how healthcare's aggregated success to reduce its environmental footprint contributes to a broader global imperative.

LESSONS LEARNED FROM PIONEERS

These substantial tools and resources in the marketplace have supported the evolution of green building strategies in the global healthcare sector. Even if every case study in this book did not actively pursue certification using a rating system, the collective performance improvements of the group have been enhanced through the existence of both self-certification and third-party certification tools. Collectively, they have driven market transformation globally.

Throughout the book are profiles of lessons learned for many of the projects. Dell Children's Medical Center of Central Texas and OHSU Center for Health and Healing (Case Studies 1 and 2, this chapter), and Providence Newberg Medical Center (Case Study 17, Chapter 7) all undertook postoccupancy evaluations to understand the outcomes of their sustainable building initiatives, which are summarized in sidebars here. Peace Island Medical Center (Case Study 3, this chapter), as the first hospital to undertake the Living Building Challenge, faced both regulatory and capital cost barriers. Partners HealthCare (Chapter 7) profiles its lessons learned through completing a series of LEED-certified projects, while Providence Health & Services (Chapters 6 and 7) is documenting lessons learned in retrofitting Providence Newberg (Case Study 17, Chapter 7) and Providence St. Peter Hospital (Case Study18, Chapter 7) for energy and water reductions. Swedish Medical Center, Issaquah (Case Study 35, Chapter 8), in all probability the lowest energy U.S. hospital building in operation today, shares its lessons learned in trying to further drive down energy intensity.

While this is by no means an exhaustive summary of the lessons learned, key ideas emerge:

- **Design matters.** Design impacts resource consumption. There are baseline design standards in healthcare that, if left unchallenged, work against reduced resource consumption. It is important to think about every design decision, from the macro issues of system selection and facade design, to the micro issues of lighting control locations and zoning.
- **Clear sustainable goal setting early in design produces better outcomes.** Moving targets result in inconsistent system solutions and a less integrated design solution.
- **Vigilance during construction is required.** Component substitution must be controlled and carefully monitored from initial installation through punchlist.
- **Continuous modeling through design, and commissioning through all seasons, is imperative.** Energy modeling cannot be a one-time event. As design evolves, the model must also evolve and calibrate. Commissioning matters for both facilities management personnel training, but simply commissioning at the point of substantial completion is not enough. Commissioning needs to extend through a full year of seasonal variation and system configurations.

- **Smart buildings require intelligent, informed operators and occupants.** There is a direct correlation between the satisfaction with the sustainable building and the engagement with both building occupants and the operations staff.
- **Not every innovative system performs as anticipated.** When innovative systems and technologies are included, there will be challenges. Recognize the reality; face the challenges; creatively adapt the systems and contribute to a broader body of knowledge that catalyzes continuous improvement.

POST OCCUPANCY EVALUATION—PROVIDENCE NEWBERG MEDICAL CENTER

Providence Health & Services and Mahlum Architects engaged UC Berkeley's Center for the Built Environment (CBE) to conduct a formal building performance evaluation following the completion of the first LEED Gold–certified hospital in Newberg, Oregon. Released in February 2008, the report followed a consistent CBE format to gauge the satisfaction of building occupants, many of whom moved from the previous Newberg facility to this replacement building on a new campus. Overall, the CBE reported that Providence Newberg obtained "outstanding scores" relative to its database of POEs, which are primarily office buildings. Study authors noted ". . .that this more complex occupancy (healthcare) scores well in comparison with office projects is noteworthy." However, Providence Newberg also outperformed other healthcare projects in the CBE database. The data suggested that the enhanced daylighting, overall improvements in indoor air quality, and features such as occupancy-sensor lighting positively influenced building occupants. Forty-five percent reported that their productivity increased by 10 percent or more over the prior work environment.

Thermal comfort, however, presented some initial challenges. "Over half (56 percent) of the staff reported dissatisfaction with temperature in the workplace, with one-quarter of all respondents saying they were 'very dissatisfied.' Dissatisfaction was somewhat worse for those over 50 (33 percent very dissatisfied) than for those younger." Ultimately, this dissatisfaction was correlated with the 100 percent outside air system and initial lack of calibration, inadequate commissioning, and training (see Chapter 7). The study gave Providence the information it needed to improve the systems (see Table 5.5). CBE researchers noted: "These problems should be understood within the larger context of the building's overall strong air quality performance."
Source: CBE (2008)

Table 5.5 Providence Newberg Building Performance Evaluation

75%	Patient safety is improved
70%	Ability to involve family in the healing process has been improved
68%	Improvement in individual productivity
83%	Increased sense of personal well-being
80%	More satisfied with their job
60%	Improvement in their stress level

Source: CBE (2008)

"Results from this project suggest that occupants and management staff will need more training about the building as complexity increases. The data also suggests that this training can have a direct effect on the level of building satisfaction reported by occupants."

Source: Center for the Built Environment (2008)

POST OCCUPANCY EVALUATION—DELL CHILDREN'S MEDICAL CENTER OF CENTRAL TEXAS

In 2003, Seton's senior management and the design team, led by Karlsberger, set out to create what would become the first LEED Platinum–certified hospital in the world. There were two important outcome goals: to create the best healing environment for the hospital's young patients and provide an exceptional work environment for staff. Correlating the tangible benefits of greening the hospital with these measurable outcomes was a compelling driver over the four-year design and construction process.

Everyone involved with the project, from Seton's senior leadership to the design and construction team, was conscious of the aspiration to achieve LEED Platinum certification. They also adhered to three strict guiding principles that kept that aspiration grounded:

- We will not do dumb things to get points.
- Less than 12 percent return on investment is dumb.
- We must know if we are being dumb.

Assisted by a successful capital campaign, including a generous gift from the Michael and Susan Dell Foundation and others tied to delivering a "green" hospital—Dell Children's Medical Center of Central Texas opened in July 2007; its LEED Platinum certification was awarded in January 2009 (see Case Study 1, this chapter).

Building Performance

Over five years of operations, Dell's senior design and engineering leadership have assessed building performance both in terms of building operations and the effect of the green building on patients and staff. Their findings have informed subsequent projects on the site: a 7,500 sq. ft. (697 sq. m) neurological suite completed in 2008 and an 83,000 sq. ft. (7,711 sq. m) third patient bed tower completed in 2013.

The 503,000 sq. ft. (46,730 sq. m) base building employed an innovative energy system, with a utility-owned district CHP energy plant adjacent to the hospital providing chilled water, steam, and power. The hospital's energy performance was carefully tracked from its first day of operation. Over the first four months, actual performance was 70 percent higher than modeled performance; by the end of the first year, the gap was narrowed to 26 percent, and by the end of 2009 it was within a 3 percent variance.

Ongoing performance has varied from 5 to 9 percent above the model; however, during this period annual degree-days have been 10 percent above average and, between 2009 and 2012, the hospital's area increased by 10,000 sq. ft. (929 sq. m). The energy reduction in the first year was the result of completing the post occupancy commissioning process; since then, further improvements have been realized through continuous commissioning.

Water Use

Actual water consumption has generally trended downward from initial modeled projections, with the exception of 2011 when historic drought conditions led to higher indoor and outdoor water consumption, including loss of water associated with the bursting of an underground pipe. An approximate 70 percent indoor/30 percent outdoor ratio of indoor versus outdoor water use has stayed relatively constant.

In 2009, average monthly water consumption was 2,100,000 gallons (7,949,365 L); in 2012, it dropped to just over 1,750,000 gallons (6,624,471 L) per month, about a 17 percent decrease, representing annual savings of 4,284,000 gallons (16,216,704 L). Reduced water use is maintained by relatively constant indoor water consumption despite increasing patient load and reducing irrigation water used for landscape maintenance.

Post Occupancy Evaluation

With an expert third-party university–led post occupancy evaluation underway, emerging data reveal that Dell's primary objective to create an environment conducive to healing and well-being is realized. Major design and construction processes and post occupancy lessons learned are summarized in the Case Study; patient care outcomes are summarized in Chapter 6.

Source: Seton Family of Hospitals

RESOURCE EFFICIENCY

Resource efficiency is the key to improved performance: conserving energy and water, reducing waste and toxic chemicals. The Infographic at the opening of this book compares the fifty-five Case Studies against a range of performance criteria; the graphic indicates, by density of color, achievements in resource efficiency.

Clearly, energy use intensity (EUI, i.e., the amount of energy required per unit of area), is a key measure of energy performance. If energy use intensity can be radically reduced, then renewable energy solutions may be physically and economically possible, resulting in a net-zero or "carbon neutral" solution. The Case Studies also reveal an enormous range of design energy use intensity: for large academic medical centers, Akershus University Hospital (Case Study 21, Chapter 8) reports an EUI of 46.3 kBtu/sf/yr (146 kWh/sm/yr), while UCSF at Mission Bay (Case Study 10, in this chapter) reports an EUI of 246 kBtu/sf/yr (775 kWh/sm/yr). What factors contribute to these vast variances? The essays in this chapter, focusing on the U.S. Environmental Protection Agency's ENERGY STAR program and the University of Washington Integrated Design Lab's Targeting 100! research, offer insights into the challenges and opportunities to radically reduce energy use. Finally, if carbon neutrality is the goal, what are specific performance challenges and project opportunities?

Water use benchmarks continue to be elusive. This chapter examines the concept of "water balance" or "net-zero water" and its characteristics, as well as the enormous range of water strategies now being implemented. Can the healthcare industry integrate strategies beyond low-water use fixtures, especially recognizing that about 70 percent of water use in a hospital is process water? Can reclaimed water be safely reused in healthcare environments? The Case Studies in this book demonstrate that hospitals are safely integrating reclaimed water reuse strategies inside facilities and establishing on-site wastewater treatment systems.

Is a zero waste hospital achievable? Across North America and throughout the world, an aspirational goal of "zero waste" has inspired thoughtful, pragmatic, and transformational policies and programs in hospitals and other healthcare facilities that collectively are redefining the global material economy.

Finally, the quest for healthy materials is fully underway. More information is now available on the chemical ingredients of key building materials than ever before. Tom Lent's essay, "The PBT-Free Challenge," examines recent developments in material health.

A new generation of healthcare projects is bringing all these aspects of health and resource efficiency together into innovative, twenty-first-century healthcare buildings. This examination of the opportunities and challenges of improving healthcare building performance highlights successes and models for the future, while critically noting significant impediments. Collectively, the work ahead is to remove the impediments to improved performance to create a robust and ecologically restorative healthcare infrastructure—in a sense, to rebrand it as healthy and high performance by design.

Energy-Demand Reduction

The healthcare sector is a massive consumer of energy. As of 2007, the 3,040 U.S. large hospitals [greater than 200,000 sq. ft. (18,581 sq. m)] comprised 1.96 billion sq. ft. (182,089,958 sq. m) of floor space, with an average of 644,300 sq. ft. (59,857 sq. m) per building. The total licensed bed capacity was 915,000 beds with an average of 2,140 sq. ft. (199 sq. m) per licensed bed. Hospitals' energy consumption continues to increase: Commercial Building Energy Consumption Survey (Briner 2012) data show that the major fuels—electricity, natural gas, fuel oil, and district heat—consumed by large hospitals totaled 458 trillion British thermal units (Btu)—5.5 percent of the total delivered energy by the commercial sector in 2007, up from 4.3 percent in 2003. The full complement of U.S. hospitals are estimated to use 836 trillion Btus of energy annually and have more than 2.5 times the energy intensity and carbon dioxide emissions of commercial office buildings, producing more than 30 pounds of CO_2 emissions per square foot (CBECS 2007).

Measurement and comparison of energy use intensity among hospitals around the world is challenging and complex. While the United States measures energy use intensity (EUI) in kilo-Btus per square foot per year (kBtu/sf/yr), much of the rest of the world uses kilowatt-hours per square meter per year (kWh/sm/yr). While U.S. hospitals typically report metered energy usage (including plug load), European and Asian hospitals do not, instead reporting the energy use intensity of the building and building systems only. This makes direct comparison of hospital energy use intensity globally difficult—Akershus

University Hospital (Case Study 21, Chapter 8), with a reported EUI of 46.3 kBtu/sf/yr (146 kWh/sm/yr), cannot be directly compared with Swedish Medical Center, Issaquah (Case Study 35, Chapter 8) with a reported EUI of 114 kBtu/sf/yr (333.9 kWh/sm/yr) as the first does not include plug load while the latter U.S. hospital measurement does.

Few published attempts to quantify and compare energy use intensities of hospital buildings globally exist. In 1996, the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) study compared the thermal and electrical intensity (in kWh/sm/yr) among roughly equally sized single hospitals in each of nine countries (see Figure 5.4). This data suggested that North American hospitals operated at more than twice the energy intensity of any of their European counterparts (Jakelius 1996). While no recent similar comparative study has been published, a review of the recent Case Study projects in this book shown in Figure 5.5—which represent many of the highest performing hospitals—support this general finding.

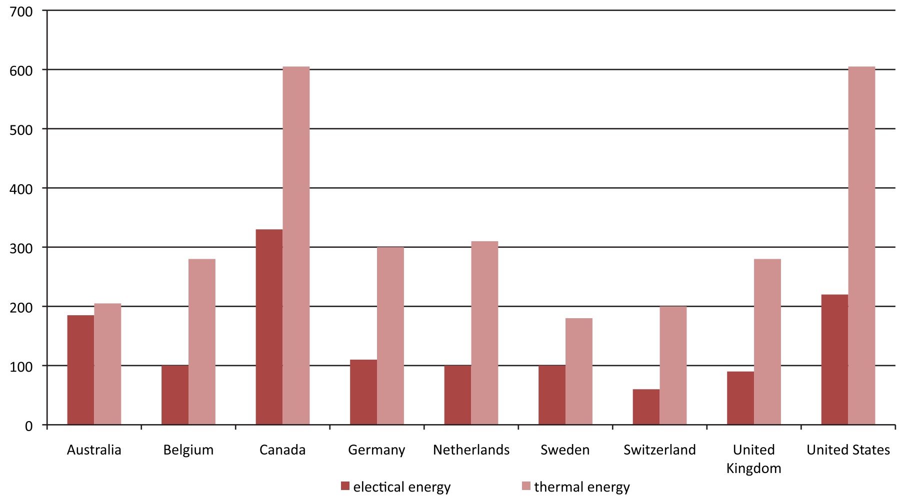


Figure 5.4 Comparative Energy Consumption for Hospitals. This chart shows approximate data for an acute-care hospital's average annual thermal and electrical energy consumption per square meter (kWh/sq. m). *Source: Jakelius (1996)*

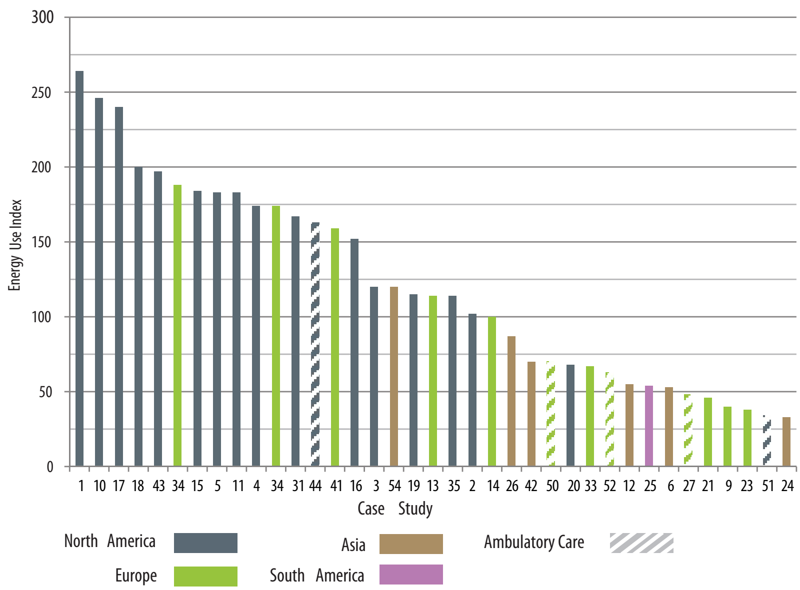


Figure 5.5 Comparative Energy Use Intensities (EUI) for Case Studies. This chart shows approximate data for the annual energy use intensity among the book Case Studies.

According to the Commercial Buildings Energy Consumption Survey (CBECS), the average age of an acute-care hospital building in the United States is 26.5 years—completed in about 1985. Since then, energy use has continued to increase as hospitals have accommodated improved medical and information technology, with attendant thermal loads and ever-escalating mandatory ventilation standards. Today, the average U.S. hospital operates in the range of 240 to 270 kBtu/sf/yr, which suggests that for every project in this book that operates at less, there is a hospital operating at even greater energy intensity.

In 2005, the U.S. Environmental Protection Agency (EPA) issued the ENERGY STAR Challenge, calling on building owners to reduce energy consumption by 10 percent; in so doing, the EPA estimates "by 2015 Americans would reduce greenhouse gas emissions by more than 20 MMTCE, equivalent to the emissions of 15 million vehicles, while saving about $10 billion" (USEPA 2007). In response, the American Society for Healthcare Engineering (ASHE) launched the Energy Efficiency Commitment (E2C) to educate hospital staffers on the environmental and economic value of improving energy efficiency within their organizations and recognize members who achieve at least 10 percent energy savings. The EPA's ENERGY STAR Challenge program goal to reduce energy use in commercial buildings with consequent CO_2 emission reductions supports the 2030 Challenge. In his essay below, Clark Reed describes the role and features of ENERGY STAR®.

Low-Energy Hospitals Today

The average energy use intensity of U.S. hospitals can be radically reduced; leading healthcare organizations and design teams are continuing to improve efficiency. A plethora of guidance tools, beginning with the Green Guide for Health Care's Prescriptive Path (GGHC 2007), are providing advice and strategies. Most notable are the ASHRAE Advanced Energy Design Guides for Small Hospitals and Healthcare Facilities: 30% Savings (2009) and Large Hospitals: 50% Savings (2012) (prepared in collaboration with the AIA, IES, and USGBC), and the National Renewable Energy Laboratory's Large Hospital 50% Energy Savings: Technical Support (2010).

Alongside these tools, important system innovations have taken place on the ground to reduce the energy intensity of U.S. hospitals. Peace Island Medical Center (Case Study 3, this chapter), with anticipated performance in the range of 120 kBtu/sf/yr (378 kWh/sm/yr) uses ground-source heat pumps, heat recovery, and natural ventilation to reduce energy use intensity. Sherman Hospital, Elgin, Illinois (Case Study 4, this chapter), with its lake-based geothermal system, offers a powerful example of how economic and environmental interests can work in concert, with measurable benefits to patients and staff and positive impacts that extend well beyond the hospital campus. This replacement hospital campus operates at 50 percent less energy use intensity than the prior facility.

In 2007, a category-5 tornado destroyed 95 percent of Greensburg, Kansas, including the town's hospital. With a commitment to rebuild Greensburg "green," the Kiowa County Memorial Hospital (Case Study 5 later in this chapter) is the second LEED Platinum–certified hospital in the United States, and the highest rated hospital in the nation (possibly in the world) under the LEED NC 2.2 rating system, achieving 55 of 69 points. As with other new buildings in Greensburg, the hospital is an all-electric facility, powered by a combination of on-site and local Greensburg grid-connected wind turbines. It has an estimated EUI of 183 kBtu/sf/yr (577 kWh/sm/yr), no fossil fuel combustion within the building, and eliminates significant water consumption for cooling tower equipment.

ENERGY STAR®: ITS NOT JUST A SCORE; IT'S A GOAL AND A STRATEGY

By Clark Reed, U.S. Environmental Protection Agency

In 1992, the U.S. Environmental Protection Agency (EPA) launched the ENERGY STAR® program to advance the adoption of energy efficient products and practices in homes, commercial buildings, and industry. ENERGY STAR is more than just a blue label designating the most energy efficient buildings and consumer products. It's also a popular voluntary program that works with hospitals and businesses to improve whole-building energy efficiency to reduce energy bills and fight climate change.

It Starts with a Score

Prior to 1999, the market defined an energy efficient building as one that was new or had modern equipment. Some relied on more complex approaches using complicated building simulation models where a building was compared against itself and presumably improved upon. While well intentioned, the end result of both approaches proved unsatisfactory. Research shows that neither the age of the building nor the presence of technologies alone is a good indicator of performance.

A fundamental shift in defining an energy efficient building came when the EPA introduced the ENERGY STAR energy performance scale in 1999. The ENERGY STAR scale assigned a score between 1 and 100 to indicate how a building performed relative to similar buildings nationwide. The scores were automatically adjusted using standardized methods to take into account differences in building attributes, operating characteristics, and weather.

The EPA created the first ENERGY STAR scale for hospitals in 2001. Over the following decade, more than 3,300 acute-care hospitals, representing about 85 percent of the total hospital square footage in the United States, have generated ENERGY STAR scores, making it the most widely used energy performance benchmark in the industry. Thousands of hospitals generate scores every month in EPA's Portfolio Manager, the free software tool that allows organizations to measure, track, and compare energy and water use online using their own private account.

ENERGY STAR scores are the cornerstone of EPA's program and also widely integrated into other green rating systems. The American Society for Healthcare Engineering uses Portfolio Manager to track energy improvements in hospitals enrolled in its Energy Efficiency Commitment initiative. The Green Guide for Health Care, Green Globes, the U.S. Green Building Council's LEED®, and the 2030 Challenge all assign points for certain ENERGY STAR scores.

Increasingly, states and municipalities are requiring that buildings—including hospitals—within their jurisdiction disclose their ENERGY STAR scores, either annually to the public or to prospective buyers or lessees. California was the first state to pass an energy disclosure law in 2007. Many others have enacted similar laws including Washington State, the District of Columbia, and the cities of Austin, New York, Philadelphia, San Francisco, and Seattle.

It's a Goal

The most energy efficient buildings in the United States, including hospitals, earn the ENERGY STAR label for scores of 75 or higher, meaning that they perform better than 75 percent of similar buildings nationwide based upon the entered data. To validate ENERGY STAR eligibility, a professional engineer or registered architect must verify actual performance and adherence to indoor air quality standards. To date, over 19,000 buildings have earned ENERGY STAR certification across all fifty states, including 158 hospitals, 149 medical office buildings, and 66 senior care facilities. ENERGY STAR certified buildings consistently use, on average, 35 percent less energy than their peers and emit approximately 35 percent less carbon dioxide. About 10 percent of all ENERGY STAR certified buildings use 50 percent less energy than typical buildings.

Attaining ENERGY STAR certification for individual buildings is the first step; maintaining it with good operations year after year is the second. Since EPA's certification is valid for only twelve months, certified buildings are encouraged to re-apply yearly to verify that top performance is being maintained.

Organizations with carbon neutral goals can track the energy performance of their entire portfolio of buildings and work to achieve broad energy reduction targets. EPA has recognized more than 250 organizations, including Memorial Hermann Healthcare System and New York Presbyterian Hospital, as ENERGY STAR Leaders for making improvements across their entire portfolio of buildings.

It's a Strategy

Leading healthcare organizations use 35 percent less energy than their peers, on average, according to the EPA. Why the big performance gap? These high performers don't achieve extraordinary savings by applying special knowledge unknown to the rest of the industry. Rather, they put into practice a structured approach to energy management, policies and procedures to ensure long-term results, and a belief that the job of saving energy is never done.

Following this strategy, EPA developed a set of guidelines to help building owners and operators institutionalize energy management. The ENERGY STAR "Guidelines for Energy Management" helps organizations develop effective energy programs by providing guidance on organizing an energy team, identifying efficiency opportunities, raising awareness, and effectively communicating results to senior leadership. To maximize energy savings in existing hospitals and other healthcare building types, ENERGY STAR also offers a five-stage technical approach that begins with retro-commissioning (or fine tuning) existing equipment, progresses on to lighting upgrades, supplemental load reductions, air distribution systems, and ends with properly sizing the HVAC system.

For new building designs, the strategy recommended by ENERGY STAR is a paradigm shift that involves comparing the modeled annual energy use of the design to how real buildings perform rather than to a hypothetical base case. Then, once the building is constructed and operational, its actual energy performance should be measured and tracked against the same market-based data. This is exactly what the ENERGY STAR tool Target Finder allows designers, architects, and building owners to do—create an energy target for specific types of buildings, grounded in real energy data from a large sample of existing buildings. Many teams use Target Finder to determine the energy performance target that meets the 2030 Challenge or other local or regional energy and carbon reduction goals.

ENERGY STAR is rooted in the power of collaborative partnerships, the importance of high-level organizational commitment, the value of a good plan, a consistent and objective way to measure real-world consumption and savings on a continuous basis, and recognition. These core values will continue to be of great importance to hospitals as they encounter the challenges of an economic recession, consumer skepticism of green claims, and growing concern about climate change.

The LEED India Platinum–certified Kohinoor Hospital, Mumbai, India (Case Study 6, this chapter), exhibits a bold approach to resource efficiency and offers a compelling comparison in terms of dramatically reduced energy use intensity. Its estimated EUI of 53 kBtu/sf/yr (166 kWh/sm/yr), not including plug load, is achieved through high performance envelope, low lighting power density, mixed mode ventilation, and roof-mounted solar photovoltaics to heat water, complemented by offsite wind generators that generate 84 percent of the hospital's energy demand.

The Case Studies of low-energy hospitals in Europe and Scandinavia, New Karolinska Solna University Hospital (Case Study 9, this chapter), Akershus University Medical Center and Deventer Ziekenhuis (Case Studies 21 and 23, respectively, Chapter 8) use long-term energy storage systems to dramatically reduce their energy use intensity. As an EU Hospital Energy Demonstration Project site, Deventer Ziekenhuis was the first hospital in Europe to employ this large-scale aquifer-based thermal storage retrieval system with a system of heat pumps and ventilation heat and moisture recovery units. These buildings use ground-source heat pumps to move reject heat in the summer, and cooling energy in the winter, to underground thermal storage banks (stationary water or ground) for withdrawal in the opposite season. This latent heating and cooling storage approach has a significant impact on thermal energy demand for these large projects; in fact, Deventer Ziekenhuis requires no fossil fuel energy for cooling.

Energy End Uses in Hospitals

Considering the magnitude of U.S. hospital energy use, it is surprising that very little reliable benchmarking data concerning end uses exists. Energy consumption data often aggregate inpatient, outpatient, and long-term care, for example, which have radically different systems, operating hours, and ventilation requirements. Even at a systems level, data can aggregate across climate zones or fundamentally different building typologies (i.e., normalizing factors), making it difficult to apply to a specific location. In a report proposing a standardized energy benchmarking protocol, Lawrence Berkeley National Laboratory (Singer 2009) described the many challenges inherent in reliably benchmarking energy use.

In 2010, Legacy Health partnered with the University of Washington's (UW) Integrated Design Lab and SOLARC Architecture & Engineering to monitor energy use patterns at Legacy Salmon Creek Medical Center in Vancouver, Washington. Legacy Salmon Creek (see sidebar), completed in 2005, operates at approximately 215 kBtu/sf/yr (675 kWh/sm/yr), and was selected due to its age, mechanical system characteristics, size and typology of bed tower/plinth design. The U.S. Department of Energy's Buildings Technology Program is developing data on energy end use consumption in three additional hospitals, expected to be available in 2013.

Legacy Salmon Creek

Vancouver, Washington

Architect: Zimmer Gunsul Frasca Architects LLP

MEP Engineer: AEI Affiliated Engineers Inc.

This freestanding medical center complex is located in Salmon Creek, the most rapidly growing area of Clark County, Washington. The campus aggregates to just over 1.1 million sq. ft. (102,193 sq. m) of development on the 24-acre (9.7 ha) site adjacent to a wooded forest area.

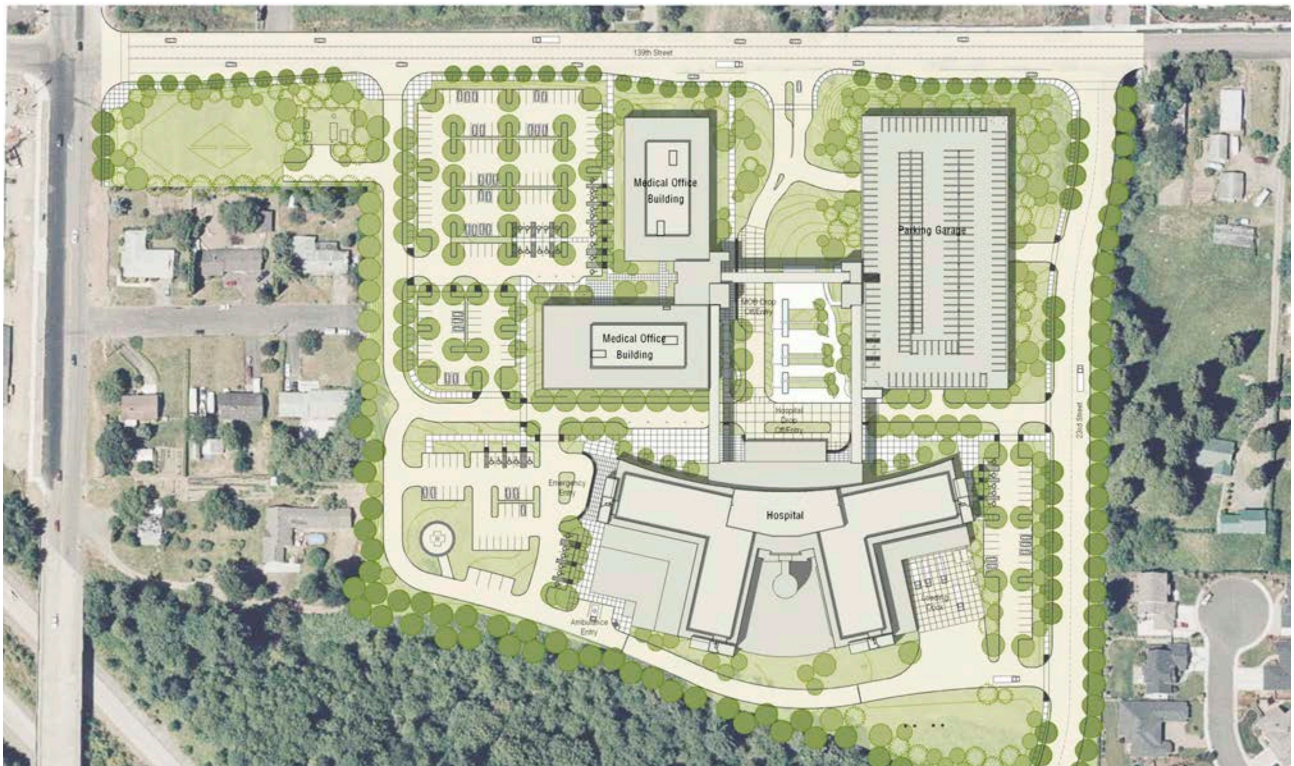
Indigenous drought-tolerant landscaping, pervious surface treatments, natural stormwater retention design, and sensitive site lighting are incorporated as sustainable design features in consideration of the protected site. The University of Oregon's Baker Lighting Lab performed studies to determine the amount of sunlight and glazing necessary to achieve the facility's daylighting performance goals throughout the building, including patient rooms. Legacy Health System prioritized indoor air quality for patients and staff, recycling, and waste reduction. Sustainable design features, such as the green roof healing garden, increased first costs though, importantly, added a significant program amenity for patients, visitors, and staff.

The design honors the connection between sustainable building practices and healthcare outcomes, including public health issues that relate to energy consumption and healthy material selection. It is a building designed to reinvigorate the senses.

Source: Zimmer Gunsul Frasca Architects LLP

Figure 5.6 Legacy Salmon Creek. *Source: Copyright © Eckert & Eckert*

Figure 5.7 Site plan. Source: *Zimmer Gunsul Frasca Architects LLP*



Energy End Use Monitoring

Annual energy consumption for the 469,000 sq. ft. (43,572 sq. m) hospital was based on the 2010 electric and gas utility bills. The 2010 energy end use breakdown shown in Figure 5.8 was calculated based primarily on utility data and adjusted in conjunction with power monitoring system data, weather service data (particularly for humidification), and calibrated energy model output. The calibrated energy model helped clarify end use when energy use data was insufficient or ambiguous in regard to a particular end use.

For the 2010 study period, fossil fuel use represents about 55 percent of total energy use, primarily used for boilers. Monthly fossil fuel use fluctuates between about 3,500 and 6,500 MBtu. Relatively high summer fuel use is associated primarily with HVAC zonal reheat, accounting for more than 42 percent of total energy demand. Boilers also provide HVAC preheat and domestic (service) water heating and process steam for humidification, food service, and sterilization. During the winter study period, only the smaller chiller was enabled on a regular basis confirming that dedicated high efficiency cooling systems for winter months have the potential to conserve chiller energy. Electricity is used for chillers, cooling towers, pumps, medical gas equipment, lighting, transportation systems, major imaging equipment, and, obviously, plug load. One major finding: Imaging equipment accounts for only 1.7 percent of total electricity consumption.

Source: University of Washington Integrated Design Lab

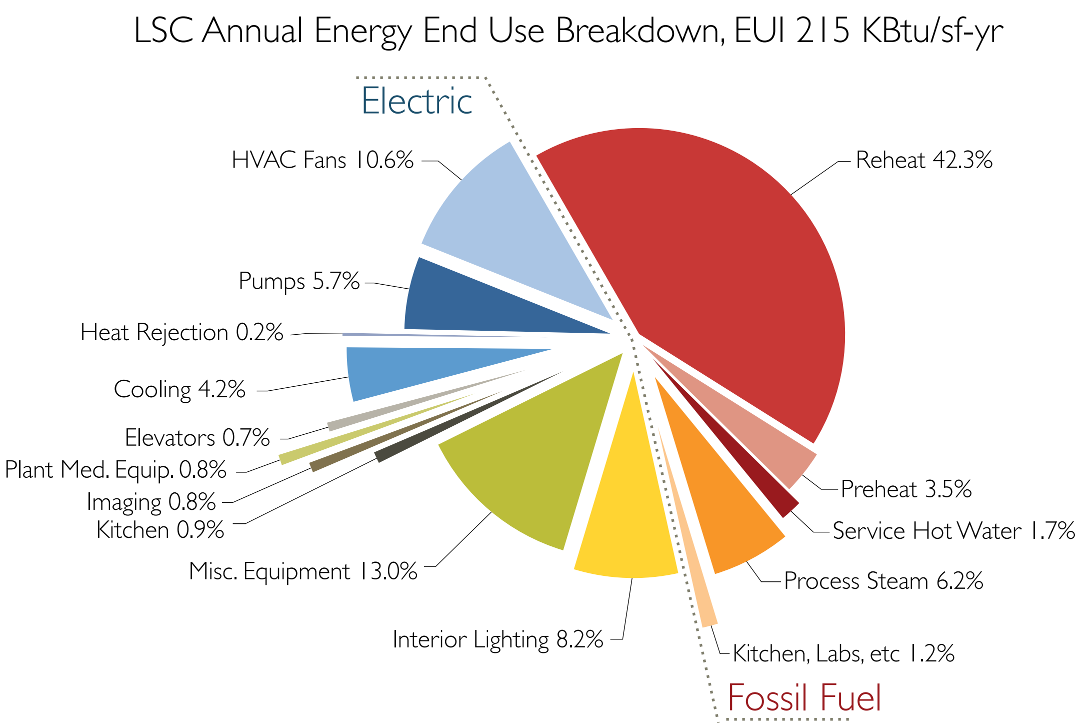


Figure 5.8 Legacy Salmon Creek Medical Center energy use intensity for 2010. The end uses were monitored over the year and supplemental metering helped determine the energy use profiles of discrete areas of the hospital. Re-heat was the biggest end use, which confirmed the team's assumptions. The energy used for imaging, however, was much lower than anticipated—at less than 1 percent, it is one of the smallest end users. *Credit: University of Washington Integrated Design Lab*

Targeting 100!

The University of Washington Integrated Design Lab's (IDL) Targeting 100! research project began in 2010, supported by the Northwest Energy Efficiency Alliance's BetterBricks Initiative and the U.S. Department of Energy. In short, the aim is to determine what system solutions might support the radical reduction of energy use intensity in U.S. hospitals to meet the 2030 Challenge goals and edge closer to the average energy use intensity of low-energy, high-technology hospitals in Europe and Scandinavia. Harkening back to the CADDET study, the Targeting 100! process began with the energy end use monitoring of Legacy Salmon Creek and continued with the development of sophisticated modeling of a range of system solutions to approach an EUI of 100 kBtu/sf/yr (312 kWh/sm/yr) for U.S. hospitals. Hence, it provides new and important insights into how energy is actually used in contemporary U.S. hospital construction and challenges prevailing wisdom.

TARGETING 100!

By Heather Burpee and Joel Loveland, University of Washington

Targeting 100! is an initiative to develop radically more energy efficient hospitals. As a roadmap for hospital owners, planners, architects, mechanical engineers, contractors, and operators, it provides guidance on achieving dramatically improved energy performance, a 60 percent reduction from common operation. Targeting 100! aligns with the energy goals of the 2030 Challenge, with little additional capital cost while complying with U.S. energy and health-related codes and improving the quality of healing and work environments. Targeting 100! challenges project teams to carry out the necessary steps to produce these radical reductions in operational energy use through an integrated team and building systems approach.

Targeting 100!'s research and building industry market transformation methodology is framed by four key questions:

- Is a hospital's energy performance greatly affected by the climate of the city in which it's located?
- Can the 2030 Challenge be achieved by hospitals in diverse climate regions across the continental United States?
- How much does it cost to implement this level of energy efficiency in different regions?
- Do utility pricing structures in combination with first cost of construction make these options viable in today's market?

Targeting 100! identifies climate-specific regional strategies for hospitals to achieve a site energy use index (EUI) of less than 100 kBtu/sft/yr (312 kWh/sm/yr), or 60 percent less than the current U.S. average energy performance of 260 kBtu/sft/yr (820 kWh/sm/year). This EUI would meet the 2030 Challenge for 2010–2015, signifying energy performance in the highest tier of U.S. hospitals. Six of the most highly populated and climatically diverse ASHRAE climate regions in the United States were chosen for this study; the most populous cities within those regions serve as the basis for weather and construction cost data: Chicago (Climate Zone 5A), New York (4A), Seattle (4C), Los Angeles (3C), Houston (2A), and Phoenix (2B) (see Figure 5.9).

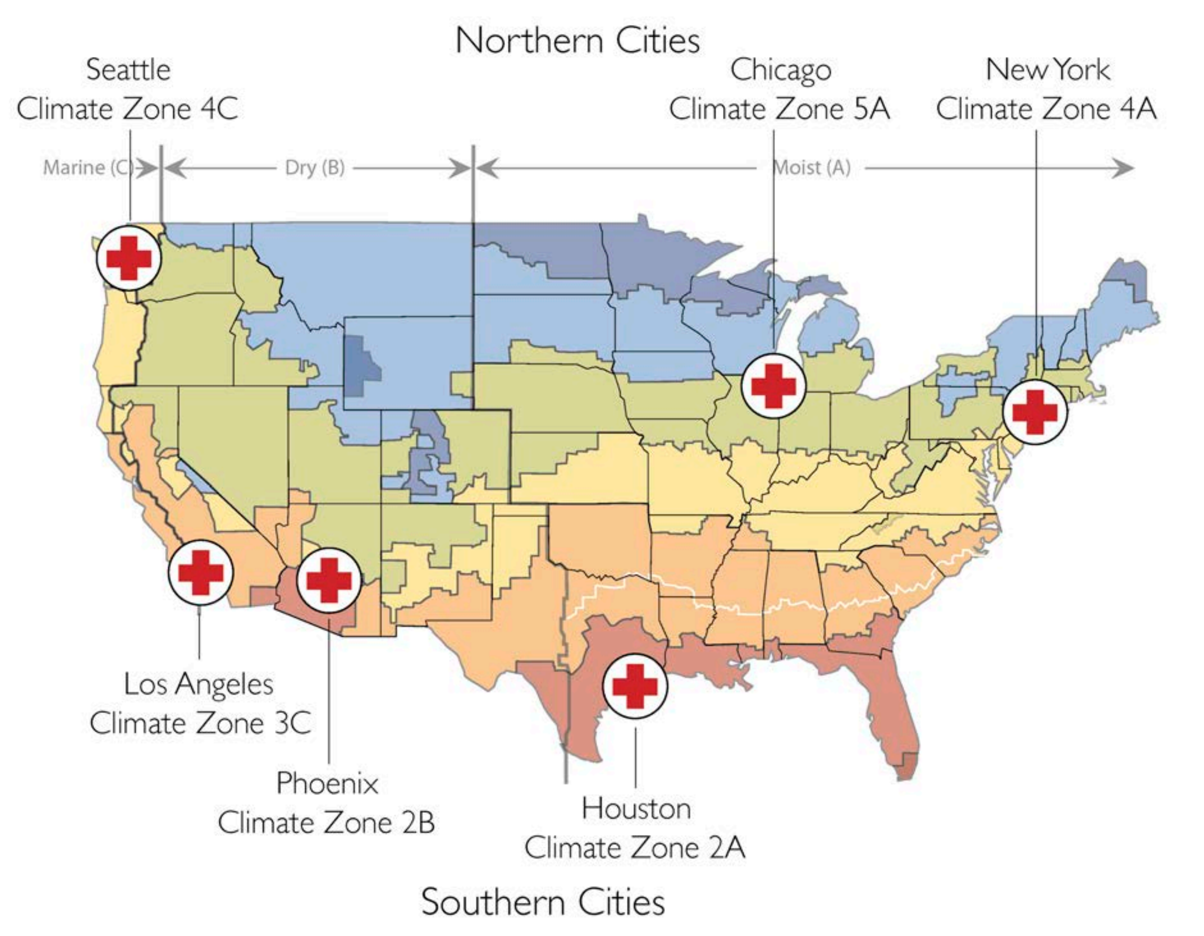


Figure 5.9 Targeting 100! focuses on six representational cities in the most diverse climate regions in the United States. These cities represent the largest population centers within each climate region: Chicago (5A), New York (4A), Seattle (4C), Los Angeles (3C), Houston (2A), and Phoenix (2B). *Credit: University of Washington Integrated Design Lab*

The Targeting 100! initiative is grounded in the local realities of hospital design, construction, and operation in each region. The UW's IDL collaborated closely with three industry leaders that were part of the project team: SOLARC Architecture & Engineering, TBD Consultants, and NBBJ. The team met with over 200 stakeholders in a series of workshops held in each of the six study regions with the goal of getting on-the-ground feedback on the project's preliminary findings and on the best region-specific approaches to achieve deep energy savings and balanced capital investment. Stakeholder feedback was critical for understanding the applicability of the models and gathering the best approaches to meeting the load reduction, energy efficiency, and cost goals in each climate region and representative city.

Integrated Solutions Lead to Energy and Cost Savings

Understanding the baseline energy demand profiles and the regional climate conditions affecting each hospital's energy use intensity were the foundation of the project's integrated building systems approach. Generally applied, the approach is to reduce loads first, then utilize energy efficient measures to reduce the building's energy demand. Meeting the 2030 Challenge using an integrated team process combining load reduction and the application of highly efficient systems tunnels through the cost barriers that can otherwise appear in high-performance buildings—this approach results in synergistic savings in both energy and cost.

Two 225-bed, 477,000 sq. ft. (44,315 sq. m) prototype hospital architectural schematic designs were developed to test the impact of building form on energy demand profiles. As shown in Figure 5.10, one scheme exemplifies a "typical U.S." hospital (Scheme A); the other has a more articulated form, allowing for more access to daylight and views (Scheme B). Four energy options were developed for each scheme. A baseline energy option represents "common practice" (complying with minimum ASHRAE Standard 90.1 2010) and three high performance options are compared to this baseline measuring energy use and first cost of construction. The high performance options emphasize integrated—or bundled—strategies that work in concert to achieve drastically reduced energy and cost profiles. All options comply with rel-

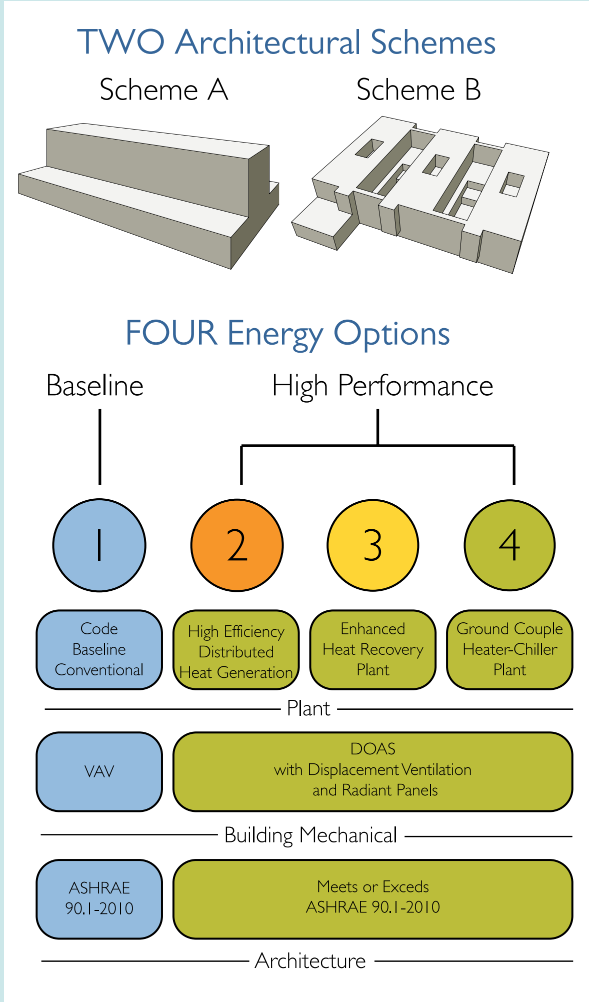


Figure 5.10 Conceptual framework of Targeting 100! Two architectural schemes with four energy options per scheme. The architectural schemes represent a "traditional" model with a deep diagnostic and treatment platform and patient tower and a "perforated" model where plan enclosed courtyards incorporate greater access to light, views, and potentially fresh air throughout the footprint, including in the diagnostic and treatment areas of the program. *Credit: University of Washington Integrated Design Lab*

evant U.S. energy and health-related codes such as Department of Health, Facility Guidelines Institute, and other relevant building-related standards.

Outcomes and Conclusions—Targeting 100!

Load Reduction: Aggressively reducing external climate-dependent loads and internal loads is the first step of an integrated approach to significantly decrease annual energy use, first cost of construction, and ultimately annual energy costs. A simultaneous focus on both peak loads and whole building annual energy loads is important for solving the energy and cost equation. Smaller peak loads mean smaller plant equipment, which translates to lower capital cost investments; lower overall load profiles allows for flexibility in ventilation system choice and means significantly reduced annual energy use profiles for heating and cooling which translate to annualized energy savings. Highly coordinated architectural and building mechanical systems strategies achieve large load reduction goals. For example, exterior shading on the envelope significantly reduces solar heat gain enabling a de-coupled approach to the building heating, cooling, and ventilation systems. De-coupling heating and cooling from ventilation of rooms enables much lower whole building load profiles and significantly reduced peak loads.

Energy Outcomes: The number one energy end-use reduction strategy across all six climate regions was in heating energy used for re-heat. This was expected, as re-heat energy is the single largest hospital energy load and therefore a key opportunity for energy savings. Strategies for reducing or eliminating re-heat included de-coupling space tempering and ventilation for most spaces; fluid rather than air-transport of heat and cool for peak conditions; and the final distribution of heating and cooling to each space via a bundle of de-coupled systems such as radiant heating and cooling panels and air delivered via displacement ventilation. This de-coupled and de-centralized scheme of heating, cooling, and ventilating systems acting in close coordination with solar heat gain load reductions, heat recovery from significant powered or heated energy sources, and a large ground-source heat pump system significantly reduces the energy demands for ventilation, space heating, cooling, and water heating.

Using these and other bundled strategies, both architectural Schemes A and B are calculated to achieve at or near a 60 percent reduction in energy use in all six climate zones, thus meeting the 2030 Challenge goal for 2010–2015 (Figure 5.11). Surprisingly similar energy results were seen between Schemes A and B. While maintaining a 30 percent window-to-wall ratio for both architectural schemes, Scheme B has nearly double the actual window area due to its overall increase in surface area. Despite this increase in surface area, Scheme B does not require significantly more energy. Hospitals are typically internally load-dominated, meaning that the systems used to heat, cool, and ventilate the building are a large source of the overall load. The high performance options in both architectural schemes significantly reduce those internal and envelope loads. In summary, it is possible to build a hospital with significantly more surface area and still meet aggressive energy targets such as the 2030 Challenge.

Synergistic Savings: The integrated nature of Targeting 100! creates complementary savings in

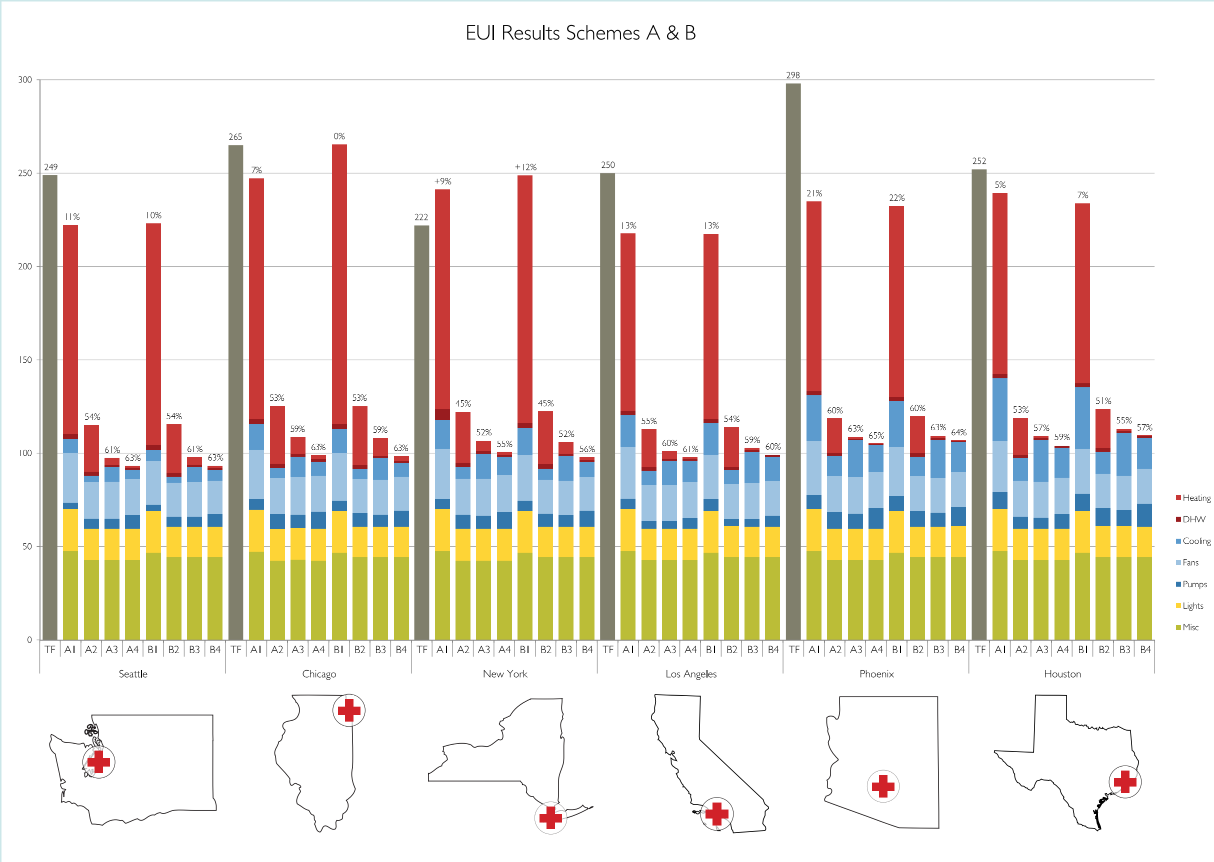


Figure 5.11 A 60 percent reduction from the Target Finder baseline—and the Target 100! goal (of 100 kBtu/sf/yr (315 kWh/sm/yr))—was achieved in most study cities. The cooling-dominated cities (Phoenix and Houston) approached that goal, and the study team is evaluating additional strategies to achieve a greater reduction in those climate zones. While the 60 percent energy use reduction goal was met, energy cost reductions were more modest. There was a vast reduction in thermal energy and a more modest reduction on the electric side resulting in an average energy cost reduction of 35 percent. Since electricity is much more expensive in many markets, especially those that charge during peak hours, saving thermal energy equates to lower energy cost savings than saving electrical energy. In many parts of the country electricity is still generated by carbon-intensive sources, thus this electricity use represents CO_2 emissions. The Targeting 100! approach is in line with developing a "net-zero ready" hospital, where an all-electric plant could be served in the future through cleaner sources of electric energy such as wind or solar. Today, an electricity-dominated building generally represents greater CO_2 emissions, and potentially shallower cost savings potential. *Credit: University of Washington Integrated Design Lab*

energy and capital construction costs; cost savings in some categories can offset incremental cost increases for energy improvements in other areas. For example, reduced cooling loads were realized by adding exterior shading systems—in this case, motorized retractable louver shades—which in turn reduced the size and first-cost of the cooling system. De-coupled systems' concepts also reduced loads, having a major beneficial impact on primary ventilation duct sizing and creating volume within the ceiling plenum to reduce the floor-to-floor height on patient floors by a minimum of one foot. Cost savings realized by reductions in floor height and ventilation ducting help offset the increased cost for other energy efficiency improvements. These integrated building and systems strategies work in concert to achieve energy and cost savings.

Cost Outcomes: Throughout the six study regions, the capital cost implications of implementing energy efficiency options, compared to building a standard practice hospital, showed about a 4 percent incremental cost premium. As expected, increasing the amount of building envelope in Scheme B yields approximately 5 percent increase in capital cost from Scheme A to Scheme B. This analysis has not attempted to quantify the quantitative or qualitative benefits of creating a more perforated hospital, such as increased daylight and its effect on staff productivity and retention or patient healing. The potential ongoing operational savings associated with these quality building attributes may more than pay back the higher capital investment required to increase the building's envelope. This analysis concluded that the relative difference in energy demand related to efficiency options are proportionally similar between Scheme A and B. Relative to each scheme's baseline cost, the cost of implementing energy efficiency options compared to a common practice baseline is proportionally similar, about 4 percent.

The Role of Incentives: In many regions, utility incentive programs can reduce the incremental capital cost outlays through electric and gas utility incentive programs that fund energy efficiency projects. For this analysis, it was estimated that an integrated whole-building energy utility incentive for this level of energy efficiency savings could support the first-cost of energy efficiency strategies at a value of approximately 1 percent of the total project cost. With this level of incentive, the total cost premium for energy efficiency strategies that meet the 2030 Challenge goal would be reduced to approximately 3 percent of the total project cost.

Budget Assumptions: Architectural, mechanical, and cost models are based on schematic level considerations. On any specific project, budget fluctuation is common at this stage; it is reasonable to assume that this modest capital cost differential between the code baseline building and the Targeting 100! high performance building options are within a reasonable range for the project to shift budget priorities to accommodate these costs; therefore, at a schematic stage of development, a 3 percent increase in capital cost could be considered "cost-neutral."

Additionally, some forward thinking hospital organizations are investing in incremental capital cost strategies that meet an acceptable rate of return. These programs emphasize that reasonable increases in first cost for strategies that yield long-term energy savings are a good investment; these investments reduce risk, bring greater stability to the organization's bottom line, reduce future liabilities, and reduce the organization's overall environmental footprint.

Integrated Design: Reducing energy in hospitals is a formidable task; the systems and architecture of the entire hospital must be reconsidered and designed in concert to reach aggressive energy goals such as the 2030 Challenge. The two overarching keys to success are: (1) the integrated nature of the project team structure, and (2) the whole-building integration of required technical solutions. While all the subject technologies and innovations are available today and comply with current codes, many are not common practice in the U.S. healthcare market today.

Health in the Built Environment: Reducing energy is only one aspect of design. Creating healthy environments for patients and especially the often-overlooked and chronically stressed staff demands a reevaluation of the typical hospital architectural form. Strategies for achieving both this level of energy savings *and* quality healing and work environments must be integrated from a project's inception. Developing a healthier and more sustainable hospital environment requires an exceptionally high level of owner support to achieve carefully gauged high performance goals. Many of the solutions work synergistically for both health and energy savings, where, for example, greater daylight penetration into the core diagnostic and treatment functions of the hospital will yield electric lighting energy savings, which can provide operational savings and create enhanced healing environments by increasing access to daylight. While presented here as bundles of architectural, building mechanical, and plant systems, an integrated design approach means that all professionals from planning, design, construction, and operations must provide insight and expertise in all of these categories from the onset of the project. A project team structure and culture that enables co-operative decision making with key stakeholders is essential for creating a truly high performance hospital: a hospital that has a low energy footprint and embodies qualities that foster health, productivity, and well-being.

For more information on Targeting 100! see http://idlseattle. com/Health/health_design.html.

In summary, the work of the U.S. Department of Energy, ASHRAE, and Targeting 100! all suggest system solutions that support a high performance healing environment requiring 60 to 70 percent less energy use intensity than the average U.S. hospital today are both possible and achievable today. In fact, Peace Island Medical Center (Case Study 4 in this chapter) and Swedish Medical Center (Case Study 35, Chapter 8) are open and operational using systems and design approaches described in the Targeting 100! study.

Carbon Neutrality and Net-Zero Energy

Carbon neutrality, energy independence and net-zero energy are emerging as the aspirational benchmarks of twenty-first-century green buildings. While related, each has a distinct definition and slightly different built manifestations.

Calculating carbon footprint is fundamental to assessing climate change impacts. Carbon footprint is defined as "a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced, measured in units of carbon dioxide" (Carbon Footprint Ltd. 2006). Because buildings represent 48.7 percent of U.S. energy use and a corresponding percentage of CO_2 releases (USEIA 2011), buildings must be a central focus in the global dialogue and strategy to achieve meaningful CO_2 emission reductions. Gundersen Health System and Partners HealthCare (see Chapter 7) illustrate different but equally impressive approaches to carbon neutrality. The first operational carbon neutral hospital in the United States is Kiowa County Memorial Hospital (Case Study 5 in this chapter), an all-electric building powered by a combination of on- and offsite wind.

A carbon neutral building can be achieved through shifting source energy from fossil fuel to zero-carbon renewables such as solar and wind. Shifting among traditional fossil fuel energy sources (coal, oil, or gas) or shifting to biomass may significantly reduce carbon emissions but may not completely eliminate them; hence, these strategies are often termed "carbon reduction" or "energy independence" strategies rather than "carbon neutral."

Gundersen Health System frames its source energy transformation as a journey to be the first "energy independent" healthcare system in the United States. A diverse set of renewable energy partnerships, ranging from partnerships to harvest landfill methane, brewery waste, and dairy manure to wind investments, are projected to result in system-wide elimination of all fossil fuel energy sources by 2014 (Chapter 7).

In the dense urban fabric of Boston, Partners HealthCare (see Chapter 7) is following its focus on efficiency, which yielded a 25 percent reduction in system-wide energy consumption (and associated carbon), with a shift from traditional grid-supplied power and thermal central utility plants to on-site gas fired co-generation. Together, this combination of energy efficiency measures and source energy transformation will meet the carbon reduction goals mandated by the Massachusetts Global Warming Solutions Act—25 percent below 1990 baseline emissions by 2020. This source energy transformation is a mid-term solution toward carbon neutrality, as the system seeks to further transform source energy to renewables.

Similar emphasis on reducing healthcare's carbon footprint is being seen internationally. For example, the UK's Carbon Trust's NHS Carbon Management Programme issued a challenge to the NHS in late 2006: reduce the NHS's annual carbon footprint by 15 percent, representing approximately 40,000 tons of carbon emissions. As UK Health Minister Andy Burnham noted, "The reduction of carbon emissions and greenhouse gases is important for the environment and helps people lead a healthy life" (Reuters 2007). The combination of low energy demand and shifting from fossil fuel energy to biomass, as illustrated at New Southwest Acute Hospital (Case Study 14, Chapter 7), Portadown Health and Care Centre and Ysbyty Aneurin Bevan (Case Studies 27 and 36, both in Chapter 8), and Jubilee Gardens Health Centre and Library (Case Study 50, Chapter 10) is part of the NHS's overall carbon reduction strategy.

Two Case Studies demonstrate yet a third path to carbon neutrality. The Dyson Centre for Neonatal Care, Royal United Hospital, Bath, England (Case Study 7, later in this chapter), a relatively modest addition to an existing hospital, demonstrates two significant innovations. First, the panelized timber and wood structure, made from renewable wood sources that sequester carbon, illustrates a willingness to reconsider timber as an appropriate material for institutional hospital buildings. Second, the project included replacement of the Royal United Hospital central thermal plant with a biomass-fed co-generation system that dramatically reduces the carbon footprint of the entire campus.

A similar concept underlies the addition to St. Mary's Hospital Sechelt, BC, Canada (Figure 5.12 and Case Study 8, this chapter). As the project took shape, the team committed to achieving a "net-zero carbon footprint" project—i.e., no campus energy increase compared with the current facility following completion of the project—a goal enabled through climate-responsive siting, envelope design, and energy-efficient lighting, coupled with an innovative ground-source heat pump energy system that serves both the existing campus and the addition. By sizing the ground-source system to serve the existing building and addition, the energy performance of the combined total, that is, a campus approximately 54,000 sq. ft. (5,017 sq. m) larger than the existing, is conditioned for the same total source energy input as the current building. By lowering the energy intensity of the whole, the new wing is both carbon neutral and net-zero energy.

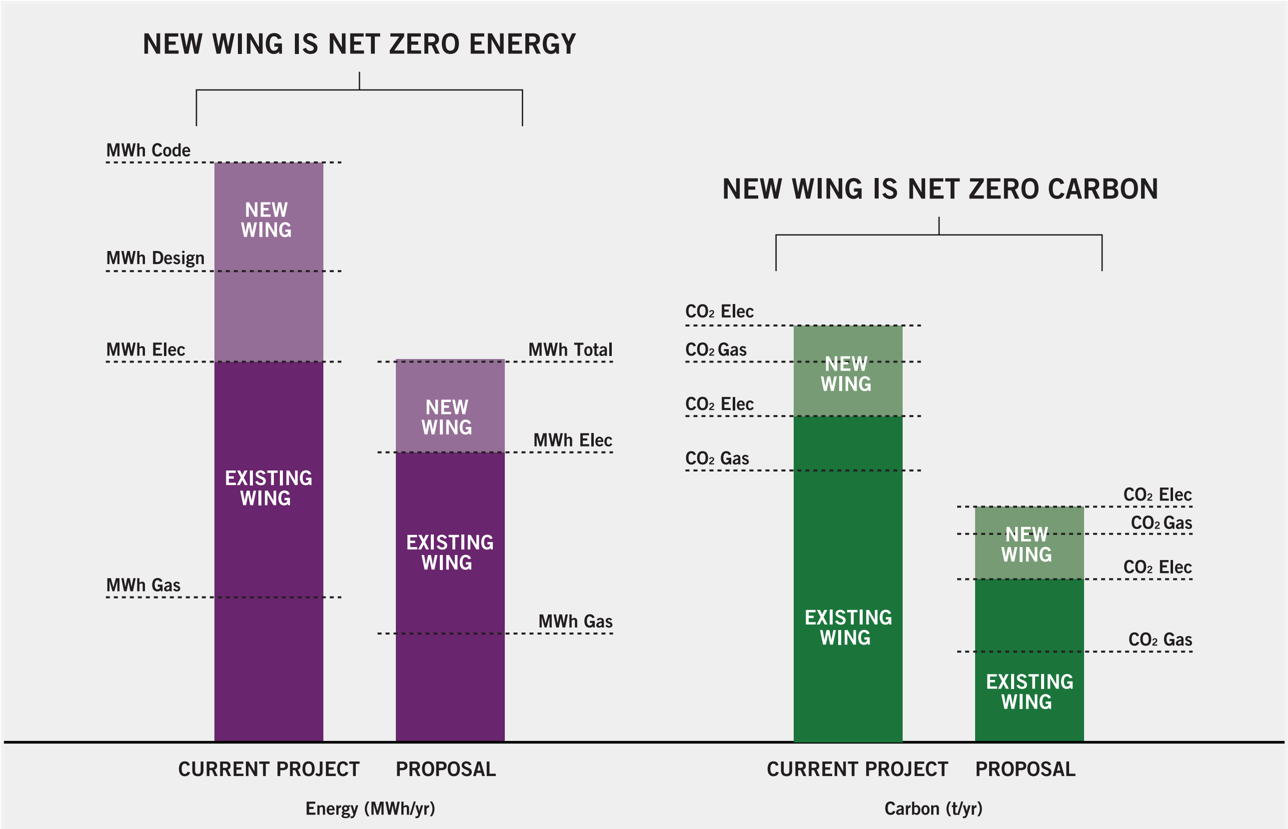


Figure 5.12 Net-zero energy and net-zero carbon at St. Mary's Sechelt (Case Study 8, this chapter). Modeling the new wing at the same performance as the existing wing yielded the current project case; installation of a ground-source heat pump system for both reduced total energy to equal current energy usage. A similar comparison for carbon emissions for the combined campus yielded carbon emissions well below the current wing emissions. *Source: Perkins+Will*

Net-Zero Energy

A net-zero energy building is a building with zero net energy consumption and zero carbon emissions annually (U.S. DOE 2008). Buildings that produce a surplus of energy over the year may be called "energy-plus" buildings while buildings that consume slightly more energy than they produce are called "near-zero energy buildings." The net-zero energy principle is viewed as a means to both eliminate carbon emissions and dependence on fossil fuels through a combination of energy demand reduction and implementation of renewable energy sources—i.e., to reduce energy demand so significantly that 100 percent of the remaining energy needs can be met through on- and off-site renewables. Most net-zero energy buildings use the grid for energy storage; however, some may be grid-independent. Energy is harvested on-site through solar and wind, while a combination of passive bioclimatic design strategies combined with technologies such as ground-source heat pumps or energy efficient mechanical systems dramatically reduce energy demand.

The Targeting 100! study defines a "net-zero ready" hospital design as a low-energy set of building and system design strategies that support net-zero energy targets with shifts in energy supply from fossil fuel—either through future implementation of on-site renewables or grid-connected renewable sources. Salam Centre for

Cardiac Surgery (Case Study 32, Chapter 8), an off-grid cardiac hospital in sub-Saharan Africa, and Mirebalais National Teaching Hospital, Mirebalais, Haiti (Case Study 53, Chapter 10) demonstrate a net-zero energy approach—the buildings are powered by on-site solar to produce all electricity (and, at Salam, steam for chillers).

The two winning entries for the Kaiser Permanente Small Hospital, Big Idea Competition (Case Study 20, chapter 7) focus on delivering net-zero energy solutions through a combination of energy efficiency and renewables, one on meeting 100 percent of the energy needs by harvesting on-site solar; the other on a hybrid solution including on-site solar and wind as well as a partnership with the local landfill to harvest methane for on-site fuel cells. Today, Gundersen Health System operates just such a landfill gas recovery partnership to meet the energy needs of its Onalaska campus (see Chapter 7). The evolution of the Passivhaus standard, originated in Germany, promises to accelerate the development of net-zero energy hospital buildings in the European Union.

Finally, the proposed Embassy Medical Center, Colombo, Sri Lanka (Case Study 54, Chapter 10) suggests the expanded role for a hospital in partnering with a community to digest organic municipal waste—removing a public health nuisance and a potent greenhouse gas with a solution that relies on a distributed network of neighborhood-based pickup locations that exchanges potable water for waste. Together, these glimpses of a net-zero approach rely on a combination of on- and offsite energy resources—considerations mapped in Figure 5.13. They collectively demonstrate that achieving net-zero energy is possible and demands that we harvest available site resources rather than simply "plugging in" the buildings to a municipal grid. These hybrid approaches are a powerful model for the future of healthcare design.

Water Use

Healthcare institutions are consistently within the top ten water users in their communities: an estimated 7 percent of total water use in U.S. commercial and institutional facilities is attributed to hospitals and other healthcare facilities (USEPA 2012b). For the first time, CBECS collected data on water use by large hospitals [greater than 200,000 sq. ft. (185,806 sq. m)] and found that they consumed about 133 billion gal (503 billion L) of water in 2007, with annual averages of 43.6 million gal (165 L) and $202,200 per building.

A 2002 estimate by H2O Applied Technologies, corroborated by the Hospital Corporation of America, reported that total annual water consumption ranges between 250,000 and 700,000 gal (946,000 and 2,650,000 L) per bed in U.S. acute-care settings

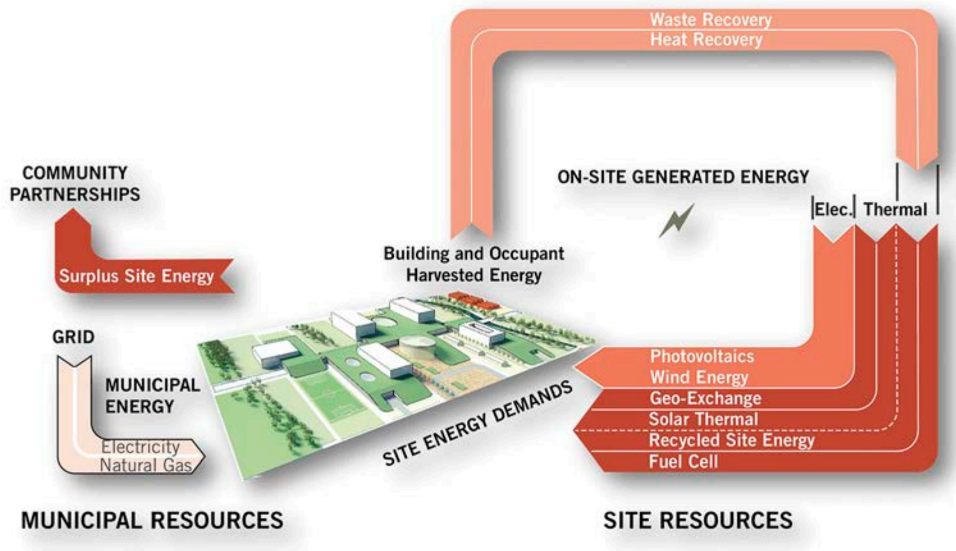


Figure 5.13 Net-zero energy. Net-zero energy begins with bioclimatic, passive design strategies to minimize energy demand and harvesting on-site building and occupant waste energy, followed by utilizing on-site renewable resources. Buildings that produce more energy than they require can send surplus energy off-site through community partnerships; likewise they can receive renewable energy from such partnerships. Finally, grid-connected source energy can be employed equal to the surplus energy generated. *Credit: Perkins+Will*

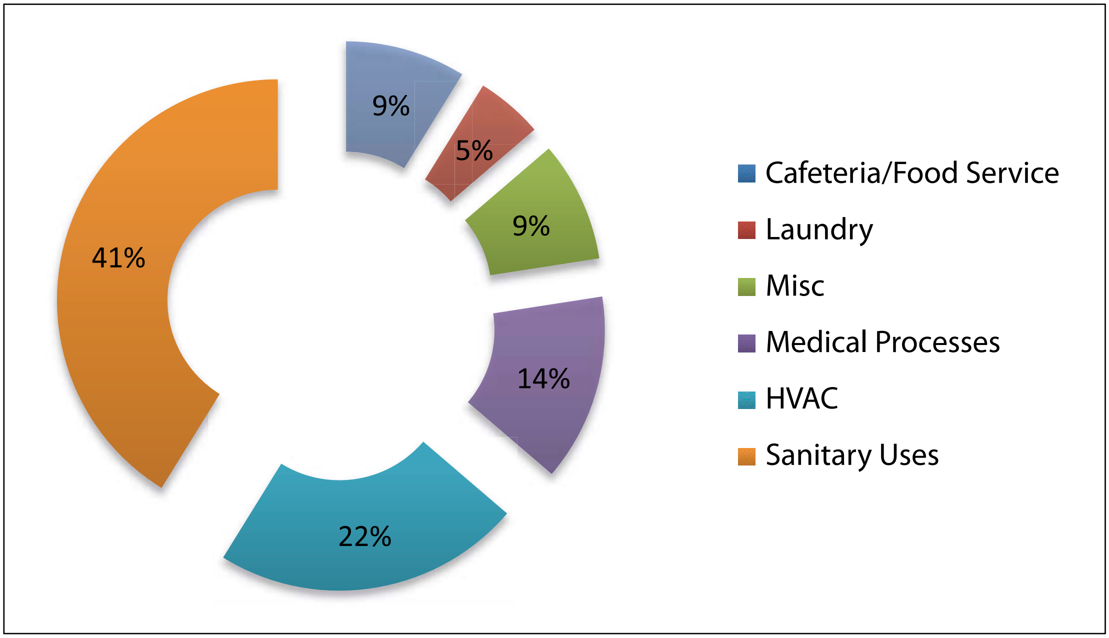


Figure 5.14 Average water use in hospitals. Facilities studied include hospitals with 138- to 550-bed capacities, in-patient admissions of 5,100 to 11,600 per year, and annual water use ranging from 15 to 67.2 million gal. The seven hospitals studied included: one large urban (Boston), one large long-term care, four small communities, and one regional urban. *Source: MWRA 1996*

(see Figure 5.14). The U.S. Federal Energy Management Program reports usage of 80 to 150 gal (300 to 550 L) of water per bed per day, roughly equivalent to European hospitals, though estimates from the Massachusetts Water Resources Authority (2008) put the upper range as high as 350 gal. (1,325 L). The wide variation in water use may be attributable to the size of the facility or number of beds (it appears that larger hospitals use more water per bed than smaller), types of services on site (e.g., laundry and sterilization), equipment, facility age, and mechanical equipment types (e.g., water-cooled versus air-cooled equipment).

Biologist Peter Warshall, PhD, in his essay "Sustainability, Water, and Healthcare" (2008), identifies four principles central to the sustainable use of water in healthcare settings:

Principle One: Protect the source, protect the delivery system, and custom design the waterworks

Principle Two: Custom design to protect the beneficiary (the human body)

Principle Three: Save water, save energy, save money

Principle Four: Techno-fixes are important but insufficient

In approaching a net-zero water solution, water sources and outflows must be carefully considered. Figure 5.15 suggests that harvesting site resources as well as municipal resources to meet water demands, and matching water quality to use, are necessary components of a net-zero solution.

The Case Studies that accompany this section focus on innovative technologies to reduce overall potable water use; as a group, they demonstrate regional variations in water conservation strategies. Water conservation strategies often save money, particularly when facilities are charged for both supply and discharge. The Massa-

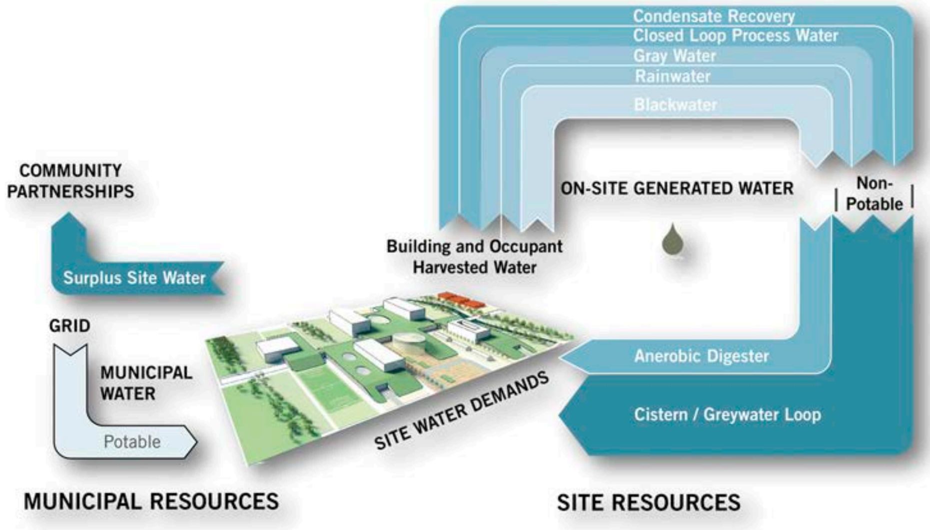


Figure 5.15 Net-zero water. Net-zero water begins with reducing both potable and non-potable demands, then matching sources to use. Sources include harvested rainwater, other on-site generated flows and on-site wells as well as municipal potable and reclaimed piped systems. Wastewater can be treated on-site or grid connected to municipal wastewater systems, though on-site systems are more effective at treating pharmaceutical residues. *Source: Perkins+Will*

chusetts Water Resources Authority (1996) estimated that in Boston, water and sewer charges averaged 22 percent of a hospital's total utility cost; since the release of the initial report, the rates have increased approximately 3.5 times (MWRA 2008).

Reducing potable water for landscape use is a widely embraced goal, though the strategies to achieve it vary by region and setting. A number of projects, like the Center for Discovery in Harris, New York (Chapter 3), eliminate irrigation systems entirely through the specification of native, drought-resistant plants. Lucile Packard Children's Hospital (Case Study 11, later in this chapter) is designed to capture and store rainwater, condensate, and reject reverse osmosis water to provide for 100 percent of irrigation needs. Others, like Dell Children's (Case Study 1, this chapter), Khoo Teck Puat (Case Study 26, Chapter 8), Ng Teng Fong (Case Study 42, Chapter 9), use municipal reclaimed water systems for irrigation. Finally, many facilities employ drip or other high-efficiency irrigation systems to reduce overall potable water consumption. Collectively, these strategies, both in new buildings and retrofits, are viewed as low-hanging fruit in sustainable healthcare.

Projects that focus on process water reduction report impressive results—in some instances more than 50 percent reductions—through strategies ranging from capturing rainwater for process uses to clever means of recycling process water. Jerry Yudelsen's Pyramid of New Water Sources offers a framework to view opportunities versus complexity and cost (Figure 5.16). As a baseline measure, sustainable healthcare buildings are, in general, eliminating once-through potable water use for cooling towers and other mechanical equipment. Rush University Medical Center (Case Study 31, Chapter 8) captures rainwater for cooling tower makeup and employs a clever sidewalk detail to capture urban stormwater runoff from the street to irrigate street trees.

Potable water use reduction strategies are moving rapidly into healthcare, despite perceived challenges of infection control and asepsis. Dual-flush toilets, low-water use urinals, and low-flow and metered devices are universally utilized in sustainable hospital projects to achieve reductions of 30 percent or more in total domestic water use.

Broader application of municipal or on-site reclaimed water to further reduce potable water use is subject to approval by local regulatory authorities or infection control professionals—lack of clear regulatory guidance has hindered industry-wide implementation to date, particularly in the United States. The Oregon Health and Science University (OHSU) Center for Health and Healing (Case Study 2, this chapter) was one of the first healthcare projects to implement on-site graywater reuse for broader building applications and on-site wastewater treatment. At OHSU, graywater is

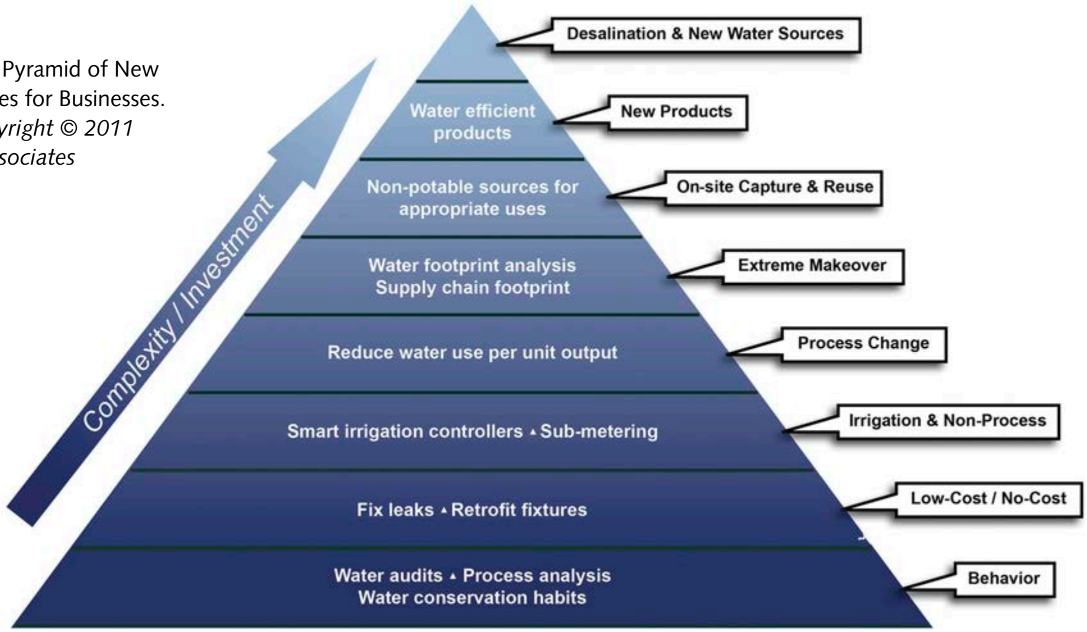


Figure 5.16 Pyramid of New Water Sources for Businesses. *Source: Copyright © 2011 Yudelson Associates*

filtered and recycled from the onsite wastewater-treatment plant and used to flush staff toilets throughout the building. Onsite wastewater treatment is slowly making its way into U.S. sustainable healthcare projects, given that most healthcare campuses have access to municipal wastewater-treatment infrastructure and therefore are often unable to justify the investment in infrastructure. At OHSU, lack of available city sewage capacity led to the innovative on-site solution. Like many urban areas, Portland has an overburdened combined stormwater/sewage system. Mirebalais University Hospital (Figure 5.17 and Case Study 53, Chapter 10) also employs on-site wastewater treatment system. Kiowa County Memorial Hospital (Case Study 5, later in this chapter) is the first U.S. hospital to use reclaimed water for some toilet flushing, while in more arid areas of the world, it is becoming more commonplace. The new Royal Children's Hospital, Melbourne, Australia, and the Santa Lucia University General Hospital, Cartagena, Spain (Case Studies 30 and 34, Chapter 8), use reclaimed water for toilet flushing.

Zero Waste

What is a zero waste hospital? Is it achievable? Across North America and throughout the world, a goal of "zero waste" has inspired thoughtful, pragmatic, and transformational policies and programs, including at hospitals and other healthcare facilities, that collectively are redefining the global material economy. Guided by the premise that "waste equals food," zero waste holds that approximately 90 percent of discards can be effectively managed through reduction, reuse, recycling, and composting strategies allowing for a disposal rate of 10 percent. The Zero Waste International Alliance (2009) offers a definition:

> Zero Waste is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing Zero Waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health.

Figure 5.17 Mirebalais Hospital has an on-site modular wastewater treatment system designed for remote applications. The technology achieves aerobic biological treatment by passing the water through several rotating drums. There is solids removal via settling plates at the beginning and end of each unit, with the rotating drums in the middle for biological treatment. The system is compact, efficient in both energy consumption and sludge production, and low-maintenance. Disinfected treated water is discharged to a local tributary of the Artibonite River. *Credit: Ann Clark Architects*

For many, adopting a zero waste goal is one facet of a broader effort to reduce their carbon or broader ecological footprint. For hospitals, the management of solid waste and other waste streams represents a significant environmental burden. U.S. hospitals produce more than 5.9 million tons of waste each year, representing about 6,600 tons per day. And while many leading healthcare organizations are approaching 50 percent diversion rates in their operational waste streams, the prospect of virtually eliminating waste seems beyond reach. Laying the groundwork for an ambitious overhaul of hospital waste management strategies are several U.S. hospitals, including Washington Hospital in Fremont, California, that organized a "zero waste" event for hospital employees where no trash containers were available and all event refuse was recycled or composted; Brigham & Women's Faulkner Hospital in Boston, Massachusetts, that sponsored a "zero waste day"; and the UCLA Health System and University Hospitals Cleveland that adopted zero waste plans.

To serve as guidance to businesses and communities aiming to advance these policies, the Zero Waste International Alliance adopted the "Zero Waste Business Principles" to guide and evaluate current and future zero waste policies and programs established by businesses (see http:zwia.org).

THE TOXIC-FREE HOSPITAL

Reducing the use of toxic chemicals in building products and operation is an essential element of a twenty-first-century healing environment. At the 2004 United Nations' Johannesburg +2 Sustainable Development Conference, delegates renewed the commitment to "achieve, by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse ef-

The ABCs of PBTs

Persistent bioaccumulative toxicants (PBTs) are "persistent" because they do not break down rapidly via natural processes once they are emitted into the environment. Many persist for months or years, allowing them to travel long distances on wind and water currents from where they were manufactured—for example, from chemical plants in Louisiana to Inuit women in the Arctic. PBTs "bioaccumulate"—they love to build up in living beings, often in fatty tissues, increasing their concentrations by orders of magnitude as they move up the food chain to humans at the top and becoming most concentrated in mothers' milk. And PBTs are "toxic"—and include some of the most potent carcinogens, mutagens, and reproductive toxicants known to humankind.

The healthcare industry has been prioritizing the avoidance of chemicals of concern since the mid-1990s, when dioxin, a potent human carcinogen, emerged as a chemical pollutant associated with medical waste incineration of PVC plastics, and cleaning chemicals were linked to occupational asthma in healthcare workers. Since then, the healthcare industry has been progressively moving to understand, reduce, and substitute chemicals of concern in construction and operation.

fects on human health and the environment, using transparent science-based risk assessment procedures and science-based risk management procedures, taking into account the precautionary approach" (WSSD 2004). As materials expert Tom Lent describes in his essay "The PBT-Free Challenge," the healthcare industry's momentum is well underway to achieve what may seem to some an elusive goal.

In 2012, the Healthier Hospitals Initiative released its Healthy Interiors Challenge, aimed at reducing purchase and inclusion of the following specific materials (Brown 2013):

Flame retardants. Most furniture, computers, mattresses, television sets, and other items have flame retardants in them to ensure they meet fire safety standards. The challenge is that the fire retardants start to degrade right away. They leach and can be found in dust and on surfaces, moving to our hands and food, and are easily ingested.

Flame retardants have been linked to diabetes, cancer, hormone disruption, and memory loss. In 2012, the *Chicago Tribune* conducted an investigation on brominated fire retardants, reporting that the science behind their efficacy doesn't hold up. Later the same year, the *San Francisco Chronicle* reported on a new study from the University of California at Berkeley on the connection between brominated fire retardant exposure and delays in child neurological development. This new study is the largest to show that children exposed to Polybrominated Diphenyl Ethers (PBDEs) (another type of fire retardant) tend to have poorer attention, motor skills, and IQ scores.

Perfluorinated compounds. Perfluorinated compounds make materials water and stain resistant. This is the material found on nonstick cookware, fabrics, carpet, and even wall finishes. Once in the environment, perfluorinated compounds can travel into humans and wildlife. Researchers are studying the health effects of this.

Polyvinyl Chloride. Polyvinyl Chloride (PVC) is an inexpensive and versatile material used throughout healthcare, including in flooring, wall covering, and fabrics. The lifecycle issues associated with PVC include the formation of dioxin, a deadly group of chemicals. Plus, PVC is naturally rigid, which is why phthalate plasticizers are added to make the material pliable—and plasticizers have been found to leach out of PVC.

THE PBT-FREE CHALLENGE

By Tom Lent, Healthy Building Network[1]

Over the past decade, scientists and medical professionals have pieced together a compelling picture of a new global health challenge as a wide range of toxic chemicals have been revealed to be accumulating in increasing concentrations in human blood and mothers' milk around the globe—a process referred to as *bioaccumulation.* Chemicals found to be ubiquitous include dioxins—the most potent synthetic carcinogens known to science and strong endocrine disruptors, polybrominated diphenyl ethers (PBDEs) and related halogenated flame-retardant chemicals linked in animal studies to disruptions in thyroid function and immune suppression, and perfluorinated chemicals (PFCs)—likely carcinogens known to cause liver damage and reproductive problems (Schecter et al. 2001; Meironyte, Noren and Bergman 1999). National and international studies are now finding many of these chemicals and more in virtually every sample taken in increasing quantity, hitting—and surpassing—levels of concern, with no end in sight. (CDC 2009, Department of Health and Human Services Centers for Disease Control and Prevention, Fourth National Report on Human Exposure to Environmental Chemicals 2009; Yeung, So, Jiang, et al. 2006; Chase 2006).

Each of the cited chemicals is from a class of chemicals known as persistent bioaccumulative toxicants (PBTs). These toxic chemicals including dioxins, halogenated flame retardants, perfluorochemicals (PFCs), and heavy metals, are often dangerous in very small quantities, doing harm to humans and other living organisms at concentrations of mere parts per billion or trillion. Efforts to manage these chemicals have been ineffective: Landfills do not diminish the hazardous properties of these chemicals, and waste incineration and landfill fires can generate new, hazardous PBT compounds. Spread by winds, water, and animals, these worst-in-class chemicals now contaminate the most pristine environments; ironically the highest concentrations have been found in the peoples and animals of the Arctic regions thousands of miles from the nearest manufacturing plant that releases these chemicals (Dewailly, Nantel, Weber, et al. 1989).

PBTs are global problems that require concerted efforts to solve. Scientists and medical professionals from around the world—alarmed by the rising incidence of breast cancer and other chronic diseases linked to PBT exposure (see Figure 5.18)—are voicing concerns that the same chemicals that have provided such a boon to industry are creating new health crises.

Organizational Commitments to Change

Responding to the weight of evidence linking PBT releases and threats to living systems, governments and institutions worldwide are initiating efforts to reduce or phase out the use of products that contain or contribute to the release of PBTs into the environment. PBDEs and PFCs have now joined dioxins, furans, and PCBs among the top PBTs targeted for elimination by international treaty—the Stockholm Convention on Persistent Organic Pollutants. The EPA prioritized thirty-one chemicals for elimination and targeted healthcare-related activities as an important source of two of the twelve most hazardous PBTs, mercury and dioxin, and has released detailed action plans on PFCs, PBDEs and HBCD (EPA 1998, EPA 2007, EPA 2009, EPA 2009a, EPA 2010). Some of these efforts are bearing fruit: Swedish PBDE levels plummeted in the early twenty-first century after a national ban was instituted while concentrations soared even higher in the United States where production continued (Lunder and Sharp 2003; Hites 2004).

[1] This essay is based on a previous essay co-authored by Julie Silas, published in *Sustainable Healthcare Architecture,* 1st edition.

Specific to healthcare, the American Hospital Association and the EPA entered into a landmark memorandum of understanding in 1998 to advance pollution prevention efforts in U.S. healthcare facilities and prioritized PBTs for elimination (EPA and AHA 1998). Kaiser Permanente's national environmental purchasing policy incorporates specific environmental criteria for all purchasing decisions, including criteria to "avoid products containing persistent bioaccumulative toxic compounds" (Kaiser Permanente 2006). Their Sustainability Scorecard released in 2010 went further, requiring suppliers to provide information on their company's environmental commitment, use of potentially harmful chemicals in their products, and information about product and packaging recycling to help Kaiser Permanente's purchasers avoid chemicals of concern (Kaiser Permanente 2010). Similarly Dignity Health (formerly Catholic Healthcare West) (CHW 2011) has established PBT avoidance purchasing policies that have virtually eliminated mercury and dramatically reduced PVC use in its facilities. And healthcare group purchasing organizations have incorporated efforts to avoid products that contain PBTs—or that contribute to their release into the environment—into their environmentally preferable purchasing goals (Premier 2004, Consorta 2007).

The design and construction industry has actively engaged in efforts to reduce the use of these and other related chemicals of concern in building materials. The Green Guide for Health Care (GGHC) was the first green building design protocol to reward avoidance of HFRs, heavy metals, and dioxin-producing PVC, followed by the Living Building Challenge Red List and the Perkins+Will Precautionary List (GGHC 2004, ILFI 2006, P+W 2009). Figure 5.18 illustrates the range of protocols and tools aimed at reducing specific chemicals of concern.

In 2010, as the USGBC's LEED program's approach to human health came under increased scrutiny (Building Green 2010) the USGBC released LEED for Healthcare with credits for avoidance of heavy metals, and included PBT-related credits in the Pilot Credit Library applicable to all building types rewarding avoidance of halogenated organic compounds

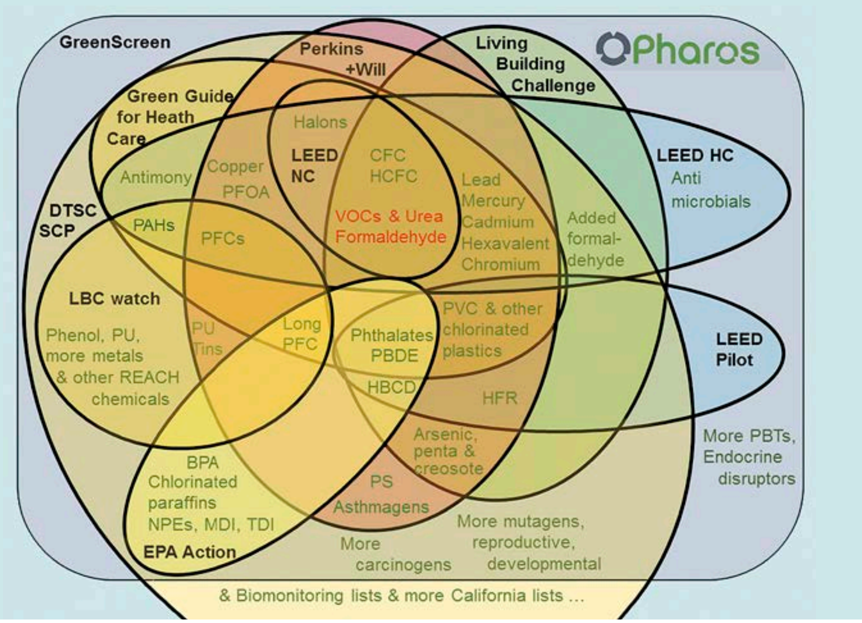


Figure 5.18 This diagram captures the range of current programs and initiatives aimed at reducing the use of chemicals of concern. *Source: Copyright © Healthy Building Network 2012*

generally, and halogenated flame retardants specifically (USGBC 2010, USGBC 2010a).

Driven by buyer demands, manufacturers are responding. Some are reducing the use of specific PBTs, and others are establishing goals to comprehensively remove all PBTs from their products. Market demand for PBT alternatives is growing, particularly from the healthcare sector where dozens of healthcare organizations have undertaken efforts to reduce PVC (HCWH 2007).

Are the alternatives actually better? A range of technical and policy tools have emerged to ensure that substitutes represent real improvements rather than just a swap of a hazardous chemical with one less well known but equally toxic, albeit potentially in other ways. The European Union's REACH legislation is driving manufacturers to begin to fill in the massive gaps in testing of chemicals in commerce (http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm). The U.S. EPA's Design for the Environment program is helping manufacturers evaluate the hazards of alternatives (www.epa.gov/dfe). The Principles of Green Chemistry provide a framework for development of chemicals that are better for human health and the environment (www.epa.gov/greenchemistry). And, designers and specifiers can take advantage of an array of tools to inform their decisions about the chemical properties of materials and products (see sidebar).

Pathway to a PBT-Free Hospital

As major consumers of PBT-related building and operations products—and as influential community specialists on health—healthcare leaders play a critical role in impelling the healthcare industry and society at-large to eliminate PBTs from the environment and spur innovation toward PBT-free options. A PBT-free hospital policy can become the cornerstone of a bigger effort to eliminate all high-hazard toxics from construction and operations. By incorporating PBT-free specifications in construction and implementing environmentally preferable purchasing policies for operations, hospitals can undertake healthy practices that simultaneously consider their own patients, staff, and local communities, and their global responsibility.

The path to the PBT-free hospital ideally starts with establishing clear policy directives at the healthcare system level. Procurement policies such as Kaiser Permanente's, described above, send a compelling message to manufacturers and help build momentum to move the marketplace to expand the availability of high-performance, PBT-free options—keys to reversing the growing public health crisis.

Construction and renovation projects provide an ideal opportunity to create a PBT-free environment. Establishing a PBT-free goal early in the project's goal-setting process and as a priority throughout the building program will reduce the likelihood of its being disregarded in the inevitable process of value engineering and contractor material substitution.

Establishing environmentally preferable purchasing policies that prioritize PBT elimination as hospitals replace materials through the course of building operations, repair, and maintenance, complemented by support for purchasing staff as they seek to find alternative products that meet the goals while fulfilling other performance requirements, is important.

Conclusion

The growing threat to human health posed by PBTs is urgent; it can be reversed, bolstered by clear market signals from the healthcare industry. Creating model PBT-free hospitals protects staff, patients, and the community while signaling larger change. Leveraging manufacturers to replace their PBT products with safer high-performance, PBT-free options ensures that the changes undertaken by hospitals cascade through the broader marketplace. To arrive at a day when all product choices will be PBT- and toxic-free, healthcare's assertive leadership is critical.

TOOLS FOR DESIGNERS AND SPECIFIERS TO DE-SELECT TOXICANTS

Pharos Project—Online building product selection tool for designers and specifiers disclosing chemical content and including a Chemical and Material Library that automatically screens for health hazards. A project of the Healthy Building Network (HBN). www.pharosproject.net

Health Product Declaration (HPD)—Open source format for facilitating communication between manufacturers and the design community of product content and associated health information for building products. The format is user driven and administered by the HPD Collaborative. www.hpdcollaborative.org

Living Building Challenge Red List—List of toxic chemicals to avoid in building materials used in Living Building Challenge projects. The Challenge is a rigorous green building standard administered by the International Living Future Institute (see earlier this chapter). https://ilbi.org/lbc/standard

Perkins+Will Precautionary List—List of substances with their known and suspected health effects, where they are found in buildings, and potential alternatives. Published as part of the Transparency web resources by Perkins+Will Architects. http://transparency.perkinswill.com

GreenScreen—The GreenScreen for Safer Chemicals (GreenScreen™) is a comparative Chemical Hazard Assessment (CHA) method to identify chemicals of high concern and safer alternatives. It is being used by industry, government, and NGOs to support product design and development, materials procurement, and as part of alternatives assessment to meet regulatory requirements. www.cleanproduction.org/Greenscreen.php.

VISUALIZING THE PATH AHEAD

In addition to the innovative Case Studies profiled earlier, the final three Case Studies in this chapter demonstrate the "next generation" of healthcare design, with ambitious resource reduction and material health goals. With the motto "patient first" and a commitment to provide an optimal indoor environment for patients and staff, the New Karolinska Solna (NKS) University Hospital, Stockholm County, Sweden (Case Study 9), skillfully integrates daylight and views as well as visually and physically accessible gardens to gracefully humanize an extraordinarily large building complex. It relies on five third-party rating systems to measure, track, and certify its environmental performance (the Swedish Environmental Classified Building (target Gold certification); LEED (target Gold certification); ISO 14001; Green Site; and Green Services), and a Swedish life-cycle-based assessment ("Byggvarubedomningen," www.byggvarubedomningen.se) to screen construction materials for environmental performance. By setting ambitious goals early in the design process, NKS has the potential to be an inspirational beacon for other hospitals aspiring to align the mission of health and healing with building performance.

The University of California San Francisco (UCSF) Medical Center at Mission Bay (Case Study 10) reflects the premise that the built environment can positively influence healing, health, safety, and well-being. This nature-infused project featuring on-site renewable energy generation and rainwater harvesting also had an early commitment to create a healthy environment with a goal to eliminate known toxins from the project's interior finishes. The project team, working with McDonough-Braungart Design Chemistry, undertook an extensive building materials assessment, focused on chemical toxicity. Using a series of filtering criteria to screen out carcinogens, endocrine disruptors, mutagens, teratogens, and reproductive, ecological, and persistent bioaccumulative toxicants, the project team estimated that only 10 percent of available materials met the project's stringent healthy material requirements (see Figure 5.19). The visual aids and diagrams prepared by the project team demonstrate an innovative focus on material health.

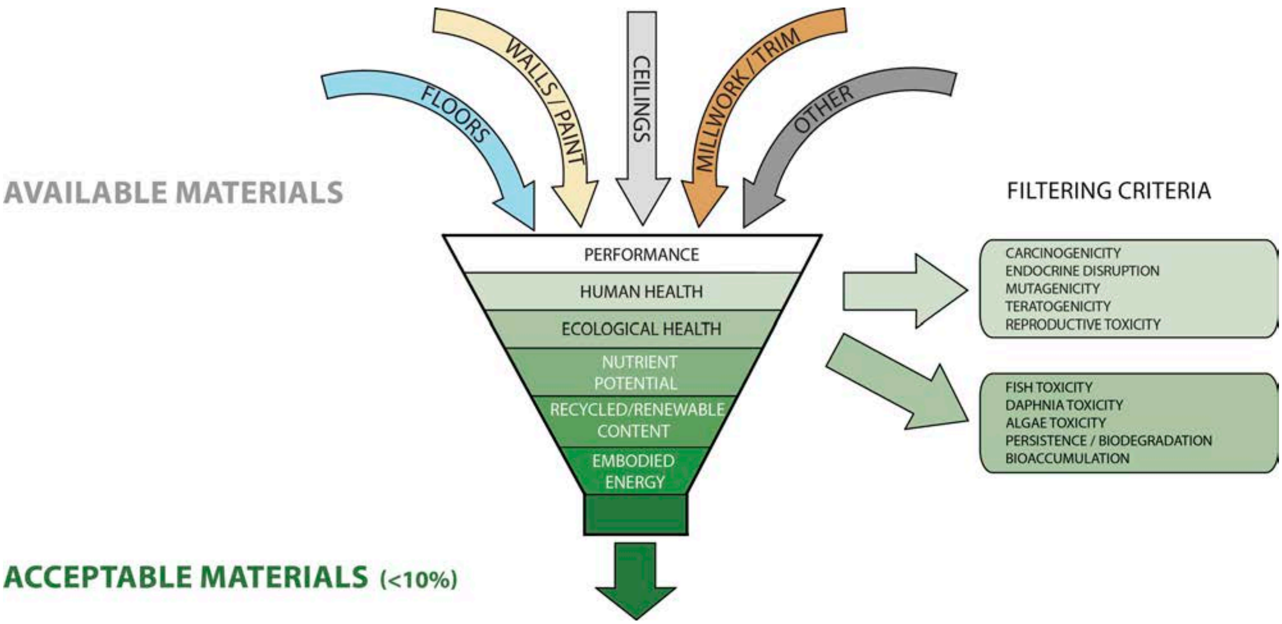


Figure 5.19 At UCSF Medical Center at Mission Bay, a material screening process was used to inform materials selection. *Source: Stantec Architecture; William McDonough+Partners*

Finally, the Lucile Packard Children's Hospital at Stanford, Palo Alto, California (Case Study 11, this chapter), features energy demand reduction through a climate responsive facade and the first significant U.S. implementation of displacement ventilation in patient units. Primarily oriented for optimized energy performance, the energy-responsive facade includes deep overhangs to block direct solar gain and minimize direct views between patient units. The building harvests and stores rainwater, condensate, and reject reverse osmosis water to meet all of its landscape irrigation needs in a semi-arid climate.

CONCLUSION

The expanding portfolio of green building tools—in the United States and abroad—catalyzes, reinforces, and extends the breadth and rigor of sustainable healthcare design, construction, and operations. It represents, in a sense, a process of discovery, as the ecologic, economic, and health-related dimensions of this work come into clearer focus. This promises to be a journey shared by the broad spectrum of people engaged in contemporary healthcare design: design practitioners, facility owners and operators, medical professionals, policy makers—and the general public. It can only benefit from sharing the richness and diversity of that collective experience, wisdom, and hope as the process continues to evolve evermore effective tools to shape the healthcare architecture of the future.

The roadmap to a sustainable healthcare facility begins to unfold as specific performance goals are identified. The goals outlined in this chapter—carbon neutrality, net-zero energy, water balance, zero waste, and PBT elimination—can be achieved in this new generation of buildings; indeed, some hospitals are already well along that path. What is clear is that the work does not reside just within the walls of the healthcare facility—success requires coordination at the community, regional, and global scales, and among manufacturers and educators as much as policy makers. The healthcare sector can be the clarion call that embraces these as both opportunities and imperatives.

Case Study 01: Dell Children's Medical Center of Central Texas

Austin, Texas

OWNER: Seton Healthcare Family

PROJECT TEAM:

Architect: Karlsberger (base building); Polkinghorn Group Architects (Neurosuite Addition and Bed Tower 3)

Landscape Architect: TBG Partners

Mechanical, Electrical, and Plumbing Engineer: CCRD Partners

General Contractor: White Construction Company (base building); The Beck Group (Bed Tower 3)

LEED Consultant: Center for Maximum Potential Building Systems

BUILDING TYPE: New Acute-Care Children's Hospital

SIZE: 600,000 sq. ft. (55,742 sq. m); Site: 32 acres (12.9 ha)

EUI: 264 kBtu/sf/yr (916.7 kWh/sm/yr) (with process and plug load)

PROGRAM DESCRIPTION: 248-bed acute-care children's hospital

COMPLETED: 2007 (base building); 2013 (Bed Tower 3)

RECOGNITION: LEED Platinum–certified (base building); LEED Gold–certified (neurosuite addition); targeting LEED-Healthcare Platinum certification (Bed Tower 3)

BIOME: Temperate Semi-Arid

CLIMATE ZONE: Humid Subtropical

PRECIPITATION: 33 in. (847 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia*: Extensive interior courtyards, 3.5 acre healing garden
- *Innovative Stormwater Management:* Participate in development-scale stormwater management approach
- *Brownfield:* Remediated to residential level
- *Reclaimed Water Reuse:* Landscape irrigated with municipally supplied reclaimed water
- *Innovative Source Energy Reduction/Heat Recovery:* Connected to utility-owned combined cooling, heating, power plant; recovers waste heat for thermal energy needs
- *On-site Renewable Energy Systems:* Solar thermal and photovoltaic
- *Low Embodied Energy, Healthy Building Materials:* Regionally sourced stone; low-VOC adhesives, sealants, flooring systems, paints + coatings, composite wood; halogenated organic compounds avoidance
- *Civic Functions:* Auditorium available for community events; provides health services to students in schools

Figure 5.20 Dell Children's Medical Center. *Source: Marc M. Swendner, Seton Healthcare Family*

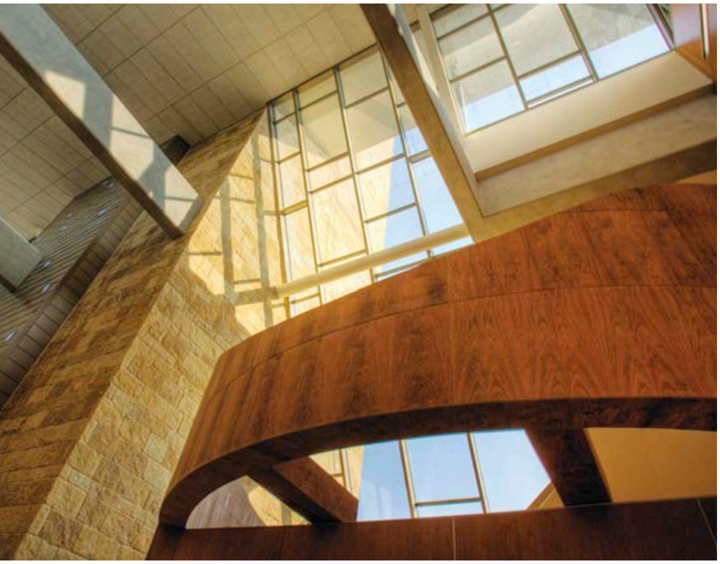


Figure 5.21 Daylit atrium and lobby. *Source: Marc M. Swendner, Seton Healthcare Family*

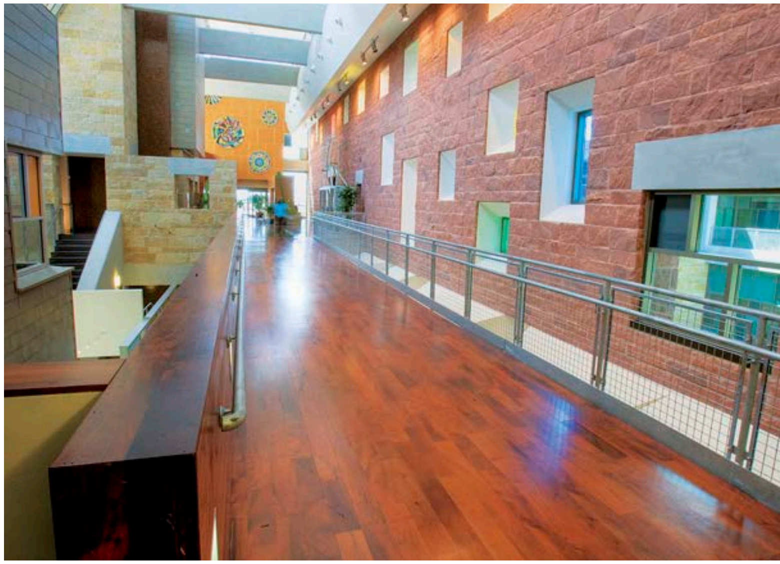


Figure 5.22 Native stone lobby wall. *Source: Marc M. Swendner, Seton Healthcare Family*

Located on a former municipal airport designated as a brownfield, Dell Children's serves as the anchor of the 700-acre (283-ha) Mueller mixed-use green urbanism development. Its location at Mueller represents a strategic decision to site its replacement facility in central Austin rather than on a greenfield site miles away from Austin's desired development zone.

While locating the hospital on a remediated brownfield site raised some concerns, it aligned with Seton's broader "healing" mission, while also mitigating urban sprawl and the resultant emissions associated with staff and visitor commuting in a city hovering just above nonattainment status for air quality (Figure 5.20).

Dell Children's design reflects a strong commitment to bring the outdoors in, achieved through a series of seven interior courtyards—"the lungs of the building." Patients and staff benefit from a light-filled environment, further enhanced with prominent use of regionally sourced stone on the building's exterior and interior and a palette of healthy materials including rubber and natural linoleum as the dominant flooring materials (Figures 5.21–5.24).

The local utility-owned natural gas–fired CCHP plant provides chilled water, steam and power to the project, dramatically increasing efficiency and reducing emissions as compared to conventional grid-based electricity. The increased efficiency of on-site power generation, coupled with the ability to utilize the waste heat for thermal energy needs, boosted the source energy efficiency equivalent to 35 percent energy demand reduction. By eliminating approximately $6 million in mechanical infrastructure costs, the project team was able to invest in additional sustainable building strategies. Being water-conscious is another priority given the context of Austin's serial years of drought. This has prompted a 17 percent decrease in water use between 2009 and 2012, primarily attributed to reduced irrigation.

Dell Children's demonstrates that a design and construction team that works well together with the same goals and agenda can accomplish superior project results. The Owner, Architect/Engineering design team, and the Construction Manager all had a successful project on their radar screen, and despite numerous significant challenges, completed the original project on schedule and on budget while also accomplishing the goal of LEED Platinum certification. Without a team approach and concerted effort, these goals could not have been met.

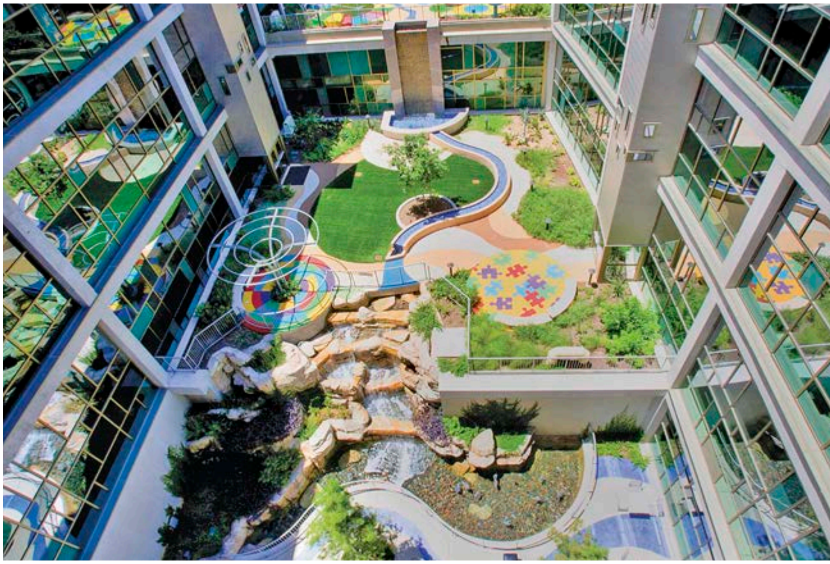


Figure 5.23 Central courtyard. *Source: Marc M. Swendner, Seton Healthcare Family*

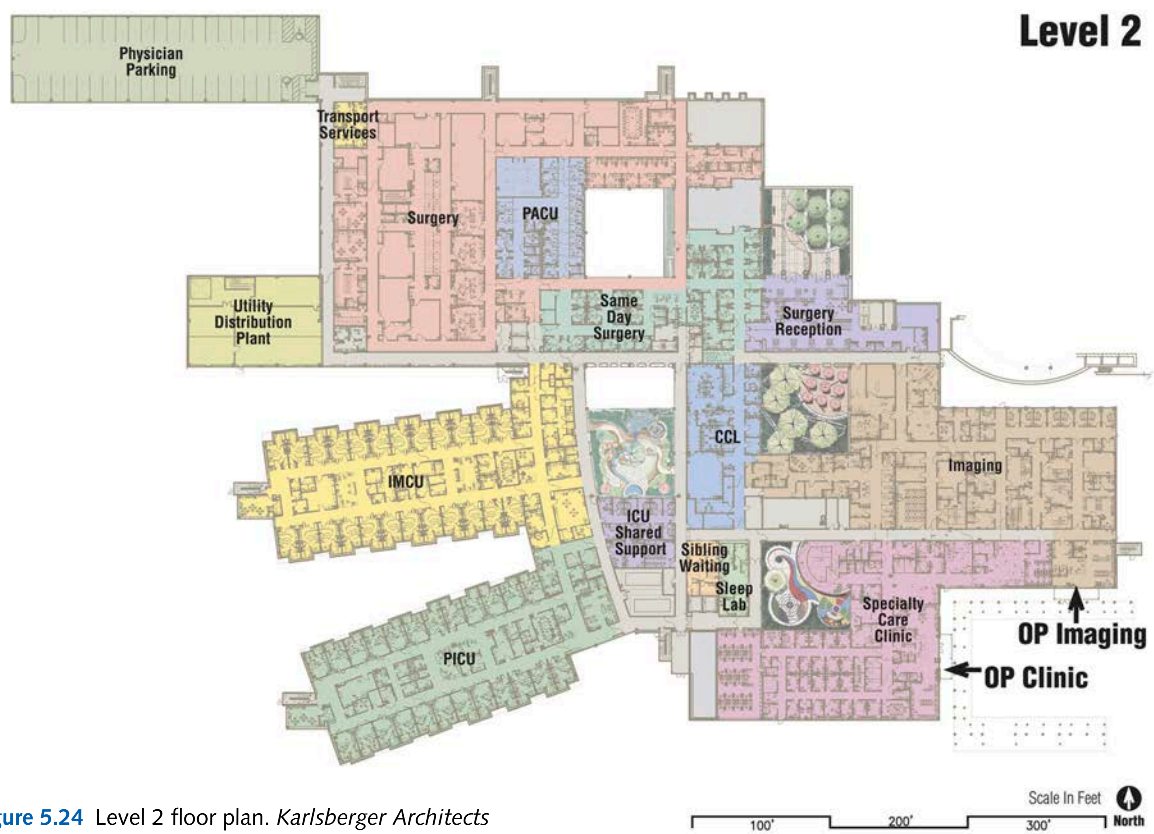


Figure 5.24 Level 2 floor plan. *Karlsberger Architects*

DESIGN AND CONSTRUCTION LESSONS LEARNED

- *An integrated team:* The design engineer and the energy modeler must provide an integrated and coordinated effort throughout the design phase to ensure that the actual building performance meets its projected metrics.
- *Program the building systems to match the model:* The HVAC/control system design must be programmed to comprehensively implement the energy conservation strategies used as a basis for energy modeling.
- *Zone systems:* Zone HVAC system for occupancy scheduling where possible.
- *Watch the submittal process:* Thorough submittal review is required to ensure design intent is met and that even obvious things do not fall through the cracks.
- *Schedule commissioning:* The Construction Manager/General Contractor should build the construction schedule with priority given to complete all commissioning prior to occupancy.
- *Conduct post-commissioning follow-up* after occupancy to follow up and close out unresolved issues.
- *Train the operations staff:* Energy management requires operations staff training beyond O&M training: Smart buildings require smart operators.

POST OCCUPANCY LESSONS LEARNED

- *Commission the envelope:* Exterior skin sealing and waterproofing QA/QC is critical to overall building performance.
- *Watch new technologies:* Electronic filter manufacturer went out of business—reverted to standard 90 percent filters; daylight harvesting system designed to dim electrical light never performed as intended; a heat recovery-water spray system that boosted energy transfer clogged heat transfer coils, and was finally turned off.
- *Monitoring performance is critical:* Use best technology for airflow monitoring and control.
- *Restricting water flow is challenging:* Changed lavatory faucet flow restrictors from 0.5 gpm to 0.7 gpm to accelerate hot water delivery.

Source: Seton Healthcare Family, Dell Children's Medical Center

Case Study 02: OHSU Center for Health and Healing

Portland, Oregon

OWNER: RIMCO, a partnership of doctors and OHSU

PROJECT TEAM:

Developer: Gerding Edlen Development

Architects: GBD Architects with Petersen Kolberg & Associates

Structural Engineer: KPFF

MEP Engineer and Commissioning: Interface Engineering, Inc.

Environmental Consultants: Brightworks

General Contractor: Hoffman Construction

BUILDING TYPE: New Ambulatory Surgery and Clinical Care Building

SIZE: 412,000 sq. ft. (38,000 sq. m); 262,000 sq. ft. (24,300 sq. m) conditioned plus underground parking

EUI: 102 kBtu/sf/yr (321 kWh/sm/yr)

PROGRAM DESCRIPTION: Entry atrium, cafe, pharmacy, retail eye clinic, day spa, wellness center, conference center, imaging, ambulatory surgery, outpatient clinics and offices, educational offices, research laboratories

COMPLETED: 2006

RECOGNITION: LEED NC Platinum–certified (2007); LEED EBOM Platinum–certified (2011)

BIOME: Temperate Humid

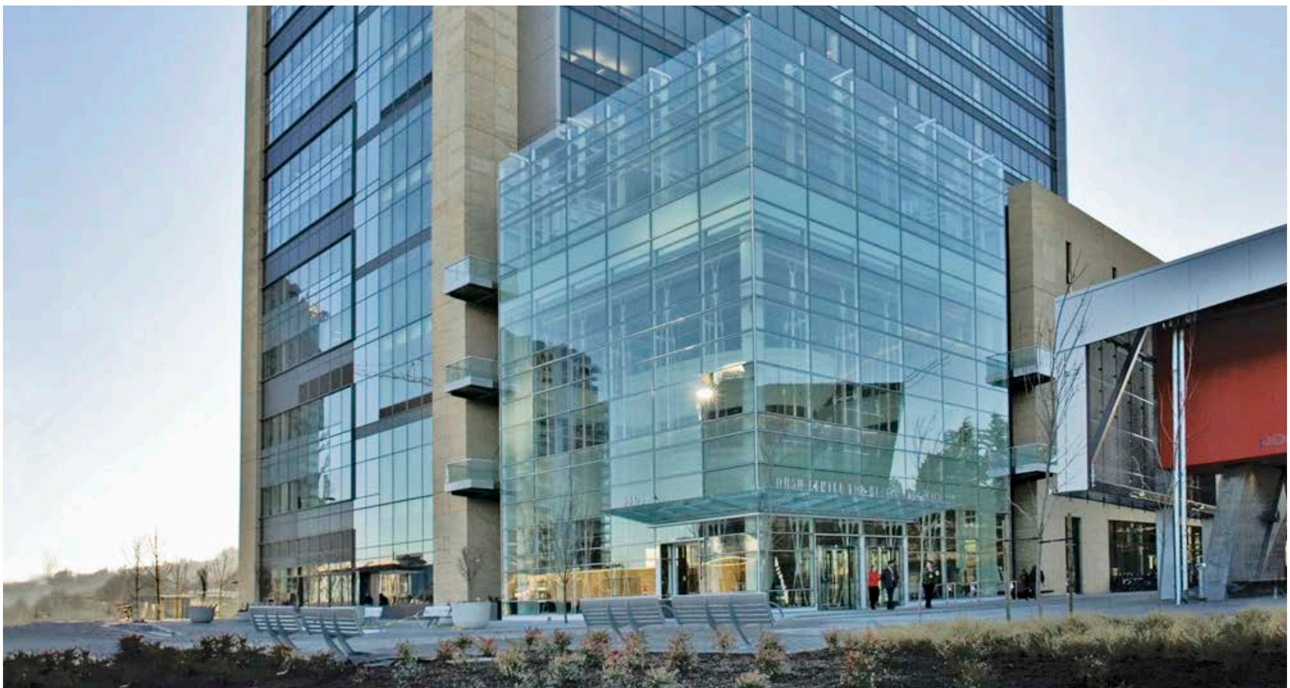
CLIMATE ZONE: Steppe

PRECIPITATION: 43.5 in. (1104 mm)

KEY SUSTAINABILITY INDICATORS

- *Energy-Responsive Facade:* High performance glazing, solar shading
- *Green Roof:* 20,000 sq. ft. with 3 eco roofs and 2 intensive green roofs
- *Rainwater Harvesting:* 100% on-site rainwater reuse system
- *Innovative Wastewater Treatment:* On-site bioreactor treats sewage; conveyance water recirculates for toilet flushing; excess water channeled to district bioswales
- *Innovative Source Energy:* CUP powered by microturbines for thermal energy and power generation
- *Innovative Energy Distribution:* Distinct heating/cooling strategies for different parts of building; radiant heating/cooling using chilled beams and displacement ventilation
- *Renewable Energy:* Building-integrated solar PVs in south sunshades; 6,000 sq. ft. (557 sq. m) solar air heating system
- *Natural Ventilation:* Portions of building are naturally ventilated

Figure 5.25 OHSU Center for Health and Healing. *Source: GBD Architects Inc./Sally Schoolmaster*



Built on the site of a former shipyard, the project is an expansion of the university's main campus into Portland's developing South Waterfront. The building includes a complex stack of uses, including wellness, fitness, and physical therapy facilities, plus a conference center on the lower floors; outpatient clinics, imaging, and ambulatory surgery on the middle floors; and offices and laboratories on top.

The city of Portland, like many older U.S. cities, has overburdened sewer infrastructure, so the project included on-site sewage treatment, with treated effluent used for toilet flushing and irrigation. Rainwater is harvested and used for irrigation, sewage treatment makeup water, and other process uses. The Center has four separate water systems, including a blackwater system that feeds a nonpotable water supply, a conventional potable water system, and rainwater collection system that feeds the fire water cistern as well as the mechanical system. One of the Center's major documented impacts for LEED EBOM includes saving more than 5 million gallons of potable water annually through these aggressive water strategies.

With the Center's near-perfect compass orientation, computational fluid dynamic modeling showed the building could be ventilated almost entirely through passive means. The north side features a ventilation system that draws air through the building, its circulation given a boost by the heat of lights and computers. The stair towers at the building's east and west ends reduce the building's solar loads and function as stacks to further draw air out.

The modeled energy performance exceeded Oregon Energy Code and ASHRAE by 61 percent; downsized systems based on modeled performance yielded approximately 10 percent capital savings, used to enhance facade performance. The building features natural ventilation at stairwells, displacement ventila-

Figure 5.26 Solar air heater at 15th floor. *Source: GBD Architects Inc./Interface Engineering*

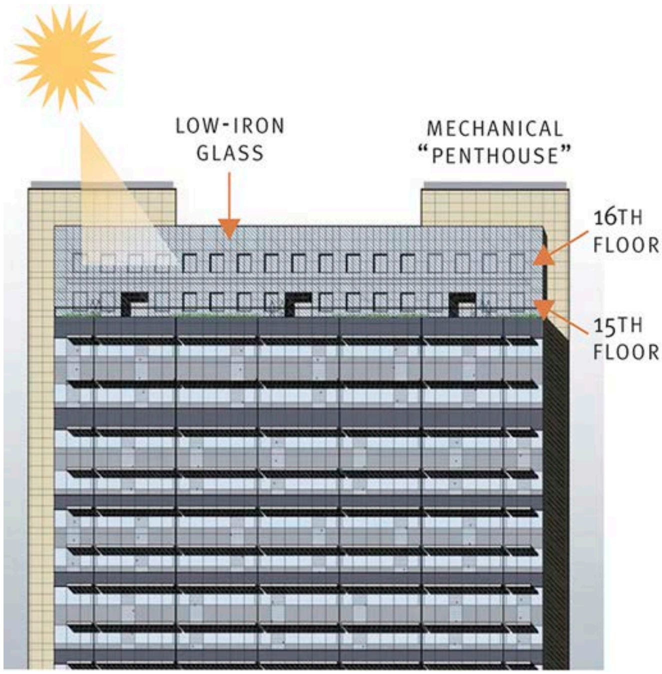


Figure 5.27 Detail of south facade. *Source: GBD Architects Inc./Sally Schoolmaster*

tion at exam rooms, and radiant heating and cooling through both hydronic systems and VAV. A Central Utility Plant with five microturbines provides thermal energy and power (and will ultimately power additional buildings in the district). A hot-water storage tank contains heat from the microturbines; a warm- water tank uses energy from the solar thermal collector and heat recovered from the heat pump chiller; a cold-water storage tank uses all the cool water from the recovered rainwater and pumped groundwater. A site-built solar thermal system heats domestic water; a 60 kW solar photovoltaic array is integrated in the south-facing window shading devices. Excess heat is stored in the building mass or used to maintain the heated lap pools in the wellness center (Figures 5.28–5.29).

The multidisciplinary integrated design process facilitated the development of building components that serve multiple functions. For example, the building's sunshades are architectural features and also serve mechanical and electrical purposes. By designing the sunshades into the south facade to keep the sun off the windows in the summer and lower the HVAC system requirements for cooling, a free surface became available for solar electricity–generating panels.

The selection of sustainable and lower toxicity materials was also emphasized for interior finishes and furnishings, including low volatile organic compound (VOC) paints and sealants, local and regional material sourcing, sustainably manufactured carpeting systems, and the use of Forest Stewardship Council (FSC)–certified wood products.

Source: GBD Architects Inc.; Gragg (2007)

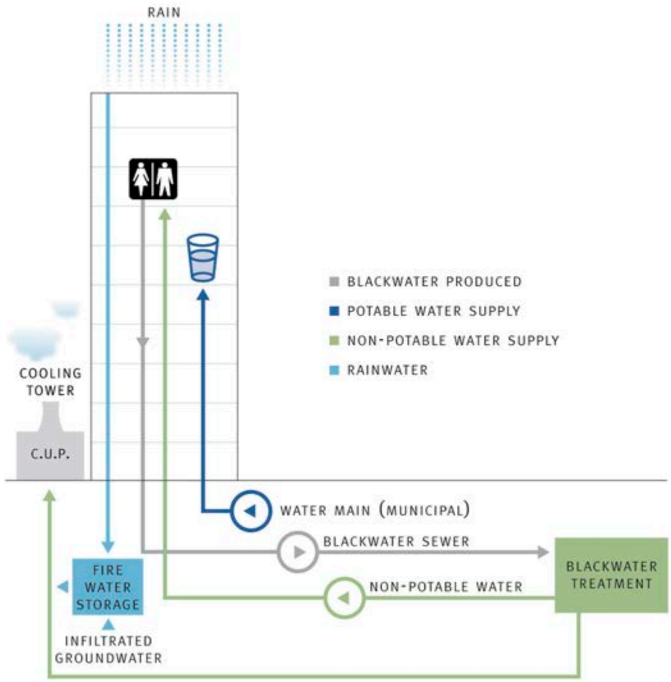


Figure 5.28 Water system at OHSU. *Source: GBD Architects Inc./Interface Engineering*

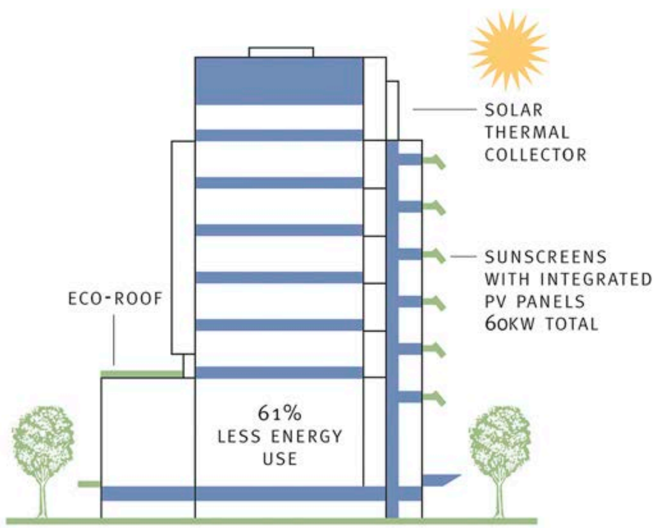


Figure 5.29 Section diagram. *Source: GBD Architects Inc.*

Case Study 03: Peace Island Medical Center

Friday Harbor, San Juan Island, Washington

OWNER: PeaceHealth and San Juan Island Hospital Committee

PROJECT TEAM:

Architect: Mahlum

Landscape Architect: Cascade Design Collaborative

Mechanical/Plumbing Engineer/Energy Model: CDi

Electrical Engineer: Hargis

Civil Engineer: 2020 Engineering

General Contractor: Howard S. Wright

TYPE: New Acute-Care Hospital

SIZE: 39,000 sq. ft. (3,623 sq. m); Site area: 22 acres (8.9 ha)

EUI: 120 kBtu/sf/yr (378 kWh/sm/yr)

PROGRAM DESCRIPTION: Critical access hospital includes 10 inpatient beds, emergency department, diagnostic imaging, surgical suite, primary and specialty care clinic, medical oncology and ancillary services

COMPLETED: 2012

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 33 in. (850 mm)

KEY SUSTAINABILITY INDICATORS

- *Habitat Restoration:* Built only on previously developed portion of site
- *Innovative Stormwater Management:* Stormwater treated on-site and infiltrated through raingardens
- *Narrow Floor plate:* Views and daylighting in 85% of occupied space
- *Energy Responsive facade:* Heat gain minimized through building orientation and shading
- *Reclaimed Water Reuse:* Designed with closed-loop net-zero water system; local jurisdiction rejected so could extend nearby infrastructure
- *Innovative Source Energy:* Geothermal/ground-source heat pump—22 vertical wells
- *Innovative Energy Distribution:* Minimize building reheat by decoupling heating/cooling from ventilation
- *Natural Ventilation:* All perimeter spaces, including patient rooms and exam rooms; operable windows in 25% of building
- *Low Embodied Energy Materials:* Reduced transport distances of materials from source
- *Healthy Materials:* Prioritized Red List chemical avoidance as possible

Figure 5.30 Peace Island Medical Center. *Source: Copyright © Benjamin Benschneider/OTTO*

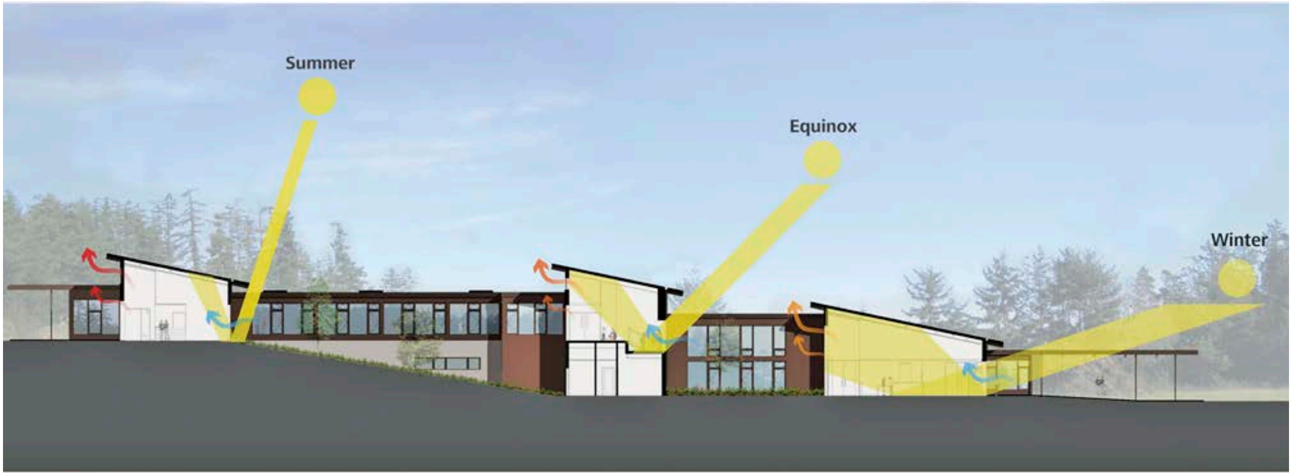


Figure 5.31 Building form and orientation to maximize daylight; stepped forms work with the land. *Mahlum*

The Peace Island Medical Center's sustainable design focuses on the remote location, limited resources, and the community's commitment to sound environmental practices. The design team began by reevaluating building system design strategies within the context of limited island resources and infrastructure.

Development is limited to the portion of the 22-acre (9 ha) site previously developed for a residence and farming, preserving the remainder as undisturbed for the community to enjoy. The facility footprint cascades down the site's slope in three narrow building forms, connected by two intervening links (Figure 5.33). Impervious surfaces are minimized; raingardens treat stormwater on site, reducing the impact on the surrounding infrastructure. Pedestrian systems are coordinated with and extend the existing local trails system.

The design team developed an aggressive approach to reducing potable water use, including rainwater harvesting, using on-site wetlands for stormwater management. Low water use fixtures are included, reducing potable water demand by 52 percent.

Building orientation maximizes the effectiveness of passive solar heating, natural ventilation and daylighting.

Thin building footprints and strategic window placement facilitate daylit interior environments for patients and staff throughout the facility (Figure 5.31). The design goal is to create light and airy spaces that connect with the outdoor environment: 85 percent of spaces are daylit and 25 percent are naturally ventilated. At Peace Island, the design reduces projected building loads by 62 percent against baseline averages and provides 93 percent of power through off-site non-fossil fuel sources with the following systems:

- Ground source heat pumps using 22 vertical wells, supplemented with an electric boiler. Extensive use of natural ventilation and external shading, reducing cooling and distribution needs
- Decentralized and distributed heating and cooling system that matches the specific and widely varying air quantity and heating/cooling needs of specific program areas, particularly focusing on eliminating re-heat
- Extensive use of occupancy sensors to "throttle down" airflow and turn off accessory equipment
- Sub-metering to provide specific and real-time information on lighting and plug loads
- Heat recovery systems to capture excess heat from medical equipment and pre-heat *outside air*

Peace Island is anticipated to be the first carbon neutral hospital in the U.S. through the purchase of offsets for the 7 percent of fossil fuel sources. At the same time, roofs are designed to accommodate the future installation of both solar thermal and photovoltaic panels, making the project "net-zero energy ready."

Figure 5.32 Interior spaces feature natural materials. *Copyright © Benjamin Benschneider/OTTO*

The focus on "local" resources includes the design team itself, with strict limits on A/E/C team travel. The design team used the Living Building Challenge Material Red List to guide selection and specification of all materials. The project eliminated PVC on all finish materials (wiring jacketing is still PVC). Trees located on the project footprint were harvested and milled to create the building's interior finish wood elements.

The project has reached out to many local groups and businesses to engage them in the development of a resource that the entire community can be proud of. Several zones of the site were preserved from development to maintain them as natural amenities, including existing forested areas and wetlands.

Source: Mahlum

Figure 5.33 Site plan. *Mahlum*

Case Study 04: Sherman Hospital

Elgin, Illinois

OWNER: Sherman Health

PROJECT TEAM:

Architect: Shepley Bulfinch with Loebl Scholssman & Hackl

MEP Engineering/Geothermal: KJWW Engineering Consultants

TYPE: Replacement Acute-Care Hospital Campus

SIZE: 652,000 sq. ft. (60,572.8 sq. m) hospital; 100,000 sq. ft. (9,290.3 sq. m) medical office building. Site area: 154 acres (62 ha)

EUI: 174 kBtu/sf/yr (548 kWh/sm/yr)

PROGRAM DESCRIPTION: Hospital with 255 private beds, Cancer Center, Emergency and medical office building

COMPLETED: 2010

BIOME: Temperate Humid

CLIMATE ZONE: Humid Continental, warm summer

PRECIPITATION: 35 in. (893 mm)

KEY SUSTAINABILITY INDICATORS

- *Habitat Restoration:* Restored prairie landscape and wetland
- *Water Use Reduction:* Low flow fixtures throughout; no cooling tower
- *Rainwater Harvesting:* No potable water for irrigation; use lake water
- *Innovative Source Energy:* Lake-coupled geothermal system reduces energy demand 35–40%
- *Innovative Energy Distribution:* Each patient room has individual heat pump
- *Energy Display:* Manifold room on display between parking and building
- *Civic Function:* Walking trail and public access around lake

Figure 5.34 Sherman Hospital. *Source: Image courtesy of Shepley Bulfinch*

Figure 5.35 Diagram of lake, manifold room, and corridor from parking to hospital. *Source: Image courtesy of Shepley Bulfinch*

Figure 5.36 The manifold room. *Source: Image courtesy of Shepley Bulfinch*

Figure 5.37 Lake-coupled geothermal system. *Source: Image courtesy of Shepley Bulfinch*

This is the largest lake-coupled geothermal heat pump system employed in a U.S. hospital to date. The project's scale and expansive site presented an ideal opportunity to solve both the hospital functional requirements, now and into the future, and make a substantive environmental statement. The design team recognized the potential for a lake-based geothermal system, and lobbied for it from the project inception. The balance of the former farmstead site is restored to its pristine prairie state, with no-mow grasses and native plantings covering a large portion of the site.

The geothermal system provides clean, reliable energy that improves energy effectiveness, reducing fossil fuel consumption by 35–40 percent. It is a relatively simple system to operate. It eliminates the need for noisy, unsightly cooling towers with associated water consumption as well as on-site fossil fuel combustion. Mechanical plant size is reduced; shaft sizes are 10 percent smaller compared to a conventional ducted heating and cooling system because a portion of the energy is hydronically supplied. A geothermal system's constant, steady supply of energy is well suited to buildings occupied 24 hours a day.

The design team retained a limnologist to size the lake and arrange the heat exchangers in a layout to derive maximum heat transfer. A delicate balance among acreage, water depth, and temperature gain ensures that the lake functions geothermally while also serving as a wildlife habitat for fish and ducks, and does not become choked with weeds or algae. The 18-foot (5.5 m) deep lake will provide 2,450 tons of cooling, with capacity to expand to 3,400 tons as the campus grows.

The location of the manifold room, tucked beneath the main entry circle, also provides an educational opportunity for visitors and staff to understand the inner workings of the geothermal system. A bike and walking path circles the lake, further emphasizing the connection between personal health and a healthy site.

Source: Shepley Bulfinch and KJWW

Case Study 05: Kiowa County Memorial Hospital

Greensburg, Kansas

OWNER: Kiowa County

PROJECT TEAM:

Architect: Health Facilities Group

Mechanical and Plumbing Engineer: Midwest Engineering, Inc.

Electrical and Structural Engineer: Professional Engineering Consultants

Civil Engineer and Landscape: Mid-Kansas Engineering Consultants

Energy Modeling: Chapek Engineering; Midwest Engineering, Inc.

BUILDING TYPE: Acute-Care Critical Access Replacement Hospital

SIZE: 50,000 sq. ft. (4,645 sq. m)

EUI: 183 kBtu/sf/yr (577 kWh/sm/yr)

PROGRAM DESCRIPTION: 15-bed replacement critical access hospital including inpatient care, clinical lab, radiology, emergency department, outpatient clinic, and daycare for employees' children

COMPLETED: 2010

RECOGNITION: LEED Platinum–certified

BIOME: Temperate Semi-Arid

CLIMATE ZONE: Steppe

PRECIPITATION: 26 in. (66 cm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia:* Site revegetated connecting patients, staff, visitors to nature; landscaped connection to community
- *Innovative Stormwater Management:* Landscape mitigates runoff
- *Rainwater Harvesting:* Rainwater stored in underground tanks; used for toilet flushing and make up water for water-cooled HVAC system
- *Water Use Reduction:* 57 percent reduction in potable water use from low flow plumbing fixtures; captured rainwater used for toilet flushing
- *Innovative Source Energy:* All-electric building uses on-site and off-site wind power; no on-site combustion
- *On-site Renewables:* On-site wind generator provides electricity
- *Heat Recovery:* Heat recovery chillers and domestic hot water
- *Occupant Control:* Lighting and thermal system controllability
- *Healthy, Recycled Content Materials:* Low-emitting, high recycled content materials
- *Civic Function:* Serves as "community shelter" for safe harbor during tornados
- *Resilience:* 100% renewable on- and off-site generated electricity

Figure 5.38 Kiowa County Memorial Hospital. *Source: Steve Rasmussen Photography*

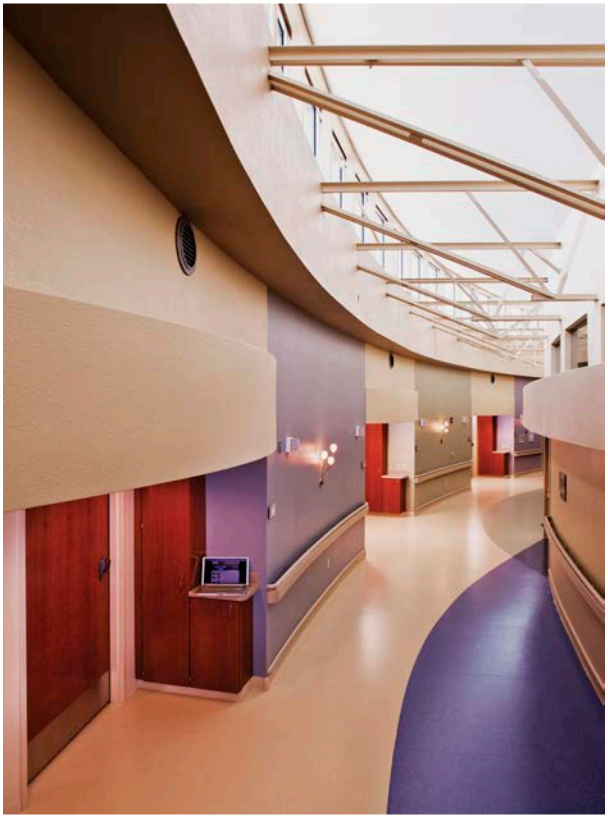


Figure 5.39 On-site grid connected 50 kW wind turbine generates 220,000 kWh annually. *Source: Steve Rasmussen Photography*

Figure 5.40 Daylight pervades the interior. *Source: Steve Rasmussen Photography*

The devastating 2007 tornado that destroyed 95 percent of Greensburg's downtown prompted reconstruction of this critical access hospital. With a commitment to rebuild Greensburg "green," it is the first U.S. hospital to be supported by 100% renewable electrical energy, with a combination of on-site wind and grid-connected wind power generation (Figure 5.38).

The replacement hospital integrates an array of environmentally sound strategies in order to increase resilience. The site's open space areas are substantially increased compared to the previous condition, with dark, impervious constructed surfaces minimized to reduce contributions to heat island effect. Full cut-off exterior lighting fixtures protect the night sky, preventing light pollution. Collected rainwater offsets dependence on potable water used for toilet flushing; potable water use is further reduced through a landscape planted with native and adapted species. Excess rainwater is further captured and stored in an open pond, providing a site amenity, habitat and support for native landscape while eliminating stormwater runoff. Overall potable water use is reduced by 57 percent over code.

The building's modeled energy cost performance is 23 percent more efficient than ASHRAE 90.1–2004; factoring in on-site wind power electricity generation it achieves a 32 percent improvement (Figure 5.39). In addition, 100 percent of purchased power is green-E certified.

The facility design improves patient and staff well-being through a variety of strategies, including improved air quality, high volume fresh air infusion, daylighting and the selection of low-emitting materials and finishes (Figure 5.40). Building occupants have a high degree of control over lighting and thermal systems to enhance occupant comfort as well as access to daylight and views. The hospital features a high percentage of regional, rapidly renewable, FSC-certified wood, and recycled materials (including paving from the original site. A public wall constructed of a distinctive local stone honors Kiowa County's unique geology and celebrates its natural heritage.

Source: Health Facilities Group

Case Study 06: Kohinoor Hospital

Mumbai, India

OWNER: Kohinoor Group

PROJECT TEAM:

Architect: Sandeep Shikre & Associates (SSA)

MEP Consultant + LEED Facilitation: Spectral Services Consultants Pvt. Ltd.

Structural Consultant: M/s. S.W. Mone & Associates

TYPE: New Acute-Care Hospital

SIZE: 227,432 sq. ft. (21,129.198 sq. m); 1.5-acre site (.6 ha)

EUI: 53 kBtu/sf/yr (166 kWh/sm/yr)

PROGRAM DESCRIPTION: Six-story multi-specialty 150-bed hospital including four operating theaters, pharmacy, convenience store, dialysis, dental, pediatric, day care

COMPLETION DATE: 2010

RECOGNITION: LEED India NC Platinum–certified; AICA-International Association of Art Critics

BIOME: Tropical Semi-Arid

CLIMATE ZONE: Humid Continental, cool summer

PRECIPITATION: 83 in. (2,110 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Glazing strategy ensures patients and staff have views to native landscape and trees within 33 ft. (10 m) of exterior walls
- *Innovative Stormwater Management:* Pervious hardscape and ground cover captures 100% stormwater runoff
- *Climatic/Bioregional Design/Orientation:* North-south orientation takes advantage of breeze, shade, solar access, daylight, views
- *Energy Responsive Facade:* Very low "U" value envelope; recessed and shaded windows with high performance glass; optimal window to wall ratio
- *Rainwater Harvesting:* Rainwater collected from roof, collected in tank and filtered
- *Reclaimed Water Reuse/On-site Water Treatment:* 100% gray- and blackwater treated in on-site sewage treatment plant; used for toilet flushing and cooling tower make-up water
- *On-Site Renewable Energy:* 51 KW photovoltaic array
- *Healthy/Recycled Content Materials:* Low VOC adhesives, sealants, carpet, paint; urea formaldehyde–free composite wood

Figure 5.41 Kohinoor Hospital. *Source: Sandeep Shikre and Associates*

Kohinoor is a master planned township within Mumbai, India's most populated city and the fourth largest in the world. High humidity and moderate year-round temperatures characterize Mumbai's climate. A pattern of record-breaking temperatures is emerging, with the coldest temperatures ever recorded in winter, 2012. Mumbai's high concentrations of smog, smoke, and airborne pollutants create unhealthful living conditions and exacerbate respiratory ailments. Within this context, the LEED India Platinum–certified Kohinoor Hospital exhibits a bold approach to resource efficiency and patient-centered practice, with substantial innovation inside the spare, unassuming facade.

Aligned with fundamental passive solar principles, Kohinoor is oriented along a north-south axis, enabling it to take advantage of breeze, shade, solar access, daylight, and views. The modest landscape is planted with native vegetation, eliminating irrigation requirements; trees and shrubs along the front provide privacy and shade. The groundcover, complemented with pervious hardscape, is designed to absorb 100 percent of the stormwater and mitigate heat island effect. The building's location is adjacent to a dense residential area with about 2,000 homes, and near bus and rail reducing staff, patient, and visitor reliance on single occupant vehicles.

A systems approach to water and energy yields impressive results. An on-site 130 kiloliter/day sewage treatment plant treats 100 percent of the building's gray and blackwater. The wastewater, treated to tertiary standards using an activated carbon and multigrade filter, fulfills 50 percent of the HVAC makeup water requirements and 100 percent of the toilet flushing needs. A 41.3 percent potable water reduction, representing an annual reduction of 297,484 gallons (1,126,099 L) was achieved through low flow toilets, water closets, lavatories, and urinals.

Kohinoor's impressive energy use intensity results from an integrated envelope/mechanical design approach: insulated walls have very low "U" value; windows are recessed and shaded, feature high performance glass,

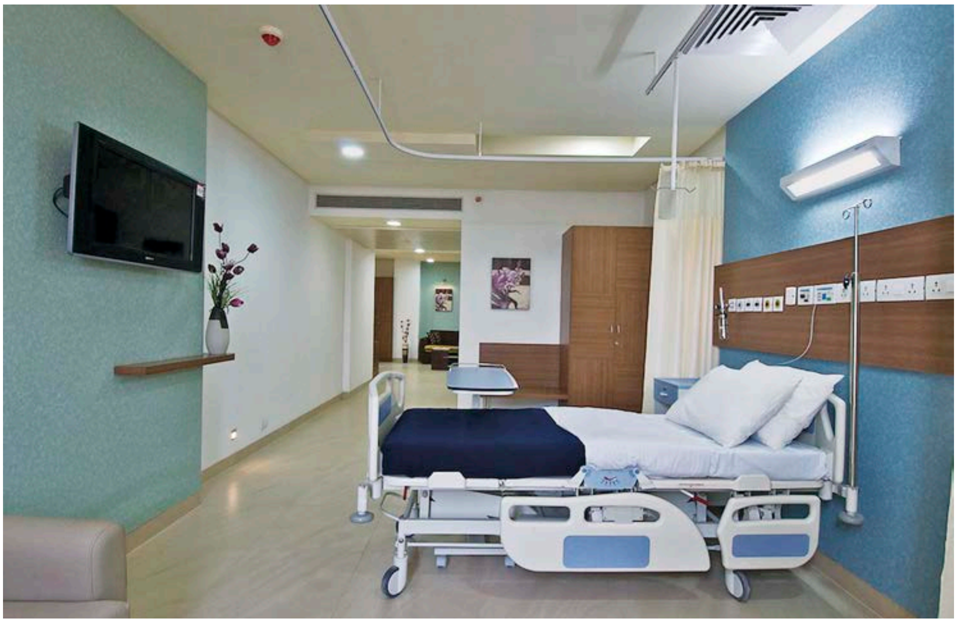


Figure 5.42 Patient room. *Source: Sandeep Shikre and Associates*

Figure 5.43 Site plan. *Source: Sandeep Shikre and Associates*

and are placed within an optimized window to wall ratio; lighting power density (LPD) is reduced by 50 percent, with high percentage of LED lamps (the low LPD also reduces internal heat loads, thereby reducing mechanical cooling requirements); occupancy sensors control lights when rooms are not occupied; high efficiency chillers have heat recovery in noncritical areas, while CO_2 sensors control ventilation levels responding to varying occupancy levels; 45 roof-installed solar photovoltaic panels generate about 51 KW directed to heat water. Complementing the high performance on-site energy strategies, the Kohinoor Group invested in off-site wind generators that generate 84 percent of the hospital's energy demand.

One hundred percent of construction debris was reused on site, donated to the project's workers for reuse, or sold to a recycler. To create a healthful healing environment, low VOC materials were specified throughout. Patients and staff within 33 ft. (10 m) of the exterior wall have ample access to daylight and views. Because of compromised outdoor air quality, natural ventilation and operable windows are not employed.

Source: Sandeep Shikre and Associates

Case Study 07: The Dyson Centre for Neonatal Care, Royal United Hospital

Bath, England

OWNER: Royal United Hospital

PROJECT TEAM:

Architect: Feilden Clegg Bradley

Healthcare Architect: SR Architects

Mechanical/Electrical Engineer: Buro Happold

Main Contractor: Vinci Construction

BREEAM Assessor: Buro Happold

TYPE: New NICU Addition

SIZE: 9,150 sq. ft. (850 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: 21-bed NICU clinical and support space, including discrete entry and family support

COMPLETION DATE: 2011

RECOGNITION: BREEAM "Excellent"

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 31 in. (780 mm)

KEY SUSTAINABILITY INDICATORS

- Habitat Restoration: Sedum roof attenuates runoff, increases biodiversity
- Rainwater Harvesting: Rainwater used for irrigation
- Innovative Source Energy: Combined heat and power unit provides low carbon electricity and heat to NICU as well as balance of base building; CO_2 emissions are 28% better than "Target Emission Rating"
- Innovative Energy Distribution: Radiant heating throughout
- Low Embodied Energy Materials: External form defined and wrapped in panelized timber laminate system with woodfiber insulation behind; interior constructed from large cross-laminated timber panels

This single story extension of Royal United Hospital (RUH) accommodates NICU clinical, support and reception functions as a discrete and contemporary intervention. The addition encloses a landscaped garden that offers connection to nature and respite spaces (Figures 5.44–5.45).

Figure 5.44 The Dyson Centre for Neonatal Care. *Source: Copyright © Craig Auckland/Fotohaus*

The addition is functionally zoned both in plan and section. In plan, patient treatment zones are clearly separated from clinical support spaces. In section, a walk-in duct runs along the spine of the building.

This duct accommodates the air handling equipment, enabling equipment maintenance activities remote from patient care. Computer animated solar studies informed the sectional form of the building—the walk-in duct eliminates direct sunlight, and its metal panel cladding provides a reflective diffuse light to the clinical areas. Clerestory glazing is provided in the care rooms to ensure privacy and reduce glare. Window seats "pop out" from the elevation as simple glazed extrusions (Figures 5.46–5.47).

The NICU is constructed from large cross-laminated timber panels. This timber solution is a clean, quiet and panelized form of construction in an acute healthcare environment, challenging conventional healthcare construction while employing a renewable, low embodied energy sustainable material. High efficiency panels yielded U-values and an air permeability up to 50 percent better than minimum standards. In the interior, the exposed timber creates a sense of warmth and calm.

Radiant heating systems are embedded in the slab-on-grade construction. An on-site CHP plant provides both low-carbon thermal energy and power for the addition, improving source energy efficiency. The CHP plant is sized for the entire RUH plant.

Source: Feilden Clegg Bradley

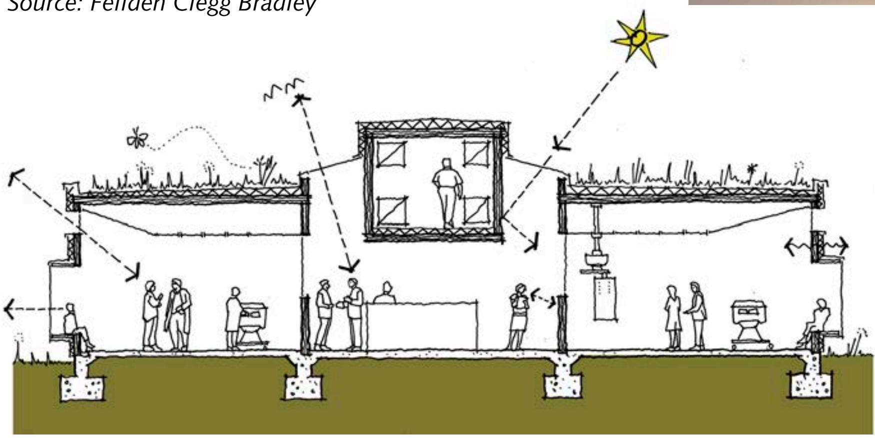


Figure 5.45 Staff respite courtyard between existing building and addition. *Source: Copyright © Craig Auckland/ Fotohaus*

Figure 5.46 Central skylit spine. *Source: Copyright © Craig Auckland/ Fotohaus*

Figure 5.47 Section through addition. *Source: Copyright © Craig Auckland/ Fotohaus*

Case Study 08: St. Mary's Hospital Sechelt Expansion

Sechelt, British Columbia, Canada

OWNER: Vancouver Coastal Health

PROJECT TEAM:

Architect: Farrow Partnership in association with Perkins+Will Canada (formerly Busby Perkins+Will)

Mechanical Engineer: Cobalt Engineering

Electrical Engineer: Acumen Engineering

Contractor: Graham Construction and Engineering

TYPE: Addition and renovation of existing acute-extended care hospital

SIZE: ADDITION: 53,820 sq. ft. (5,000 sq. m); Renovation: 15,070 sq. ft. (1,400 sq. m)

EUI: 78.6 kBtu/sf/yr (248 kWh/sm/yr)

PROGRAM DESCRIPTION: Expanded emergency, imaging and bed replacements: 45 medical/surgical, 4 LDRP, 4 ICU, 4 step-down, 6 mental health

COMPLETION DATE: 2012

RECOGNITION: Targeting LEED NC Canada Gold certification

BIOME: Boreal Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 44 in. (1,110 mm)

Figure 5.48. St. Mary's Hospital Sechelt Expansion. *Source: Perkins+Will Canada*

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia*: Landscape as a therapeutic tool
- *Narrow Floor Plate:* Skylights in deep floor plate ED
- *Energy Responsive Facade:* Motorized external blinds on south, east and west elevations; activate by solar exposure
- *Water Use Reduction:* No potable water for irrigation; low flow fixtures
- *Innovative Source Energy:* New ground-source heat pump mechanical plant for entire campus; no increase in energy consumption; carbon-neutral and net-zero energy addition
- *Renewable Energy:* Roof mounted PV system
- *Low-embodied Energy Materials:* Local and regional; indigenous source/manufacture
- *Acoustics:* Sound attenuation to accommodate drumming rituals
- *Civic Function:* Larger windows to free departing spirits for Salish traditions; larger rooms to accommodate large extended family members

This modest intervention demonstrates how an addition can transform the energy performance of an entire existing campus. Climate-responsive siting, envelope design, and energy-efficient lighting, coupled with an innovative ground-source heat pump energy system that serves both the existing campus and the addition, results in a carbon neutral solution.

The area's First Nations' peoples believe a connection to nature is necessary for healing and overall health in all living things; hence the new patient rooms required oversized windows for optimum daylight and views and to free departing spirits. To achieve the required energy performance, sensor-activated motorized external blinds on south, east and west elevations reduce unwanted solar gain. The design team consulted with Salish elders to simulate traditional bent wood box forms in the addition, which features above code-minimum envelope performance: R-60 roof construction, R-40 exterior walls, and high performance glazing.

The geo-exchange system provides the entire campus with heating and cooling energy. A proposed geo-exchange system was modeled, sized to provide source energy for both the existing building and the high-performance extension and renovated interior. The model suggested that energy performance of the combined total, i.e., a campus approximately 54,000 sq. ft. (5,017 sq. m) larger than the existing, could be conditioned for the same total source energy input as the current building. Hence, the addition can be considered "net-zero energy." A second comparison, based on CO_2 emissions, suggests that the expanded campus carbon footprint is actually less than the current carbon emissions, and 50 percent less than had the addition been completed by expanding the existing systems (Figure 5.12 earlier in chapter).

Source: Perkins+Will Canada/Farrow Partnership

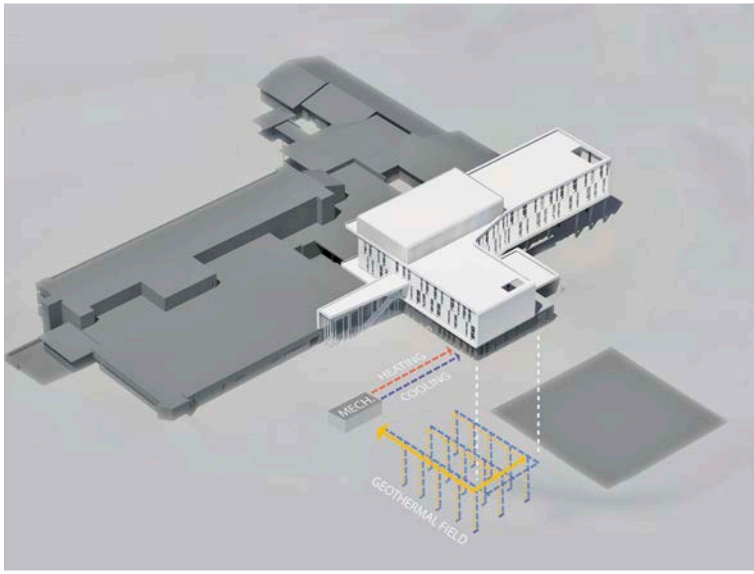


Figure 5.49 Site axonometric of existing hospital and addition showing borefield. *Source: Perkins+Will Canada*

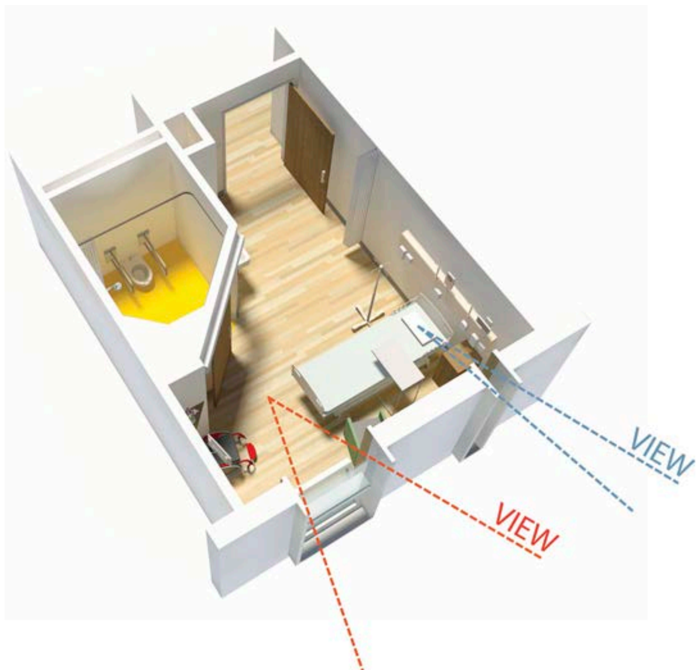


Figure 5.50 Patient room features innovative window arrangement that affords both patients and families view. *Source: Perkins+Will Canada*

Case Study 09: New Karolinska Solna University Hospital

Solna, Stockholm County, Sweden

OWNER: Skanska Hospital Partners & Nya Karolinska Solna

PROJECT TEAM:

Architect/Landscape Architect: White Tengbom Team

Mechanical Engineer: Sweco-ÅF

Civil Engineer: Sweco-ÅF and White Tengbom Team

Contractor: Skanska Healthcare

TYPE: New Acute-Care University Hospital

SIZE: 2,000,000 sq. ft. (185,806 sq. m)

EUI: 40 kBtu/sf/yr (126.6 kWh/sm/yr)

PROGRAM DESCRIPTION: 550-single-bed inpatient hospital including 130 intensive care and intermediate; 36 operating theaters (including 3 "hybrid" theaters); 8 radiation therapy rooms; 165 outpatient clinic rooms; patient hotel with 100 beds; research lab supporting 800 scientists.

COMPLETED: Anticipated 2016 with phased opening through 2017

BIOME: Boreal Humid

CLIMATE ZONE: Humid Continental

PRECIPITATION: 21 in. (53 cm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia*: Green parks and vegetated areas connect to campus; interior landscaped courtyards accessible to patients, staff and visitors
- *Innovative Stormwater Management:* Hardscapes designed to divert stormwater to irrigate vegetated areas
- *Transit:* Bus stop located at main entrance; planned subway connection
- *Innovative Parking:* Electric vehicle charging stations
- *Energy Responsive Facade:* Double-skin envelope; high performance glazing and integral variable blinds reduce solar incident radiation
- *Innovative Source Energy:* Combination geothermal plant; district heating and cooling
- *Occupant Control:* Patient rooms have individual climate controls
- *Healthy Materials:* All construction materials must comply with Byggvarubedömningen (Building Materials Assessment); avoid materials with toxic chemicals
- *Acoustics:* Meet sound class A for isolation from airborne sound, impact sound, HVAC noise, outdoor use
- *Civic Function:* Campus part of plan to connect Stockholm to Solna

Figure 5.51 New Karolinska Solna University Hospital. *Source: Skanska/White Tengbom Team*

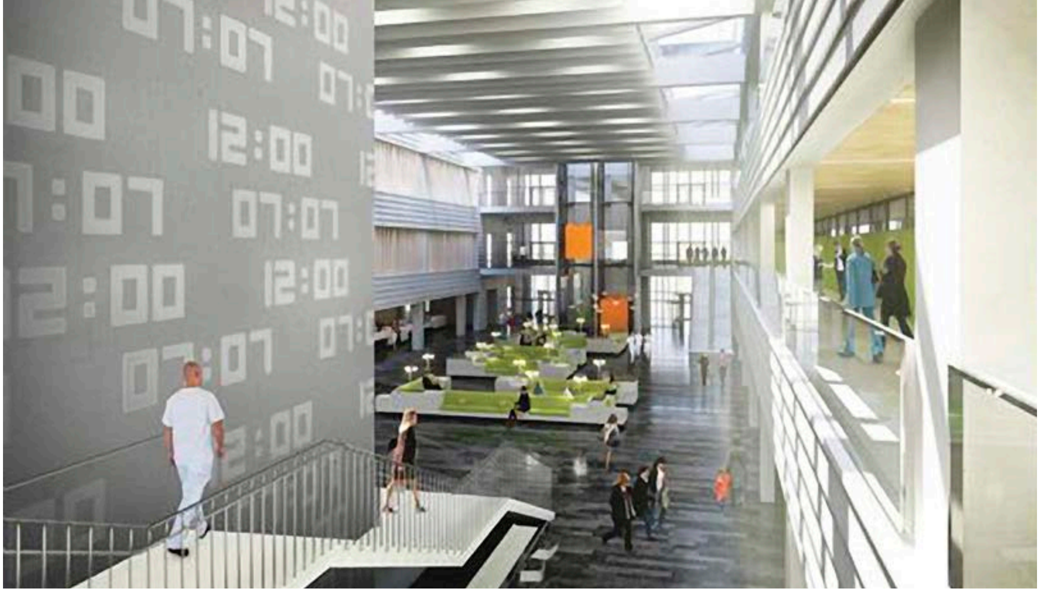


Figure 5.52 Central street. *Skanska/White Tengbom Team*

The New Karolinska Solna (NKS) aspires to be the most environmentally friendly university hospital in the world, inspired by a vision to set a new standard for safety, quality, efficiency, and patient experience—in their words, to create a "humane hospital." Structured as a Public-Private Partnership (PPP), all parties agreed on high environmental performance goals and to promote human health. The five rectilinear buildings form a district connected by a transparent mantle glass structure that facilitates pedestrian circulation between facilities and continues the existing inner city grid pattern (Figures 5.51–5.53). A new urban commuter transit station is included as a visible expression of sustainable public infrastructure.

A low-carbon, energy efficient building with low life cycle costs was an early NKS hallmark requiring careful attention to all aspects of design. A well-insulated, double-skin envelope complemented by a low-energy lighting scheme improves energy performance. Daylight is required in all regularly occupied spaces—defined as occupied 30 minutes or more—with a measured daylight factor of 1.2, augmented by low-mercury fluorescent and LED lamps. High performance glazing minimizes heat loss. Windows on east, south, and west facades have integral variable blinds between the insulated and exterior glass to reduce solar incident radiation and cooling loads.

The energy strategy is further advanced by a flexible energy supply and distribution system, housed in a dedicated "technical" building, distributing energy throughout the campus and designed to adapt to varying low-carbon energy types and sources. A geothermal ground source heat pump system consisting of 140 on-site wells, 722 feet (220 m) deep provides seasonal storage of heating and cooling energy; heat pumps balance the simultaneous base heating and cooling demands, lowering the heat recovery system's energy intensity. When campus energy demand exceeds on-site supply, an off-site district heating and cooling plant fueled by biomass, waste, and other resources is tapped to provide supplemental energy (Figure 5.54).

Ventilation flow is managed by time of day and motion detection controls where occupancy levels vary, reducing energy intensity. The system takes advantage of "free" cooling from the outdoor air, with outdoor temperatures below 7°C; high efficiency heat recovery between supply and exhaust air, and low resistance in ducts to reduce electrical requirements

Figure 5.53 Site plan. *Source: Skanska/White Tengbom Team*

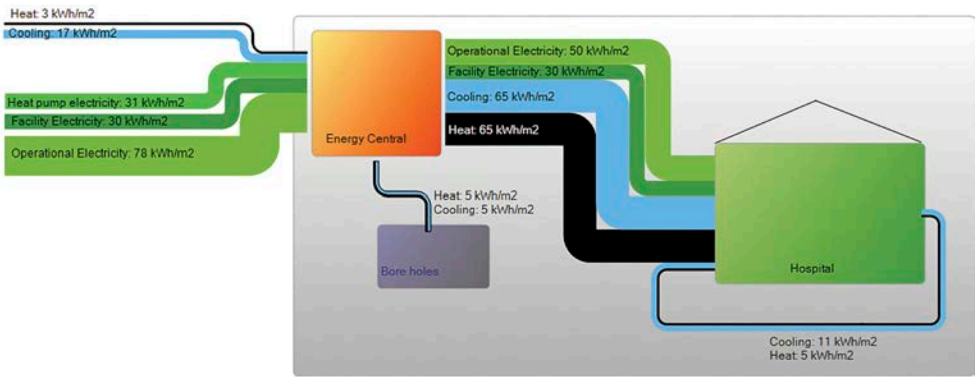


Figure 5.54 Energy system diagram. *Source: Skanska/White Tengbom Team*

of fan motors, further enhances energy performance. Patient rooms are equipped with individual climate controls to enhance patient comfort.

Stringent environmental standards implemented during construction create a "green workplace." All construction materials comply with "Byggvarubedomningen," a Swedish life cycle based environmental evaluation standard. A key innovation to reduce the operational environmental footprint is a system to recapture and purify spent nitrous oxide, an anesthetic agent and potent greenhouse gas. In summary, the New Karolinska Solna is committed to a healthy construction site and healthy building.

Source: Skanska Healthcare

Case Study 10: UCSF Medical Center at Mission Bay

San Francisco, California

OWNER: University of California at San Francisco

PROJECT TEAM:

Architect: Stantec/Anshen+Allen in association with William McDonough+Partners

Landscape Architect: EDAW AECOM

MEP Engineer: Arup

General Contractor: DPR Construction

TYPE: Replacement Children's, Women's, and Cancer Hospitals

SIZE: 868,020 sq. ft. (82,314 sq. m); Site: 14 acres (5.6 ha)

EUI: 246 kBtu/sf/yr (775 kWh/sm/yr)

PROGRAM DESCRIPTION: 289-bed medical center comprised of three hospitals: UCSF Benioff Children's Hospital (183 beds), women's specialty (36 beds) and cancer (70 beds), with 207,400 sq. ft. (19,268 sq. m) outpatient medical office building, helipad, central plant

COMPLETED: Anticipated 2015

RECOGNITION: targeting LEED Gold certification

BIOME: Mediterranean Warm

CLIMATE ZONE: Mediterranean

PRECIPITATION: 21 in. (238 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia:* Abundant gardens and green space visually and physically accessible to patients, staff and visitors
- *Habitat Restoration:* Four acres of vegetated landscape restores blighted site
- *Innovative Stormwater Management:* Planted swales and landscape provide stormwater filtration and flood control
- *Brownfield:* Remediated former rail yard site
- *Energy Responsive Facade:* High performance glazing; exterior shading
- *Green Roofs:* 1.2 acres (0.49 ha) of rooftop gardens
- *Rainwater Harvesting/Reclaimed Water Reuse:* Collected rainwater and cooling tower blowdown used for landscape irrigation
- *On-site Renewables:* Roof-mounted photovoltaic array prevents 500 tons of CO_2 emissions
- *Healthy Materials:* Low-emitting interior finish materials

Figure 5.55 UCSF Medical Center at Mission Bay. *Source: Stantec Architecture, William McDonough+Partners*

UCSF Medical Center at Mission Bay integrates access to nature, healthy materials, and energy and water conservation in this new medical complex located on the same campus as UCSF's research center. The remediated brownfield site has been transformed with the introduction of the new extensively landscaped complex: ten ground level and rooftop gardens totaling more than four acres function as native habitat, air filters, and stormwater filters and absorbers using planted swales. The gardens are strategically located to offer accessible places of respite for patients, staff and visitors, a large, verdant outdoor space for children undergoing physical therapy, and views of nature (Figure 5.55).

An early focus on creating a healthy environment informed materials selection. The project team undertook an extensive building materials assessment, focused on chemical toxicity. Together with chemists from McDonough-Braungart Design Chemistry, the team set a goal to eliminate known toxins from the project's interior finish materials (Figures 5.56–5.57).

A variable air volume air distribution system providing 100 percent outdoor air to all spaces, heat recovery ventilators (reclaiming energy from exhaust ventilators), high performance glazing and exterior shading, and energy efficient lighting, contribute to energy performance. A rooftop photovoltaic array is estimated to offset 500 tons of CO_2 emissions associated

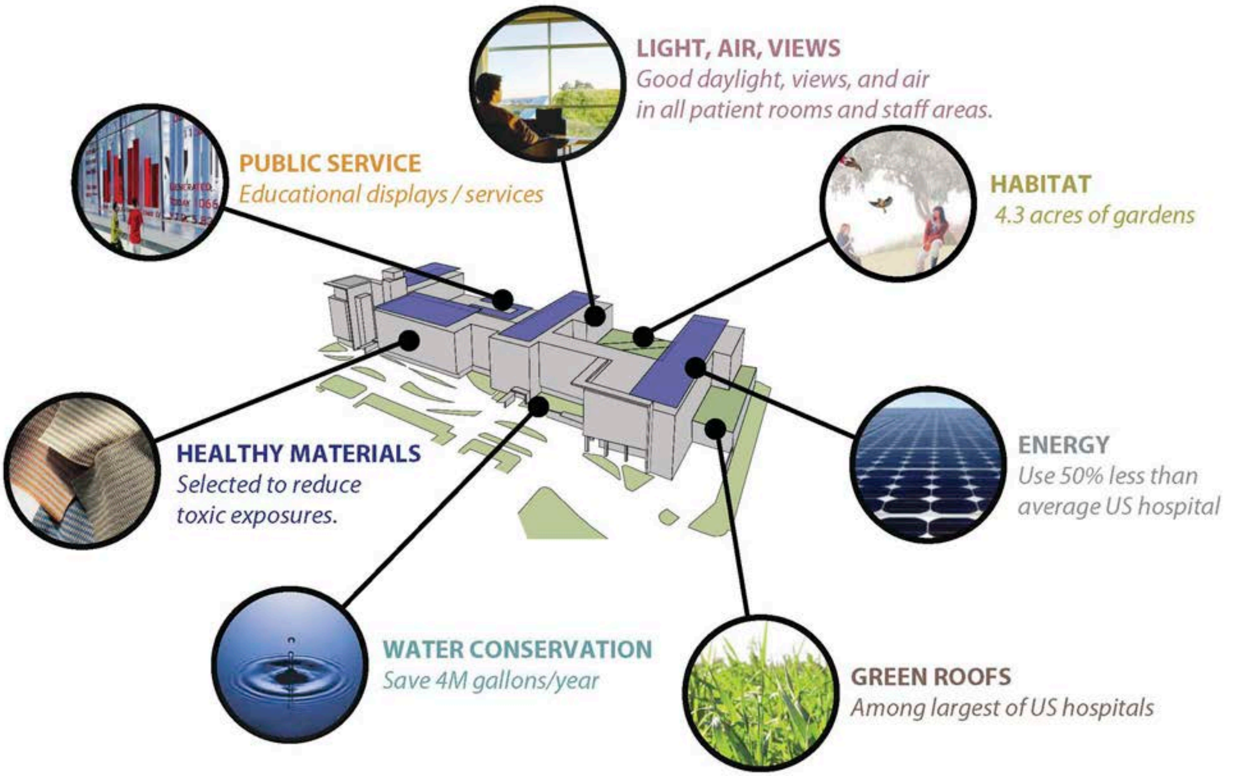


Figure 5.56 High performance strategies. *Source: Stantec Architecture, William McDonough + Partners*

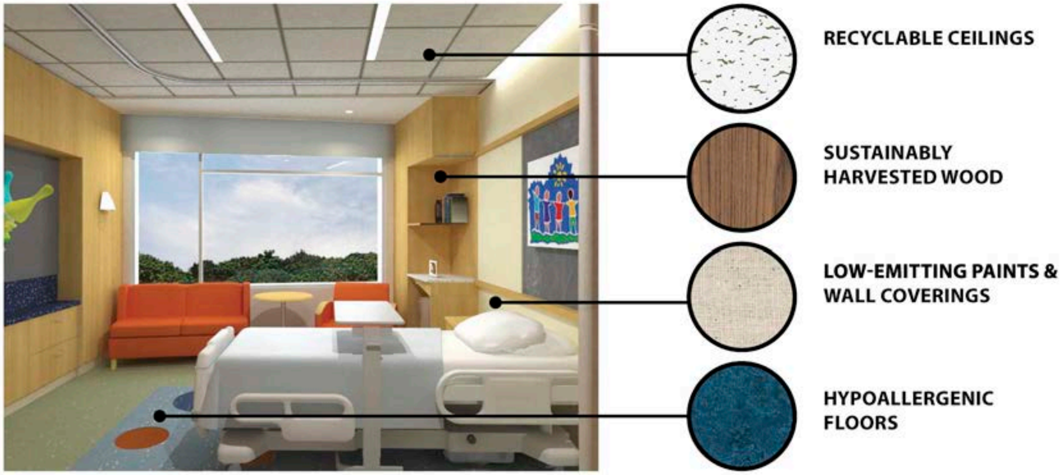


Figure 5.57 Patient room materials. *Source: Stantec Architecture, William McDonough + Partners*

with a comparable amount of fossil fuel generated electricity. To ensure high quality daylight within the building, floor plates were designed as narrow rectilinear fingers. Every patient care unit has outdoor balconies and terraces, with 75 percent of patient rooms with northern or southern orientation providing glare-free direct daylight. Patient care units are oriented to provide daylight and views into most staff workstations.

Source: Stantec/Anshen+Allen

Case Study 11: Lucile Packard Children's Hospital at Stanford

Palo Alto, California

OWNER: Lucile Packard Children's Hospital at Stanford

PROJECT TEAM:
Executive Architect: HGA
Design Architect/Interiors/Sustainability: Perkins+Will
Landscape Architect: EDAW (now AECOM)
MEP Engineer: Mazzetti
Construction Manager: DPR

TYPE: Major Addition to Children's Hospital

SIZE: 521,000 sq. ft. (48,402 sq. m)

EUI: 183 kBtu/sf/yr (576.45 kWh/sm/yr)

PROGRAM DESCRIPTION: 200 new private acute and critical care patient beds, extensive new surgical and diagnostic services, below grade parking structure for patients, three multi-use outdoor garden spaces

COMPLETED: Anticipated 2016

RECOGNITION: Seeking LEED certification; Finalist: 2011 WAN Awards, Healthcare

BIOME: Mediterranean Warm

CLIMATE ZONE: Mediterranean

PRECIPITATION: 15 in. (388 mm)

KEY SUSTAINABILITY INDICATORS

- Habitat Restoration: Adjacent to Stanford Arboretum; native planting to restore habitat
- Narrow Floor Plate: Virtually all staff occupied spaces on nursing units have windows; only supply and team rooms in center of racetrack unit
- Energy and Climate Responsive Facade: Fixed exterior solar shading system designed to keep 95% direct sun from occupied spaces
- Rainwater Harvesting: Rainwater captured and stored for irrigation
- Reclaimed Water Reuse: Condensate and reverse osmosis reject water capture for irrigation
- Innovative Source Energy: Thermal energy provided from Stanford district energy plant (co-generation)
- Innovative Energy Distribution: Displacement ventilation at inpatient units
- On-site Renewable Energy: Photovoltaic canopy and wind turbine
- Healthy Materials: Materials comply with Perkins+Will Precautionary List

Figure 5.58 Lucile Packard Children's Hospital at Stanford.
Source: HGA/Perkins+Will

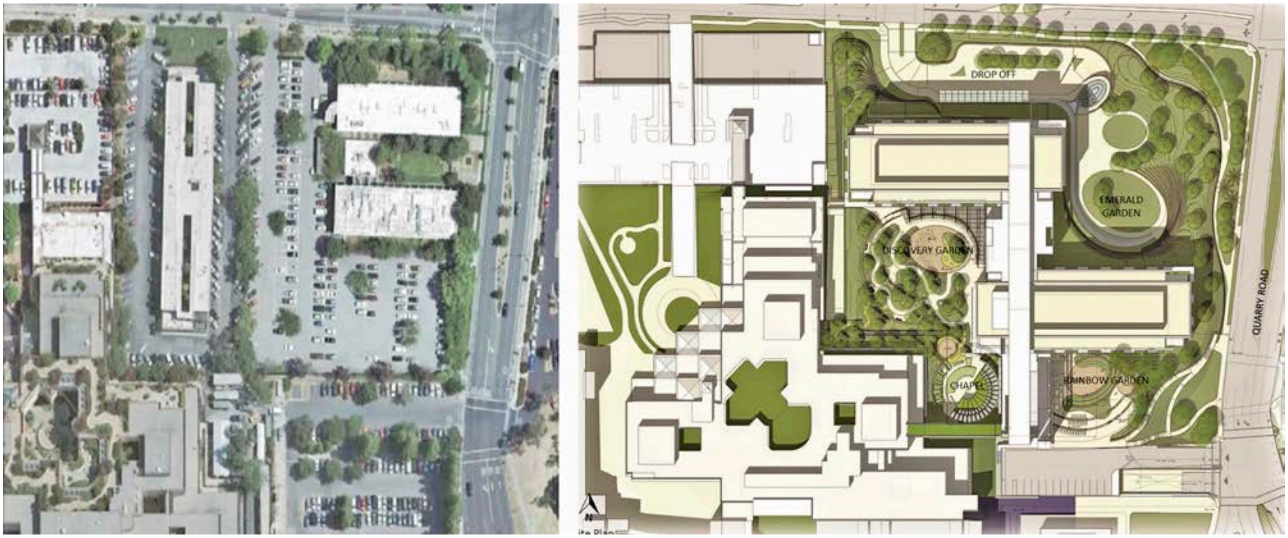


Figure 5.59 Existing site is primarily surface parking (left); final site plan increases habitat by 4.5 acres (1.8 ha). *HGA/Perkins+Will*

Adjacent to the Stanford Arboretum, this major addition to the 1990 Lucile Packard Children's Hospital restores an existing "grayfield" site, i.e., one that is primarily surface parking and low-rise buildings, to provide the hospital with much needed area for expansion (Figure 5.58). The site development creates four major garden spaces: a publicly accessible walking and bike path at the prominent corner; the public Emerald Garden; the rooftop Discovery Garden that includes outdoor dining and meditation labyrinth and chapel; and finally the Rainbow Garden for staff respite. Collectively, the development yields an additional 500,000 sq. ft. (46,452 sq. m) of building and an additional 4.5 acres (1.8 ha) of habitat (see Figure 5.59), demonstrating that sustainable building can solve for both human needs and enhancing natural systems.

The building responds to this context through the introduction of exterior overlook terraces at each nursing unit (Figure 5.60). Primarily oriented for energy performance, the energy-responsive facade includes deep overhangs to block direct solar gain and minimize direct views between patient units. The Discovery Garden is actually a green roof, and includes skylights to bring natural light to the surgery department, which aligns in section with existing below-grade surgery facilities in the adjacent building.

Palo Alto is a semi-arid climate; the limited rainfall is concentrated in the fall and winter months. To provide 100 percent irrigation from rainwater and reclaimed sources, the project includes an underground cistern, collecting an estimated 700,000 gallons (2,649,788 L) annually. Significant summer irrigation needs are satisfied through the cistern supply, supplemented by collection of condensate and reverse osmosis reject water throughout the summer months. Gardens and planter boxes are irrigated; the remainder of the landscape utilizes drought resistant xeriscaping and bioswales. A rain garden near the front entrance is dry throughout the summer and blooms in the fall and winter months (Figures 5.61–5.63).

Figure 5.60 Patient room features planter boxes and fixed solar shading. *Source: HGA/Perkins+Will*

A. Painted Steel Maintenance Catwalk
B. Aluminum Louvers
C. Interior Privacy Shade
D. Fixed Low E Glazing
E. Laminated Glass Vertical Shade
F. Planters

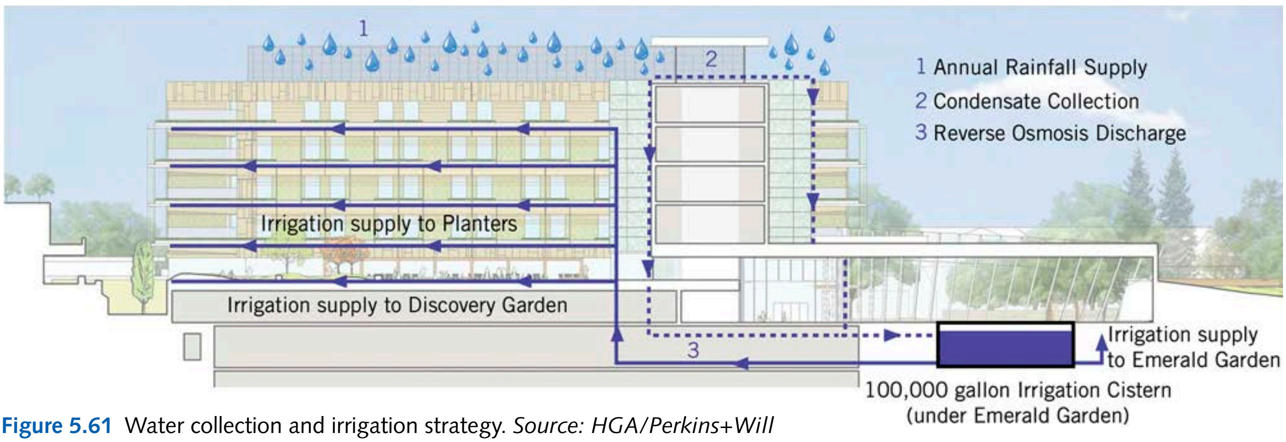


Figure 5.61 Water collection and irrigation strategy. *Source: HGA/Perkins+Will*

An integrated energy approach takes advantage of innovative source, distribution and envelope strategies, reducing the hospital's carbon footprint. Patient units feature displacement ventilation. An innovative fixed solar shading system ensures that direct solar gain is eliminated from patient rooms; a planter box located outside of each patient window connects all children to nature.

The building has no central plant; it receives thermal energy from the Stanford University CUP, and power from the local Palo Alto utility, which as of 2011, boasts 85 percent from carbon-free sources (including 64 percent large hydro, and the 21 percent renewables from a combination of small hydro, wind and landfill gas).

Source: Perkins+Will

CONTRIBUTORS

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Through her work at the University of Washington's Integrated Design Lab, Ms. Burpee has established thorough research on energy efficiency of hospitals working with leading architects, mechanical engineers, and owners to establish goals to radically reduce energy consumption, while maintaining high quality healing and work environments. This work bridges practice, research, and education with collaboration between practitioners, faculty, and students.

Tom Lent, Policy Director, Healthy Building Network

Tom Lent is Policy Director for the Healthy Building Network, assessing the health and environmental impact of building materials. He helped coordinate development of the Green Guide for Health Care, LEED™ for Healthcare, Sustainable Bioplastic Guidelines, Health Product Declaration Standard, and the Pharos Project and sits on a variety of standards setting committees for indoor air quality and safer materials.

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BIBLIOGRAPHY

American Society of Heating Refrigeration and Air Conditioning Engineers [ASHRAE]. (2012). The Advanced Energy Design Guide for Large Hospitals: 50%. www.ashrae.org/standards-research—technology/advanced-energy-design-guides/50-percent-aedg.

______ [ASHRAE]. (2009). The Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities: 30% Energy Savings.

Bonar, R. (2008). Dell Children's Medical Center is the Worlds First Platinum Hospital. Press Release: January, 2008. www.dellchildrens.net/about_us/news/2009/01/08/dell_childrens_medical_center_is_worlds_first_platinum_hospital_2.

BREEAM [BRE] (2012). www.breeam.org/ accessed on November 30, 2012.

Briner, K. (2012). Despite conservation efforts, hospitals still consume large amounts of energy. Healthcare Finance News, August 24, 2012.

Brown, J. (2013). The Material Challenge of Healthier Interiors. Healthcare Design, January 8, 2013. www.healthcaredesignmagazine.com/article/material-challenge-healthier-interiors.

Carbon Footprint Ltd. (2006). www.carbonfootprint.com/carbon_footprint.html.

Center for the Built Environment [CBE] (2008). Providence Newberg Hospital: Building Performance Evaluation Report. February 29, 2008.

Centers for Disease Control and Prevention (2009). Chronic Diseases: the Power to Prevent, The Call to Control: At A Glance 2009. www.cdc.gov/chronicdisease/resources/publications/aag/chronic.htm.

China Trend Building Press Ltd. (2011). China announced construction of 20,000 new hospitals. July 18. www.building.hk/view.asp?id=813.

The Climate Group (2005). Carbon Down, Profits Up. www.theclimategroup.org/assets/CDPU_2005_v2.pdf.

Commercial Buildings Energy Consumption Survey [CBECS] (2007). Energy Characteristics and Energy Consumed in Large Hospital Buildings in the United States in 2007. Release date: August 17, 2012. www.eia.gov/consumption/commercial/reports/2007/large-hospital.cfm.

Gragg, R. (2007). Case Study: Center For Health And Healing. GreenSource. October.

Green Building Certification Institute [GBCI] (2012). Personal communication with Sarah Alexander, 12/6/12.

Green Building Council of Australia [GBCA] (2012). Green-Star – Healthcare. www.gbca.org.au/green-star/rating-tools/green-star-healthcare-v1/1936.htm.

Green Guide for Health Care (2012). www.gghc.org.

Green Guide for Health Care [GGHC] (2007). A Prescriptive Path to Energy Efficiency Improvements for Hospitals. December 19. www.gghc.org/documents/Reports/GGHC_PrescriptivePath.pdf.

Hansen, J. (2012). Game Over for the Climate. New York Times, May 9, 2012. www.nytimes.com/2012/05/10/opinion/game-over-for-the-climate.html

HSBC (2013). Carbon Neutrality. www.hsbc.com/1/2/carbonneutrality

International Living Future Institute [ILFI] (2012). Living Building Challenge 2.1: A Visionary Path to a Restorative Future. Seattle. https://ilbi.org/lbc/LBC%20Documents/lbc-2.1.

Jakelius, S. (1996). Learning from Experiences with Energy Savings in Hospitals. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). www.caddet.org/public/uploads/pdfs/Report/ar_20.pdf

Kats, Greg (2010). Greening Our Built World: Costs, Benefits, and Strategies. Washington, DC. Island Press.

Koster, J. (2006). Quoted in R. Guenther, G. Vittori, and C. Atwood. "Values Driven Design and Construction: Enriching Community Benefits through Green Hospitals." In Designing the 21st Century Hospital: Creating Safe and Healthy Environments for Patients and Staff. Concord, CA, Arlington, VA, and Princeton, NJ: The Center for Health Design, Health Care Without Harm, and Robert Wood Johnson Foundation, Sept. 2006. www.healthdesign.org/research/reports/documents/CHD_Guenther-VittoriAtwood_edit_v2.pdf.

Massachusetts Water Resources Authority [MWRA] (1996).

______ (2008). Water Use Case Study: Norwood Hospital. www.mwra.state.ma.us/04water/html/bullet1.htm accessed on Jan 10, 2013.

National Coalition on Health Care (September 2011). Health Care Spending as Percentage of GDP Reaches All Time High. http://nchc.org/node/1171.

National Renewable Energy Laboratory (2010). Large Hospital 50% Energy Savings: Technical Support. www.nrel.gov/docs/fy10osti/47867.pdf.

Northumbria University (2012). BREEAM for Healthcare: Report for NHS Estates and Facilities Policy. Northumbria University: Newcastle upon Tyne, July 20, 2012. http://nrl.northumbria.ac.uk/8207/1/BREEAM_Healthcare_Report__v_1.pdf.

Organisation for Economic Co-operation and Development (2010). OECD Health Data. OECD Health Statistics. www.kff.org/insurance/snapshot/oecd042111.cfm.

Orszag, Peter R. (2008). Growth in Health Care Costs. Statement before the Committee on the Budget, United States Senate. Washington, DC. Congressional Budget Office. www.cbo.gov/sites/default/files/cbofiles/ftpdocs/89xx/doc8948/01–31-healthtestimony.pdf.

Passivhaus Trust (2012). www.passivhaustrust.org.uk/. Accessed on December 20, 2012.

Reuters News Service [Reuters] (2007). UK Hospitals Get Cash to Fight Global Warming. January 5. http://u3a-climatestudy.pbworks.com/w/page/5216825/UK%20Hospitals%20Get%20Cash%20to%20Fight%20GW.

Roberts, R.R., B. Hota, I. Ahmad, et al. (2009). Hospital and societal costs of antimicrobial-resistant infections in a Chicago teaching hospital: implications for antibiotic stewardship. Clin Infect Dis 2009 Oct 15;49(8):1175–84.

Robertson, J. (2011). OHSU Center for Health & Healing Achieves LEED EBOM Platinum Certification. OHSU Press Release, September 22, 2011. www.ohsu.edu/xd/about/news_events/news/2011/09–22-ohsu-chh-achieves-leed-e.cfm.

Singer, B. et al. (2009). Hospital Energy Benchmarking Guidance—Version 1.0. LBNL Report LBNL-2738E. Lawrence Berkeley National Laboratory, Berkeley, CA. October, 2009.

U.S. Department of Energy [US DOE] (2008). Net-Zero Energy Commercial Building Initiative. Office of Energy Efficiency and Renewable Energy. http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/cbi_fs.pdf.

U.S. Energy Information Agency (USEIA). (2011). U.S. Energy Consumption by Sector.

U.S. Environmental Protection Agency [USEPA].

______ (2012a). ENERGY STAR for Healthcare. www.energystar.gov/index.cfm?c=healthcare.bus_healthcare.

______ (2012b). Water Sense. http://epa.gov/watersense/commercial/types.html#tabs-hospitals.

______ (2007). The Energy Star Challenge: Build a Better World 10% at a Time. www.energystar.gov/index.dfm?c-=leaders.bus_challenge.

U.S. Green Building Council (USGBC) (2011). www.usgbc.org/DisplayPage.aspx?CMSPageID=1779.

Warshall, P. (2008). Sustainability, Water and Healthcare, in Sustainable Healthcare Architecture, First Edition: R. Guenther and G. Vittori. New York: Wiley and Sons, pp. 272–274.

World Summit on Sustainable Development [WSSD] (2004). Plan of Implementation of the World Summit on Sustainable Development. United Nations Treaty Series 1954 (33480): 13.

Zero Waste International Alliance (2009). ZW Definition. http://zwia.org/standards/zw-definition/ accessed on December 18, 2012.

——— (2005). ZW Business Principles. http://zwia.org/standards/zw-business-principles/ accessed on December 18, 2012.

The PBT-Free Challenge—Tom Lent

Building Green (2010). New Report Criticizes LEED on Public Health Issues, *Environmental Building News*, www.buildinggreen.com/auth/article.cfm/2010/6/3/New-Report-Criticizes-LEED-on-Public-Health-Issues/. Accessed 7/1/2012.

Calafat, A. M., Z. Kuklenyik, J. A. Reich, et al. (2003). Quantitative analysis of serum and breast milk for perfluorochemical surfactants. *Organohalogen Compounds.* 62:319–322.

Catholic Healthcare West [CHW] (2011), "Healthy Chemicals, Healthy Patients" Case study. www.saferchemicals.org/PDF/resources/CatholicHealthcareWest_casestudy.pdf.

Centers for Disease Control and Prevention [CDC] (2009).

Chase, R. (2006). Board: Teflon chemical a likely carcinogen. *Associated Press*, February 16.

Clean Production Action (2007). http://www.cleanproduc tion.org/.

Consorta. (2007). Consorta's EPP Program: Green Building and The Green Guide for Healthcare Construction. www.consorta.com/wings/resource_mgmt/epp/green building.asp.

Dewailly, E. A., J. P. Nantel, J.P. Weber, and F. Meyer (1989). High levels of PCBs in breast milk of Inuit women from Arctic Quebec. *Bulletin of Environmental Contaminations and Toxicology.* 43 (5), November.

Environmental Protection Agency [EPA] (1998). A Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic [PBT] Pollutants. www.epa.gov/pbt/pubs/pbtstrat.htm.

——— (2007). Perfluorooctanoic Acid (PFOA) and Fluorinated Telomars. www.epa.gov/oppt/pfoa/.

——— (2009). Long-Chain Perfluorinated Chemicals (PFCs) Action Plan, 12/30/2009, www.epa.gov/oppt/existingchemicals/pubs/pfcs_action_plan1230_09.pdf. Accessed 6/23/2011.

——— (2009a). Polybrominated Diphenyl Ethers (PBDEs) Action Plan 12/30/2009, www.epa.gov/oppt/existingchemicals/pubs/actionplans/pbdes_ap_2009_1230_final.pdf. Accessed 7/1/2012.

——— (2010). Hexabromocyclododecane (HBCD) Action Plan, 8/18/2010, www.epa.gov/oppt/existingchemicals/pubs/actionplans/RIN2070-AZ10_HBCD%20action%20plan_Final_2010–08–09.pdf.

——— (2000). Cadmium Compounds. January. www.epa.gov/ttnatw01/hlthef/cadmium.html. Accessed 2/18/13.

Environmental Protection Agency and American Hospital Association [EPA and AHA] (1998). Memorandum of Understanding between the American Hospital Association and the U.S. Environmental Protection Agency. www.noharm.org/library/docs/going_green_memorandum_of_understanding_between.pdf.

European Union [EU] (2011). "Chemicals/REACH: Six dangerous substances to be phased out by the EU," February 17, 2011, http://europa.eu/rapid/pressReleasesAction.do?reference=IP/11/196&format=HTML&aged=0&language=EN&guiLanguage=en. Accessed 6/23/2011.

European Union Commission [EU Commission] (2011). Regulation No. 143/2011 of February 17, 2011, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:044:0002:0006:EN:PDF. Accessed 6/23/2011.

Green Guide for Health Care [GGHC] (2004) *Development History*, www.gghc.org/about.history.php. Accessed 7/1/2012.

Health Care Without Harm [HCWH] (2007). *Health Care Institutions.*

Undertaking Efforts to Reduce Polyvinyl Chloride [PVC] and / or Di(2-Ethylhexyl) Phthalate (DEHP). www.noharm.org/us/pvcDehp/hospitalsreducingpvc.

_____ (2008a). *Alternatives to Polyvinyl Chloride (PVC) Medical Devices for the Neonatal Intensive Care Unit (NICU).* www.noharm.org/lib/downloads/pvc/Alternatives_to_PVC_in_NICU.pdf.

_____ (2008b) *Alternatives to Polyvinyl Chloride (PVC) and Di(2-Ethylhexyl) Phthalate (DEHP Medical Devices.* www.noharm.org/lib/downloads/pvc/Alternatives_to_PVC_DEHP.pdf.

Hites, R. (2004). Polybrominated diphenyl ethers in the environment and people: A meta analysis of concentrations. *Environmental Science Technology*, 38:945–956.

Inoue, K., F. Okada, R. Ito et al. (2004). Perfluorooctane sulfonate (PFOS) and related perfluorinated compounds in human maternal and cord blood samples: Assessment of PFOS exposure in a susceptible population pregnancy. *Environmental Health Perspectives.* 112 (11):1204–1207.

International Living Future Institute [ILFI]. (2006), Living Building Challenge Red List, www.ilbi.org/lbc. Accessed 7/1/2012.

Kaiser Permanente. (2006). National Environmental Purchasing Policy. www.sehn.org/rtfdocs/KP_EPP_Policy_rev._04.12.06.doc.

______ (2010). Kaiser Permanente Launches Sustainability Scorecard for Medical Products, http://xnet.kp.org/newscenter/pressreleases/nat/2010/050410sustainability.html.

Kannan, K., S. Corsolini, J. Falandysz et al. (2004). Perfluorooctanesulfonate and related fluorochemicals in human blood from several countries. *Environmental Science and Technology.* 38 (17):4489–4495.

Lunder, S., and R. Sharp (2003). *Mother's Milk: Record Levels of Toxic Fire Retardants Found in American Mothers' Breast Milk.* Washington, DC: Environmental Working Group.

Meironyte, D., K. Noren, and A. Bergman (1999). Analysis of polybrominated diphenyl ethers in Swedish human milk: A time-related trend study, 1972–1997. *Journal of Toxicology and Environmental Health Part A.* 58 (6):329–341.

Perkins+Will [P+W] (2009). Perkins+Will Precautionary List, http://transparency.perkinswill.com. Accessed 7/1/2012.

Premier (2004). Premier's Position Statement: Environmentally preferable purchasing. www.premierinc.com/safety/topics/epp/#Premier's position on EPP.

Schecter, A., P. Cramer, O Päpke et al. (2001). Intake of dioxins and related compounds from food in the U.S. population. *Journal of Toxicology and Environmental Health.* 63 (1):1–18.

Stein, J., T. Schettler, D. Wallinga, and M. Valenti (2002). In harm's way: Toxic threats to child development. *Journal of Developmental and Behavioral Pediatrics.* 23(0): Supplement, S13–S22.

Stockholm Convention on Persistent Organic Pollutants (POPs). (2001). www.pops.int.

U.S. Green Building Council [USGBC]. (2013). Personal communication with Jeremy Sigmon, 1/14/13.

U.S. Green Building Council [USGBC]. (2012). Pilot Credit 54: Avoidance of Chemicals of Concern, www.usgbc.org/ShowFile.aspx?DocumentID=10107. Accessed 12/19/2012.

U.S. Green Building Council [USGBC]. (2010). LEED 2009 for Healthcare, www.usgbc.org/DisplayPage.aspx?CMSPageID=1765. Accessed 7/1/2012.

______ (2010a). Pilot Credit 11: Chemical Avoidance in Building Materials. www.usgbc.org/ShowFile.aspx?DocumentID=8149. Accessed 7/1/2012.

Washington State Department of Ecology [WSDE] (2005). Memorandum of Understanding: Washington State Department of Ecology and Washington State Hospital Association. www.ecy.wa.gov/mercury/hospitals/hospital_mou.html.

Weeks, J. (2006). PBT Profiler Use in Industry to Screen HPV Chemicals: SC Johnson Case Study. PowerPoint presentation at First U.S. Conference on Characterizing Chemicals in Commerce: Using Data on High Production Volume (HPV) Chemicals, Austin, TX, December.

Yeung, L.W.Y., M. K. So, G. Jiang et al. (2006). Perfluorooctanesulfate and related fluorochemicals in human blood samples from China. *Environmental Science Technology.* 40 (3):715–720.

CHAPTER 6

MEASURING VALUE

> When one tugs at a single thing in nature, one finds it attached to the rest of the world.
>
> JOHN MUIR

> Ever since sustainability became foreshortened as a quantifiable term in public consciousness, i.e., reduced purely to measurements of energy use, it has become fashionable, achieving wide recognition as a discipline. The many facts and more subtle aspects of sustainability, for example the unity of nature and the human being, or the long overdue redefinition of "comfort," are essentially lost in the shuffle. Here too, the prevalent orientation is apparently exclusively to the quantifiable. It is important to counter this development.
>
> BEHNISCH, BEHNISCH & PARTNER

INTRODUCTION

In *Redefining Health Care: Creating Value-Based Competition on Results*, business strategist Michael Porter and innovation expert Elizabeth Olmsted Teisberg (2006) begin their analysis of the U.S. health system with a sweeping critique: "The U.S. health care system is on a dangerous path, with a toxic combination of high costs, uneven quality, frequent errors, and limited access to care." Their central thesis—that hospitals are failing to deliver value to patients—corresponds with trends linking value to mission and differentiates healthcare's definition of bottom line from other businesses. In "The Big Idea: How to Solve the Cost Crisis in Health Care," business professor Robert S. Kaplan and Michael Porter (2011) posit, "More care and more expensive care is not necessarily better care." Porter, Teisberg, and Kaplan aim to convert the dysfunctional U.S. healthcare system into one in which value-based competition produces better health outcomes and greater efficiency.

It is, indeed, a system ripe for improvement. At more than 18 percent of the gross domestic product (NCHC 2011), the U.S. healthcare system is the most expensive in the world with annual spending of about $2 trillion (OECD 2010). Approximately 75 percent of every dollar spent is associated with the treatment of chronic diseases (CDC 2009), with many of those diseases linked to the consequences of the built environment—where we build, what we build with, how we build, and how we operate. Fueled by cancer and looming epidemics of obesity and asthma, among other chronic diseases, the U.S. Congressional Budget Office (CBO) projects healthcare expenditures to reach 25 percent by 2025.

> *Healthy competition is competition to improve value for customers, or the quality of products or services relative to their price. It leads to relentless improvements in efficiency. Product quality and customer service improve. Innovation propels advances in the state of the art. Quality adjusted prices fall, and the market expands and more customer needs are met. Choice expands. It is a far cry from what we see today in health care.*
>
> —Porter and Teisberg (2006)

Other factors contribute to this explosive growth, including some not immediately evident. For example, the CBO finds that "... the most important factor to the growth in health care spending in recent decades has been the emergence, adoption, and widespread diffusion of new medical technologies and services" (Orszag 2008). In a completely different realm, the U.S. healthcare system spends more than $20 billion each year to manage antibiotic resistant infections (Roberts et al. 2009), approximately 10 percent of total annual expenditures.

By virtue of the services it provides and the intrinsic public trust it holds, healthcare is held to higher moral and ethical standards than virtually any other business sector. One demonstration of this is a blurring of distinction between for-profit and nonprofit hospitals. While U.S. nonprofit hospitals have a legal obligation to deliver community benefit, it is common for for-profit systems to also make investments in this realm. Healthcare providers recognize the value of community health as a visible connection with mission—and as a means to gain advantage in a competitive marketplace (Schlessinger and Gray 1998).

Increasingly, as the causal links between public health, environmental quality, and buildings are better understood, the reasons for extending the definition of community benefit beyond public health to include environmental stewardship become axiomatic. Joined with the necessity to be economically sustainable, this broader construct is underpinning how today's hospitals are defined. Triple bottom line accounting—marrying the measures of economy, community, and environment—resonate with the Hippocratic Oath, "First, do no harm" and is a powerful framework for a mission-driven sector in which the values of health and healing—applied at facility, regional, and global scales—ultimately define success.

Triple bottom line accounting is bolstered by U.S. and international green building protocols customized for the healthcare sector that both include and prioritize health-based metrics—a distinct enterprise from tools designed for other building sectors, reflecting healthcare's technical sophistication, complex programs, and the fundamental nature of the activities that happen within their walls—health promotion and healing (see Chapter 5). The promise of quantifying performance benefits makes such tools an essential element of the contemporary healthcare design rubric, and elicits these questions: What defines a high-performance healing environment? What are the values inherent in the healthcare sector that position them as the measures of success?

This chapter explores the complex, multidimensional value proposition for sustainable building in the healthcare sector. It examines triple bottom line precepts to define three distinct value streams: economic, social (equity), and environmental. It includes summary data from a 2012 study of capital cost premiums associated with green healthcare facility design and construction; insights gained from a 2012 study identifying savings from sector-wide implementation of four operational efficiency standards; and the financial implications for a hospital to meet the Living Building Challenge.

HEALTHCARE AND THE TRIPLE BOTTOM LINE

The idea of a triple bottom line dates back to the mid-1990s (SustainAbility and UNEP 2002) and gained popularity with the 1998 publication of the British edition of John Elkington's *Cannibals with Forks: The Triple Bottom Line of 21st Century Business.* The triple bottom line concept describes a framework for measuring and reporting business performance against economic, social, and environmental parameters, rather than simply maximizing profits or growth. Figure 6.1 demonstrates the triple bottom line of socially responsible businesses, which seek to integrate these values in their products and services.

That the healthcare industry has a responsibility beyond the economic bottom line is undeniable. David Lawrence (2000), a former CEO of Kaiser Permanente, said, "Just as we have responsibility for providing quality patient care [and] . . . keeping our facilities and technology up to date, we have a responsibility for providing leadership in the environment." Lloyd Dean (2000) of Dignity Health (formerly Catholic Healthcare West) agreed: "We will not have healthy individuals, healthy families, and healthy communities if we do not have clean air, clean water, and healthy soil."

Globally, leading government-financed single-payer systems are increasingly balancing triple bottom line concerns. Dominated by government-sponsored care and nonprofit organizations, the U.S. healthcare industry is always engaged in triple bottom line accounting. Healthcare service lines are developed and continued despite poor economic performance for the sake of social and health needs. U.S. healthcare executives often use the concept of "margin into mission" to describe the notion of using economic margins generated from disease-care to fund a range of services that have no economic "return." If U.S. healthcare organizations based their service decisions solely on economic criteria, the system would be very different indeed!

For U.S. healthcare organizations, this perspective provides a complex decision-making structure that attempts to balance multiple priorities. In essence, there are multiple business cases, each responding to a different aspect of the triple bottom line. An economic business case is required for healthcare operations executives; a health, safety, and quality business case is persuasive to medical leadership. The environmental, vision, and values business case may be appropriate for chief executives and boards. Governing principles for the healthcare sector and its margin-to-mission reality are more complex and multidimensional than simple economic accounting might suggest. Ultimately, the task for healthcare leaders is to weave together a unified case for change.

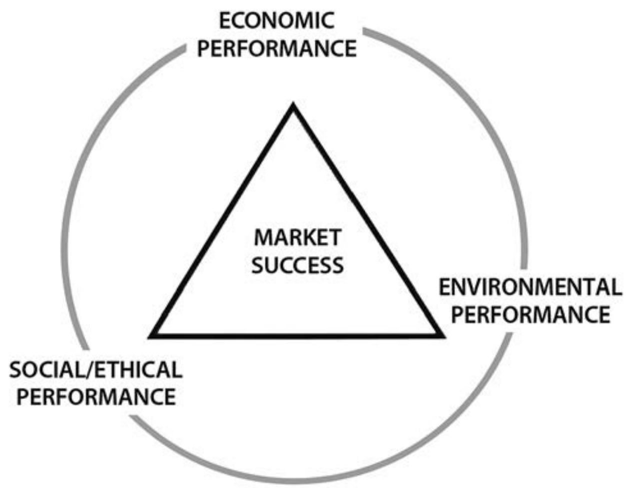


Figure 6.1 Triple bottom line frameworks balance economic, ethical (social), and environmental issues to determine optimal intersections.

THE ECONOMICS OF SUSTAINABLE HEALTHCARE

Between 2008 and 2011, green building as a percent of U.S. healthcare construction grew from 13 to 35 percent: a 23 percent increase, with a doubling of overall investment, from $4 billion to $8 billion over this same timeframe—an astonishing trend in the midst of an economic downturn (McCook 2012). This may well be a marker of transitioning from green building as the domain of innovators, early adopters, and visionaries, to that of early majority pragmatists and late majority conservatives, as the broader market gains more confidence in new design approaches, products, and technical systems (see Chapter 5).

Yet, despite these favorable statistics, questions persist about costs associated with green healthcare facilities, and whether capital cost premiums—if they even exist beyond a nominal amount—are justified. A persistent notion in today's market is that green buildings cost more. "More than what?" is the first question that should be carefully framed. Does a green hospital cost more than the exact same building without the green features (also termed a "brown building")? More than the available capital budget? Or more than a neighboring comparable building of the same size and complexity? Does it cost more to construct, or more to construct and operate over its lifetime? A related question is, of course, just how much does a hospital cost to construct? And, finally, what is the cost of not constructing a green hospital, particularly in the context of measuring triple bottom line values? Already, it is clear that this is a complex question requiring careful analysis and response.

With more than 15,400 LEED certified commercial buildings globally as of December 2012 (USGBC 2012), accompanied by a range of studies assessing the costs and benefits of green building generally and green healthcare buildings specifically, the economic value proposition is influencing the global market reality. Common to most analyses is that integrated design is central to a positive business case; that is, that sustainable design strategies are not simply individually layered on to conventional buildings, but rather work together to create economies and value. Describing this phenomenon as "tunneling through the cost barrier," researchers at the Rocky Mountain Institute postulated that while capital costs would initially increase as sustainable building features were added on to conventional buildings, an integrated design process would ultimately lead to synergies between building systems that would drive initial construction costs lower than conventional construction. In fact, a number of cost studies, as well as case studies in this book, have realized exactly this outcome (Figure 6.2).

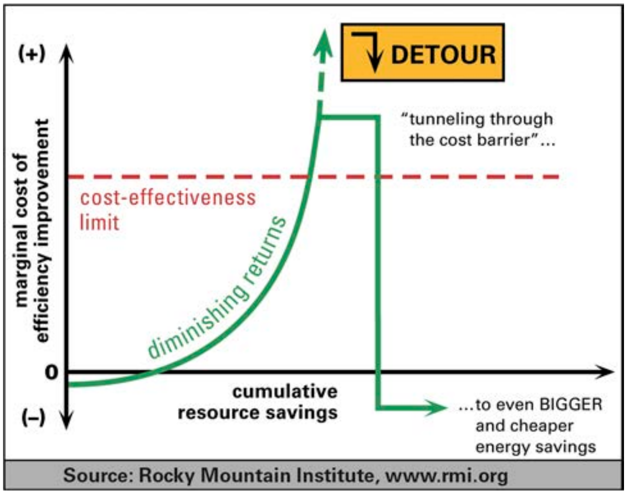


Figure 6.2 This cost model proposes that as strategies are added to produce increased cumulative resource savings, a cost-effectiveness limit is reached, after which strategies no longer produce resource savings. However, stretching design beyond this boundary condition will ultimately "tunnel through the cost barrier," with system synergies that realize more resource savings with lower costs. *Credit: Rocky Mountain Institute*

As early as 2003, studies based on completed green buildings demonstrated that anticipated capital cost premiums have been largely overstated, especially as green building practices and expertise mature:

- A 2003 article in *Building Design and Construction* magazine concluded that many green buildings cost no more than their brown equivalents (Cassidy 2003).
- Greg Kats' (2010) study analyzed 170 green buildings and found a median 1.5 percent first cost premium as compared to conventional buildings.
- Factoring in direct and indirect benefits such as operational energy and water savings, and emissions reductions, a positive return on investment (ROI) offsets the premium over the early years of facility operation.

Importantly, these studies point to a consistent set of key factors that influence building costs across building sectors, including:

- The earlier the green features are incorporated into the design, the lower the cost.
- Costs decline with increasing experience and as market transformation occurs.

> *"The cost of green building is minimal—and makes for a very good investment. From energy savings alone, the average payback time for a green building is six years. Additional benefits include reduced water and infrastructure costs, and health and productivity gains; these benefits more than double the financial gains for green building owners and occupants. Over twenty years, the financial payback commonly exceeds the additional cost of greening by a factor of between four and six. And broader benefits, such as reductions in greenhouse gases and pollution, have large positive impacts on surrounding communities and on the planet."*
>
> —Greg Kats (2010)

- Green buildings provide financial benefits that brown buildings do not.
- Higher LEED certification levels do not directly correlate with higher first costs.

In 2008, *Demystifying the First Cost Green Building Premiums in Healthcare* reviewed the capital cost premiums associated with green buildings in the healthcare sector through interviews with 13 LEED certified project teams. Key findings include (Houghton, Vittori and Guenther 2009):

- Projects are achieving a broad range of energy demand reductions; a limited subset of projects are using projected reductions in operating costs as a component of a business case for increased capital spending.
- First-cost premiums range from 0 to 5 percent before financial incentives are accounted for, and 0 to 3.8 percent after financial incentives are included. In this study, financial incentives include philanthropic gifts, grant programs, and public or utility incentive programs.
- First-cost premiums do not directly correlate with the project's LEED certification level. Indeed, consistent with other studies, healthcare facilities achieving LEED-Gold or -Platinum certification do not bear higher first-cost premiums than those that achieve LEED-Certified or -Silver.
- Projects that achieved LEED certification early in this decade indicated higher premiums than those achieving certification later. In general, consistent with other studies, projects are trending toward reduced first-cost premiums over time.
- Projects are benefiting from a wide range of financial incentive programs and private philanthropy, which are leading to higher levels of sustainable building achievement across a broad range of strategies.
- Benefits attributed to green building include productivity/health benefits, staff recruitment/retention, and improved community perception; however, these benefits are difficult to quantify and are beyond the scope of this analysis.

In addition, the study noted that the baseline of healthcare design is changing, as a wider and more affordable range of sustainable materials and systems enter the marketplace. Green design strategies that were included as premiums in early projects, either because of lack of market-available alternatives or the perception of "above standard" solutions, have become embedded in the definition of a baseline healthcare building today. Further, many "premium" and environmentally preferable products have additional performance benefits, so their environmental attributes are simply seen as a co-benefit. Most surprising, the study concluded that while the actual building components included in the first-cost premium are widely variable, the overall aggregate premiums fell within a fairly narrow range.

In 2012, architectural researcher Breeze Glazer, with the authors, updated and expanded the 2008 study to understand current trends in capital cost green premiums, drivers for green building, and benefits. The 2012 findings yield similar results as the 2008 study: capital cost green premiums range from 0 to 5 percent, with an average of 1.24 percent, and result in operational cost savings and improved health and environmental outcomes.

LEED CERTIFIED HOSPITALS: PERSPECTIVES ON CAPITAL COST PREMIUMS AND OPERATIONAL BENEFITS

Breeze Glazer, Robin Guenther, and Gail Vittori

Since the release of *Demystifying First Cost Green Building Premiums in Healthcare* in 2008, there has been a decided shift in the landscape as LEED® has become a design and construction standard for many healthcare organizations. In 2011, Health Facilities Management reported: "Hospitals increasingly are embracing the idea that going greener is cost-effective over the long run. 60 percent were evaluating the cost and benefit of green construction methods for most or all projects, up sharply from a year earlier." At the same time, the ongoing global recession has put an even greater emphasis on cost control and reducing or eliminating what may be perceived as "unnecessary" capital costs. With this shifting market dynamic, questions still remain concerning the capital cost premium for hospitals and other healthcare facilities to achieve LEED certification—questions about how much added capital, whether higher achieving projects correlate with higher capital investments, and uncertainty about the value proposition—direct and indirect benefits—associated with LEED certification. A plethora of recent industry reports and surveys (DPR, The Future of Healthcare, 2012; Healthcare Facility Management Energy Survey 2011) suggest healthcare institutions may be placing a lower priority on LEED certification in the future because of perceptions of additional costs with little evidence of value.

Despite an increasing number of completed healthcare projects, there has been virtually no consolidated survey of market data centered on these questions since the 2008 study. In fact, the 2008 study concluded that capital cost premiums, then an average of 2.4 percent, appeared to be decreasing over time, reflecting design and construction teams' increased knowledge of and facility with green materials and methods, and continued development of competitively priced, market-available technologies. Nearly five years later, this study, based on interviews with project design teams representing 15 LEED-certified hospitals completed between 2010 and 2012, expands and updates the 2008 study to better understand how capital cost green building premiums have evolved, reasons that influence hospitals' decisions to pursue LEED certification, and what future trends are on the horizon.

The Study Project Participants

The 2008 study included data on 8 hospitals certified as of the end of 2007. From the projects certified since 2008, fifteen additional LEED for New Construction (LEED NC) certified U.S. hospitals were selected for this study, representing a range of sizes and geographic locations. Together with the prior subjects, this combined cohort includes approximately one-third of the total LEED certified hospitals. Unlike the previous study that included ambulatory care and mixed-use projects, only hospitals—both new construction and major additions—were selected for this update. There remains an industry perception that the inherent complexities of a 24/7 acute care hospital project necessitate a higher capital cost premium to achieve LEED certification using a rating system created primarily for commercial office buildings (i.e., LEED for New Construction) compared to ambulatory healthcare spaces, considered to share more similarities to commercial offices in construction costs and capital cost premiums, for which research already exists in the public realm.

The 15 selected hospitals for this study (Figure 6.3), completed between 2010 and 2012, range in size from 49,000 to 849,000 sq. ft. (4,552 – 78,875 sq. m); they represent diverse geographic regions, contexts, and include all certification levels. Architects and sustainability consultants from 12 firms constitute the majority of study participants, who completed both a standard-

Figure 6.3 Sample hospitals: Fifteen LEED for New Construction (LEED NC) –certified U.S. hospitals were selected for this study, representing a range of LEED certification levels, sizes, and geographic locations. *Source: Breeze Glazer*

ized web-based information survey and telephone interview. The data were compiled and analyzed both as a unique set and combined with projects from the 2008 study.

Green Building Capital Cost Premiums—Perceptions and Challenges

Anecdotally, the majority of the 2012 study respondents believe that capital cost green premiums have decreased over the last five years; consistent with the findings of the 2008 report, they believe there is not a significant cost difference between green hospitals and standard hospital buildings today. While they differ in their perception of the magnitude of the premiums today, most see at best only minor reductions in capital cost premiums over the next five years. This is likely based on two factors:

- Cost parity between "green" and "standard" methods and materials has nearly been achieved and so no further reductions in "premium" are possible.
- "Standard" hospitals today are incorporating sustainable features in the basis of design; truly "brown" hospitals are becoming virtually non-existent as a baseline comparison.

Consistent with the 2008 study, projects that reported zero first-cost green building premiums delivered a LEED-certified project within the established budget; hence they did not track or report the additional capital costs associated with specific sustainable strategies. Conversely, projects that reported premiums tracked the capital cost of specific strategies or design options as additional costs to the project, regardless of the basis of design and budget parameters. The 2008 study reported little consistency about specific strategies that were included in premiums; this study revisited this question as well as the role of grants and incentives.

For most of the 15 hospitals in the 2012 sample, LEED was not included in the original project basis of design and budget; it was typically incorporated during the schematic design phase, and, for several, even later in the design development and construction document phases. This undoubtedly reflects the limited albeit rapid uptake of LEED during the 2004 to 2007 period when major projects completed in 2010 to 2012 were initiated. Related, respondents shared that the most significant obstacles to controlling capital cost green premiums was lack of clear design goal and mid-stream attempts to pursue LEED. The second most commonly cited barrier was the project teams' lack of experience with LEED.

The data also revealed a trend toward LEED "over-achievement": 56 percent of hospitals achieved a higher LEED certification level than initially planned, with Silver to Gold the most common increase. This reflects the growing expertise of design and construction teams and corresponds with a consistent theme articulated by the study respondents: achieving LEED Silver-certification is the cost neutral performance baseline and standard practice for many design and construction firms. LEED Gold was the "stretch goal" for many in this cohort; in the future, LEED Gold-certification will become the new baseline.

Sustainable Design Drivers

Why healthcare organizations choose to pursue LEED certification is multifaceted; understanding what influences these decisions can reveal the value proposition for healthcare owners. Respondents were asked to rank seven sustainable design drivers (note: these rankings reflect perspectives of design team representatives, not hospital owners). *Civic Leadership* was selected as the most important driver, followed closely by *Occupant Health & Safety* and *Community Benefit*. Strategies that improve indoor air quality, for example, or staff respite are important to project teams and owners. Also driving these strategies is a business and marketing advantage: 40 percent of respondents stated that the hospital gained a competitive advantage from achieving LEED certification.

Defining the Capital Cost Green Premium

The 2008 study reported that the industry lacked a standard definition of a capital cost premium associated with green building; the question was again posed for the 2012 update to understand if this had changed. Respondents were provided four commonly used definitions and asked to select any and all that aligned with their understanding. The exercise confirmed that no consistent definition exists across the industry (or even within individual project teams): 60 percent of respondents selected two or more and 50 percent selected three or more definitions (Figure 6.4).

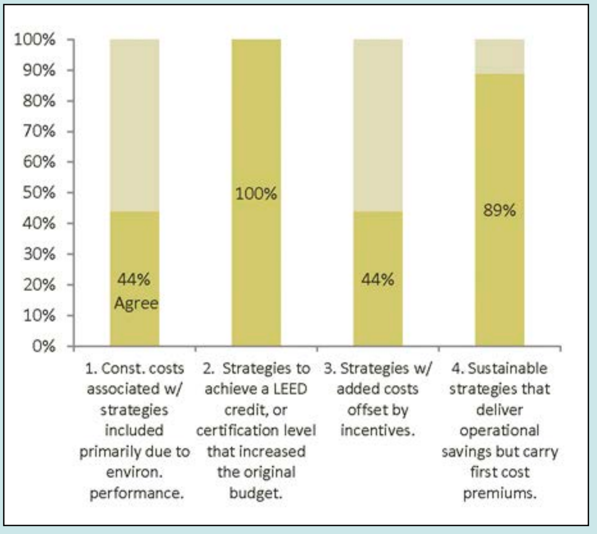


Figure 6.4 Defining the cost premium: Respondents were asked to define their understanding of a capital cost premium; the results confirm that no consistent definition exists across the industry (or even within a single project team). Despite this lack of consistency, reported cost premiums fall within a relatively narrow range. *Source: Breeze Glazer*

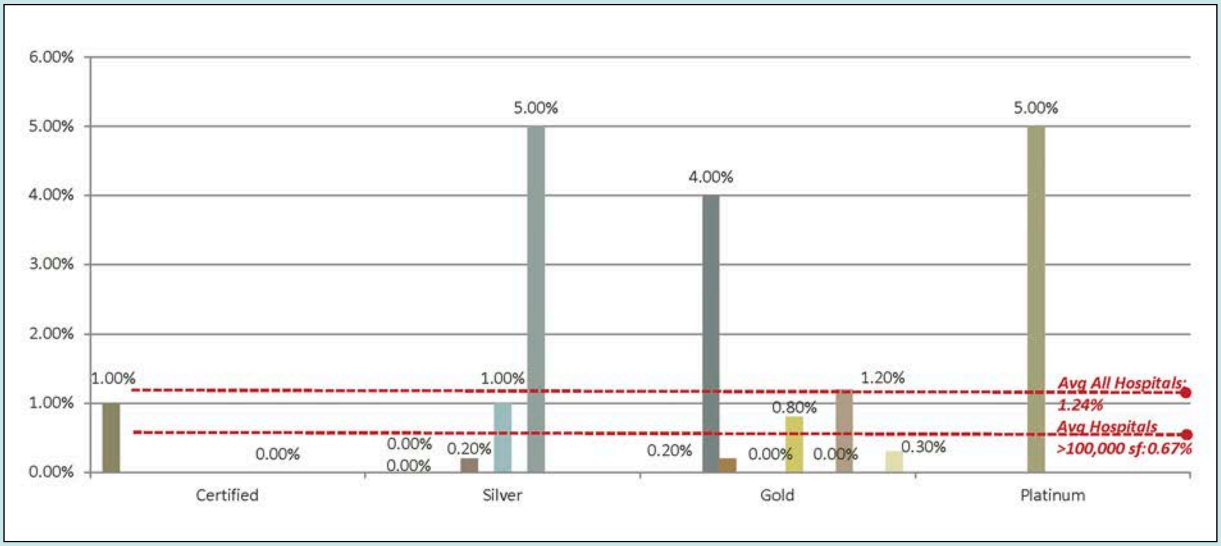


Figure 6.5 Capital cost premiums: The reported capital cost green premiums for the 15 hospitals average 1.24%. For the 13 sample hospitals greater than 100,000 sq. ft. (9,290 sq. m), the average capital cost green premium was less than 1 percent, or 0.67 percent. The results are consistent with a key finding from the 2008 study: There is no established correlation between LEED achievement level and capital cost green premiums. *Source: Breeze Glazer*

Follow-up interviews with respondents determined that the most common definition of a capital cost green premium is "an increase in the established project budget." Hence, a zero percent capital cost green premium is reported for projects for which the budget was not increased after LEED was incorporated; i.e., projects for which sustainable strategies are incorporated within an initial basis of design or subsequently incorporated with no increase in project budget. For the 2012 study hospitals, one-third reported a zero percent capital cost green premium.

For the 15 hospitals in this study, capital cost green premiums were calculated using three distinct methodologies depending on the data provided by respondents:

1. A self-reported aggregate premium (calculated by the project team)
2. An aggregate premium calculated by the research team based on individual strategy cost information provided by respondents for components they defined as included in a capital cost premium
3. The incremental increase from the original construction budget attributed to green building strategies that was developed for the project (often calculated by other members of the project team)

The reported capital cost green premiums for the 15 hospitals range from 0 to 5 percent, the same as for the 2008 study, with an average of 1.24 percent (Figure 6.5). For the 2012 study, the two highest capital cost green premiums were reported by the two smallest hospitals in the sample, both under 100,000 sq. ft. (9,290 sq. m). While not a focus of this research study, this correlation prompts an important question as to whether there is a relationship between economy of scale/facility size and capital cost. The researchers found that for the 13 sample hospitals greater than 100,000 sq. ft. (9,290 sq. m), the average capital cost green premium was *less than 1 percent,* or 0.67 percent. Both averages from the 2012 study—the overall average and that associated with the hospitals <100,000 sq. ft.—are lower than those of the 2008 study which reported an average capital cost green premium of 2.4 percent before applying grants and incentives (2.1 percent for projects under 100,000 sq. ft.). This supports a continued downward trend of capital cost premiums over the last nine years, approaching cost neutrality (Figure 6.6).

The 2012 study results are also consistent with a key finding from the 2008 study: There is no established correlation between LEED achievement level and capital cost green premiums. The findings from the 2012 study sample were aggregated with the results from the 2008 study to establish an average capital cost premium of 1.2 percent across 28 LEED certified healthcare projects. Although the methodologies vary for defining the cost premiums in this study, they all fall within a relatively narrow range.

Respondents were asked to identify individual strategies across all LEED credit categories that contribute to a capital cost green premium, regardless of impact on budget or whether the strategies produce operational savings or performance benefits. Many of the most commonly cited strategies deliver significant operational performance benefits, such as low flow water fixtures, optimized energy systems and enhanced commissioning; hence, they were included in projects despite the additional capital cost. Bicycle storage remains a common cost premium item and the highest ranked among the 2012 respondents; many hospitals pursue this strategy purely to achieve the associated LEED point despite low expectations of

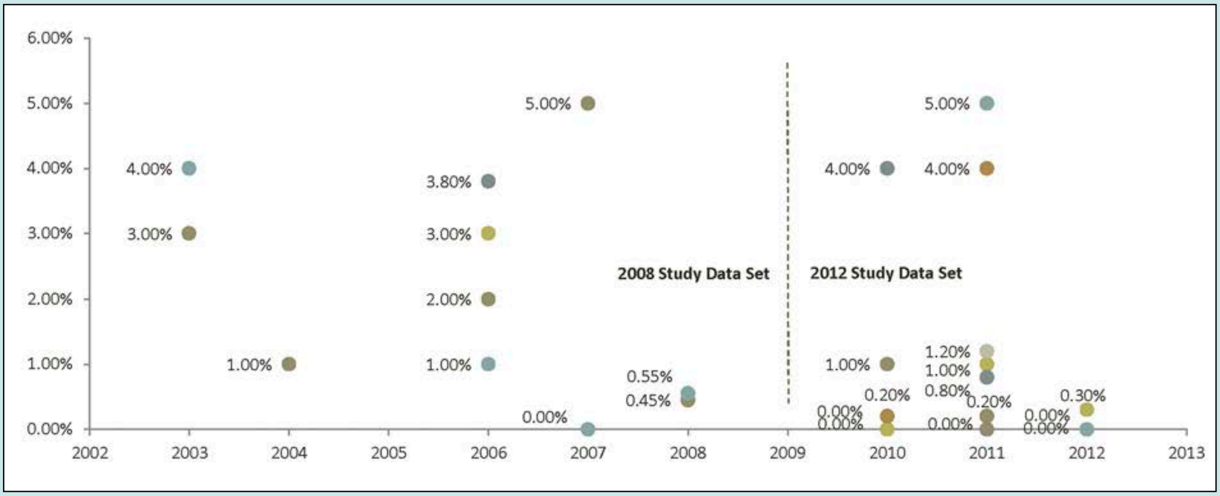


Figure 6.6 Capital cost premium trends: The findings from the 2012 study sample were aggregated with the results from the 2008 study to establish an average capital cost premium of 1.2% across 28 LEED certified healthcare projects. The data convey a clear downward trend in capital cost premiums over time. *Source: Breeze Glazer*

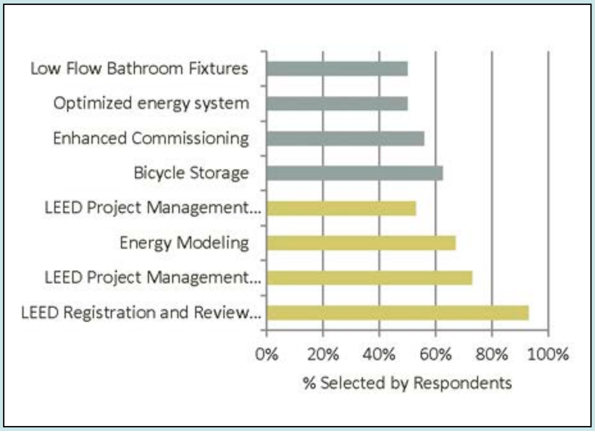


Figure 6.7 Capital cost premium components: Respondents were asked to identify individual strategies that contributed to a capital cost green premium, regardless of impact on budget. Many of the commonly cited capital cost premiums include strategies that deliver operational performance benefits, in addition to soft costs associated with LEED certification.

bicycle use among building occupants (Figure 6.7). Beyond this initial group of strategies, there is significant variability among strategies selected by respondents supporting the 2008 study conclusion that there is no common understanding of which components contribute to a capital cost green premium.

On the other hand, there is common consensus with regards to soft costs, i.e., costs associated with the process of obtaining LEED certification. These soft costs represent an isolated premium only faced by projects pursuing LEED certification and may become more pronounced in the future as even greater cost parity is reached with respect to hard cost elements, i.e., mechanical system and material choices. The 2008 study noted that the costs associated with LEED certification were not generally included if and when LEED certification was a requirement of a grant or incentive program; presumably the incentive dollars "paid for" the additional cost of certification.

Financial Incentives

There appears to have been a shift in the use of green building grants and incentives by hospitals pursuing LEED certification, from 61 percent of sample projects in the 2008 study to only 20 percent in the 2012 sample. External funding for the hospitals in the 2012 sample included grants for green roofs, energy performance and on-site renewable energy systems. This study did not examine the reasons behind this reduction; it may be related to diminishing funding opportunities as a result of the financial recession, a shift in philanthropic priorities, or that incentives are no longer required to support strategies as they have become standard practice. Regardless, no respondents reported that the lack of a grant or incentive prevented them from achieving a desired LEED certification level.

The LEED Platinum critical-access hospital in the 2012 sample received federal and corporate grants and incentives to offset the majority of the 5 percent cost premium. Kiowa County Memorial Hospital includes robust on-site renewable wind energy systems to provide the entire base energy load of the facility representing approximately 40 percent of total energy use. The cost of the turbine is the major contributor to the 5 percent premium—since the hospital itself is just over 50,000 sq. ft. (4,645 sq. m). In addition, the hospital also offsets water use by 57 percent and incorporates on-site bioswales to treat stormwater and greywater. Together, these systems reduce the energy load on the municipal power grid and reduce potable water and sewage usage while solving a significant drainage problem for the city.

The Cost of Certification

The study posed this question: What is the value of LEED certification compared to simply building to a "LEED equivalent" and foregoing certification? In the healthcare industry, increasing questions concerning the value of actual certification are arising, confirmed by project teams and interviews with construction firms. Construction firms note that owners are increasingly asking to "design to LEED standards" without engaging in certification processes.

Based on this study's findings, and those of 2008, LEED certification costs typically represent somewhere in the range of 0.05 to 0.1 percent of a hospital's total construction budget, largely depending on its size. More often than not, owners or design and construction teams reluctant to expend the level of effort required to successfully navigate the relatively rigorous LEED certification process will identify higher costs as a deterrent.

All teams agreed that costs associated with LEED certification include the fees paid to the Green Building Certification Institute (GBCI) and team members for required documentation; some participants included the costs of energy modeling and enhanced commissioning. In fact, energy modeling is key to understanding the energy impact of design decision-making regardless of LEED certification intent; any and all energy-responsive buildings require energy modeling. Likewise, enhanced commissioning ensures that building operators understand how to operate sustainable systems, and that the predicted savings are actually achieved. Again, this task is relatively independent of the intent to obtain certification. The fees associated with energy modeling and enhanced commissioning can be significant; hence both the variation in including these costs within the cost of certification lead to significant differences in reported total cost. A related research study is required to compare the operational performance of LEED certified hospitals to hospitals that only incorporated green features.

Operational Benefits

This study quantified the capital cost green premium of LEED certified healthcare buildings, but that is only one aspect of establishing the value proposition. Are projects estimating the operational savings associated with energy, water, site planning and material strategies? Are projects quantifying the human and environmental health benefits realized from building a LEED certified vs. conventional hospital? Operational benefits provide hospitals with a financial return on investment; however, there is a glaring lack of operational benefit data from completed facilities. Indeed, design teams, including the respondents to this study, often lack access to operational data when trying to make the case to pursue LEED certification, as well as consensus findings on human and environmental health benefits. Less than one-third (29 percent) of the 15 sample hospitals reported to have completed a post-occupancy evaluation (POE). On the other hand, in the healthcare sector and more generally, POEs are only beginning to be viewed as an important mechanism to gauge the effectiveness and associated benefits of a range of design strategies; thus the reported 29 percent should not be viewed as representative of the industry average, which could be higher or lower. This, too, is an area that requires further research.

A common trend expressed by respondents is a groundswell in healthcare organizations' interest to reduce operational utility costs by optimizing energy and water systems. A majority of the sample hospitals are tracking energy performance and savings over time, and most are also tracking water savings. Nearly half of respondents reported cost savings to the local municipality from stormwater-related reductions, including innovative on-site management through strategies such as pervious paving and infiltration planters. One hospital partnered with its county on a landfill gas infrastructure project that harvests waste methane used as fuel to produce heat and hot water. This system provides the hospital with clean-burning thermal energy while lowering the carbon emissions for the town and reducing demand on the municipal power grid. Even so, utility costs constitute a relatively small portion of a hospital's annual operating budget; of far greater magnitude are employee costs.

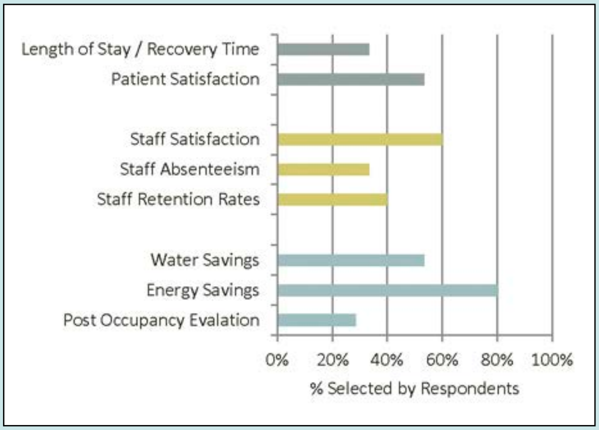


Figure 6.8 Evaluating operational benefits: Operational benefits are being tracked over time; respondents identified the hospitals that are conducting post-occupancy evaluations; evaluating impacts on staff and patients, along with tracking utility costs.

Respondents noted that for many healthcare organizations, measuring impacts on staff was important, with measurements of retention rates, absenteeism, and most commonly, increased staff satisfaction reported. Lastly, almost 50 percent of the hospitals sampled are evaluating patient-related impacts, such as patient and staff satisfaction and changes to average length of stay attributable to their sustainable buildings (see Figure 6.8). For both healthcare organizations and design firms, the relationship of the built environment on improved patient health outcomes and staff well-being and performance is the most important benefit to be understood and will likely guide healthcare design research for many years to come.

Conclusion/Forecasting

The overarching aim of this study is to provide the industry with current empirical data on the capital cost green premiums associated with LEED certified hospitals. The value of the data cannot be overstated: While the cost difference between green and standard hospital construction today is relatively minimal, the environmental and resource-use differences can be significant.

The data show that capital cost green premiums are generally lower than commonly perceived and can approach cost neutrality when integrated into the basis of design and budget at the earliest design phase. As capital cost premiums related to sustainable strategies continue to decrease, the soft costs required to pursue LEED certification will become more apparent. Concurrently, 40 percent of survey respondents shared that their healthcare clients may be less likely to pursue LEED certification in the future, while still adhering to LEED credit strategies. When considering the objectives conveyed by healthcare organizations, along with the due diligence, accountability, and third-party verification provided by the LEED review process, LEED certification is in fact one of the more sound investments a hospital can make in today's economy, delivering measurable economic, environmental, and human health benefits.

"The cost of green" is a persistent theme, and a real and perceived barrier to the widespread adoption of more innovative building systems that carry significant first cost premiums. As the case studies in this book reveal, for countries with much higher fossil fuel costs there is a fundamentally different calculus about prioritizing high-performance, low-energy buildings and accepting return-on-investment thresholds in excess of ten years to realize them. Clearly, the U.S. reliance on subsidized, low-cost fossil fuel energy has been a significant obstacle to achieving higher performance, low-energy solutions. The good news is that projects in this book from the U.S., such as Gundersen LaCrosse Hospital Addition (Case Study 19, Chapter 7) and Swedish Medical Center, Issaquah (Case Study 35, Chapter 8), show that this may in fact be changing for leadership healthcare systems.

TRADING CAPITAL COST FOR OPERATIONAL SAVINGS

While modest capital cost premiums are sometimes associated with green strategies, many deliver operational savings: reduced energy and water costs and ongoing maintenance costs. Healthcare organizations are devising creative ways to find incremental capital to invest in strategies that deliver long-term operational savings. Much of the acute-care hospital infrastructure around the globe is government-sponsored, where operational savings accrue to the publicly funded healthcare system. In the European Union, for example, innovative energy systems with a fifteen-year payback (at relatively high fossil fuel costs) are implemented. Akershus University Hospital (Case Study 21, Chapter 8), for example, has one of the largest ground-source heat pump systems in Europe and one of the lowest energy use intensities (EUIs) of the featured case studies. Acute-care hospitals in the United States, generally designed for fifty-year-plus life spans, are primarily owner-occupied; hence, hospital owners should be receptive to longer payback periods on design elements that reduce energy consumption. Houghton, Vittori, and Guenther (2009) note:

> The U.S. healthcare industry is deeply divided when it comes to delivering additional capital dollars linked to operational savings—some organizations are able to manage this financial model, while others report difficulty converting operational savings to funding for additional capital. This remains an important and provocative issue that profoundly impacts the sector's ability to implement advanced technologies and energy demand reduction strategies.

Many of the case studies and featured healthcare systems in this book employ some aspect of return-on-investment calculations to justify investments in energy efficiency measures. For example:

- Providence Health & Services (see Figure 6.9 and Chapter 7) employs return-on-investment methodologies to make the case for using operational savings to fund first-cost premiums necessary to purchase energy conservation technologies.
- Partners HealthCare (see Chapter 7) has set an eight-year return-on-investment threshold.
- Dell Children's Medical Center of Central Texas (see Chapter 5) expected a minimum 12 percent ROI for major expenditures.

CROSSING THE CAPITAL OPERATIONS CHASM: PROVIDENCE HEALTH & SERVICES

Providence Health & Services employs return-on-investment methodologies to make the case for using operational savings to fund first-cost premiums necessary to purchase energy conservation technologies. Richard Beam, Director of Energy Management Services, Office of Supply Chain Management, developed this simple graphic to convey the impact of reducing energy consumption on the overall system margin (Figure 6.9). After all, healthcare executives are keenly aware that it is margin that propels mission in the nonprofit healthcare community.

Simply stated, $50,000 of energy savings delivers $50,000 to the bottom line; the chart in Figure 6.9 illustrates the range of healthcare business revenue that must be generated to deliver the same $50,000 revenue to the bottom line. In essence, the lower the hospital's net operating margin, the more healthcare service delivery revenue is necessary to deliver a given amount to the margin.

Source: Richard Beam, Providence Health & Services

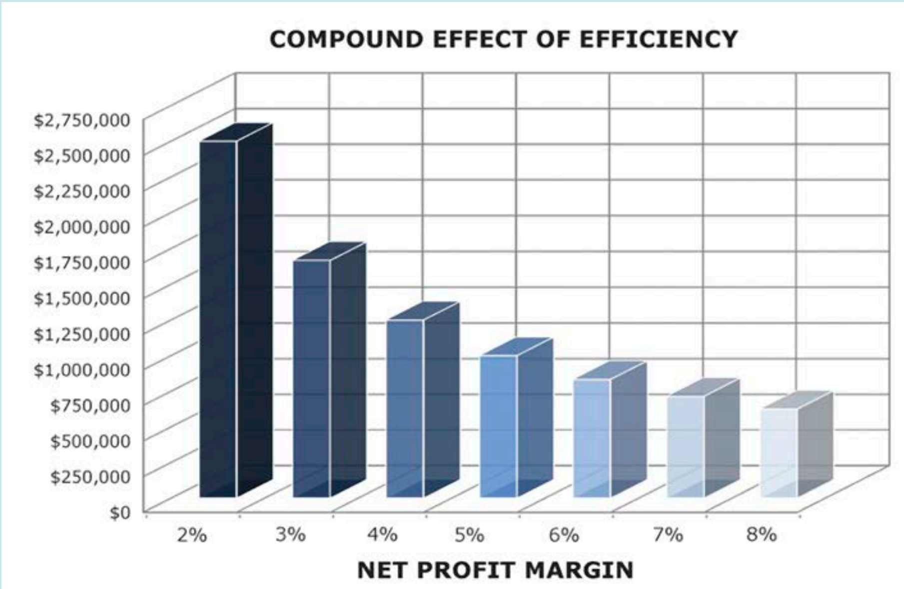


Figure 6.9 The chart shows how much revenue is needed to have the same bottom line impact as $50,000 in operating cost savings given different hospitals' operating margins. *Source: Providence Health & Services; Figure Credit: Breeze Glazer*

Bending the Cost Curve

Even if individual measures yield relatively modest savings, the aggregate impact of those strategies applied across a healthcare system or the entire sector may be more significant. Healthcare researcher Susan Kaplan and her colleagues analyzed individual hospitals that had saved money through a range of exemplary energy, waste, and operating room supply efficiency measures. Extrapolating those relatively modest individual savings across the U.S. healthcare sector, the team concluded that savings exceeding $5.4 billion over five years and $15 billion over ten years were achievable (see sidebar).

CAN SUSTAINABLE HOSPITALS BEND THE HEALTHCARE COST CURVE?

This groundbreaking 2012 study concludes that aggregated savings resulting from strategies for reduced energy use, waste, and operating room supply efficiencies, applied across the entire U.S. healthcare sector, would exceed $5.4 billion over five years and $15 billion over 10 years (Figure 6.10). The key recommendation is that *all* hospitals implement these programs. Given the potential for economic savings and environmental benefit, the report recommends that financially challenged facilities, especially safety-net hospitals, should procure loans and grants from public entities to support these activities.

To ensure that the findings reflected "possible" vs. "average" cost savings, data were gathered from what were considered "exemplar" U.S. hospitals: five sites for energy use reduction, four for waste reduction, seven for single use device reprocessing, and two for operating room pack reformulation. The findings are particularly impressive given that the strategies implemented to achieve these savings are "state-of-the-shelf"—essentially market-ready and technically proven, with only initial cost for energy and waste measures a possible barrier.

Energy reduction strategies include lighting upgrades, variable-frequency drives, high-efficiency electric motors and motor upgrades, occupancy sensors for public areas, boiler and central plant chiller replacements, hydronic heating controls, and solar film on windows. Another key strategy is reducing air changes and temperatures in the operating room (OR) when not in use. The combined net savings over five years are $980 million, reflecting 27.2 kBtu/sf (85.77 kWh/sm) savings (or 9.8 percent compared to an estimated average baseline of 276 kBtu/sf (870 kWh/sm)), and $2.12 gross and $0.72 net cost savings per square foot. While the initial years show a negative payback due to the initial capital investment, over 10 years, aggregate energy savings rise most dramatically of all categories, accounting for approximately $6 billion of the total aggregate $15 billion savings.

Beyond saving billions of dollars, these measures also can bend the environmental impact curve: Reducing carbon dioxide emissions, toxic chemicals, and waste aligns the healthcare sector with its mission and embraces the sector's civic role to protect the public health.

Source: Can Sustainable Hospitals Help Bend the Health Care Cost Curve? *Susan Kaplan, Blair Sadler, Kevin Little, Calvin Franz, Peter Orris, 2012*

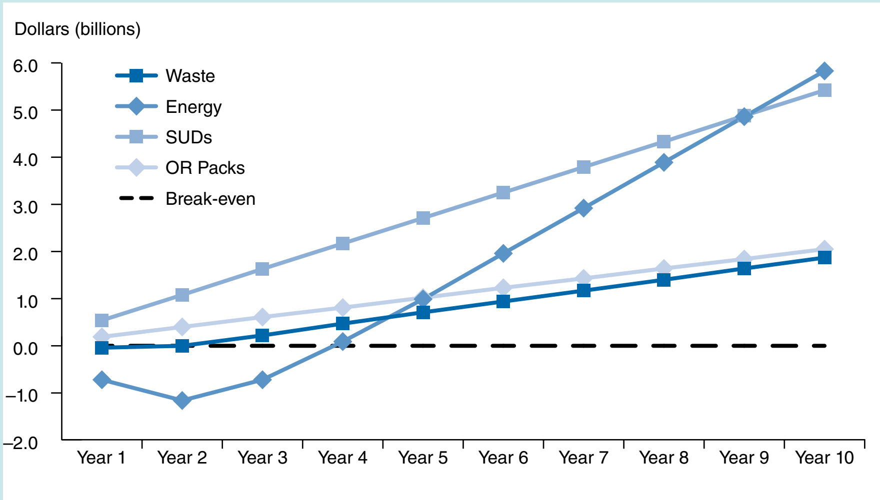


Figure 6.10 Ten-year savings estimate, by intervention. This graph shows the cumulative $15 billion savings possible if all U.S. hospitals implemented a series of four sustainable design strategies, including energy efficiency measures. *Credit: The Commonwealth Fund*

This study suggests that average energy cost reductions of 10 percent are easily achieved through site-specific, limited first cost investments. "With little or no capital investments, significant operating savings can be realized," says Blair L. Sadler, one of the study authors and former CEO of Rady Children's Hospital, San Diego. Given the volatility of utility prices, investments in energy conservation not only save money in the present, they insulate healthcare organizations from future economic risks associated with spikes in fossil fuel prices.

Monetizing Human Factors

Further evidence of the financial benefits of green building lies in monetizing human factors such as health and productivity gains. Recognizing that people in the United States, on average, spend approximately 90 percent of their time in buildings, the consequences of indoor environmental quality on health and productivity can be considerable. Table 6.1 presents estimates of health and productivity gains that might be realized from improved indoor environmental quality (IEQ)—a combination of daylight, views, and access to improved ventilation and outdoor air. The findings, originally published in 2000, were largely corroborated by a 2012 study by the same author (Fisk 2012).

Table 6.1 Estimated Health and Productivity Gains from Improved IEQ for the United States

Health Effect	Low	Medium	High
Reduced respiratory disease*	6	10	14
Reduced allergies and asthma	2	3	4
Reduced sick building syndrome symptoms	10	20	30
Health-related total	18	33	48
Improvements in productivity/performance unrelated to health	20	90	160
Combined health and productivity total	38	123	208

**All figures in $ billions.*

This chart aggregates the financial savings attributable to health and productivity gains that arise from improved building IEQ. Source: Adapted from Fisk 2000

At the same time, this financial cost/benefit is only part of the business case. Clearly, research suggests that while the financial benefits are quantifiable and may be important in implementing a range of sustainable design measures, social and leadership factors are also at work in driving these improvements.

> *. . . there is understandable concern that isolating the subject of first-cost premiums from a broader discussion of benefits does not serve the healthcare sector well, as it is a sector that applies triple bottom line thinking to its core business—the provision of healthcare services—and that dissociating benefit from cost places unwarranted emphasis on the first-cost component. Many of our study subject teams expressed this concern openly and passionately.*
>
> —Houghton, Vittori, and Guenther (2009)

THE SOCIAL VALUE OF SUSTAINABLE HEALTHCARE

Defining organizational and community benefits that arise from sustainable building strategies is a current challenge in healthcare. These benefits need to be defined, quantified, and communicated through industry. Despite studies such as the Fable Hospital (2012), health and productivity benefits continue to elude quantification. Benefits such as reduced staff illness and absenteeism, improved staff performance (including through reduced medical errors), reduced hospital-acquired infections, and improved staff recruitment and retention continue to be largely anecdotal; even when they are quantified through empirical study, as in the Dell Children's Medical Center Post-Occupancy Evaluation, the monetization of the benefits remain elusive. Ray Pradinuk, in his essay "Doubling Daylight" (Chapter 9), postulates that a daylit work environment could reduce adverse events in healthcare, a position supported by a number of peer-reviewed studies.

> *Perhaps the bottom line on the health and human performance benefits of green buildings comes to this: a) if we know from personal and anecdotal experience that having a thermally comfortable, well-lit, properly ventilated work space, preferably with daylight and a view of nature, is likely to have a positive effect on our well-being and morale, and therefore would inspire greater work performance; and b) if sustainable physical elements, such as adequate air exchange, produce any positive benefits in employee health and well-being; and c) if we can build green offices to a high standard at little or no extra cost, then d) why wouldn't we do so?*
>
> —*Building Design and Construction* (2006)

At the same time, hospitals have realized that enormous social benefits accrue from implementing improved environmental performance strategies through operations. Whether organizations receive recognition for recycling programs, reductions in medical waste incineration, or implementation of farmers' markets onsite, environmental improvement programs resonate with communities. To date, many sustainable healthcare projects have engaged in sustainable design to reduce both real and perceived community impacts from their development footprint. Sustainable site planning, from innovative stormwater management strategies to habitat restoration, tie projects to a particular place and have a positive impact on community engagement. Some municipalities have instituted expedited approval processes for LEED projects, particularly for sites with drainage and water-quality challenges.

Evidence-Based Design

There has been significant industry dialogue surrounding the synergies and potential conflicts between evidence-based design and sustainable design strategies. The article "Eco-Effective Design and Evidence-Based Design: Perceived Synergy and Conflict" (Shepley et al. 2009) suggests that the most obvious points of alignment are the strategies that focus inside the four walls

DELL CHILDREN'S MEDICAL CENTER OF CENTRAL TEXAS POST-OCCUPANCY EVALUATION

With an expert third-party university-led post-occupancy evaluation underway, emerging data reveal that Dell's primary objective to create an environment conducive to healing and well-being is being realized. Dell Children's Medical Center opened in 2007, replacing an existing facility with a LEED Platinum–certified building; major patient care outcomes are summarized here:

- *Average length of patient stay* decreased by 14 percent from the previous children's hospital to the replacement facility.
- *Nursing turnover rate* was 2.4 percent in the first year of operations, compared to average staff turnover from 10 to 15 percent nationally and as much as 30 percent for new hospitals operating in their first year. Given an estimated cost of $70,000 to replace one nurse, this dramatic reduction in turnover yields a substantial bottom line economic benefit, while also providing important continuity in the delivery of care.

Source: Seton Family of Hospitals

of a building: indoor environmental quality goals that focus on improved air quality, thermal comfort, daylighting, places of respite, and the like. Given their potential to affect the workplace and therapeutic outcomes, their alignment with evidence-based design is apparent. Major points of conflict arise from a perception that sustainable design is, by definition, "less," and that sustainable buildings will compromise patient safety and clinical outcomes.

The examples cited—larger patient rooms require more resources to construct, handwashing sinks (in lieu of sanitizers) use more potable water, energy conservation leads to less light and fresh air—are all based on a definition of sustainability rooted in using less—deprivation—rather than on a model of integrated, sustainable design that delivers all necessary services abundantly with inherently fewer adverse environmental effects—doing the same—or better—with less. None of the built examples of sustainable hospitals support this notion of a diminished environment. Swedish Medical Center Issaquah (Case Study 35, Chapter 8) is an acute-care environment that uses 60 percent less energy than a comparable baseline building with no noticeable performance reduction; that is, no reduced lighting levels that might lead to errors, no reduction in ventilation effectiveness. Projects employ handwashing sinks outfitted with water-conserving controls to meet requirements for reduced potable water usage (LEED does not recognize use of hand sanitizers in lieu of handwashing sinks as a strategy for water conservation); and sustainable building strategies focus on durability and long-term flexibility rather than initial size. Not one project executive included in this book believes that patient safety or quality of care was compromised by his or her sustainable buildings—even those that approach half the standard energy intensity of baseline acute-care hospitals; as a group they believe they provide better care with a smaller environmental footprint.

One of the major distinctions between sustainable design and evidence-based design is that evidence-based design is a process of investigation centered on medical and workplace outcome objectives that lead to a recommended set of built environment strategies (Hamilton 2006); sustainable design is a process that defines a set of built environment strategies informed by broader considerations—strategies often informed by and linked to larger public health, community, and societal concerns. This important idea frames the third aspect of triple bottom line thinking: strategy and leadership in environmental values.

Strategic Value of Sustainable Healthcare

For many leaders undertaking green buildings, some sustainable building strategies have no quantifiable direct or indirect financial benefits. Yet organizations are undertaking them anyway. There are, indeed, abundant leadership, public relations, and marketing benefits from green building initiatives. Many healthcare organizations' spokespeople remark that it is difficult to get positive local press—until they undertake green building. Such are among the most powerful benefits that early adopters have realized. In some markets, public relations saturation may already be approaching, but for healthcare, the groundswell is only beginning. As healthcare organizations develop and sell their improved building and operational performance, their communities will continue to respond.

Another factor shaping the business case is the perception that green building provides a reduction in obsolescence and reduces risks such as employee errors, slip-and-fall accidents (due to improved materials), and mold occurrence. "Future proofing"—a design strategy that anticipates future developments to lessen negative consequences—often is cited as a benefit of sustainable buildings. The Fireman's Fund became the first U.S. insurance company to offer discounted premiums on green buildings; since then, Allianz, Acadia, AIG, Travelers, and the Hartford provide policy upgrades to projects that are built green following a loss (Srinivasan 2012). Globally, more than 643 green-based insurance products and services have been documented by Ceres, a Boston-based environmental research organization, a 50 percent increase compared to 2007 data (Mills 2009). Another important benefit, passive survivability, describes the ability of the hospital to remain in operation during prolonged disruption to utility supplies or service deliveries. Sustainable design measures provide an added level of resilience to buildings that may be required to remain in service through prolonged service disruption—whether from extreme weather events or utility infrastructure disruption. Given the scale and scope of extreme weather events in 2012 alone, designing twenty-first-century healthcare facilities to "weather the storm" is prudent and pragmatic—it is, indeed, an acknowledged imperative.

Resilience thinking has gained recent attention in light of the tragic consequences of climate-induced weather calamities. In essence, it harkens to the timeless truths of climatic design and bioregional principles—buildings as part of the metabolic flow of place, with the intrinsic capacity to spring back when stressed, and to ensure that basic life support systems—air, energy, water—are sustained under duress.

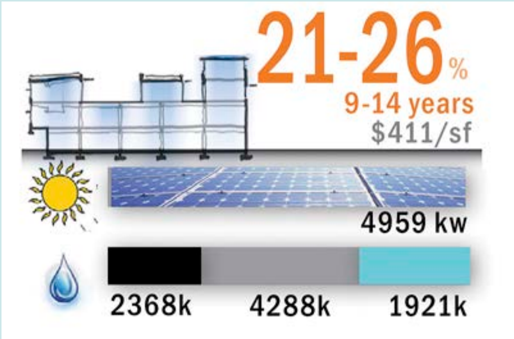
Resilience thinking also underlies the core concepts of the Living Building Challenge—originally an initiative of the Cascadia Green Building Council and now under the auspices of the International Living Future Institute (see Chapters 1, 5, and 10). Referred to as "a visionary path to a restorative future" the Living Building Challenge (LBC) is viewed by some as beyond the reach for many building types, including hospitals. To respond to these concerns, the Cascadia Green Building Council commissioned a study in 2009 to determine the financial implications to modify a LEED Gold–certified hospital to fulfill LBC prerequisites, modeled for four different U.S. climate zones.

Using the Providence Newberg Medical Center (Case Study 17, Chapter 7) as the hospital base case design by Mahlum Architects (at the time of the study, this was the first and only LEED–Gold certified hospital building), the study proposed a series of specific design interventions to achieve "Living Building" status (see sidebar). Comparing results across nine building types including schools, commercial office buildings, and multifamily residential, hospitals realized a shorter return on investment for net zero energy and water technologies than for other building types, reflecting their higher water and energy use patterns.

THE LIVING BUILDING FINANCIAL STUDY

In 2009, the Cascadia Green Building Council commissioned "The Living Building Financial Study," which applied to nine distinct building types, including hospitals. The analysis compares the capital cost differential of applying the Living Building Challenge to a representative sampling of nine LEED Gold–certified buildings (one per building type). To do this, each base building was conceptually re-designed to meet the Living Building Challenge requirements, modified to meet the specific climatic conditions of four U.S. cities. A consultant team comprised of the New Buildings Institute, Skanska, Interface Engineering, SERA Architects, and Gerding Edlen undertook the study, with funding from The Russell Family Foundation.

The 180,231 sq. ft. (16,744 sq. m) Providence Newberg Medical Center LEED Gold–certified hospital, designed by Mahlum Architects, was conceptually modified to fulfill Living Building Challenge requirements. These design modifications, modeled for four U.S. cities representing four distinct climate zones, reduced the energy intensity of the building by approximately 20 percent, from 243 kBtu/sf/yr to 200 kBtu/sf/yr (766 kWh/sm/yr to 645 kWh/sm/yr); renewable energy systems were added to meet the reduced demand and produce a net-zero, carbon-neutral solution (Figures 6.11–12). Collectively, these modifications added a capital cost premium of 21 to 37 percent depending on city. This graphic summarizes the modifications and costs associated with Portland—the location closest to the actual location of the Newberg facility.



Specific building design additions and modifications included:

- New light courts at nurses' stations and skylights at corridors—*increases daylight*
- Rainwater tank—*for water balance*
- Biological bio-reactor—*for on-site wastewater treatment/water balance*
- Photovoltaic cell array—*for on-site renewable energy generation*
- Red List compliant building materials—*healthy materials*

One of the more surprising results of the study was the significant differences in ROI, based on the region of the country, a factor dependent on the cost of energy (see Table 6.2).

Source: The Living Building Financial Study: The Effects of Climate, Building Type and Incentives on Creating the Buildings of Tomorrow, Cascadia Region Green Building Council, 2009

Figure 6.11 Site plan diagram. The site and rooftop is extensively covered with solar photovoltaic panels; a wastewater retention pond is used as a landscape feature. *Source: SERA Architects*

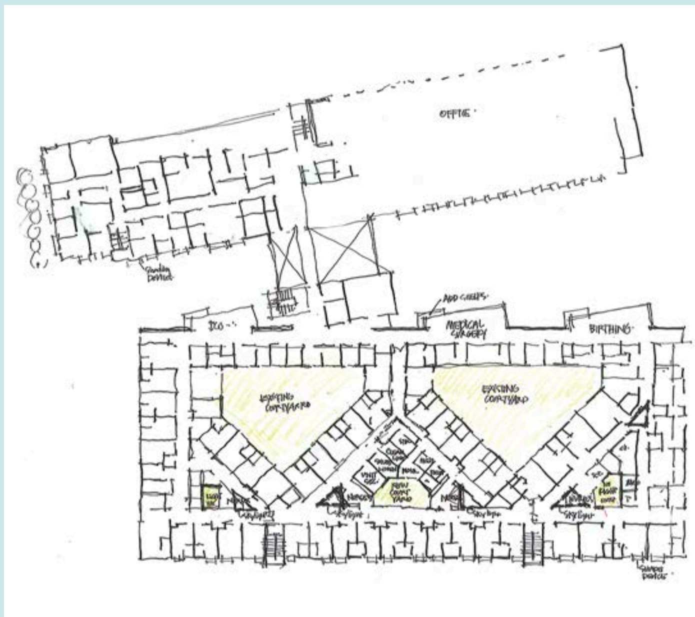


Figure 6.12 Plan sketch. Plan modifications include the introduction of light courts at nurses' stations; the large triangular courtyards are included in the actual design. *Source: SERA Architects*

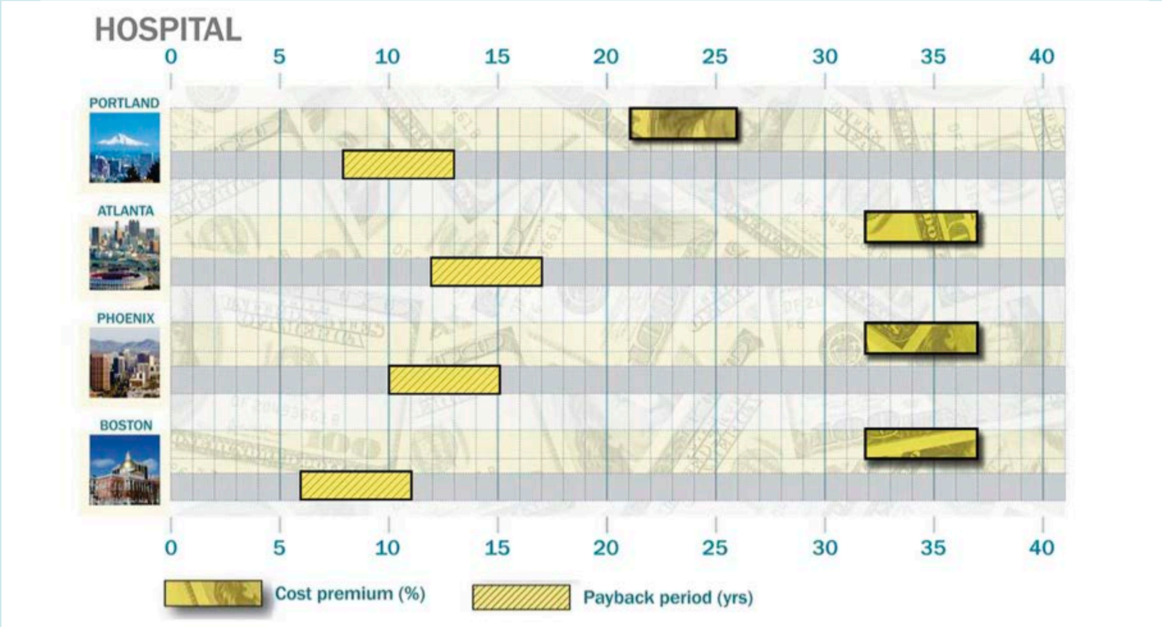


Figure 6.13 Life cycle cost. Payback for this net-zero energy, net-zero water hospital varied from 6 to 17 years, depending on location. *Source: SERA Architects*

Table 6.2 Living Building Hospital Costs

City	Cost Premium %/ Payback Years	Cost per Square Foot	Energy Use Index (in kBtu/sf/yr)	Photovoltaic Capacity in kw	Water (in gallons)	Rainwater Tank Size (in gallons)
Portland, OR	21–26% / 9–14 years	$411	123.9	4959	2,368,000 (blackwater) 4,288,000 (graywater) 1,921,000 (rainwater)	120,000
Atlanta, GA	32–37% / 11–16 years	$363	117.4	4465	1,601,000 (blackwater) 4,288,000 (graywater) 2,688,000 (rainwater)	10,000
Phoenix, AZ	32–37% / 10–15 years	$368	118.7	3439	3,903,000 (blackwater) 4,288,000 (graywater) 386,000 (rainwater)	130,000
Boston, MA	32–37% / 6–11 years	$469	148	5666	2,093,000 (blackwater) 4,288,000 (graywater) 2,196,000 (rainwater)	70,000

Source: Living Building Financial Study

While the first cost increases seem insurmountable, the fact that hospitals are so energy-intensive served to accelerate the ROI compared to other building types (Figure 6.13). Many of the projects in this book, along with the University of Washington Integrated Design Lab's Targeting 100 research (see Chapter 5), demonstrate that the key factor in achieving net zero performance is reducing demand. If Providence Newberg Medical Center's proposed redesign had reduced energy demand to 100 kBtu/sf/yr (315 kWh/sm/yr), for example, the premiums would have been half what they were in the study. Likewise, the magnitude of the premiums directly correlates to the cost of onsite renewables; as those costs reduce, as they have in the years since the study, the premium likewise reduces. At the same time, the payback, estimated at 8 to 15 years, is within the parameters of many of the very low–EUI European case study examples in this book, including Akershus University Hospital (Case Study 21, Chapter 8), Deventer Ziekenhuis (Case Study 23, Chapter 8), and others.

CONCLUSION

Hospital leaders and design teams engaged in sustainability are pursuing effective design that balances the needs within their walls with their responsibilities as community leaders and global citizens. Ultimately, healthcare is making a multidimensional business case using economic, social, and environmental benefit calculations. The innovators and fast followers did not wait for a proven business case; they have forged ahead and created it as they have designed and operated their buildings. Many viewed the business case in terms of improved health, a connection to mission, and a certain risk-reward equation. Whatever the risk, there was an inherent belief that the rewards would ultimately emerge—whether in reduced utility bills, improved staff retention and morale, patient health, or perceived community leadership.

These organizations are propelled by the belief that everything they do matters and makes a difference, even if they are not certain that it will. This belief is now corroborated by data, and the market redefined with a decidedly changed view of standard practice. While the motivation of these pioneers was not necessarily to be leaders, they have set healthcare's built environment on a new path with the future in mind. It represents, in a sense, a process of discovery, as the ecologic, economic, and health-related dimensions of this work come into clearer focus. This promises to be a journey shared by the broad spectrum of people engaged in contemporary healthcare design: design practitioners, facility owners and operators, medical professionals, policy makers—and the general public. It can only benefit from sharing the richness and diversity of that collective experience, wisdom, and hope as the process continues to shape the healthcare architecture of the future.

CONTRIBUTORS

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Breeze Glazer is a designer and researcher who has focused his career on sustainability in architecture and is passionate about redefining the role and impacts of the built environment on human and ecological health. Breeze has applied this expertise to a broad variety of projects across a multitude of scales from academic medical centers to corporate office renovations.

BIBLIOGRAPHY

Armour, S., S. Pettypiece, and M. Cortez (2012). Hospital Evacuation in N.Y. Exposes Outdated Power Backup. In *Bloomberg Businessweek.* October 31. www.businessweek.com/news/2012–10–30/new-york-hospital-evacuates-patients-as-sandy-hits-power.

Building Design and Construction [BDC] (2006). White Paper on Sustainability. www.bdcnetwork.com/article/ca6390371.html.

Cassidy, R. (2003). White Paper on Sustainability. *Building Design & Construction* (November):1.

Centers for Disease Control and Prevention (2009). Chronic Diseases: The Power to Prevent, The Call to Control: At a Glance 2009. www.cdc.gov/chronicdisease/resources/publications/aag/chronic.htm.

Dean, L. (2000). Remarks, *Setting Healthcare's Environmental Agenda Conference,* San Francisco, October 16. In *Papers and proceedings from the conference.* www.noharm.org/details.cfm?type=document&ID=477.

Fisk, W. (2012). Benefits of Improving Indoor Environmental Quality. Lawrence Berkeley National Laboratory Indoor Environment Group. http://energy.lbl.gov/ied/.

Fisk, W. (2000). Review of health and productivity gains from better IEQ. In *Proceedings of Healthy Buildings 2000 Conference*, vol. 4, Espoo, Finland, August 6–10.

Glazer, B., R. Guenther, and G. Vittori.(2013). *LEED Certified Hospitals: Perspectives on Capital Cost Premiums and Operational Benefits.*

Hamilton, D. K. (2006). Four levels of evidence-based practice. *AIA Journal of Architecture.* December 1, 2006.

Houghton, A., G. Vittori and R. Guenther (2009). Demystifying First Cost Green Building Premiums in Healthcare. In *Health Environments Research & Design (HERD) Journal.* Summer. 2(4), 10–45.

Kaplan, R., and M. Porter (2011). The Big Idea: How to Solve the Cost Crisis in Health Care. In *Harvard Business Review,* September.

Kaplan, S., B. Sadler, K. Little et al. (2012). Can Sustainable Hospitals Help Bend the Health Care Cost Curve? *Issue Brief*, November. The Commonwealth Fund.

Kats, G. (2010). *Greening Our Built World: Costs, Benefits, and Strategies.* Washington, DC. Island Press.

Lawrence, D. (2000). Remarks, *Setting Healthcare's Environmental Agenda Conference,* San Francisco, October 16. In *Papers and proceedings from the conference.* www.noharm.org/details.cfm?type=document&ID=477.

McCook, K. (2012). 2012 Construction Outlook. McGraw-Hill Construction. www.carpetrecovery.org/pdf/annual_conference/2012_conference_pdfs/Presentations/USGreenMarketTrends.pdf.

Mills, E., and E. Lecomte (2006). *From Risk to Opportunity: How Insurers Can Proactively and Profitably Manage Climate Change.* Boston: Ceres.

Mills, E. (2009). *From Risk to Opportunity: Insurer Responses to Climate Change.* Boston: Ceres.

National Coalition on Health Care [NCHC]. September 2011. Health Care Spending as Percentage of GDP Reaches All Time High. http://nchc.org/node/1171.

Organization for Economic Co-operation and Development [OECD] (2010). OECD Health Data. OECD Health Statistics. www.kff.org/insurance/snapshot/oecd042111.cfm.

Orszag, Peter R. (2008). Growth in Health Care Costs. Statement before the Committee on the Budget, United States Senate. Washington, DC. Congressional Budget Office. www.cbo.gov/sites/default/files/cbofiles/ftpdocs/89xx/doc8948/01–31-healthtestimony.pdf.

Porter, M., and E. O. Teisberg (2006). *Redefining Health Care: Creating Value-Based Competition on Results.* Chicago: American College of Healthcare Executives.

Roberts, R. R., B. Hota, I. Ahmad et al. (2009). Hospital and societal costs of antimicrobial-resistant infections in a Chicago teaching hospital: Implications for antibiotic stewardship. *Clin Infect Dis,* 2009 Oct. 15:49(8):1175–1184.

Schlessinger, M., and B. Gray (1998). A broader vision for managed care, part I: Measuring the benefit to communities. *Health Affairs* 17(3):152–168.

Shepley, M. M., M. Baum, R. Ginsberg, and B. Rostenberg (2009). Eco-effective design and evidence-based design: Perceived synergy and conflict. *Health Environments Research and Design (HERD) Journal* 2(3):56–70.

Srinivasan, S. (2012). Green Insurance May Get Boost from Sandy. Washington, DC. National Public Radio. www.ceres.org/press/press-clips/green-insurance-may-get-boost-from-sandy.

SustainAbility and United Nations Environment Programme [UNEP] (2002). *Trust Us: The Global Reporters 2002 Survey of Corporate Sustainability Reporting.* London: SustainAbility. www.sustainability.com/trust-us.

U.S. Environmental Protection Agency (2012). ENERGY STAR for Healthcare. http://www.energystar.gov/index.cfm?c=healthcare.bus_healthcare.

U.S. Green Building Council (2012). Personal communication with Doug Gatlin.

CHAPTER 7

LESSONS FROM HEALTH SYSTEMS

> Boldness has genius, power, and magic in it. Begin it now.
>
> JOHANN WOLFGANG VON GOETHE

> The future can't be predicted, but it can be envisioned and brought lovingly into being. Systems can't be controlled, but they can be designed and redesigned. We can't surge forward with certainty into a world of no surprises, but we can expect surprises and learn from them and even profit from them.
>
> DONELLA MEADOWS

While individual building accomplishments are the subject of the Case Studies within this book, these achievements are often situated within the context of a larger health system's vision and goals.

A global view leads us immediately to the UK National Health Service, a national health system at the forefront of policy and green building initiatives that are literally transforming the healthcare delivery system and the built environment. Within the United States, this chapter focuses on four diverse regional systems that are changing the face of sustainable healthcare—Partners HealthCare, Massachusetts; Providence Health & Services, Washington, Oregon Alaska, California, Montana; Gundersen Health System, Wisconsin, Minnesota and Iowa; and Kaiser Permanente, California, nine other states and the District of Columbia. Their accomplishments demonstrate that innovative sustainable healthcare is achievable across a system, even within the constraints and challenges of the healthcare and construction industries today.

UNITED KINGDOM'S NATIONAL HEALTH SERVICE

The UK National Health Service (NHS) is aligning its core principles of "improving health and preventing disease" to both its approach to health delivery, and to the scale, location, and environmental performance of its buildings. While it is continuing to evolve, the NHS's initiatives provide insights into how a suite of policy initiatives, tools, and aggressive goals can positively impact the design of the built environment. These efforts are shaping the form and future of the NHS healthcare delivery infrastructure, and present an emerging vision of how shifts in healthcare delivery impact the built environments that support it.

Background

Established in 1948, the NHS is the shared name of three of the four publicly funded healthcare systems in the United Kingdom (UK). They are primarily funded through general taxation rather than requiring insurance payments. They provide a comprehensive range of health services, the vast majority of which are free at point of use to UK residents. Only the English NHS is officially called the National Health Service, the others being NHS Scotland and NHS Wales. In Northern Ireland, it is called the HSC rather than the NHS. Combined, the NHS is the world's fifth largest employer, comprising approximately 1.7 million staff (BBC 2012). It is the largest employer in Europe (NHS 2012). With an annual budget of more than £90 billion (approximately $142.4 billion), the NHS represents approximately 8.0 percent of the UK's gross domestic product (ONS 2012).

An enormous period of hospital replacements and new construction in the past fifteen years has significantly shifted the profile of physical facilities—prior to this investment, approximately 50 percent of the hospital building stock predated the birth of the NHS (i.e., 1948); today, it stands at approximately 20 percent. Since May 1997, 115 major hospitals opened or are nearing completion; 200 primary care buildings have been completed (CABE 2009). Ysbyty Aneurin Bevan (Aneurin Bevan Hospital), Ebbw Vale, Wales, is a clear demonstration of the enormous evolution of this system. It is the first private room hospital in the NHS, dedicated on the NHS's 60th anniversary, and is named for its founder (Case Study 36, Chapter 8).

Policy Initiatives

Recognizing that the healthcare delivery system organization impacts community and global health through carbon emissions, the NHS Sustainable Development Unit has guided the development of a Route Map for Sustainable Health, focused on synergistically reorganizing services to both improve community health and reduce environmental impacts. The Sustainable Development Unit has also developed, released, and is tracking carbon footprint data for the NHS in the context of the broader UK Climate Change Act. Each of these initiatives is described here.

The NHS Carbon Reduction Strategy

The NHS Carbon Reduction Strategy for England sets out the framework for the healthcare sector to make progress toward a low carbon society. This is driven by the requirements of the UK Climate Change Act, which has created a legally binding framework to work toward the 2050 target of reducing greenhouse gas emissions by 80 percent over the 1990 baseline.

The first NHS England carbon footprint was published in 2009; based on 2004 data, the report estimated emissions of 18.4 million tonnes (NHS SDU 2009). The report concluded that despite increases in efficiency, the NHS has increased its carbon footprint by 40 percent since 1990. Based on this assessment, the NHS established a target to reduce its 2007 carbon footprint by 10 percent by 2015 (see Figure 7.1). The Carbon Reduction Strategy suggested a range of measures across the three emissions sectors: procurement, building energy, and travel, as well as a cross-sector measure of shifting the national grid to higher percentages of renewable energy. While this focus on carbon emissions is bold, a 2012 poll indicated that 95 percent of the British public supported these carbon reduction initiatives (NHS SDU 2012).

Are these measures working? The 2012 carbon footprint of the NHS England indicates that total carbon emissions have stopped rising and are leveling off, while carbon intensity has significantly dropped—to approximately one-third of the 1990 levels. As some improvements are noted in the building sector (attributed to a reduction in coal and oil to a greater reliance on natural gas and bio-gas sources) and there is increased renewable energy in the national grid, the carbon footprint associated with procurement looms ever larger (see Figure 7.2). The pharmaceuticals sector remains the largest economic sector contributing to the NHS England carbon footprint, dwarfing the second

> *We can increase physical activity; promote a better diet; improve mental health; reduce obesity; promote safe travel, improve air quality; and help regenerate local communities and economies through carbon reduction, which in turn leads to safer, healthier, and more fulfilled communities.*
>
> *Source: NHS Carbon Reduction Strategy for England (NHS SDU 2009)*

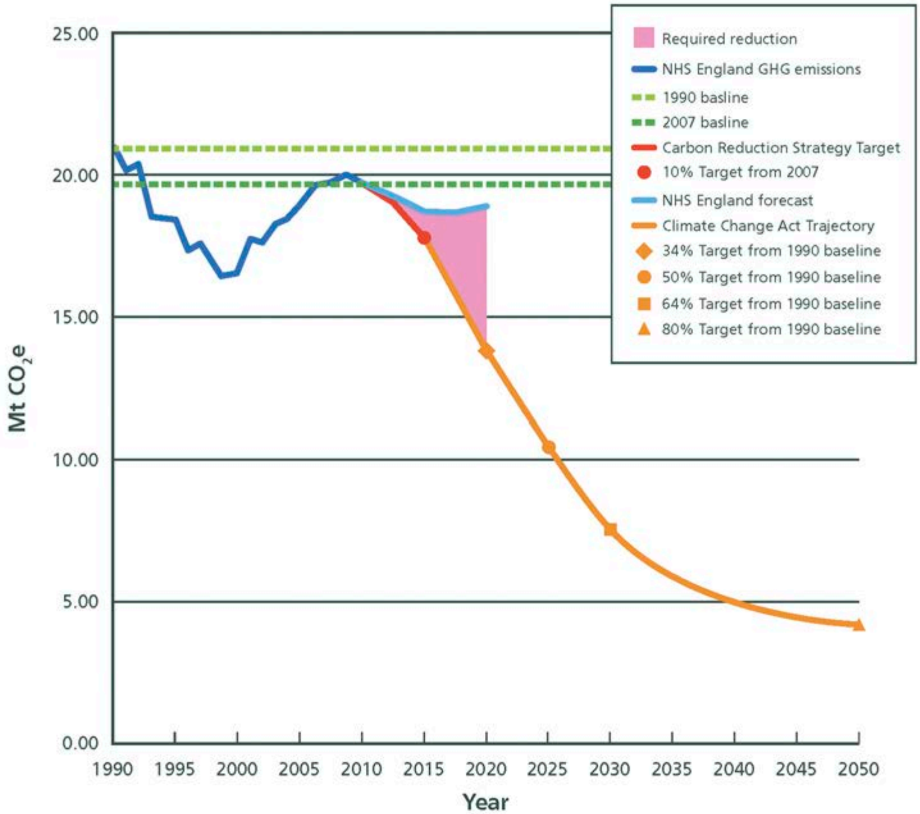
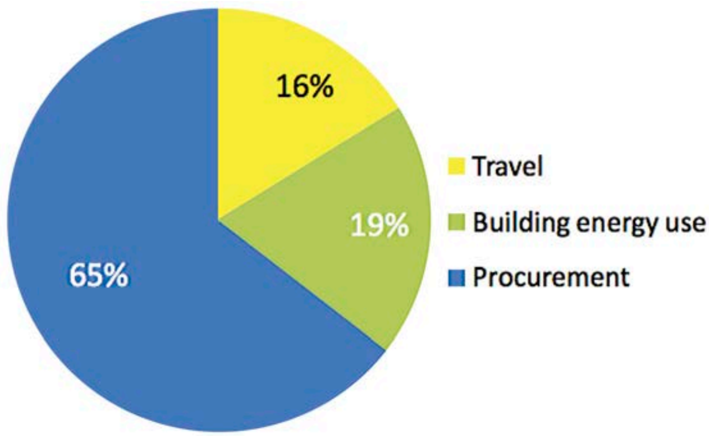


Figure 7.1 NHS England CO_2e footprint 1990–2020. This diagram shows the rapid rise in carbon footprint, the forecast, and the necessary reductions to align with UK national goals. *Source: Sustainable Design Unit NHS*



Travel	3.19	$MtCO_2e$	16%
Building energy use	3.80	$MtCO_2e$	19%
Procurement	12.72	$MtCO_2e$	65%

Figure 7.2 Breakdown of the NHS England Carbon Footprint 2010. *Source: Sustainable Design Unit NHS*

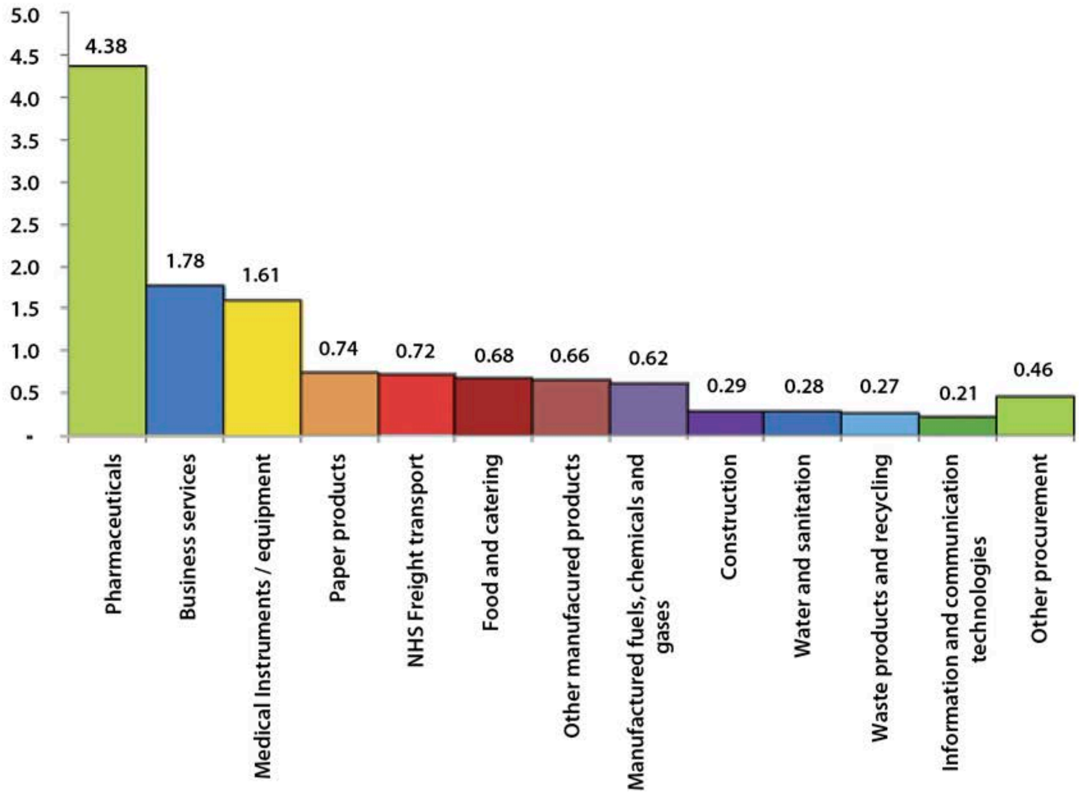


Figure 7.3 NHS England Procurement table. *Source: NHS Sustainable Development Unit, NHS England carbon footprint update (NHS SDU 2012)*

largest subsector of business services (see Figure 7.3). At the same time, the projections for the period 2015–2020 indicate a widening gap between emissions and the aggressive UK Climate Change Act targets.

The NHS has identified 8 potential reduction areas to level off and reduce carbon emissions (see Figure 7.4). The first two measures, refurbishing and replacement of buildings, is projected to stem the "business-as-usual" increase. Siting healthcare delivery near public transit and convenient to communities is anticipated to reduce travel by 20 percent by 2020. The fourth measure, purchasing 40 percent renewable electricity from grid, parallels larger public programs. Strategies 5 through 7 are aimed at procurement, while Strategy 8 specifically addresses those carbon benefits associated with moving care closer to communities and home, as well as prevention initiatives.

Route Map for Sustainable Health

The Route Map describes a socially, financially, and environmentally sustainable health system and the components needed to achieve it. The Route Map is built on the actions described in the NHS Carbon Reduction Strategy (described above), ideas developed in the health scenario publication *Fit for the Future*, and collaboration across the regions in England. It reflects the great work already taking place in many NHS organizations. It is a framework for local health trusts to use to develop a "sustainable" health system, organized around six themes:

- Models of care
- Technology
- System governance

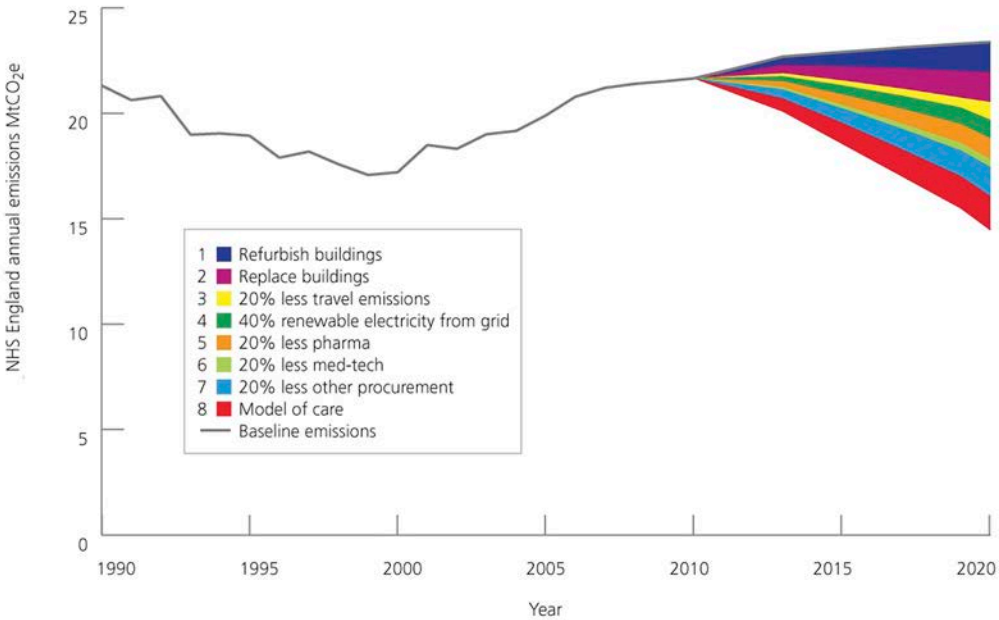


Figure 7.4 The potential impact of a series of sustainable initiatives on NHS England CO_2e levels. *Source: Sustainable Development Unit NHS*

- Use of resources
- Societal behaviors and attitudes
- Individual behaviors and attitudes

It is based on the recognition that the economic, energy, and environmental situations, individually and collectively, will continue to place increasing stresses on the provision of healthcare services (see Figure 7.5).

The Route Map postulates that transforming the NHS to become a sustainable system will require a new way of thinking and envisions significant shifts (see Figure 7.6). These shifts require a collaborative approach across many stakeholders, and are consistent with restorative and regenerative thinking, moving beyond "less harm" toward a system that "heals" communities and ecosystems (see Chapter 10).

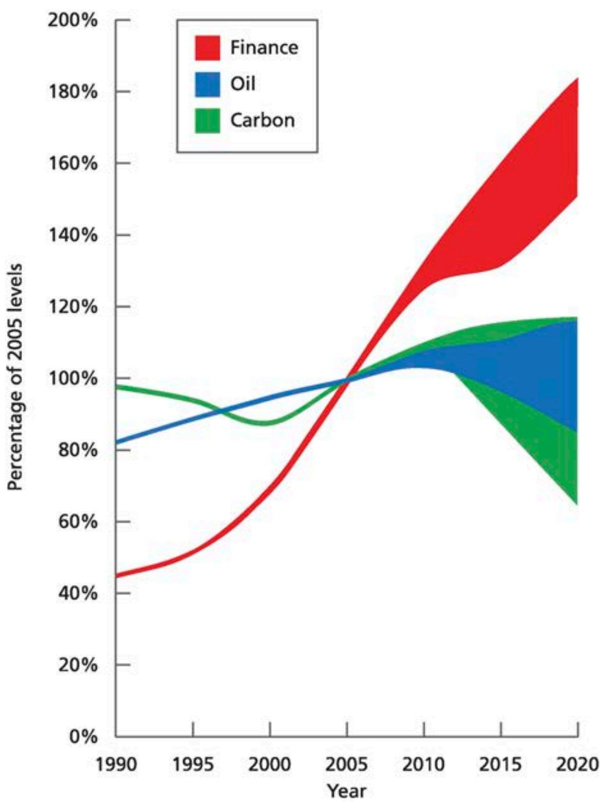


Figure 7.5 This graph overlays the impending shortfalls between healthcare need (finance), energy resources (oil), and carbon emissions (carbon) to demonstrate that fundamental change is required to reduce or eliminate projected shortfalls. *Source: Sustainable Development Unit NHS*

From	health care as an institution-led service	**To**	health and social care as part of the community
From	curative and fixing medical care	**To**	early intervention and preventative care
From	sickness	**To**	health and well-being
From	professional	**To**	personal
From	isolated and segregated	**To**	integrated and in partnership
From	buildings	**To**	healing environments
From	decision making based on today's finances	**To**	an integrated value of the future that accounts for the impacts on society and nature
From	single indicators and out-of-date measurements	**To**	multiple scorecard information and in real time
From	sustainability as an add on	**To**	integration in culture, practice, and training
From	waste and overuse of all resources	**To**	a balanced use of resources where waste becomes a resource
From	nobody's business	**To**	everyone's business

Figure 7.6 The Route Map postulates significant changes to the form and shape of service delivery and the buildings that support healthcare. *Source: Sustainable Development Unit NHS*

Sustainable Buildings

In addition to organizational change through policy initiatives, the NHS is exploring sustainable design and operational improvements relevant to the global healthcare sector. Its enlightened view of healthcare is deeply rooted in organizational culture, captured in one of its founding principles: "[to] improve health and prevent disease, not just provide treatment for those who are ill" (NHS Department of Health 2004). Sustainable design and operations are key components of a broad commitment to achieve effective quality healthcare for all citizens of the United Kingdom. The building portfolio continues to strive for improved performance and reduced carbon impacts, while the basic organization of services is transformed to both improve access and care as well as reducing transportation and built environment impacts.

Mittal Children's Medical Centre embraces an innovative approach to sustainable design for the first phase of a replacement facility on the site of Great Ormond Street Hospital, London (Case Study 12, this chapter). In contrast, a residential mental health facility in a less urban context, the Bluestone Unit at Craigavon Area Hospital, Craigavon, Northern Ireland, demonstrates a clear focus on seamlessly blending sustainable design, care quality, and service efficiency goals (Case Study 13, this chapter). St. Barts and The Royal London, two expanded sites that comprise the largest single project undertaken to date (Case Study 34, Chapter 8), demonstrate that even complex, multiphase replacements can be aligned with significant carbon reduction goals.

The NHS is now shifting its capital focus toward local and primary health facilities as well as renovations of existing buildings. One notable renovation project is the recladding of Guy's Tower, described here. This 1970s era high-rise hospital building is being completely reclad while it remains in full operation, integrated with future goals for central plant replacement. The Dyson Centre for Neo Natal Care at Royal United Hospital in Bath, England Case Study 7, Chapter 5), demonstrates how a relatively modest addition coupled with a central plant replacement on an existing campus can innovate construction methods and achieve significant carbon reductions.

Guy's Hospital Tower, London

Architects: Penoyre & Prasad

Prominent on the London skyline at 34 stories, 470 feet (143 meters), Guy's Tower is the tallest hospital in the world. While most of the building's program uses have changed over its 40 year life, it continues to be a vital part of the facilities of the Guy's & St. Thomas's NHS Trust, containing one sixth of the Trust's floor area. The programmatic adaptability of the building owes much to the design of the vertical circulation and services as a separate Communications Tower distinct from the adaptable User Tower floor plates of 12,900 sq. ft. (1200 sq. m).

Typical of commercial and civic buildings of the sixties and seventies and common in the UK's healthcare estate, the concrete external walls are spalling and weather stained; the uninsulated and single-glazed envelope is very energy inefficient. Early studies included an option to demolish and re-build, but this was shown to be both disruptive and highly wasteful of embodied carbon. Hence, the recladding program emphasizes safety, fitness for purpose, and prioritizes energy efficiency—a design competition also sought to give this iconic building a distinct profile befitting the significance of the NHS and symbolizing the resurgence of a historic London neighborhood (see Figure 7.7).

The project scope excluded consideration of mechanical and electrical plant, confining the intervention to only the external envelope. Penoyre & Prasad approached the project as constituting the first step towards a post fossil fuel future—a first step that should achieve the highest performance for the investment while ensuring that none of the work would need to be undone in the future.

Recladding options, including a total external second skin and the creation of an interstitial "winter garden" zone and lighter touch measures, were evaluated based on thermal modeling. The selected option is a total surface reclad of both towers. The User Tower will have new composite windows and insulated cladding assemblies fitted from the outside; removal of the old external walls and windows will follow incrementally to suit uses and budgets in this multi-tenant building. When the external fabric is removed a small but significant amount of extra area will be created within each room or space, with the floor plate as a whole growing by approximately 540 sq. ft. (50 sq. m). The taller Communications Tower will be highly insulated and clad in anodized aluminum panels with a stiffening geometrical fold. All the work will be accomplished without interrupting the functioning of any part of the building (see Figure 7.8).

Figure 7.7 New façade elements fitted from the exterior. *Source: Penoyre & Prasad*

Figure 7.8 The proposed recladding. *Source: Penoyre & Prasad*

The emerging focus on local and primary health facilities is yielding an exceptional group of community health facilities. Jubilee Gardens Health Centre and Library (Case Study 50, Chapter 10), is a unique programmatic pairing of a primary health facility with a public library to develop synergies between prevention, health management, and education. Waldron Health Centre (Case Study 52, Chapter 10), was one of the first two NHS buildings to achieve a NEAT "Excellent" performance rating. In this instance, the architects were as concerned with the building anchoring the community as they were with solving for the medical program. Kaleidoscope, described below, is a second facility in Lewisham that demonstrates both a deep understanding of community connectivity and sustainable design integration.

One of the more notable system transformations is evident in Northern Ireland, where a new generation of facilities is supporting a reimagined healthcare delivery system. Northern Ireland differs from other NHS components in that it provides both healthcare and social care. In 2011, it announced a radical restructuring of healthcare delivery (Black 2012):

- From a focus on acute-care settings toward ambulatory and home care. Structurally, this includes reconstruction of a smaller number of acute hospitals (from 10 to between 5 and 7)
- A shift of healthcare from hospitals to community and primary care accompanied by an expansion of that network of facilities
- An emphasis on prevention, focusing on obesity, smoking, and alcohol
- A shift toward greater care at home

The Bluestone Unit at Craigavon Area Hospital (Case Study 13, this chapter), the New South West Acute Hospital (Case Study 14, this chapter), and Portadown Health and Care Centre (Case Study 27, Chapter 8) demonstrate the emergence of both residential (i.e., acute-care and behavioral health) and ambulatory facilities aimed at specifically supporting these programmatic goals. As described in "Sustainable Development in the NHS":

> The environment in which people live and work has a key influence on their health. Environmental considerations must therefore be taken into account when building or adapting facilities in which NHS services are delivered. In addition, NHS facilities can have an impact on the surrounding environment. Job opportunities can bring social benefits to a community; traffic congestion and noise pollution can have a detrimental impact. Environmental impact assessments should therefore be undertaken by all new and existing facilities (DH 2009).

Conclusion

Taken together, this combination of policy and built work form a powerful beginning toward an emergent healthcare sector. While the current landscape for the NHS is uncertain, the sustainability agenda is now an integral part of healthcare operations focusing on social, environmental, and economic development. Sustainability is believed to support the two crucial goals of staff engagement and creating a caring culture; that is, it reinforces a sense of organizational purpose and values for both present and future generations (Ling et al. 2011). Clearly, the NHS is an important model for all.

Case Study 12: Mittal Children's Medical Centre Morgan Stanley Clinical Building, Great Ormond Street Hospital

London, United Kingdom

OWNER: Great Ormond Street Hospital for Children NHS Foundation Trust

PROJECT TEAM:

Architect/Interior Design/Landscape: Llewelyn Davies Yeang

Engineer: WSP Group

Project Managers and Cost Consultants: Gardiner & Theobald

Contractor: BAM Construct UK

TYPE: New addition to Children's Hospital

SIZE: Phase 1: 199,132 sq. ft. (18,500 sq. m) Total project: 333,681 sq. ft. (31,000 sq. m)

EUI: 55 kBtu/sf/yr (175 kWh/sm/yr)

PROGRAM DESCRIPTION: Two phase addition to existing children's hospital: Phase 1 includes Clinical Building: 7 floors of inpatient beds; cardiac and neuro operating theaters, Kidney Centre, Neurosciences Centre, Heart and Lung Centre, offices and restaurant

COMPLETED: 2011 (phase 1); 2016 (phase 2)

RECOGNITION: NEAT Excellent

BIOME: Temperate humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 33 in (834 mm)

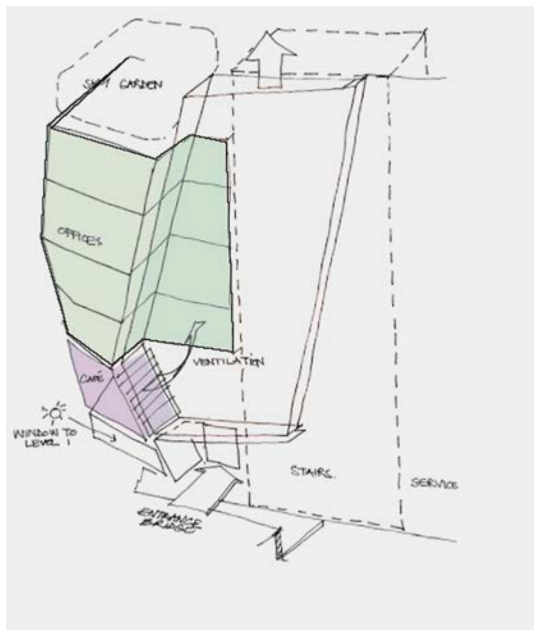
KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Green roof plus landscaped gardens and courtyard
- *Narrow floor plates:* Positioning and "cranking" the building within the dense urban site maximizes daylight penetration
- *Water Use Reduction:* Conserving showers, toilets, appliances
- *Low EUI:* CHP, innovative energy distribution, mixed-mode ventilation
- *Low-Carbon Strategies:* Daylight, occupancy sensors, LED lighting
- *Innovative Energy Distribution:* Chilled beams, underfloor radiant heating/cooling; concrete structure provides thermal mass
- *Natural Ventilation/Operable Windows:* Mixed-mode natural/mechanical ventilation; operable windows in patient wards

Figure 7.9 *Source: Great Ormond Street Hospital for Children*

Figure 7.10 *Source: Llewelyn Davies Yeang*

Figure 7.11 *Source: Llewelyn Davies Yeang*



The Mittal Children's Medical Centre strives to be the greenest medical facility in the UK, and is on track to set new sustainable design benchmarks for the healthcare sector. It is one of four hospitals in the UK to participate in a natural ventilation study. Their groundbreaking work to create a low-carbon, healing environment is achieved through a carefully integrated strategy of natural ventilation, thermal mass, daylight, and an on-site combined cooling, heating and power plant, in addition to a materials palette emphasizing low-emitting and naturally-derived products (Figures 7.9–7.11).

Founded in 1852, the Great Ormond Street Hospital (GOSH) is the largest provider of specialist services for children in the UK. Challenged by its aging, outmoded buildings, the hospital embarked on a redevelopment process in 2007 to ensure that its physical infrastructure is commensurate with its stature as a global leader for pediatric care and research and to respond to 21st century environmental imperatives. The resulting design is two linked, narrow floor plate buildings constructed in two phases over nine years that will inspire UK's next generation of healthcare buildings (Figure 7.15).

The facility features significant breakthroughs in low-carbon energy strategies. Modeled energy performance indicates an offset of 5,000 tonnes of CO_2 annually. Natural ventilation is key to this strategy: patient wards are designed with mixed-mode ventilation, controlled by a building management system equipped with manual override for important patient control. During moderate spring and fall seasons, the upper quarter of the windows in patient rooms can be opened to allow fresh air to enter. During summer and winter months, windows are closed, and chilled beams are used for comfort control.

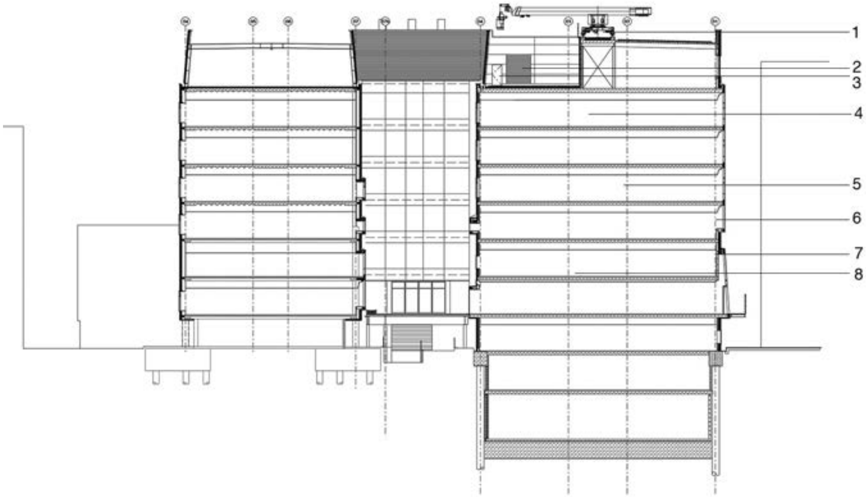
In addition, a glazed natural ventilation updraft flue extends through the seven-story structure; it is an iconic architectural feature, providing natural ventilation to the ground floor restaurant, and making a statement about GOSH's environmental aspiration (Figures 7.9–11). The building envelope has been carefully considered for its airtightness and thermal performance, with the overall thermal performance or U-value reduced by 34 percent compared to a standard hospital building.

An on-site tri-generation cooling, heating and power (CHP) plant, is designed to fully supply Mittal's energy needs and 60 percent of energy demand in other parts of the hospital. Initially fueled with natural gas, the CHP is able to convert to bio-fuels, further reducing its carbon intensity. After incorporating various energy efficient measures (e.g., mixed-mode ventilation, LED lighting, photocell lighting controls) Phase 1 predicted annual CO_2 emissions is 2,237 tonnes, but this is completely displaced by the tri-generation plant and further reducing the current site-wide CO_2 emissions by an additional 1,515 tonnes, which results in the facility achieving 163 percent CO_2 reduction.

Creating a healthy building and healing environment for children, their families and hospital staff—and the broader community—is another overarching objective. A partially glazed façade includes extruded glass bays that add value and interest in all of the "important people places" including waiting areas, play rooms, four bed bays and staff areas. These areas maximize daylight penetration while controlling solar gain and glare. Low-emitting materials are specified for most interior finish materials, in addition to naturally derived paints and linoleum flooring (Figure 7.12). All timber used in the project is certified by the Forest Stewardship Council. And, finally, the building is topped off with a sedum covered "sky garden" that creates habitat and enhances thermal performance (Figure 7.13).

Figure 7.12 Interior at restaurant. *Source: Llewelyn Davies Yeang*

Figure 7.13 Green roof. *Source: Llewelyn Davies Yeang*



1. Sedum roof
2. Combined cooling heat and power
3. Absorption
4. Glazed vertical stack evacuates restaurants and solar gain through façade
5. Mixed-mode ventilation in wards
6. Balcony with sliding door for cross ventilation
7. Mixed-mode ventilation to restaurant
8. Exposed concrete structure in restaurant for thermal mass

Figure 7.14 Environmental design strategy. *Source: Llewelyn Davies Yeang*

Figure 7.15 Site plan. *Source: Llewelyn Davies Yeang*

Case Study 13: The Bluestone Unit, Craigavon Area Hospital

Craigavon, Northern Ireland

OWNER: Southern Health and Social Care Trust

PROJECT TEAM:

Architect: David Morley Architects/Hall Black Douglas Architects

Structural and Services Engineer: Buro Happold

Landscape Architect: Livingston Eyre Associates

Contractor: Heron Brothers Ltd

TYPE: New Psychiatric Hospital

SIZE: 67,769 sq. ft. (6,296 sq. m)

EUI: 114 kBtu/sf/yr (359 kWh/sm/yr)

PROGRAM DESCRIPTION: Free-standing 74 bed mental health and psychiatric unit

COMPLETED: 2008

AWARDS/RECOGNITION: NEAT Excellent rating; Best Mental Healthcare Building, Building Better Healthcare Awards, 2008; Highly Commended, International Design & Health Awards, 2009; Civil Trust Award Finalist, 2009

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 10 in. (257 mm)

KEY SUSTAINABILITY INDICATORS

- *Biophilia:* Organic forms of building merge with natural environment creating intimate and secluded gardens for the patients
- *Innovative Stormwater Management:* Porous paving areas and porous gravel surfaces to landscaped gardens
- *Narrow Floorplate:* Highly articulated, single loaded corridor scheme prioritizes daylighting
- *Rainwater Harvesting:* Rainwater used for water closet flushing
- *Natural Ventilation:* Natural ventilation and operable windows throughout communal space and bedrooms
- *Innovative Energy Distribution:* Hydronic heating
- *Healthy Materials:* Materials chosen for their natural, soft, qualities
- *Safe Construction Practices:* Considerate Constructors Scheme ensured construction managed in environmentally and socially considerate manner

Figure 7.16 *Source: Copyright © Chris Hill Photographic*

The Bluestone Unit, part of the Craigavon Area Hospital site, is a free-standing 74 bed mental health and psychiatric unit, purposely designed to maximize therapeutic values through contact with nature. The single story concrete block and timber buildings have been carefully sited to blend with the existing sloping landform and to engage with the existing landscape. Landscaped courtyards and spaces permeate the layout (Figures 7.16, 7.19–21).

Art element walls, a key feature linking landscape and architecture, are reflected within the wards, both in thickness and color, linking inside and outside. The glazing ties in with the entrance by using the same timber supports, integrating landscape and materials (Figures 7.17 and 7.18).

The building is designed on a domestic scale using natural materials wherever possible. Purposeful spatial hierarchy begins with the more formalized staff and reception areas at the front of the building and progresses to more private, relaxed and intimate residential spaces at the back. The entrance buildings are white, orthogonal, definitive and familiar while the shapes become more organic to embrace and provide privacy for patients to the rear.

Hardscape paving is minimized; parking is permeable grass-block. Water efficient fittings are used throughout the unit. Rainwater harvesting captures, stores, and recycles rainwater for toilet flushing.

The building is predominantly naturally ventilated via operable windows in the corridors and bedrooms with assistance in the wards from automatic opening high level clerestory windows in the central corridors. Mechanical ventilation is only used in critical areas such as bathrooms. Three high efficiency dual-fired boilers are installed in the main mechanical plant room to provide heat to the day hospital and each of the ward buildings.

Source: David Morley Architects

Figure 7.17 Exterior art element walls. *Source: Copyright © Chris Hill Photographic*

Figure 7.18 Expressed timber framing of link elements. *Source: Copyright © Chris Hill Photographic*

Figure 7.19 Landscape courtyard. *Source: Copyright © Chris Hill Photographic*

Figure 7.20 Floor plan. *Source: David Morley Architects*

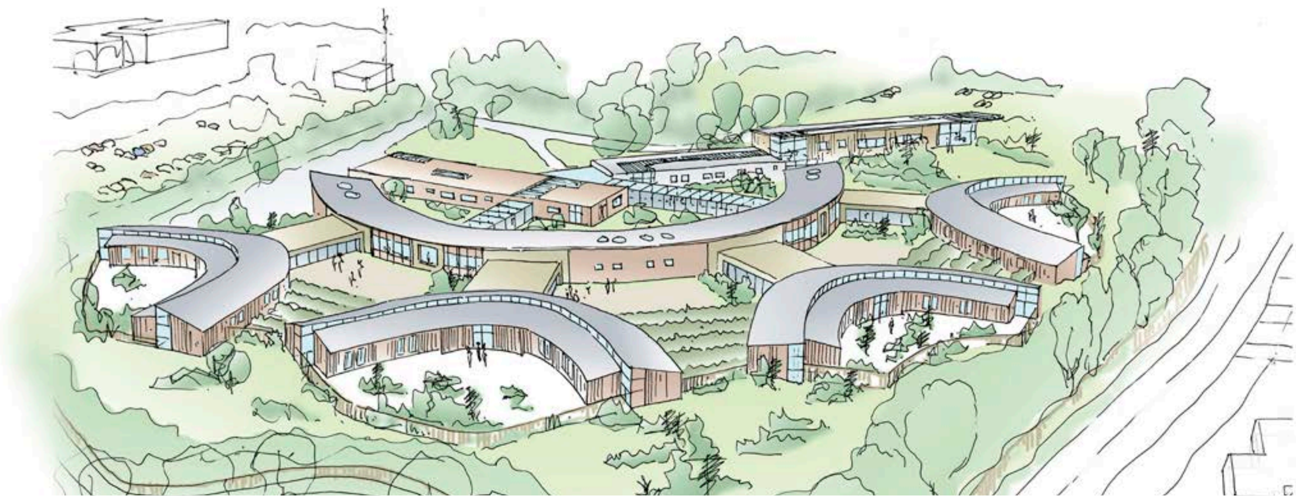


Figure 7.21 Campus view. *Source: David Morley Architects*

Case Study 14: New South West Acute Hospital

Enniskillen, Northern Ireland

OWNER: Northern Ireland Health Group (NIHG)

CLIENT: Western Health and Social Care Trust (HSC)

PROJECT TEAM:
Architect: Stantec Anshen+Allen
Mechanical and Electrical Engineer: DSSR/Mercury
Landscape Architect: Land Use Consultants
Constructor: FCCE (FCCElliott)

TYPE: New Acute Care Hospital Campus

SIZE: 726,564 sq. ft. (67,500 sq. m); Site: 52 acres (21 ha)

EUI: 100 kBtu/sf/yr (312 kWh/sm/yr)

PROGRAM DESCRIPTION: 312 private acute care beds, including pediatrics, critical care, general medicine, rehab, general surgery, laparoscopic surgery and care of the elderly as inpatient care, accident and emergency services, imaging and diagnostics, maternity services

COMPLETED: 2012

RECOGNITION: NEAT Excellent

BIOME: Temperate Humid

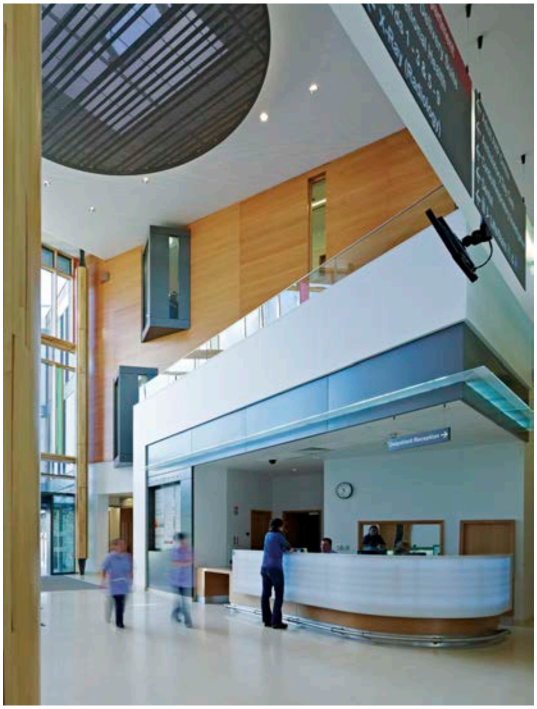
CLIMATE ZONE: Marine West Coast

PRECIPITATION: 59 in (1,500 mm)

KEY SUSTAINABILITY INDICATORS

- *Habitat Restoration:* Restored hydrology, wetlands and native ecosystems
- *Bioregional Architecture*: Local materials and traditional forms
- *Narrow Floor Plate*: Narrow building incorporates plan enclosed courtyards
- *Energy Responsive Façade:* Highly insulated, high performance façade elements; exterior solar shading
- *Water Conservation:* Low water use fixtures
- *Rainwater Harvesting:* Capture from roof of central energy facility for process make-up water
- *Renewable Energy*: Biomass boiler fueled by timber pellets for entire heating load
- *Natural Ventilation*: Hospital street naturally ventilated; operable windows in patient rooms for enhanced thermal comfort
- *Healthy Materials*: A focus on natural materials

Figure 7.22 *Source: Copyright © Timothy Soar Photography*



This PFI (private finance initiative) hospital project is designed to be the greenest hospital in the UK. The campus is situated on Wolf Lough just north of Enniskillen, a town of about 13,500 residents (Figure 7.22). Enniskillen is a maritime climate, characterized by cool summers and mild winters—high temperatures of 78°F (25.5°C) and lows of 17°F (–8°C).

This is the first NHS hospital in Northern Ireland to have 100 percent single patient bedrooms. The site planning and placement of the building form on a beautiful greenfield site with the Loch Erne in the background supports a master plan that preserves and enhances the site drainage patterns and surrounding ecosystems—the project features a fully integrated and sustainable landscape that enhances ecosystems and habitat. Intensive and extensive green roofs create opportunities for ecological niches to flourish.

The design incorporates several passive environmental features such as narrow floor plates that maximize daylight, solar shading for occupant comfort and provision of natural ventilation where clinically viable (Figures 7.23–24). All clinical areas are mechanically cooled. Renewable source thermal energy is provided by biomass steam boilers fueled by timber pallets, backed up by oil-fired boilers. All biomass is locally sourced.

The hospital buildings are organic in form and sit naturally in their landscape—the hospital is broken up into a number of smaller blocks to humanize the scale. A palette of predominantly natural materials—locally sourced stone, slate, and timber—further ground the building in its place. A series of internal linear gardens provide the main organizational feature of the hospital (Figures 7.25–27).

Source: Stantec Anshen+Allen Architects

Figure 7.23 Lobby. *Source: Copyright © Timothy Soar Photography*

Figure 7.24 View through exterior shading. *Source: Copyright © Timothy Soar Photography*

Figure 7.25 Linear courtyard with chapel. *Source: Copyright © Timothy Soar Photography*

Figure 7.26 Exterior detail with local stone. *Source: Copyright © Timothy Soar Photography*

Figure 7.27 Campus model. *Source: Stantec Anshen+Allen*

PARTNERS HEALTHCARE

Partners HealthCare, founded in 1994, is a nonprofit healthcare system that includes seven greater Boston area and three Cape Cod hospitals with their related ambulatory services; in aggregate, the system encompasses more than 17 million square feet of owned and leased space and employs 60,000 people. Partners HealthCare has made sustainability a top priority. Its journey toward sustainable and restorative operations demonstrates a systematic, growing accomplishment over time as new environmental programs are launched, buildings are constructed and retrofits are completed.

Partners is a founding member of the Healthier Hospitals Initiative (HHI). John Messervy, AIA, Director of Capital and Facility Planning, and Hubert Murray, FAIA, Manager of Sustainable Initiatives, direct the system's sustainability initiatives. At the same time, each hospital sets its own priorities. For example, both the system and member hospitals are active in all six HHI Challenge areas, including:

- ***Engage leadership on environmental health.*** The system CEO, Dr. Gary Gottlieb, is the co-chair of the healthcare sector of the Boston Green Ribbon Commission. John Messervy chairs the HHI Steering Committee.
- ***Reduce waste and recycle.*** North Shore Medical Center and Brigham and Women's Hospital have adopted a single-stream waste management program.
- ***Use safer chemicals.*** Brigham and Women's Hospital and Massachusetts General Hospital are pioneering a radical reduction in the use of hazardous chemicals in their research labs.
- ***Purchase environmentally preferable products.*** Partners has made a systemwide commitment that, beginning in late 2012, they will no longer purchase clinical products containing DEHP if available substitutes exist, beginning with DEHP-free IV bags and tubing. McLean Hospital has replaced bottled water with filtered tap water dispensers.
- ***Serve healthier foods and beverages.*** Massachusetts General and Newton-Wellesley Hospitals have initiated lines of healthy food choices.
- ***Reduce energy.*** Partners is proceeding with a range of energy programs following its 2008 Strategic Energy Master Plan, which commits it to the ambitious goal of reducing overall energy consumption by 25 percent by 2013 (relative to a 2008 baseline). It is also committed to LEED-Silver and -Gold on all major capital projects.

Partners frames its sustainable initiatives around long-term cost control and risk mitigation, improved patient and employee health and safety, and improved public and environmental health. There are Green Teams in each hospital, with representatives from Environmental Services, Facilities, Nutrition, Safety, Chemicals and Materials Management. Energy efficiency provides the backbone of the business case; other sustainable features are incorporated based on the success of energy conservation.

Beginnings

Partners HealthCare's journey toward sustainable and restorative operation began in 2000 with the design of the Yawkey Center for Ambulatory Care, a 447,000 sq. ft. (41,528 sq. m) ambulatory-care building at the heart of the Massachusetts General Hospital campus in central Boston. The long, narrow site forced a single-loaded corridor design that maximized the penetration of natural light deep into waiting and practice spaces (see Figure 7.28). Its location overlooking the Charles River and Esplanade provided dramatic views for patients undergoing dialysis on the top floor. An 8,000 sq. ft. (743 sq. m) rooftop gave rise to the concept of a healing garden for pediatric and adult patients undergoing treatment in the building (see Figure 7.29). These ideas and more coalesced in 2004 when system leaders attended the Massachusetts Design for Health Summit, organized by Health Care Without Harm and Rocky Mountain Institute. Leaving the meeting, they determined that they would incorporate additional strategies from the Green Guide for Health Care (GGHC) into Yawkey, such as healthier materials, even though they were midway through construction. The transformational impact of

Figure 7.28 Yawkey Center interior. *Perkins+Will*

Figure 7.29 Charles Ulfelder Healing Garden at the Yawkey Center. *Ben Watkins, Halvorson Design Partnership*

these relatively modest strategies provided a positive foundation for continued sustainable design exploration.

The Carl J. and Ruth Shapiro Cardiovascular Center at Brigham and Women's Hospital offered the next significant system capital project opportunity. The hospital leadership agreed in 2006 to target LEED-Silver for this complex inpatient and diagnostic building on a tight urban site. The team registered the project as a GGHC Pilot and with LEED, focusing on energy demand reduction and indoor air quality. Shapiro was the first large-scale installation of rubber flooring in the system; Environmental Services now views rubber as the standard flooring product for comfort under foot, acoustics, and reduced maintenance—from a sustainable design perspective, it reduced caustic wax and strip protocols and supported PVC avoidance goals (see Figure 7.30). One of the unique project innovations was the relocation of six existing Boston "triple decker" houses located on the site in lieu of demolition. The homes were physically moved to scattered vacant lots in the surrounding neighborhood, replacing gaps in the urban residential neighborhoods with consistent architectural typology (see Figure 7.31).

Shapiro was one of the first large hospital buildings in the Northeast to achieve LEED certification in early 2009; Partners continues to track its energy performance against predictive modeling with some surprising lessons learned. Today, more than five years after opening, Shapiro operates at only 46 percent of the projected electrical load, leading Partners to question the engineering basis of design for electrical loads. Lessons learned:

- Electrical design must be based on a room-by-room load assessment rather than a general factor applied to a floor or suite of rooms.
- Equipment faceplate ratings are generally not accurate. Assumed utilization rates and safety factors may not provide sufficiently accurate design data for complex medical and research buildings.
- Sustainable design measures can be achieved for modest construction premiums.

Figure 7.30 The Shapiro Cardiovascular Center at Brigham and Women's Hospital. *Source: Copyright © Anton Grassl/ESTO*

Figure 7.31 Relocation of existing houses on the site. *Source: Arthur Momborquette*

The estimated first cost premium for Shapiro's sustainable design features was less than three-fourths of one percent. A business case based on energy cost savings, improved indoor air quality, and enhanced working conditions for staff was recognized but not quantified; increased employee satisfaction with the work environment is another acknowledged benefit.

Strategic Energy Master Plan

Over the past decade, the U.S. healthcare industry has become more keenly aware of the health implications of fossil fuel use. John Messervy notes: "Within our organization, up to the senior management level, there is a growing understanding of the relationship between fossil fuel combustion, health, and disease. We needed to address it through our energy choices." In August, 2008, Massachusetts passed the Global Warming Solutions Act, making it one of the first states in the nation to move forward with a comprehensive regulatory program to address climate change. It set forth aggressive statewide targets for all industries:

- Between 10 and 25 percent below 1990 GHG emission levels by 2020
- 80 percent below statewide 1990 GHG emission levels by 2050

At the same time, the rapid rise in the cost of energy in the energy-intensive healthcare sector demanded a strategic response to long-term energy management. The combination of escalating energy charges and increasing demand demonstrated that inactivity would result in an increase in energy costs from $70 million per year in 2010 to $140 million by 2022. A key question emerged: Could compliance with the Massachusetts legislation also provide a path to avoiding the financial consequences of energy cost escalation?

This question led to development of the ten-year Strategic Energy Master Plan (SEMP) that is guiding Partners' investments and creating their short- and long-term compliance pathway. In summary, the SEMP demonstrated that achieving the statewide 2020 GHG reduction targets required extensive efficiency retrofit measures and integration of co-generation (CHP), while the 2050 goals demand a wholesale integration of renewable energy sources. The SEMP defined a set of energy efficiency measures and central plant retrofits that would yield the required reduction in energy demand at a projected capital investment of approximately $25

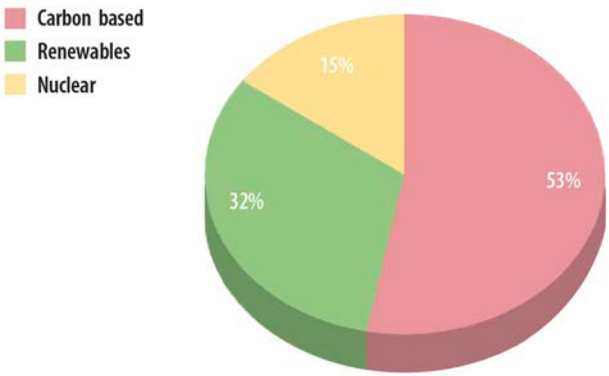


Figure 7.32 Massachusetts regional energy mix. *Source: Partners HealthCare*

million per year over ten years, or $250 million in aggregate. Overall energy utility expenditure is expected to remain relatively constant; by 2022, system-wide energy costs may be as much as 44 percent less than if Partners did nothing. Partners is now implementing these measures, inspired by the legislation but impressed by the financial rate of return. Messervy notes: "CHP is a necessary bridging strategy between today's reliance on fossil fuels and a future with affordable renewables."

The Starting Point

Partners began this journey from an interesting regional energy mix base, shown in Figure 7.32. Compared to a national average of 10 percent renewables and 70 percent carbon based, the local energy market leaves little opportunity for source fuel substitution to achieve significant GHG reductions. Using Practice Greenhealth's Energy Impact Calculator, they calculated GHG emissions of 115,000 tons annually with close to $1 million per year in unintended health impacts within their local community.

The SEMP targets are illustrated in Figure 7.33. Using 2008 as the base year, Partners projected its GHGs

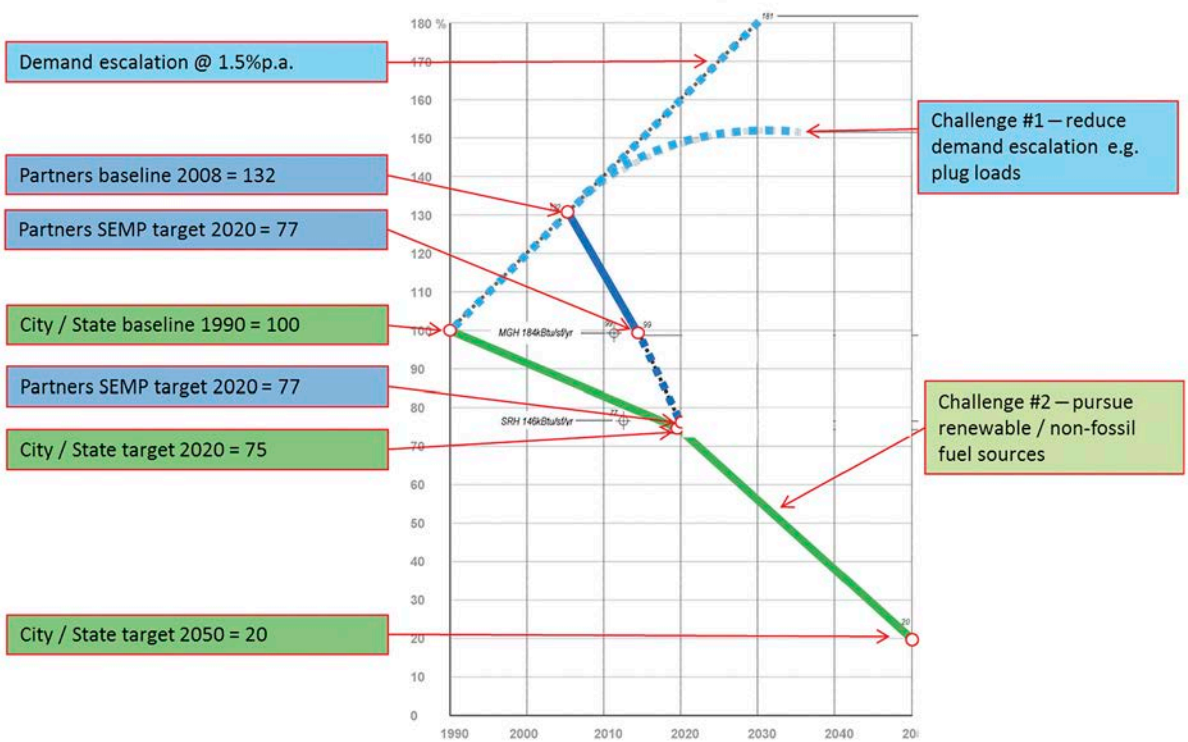


Figure 7.33 Partners Strategic Energy Master Plan (SEMP) targets. *Source: Partners HealthCare*

backward to 1990 to determine the baseline for the Global Warming Solutions Act, based on an historical average metered energy intensity increase of 1.5 percent per year. Next, they projected the impact of the SEMP measures in two phases: Phase 1 (2008–2014) to reduce consumption by an estimated 25 percent; Phase 2 (2014–2022) to meet the Global Warming Solutions Act 2020 target, or return them to their 1990 baseline. In summary, they realized that both demand reduction and source efficiency measures will come close to the 2020 goal, but meeting the 2050 goal requires implementation of renewables, a formidable challenge for an urban system without proximate real estate to locate photovoltaics or wind turbines.

Conclusions

Hubert Murray notes: "The SEMP clearly demonstrated that a concentrated focus on reducing energy demand and improving source energy efficiency would be required to achieve the immediate required GHG reductions." The SEMP concluded with the following action plan for the first two phases (2008 to 2022):

- Invest in Energy Conservation Measures (ECMs)
  - $61 million investment in 230 ECMs yields 28 percent energy reduction
  - 3.7 year payback (27 percent annual return)
- Implement Cogeneration at major Boston Hospital sites
  - 33 megawatt (MW) total at four hospital and one research lab locations
  - 7.8 year payback (13 percent annual return)

These measures were then phased over a ten-year period to achieve a relatively equal investment each year—approximately $20–$25 million per year. The SEMP included the ROI assessment for each component—based on the projected returns of 27 and 13 percent, respectively; system leadership agreed to implement the program. If renewable energy project opportunities arise, they will be implemented alongside the identified efficiency projects. A 12 percent hurdle rate is the acceptable threshold for system finance leadership (see Figure 7.34).

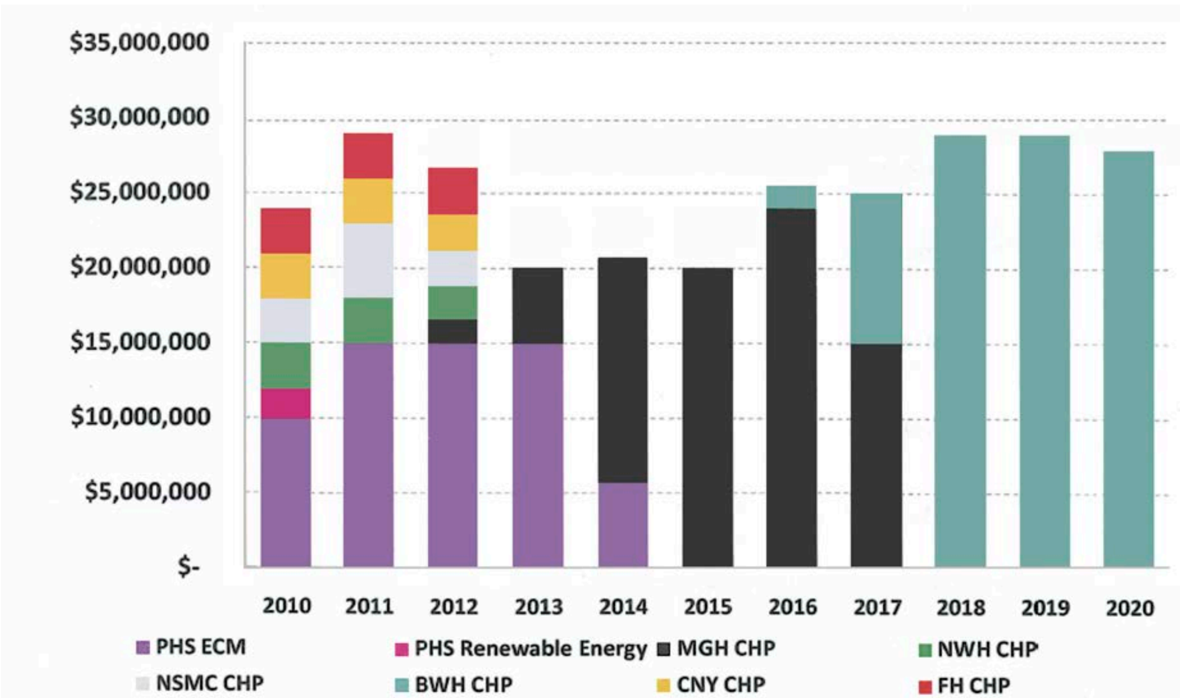


Figure 7.34 Ten-year investment profile. *Source: Partners HealthCare*

CHP is introduced as an essential strategy, given the difficulty of implementing sufficient renewables in time to meet the 2020 targets. Overall, CHP will improve source energy efficiency from 47 percent to 83 percent. One of the more innovative CHP projects is the expansion of an existing relationship with GenOn Kendall Station, a CHP utility plant located across the Charles River from Massachusetts General Hospital. Currently, GenOn pipes excess steam across the river to MGH for heating and sterilization; in the future, it will increase steam supply to power two 15 megawatt steam turbines on the MGH site for power generation as well.

A critical aspect of the SEMP was energy cost forecasts, which were generated to illustrate the impact of energy efficiency measures alone, conversion to CHP alone, and the combined impact of the two strategies. These graphs (see Figure 7.35) demonstrated that the SEMP, fully realized, would serve to hold energy costs level as opposed to the "business as usual" projections, which targeted an increase from $70 million annually to $140 million per year over the next ten years.

Lower Energy Buildings

Alongside this system focus on energy demand reduction, Partners HealthCare was continuing to construct significant new clinical facilities. Adjoining the Yawkey Building on the Massachusetts General campus, the 535,000 sq. ft. (49,703 sq. m) Lunder Building opened in late 2011, commemorating the bicentennial of Massachusetts General Hospital (see Case Study 15, this chapter). Partners reports no first cost premium related to sustainable design; in fact, because the Department of Public Health and Boston Redevelopment Authority require LEED equivalency, the advantages of market normalization are being realized. Messervy notes: "These buildings are major investments that will consume energy for a lifetime. We continue to look to reduce energy intensity, to learn from our portfolio, while we focus on providing a high level of care and inspiring workplaces. Investing in energy efficiency and LEED certification makes sense."

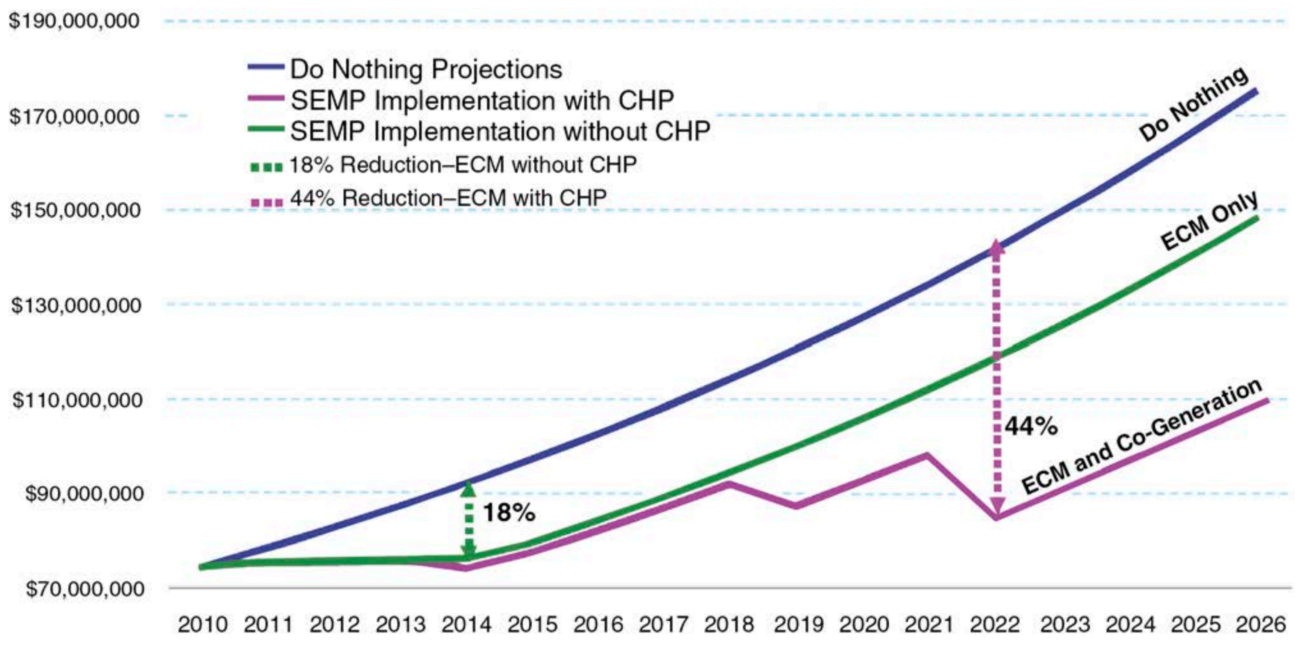


Figure 7.35 Partners' total energy cost projections. *Source: Partners HealthCare*

Following the Lunder Building, Spaulding Rehabilitation Hospital embarked on a replacement hospital facility on an industrial brownfield site in the Charlestown Navy Yard, a promontory site at the junction of Boston Harbor and Little Mystic Channel (Case Study 16, this chapter). According to David Burson, Project Executive: "Locating the Spaulding replacement facility on an ecologically damaged site in an underdeveloped community allowed us to combine program and place to build an inclusive facility that aims to restore health to both its patients and the surrounding community." Remediation of this site, while restricted in area, provided a unique opportunity for Partners to explore a range of innovative renewable energy systems, including tidal, wind, and solar as well as water heat pump systems to reduce energy demand. Ultimately, Partners selected a CHP power generation system with roof infrastructure for future PV. Three patient rooms have been designed with a displacement ventilation system to enable Partners to conduct research into its effectiveness for future buildings. Working with the Perkins+Will Precautionary List extended their focus on sustainable materials and has influenced system standards.

The healthcare delivery issues associated with severe weather events in New Orleans in 2005 and Nashville in 2010 had a significant impact on design decisions. Spaulding is the first building on the Boston Harbor waterfront to be designed to anticipate projected sea level rise, with its primary entrance elevated 30 inches (2.54 cm) above the 500-year flood level to protect the ground floor for most of the building's seventy-five-year life. Additional protection is achieved by placing critical mechanical and electrical infrastructure on the roof rather than in the basement. This focus on passive survivability and resilience; for instance, the capability of the structure to remain operational in periods of significant infrastructure disruption, extends to keyed operable windows in patient rooms and automated natural ventilation systems in gymnasiums and therapy areas. Murray notes: "We want the building to remain in service as a safe haven for the patients, staff, and the immediate community." In summary, it provides a glimpse of future directions in sustainable design for the Partners' system.

Conclusion

In summary, Partners HealthCare has embarked on a sustainability journey to aggressively cut GHG emissions, improve building energy efficiency, and improve passive survivability and reliability in the service of improved community health and quality patient care. LEED-certified facilities now represent 11 percent of their owned real estate portfolio—comprising more than 1.2 million sq. ft. (111,484 sq. m). In the first eighteen months of implementation, they have realized close to half of the 28 percent energy reduction goal related to implementing energy efficiency measures across the system. They are installing 14 megawatts of CHP, with 48 megawatts of additional capacity in the planning stages. They have issued a request for proposals for grid-connected solar. Collectively, by 2022 they will reduce carbon-based fuel use by 43 percent alongside increasing renewables from 32 percent to 37 percent; they will meet the most aggressive reduction target of the Massachusetts policy. They will also significantly reduce the financial risks associated with rising fossil fuel energy prices. In so doing, Partners HealthCare will demonstrate how some of the nation's best hospitals can dramatically reduce their environmental footprint.

Source: Partners HealthCare

Case Study 15: The Lunder Building, Massachusetts General Hospital

Boston, Massachusetts

OWNER: Massachusetts General Hospital

PROJECT TEAM:
Architect: NBBJ
MEP Engineer: Thompson Consultants Inc.
Landscape Architect: Michael Van Valkenburgh Associates, Inc.
Construction Manager: Turner Construction Company

TYPE: New Acute-Care Academic Medical Center Building

SIZE: 535,000 sq. ft. (49,703.1 sq. m)

EUI: 184 kBtu/sf/yr (580 kWh/sm/yr)

PROGRAM DESCRIPTION: 150 inpatient general hospital with progressive technologies, procedural programs, emergency and radiation oncology departments

COMPLETED: 2011

RECOGNITION: LEED Gold–certified

BIOME: Temperate Humid

CLIMATE ZONE: Humid Continental

PRECIPITATION: 33 in (850 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Innovative form maximizes nature connectivity on compact downtown urban site
- *Green Roof:* More than 50% of building footprint covered in vegetated roofing
- *Narrow Floor Plate:* Insertion of atria provide increased perimeter and bring daylight deep into floor plate
- *Energy Responsive Façade*: Exterior glazing system, vertical louvers, and operable interior shading minimize heat gain and loss
- *Rainwater Harvesting:* Rainwater irrigates gardens
- *Low Embodied Energy/Healthy Materials:* More than 33% recycled content or locally sourced; toxic chemical avoidance and low emitting
- *Acoustics:* Rubber flooring, sliding doors, decentralized nursing stations reduce ambient noise levels

Figure 7.36 *Source: Copyright © Anton Grassl/ESTO*

The Lunder Building is a high-tech, flexible structure located on a compact urban campus in downtown Boston. The building is split into a base of procedural programs and an upper bed tower, with a key design element of connections to natural light and gardens (Figure 7.36). A five-story atrium adjacent to the main circulation core penetrates deep into all patient floors (Figure 7.37). Site modeling was used to understand contextual and proportional balance, arrival and egress routes, and environmental issues such as shading and wind impact. Circulation modeling developed ideal connections to five pre-existing buildings via bridges and walkways (Figure 7.38–39).

The project brief specified single patient rooms to enhance infection control, privacy, and greater family-centered care. In order to maximize rooms on the constrained site, the MGH floor plate was "fractured" into two interlocking, C-shaped groups of patient rooms, traversed by a central circulation spine (Figure 7.40). Floor-to-ceiling curtain wall floods the pa-

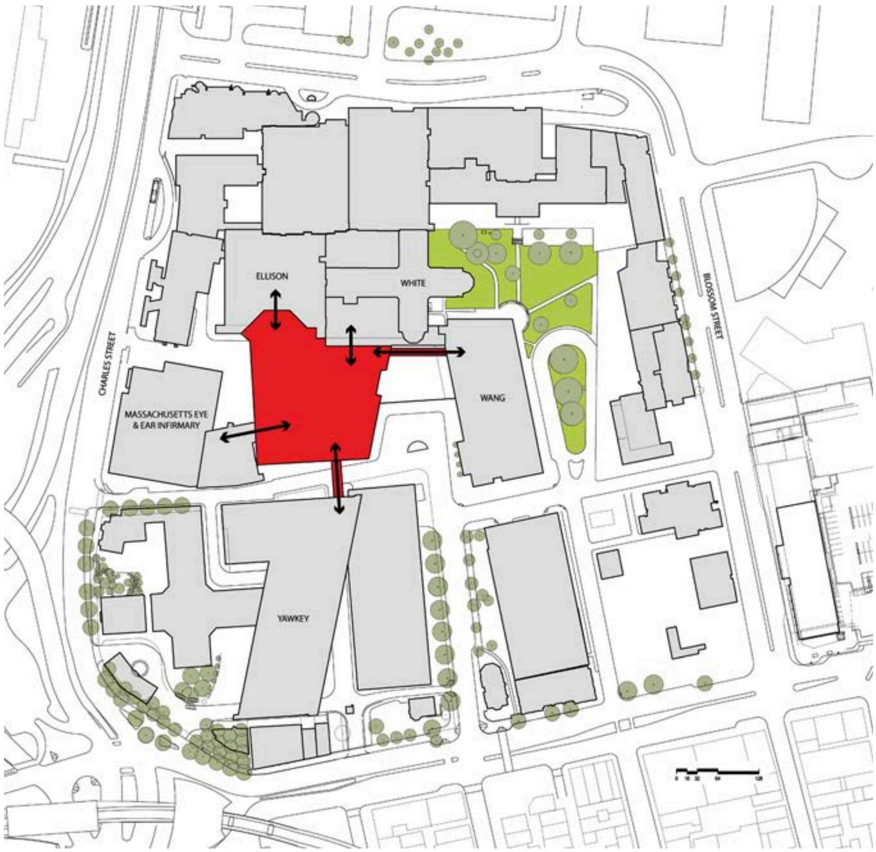


Figure 7.37 The atrium. *Source: Copyright © Anton Grassl/ESTO*

Figure 7.38 Daylit surgical corridor. *Source: Sean Airhart/NBBJ*

Figure 7.39 Site plan with connections. *Source: NBBJ*

Figure 7.40 Typical patient floor plan.
Source: NBBJ

tient rooms with natural light, while many rooms are afforded views to either a sixth-floor rooftop bamboo garden, indoor atrium, and/or the nearby Charles River. The atrium creates a healing environment that is visible and accessible to everyone, as well as a space for special events.

Sustainability permeated all design and construction decisions of this LEED Gold–certified building. More than half of the building's footprint area is covered in green roofs that harvest rainwater for irrigating the gardens. Aided by low-flow plumbing fixtures throughout, water use was reduced by 1.4 million gallons per year. The exterior glazing system, vertical louvers, and operable interior shading devices minimize heat gain and loss while maximizing daylight, improving thermal performance by 39 percent and reducing baseline solar heat gain by 31 percent. The building achieves an overall 10 percent reduction of energy demand.

Qualitatively, MGH has already documented a significant decrease in hospital noise—which can impede patient recovery—since occupancy, attributable to design solutions including rubber flooring, sliding doors, the removal of doors that open and close across from patient rooms, and the decentralization of nursing stations. The end result is a safe, healthy, sustainable and productive environment for patients, families, and staff.

Sources: NBBJ/ Partners HealthCare

Case Study 16: Spaulding Rehabilitation Hospital

Boston, Massachusetts

OWNER: Spaulding Rehabilitation Hospital

PROJECT TEAM:

Architect: Perkins+Will

MEP Engineer: Thompson Consulting Engineers

Site Landscape Architect: Copley Wolff Design Group

Sustainable Engineering Consultant: Buro Happold

Construction Manager: Walsh Brothers Inc.

TYPE: Replacement Rehabilitation Hospital

SIZE: 378,367 sq. ft. (35,150 sq. m)

EUI: 152 kBtu/sf/yr (480 kWh/sm)

PROGRAM DESCRIPTION: Large, comprehensive rehabilitation facility with 132 inpatient beds (120 adult and 12 pediatric), inpatient and outpatient rehabilitation gyms, pool, and therapy spaces

COMPLETED: 2013

RECOGNITION: Seeking LEED certification

BIOME: Temperate Humid

CLIMATE ZONE: Humid Continental

PRECIPITATION: 42 in (1,071 mm)

KEY SUSTAINABILITY INDICATORS

- *Brownfield Site:* Extensively remediated former industrial site
- *Innovative Parking:* All on-site parking below grade
- *Green Roof:* Extensive vegetated and planted roofs
- *Energy Responsive Façade:* High performance envelope with increased insulation and triple glazed windows at patient rooms; daylight harvesting with automatic sensors
- *Innovative Source Energy:* Gas-fired co-generation unit produces thermal energy and power
- *Natural Ventilation:* Operable windows tied to HVAC controls in inpatient and outpatient gymnasia, multipurpose rooms, patient education rooms, lounges
- *Renewable Energy:* Infrastructure to support future PV on roof
- *Healthy Materials:* Selections based on Perkins+Will Precautionary List; low emitting
- *Civic Function:* 75% of ground floor dedicated to public uses; 50% of site area open space accessible to the public, including Harbor Walk
- *Resilience:* Site grading responds to anticipated sea level rise over buildings' lifetime

Figure 7.41 *Source: Perkins+Will*

Figure 7.42 The high gymnasium with automated operable windows. *Source: Perkins+Will*

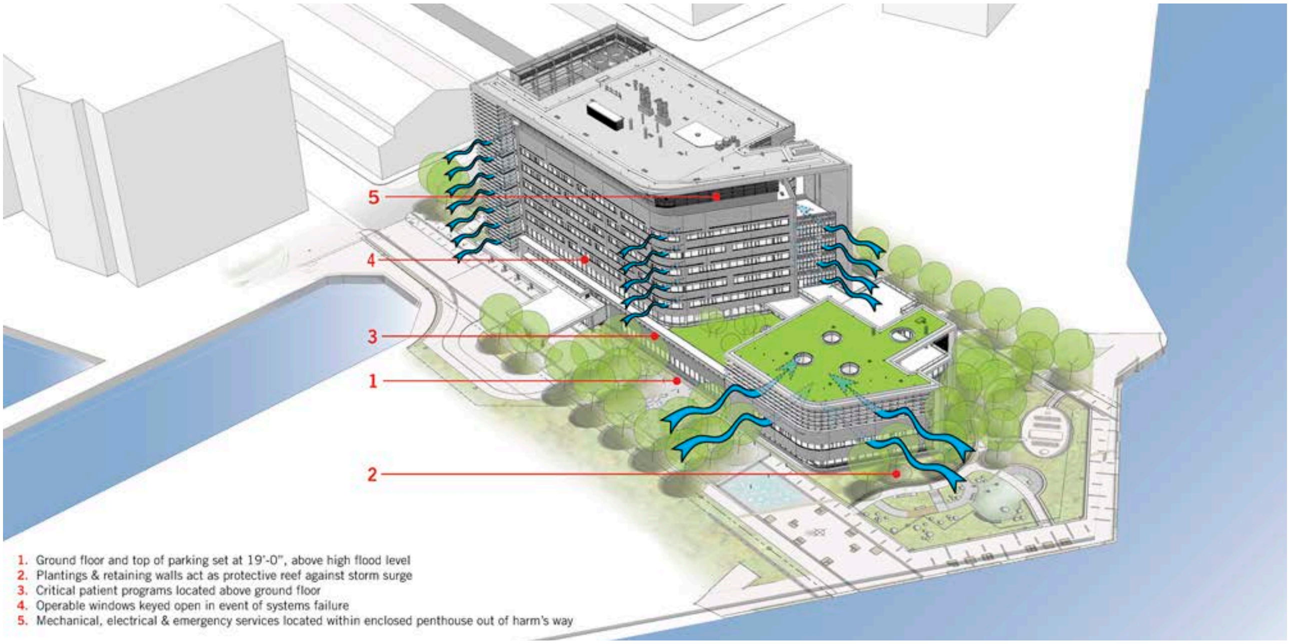


Figure 7.43 Resilience features. *Source: Perkins+Will*

The Spaulding Rehabilitation Hospital is a unique merging of program, place and sustainable features to create an exceptional healing environment and public building. Located within Boston's Charlestown Navy Yard, the building is located on a former industrial brownfield site; it is constructed on manmade landfill at the harbor's edge (Figure 7.41).

The Boston Redevelopment Authority imposed strict development conditions that completely dovetailed with Spaulding's mission to rehabilitate adults and children in a noninstitutional, inspirational and normalized setting. First, harbor view corridors and pedestrian access from the adjacent streets were maintained. Next, 50 percent of the site area was required to be publicly accessible, as well as 75 percent of the interior ground floor (Figure 7.44). Spaulding includes a publicly and universally accessible restaurant/café with outdoor seating and extended the City Harborwalk at the waterfront edge. Their signature water sport rehabilitation program includes a dock structure. Gardens surrounding the building utilize native, drought-tolerant vegetation and provide therapeutic spaces for patient use. Interior public ground floor uses include a conference center, meditation space, pool, and toilet facilities supporting the programmatic goals of community inclusion while offering residents

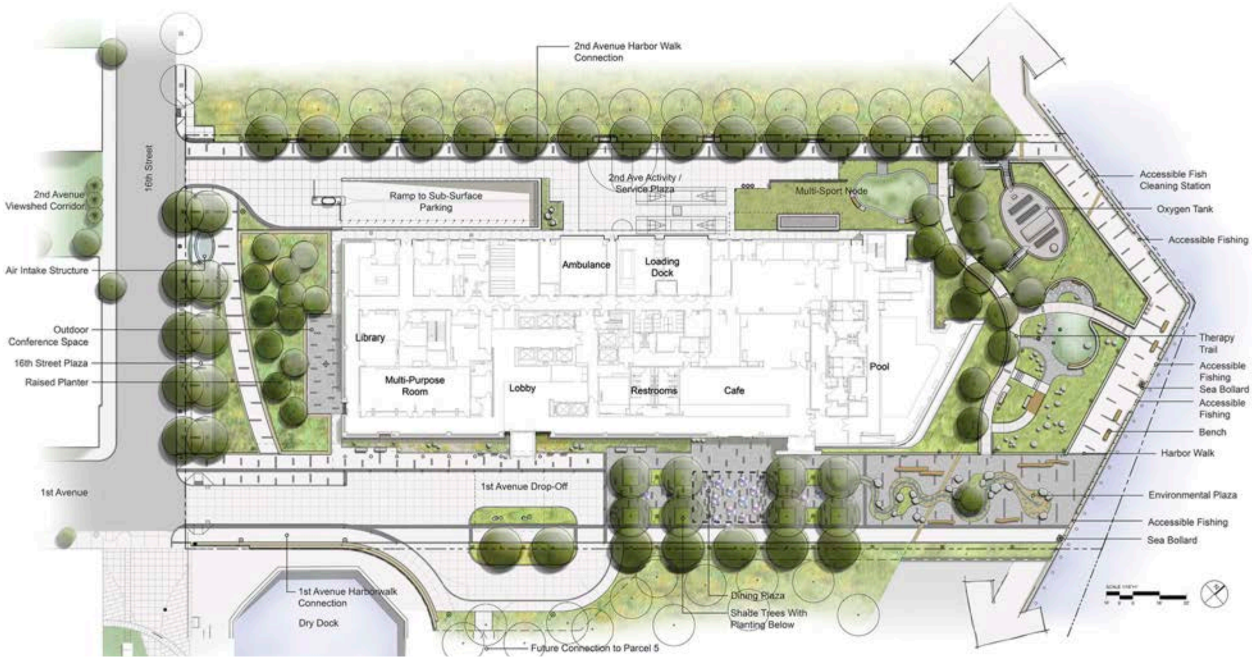


Figure 7.44 First floor plan. *Source: Perkins+Will*

the opportunity to interact in the public realm while patients are receiving treatment.

The constricted site posed unique challenges for a residential program. Historically, rehabilitation facilities are located on sites with large, accessible grounds—in this instance, the building separates the pool, gymnasia and treatment spaces in a low rise structure at the water's edge, while beds are distributed in a narrow tower beyond (Figure 7.42). The distributed massing yields a series of outdoor terraces and green roof gardens at multiple floors that become the Spaulding residents' private outdoors and mitigate stormwater runoff. All parking is below grade.

The building design celebrates high performance envelope and energy systems. Clerestories and shading devices reflect daylight deep into the interior; the highly insulated façade includes triple glazed windows that eliminate the need for perimeter conditioning. The zoning of the building supports the introduction of seasonal natural ventilation at gymnasia and treatment spaces; automatic operable windows are interconnected to the building management system, activated when ambient conditions are appropriate. Narrow floorplates prioritize daylighting. All patient rooms include key-operated manual operable windows as a resilience measure. A gas-fired co-generation system provides both thermal energy and base load electricity.

Finally, the building is the first structure located on the Boston Harbor waterfront to anticipate sea level rise and extreme weather event vulnerability (see Figure 7.43). The ground floor was raised one foot; landscape is bermed around the perimeter to three feet. All significant mechanical and electrical infrastructure is located on the roof, out of harm's way in the event of extreme weather events. Operable windows in patient rooms and all major treatment spaces allow the building to remain operational—and potentially provide a safe haven for the immediate community—if mechanical systems are interrupted.

Sources: Perkins+Will/ Partners HealthCare

PROVIDENCE HEALTH & SERVICES

Providence Health & Services, a not-for-profit Catholic healthcare ministry, continues a tradition of caring that the Sisters of Providence began more than 155 years ago; they view environmental stewardship as a legacy value well embedded in the organization's mission and goals. In 2012, Providence affiliated with Swedish Health Services. With this affiliation, the combined scope of services includes 32 hospitals, 350 physician clinics, senior services, supportive housing, and many other health and educational services. The health system employs more than 64,000 people across five states—Alaska, California, Montana, Oregon, and Washington.

According to John Koster, MD, Providence President and CEO: "Providence's journey is really about bottom up and top down stewardship." Richard Beam, Director of Energy Management Services, Office of Supply Chain Management, summed it up this way: "As an industry sector, health care is uniquely positioned because it reaches across all classes, all economic strata, geographically. It's mission-driven and we're in the healing business. And it's a natural, when you're in the business of healing people, that you want to heal the Earth as well." He describes meeting Janine Benyus, author of *Biomimicry: Innovations Inspired by Nature*, at a conference in 2007:

> I met with her at an inland Northwest sustainability conference and I asked her to inscribe something in my copy of her book about her work, and how her work and mine really meshed in some way. She wrote: "Providence Health & Services has two patients, the medical patient and the earth. To heal one without the other will not last." It's true for health care. We have to do both.
>
> (GUENTHER AND VITTORI, 2007)

The Providence stewardship journey has been long and not without challenge and complexity. As a system, they began implementing sustainable strategies as early as 1998 at Providence St. Peter in Olympia, Washington; completed the industry's first LEED Gold–certified hospital in Newberg, Oregon, in 2006; and in 2012 announced their affiliation with Swedish Health System (Case Study 35, Chapter 8). Providence St. Peter's continues to trial many of the system's energy and water reduction measures, while Providence Newberg, six years after opening, continues to offer both inspiration and valuable lessons learned. As a longtime member of Practice Greenhealth, Providence continues to focus on sustainable operations.

A capital freeze since 2009 has hindered facility upgrades and expansions: as a result, their building portfolio's Energy Use Index (EUI) is creeping upward despite continued implementation of individual modest energy conservation measures. Their hospital facilities, in particular, are using space more intensively—doing more with less. Their \$100 million/year utility expense is likewise under pressure. At the same time, Providence's carbon emissions are slightly improving, largely as a result of utility level investments. Legislation in Washington State aimed at achieving 20 percent nonhydro renewables by 2015 is spurring utility level development of renewables (Figure 7.45), while a massive wind investment in Northeast Oregon is scheduled to come online in the near future. Together with improved turbine efficiency at hydro facilities, the regional electric grid is improving. At the same time, low purchase utility rates (approximately 8 cents per KW) make the economics of on-site renewable generation investments difficult. In summary, Providence is continuing to focus on demand efficiency at the facility level and on incremental operational improvements.

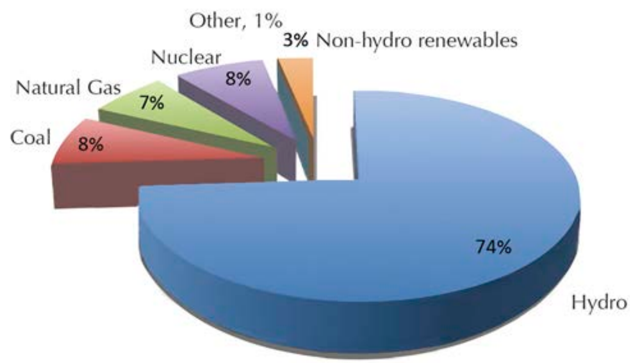


Figure 7.45 Washington State electricity grid fuel sources, 2007.

The Providence Approach

Rather than establishing system-wide performance goals, Providence has integrated sustainability initiatives based on carefully constructed business case metrics developed and reviewed by their BOAT (Business Opportunity Assessment Team), comprised of Providence leaders from diverse functional areas such as medicine, finance, and engineering. The BOAT developed a financial template for all capital projects over $5 million—one that integrates capital and operational costs in an initial attempt to instill a life cycle approach into capital and environmental decision-making.

Providence defines the direct cost of additional capital requirements, the monetary value of rebate programs (including direct utility programs and tax credits), and the estimated operational savings related to each resource-saving strategy. Provided the strategies meet the defined return on investment—"hurdle rate"—additional capital is then approved. Even before the opening of Providence Newberg, Beam estimated that the process had yielded upward of $600,000 in annual savings and avoided costs through a range of system initiatives; since 2008 that number has grown to over $1 million annually. Within this overall framework, each Providence site develops specific regional and local responses to resource demand reduction.

Providence Newberg

According to Beam, "Newberg is a story of reality and redemption." It was the first LEED Gold–certified hospital, and Providence's first project to pursue LEED certification—hence, the learning curve was substantial (see Case Study 17, this chapter). Upon completion and move-in, Providence opted to conduct a post-occupancy evaluation (POE) through UC-Berkeley's Center for the Built Environment and allow a full year of operation before publishing results of both (see Chapter 5). The POE, while accurately reflecting the largely positive experience of facility staff, revealed some problems associated with thermal comfort and acoustics. After a year of operation, energy consumption data revealed Newberg to be the most energy-intensive building in the Providence system, nowhere close to the modeled performance targets that were the basis of the LEED certification and the business case. It achieved an ENERGY STAR score of 25 (based on a 1–100 scale).

Beam and his team addressed the issues head-on: After three years of retro-commissioning, retrofits (including a boiler replacement) and staff training, the building received a 2010 ENERGY STAR score of 65 and now operates with an EUI of 240 kBtu/sf/yr (624 kWh/sm/yr). Ultimately, Beam believes the energy penalties associated with the 100 percent outside air system (even with heat recovery technology) restrict further improvements—in the long term, a heat recovery system retrofit may offer some additional energy benefit as technologies improve. Key lessons learned are summarized here (see page 217); at the same time, the positive aspects of the Newberg healing and work environment revealed in the POE continue to be an example for sustainable hospitals everywhere—in short, people continue to love the building. Beam sums it up this way: "Being a change agent requires a thick skin and a conviction that what you're doing has value to your organization. And eventually, what you start to see is hearts and minds changing."

Providence St. Peter

As the accompanying case study suggests, Providence St. Peter remains the flagship of the system's energy and water conservation initiatives, led by Geoffrey Glass, PE, Director for Facility and Technology Services, and his Stewards for a Sustainable Environment (SSE) team. According to Glass, sustainability at St. Peter begins with land stewardship: "Only 35 percent of our existing campus is developed—the adjacent Class 1 salmon wetland precludes development of another 40 percent. We regard our site as a valuable community resource—and our community agrees with that."

While initially focused on energy conservation measures, Geoffrey Glass, Troy Aichele, and Keith Edgerton have completed a series of potable and process water retrofits that save an estimated 31 million gallons per year from a 1998 baseline—or 59 percent (see Table 7.2). Their strategies, organized around Jerry Yudelson's pyramid of new water sources diagram (see Chapter 5, Fig-

PROVIDENCE NEWBERG: FIVE LESSONS LEARNED

1. *100 Percent Outside Air.* When considering these systems, carefully analyze the building microclimate and outside air quality threats. In Newberg, Oregon, major forest fires (increasing with climate extremes) create smoke events in the valley, adversely impacting building performance for extended periods. There is no resilience in the system to either episodic or prolonged outdoor air quality disturbances —the building cannot be shut off from the ambient air. Further, even with heat recovery, the system is more energy intensive than recirculating air systems. When Newberg was designed, bio-terrorism concerns weighed heavily in the decision. While the staff appreciates the "fresh air," the noise, energy performance, and potential for compromise are substantial drawbacks.
2. *Energy Modeling.* The model matters. Energy modeling is an ongoing team effort; the model should be created and updated periodically through design phases, and again during construction if significant program or system changes occur. The Newberg model was completed; results were published early, even as programmatic and system value engineering occurred. It was not periodically updated. As a result, the model could not accurately predict the building performance, and the team was unaware of the impact of later decisions on the overall energy performance.
3. *Understand Impacts of Value Engineering and Schedule Decisions.* Newberg was heavily value-engineered; the initial budget was modest and proved difficult to achieve. The schedule was compressed by one year due to the sale of the existing Newberg Hospital property. Energy efficiency measures were sacrificed for budget and schedule reasons without sufficient understanding of their performance implications. Heat recovery technology, a key component of maintaining energy performance in a 100 percent outside air building, was downgraded.
4. *Fully Commission the Building and Train Engineering Staff to Understand and Manage Innovative and Complex Systems.* Commissioning was completed quickly to meet the demands of grant funders and LEED; it could and should have more fully included facility operations staff. The engineering staff did not understand how to monitor and respond to system and energy performance issues through all seasons.
5. *Building Occupants Need Time to Adjust to Sustainable Features.* The initial POE indicated staff had issues with occupancy sensor lighting controls, water conservation features, and acoustics/noise. Following one year of occupant engagement programs and education, it became one of the most revered clinical workplaces in the Providence system.

ure 5.16) and accomplished over the last decade, have saved the organization $1,534,000 in water and sewer charges over the same period. The process water retrofits are highlighted in the following St. Peter's Case Study 18.

Under the direction of Southwest Service Area Sustainability Coordinator Keith Edgerton, Providence St. Peter is also using simple occupant engagement strategies to trial the impact of nonoccupancy settings on energy consumption. Edgerton and Glass devised a "room cleaned" door magnet (Figure 7.52) that Environmental Services staff can place on unoccupied rooms after cleaning that indicates that the room is "off limits." This simple strategy has had a noticeable positive impact on energy use, as incidental use of the room during nonoccupied periods has dropped significantly. Drawn window shades, lights off, thermostats adjusted, and closed doors significantly improve cooling system performance for the overall floor.

Figure 7.46 Occupancy magnets assist control setback. *Source: Providence St. Peter*

The Future

What's next for Providence? Beam applauds the Swedish Medical Center Issaquah team for recognizing and delivering a "next generation low-energy" hospital campus using similar rigorous methods for building a convincing business case (Case Study 35, Chapter 8). Beam is eager to bring the Swedish lessons learned to the next round of capital projects for the affiliated systems. Beam and Glass believe that the complete integration of design, construction, and operation will be the source of future savings—*designing for operations.* Integrating building management systems with patient scheduling systems, for example, will yield more automated control over occupied versus unoccupied spaces.

In closing, the values are what resonate consistently throughout: "Respect, compassion, justice, stewardship, and excellence—these are our values," says Beam. "Every single institution lives those values—stewardship and excellence speak to our role in being environmentally conscious."

Source: Providence Health & Services; Providence St. Peter

Case Study 17: Providence Newberg Medical Center

Newberg, Oregon

OWNER: Providence Health & Services

PROJECT TEAM:

Architect: Mahlum Architects

MEP Engineer: Glumac International

Construction Manager: Skanska USA Building Inc.

Sustainability Consultant: Green Building Services

TYPE: Replacement Acute-Care Hospital Campus

SIZE: Hospital: 143,000 sq. ft. (13,300 sq. m); medical office building: 44,000 sq. ft. (4,100 sq. m). Site: 60 acres (24.28 ha)

EUI: 240 kBtu/sf/yr (624 kWh/sm/yr)

PROGRAM DESCRIPTION: Forty-bed community hospital and medical office building

COMPLETED: 2006

RECOGNITION: LEED Gold-certified

BIOME: Temperate Humid

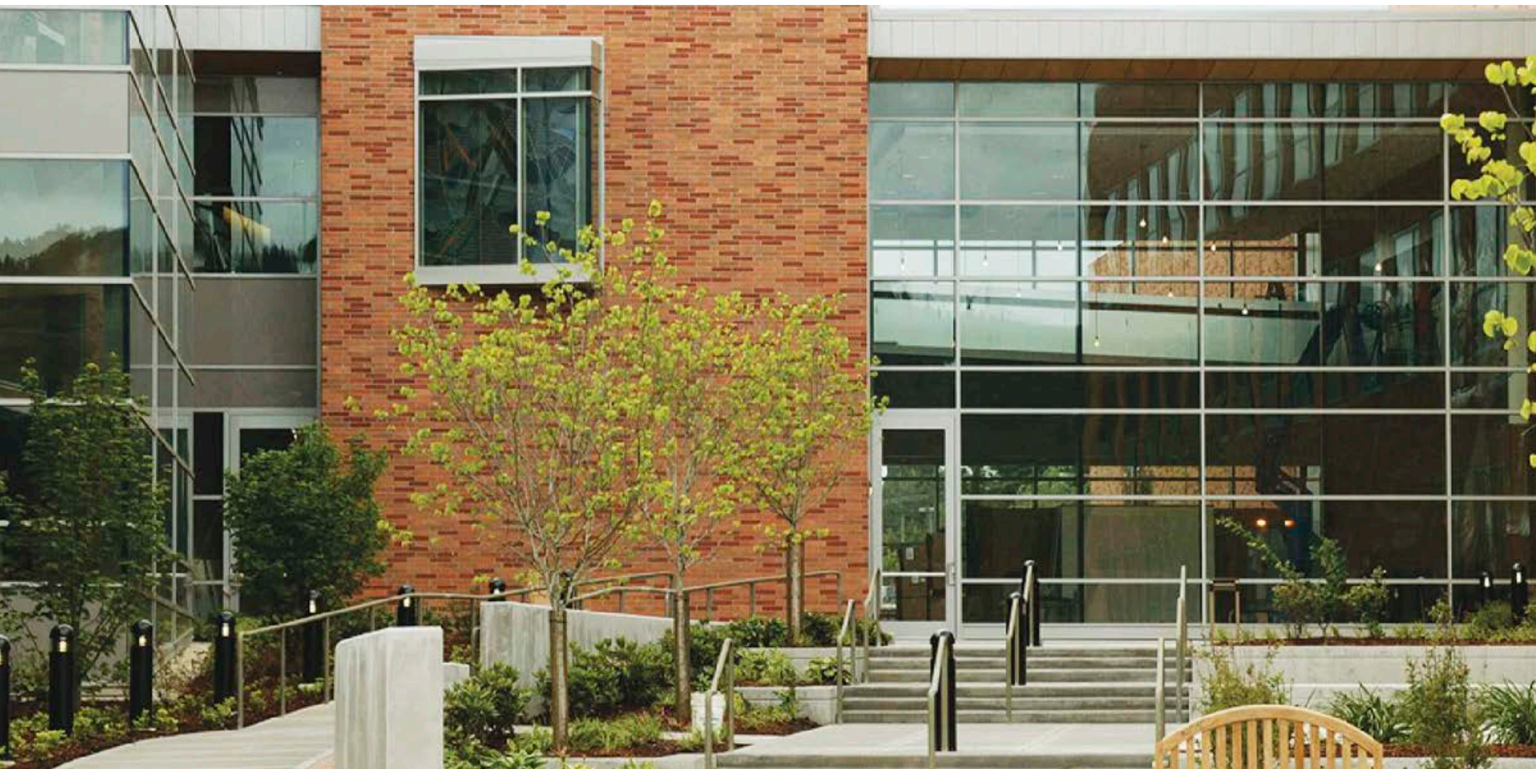
CLIMATE ZONE: Mediterranean

PRECIPITATION: 40 in (1,015 mm)

Figure 7.47 *Source: Copyright © Eckert & Eckert*

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Healing and wellness gardens positioned to enjoy morning sunlight and views of the mountain
- *Narrow Floorplate:* Building massing divided into distinct blocks to increase access to daylight
- *Lighting Controls:* Occupancy sensors, daylight controls, centralized lighting-control system turn off lights when spaces unoccupied or lighting not needed
- *Healthy Materials:* High-level air quality supported by using low-VOC paints, coatings, adhesives, sealants, and carpets
- *Salvage Structures:* Existing on-site structures donated to community for adaptive reuse
- *Community Integration:* Network of walking and biking trails
- *Resilience:* 100% outside air delivery system provides resilience to pandemic disease outbreaks



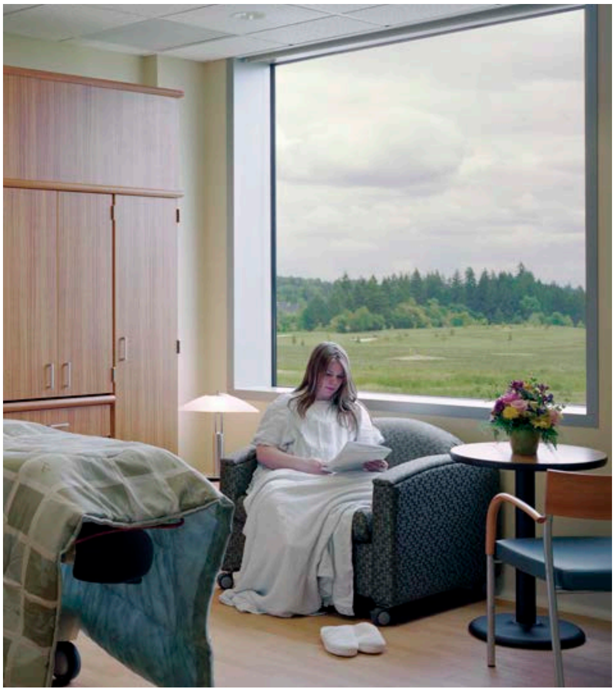


Figure 7.48 Exterior and gardens. *Source: Copyright © Eckert & Eckert*

Figure 7.49 Patient room. *Source: Copyright © Eckert & Eckert*

In 2000, Providence Health System began planning for a new hospital campus in Newberg, a town that has evolved to become a suburb of Portland, Oregon. As the health system's first such facility in almost three decades, and a relatively modestly scaled campus, the Providence team used the Newberg project to test an innovative, integrated planning process to achieve sustainable design goals. The building form prioritizes daylight and connection to nature; patient room glazing options were modeled to maximize daylight penetration (Figures 7.47–49).

The impact of this project on the U.S. sustainable healthcare marketplace was phenomenal. Providence Health & Services undertook a major Post Occupancy Evaluation with the UC-Berkeley Center for the Built Environment. Occupants reported a high degree of satisfaction with the working environment, particularly the access to daylighting and attention to "fresh air" while acoustical issues associated with the 100 percent outside air were an initial drawback (see Chapter 5).

Providence Newberg continues to be a focus of study and discussion, due to its status as the first LEED Gold–certified project and the innovative 100 percent outside air and heat recovery systems. The Living Building Challenge selected it as a reference scheme for their study on the cost of shifting from typical green building practice to Living Building achievement (see Chapter 6).

Today, the building operates close to the modeled performance, or approximately 28 percent less than the ASHRAE 90.1–1999 baseline. The building pays an energy penalty for the 100 percent outside air system, even with average heat recovery components. Occupant engagement and staff interest in the building remains strong, with many staff continuing to express profound positive feelings for the building and the work environment it fosters.

Source: Providence Health & Services

Case Study 18: Providence St. Peter Hospital

Olympia, Washington

OWNER: Providence Health & Services

TYPE: Existing Community Hospital

SIZE: 720,000 sq. ft. (66,930 sq. m)

EUI: 200 kBtu/sf/yr (624 kWh/sm/yr)

PROGRAM DESCRIPTION: 360-bed Existing Community Hospital

COMPLETED: 1970; addition 2007

BIOME: Temperate Humid

CLIMATE ZONE: Mediterranean

PRECIPITATION: 51 in (1,290 mm)

KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management:* Natural bio-retention stormwater management results in zero discharge
- *Habitat Restoration:* 40% of site area protected wetlands; 35% currently developed
- *Innovative Parking:* Wooded (forested) and structured parking
- *Water Use Reduction:* 59% potable water use reduction since 1998
- *Heat Recovery:* Boiler stack heat recovery system provides hot water heating and offsets reheat energy
- *Innovative Source Energy:* Seasonal air-cooled chiller at ambient temperatures below 55°F reduces energy and water associated with major chillers at low-load periods
- *Community Integration:* Walk for Health Trillium Loop: Constructed trail from hospital entrance to connect to 1.5-mile walking trail, with signage, on campus

Figure 7.50 *Source: Copyright © Eckert & Eckert*

The community cherishes the hospital's beautiful, wooded 173-acre (70 ha) site (Figure 7.50). Dating from the early 1970s, this campus has undergone continuous renovation projects and focused resource conservation efforts. Since 1998, the hospital has reduced electricity use by 2 percent, natural gas use by 23 percent, and water use by 59 percent through a variety of creative initiatives (see Table 7.2). These efficiencies freed capacity for a 13 percent increase in campus built area without added central plant space or equipment. The campus received EPA ENERGY STAR certifications in 2003, 2006, 2007, 2008, 2009 and 2010.

Since 2000, Providence St. Peter has been engaged in a series of innovative water conservation efforts, reducing overall water use by 59 percent over a ten-year period. Key strategies include low-flow and -flush fixture retrofits and a series of process water-conservation initiatives outlined in the sidebar and summarized in Table 7.2 (below).

Table 7.2 1998–2009 Water Savings (per 1000 gallons)

Years	Start	End	Change (%)
1998–2000	62,203	53,652	–13.7
2001–2002	53,652	47,109	–12.1
2003–2004	47,109	39,098	–17.0
2005–2006	39,098	33,329	–14.8
2007–2008	33,329	34,498	+3.50
2009	34,498	31,034	–10.0

Source: Providence St. Peter

Energy conservation retrofits have continued to drive down the hospital's energy demand. In 2007, EUI was estimated to be 208 kBtu/sf/yr (655 kWh/sm/yr); today, it hovers near 200 kBtu/sf/yr (630 kWh/sm/yr), despite increasing patient volumes and rising plug load. Providence St. Peter continues to trial energy conservation strategies for the broader Providence system, including control systems enhancements and equipment retrofits. In

Figure 7.51 Boiler heat recovery system. *Source: Providence St. Peter*

addition to air-cooled chiller and run-around heat recovery for exhaust air streams, a key success story is the installation of a boiler stack heat recovery system in 2009, which eliminated natural gas energy for domestic hot water heating at an estimated savings of $60,000 per year. They continue to mine the flue heat for reheat energy as well, and are proud of releasing flue air at lower temperatures than ambient air on hot summer days (Figure 7.51).

Other electricity conservation measures include time of day shutdown controls, occupancy lighting control retrofits, improved garage lighting controls, conversion to LED lighting (estimated to be 25 percent completeas of this writing), and parking lot lighting replacement. Many of these retrofit projects are grant funded.

When the initial campus was constructed in 1970, all the parking was tucked between the fir and cedar trees to minimize the impact of the hospital on the one-hundred-year-old second-growth forest. The hospital opted to solve its need for additional parking through construction of a structured employee garage rather than disturb the heavily wooded site. Through nego-

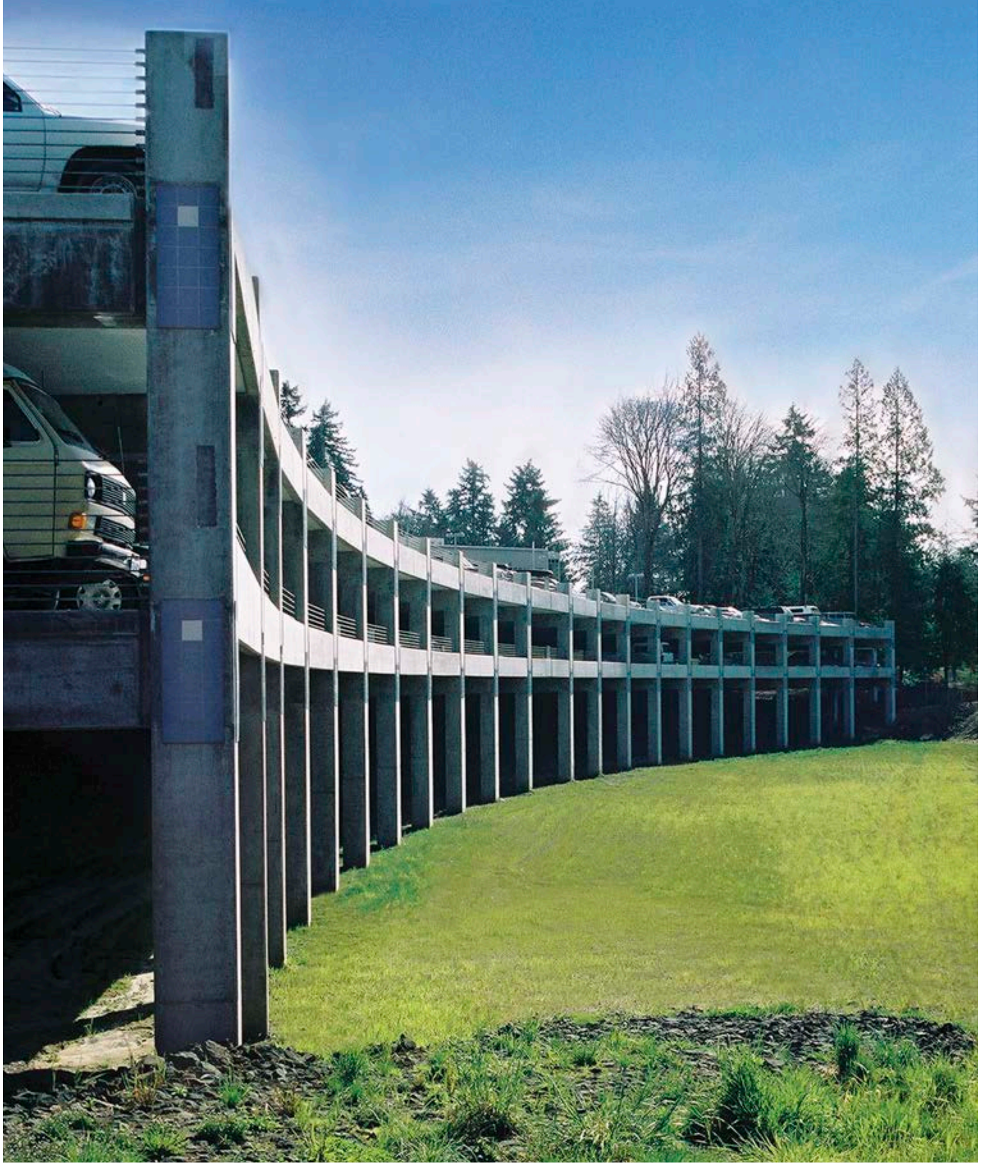


Figure 7.52 Structured parking integrated with bioswale. *Source: Copyright © Eckert & Eckert*

tiation with the city of Olympia, Providence St. Peter was required to provide only the quantity of parking functionally necessary, which was less than the minimum mandated in city regulations. The 420-car garage satisfies the need for expanded parking with minimal impacts—its curved shape tiers into a hillside to lessen its presence on the site and shares an expanded stormwater retention basin. The hospital filters all rainwater through natural bio-retention systems; no runoff is released to the wetland (Figure 7.52).

Providence St. Peter stands as a testimony to the value of investing in existing healthcare building infrastructure, and demonstrates that the most sustainable projects need not always be new buildings. The dedication and enthusiasm of the St. Peter facilities team—the creative solutions and "out-of-the-box" retrofit thinking accompanied by robust, verifiable business cases—serves as an inspiration to all.

Source: Providence St. Peter

Process Water Conservation Measures at Providence St. Peter

- Periodically analyze facilities for leaks (found in irrigation and hot water systems)
- Replace water-cooled ice machines/refrigeration equipment (save 900 GPD)
- Retrofit vacuum sterilizers. Removed orifice venturi and replaced with electric vacuum pumps and piped condensate to receiver and pumped back to boiler plant (save 4,320 GPD)
- Reduce/eliminate irrigation (shift to micro-irrigation systems, xeriscaping, and native planting)
- Meter irrigation and cooling tower water use (deduct cost from savings)
- Increase cooling tower and boiler cycles of concentration; work closely with the water treatment advisor to minimize make-up water
- Upgrade kitchen equipment (dishwashers) to water efficient (save 1,800 GPD)
- Upgrade to waterless vacuum pumps or water recycling systems for vacuum pump cooling (save 2,880 GPD)
- Upgrade to waterless air compressors (save 2,160 GPD)
- Waterless waste anesthesia gas (WAG) pumps (save 1,440 GPD)

GUNDERSEN HEALTH SYSTEM

Like many healthcare organizations, while Gundersen Health System's energy costs were climbing at alarming rates, environmentally sustainable business decisions were not at the top of everyone's priority list. Realizing this disconnected decision-making model was not good for patients or the communities they serve, Gundersen's leadership set about turning good intentions and "green theory" into action. In 2007, the health system's environmental stewardship program, Envision®, was born. Gundersen Health Systems, Inc. is an integrated healthcare network, including one of the nation's largest multispecialty group medical practices, regional community clinics, hospitals, home care, behavioral health services, vision centers, pharmacies, and air and ground ambulances operating in nineteen counties in Wisconsin, southeastern Minnesota, and northeastern Iowa.

Through Envision®, Gundersen has developed a multifaceted portfolio of innovative sustainability projects intended to lower costs, encourage community partnerships, and reduce the organization's environmental footprint. In a few short years, the health system has become a model for other healthcare organizations looking to do the same.

The Path to Energy Independence

Gundersen set an aggressive and challenging system-wide energy goal—become 100 percent energy independent by 2014. Energy independent means the health system will produce as much renewable energy as it uses, through a combination of energy conservation and renewable energy projects. The first step toward energy independence began with conservation, when Gundersen took a close look at its energy usage. System leadership recognized that an aggressive energy conservation program was essential to make a difference—and that reducing energy demand was the first necessary step in moving to renewable sources. Less energy demand equals less renewable energy infrastructure.

Gundersen set its initial energy conservation goal at an aggressive 20 percent energy use reduction across a two-year implementation period. Starting in early 2008, Gundersen completed comprehensive energy audits at several campuses. In May 2008, combining expertise from Gundersen, Focus on Energy (a Wisconsin statewide program to promote energy efficiency and renewable energy alternatives), and other outside engineering resources, the health system began a retro-commissioning process focused on "low-hanging fruit." Retro-commissioning examines heating and cooling systems, lighting, and employee behavior, and uses low- or no-cost measures to improve efficiency and reduce energy demand. The process allowed Gundersen to recognize how their existing buildings' programs and energy needs had evolved, and to ensure their systems were being used in the most energy efficient way. Gundersen sites began seeing paybacks almost immediately—by the end of 2010, they reduced total energy consumption by 30 percent from a 2007 consumption baseline.

One of Gundersen's first retro-commissioning efforts was zone scheduling. Zone scheduling led to a reduction of more than $78,000 in energy costs and saved more than 1.2 million kWh a year across multiple hospital, outpatient, and administration buildings. Because no capital construction project was needed to accomplish the air handler scheduling, payback was immediate.

Other Gundersen retro-commissioning efforts included:

- Changing boiler use: By using pressure-reducing valves, one hospital was able to convert high-pressure steam to low-pressure. This allows Gundersen to turn off several boilers for much of the year in one of its outpatient buildings, saving the health system nearly $64,000 and just over 74,000 therms annually.
- Reprogramming cooling system controls reduced energy consumption by about 1.1 million kilowatt hours a year. Chiller/tower optimization led to an annual savings of approximately $65,000.
- Retrofitting light fixtures (light bulbs, ballasts, and reflectors) with updated technology reduced energy consumption by 4.4 million kilowatt hours a year and an annual associated energy cost savings of approximately $265,000.

The retro-commissioning program was so successful that Gundersen improved energy efficiency by 25 percent by the end of 2009, resulting in more than $1 million in annual savings.

Renewable Energy Infrastructure

With energy conservation practices well underway, Gundersen explored opportunities to develop its own renewable energy infrastructure rather than purchasing renewable power at premium rates. Gundersen's creative renewable energy portfolio utilizes power generation opportunities available through partnerships with municipalities, utility companies, and private businesses. These partnerships have proven to be key drivers for success in Gundersen's renewable energy program, leading to energy independence—that is, 100 percent of energy consumed generated from renewable sources by 2014. Their path to this remarkable achievement is diagrammed in Figure 7.53.

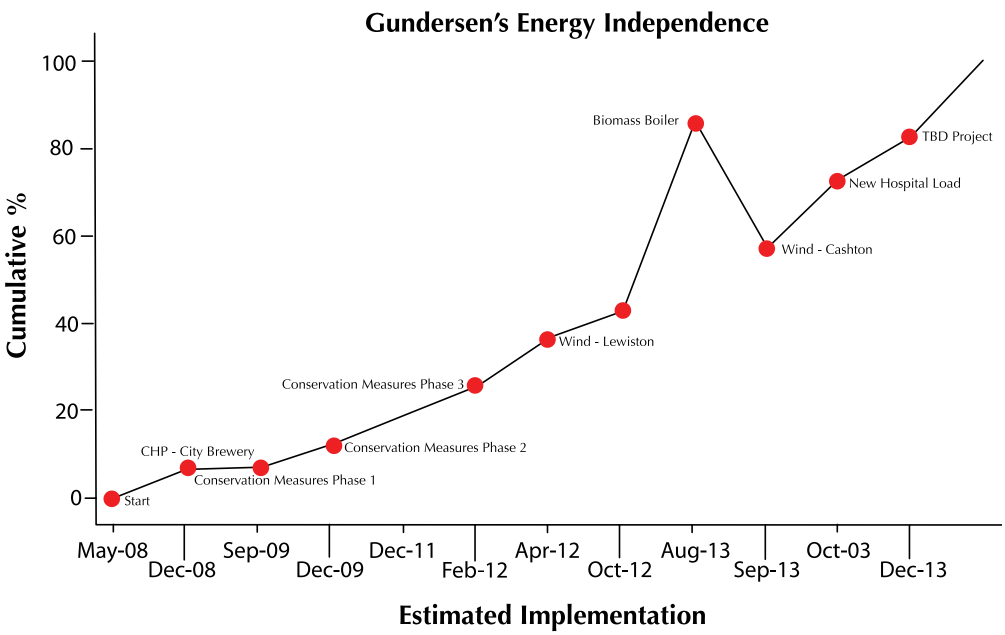


Figure 7.53 The path to energy independence. *Source: Gundersen Health System, redrawn by authors*

Figure 7.54 Onalaska landfill gas project captures landfill methane to provide 100 percent of the hospital's thermal energy. *Source: Gundersen Health System*

Figure 7.55 The equipment on display. *Source: Gundersen Health System*

Gundersen's gas-to-energy project with the La Crosse County landfill is a compelling example of what a public-private partnership can achieve. In Onalaska, Wisconsin, where two of Gundersen's largest buildings are located, the health system is teaming up with the LaCrosse County Solid Waste Department to harvest biogas created from organic waste at the landfill, converting methane into electricity and heat—an excellent use of a previously unused energy resource, and an opportunity to capture a potent greenhouse gas for beneficial use (Figure 7.54).

Customarily, the methane generated at the landfill as a byproduct of organic waste decomposition is captured and flared off. In contrast, the Gundersen-County partnership project allows the County to pipe the gas to an engine installed a few miles away on the Gundersen–Onalaska Campus (Figure 7.55). The landfill gas powers the engine, and turns a generator that produces electricity. The clean electricity is sent to the power grid to be used by households and businesses throughout the community. The waste heat created by the engine is used to heat buildings and water on the Gundersen campus.

While many examples of landfill gas-to-energy projects exist in the United States, it is rare to capture waste heat from electricity generation and use it to heat buildings. The project produces as much thermal energy as the Gundersen–Onalaska Campus consumes, offsetting 100 percent of the Onalaska Campus energy needs. For the Gundersen system, the project offsets about 8.5 MkWh and 12,000 MMBtu of gas, equivalent to 11 percent of total energy use. The project started production in March 2012.

Another innovative waste-to-energy project is the Dairy Digester project. Still under partnership negotiations, the dairy manure digester will produce 11 MkWh annually and offset 9 percent of Gundersen's total annual energy need. In addition, the digester creates a fiber byproduct that enhances the revenue stream and removes phosphorous from groundwater.

The wind turbine projects, implemented in 2011–2012 in Lewiston, Minnesota, and Cashton, Wisconsin, have two commercial turbines at each site. The Cashton, Wisconsin, project was a partnership with Organic Valley, the nation's largest cooperative of organic farmers and a leading organic brand. The combined wind projects are expected to offset an additional 13 percent of Gundersen's energy use. The Cashton wind turbines, which sport both the Gundersen and Organic Valley logos, will reduce the amount of carbon dioxide in the atmosphere by 12 million pounds each year (Figure 7.56). The energy created from that single, two-turbine wind project is enough to power about 1,000 homes per year. Dr. Jeff Thompson, CEO of Gundersen Health System, says community excitement is something he's seen time and again with Gundersen's sustainability projects. "The village of Cashton is very proud of its wind farm. It gives them green energy and distinguishes them from other rural communities," he says.

GREEN BUILDINGS

Gundersen is constructing a major addition on its La Crosse, Wisconsin, campus. Due to be completed in 2015, the goal is to be among the most energy efficient healthcare buildings in the United States (Case Study 19, this chapter). Key to the exceptional energy performance is a ground-source geo-exchange system, which Gundersen estimates reduces the overall energy use intensity (EUI) by 60 to 70 kBtu/sf/yr (190 to 220 kWh/sm/yr). Coupled with the extensive lessons from system-wide retro-commissioning, the building stands as a beacon for low-energy hospital buildings of the future.

Conclusion

Gundersen Health System is on track to realize its objective of energy independence by 2014 through aggressive energy management and creative, bioregionally appropriate renewable energy generation. It is making conscious choices to partner in ways that both reduce reliance on fossil fuel energy sources and, in the case of methane harvesting, remove a potent greenhouse gas from the environment. It recognizes that these investments improve its operational "bottom line" and contribute to healthier, more sustainable communities.

Dr. Jeff Thompson, CEO, believes that there are only a few activities a health system can do that will not only improve the health of community members and save money, but also engage staff and inspire their communities. Gundersen's sustainability work is directly connected to its mission, core values, and commitment to the community. In summary, Gundersen's Envision® program is unique, ambitious, and demonstrates that "green" is a healthy, socially responsible, and economically beneficial strategy for the healthcare industry.

Sources: Gundersen Health System/Practice Greenhealth

Figure 7.56 Gundersen Cashton wind turbine installation. *Gundersen Health System*

Case Study 19: Gundersen LaCrosse Hospital Addition

LaCrosse, Wisconsin

OWNER: Gundersen Medical Center

PROJECT TEAM:
Architect/Structural/MEP: AECOM
Civil Engineer: TKDA
Landscape Architect: Close Landscape Architecture
Construction Manager: Kraus-Anderson Construction Co.

TYPE: New Acute-Care Community Hospital Addition
SIZE: 420,000 sq. ft. (39,019 sq. m)
EUI GOAL: 115 kBtu/sf/yr (363 kWh/sm/yr)
PROGRAM DESCRIPTION: 325 private inpatient and critical care beds (at completion); new operating rooms and expanded pre- and post-op areas; centralized services for women and children, including new Neonatal Intensive Care Unit; regional Trauma & Emergency Center with adjoining full-service imaging services; new entrance and lobby
COMPLETION: 2015
RECOGNITION: Seeking LEED certification
BIOME: Temperate Humid
CLIMATE ZONE: Humid Continental
PRECIPITATION: 31 in (787 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Three rooftop gardens with container plantings, including some used for kitchen herbs and vegetables
- *Energy Responsive Facade:* Well insulated, climate responsive
- *Innovative Source Energy:* Ground source heat pump system (156 wells, 400 feet deep)
- *Heat Recovery:* Heat recovery chillers
- *Healthy Materials:* Conscious avoidance of PVC: examples include rubber flooring; wall covering; wall protection and carpet backings; urea-formaldehyde free and low-VOC paints and interior coatings
- *Modular Construction Elements*: Efficient modules eliminate, reduce cutting and waste, such as drywall specified for 54-inch widths at 9-foot high partitions, 48-inch widths at 8-foot high partitions

Figure 7.57 *Source: AECOM*

Figure 7.58 One of three rooftop gardens. *Source: AECOM*

Figure 7.59 Internal healing garden. *Source: AECOM*

The Gundersen LaCrosse campus has evolved and grown over 100 years into a series of interconnected and stand-alone buildings that date from the early 1900s to today. This hospital addition supports the hospital's needs for a more prominent campus front door, more surgical space, clearer wayfinding, and all private inpatient rooms (Figure 7.57). It will provide a flexible, efficient facility that creates a healing environment focused on patient care, family involvement, and staff support, while meeting important sustainable design and energy goals.

The hospital addition project, which physically links to the existing hospital, reorients overall circulation patterns to clarify wayfinding throughout the campus. A new northwest entry courtyard and lobby will join the addition to the existing central spine of the hospital chassis (Figures 7.58–60). The new tower includes imaging and surgery department relocations to improve their adjacency to the emergency department and to the new critical care inpatient beds.

To contribute to Gundersen's aggressive plan to achieve energy independence by 2014, the hospital addition has an ambitious energy demand reduction goal. Energy modeling predicts performance in the range of 115 kBtu/sf/yr (363 kWh/sm/yr). Achieving this goal will place the building in the top 1 percent for the climate adjusted energy efficiency of U.S. hospitals. At 2011 energy costs, achieving this performance will save

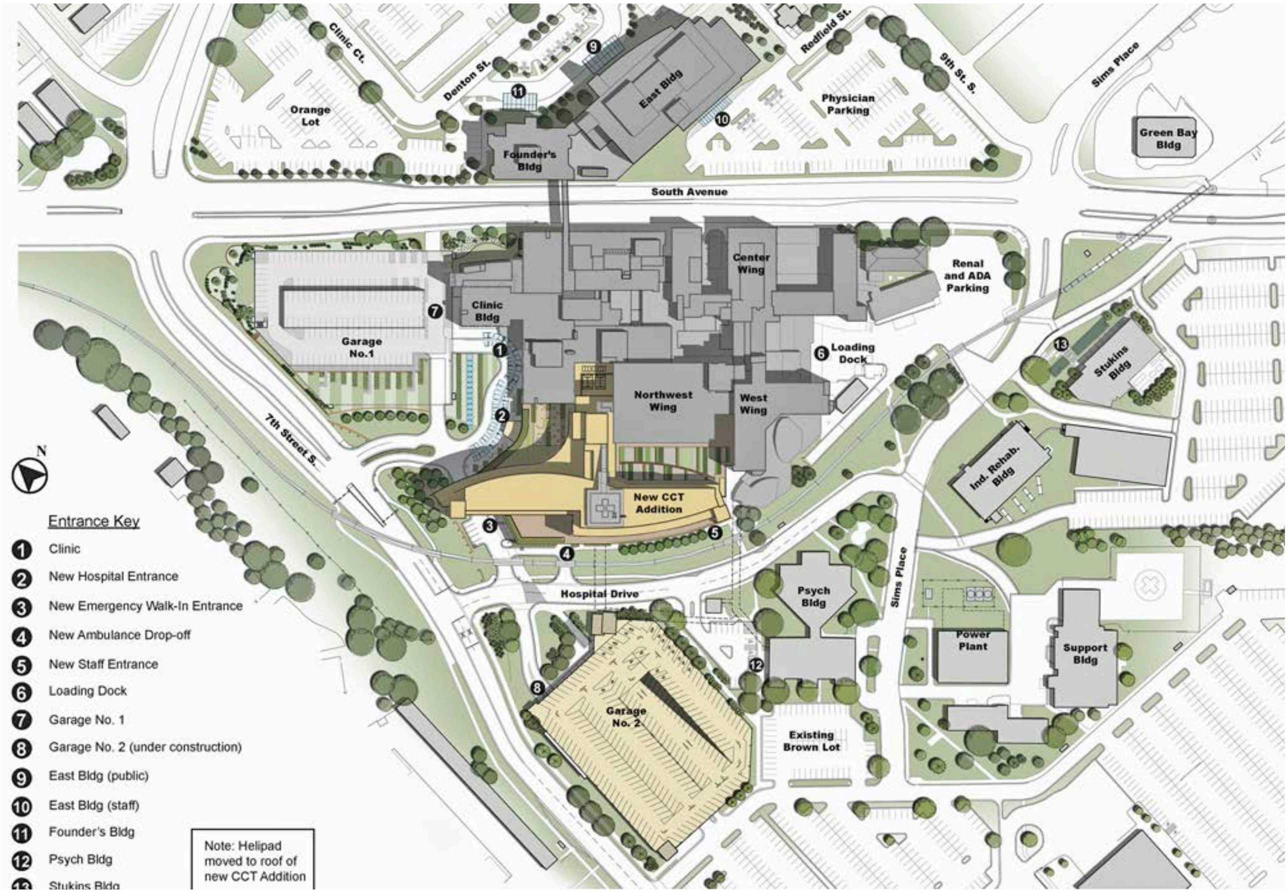


Figure 7.60 Campus site plan. *Source: AECOM*

Gundersen LaCrosse about $660,000 annually over an average performing building. Key to achieving this performance is the Combined Central Geothermal and Heat Recovery Chiller/Heater system; the ground source system is the primary source of heating and cooling energy and linked to a heat recovery heat pump chiller to recover heat from primary chiller equipment.

The heat recovery chillers at the heart of this system recover heat when it is available, and extract heat from the ground when heat recovery is not an option. System efficiency is dependent on the temperature of the heat source. The system controls are set up to preferentially extract heat from the return chilled water, since that is hotter than the geothermal field. In hot weather, the system will typically extract all the heat it needs from the returned chilled water flow. Though the building requires cooling year-round in some spaces, there is more heat required in cold weather than can be extracted from the return chilled water flow. At those times, the system draws additional heat from the geothermal field. The system is sized to provide about 70 percent of the building's year-round heating needs. The additional capacity required to provide heat in the coldest weather is supplied by steam from the central plant.

Source: AECOM/ Gundersen Lutheran

KAISER PERMANENTE

Kaiser Permanente is one of the largest not-for-profit healthcare plans in the United States with more than 9 million members, 37 hospitals, and 611 medical offices and other outpatient care facilities in California, 9 other states, and the District of Columbia. Headquartered in Oakland, California, its origins trace back to the Great Depression when Sidney Garfield, MD, began offering prepaid health services to 10,000 workers and their families at the Grand Coulee Dam in Washington State. Dr. Garfield's model emphasized health and safety versus treating sickness and injury. Today, Kaiser Permanente is uniquely positioned in the U.S. healthcare marketplace as an integrated delivery model—a health plan, hospital system, and a medical group all working together to provide high-quality, coordinated, and affordable care to its members.

Kaiser Permanente has a long-standing commitment to environmental stewardship and the relationship between the health of its members, communities, and the planet. Today, that commitment is reflected in the design, construction, and operation of greener hospitals and many specific goal-oriented health initiatives overseen by its Environmental Stewardship and Sustainable Energy councils. For example:

- *Reduce carbon footprint:* Reduce overall greenhouse gas emissions by 30 percent by 2020, compared to 2008 levels including energy conservation and investments in clean and renewable energy sources including generating 13.5 percent of its energy needs onsite with solar photovoltaics and fuel cells.
- *Support healthy food:* More than 50 farmers' markets and farmstands are located at Kaiser Permanente hospitals and facilities to improve access to fresh, local, and organic foods to members and staff.
- *Waste reduction:* Reuse, recycle or compost at least 40 percent of waste materials by end of 2015.
- *Eco-friendly medical supplies:* Purchase 100 percent PVC- and DEHP-free IV solution bags and 100 percent DEHP-free IV tubing.

Kaiser Permanente has continually been at the forefront of healthcare's environmental leadership. It is a founding member of the Healthier Hospitals Initiative and multiyear recipient of Practice Greenhealth environmental leadership awards. It has been an outspoken advocate for both mitigation and adaptation in the face of climate change, and lobbied for chemicals reform and elimination of antibiotics in meat and dairy production—all in the name of healthier members and communities. It frames sustainability objectives around the triple bottom line shown in Figure 7.61.

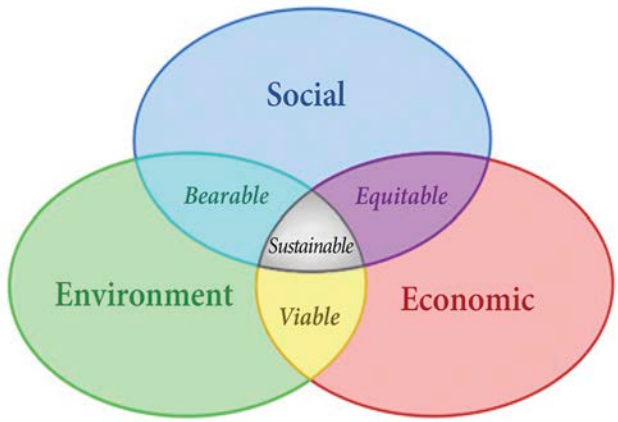


Figure 7.61 Sustainability triple bottom line. *Kaiser Permanente*

In 2012, Kaiser Permanente announced its commitment to reducing greenhouse gas emissions by 20 percent by 2020. The result of strategic energy master planning, it recognized, like many systems, that business as usual would lead to increasing consumption and escalating costs. Energy efficiency measures and building efficient new buildings, Kaiser Permanente believes, can reduce demand by 30 percent by 2020 relative to a "business as usual" baseline. Likewise, increasing the percentage of energy derived from renewables will

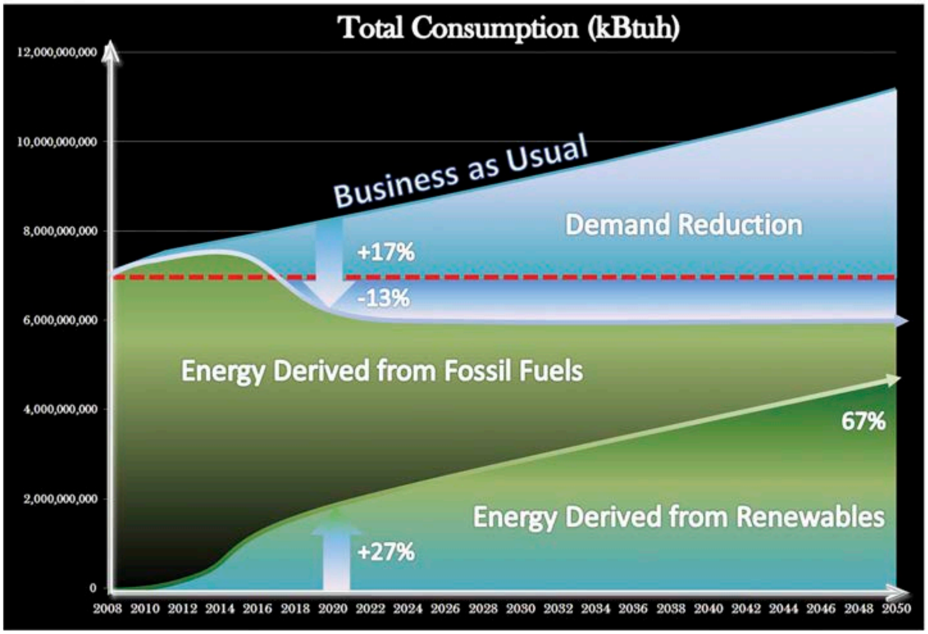


Figure 7.62 The "wedge." *Source: Mazzetti, courtesy of Kaiser Permanente*

create a dramatically different profile of energy use by 2050, one in which only 32 percent of total energy use is derived from fossil fuels (see Figure 7.62).

Green Building

Kaiser Permanente has been an early and continual advocate for green building in healthcare. In October 2000, it convened the landmark conference, Setting Healthcare's Environmental Agenda (SHEA). At that conference, SHEA participants endorsed a health-based framework to guide the healthcare design and construction sector: "Guidelines and regulations overseeing hospital design and construction should be evaluated based on their impacts on environmental quality and human health and revised so they reflect these as priority considerations" (Vittori 2000). This led to Kaiser Permanente's participation in development of healthcare green building tools, as leadership served on both the Steering Committee of the Green Guide for Health Care and LEED for Healthcare core committee shaping the "health based frameworks." From 2004 to 2008, it championed the Green Guide for Health Care as a key component in its $30 billion facility replacement and expansion program—four Kaiser Permanente template hospitals that implemented the Green Guide for Health Care pilot program. Today, Kaiser Permanente is considerably "raising the bar" in aggressive energy use reduction targets, including a "net zero" medical office building at Kaiser Antelope Valley (Figure 7.63) and a low-energy hospital at Kaiser San Diego Central Hospital (Figure 7.64). This new generation of buildings has been influenced by the results of the Small Hospital, Big Idea design competition.

The Small Hospital, Big Idea Design Competition

Recognizing that "sustainability is a health issue," Kaiser Permanente launched the "Small Hospital, Big Idea" international design competition in February 2011—the first hospital design competition in its 65-year history. The objective was to catalyze transformative thinking about building patient-centered healing environments and the potential to achieve a near-zero environmental footprint by taking advantage of cutting edge technology while also improving quality and reducing costs. The solicitation yielded 105 proposals offering inspired concepts that represented a radical departure from conventional hospital typology. After an extensive evaluation process that involved a diverse, 35-member review team, and, later, a multidisciplinary design jury, Kaiser Permanente selected nine semi-finalists based on their performances relative to the design criteria of innovation, reducing life cycle costs, incorporating ways to improve healthcare, flexibility, efficiency, and environment of care. Based on an exhaustive interview process, three finalist teams were selected from this field to design a prototype small hospital able to be replicated with appropriate adaptations in many locations.

Two winning teams—Aditazz/Arup and Perkins+Will/Mazzetti—were announced in March 2012. The jury considered that, together, these two teams "offered an exciting, game-changing approach to improving the quality and personalization of care and the development of healthy communities." Big ideas that emerged from the winning designs include:

- Create spaces to inspire human-to-human connection and collaboration.
- Include civic spaces that blur the boundaries between the community and traditional hospital setting.
- Bring nature inside with light-wells and rooms oriented around a large central courtyard, recognizing research that positively correlates connection to nature and healing.
- Move beyond carbon neutrality to restore ecosystems and biodiversity, and improve conditions for community health.
- Make use of a unique tool that enables designers and frontline professionals to quickly explore myriad operational and space options.

Having cast a very wide net to tap into the best and brightest healthcare design ideas from around the world, Kaiser Permanente will pool concepts from the two winning designs and from all the entries to inform their future design and construction activities, acknowledging that their prototype of the future is a coalescence of many big ideas. The winning entries are profiled in Case Study 20 in this chapter.

Figure 7.63 Kaiser Antelope Valley medical office building anticipates an EUI of less than 50 kBtu/sf/yr, and may implement on–site wind turbines to achieve net zero energy. *Source: Taylor Architects, courtesy of Kaiser Permanente*

Figure 7.64 The new Kaiser San Diego Central Hospital features active chilled beams, a tri-generation system and on-site photovoltaics as elements of a low energy solution. *Source: CO Architects, courtesy of Kaiser Permanente*

KAISER PERMANENTE'S JOURNEY TO SUSTAINABILITY

In January 2012, Gail Vittori interviewed Kaiser Permanente's John Kouletsis, AIA, EDAC, Vice President Facilities Planning, on Kaiser Permanente's leadership in greening the healthcare sector.

GV: ***Describe Kaiser Permanente's leadership role within the healthcare sector and beyond and some specific initiatives.***

JK: We have a positive track record of working with manufacturers—whomever wants to come to the table—to develop better products that improve the marketplace and support public health. We believe industry wants to do this, and that they are looking for guidance. We can provide clear direction, be proactive, and make commitments to follow through. We can partner with the Department of Veterans Affairs and Department of Defense Military Health System, for example—together we represent a huge number of people who rely on us for their healthcare—to leverage our substantial economic weight. We can move industry.

We have created tools like Kaiser Permanente's Sustainability Scorecard, which evaluates vendors based on the sustainability of their medical equipment and products. We helped create the Green Guide for Health Care, the precursor to LEED for Healthcare, and encourage use of these tools on all our projects. We prioritize design to support active living and smart growth, for example by encouraging biking, walking, people going outside to exercise, creating community gardens with local communities on our campuses. LEED, in a sense, becomes our trampoline. We use it as a minimum, and then ask people to stretch beyond the checklist.

We recognize the need to move beyond a fixation on first costs and transition to a life cycle/total-cost-of-ownership approach to managing our buildings. We need new tools to manage the complexity.

GV: ***What trends do you see influencing design decisions in the future?***

JK: Water conservation is emerging as an essential part of our future design reality, along with energy. Kaiser Permanente recently passed a national energy policy with the goal of reducing greenhouse gas emissions 30 percent by 2020. The policy will generate immediate economic returns and environmental benefits. With water, the interventions are more complex and the immediate benefits are smaller. We will finalize our strategy and goal in 2012, and will establish a water demand target (G/sf or bed/yr) and set of required strategies (such as using no potable water for irrigation). But we will encourage design teams to go beyond even the Kaiser Permanente water requirements to reduce potable water demand.

GV: How does Kaiser Permanente's investment in research leverage market opportunities and contribute to a learning community?

JK: Kaiser Permanente has made significant investments in clinical research. The Sidney R. Garfield Health Care Innovation Center is a great example of where we are expanding research into the linkages between physical design and patient outcomes. We've learned over the five years of its operation that we need to look at opportunities where clinical care, physical space, and technology intersect to the benefit of patients, caregivers, and the communities we serve. We also need to get to results within a reasonably short timeframe—we can't wait multiple years for the results of the most rigorous level of academic research.

We need to balance scientific rigor with our need to implement change in a meaningful timeframe. For example, we wanted to look at the feasibility of doing displacement ventilation in hospital spaces. Ultimately, we were able to influence a change in the building codes to allow this innovative approach to HVAC in our facilities. The research was very rigorous, included various disciplines, and took approximately three years to complete, which meant that we did not implement displacement ventilation on the projects that initially generated the question and were on tighter schedules. We also believe in sharing our experience with others, most recently with the Department of

Defense, which is interested in building a facility in Washington similar to the Garfield Center.

On the building scale, we're asking ourselves how we can build hospitals and medical office buildings with significantly longer life spans. There are many reasons for shorter life spans in facilities, including the very short schedules that are allocated for our projects to move from design to occupancy. We have to take more seriously our obligation to train and educate consultants. If we are committed as a learning organization to improve what we do, we need to be explicit about our expectations and have that reflected in what we build.

On the environmental scale, Kaiser Permanente has been a leader in banning specific chemicals of concern ahead of legal requirements. We do this because some chemicals have direct or strongly suspected links to public health. And we are abundantly clear as a corporation about what Kaiser Permanente can do to change the marketplace—not just for us, but for consumers more broadly. For example, a few years ago we adopted a no/low-VOC content policy for paints. This year we're identifying other chemicals in paint that might pose health risks. We're finding manufacturers with products that don't have these chemicals, and still guarantee performance. We are moving the marketplace and setting higher expectations. We also have prioritized PVC-free IV bags as another step to move the marketplace and the community standard of care. PVC-free IV bags are now our standard.

GV: ***What were the key drivers for launching the Small Hospital, Big Idea competition?***

JK: Kaiser Permanente recognizes there's nothing new about a 100-bed hospital. There are a lot of them. We do, however, acknowledge that this is a unique moment in time, when technology is changing at an increasingly rapid rate, knowledge about climate change and its public health implications is becoming more obvious, and people's expectations about their workplaces are changing. We also recognize there are higher and different expectations from our patients, especially younger people. We have learned that we need to design for patients as people. With knowledge about what patients want to support them through the clinical experience, and our own business need to improve access to care in certain markets, the time was right for out-of-the-box solutions. Thus, the Small Hospital, Big Idea competition was born. Kaiser Permanente launched the contest to raise the design bar from what has been typical acceptable healthcare facility design to an inspired design that integrates the healthcare experience into daily life, and aspires to bring restorative and regenerative elements to a site.

Source: Kaiser Permanente

Case Study 20: Small Hospital, Big Idea Competition

Prototype

OWNER: Kaiser Permanente

WINNING PROJECT TEAMS:

Architects/Engineers: Aditazz/Arup (A/A)
Perkins+Will/Mazzetti (P+W/Mazzetti)

Business Planning: Aditazz/Arup: KSA
Perkins+Will/Mazzetti: Innova Group

TYPE: Prototype Acute-Care Community Hospital and Ambulatory Clinic Campus

SIZE: 200,000 sq. ft. (18,810 sq. m) hospital; 100,000 sf (9,290 sq. m) MOB

EUI: 68.4 to 100 kBtu/sf/yr (215 to 312 kWh/sm/yr)

PROGRAM DESCRIPTION: Approximately 100-bed acute-care hospital, including emergency, surgery, and imaging, medical office building.

COMPLETED: N/A

BIOME: Desert Temperate

CLIMATE ZONE: Steppe

PRECIPITATION: 7.5 in (190 mm)

Figure 7.65 *Source: Perkins+Will/Mazzetti, courtesy of Kaiser Permanente*

KEY SUSTAINABILITY INDICATORS

- *Habitat Restoration:* Restoration of creek ecosystem facilitated by on-site wastewater treatment facility (P+W/M); native and adapted herb garden entry pathway (A/A)
- *Net-zero Water*: Rainwater harvesting, well water, and on-site blackwater treatment system (P+W/M)
- *Rainwater Harvesting*: Rainwater harvesting for process uses*
- *On site Blackwater Treatment:* Produce net-zero water impact and seed creek restoration (P+W/M)
- *Climate Responsive Facades:* Overall canopy structure (A/A); high efficiency envelopes and extensive solar shading*
- *Innovative Source Energy:* Landfill bio-gas fuel cells; ground source heat pumps (P+W/M)
- *Renewable Energy:* Solar PV as primary energy (A/A); solar and wind turbine as supplement (P+W/M)
- *Community Connectivity:* Focus of design is a community wellness facility and health club/retail use (P+W/M)

*Strategies common to both winning entries

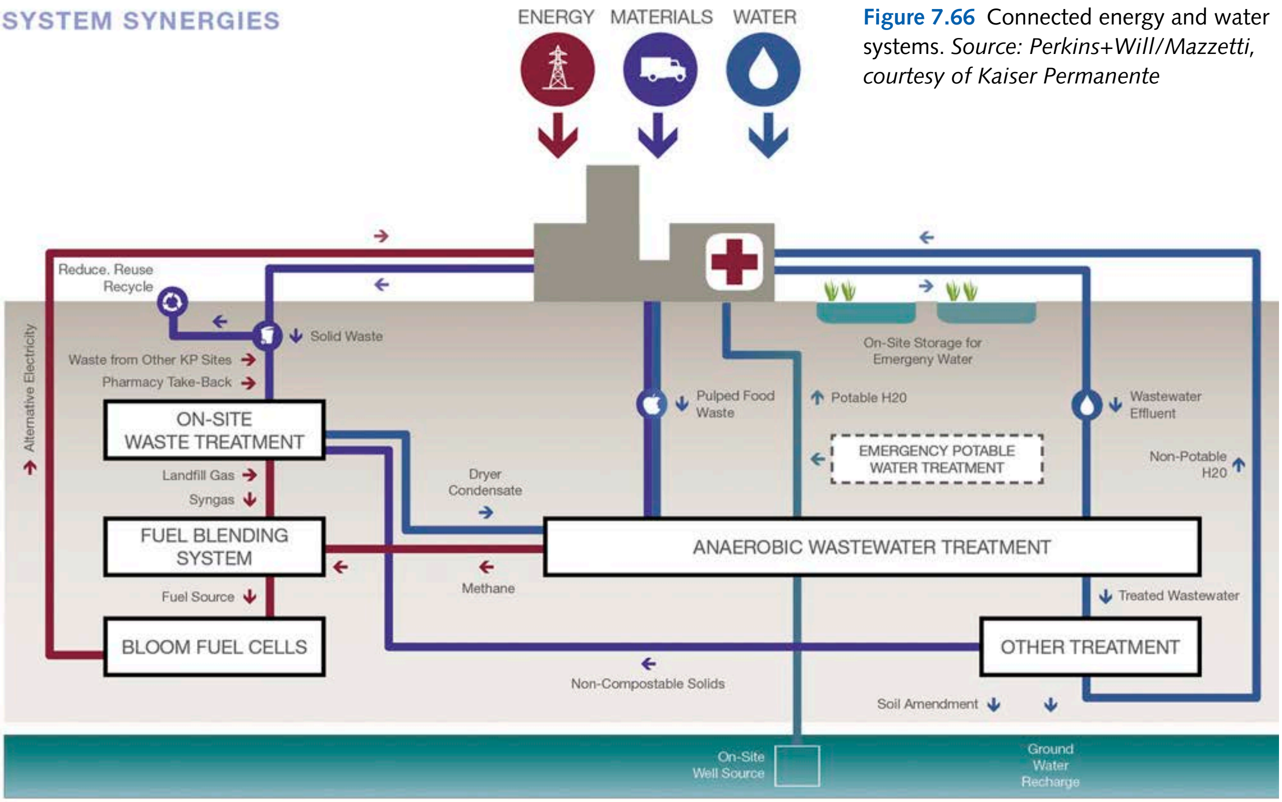


Figure 7.66 Connected energy and water systems. *Source: Perkins+Will/Mazzetti, courtesy of Kaiser Permanente*

These two winning schemes provide innovative site and building design as well as system solutions for a small hospital that for the purposes of the design challenge was located hypothetically in Lancaster, California. Beginning with their regenerative design and health framing, the two submissions demonstrate a range of convergent and divergent design ideas. Together, they demonstrate that zero net energy, carbon neutral small hospitals are achievable with current technology and regulatory environments.

The Perkins+Will/Mazzetti scheme (Figures 7.65 and 7.66) begins with these two major sustainable design ideas:

> The small hospital is on the front line of a consumer revolution around health management, prevention, and early detection. By redefining the small hospital from a "sickcare" institution to a "total health" environment, the small hospital actualizes its role as the new civic architecture, becoming a central community resource that catalyzes a focus on health management and care.
>
> The small hospital is a regenerative place of healing, moving beyond carbon neutrality to a development that restores ecosystems and biodiversity and improves the conditions for community health.

The Aditazz/Arup solution (Figures 7.67 and 7.68) likewise focuses on the connection between the built environment and human/ecological health:

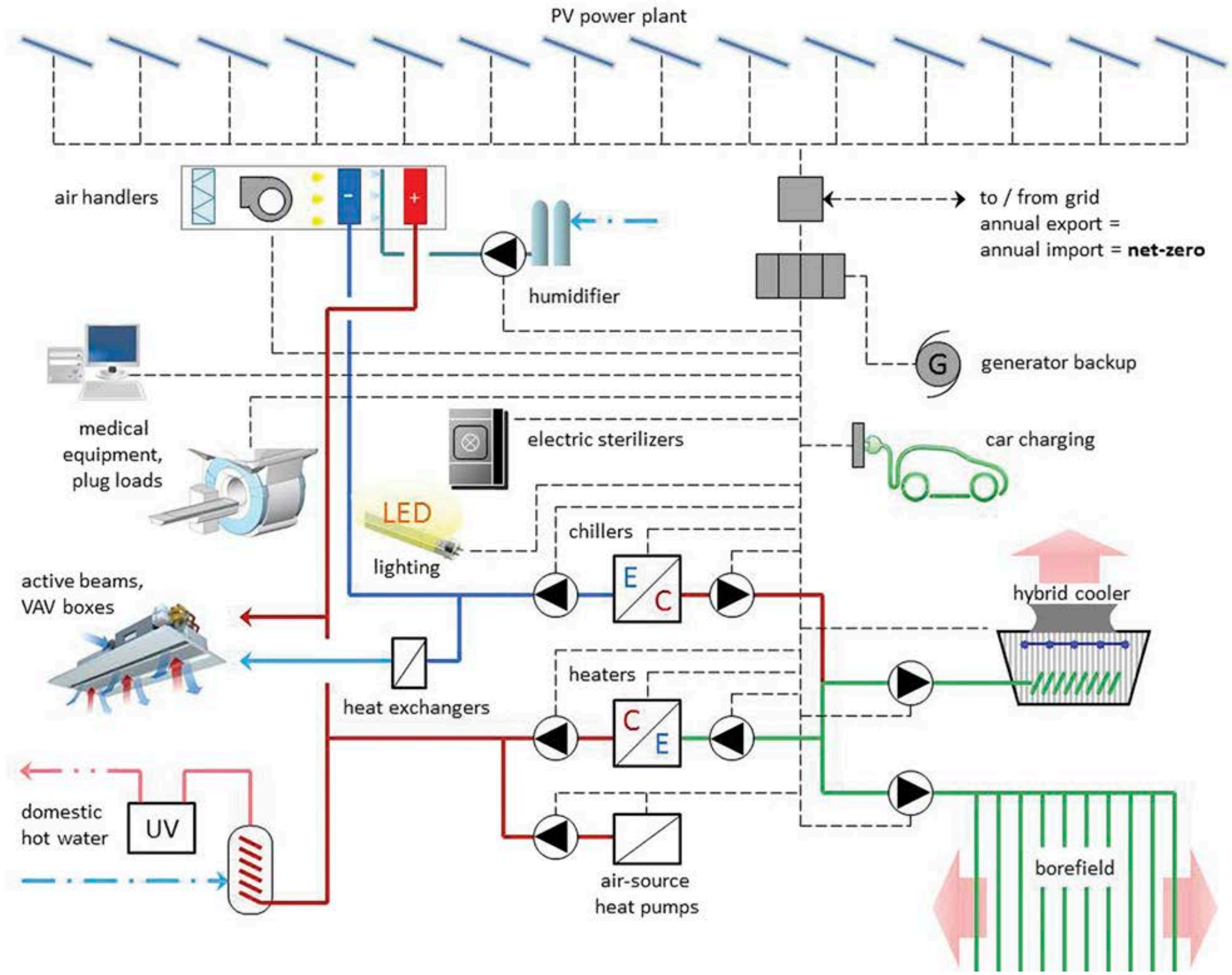
> The small hospital represents an opportunity to demonstrate and celebrate the profound connection between buildings and health in all its aspects, and in so doing position Kaiser Permanente as a true partner in developing and contributing to healthy communities.
>
> The small hospital creates a supportive healing environment by emphasizing abundant but controlled

daylight, easy access to outdoor environments, thermal comfort, healthy materials, and high indoor air quality. The facility design will also enhance staff well-being and productivity, provide exemplary infection control, and be easy and inexpensive to maintain.

Both aspire to create unique and inspired healing environments and workplaces, with a focus on productivity, safety, and quality of care. The Perkins+Will/Mazzetti solution focuses on a new typology for public space, the "wellness pavilion," that catalyzes member health management; the Aditazz/Arup solution uses the large roof to create a shaded outdoor "town square" for the campus.

In terms of site development, the Perkins+Will/Mazzetti solution demonstrates its focus on resilient and regenerative design through an innovative approach to site planning, where the southern California site, damaged from generations of agricultural practices and modified hydrology, is "restored" through reintroduction of former stream flows. The restoration is made possible through the biological onsite waste treatment plant, which is also included to filter pharmaceutical contaminants prior to release. Together, the systems produce a net zero water use baseline.

Figure 7.67 The "agora" space created under the PV frame roof structure. *Source: Aditazz/Arup, courtesy of Kaiser Permanente*



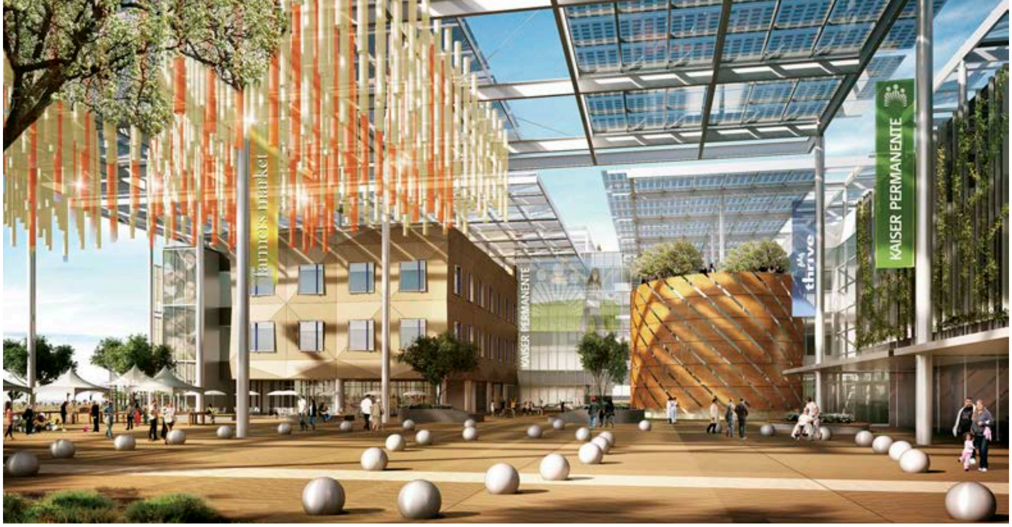


Figure 7.68 Energy systems. *Source: Aditazz/Arup, courtesy of Kaiser Permanente*

Likewise, drastic energy reduction is achieved through optimized solar management, narrow floor plate punctuated by courtyards, and high-performance envelope, coupled with system innovations (Figure 7.66). Ground-source heat pumps eliminate boilers and a geo-coupled well-field replaces a cooling tower. Controlled natural ventilation systems coupled with displacement delivery and direct outside air fan systems deliver ventilation air. All lighting is LED. As the systems minimize thermal energy needs, electrical power generation becomes the primary focus. In many cases, local landfills flare off more methane than the required energy to power the small hospital—fuel cells can capture this methane as a fuel source. Parallel, modular, redundant fuel cells supply a constant, renewable, no-emission source of power from landfill and wastewater treatment methane, supplemented by wind (a single, on-site turbine) and building integrated solar. Thus, source energy is not only carbon-neutral, but in fact carbon-negative, reducing the climate impacts within a current community. This solution derives from a prototypical resource decision process that emphasizes both resource reduction and reclaiming waste.

The Aditazz/Arup solution focuses on a site-specific solution, taking into careful consideration the environmental context—hot and dry in summer, cold in winter, with abundant clear sky conditions ideal for solar energy generation with onsite photovoltaic panels. The hospital functions are split into a series of buildings oriented around a protected outdoor activity courtyard, called the Agora, and the entire complex of buildings and public spaces is covered by a PV panel–covered roof canopy that provides shade for human comfort and reduces environmental loads on building envelopes (see Figure 7.66).

The solar roof, together with ground-mounted PV parking trellises, become the basis of engineering design for the project, enabling an all-electric systems approach where all components utilize site-generated electrical power and no natural gas is necessary. Mechanical, electrical, and plumbing systems are conceived as an integrated set of subsystems that work together in conjunction with the photovoltaic array to achieve net zero energy use, a very low carbon footprint, and environmental comfort (see Figure 7.67).

Both low-energy system solutions offer significant operational cost savings and meet the 2030 Challenge carbon neutral goals. They also demonstrate how integrating high environmental aspirations inform building and site design.

Source: Kaiser Permanente; Perkins+Will/Mazzetti; Aditazz/Arup

CONTRIBUTORS

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Richard Beam is System Director of Construction & Sustainability at Providence Health & Services. He previously served as Providence's Corporate Energy Manager for 18 years. In 2009, Providence received the US EPA's ENERGY STAR Partner of the Year for Sustained Excellence in Energy Management. Beam was named 2007–2008 Energy Manager of the Year for the Association of Energy Engineers' Western Region. He has an MBA and degrees and certificates in mechanical engineering, communications, and business.

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Geoff has worked to "green healthcare" for the past 25 years, at four large hospitals in Western Washington—most recently at Providence Health and Services, Southwest Washington where his facility was designated the Smartest Building in America. He has been certified as an Energy Engineer, a Healthcare Facility Manager and is licensed as a Professional Engineer in Washington State.

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Lin Hill is the Director of Awards at Practice Greenhealth, the nation's leading membership and networking organization for the healthcare sector. Lin is responsible for managing all aspects of the Awards program, and has worked in healthcare sustainability since 2003. She has over 16 years of experience in pollution prevention and has worked both inside and outside of the regulatory arena.

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John Kouletsis is Vice President of Facilities Planning at Kaiser Permanente. He has developed a comprehensive set of design criteria that have established Kaiser Permanente as a leading proponent of human-centered and green building design. John holds a BA in Architecture from the University of Southern California and did post graduate research at Kyoto University. He is 2013 president for the San Francisco chapter of the AIA.

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Sonia Roschnik has worked in health and social care for the past 20 years as an occupational therapist, manager and at director level. Sonia has always nurtured an interest in sustainable development and having worked in many countries is keen to align the principles of health and wellbeing with sustainable development and global health.

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Susan Saito is a former newspaper reporter and advertising copywriter. Her work at Kaiser Permanente promotes and advances the organization's green building, sustainability programs, and other innovative initiatives to design and build hospitals that support patients' total health and contribute to healthy communities. She has a bachelor's of English literature from the State University of New York at Buffalo.

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Tom Thompson assists in the implementation of Gundersen Health System's energy conservation and environmental impact programs and recycling efforts. He is finding creative and engaging methods to educate and empower Gundersen employees on personal choices in their daily lives to make an authentic, positive impact on the environment.

Corey Zarecki, Director of Engineering and Operations, Envision, Gundersen Health System

Corey Zarecki is responsible for the technical engineering support and operations for Gundersen Health Systems' Envision. He develops and oversees construction for renewable energy projects, and manages the daily operations of the Gundersen Envision portfolio. Additionally, he identifies new project opportunities and drives operational improvements, which help to advance the Gundersen Envision brand.

Bibliography

Black, Dr. T. (2012). Reforming Northern Ireland's Healthcare, GP Online, Feb. 17, 2012. www.gponline.com/Medeconomics/article/1117875/reforming-northern-irelands-healthcare/.

British Broadcasting Company [BBC] (2012). Which is the world's biggest employer? By Ruth Alexander. March 19, 2012. www.bbc.co.uk/news/magazine-17429786. Accessed on May 12, 2012.

Borger, C., S. Smith, C. Truffer et al. (2006). Health Spending Projections Through 2015: Changes on the Horizon. *Health Affairs*, Web Exclusive W61: February 22. http://content.healthaffairs.org/cgi/content/full/25/2/w61.

Building Research Establishment [BRE] (2012). www.breeam.org/about.jsp?id=66. Accessed on October 27, 2012.

Commission for Architecture and the Built Environment [CABE] (2009). Future Health: Sustainable places for health and well-being. www.cabe.org.uk/publications/future-health. Accessed on May 12, 2012.

——— (2006a). *The Cost of Bad Design.* www.cabe.org.uk/default.aspx?contentitemid=1342.

——— (2006b). *Designed with care: Design and neighbourhood healthcare buildings.* February 14.

www.cabe.org.uk/default.aspx?contentitemid=1158.

Coote, A. (2006). Health and sustainable development. Commission for Architecture and the Built Environment [CABE]. www.cabe.org.uk/default.aspx?refid=182&sl=4.2&contentitemid=1299.

Department of Health [DH] (2009). Sustainable Development in the NHS. www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/SustainableDevelopment/SustainableDevelopmentArticle/fs/en?CONTENT_ID=4119123&chk=sS5n8V.

——— (2008). *Achieving Excellence Design Evaluation Toolkit Evolution.* http://www.dh.gov.uk/en/Publicationsand-statistics/Publications/Publications PolicyAndGuidance/DH_082089.

——— (2008). ASPECT: A Staff and Patient Environment Calibration Tool. www.dh.gov.uk/en/Publicationsand statistics/Publications/PublicationsPolicyAndGuidance/DH_082087.

Design Council [DC] (2012). Our merger with CABE. www.designcouncil.org.uk/about-us/The-Design-Council-and-CABE/. Accessed on October 28, 2012.

Jenkin, N., ed. (2004). *Material health: A mass balance and ecological footprint analysis for the NHS: Executive Summary.* Best Foot Forward. www.materialhealth.com.

Ling, T., J. S. Pedersen, S. Drabble, C. Celia, L. Brereton, and C. Tiefensee (2011). Sustainable Development in the NHS: The Views and Values of NHS Leaders. RAND Europe. www.sdu.nhs.uk/documents/publications/RAND_Europe.pdf. Accessed on October 20, 2012.

National Health Service [NHS] (2006). www.nhs.uk/England/AboutTheNhs/Default.cmsx.

——— (2012). NHS Careers. www.nhscareers.nhs.uk/details/Default.aspx?Id=796. Accessed on May 20, 2012.

National Health Service Department of Health (2006b). NHS Environment Assessment Tool Guidance. www.dh.gov.uk/PublicationsAndStatistics/Publications/PublicationsPolicyAndGuidance/PublicationsPolicyAndGuidanceArticle/fs/en?CONTENT_ID=4119943&chk=/zNIF4.

——— (2004). Choosing Health: Making healthy choices easier. The Stationery Office Limited on behalf of the Controller of Her Majesty's Stationery Office, November: p.5.

National Health Services Sustainable Development Unit [NHS SDU] (2012). NHS England Carbon Footprint Update. www.sdu.nhs.uk/documents/publications/Health_Check_Carbon_Footprint_2012.pdf.

——— (2009). Saving Carbon, Improving Health: NHS Carbon Reduction Strategy for England. www.sdu.nhs.uk/documents/publications/1237308334_qylG_saving_carbon,_improving_health_nhs_carbon_reducti.pdf.

National Health Services Sustainable Development Unit [NHS SDU] (2011). Route Map for Sustainable Health. www.sdu.nhs.uk/documents/Route_Map_FinalPrint_no_timeline.pdf.

Office for National Statistics [ONS] (2012). Expenditure on healthcare in the UK 1997–2010. Author: Adam Jurd. www.ons.gov.uk/ons/dcp171766_264293.pdf. Accessed on May 20, 2012.

Vittori, G. (2000). Green and Healthy Buildings for the Healthcare Sector. Paper presented at *Setting Healthcare's Environmental Agenda*, San Francisco, October 16. In *Papers and proceedings from the conference*, pp.1–10.

PART 3

SUSTAINABLE HEALTHCARE TODAY

CHAPTER 8

GLOBAL SURVEY

Case Study 21: Akershus University Hospital

Loreskøg, Norway

OWNER: Helse Sør-øst RHF (public health region)

PROJECT TEAM:

Architect: C. F. Møller Architects

Structural Engineer: Multiconsult AS

Mechanical Engineer: SWECO AS

Electrical Engineer: Hjellnes COWI AS/Interconsult ASA

Landscape: Bjørbekk & Lindheim AS, Schønherr Landskab A/S

Contractors: Skanska, PEAB, HENT

TYPE: Replacement Academic Medical Center

SIZE: 1,474,656 sq. ft. (137,000 sq. m)

EUI: 46.3 kBtu/sf/yr (146 kWh/sm/yr)

PROGRAM DESCRIPTION: Teaching hospital with 555 medical/surgical (somatic) beds with 60% single-rooms; 216 psychiatric beds; 27 substance abuse beds; 22 operating theatres serving 13 municipalities representing about 340,000 people

COMPLETED: 2008; final phase completed 2012

RECOGNITION: 1st prize in international design competition, 2000; UK Building Better Healthcare Awards, Award for Best International Design, 2009

BIOME: Boreal Humid

CLIMATE ZONE: Humid Continental

PRECIPITATION: 39 in. (1,000 mm)

KEY SUSTAINABILITY INDICATORS

- *Narrow Floorplate:* Form and interior courtyards facilitate daylight in all occupied spaces
- *Rainwater Harvesting:* Reduces stormwater run-off and provides irrigation water
- *On-site Wastewater Treatment:* Wastewater is filtered prior to release for disease/infection control and to remove medical/pharmaceutical residues
- *Innovative Source Energy Reduction:* 40% of total energy use, 85% demand supplied by borehole thermal energy storage (BTES)
- *Natural Ventilation:* Natural ventilation in glazed street; operable windows in offices and patient rooms
- *Heat Recovery:* Extensive heat recovery as part of the BTES system
- *Low Embodied Energy Materials:* Locally sourced wood, stone
- *Construction Waste Diversion:* 88% diversion rate achieved
- *Civic Function:* Retail functions integrated along central spine
- *Community Partnerships:* Adjacent farmland in continuous cultivation used for geo-thermal boreholes

Figure 8.1 Akershus University Hospital. Source: *Torben Eskerod*

This university hospital's low energy design features one of Europe's largest geo-exchange systems, reducing CO_2 emissions by more than 50 percent compared to the previous hospital's consumption. Its narrow footprint prioritizes daylight for all workplaces, and it provides a visible connection to place with locally sourced sustainable materials. It builds on the successes of the earlier Rikshospitalet while achieving more ambitious energy goals.

CONTEXT

Akershus University Hospital is one of Europe's leading innovative hospital designs, integrating patient-centered care with a humanistic design ethic and use of local, familiar materials that, together, diffuse the institutional nature of the building. The outcome of architectural firm C.F. Møller's winning entry from an international design competition held in 2000, Akershus exudes a welcoming environment. It overcomes its significant size with unifying design elements that emphasize transparency and depth evident throughout the building (Figure 8.1).

SITE AND BUILDING

The building's long, central mall—a five story "glass street"—has a glass roof and provides a public axis that spans the length of the building (Figures 8.2–8.3). It is anchored with the building entrance at one end and a clinic for children and youth at the other. Treatment wings and emergency department flank one side, and patient wards, designed as three "fingers," the other. The building orientation and narrow floorplate creates open, inviting spaces, and provides daylight for all workspaces, views of the landscape, and tangible connection with the outdoor environment. Art projects distributed on the hospital's grounds and inside infuse cultural vitality. A church, pharmacy, hairdresser, florist, and many other community amenities are located along a naturally ventilated central glass promenade, creating a familiar sense of neighborhood amidst the rigorous programmatic requirements of a large teaching hospital. Vertical elements and flooring constructed of native soft wood are prominent along the glass street, invoking a sense of familiarity and informality and connection to the natural environment—a welcome departure from a conventional institutional environment that complements patient care.

A fundamental design feature is to provide daylight to all above-grade spaces and rooms. While a few rooms "borrow" light from the glazed "street," 80 to 90 percent of regularly occupied spaces benefit from direct daylight from the outside. To accomplish this, treatment wings are centered on a series of four courtyards. Patient wards extend into the green landscape providing both daylight and views.

Cladding materials differentiate the building's programmatic areas: To create a welcoming environment, the entrance and main arrivals area are composed of glass, plaster, and glass tiling (Figures 8.4 and 8.5). Treatment areas are clad with glass, plaster, and aluminum paneling, with white-lacquered sinusoidal aluminum panels in the courtyards; patient wards are distinguished with dark screen tiling, and the children's department with wood facades (Figure 8.6).

Complementing the emphasis on a human-centered environment, Akershus demonstrates impressive environmental stewardship prioritizing high-performance, low-carbon energy systems while ensuring a safe and comfortable environment for patients and staff. Akershus is designed with a hybrid ventilation system: The glazed street is naturally ventilated, while the rest of the facility is mechanically ventilated with heat recovery as part of the BTES system.

Akershus's mechanical system design responds to hospitals' energy intensity with an innovative solu-

Figure 8.2 Wood and natural stone are dominant materials in the glazed street. *Source: Torben Eskerod*

Figure 8.3 Detail of medical info-points in glazed street. *Source: Torben Eskerod*

tion. Its borehole thermal energy storage and recovery system (BTES) is considered one of the largest such systems in the world (Figure 8.7). The BTES is integrated with a heat pump system, enabling heat recovered from the hospital's surplus sources to supply heating energy most of the year. In intense periods of winter heating or summer cooling, stored energy can be recovered from the BTES. This system results in 80 to 85 percent of the facility's heating energy, supplied via the heat pump system. About 57 percent of this energy is recovered through the BTES. The system is estimated to result in a reduction of 3,000 tonnes of CO_2 per year. To accomplish this, the BTES requires a large physical footprint. The area used to contain the wells covers 4.9 acres (2 ha) of farmland that will continue to be used to cultivate crops. The system includes about 93 miles (150 km) of pipe that have been laid to connect the 350 wells filled with about 66,043 gallons (250,000 L) of antifreeze solution.

Akershus's project team addresses its responsibility to the water cycle at both source and discharge phases of the cycle. Rainwater is collected from the building's expansive rooftops and used primarily to irrigate the facility's landscaped area, offsetting reliance on treated potable water. Captured rainwater is collected in "rainwater cassettes" that are directly integrated into the built-up landscape features in the courtyard, rather than using external storage tanks that would require piping to the landscaped areas. Native plant selection reflected the Owner's interest to create a natural, familiar aesthetic; while native plants resulted in reduced water dependence, the decision was driven more by aesthetics than function.

The building's wastewater is treated prior to release into the sewage treatment system to ensure it is free of contaminants that may lead to the spread of infection or disease. Through this process, pharmaceutical residuals are filtered out of the water to limit their downstream exposure. This is an important provision as contact by wildlife, livestock, and humans with medically contaminated water can be problematic and result in endocrine disruption and other adverse health outcomes. While Nordic countries have stringent regulations for wastewater management, Akershus was a catalyst to strengthen regulations concerning discharge, resulting in an environmental health benefit for this project and others to be built in the future.

Other signature achievements include locally sourced materials, particularly the prominent soft wood species in the glass street, and reducing and recycling construction debris. For the latter, the project team set an aggressive goal to divert 90 percent of total construction debris from landfill. The goal was almost achieved: A final tally accounts for an 87.9 percent diversion rate, with only 12.1 percent managed as waste to be landfilled.

In summary, Akershus is innovative in its energy performance and systems selection, wastewater treatment to filter pharmaceuticals, and in its extensive daylighting and narrow floorplates (Figures 8.8–8.12). It demonstrates that in cold climates, hospitals can in fact provide comfortable thermal conditions with connection to daylight and nature, while minimizing use of fossil fuel energy.

Source: C. F. Møller Architects

Figure 8.4 Main entrance cantilevered canopy welcomes patients. *Source: Torben Eskerod*

Figure 8.5 Canteen space is in close relation to the landscape. *Source: Torben Eskerod*

Figure 8.6 South facade with children's ward. *Source: Torben Eskerod*

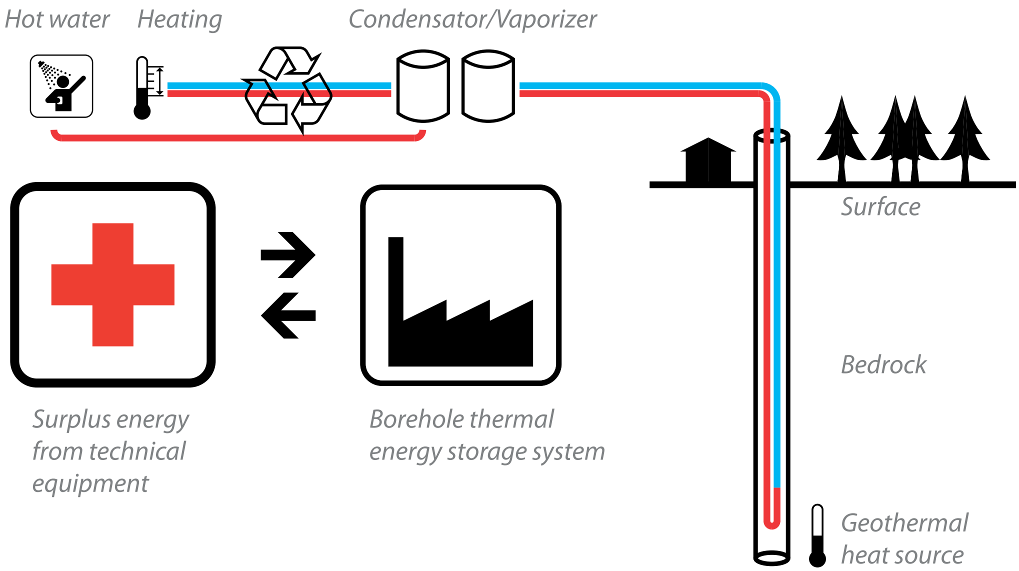


Figure 8.7 Energy system diagram. *Source: Møller Architects*

Figure 8.8 Site plan. *Source: C. F. Møller Architects*

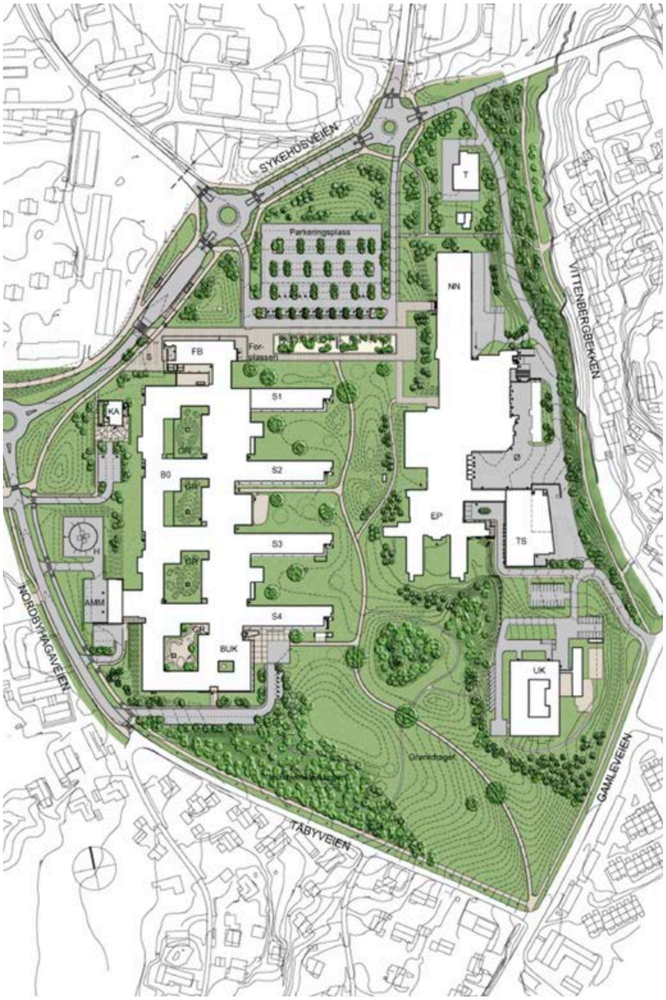


Figure 8.9 Landscape plan. *Source: Moller Architects*

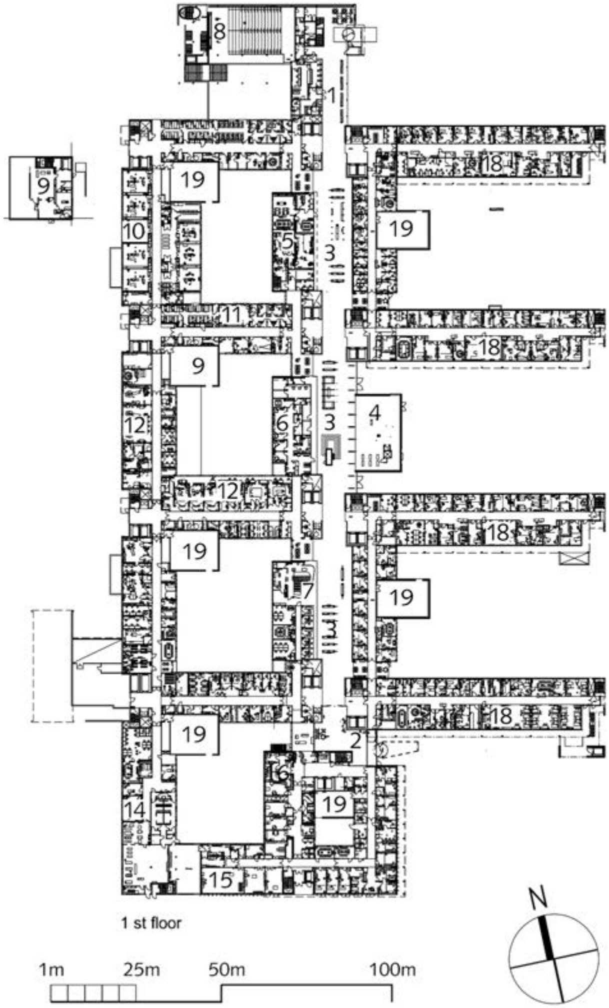


Figure 8.10 Level 1 plan. *Source: Moller Architects*

Level 1

1. Main entrance and reception
2. Children's entrance and reception
3. Glass covered mall
4. Cafe/Kiosk
5. Pharmacy
6. Blood sampling
7. Church
8. Auditorium
9. Chapel
10. Day surgery
11. Anesthesia/Recovery
12. Diagnostic imaging
13. Pain clinic
14. Physiotherapy/ Rehabilitation
15. Rehabilitation children
16. Sampling children
17. Polyclinic children
18. Out-patient depart-ments polyclinics
19. Technical towers

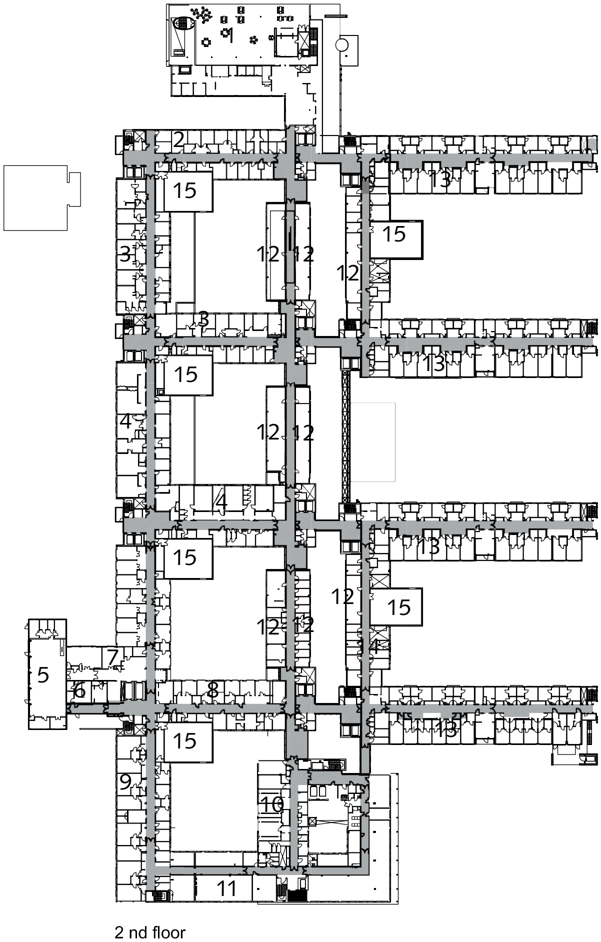


Figure 8.11 Level 2 plan. *Source: Møller Architects*

Level 2

1. Canteen
2. Polyclinic hematology/oncology
3. Polyclinic gastrology
4. Diagnostic imaging
5. Emergency
6. Triage
7. Emergency surgery
8. Emergency treatment
9. Emergency observation
10. Treatment/observation children
11. Rehabilitation children
12. Offices
13. Standard bed wards
14. Ward services, kitchen, bed cleaning, etc.
15. Technical towers

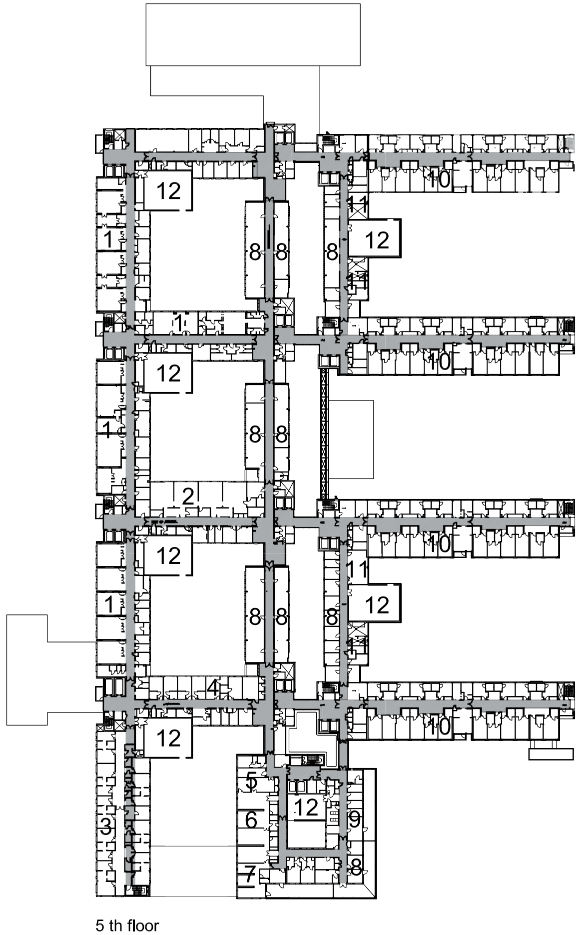


Figure 8.12 Level 5 plan. *Source: Møller Architects*

Level 5

1. Operating theaters/surgery
2. Recovery
3. Maternity
4. Maternity observation
5. Neonatal intensive care unit
6. Neonatal observation
7. Neonatal convalescent
8. Offices, administration, staff
9. Family rooms
10. Standard bed wards
11. Ward services, kitchen, bed cleaning, etc.
12. Technical towers

Case Study 22: Butaro Hospital

Burera District, Rwanda

OWNER: Rwandan Ministry of Health, Partners In Health (PIH)

PROJECT TEAM:

Architect: MASS Design Group

Structural Engineer: ICON

Construction Supervision: Partners In Health

Sewage Plant Engineering: EcoProtection

Landscape Design: Sierra Bainbridge and Maura Rockcastle

TYPE: New Acute-Care Hospital

SIZE: 65,014 sq. ft. (6,040 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: 140-bed acute-care hospital (Men's Ward, Women's Ward, Pediatrics, Post-Partum), with 10-bed infectious isolation unit, 2 Operating Rooms, Imaging, Obstetrical unit, 5-position neo-natal ICU, ED with trauma bay

COMPLETED: 2011

RECOGNITION: Acute Medical Care Facility of the Year (2011) by *Contract Magazine*; London Design Museum's Design of the Year Finalist (2011); Top 10 Projects of the Year (2011) for the Public Good by Archinect

BIOME: Tropical Humid

CLIMATE ZONE: Tropical Savanna

AVERAGE ANNUAL PRECIPITATION: 39 in. (991 mm)

KEY SUSTAINABILITY INDICATORS

- *Narrow Floor Plate:* Buildings naturally ventilated and daylit
- *Innovative Ventilation:* Natural ventilation in wards assisted by vaulted ceilings with large ceiling fans
- *Water Heating:* No domestic hot water heating
- *Rainwater Harvesting*: For toilet flushing and landscape irrigation
- *On-site wastewater treatment*
- *Low Embodied Energy Materials*: Extensive use of local materials (volcanic rock from the Virunga Mountain, local stone foundations); revived traditional stone construction methodology in the region
- *Local Labor:* Constructed with 100% local labor; trained 3,898 workers
- *Capacity Building:* Prior to this hospital, there was only 1 community physician in Butaro; since the opening there are 12 Ministry of Health doctors, 5 visiting Partners In Health (PIH) doctors, and a visiting PIH doctor in residency

Figure 8.13 Butaro Hospital. *Source: Copyright © Iwan Baan*

Butaro Hospital represents a radical rethinking of hospital construction to provide acute and ambulatory healthcare in resource-constrained settings. Recognizing that high-quality healthcare (even for infectious diseases) can be delivered in beautiful, healthy, bioregionally appropriate, appropriate technology buildings is a revolutionary "return to the past" that informs the future (Figures 8.13, 8.16, and 8.17).

CONTEXT

Rwanda has a temperate tropical highland climate, with lower temperatures than are typical for equatorial countries due to its high elevation. Daily temperatures range between 12°C (54 °F) and 27°C (81°F), with little variation through the year. The climate is classified as a tropical savanna (winter dry season), with a warm temperate moist forest biozone. Rwanda is a country of few natural resources; the economy is based mostly on subsistence agriculture with local farmers using simple tools. Since 2000, the Rwandan government has prioritized funding of water supply development; the country's population with access to clean water since 2005 has increased from under 50 percent to more than 80 percent—in rural areas, access is primarily through wells or springs. Despite rainfall in excess of 39 in. (991 mm) annually in much of the country, there is little rainwater harvesting. Only 6 percent of the population had access to electricity in 2009.

Burera District, with a population of over 340,000, has historically had very poor health indicators compared to other areas of Rwanda. It is one of the most impoverished districts in the country. Prior to Partner In Health's arrival in 2007, Burera was one of the last two districts in the country without a functioning district hospital and had, at most, a single doctor. The hospital's design and construction aimed to deliver an appropriate, state of the art acute-care facility while also fully choreographing the process of construction to employ, educate, and empower the local community.

The significant issue of hospital-borne (nosocomial) infection was the project's key design driver. In rural clinics and impoverished settings, crowded corridors and insufficient ventilation often subject patients and healthcare providers to the high risk of contracting airborne diseases inside health facilities. After immersion in the field through living and working at the Butaro Health Center, and consultation with global health experts from Partners In Health, Harvard School of Public Health, Harvard Medical School, and the Centers for Disease Control and Prevention, MASS Design Group developed a typology to mitigate and reduce the transmission of airborne diseases through several key measures including overall layout, patient and staff flow, and natural ventilation. This typology provides a prototype that can be replicated in areas of high risk for TB transmission and other airborne diseases in resource-constrained settings.

SITE AND BUILDING

The Butaro Hospital design incorporates a range of innovative features designed to minimize risk of infection. Elimination of interior corridors and carefully positioned louvered windows ensure frequent air exchange, a key strategy in reducing disease and infection transmission. To produce the necessary air changes in the ward, high-volume, low-speed fans with diameters of 12 ft. (3.66 m) move air from the wards out the louvers and open windows; in doing so they remove potentially harmful microbes (Figure 8.15).

The airflow modeling predicts approximately 12 air changes per hour in wards, anticipated to reduce nosocomial transmissions by 35 percent as compared to

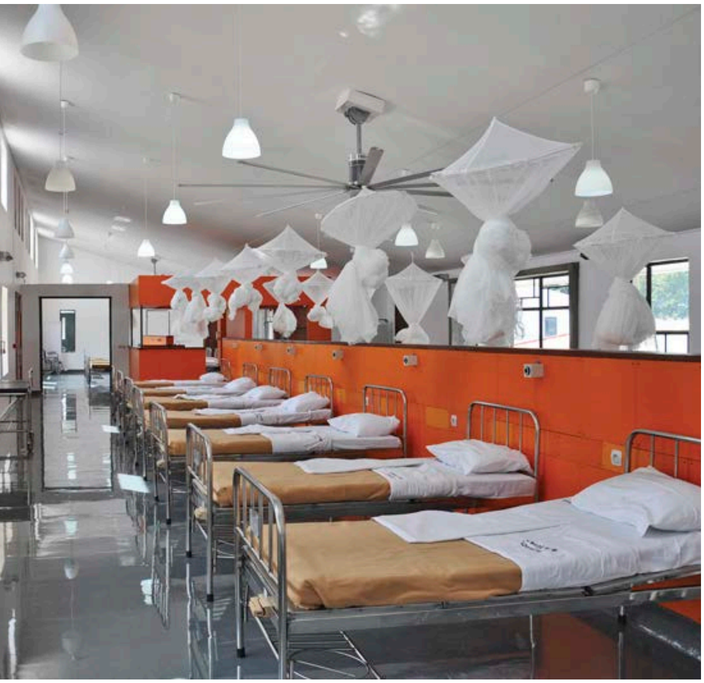


Figure 8.14 The project features local stone construction. *Source: MASS Design Group*

Figure 8.15 Ward designed for optimum natural ventilation. *Source: MASS Design Group*

similar facilities. Germicidal UV lights kill or inactivate microbes as air is drawn through the upper regions of the rooms. The use of an impermeable, continuous floor finish provides a surface devoid of joints prone to bacterial growth. The floor type is easy to clean and durable.

The region has historically lacked a reliable source of electricity. A hydroelectric power generation facility opened in early 2011, improving availability and reliability. An on-site oxygen generation plant produces 10 cylinders (3,700 gal; 14,130 L) of O_2 per day for clinical uses.

Two boreholes tap an underground water source. The potable water is delivered to a main cistern at the rear of the campus, which then is distributed to 1,320 to 2,650 gal (5,000 to 10,000 L) water tanks in each building, ensuring adequate reserve supplies if the borehole pumps fail. There is no hot water production. Rainwater is harvested for toilet flushing and landscape irrigation: 19,160 sq. ft. (1,780 sq. m) of roof area channels rainwater to two 80,000 gal (305,000 L) cisterns.

Beyond providing access to first-rate healthcare facilities, the Butaro Hospital project catalyzed grassroots business and development. Close to 4,000 local people were trained and hired to help excavate, construct, and manage the project. Construction workers were organized into six teams, each of which worked a two-week shift. This allowed for six times as many people to be hired and involved in the building process. All employees were provided with food, water, and healthcare. Employing more laborers was less expensive and faster than using solely heavy equipment to excavate the hillsides and move the earth—more importantly, it provided the added benefits of both creating jobs and engendering community investment in the project.

Figure 8.16 Aerial view. *Source: Copyright © Iwan Baan*

Figure 8.17 Site plan. *Source: MASS Design Group*

Figure 8.18 Detail of ward building. Source: *Copyright © Iwan Baan*

Capacity building and two way learning happened naturally at all stages and areas of the project, from design workshops with the local builders through on-site development of specific construction methods. Volcanic stone is ubiquitous in the northern Rwandan landscape and is commonly considered a nuisance by farmers clearing their fields. The stone is typically used in building only for foundations or courtyard walls, and is often covered partially or completely with mortar. In an effort to reveal the stone's exceptionally unique and beautiful texture, MASS Design Group sought to minimize mortar, and create an even and nearly seamless expanse of deep gray porous walls (Figure 8.14). After multiple mock-ups, the masons began to get excited about the product that was appearing, and finally were given the go-ahead. As they progressed through the various buildings on the hospital campus, their work became more refined. Recognizing how their skill had advanced as they worked, the masons eventually offered to replace their initial work, out of a sense of pride. Contractors in other parts of the country now seek out these newly trained, highly skilled masons to replicate the "magnificent stone walls of Butaro."

Source: MASS Design Group, Partners In Health

Case Study 23: Deventer Ziekenhuis

Deventer, The Netherlands

OWNER: Deventer Ziekenhuis

PROJECT TEAM:

Architect: deJong Gortemaker Algra Architecten

Engineer: Deerns Raadgevende Ingenieurs

Landscape Architect: Buro Poelmans Reesink

Constructor: Heijmans Bouw

TYPE: Regional Acute-Care Hospital

SIZE: 592,015 sq. ft. (65,000 sq. m) (main hospital) plus psychiatric center, radiation therapy clinic; Site area: 45 acres (18.2 ha)

EUI: 38 kBtu/sf/yr (120 kWh/sm/yr)

PROGRAM DESCRIPTION: 380-bed regional acute-care hospital, including emergency services; adult/pediatric ambulatory care.

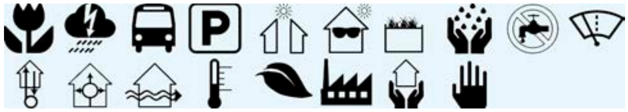
COMPLETED: 2008

RECOGNITION: European Union Hospital Demonstration Projects; nominated Hedy d'Ancona Award for excellent health architecture

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 28 in. (700 mm)



KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management:* Pervious paving, bioswale surface parking design
- *Innovative Parking*: 50% of parking is below plaza and clinics
- *Climate Responsive Facade:* Fixed and motorized external shading systems
- *Narrow Floor Plate:* Narrow wings and extensive courtyards enhance daylighting and connection to nature
- *Green Roof:* 50% roof area vegetated to filter rainwater and for visual appeal
- *Rainwater Harvesting:* Collected rainwater used for landscape irrigation
- *Low EUI:* System reduces annual heating costs by 70%, cooling by 50%, and annual electrical consumption by 15% compared to conventional systems
- *Innovative Source Energy:* Ground source cooling storage and thermal storage/retrieval system with a system of electrical heat pumps and peak load gas boilers; no fossil fuel cooling energy
- *Innovative Energy Distribution:* All air system with variable air volume system; underfloor air distribution in administrative areas; operable windows throughout inpatient units, outpatient, administrative, and support spaces
- *Modular Construction:* for future flexibility

Figure 8.19 Deventer Ziekenhuis. *Source: deJong Gortemaker Algra Architecten*

Deventer Ziekenhuis is an innovative, large-scale, low-energy regional hospital. As a European Union Hospital Energy Demonstration Project, it has influenced a generation of hospital buildings in Northern Europe. With its innovative and elegant energy storage and retrieval system, Deventer sets a formidable benchmark for low energy design while achieving high levels of thermal comfort (Figure 8.19).

CONTEXT

The campus is situated on a greenfield site located on the outskirts of Deventer, the Netherlands, in a metro area of 170,000 residents. Geography is generally low and flat; the inland area is in some places below sea level; without sea defenses, as much as 40 percent of the country would be under water. The Netherlands' climate is temperate, with gentle winters, cool summers, and rainfall in every season. Average temperature ranges are from 30° to 39°F (–1 to 4°C) in January to 55° to 72°F (13 to 22°C) in July.

The first major design goal was to break down the institutional scale of a typical regional hospital into a series of smaller elements. Hence, Deventer is designed more as a collection of separate buildings, each with their unique characteristics, than one massive structure. There are five major building elements: the entrance court/ambulatory pavilions, the central spine, the bedded care platforms, and the distinct Radiation Therapy and Psychiatric pavilions. Non-patient-related areas are centrally located to support all types of care, for example in the basement and on the third floor. The result is a highly articulated, narrow floor plate combined with a deep ambulatory building that maintains connection to daylight through a system of skylights and courtyards (Figures 8.27 and 8.28).

SITE AND BUILDING

To preserve open space, parking is a combination of 50 percent below grade and 50 percent surface. The parking garage below the building is half below an elevated ground level at the entry plaza; additional parking fans out from the entrance pavilion, constructed of grass block pavers and bioswales to capture and store rainwater for landscape irrigation in dry periods (Figure 8.25).

In the center, the entrance is defined by a large public square with bus stops and dedicated drop-off for taxis and cars; on the square, the main entrance is located under a large overhang (Figure 8.20). The front is formed by the curved steel structure, about 26 feet (8 m) above ground level—this structure can be ex-

Figure 8.20 Entry court. *Source: Perry Gunther*

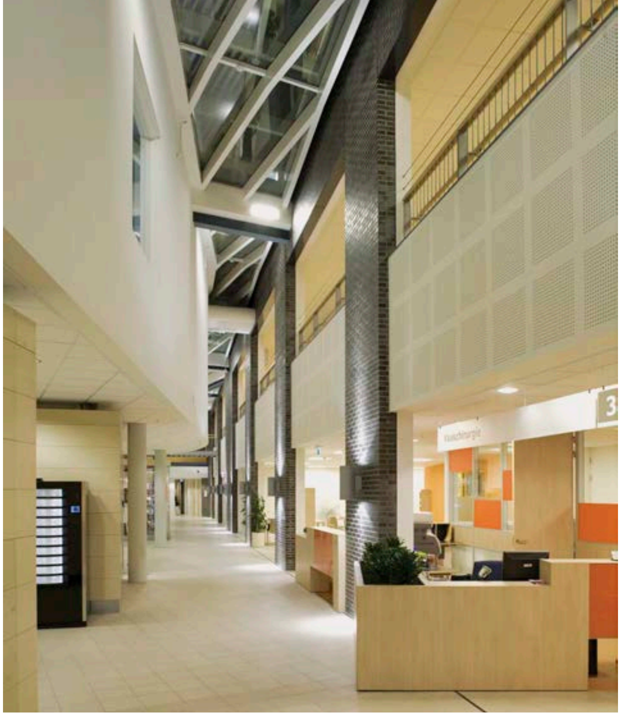


Figure 8.21 Interior at spine. *Source: Phillip Driessen*

Figure 8.22 Elevated bed unit wings respond to risk of periodic flooding. *Source: Phillip Driessen*

tended in the future. This side of the hospital reveals itself as a small, expandable ambulatory care and administration structure under a large roof, characterized by a system of walls and removable/reconfigurable colored glass panels. This continuous roof includes openings for atriums and open courtyards, areas of vegetation, and an accessible roof garden terrace (Figure 8.23). These openings are shaded by a system of fixed and automated horizontal blinds. The outpatient clinic is flexible in design with uniform consultation rooms for most specialists on the ground floor and a highly flexible office level on the first floor. Interior walls can easily be removed; underfloor air distribution systems, data and power outlets facilitate easy reconfiguration. Both the size and layout are relatively easy to adapt to different requirements.

The spine building contains the core hospital functions such as operating rooms, intensive care, and research/treatment rooms (Figure 8.21). Internal flexibility was achieved by integrating standard features such as consultation rooms, work areas, and storage into strategic locations. These can later be moved to the office level or the basement to make room for additional research or treatment rooms.

A second major goal was to maximize natural light and ventilation. The form is a series of "fingers" that emerge from the staggered, curvilinear spine building—with inpatient rooms and diagnostic care in each. The overall intention was to give it the feeling of several smaller hospitals meandering along a unified backbone, like a main street with different orientation points, destinations, and outdoor accessibility to preserve human scale and nature connectivity. Patient rooms are a mix of private, semi-private (2 beds) and semi-private suites (3–4 beds) (see Figure 8.22). These elements taper to their endpoints in a modified racetrack configuration. Operable windows are in patient rooms and elsewhere throughout much of the hospital (Figures 8.22, 8.27, and 8.28).

TRIAS ENERGETICA

Reduce Demand. A high-efficiency thermal envelope and a combination of fixed and movable solar shading reduce energy demand. Also, heat and moisture recovery units reduce energy demand. Spaces were coordinated and clustered based on daily use-occupancy ratios to improve natural thermal temperature—systems appropriate to each use are implemented in each section of the building. For example, underfloor air distribution systems are used in clinics and administrative areas. Patient rooms utilize natural and displacement ventilation systems.

Use Renewable, Sustainable Energy. An innovative energy system was developed using heat recovery and geo-exchange systems. The seasonal surplus of heat and cold is stored in the underground aquifer and heat exchangers buffer the desired temperatures. The pre-warming from this system provides 80 percent of required heating in winter and 100 percent of required cooling in summer.

Efficient Use of Energy. High-efficiency gas boilers produce both steam and domestic hot water. The hospital's standard heating demand is supplied by a low temperature system with an energy efficient heat pump, which covers about 80 percent of the total demand. Only the peak loads (approximately 20 percent of the total capacity) require high-efficiency gas-fired boilers. The cold storage system is able to provide 100 percent of the necessary cooling energy. No nonrenewable energy resources are required. During summer, the warm outdoor air is cooled with the cold water from the cold source, which has a temperature of about 46–50°F (8–10°C).

Figure 8.23 Trias energetica approach. *Source: Deerns Raadgevende Ingenieurs.*

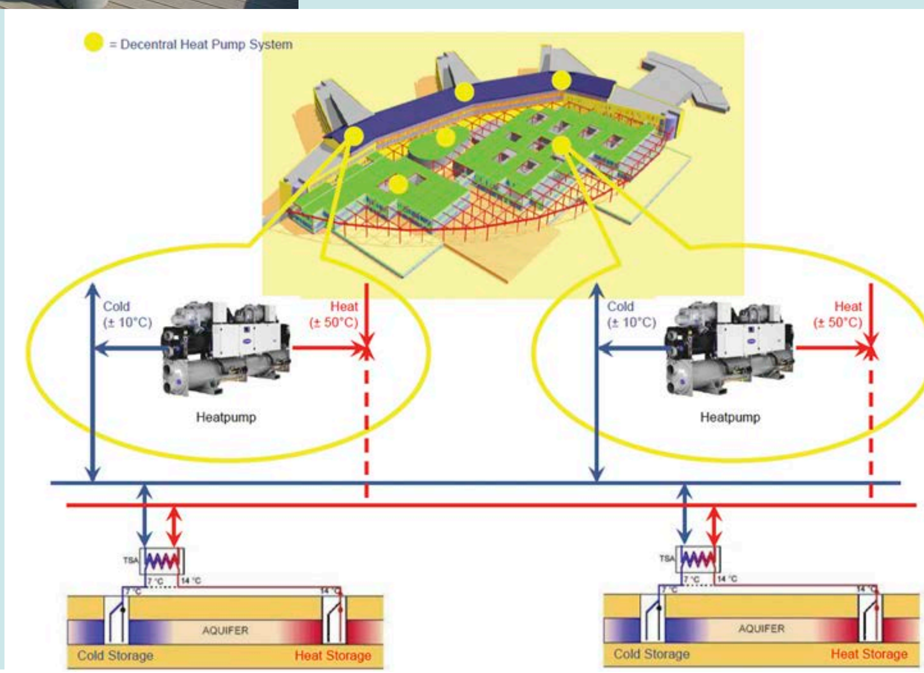


Figure 8.24 Decentralized heat pump systems. *Source: Deerns Raadgevende Ingenieurs*

Figure 8.25 Entry plaza. *Source: Deerns Raadgevende Ingenieurs*

Sustainable building design principles developed by the Dutch government emphasize a building's total life cycle operational costs. The hospital design benefited from consultations with outside engineers and energy modelers, who modeled dozens of innovative massing configurations and site plan options. Modeled energy efficiency measures anticipated annual emissions reductions of 1.299 tons of CO_2, 8.7 tons SO_x, and 3.35 tons NO_x—a reduction of 47 percent on heating and 13 percent on electricity compared to the average Dutch hospital.

The energy system is based on seasonal storage of surplus heat and cold in aquifers. Using a ground-source borefield with heat exchangers, the buffered warmth and cold is used for pre-warming during the winter and cooling during the summer. No additional cooling energy is required. Deventer Ziekenhuis is the first hospital in Europe to employ this large-scale ground source cooling storage and thermal storage/retrieval system with a system of heat pumps and ventilation heat and moisture recovery units. The building's energy-saving strategy is based on the principles of Trias Energetica, or Energy Triangle approach (see Figures 8.23 and 8.25).

The heat storage is charged during summer season with surplus heat from the cooling process. During winter, the cold outdoor air is preheated with the heat source, which has a temperature of about 59–63°F (15–17°C). Less extra energy is needed from the heat pumps to achieve a supply air temperature of about 70°F (21°C). Moreover, heat pumps gain efficiency with a smaller temperature differential. All conditioning is distributed via the ventilation air ("all air concept"). There are no heating or cooling elements at the facade.

Decentralized systems for heating and cooling in every building component make demand control possible, saving energy by avoiding energy loss in the distribution systems and providing operational flexibility. The use of a demand control system for ventilation, cooling, and heating enables energy to be efficiently used where and when needed. To further boost efficiency, a heat exchanger recovers heat from the exhaust air.

Source: deJong Gortemaker Algra Architecten with Deerns Raadgevende Ingenieurs

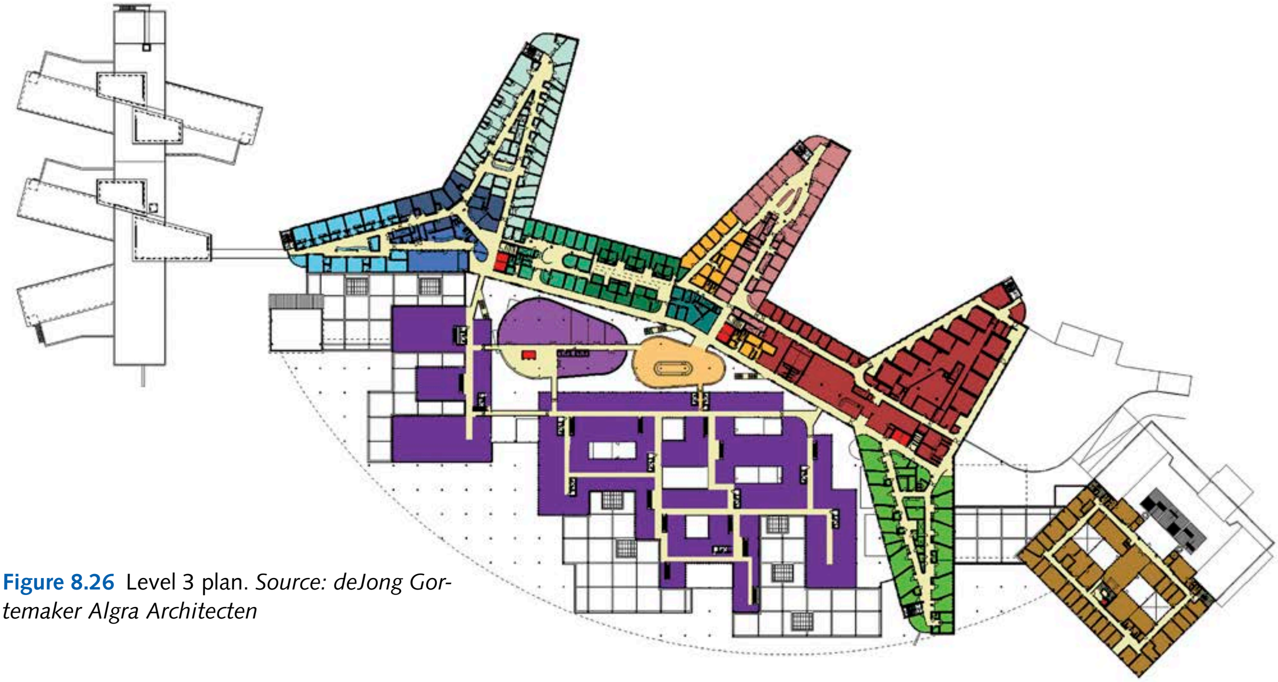


Figure 8.26 Level 3 plan. *Source: deJong Gortemaker Algra Architecten*

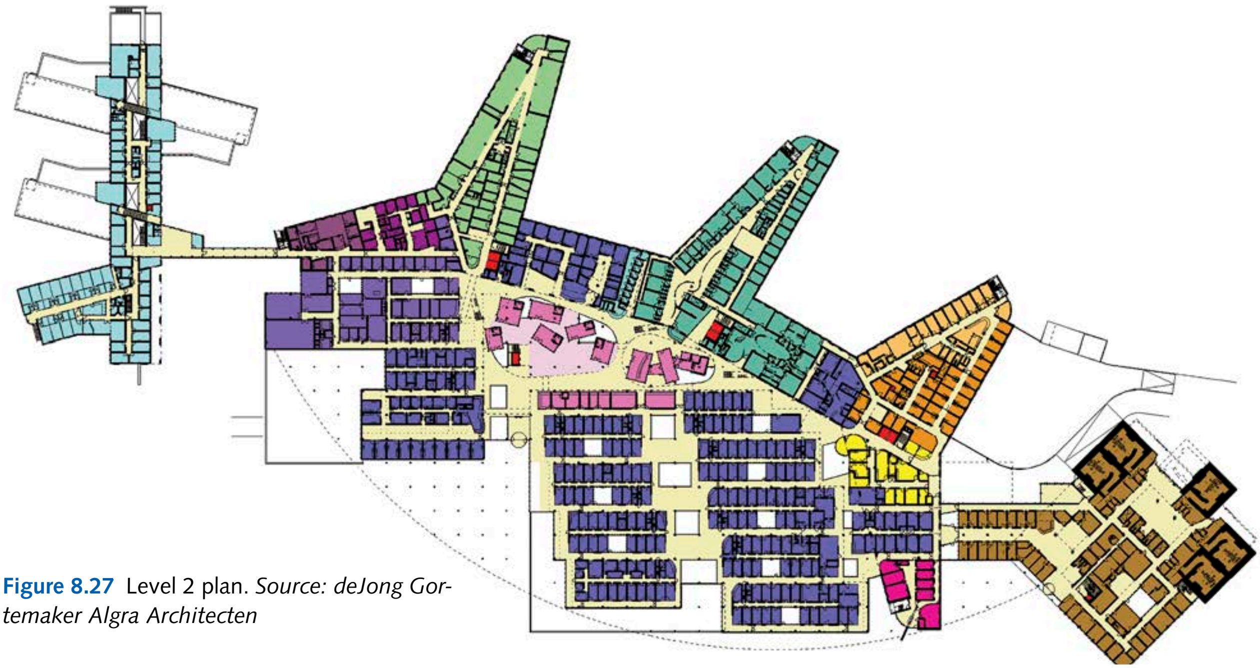


Figure 8.27 Level 2 plan. *Source: deJong Gortemaker Algra Architecten*

Case Study 24: First People's Hospital, Shunde District

Foshan City, Guangdong Province, People's Republic of China

OWNER: Shunde District

PROJECT TEAM:

Design Architect: HMC Architects

Executive Architect: Shunde Architectural Design Institute

MEP, Civil, Structural Engineer: SDADI

Landscape Architect: HMC Architects and SDADI

Interior Designer: HMC Architects and SDADI

Contractor: ZheJiang ZhongYuan Construction Design Co.

TYPE: New Tertiary Medical Center

SIZE: 2,800,000 sq. ft. (225,000 sq. m); Site: 33 acres (13.3 ha)

EUI: 32 kBtu/sf/yr (100 kWh/sm/yr)

PROGRAM DESCRIPTION: Inpatient tower with 2,000 beds, acute-care facility, outpatient facilities with 6,000 daily visits, Chinese medicine center, medical research labs, cancer center, and infectious disease facility, staff dormitory, 2,000 parking spaces

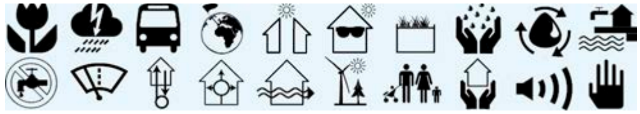
COMPLETED: 2013

RECOGNITION: AIA ACHA National Design Award, 2011; Finalist, Healthcare/World Architecture Network, 2010

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

ANNUAL PRECIPITATION: 68 in. (1,727 mm)



KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management*: Bioswales and water catchments harvest and manage stormwater
- *Narrow Floorplate*: Maximizes daylighting and facilitates natural ventilation; operating suites daylit
- *Energy Responsive Facade*: Efficient curtain wall with light-shelves; extensive fixed solar shading incorporates building integrated photovoltaics
- *Rainwater Harvesting*: Used for irrigation
- *On-site Wastewater Treatment/Reclaimed Water Reuse*: Gray- and blackwater fulfill 25% of total water use
- *Innovative Energy Distribution*: Air dehumidified using natural ventilation, stack effect and chilled beams
- *Natural Ventilation*: Operable windows in inpatient med/surg floors and naturally ventilated "eco-atrium"
- *On-site Renewable Energy:* 161,500 sq. ft. (15,000 sq. m) building integrated photovoltaic system designed into facade shading screen, skylight, and roofing system
- *Low Embodied Energy Materials*: Regional resources including traditional, locally manufactured terracotta
- *Civic Function*: Anchors new urban development while incorporating on-site retail functions; catalyzed new public transit system
- *Resilience*: Designed to curtail spread of infections with ability to sequester discrete sections of buildings

Figure 8.28 First People's Hospital. *Source: HMC Architects*

China is investing in a widespread replacement and expansion of its healthcare infrastructure; 80 percent of its existing hospitals are projected to be replaced over the next 10 years. First People's Hospital in Foshan is piloting sustainable strategies and methods to influence the next generation of China's hospitals, and is on the vanguard of integrating low-carbon energy strategies including natural ventilation, chilled beams, and site-installed building integrated photovoltaics with strategies such as daylight and views to enhance the patient and staff experience (Figures 8.28 and 8.33).

CONTEXT

In November 2002, doctors at First People's Hospital in Foshan City's Shunde District were unable to save the life of a farmer admitted with a fever and cough. Just days later the doctors reported an alarming strain of pneumonia. This seemingly isolated episode foreshadowed what rapidly emerged as a global outbreak of SARS (severe acute respiratory syndrome), responsible for the deaths of more than 900 people around the world and, for China, an economic loss of RMB300 billion ($47.4 billion).

The new First People's Hospital is a direct response to the deficiencies of hospital infrastructure revealed by the SARS outbreak. The design is the winning entry in an international design competition. It serves as an iconic beacon for a new planned urban community located in southeastern Guandong Province. And, importantly, it is an influential pilot of sustainable methods and materials for China's next generation of hospitals. It is specifically designed to curtail the spread of infections, with the ability to close off and quarantine discrete sections of the buildings. It includes bioregional and cultural references, honoring Shunde's rich heritage both as a center of terracotta manufacture and the "City of Water": The new hospital features locally manufactured terracotta cladding, while a historic network of canals inspire prominent water features throughout the campus as part of its stormwater management system.

SITE AND BUILDING

The 33-acre (13 ha) greenfield parcel is the site of one of the first substantial buildings in the new city, linked by an extensive public transit system to respond to patient and staff commuting needs. The campus' slender rectilinear buildings, laid out in a simple grid to reduce building footprint while responding to daylight and ventilation, are organized in four zones—inpatient, outpatient, support, and staff (Figure 8.30).

A major site planning achievement is the retention of open space even with the large program: 75 percent of the site will remain as open space, with 40 percent vegetated, exceeding zoning requirements by 50 percent. The campus' extensive vegetation, including vertical and horizontal gardens, a private healing garden, "sky" garden and green terraces, are physically and visually accessible to patients and staff and artfully integrate nature throughout the enormous campus.

The buildings' optimal orientation and massing along an east-west axis supports the introduction of low carbon strategies appropriate for this hot humid climate (Figure 8.34). Overall, building energy performance is anticipated to be 60 percent better than local code minimum. Strategies contributing to the dramatic energy reduction include daylighting of spaces regularly occupied by patients and staff; a comprehensive dehumidification scheme achieved through an integrated approach of natural ventilation, stack effect and chilled beams; and a natural/mechanical ventilation mixed mode approach throughout inpatient bed floors. Operable windows in patient rooms along the double-loaded corridor are able to naturally ventilate the unit; this is made possible with a flexibly designed forced air system, zoned per floor, and calibrated to individually controlled VAV boxes in each room. The heart of the campus is the prominent naturally ventilated and passively conditioned indoor/outdoor "eco-atrium" that

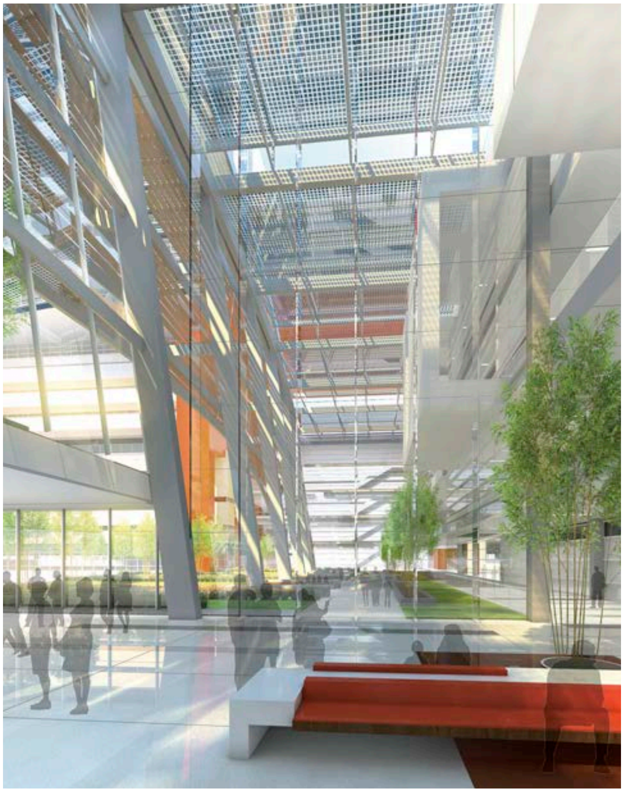


Figure 8.29 Eco-atrium view. *Source: MC Architects*

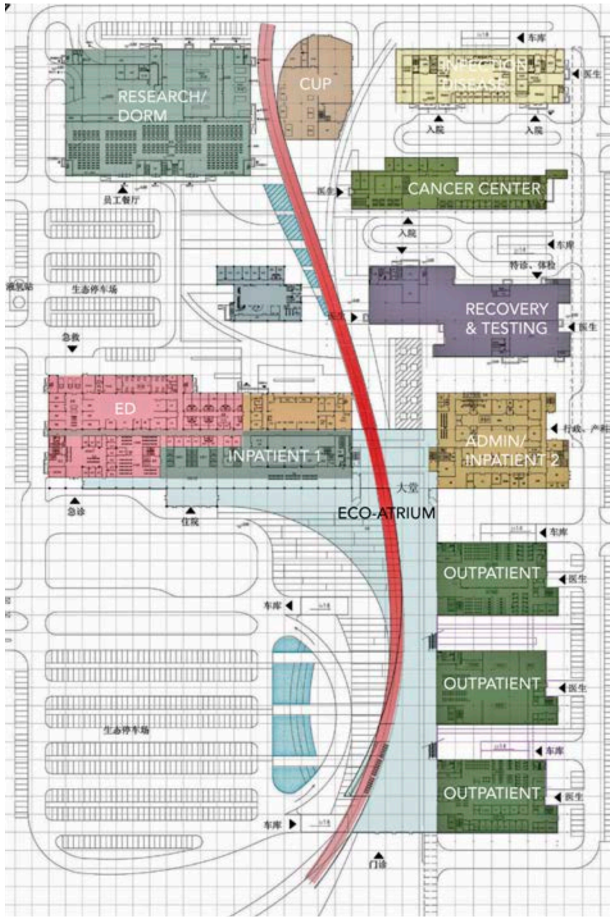


Figure 8.30 Ground floor plan. *Source: HMC Architects*

functions as the visitors' waiting area, with registration functions conveniently clustered with food services and retail facilities (Figure 8.31). It also serves as the central connecting hub for the spine that interconnects facilities throughout the campus. The eco-atrium's terracotta wall surface blends historic relevance with climatic design efficacy, functioning as both sunscreen and thermal mass, reducing heat gain during daytime hours and releasing absorbed heat at night.

More broadly, the building facades are integral to the project's energy strategy, with specific design approaches responding to varying solar exposures (Figure 8.32). The balcony system reduces solar and heat exposure to patient rooms with southern exposure while also providing views to the garden. The curtain wall on the north facade maximizes indirect sunlight and views to the outdoors; the light shelf curtain wall on the south facade provides controlled shading and enables daylight to penetrate deep into the room.

A 161,500 sq. ft. (15,000 sq. m) photovoltaic system generates 1,500 MWh of electricity, integrated into the south facade's shading screen, skylight, and roofing system. The screening is multifunctional as it generates electricity, filters sunlight, and also provides transparency to maintain views to the outdoors. In addition, glass solar fins on the north facade and solid solar fins on the roof trellis add to the project's substantial on-site renewable energy generation.

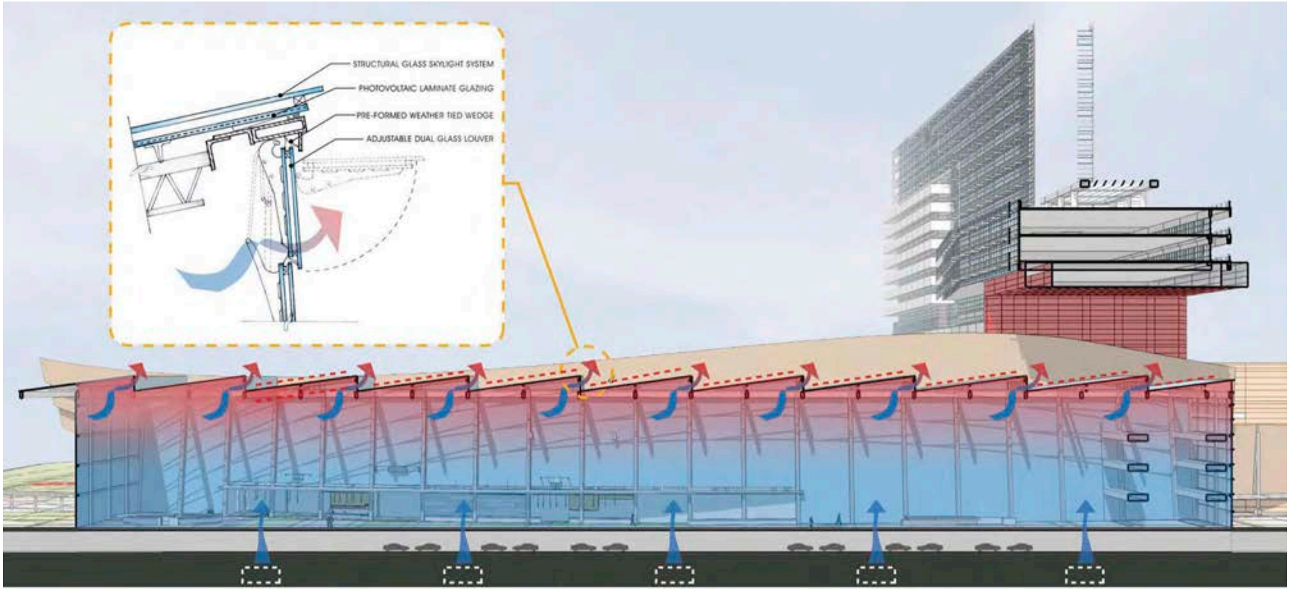


Figure 8.31 Eco-atrium section. *Source: HMC Architects*

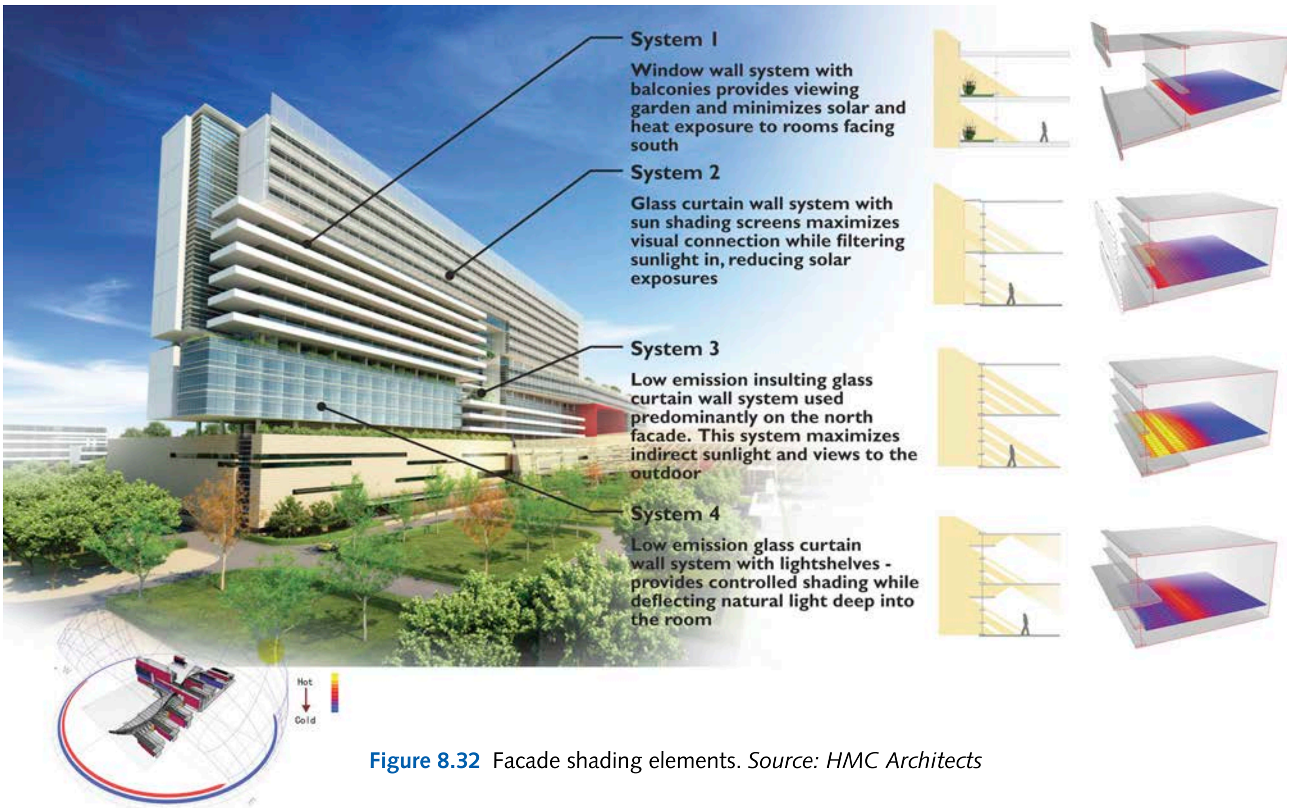


Figure 8.32 Facade shading elements. *Source: HMC Architects*

Figure 8.33 Entry court. *Source: HMC Architects*

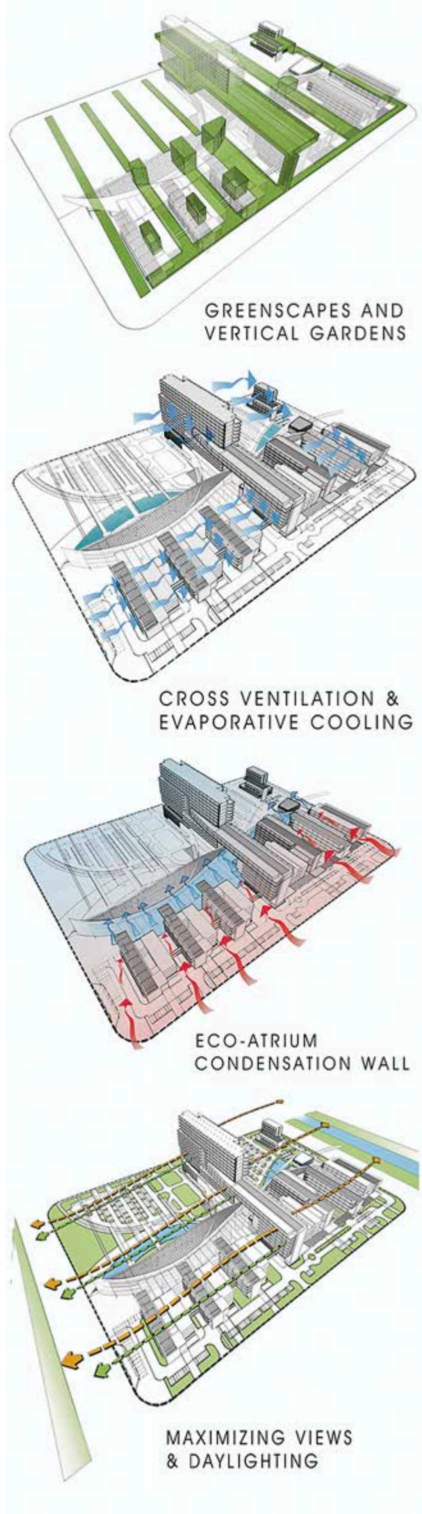


Figure 8.34 Site design and natural system flows. *Source: HMC Architects*

The hospital's water cycle balances on-site sources, uses and reuses, with water features and rainwater cisterns designed as aesthetic amenities. Reclaimed water sources, including collected rainwater and filtered and treated collected gray- and blackwater, fulfills an estimated 25 percent of potable water use. The campus' extensive landscape is planted with native species and is irrigated with collected rainwater. A green infrastructure system manages stormwater on-site relying on bio-retention swales.

Underscoring the high-performance building strategies is an unwavering commitment to create a culturally relevant healing environment, blending traditional Chinese practices with advanced western approaches. Just as the building is integral to its energy performance, it also is an essential element of the healing experience. Daylight and views, abundant indoor and outdoor landscaped areas, operable windows, and a zoned approach to acoustical control are hallmarks of a timely and innovative platform to steer the next generation of China's hospital design, construction and operations along a coherent path that advances environmental stewardship and promotes human health.

Source: HMC Architects

Case Study 25: Hospital Universitario San Vincente de Paul

Rionegro, Colombia

OWNER: Hospital Universitario San Vicente de Paul, Sede Rio Negro, Medellin, Colombia

PROJECT TEAM:

Architects: Condiseño SA with Perkins+Will

Mechanical Engineers: José Tobar y Cïa Ltda with TLC Engineering for Architecture

Civil Engineers: Mario D'Amato with Miller Legg

Contractor: Ingenieria Estructural SA

Bioclimatic Consultant: Jose Dario Franco

TYPE: New Regional Acute-Care Hospital and Clinics

SIZE: 726,564 sq. ft. (67,500 sq. m); Site area: 26.7 acres (10.8 ha)

EUI: 54 kBtu/sq. ft./yr (171.5 kWh/sq. m/yr)

PROGRAM DESCRIPTION: 260-bed acute-care hospital and ambulatory center, including Oncology, Surgical, Imaging, Intensive Care, Emergency Care, Women's Clinic, Pediatric Clinic, Outpatient Day Hospital facilities, Rehab Clinic, Cancer Clinic, Digestive Clinic, Plastic Surgery Clinic

COMPLETED: 2011

RECOGNITION: LEED® Certified-Silver, first LEED certified hospital in South America

BIOME: Tropical Humid

CLIMATE ZONE: Tropical Savanna

PRECIPITATION: 70–98 in. (1,800–2,500 mm)

KEY SUSTAINABILITY INDICATORS

- *Habitat Restoration*: 79% of site area restored using native and/or adaptive planting; 67% open space
- *Innovative Stormwater Management*: Stormwater structures and bioswales filter and remove pollutants
- *Innovative Parking*: Pervious grass-block paving
- *Energy Responsive Facade*: Fixed solar shading reduces direct solar heat gain on facade
- *Narrow Floor Plate:* Nursing units are naturally ventilated and daylit
- *Rainwater Harvesting*: Rainwater stored in retention pond for (limited) irrigation and wastewater systems
- *Innovative On-site Wastewater Treatment:* 100% wastewater treated on site to tertiary standards; provides water for toilet flushing
- *Reclaimed Water Reuse*: Blackwater toilet flushing
- *Natural Ventilation:* 70% of building area is naturally ventilated and passively cooled
- *Renewable Energy*: Solar thermal provides 100% of daytime domestic water heating requirements
- *Public Function*: Community chapel integrated in site planning

Figure 8.35 Hospital Universitario San Vincente de Paul. *Source: Condiseño SA*

This building demonstrates that regionally scaled academic acute-care delivery can be accomplished with low resource use. Located in a rapidly developing region of Colombia, it takes advantage of its equatorial location and mild climate to focus on passive and natural systems coupled with innovative water management (Figures 8.35 and 8.39).

CONTEXT

Located near the Equator at an average elevation of 6,970 ft. (2,125 m) above sea level, Ciudad Santiago de Arma de Rionegro, Colombia (aka Rionegro; population 101,000) is named for the Negro River, the city's most prominent geographical feature. A tributary of the river defines one of the site's boundaries; the site itself is part of the alluvial plain of the Negro River and its tributaries. The region's electrical grid is dominated by large- and small-scale hydroelectric generation. Rionegro is strategically positioned in eastern Antioquia, and is experiencing dramatic growth based on both industry and trade. Temperatures are steady year round, with lows of 66°F (19°C) and highs of 79°F (26°C).

This full-service acute-care hospital represents an important milestone in the region's development. Strongly influenced by U.S. trends in patient care and hospital design—including single bed, same handed rooms, independent clinical identities with retail functions, and intuitive wayfinding—it is designed to meet regional healthcare needs of the growing Medellin-Rionegro region.

SITE AND BUILDING

Site planning placed the hospital building close to the highway entrance to reduce the impacted site area. The seven- to nine-story building limits the developed area of the site and reduces impervious roof area, while green roofs between patient wings further reduce stormwater intensity and provide a patient amenity (Figure 8.37). Stormwater management is achieved through limiting the use of paved areas, prioritizing open-grid paving systems, using native vegetation and landscape and dedicated stormwater structures (Stormceptor®) to filter high volumes of rainwater before it reaches the creek system at the site boundary (Figure 8.38).

The project blends naturally ventilated areas with mechanically conditioned diagnostic and treatment functions, such as ORs and diagnostic imaging. Approximately 70 percent of the building gross area is naturally ventilated—including labs, administrative areas, and public/family zones; hot water is produced using 60 solar thermal panels and stored in two tanks with a capacity of 4,491 gal (17,000 L). Only 2 percent of annual electricity use is required for space cooling; 4 percent of thermal energy for space heating. Electric lighting (42 percent) and equipment plug load (38 percent) are the dominant electrical uses. The balance of thermal energy is used to supplement the solar hot water heating.

With no municipal sewage treatment facilities to support it, the hospital includes an innovative on-site wastewater treatment plant that treats water to tertiary standards, used for toilet flushing and before final discharge to the creek. Rainwater harvesting ensures that limited irrigation needs can be met without relying on potable water sources and provides supplemental water for the sewage treatment facility. Low-flow fixtures reduce dependence on potable water resources.

Taken together, these strategies create an inherently resilient, low-energy medical campus and demonstrate the power of a bio-climatically responsive system solution. The building is firmly "of its place."

Sources: Condiseño SA and Perkins+Will

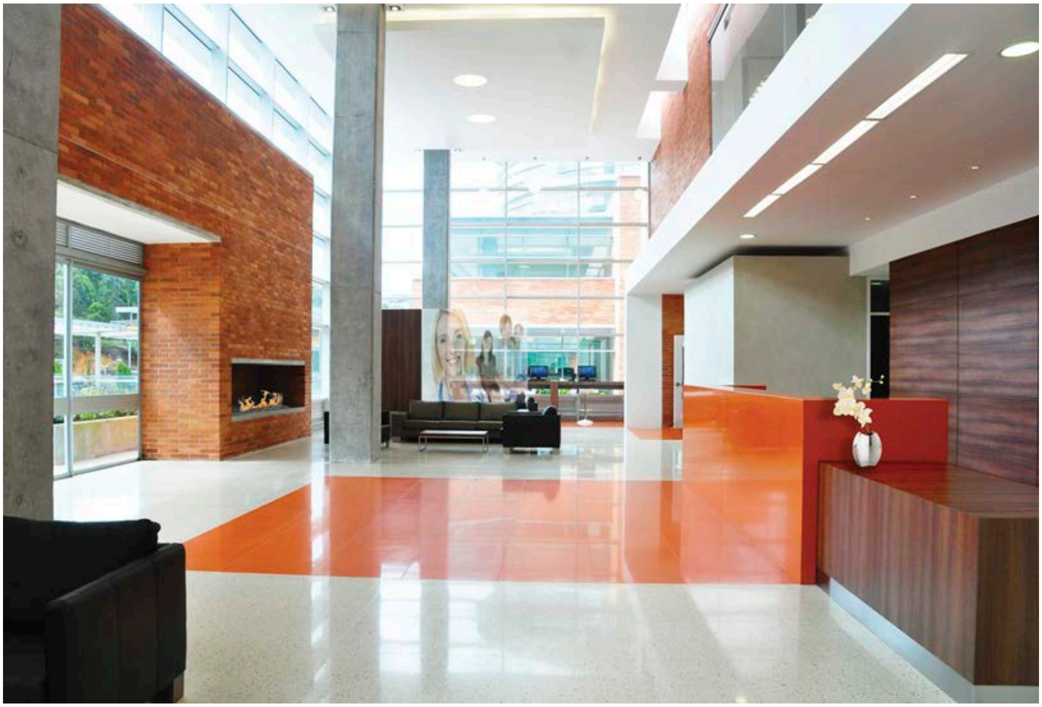


Figure 8.36 Lobby at entrance. *Source: Perkins+Will*

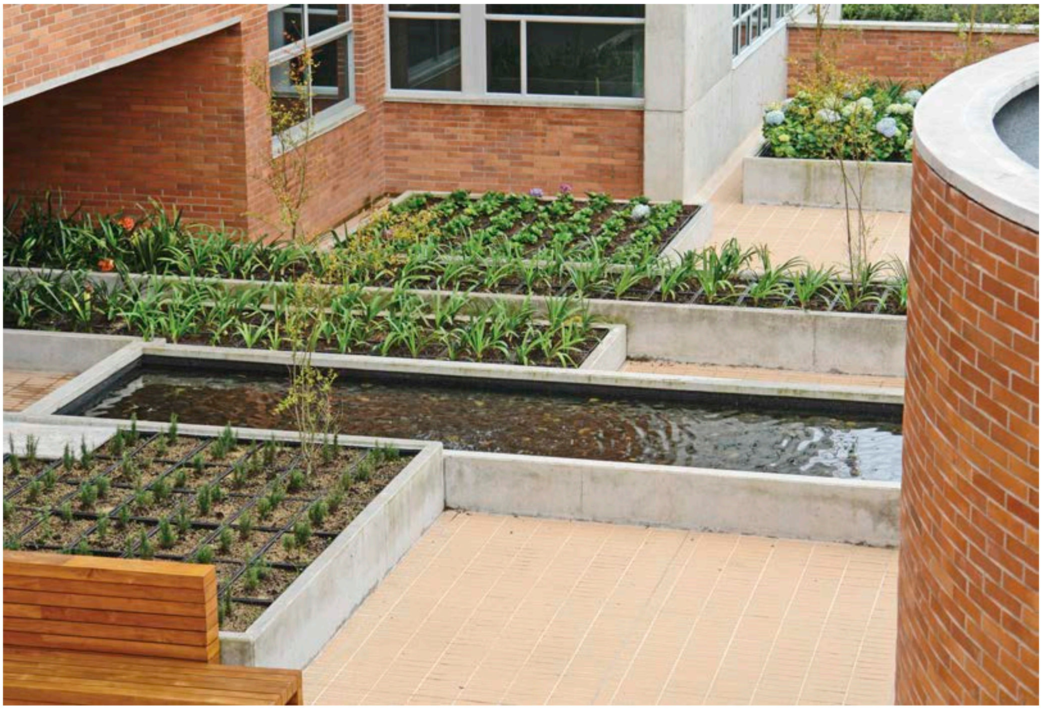


Figure 8.37 Roof gardens and outdoor water features. *Source: Perkins+Will*

Figure 8.38 Permeable paving systems at parking areas. *Source: Condiseño SA*

Figure 8.39 Site plan indicating future expansion location. *Source: Perkins+Will*

Case Study 26: Khoo Teck Puat Hospital

The Republic of Singapore

OWNER: Ministry of Health, Singapore

PROJECT TEAM:

Architect: CPG Consultants Pte Ltd.

Design Consultant: RMJM Hillier

Structural and MEP Engineering: CPG Consultants Pte Ltd.

Green Consultant: Total Building Performance Team

Contractor: Hyundai Engineering and Construction Co. Ltd.

TYPE: New Acute-Care Regional Medical City

SIZE: 1,169,780 sq. ft. (108,676 sq. m); 8.4 acres (3.4 ha)

PROGRAM DESCRIPTION: 556 beds (acute hospital), primary care (specialist outpatient clinics and day surgery), and emergency department with a 107,600 sq. ft. (10,000 sq. m) underground disaster-preparedness facility

EUI: 87.2 kBtu/sf/yr (275 kWh/sm/yr) (projected)

COMPLETED: 2010

RECOGNITION: Winner World Health Design Competition 2011; First Prize in Skyrise Greenery Award 2010; Green Mark Platinum Award 2009

BIOME: Tropical Humid

CLIMATE ZONE: Tropical Savanna

PRECIPITATION: 100 in. (2,540 mm)

Figure 8.40 Khoo Teck Puat Hospital. *Source: CPG Consultants Pte Ltd.*

KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management*: Restored Yishun Pond (a municipal stormwater retention basin)
- *Climatic Design*: Facade design responds to orientation; external shading; courtyards
- *Energy Responsive Facade*: High-performance glass curtain wall with "low-emissivity" coatings to reduce heat gain
- *Rainwater Harvesting*: Rainwater is channeled to Yishun Pond; water is withdrawn for the hospital's irrigation system
- *Reclaimed Water Reuse*: Hospital uses NeWater (municipal reclaimed water system) for cooling tower makeup water
- *Innovative Source Energy*: Gas-powered combined cooling, heating, and power plant (CHP)
- *Natural Ventilation*: 35% of building naturally ventilated
- *On-site Renewable Energy*: Solar vacuum tubes generate 100% domestic hot water; Solar PV supplements grid energy with renewably sourced energy—150,000 kWh annually
- *Healthy Materials*: Building materials certified under the Singapore Green Labeling Scheme
- *Resilience*: Large underground pandemic and disaster-preparedness facility as well as civil defense shelter

Khoo Teck Puat Hospital (KTPH) is the first of a new generation of Singapore hospitals to seek a bioregionally appropriate, low-resource-use solution for large-scale hospital facilities. The integration of nature, gardens, and food production is a defining characteristic that supports habitat restoration and improved biodiversity. Through its focus on health promotion, it sets a new standard for both the quality of inpatient care and sustainable design (Figure 8.40).

CONTEXT

Khoo Teck Puat Hospital (formerly known as Alexandra Hospital at Yishun) is the region's leading healthcare institution and plays a major role in emergency and infectious disease management. Singapore's experience with the SARS epidemic in 2003 and the tsunami in 2004 challenged the government to develop new high-tech facilities capable of handling increasingly complex scenarios. The hospital incorporates a large underground disaster-preparedness facility (Day Surgery in nonemergency periods) and a civil defense shelter (parking garage). Rising energy costs, meanwhile, have driven a focus on efficiency.

It also represents an emerging focus on health promotion—an approach to the design of public hospitals demonstrating the beneficial effects architecture can have on the psychological well-being of patients. Commercial venues focused on health products are located in the hospital to promote health awareness. KTPH attracts the local population to listen to public lectures, view exhibitions and participate in health education programs. This landmark development brings out the best of its unique legacy—"a hospital in a garden, a garden in a hospital." The opportunity created by the brief and the site next to Yishun Pond results in a design in which nature nurtures—where patient recovery and general well-being are enhanced.

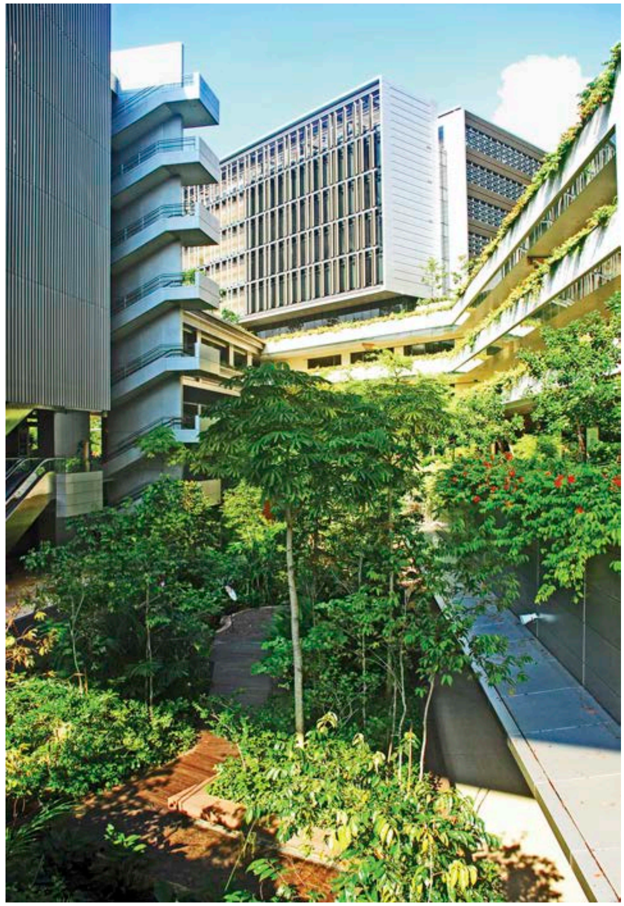


Figure 8.41 Central courtyard garden from linkbridge.
Source: CPG Consultants Pte Ltd.

SITE AND BUILDING

The complex consists of a 4-story podium, a 6-story tower for Specialist Outpatient Clinics, an 8-story Private Ward Tower, and a 10-story Subsidized Ward Tower. The building scale was deliberately kept low to relate to the surrounding community; fragmenting the functional blocks creates a more residential scale.

The hospital's distinctive modern aesthetic, featuring different facade designs for the three blocks, represents innovative approaches to solar control and natural ventilation design. Planting terraces, green

Figure 8.42 Rooftop vegetable garden.
Source: CPG Consultants Pte Ltd.

roofs, trellises, and louvered screens support a resort-like appearance and bring nature deep within the campus.

A key feature is the numerous distinctive garden settings (Figure 8.41). All buildings overlook a central garden courtyard at the Basement and Ground levels—the "heart" of the hospital serves as an important wayfinding device and opens out toward the adjacent Yishun Pond. Each of the eight roof gardens portrays interesting themes for both entertainment and education. For example, gardens at the Outpatient Clinics carry edible species, while citrus plants flourish at L4 podium and fruit-bearing trees are grown at eighth and tenth floor Inpatient Unit roofs. The herbs, fruits, and vegetables provide an organic food source for the hospital kitchen (Figure 8.42). Other roof gardens cater to specific clinical needs—geriatric, dementia.

One final highlight is the terraced gardens at the podium roof deck levels of the inpatient towers: Patients and guests can weave through terraced levels and discover private niches and trellised alcoves for reflective solace or enjoy the company of family and friends. These gardens also benefit from the cool air rejected from operating theaters. Outdoor water plants in shallow streams serve as primary filtration of captured rainwater.

Khoo Teck Puat is currently the most energy efficient operational hospital in Singapore. A combination of high-performance facade design, carefully engineered natural ventilation, and high-efficiency mechanical systems reduce energy demand by an estimated 30 percent relative to a minimally code compliant Singapore baseline hospital. Renewable energy sources reduce the reliance on fossil fuels, with associated decrease in greenhouse gas emissions.

The facade is designed to optimize daylight while controlling solar gain. Operable, modular jalousie windows facilitate controlled/enhanced air flow contingent on external climatic factors into the subsidized patient units (Figures 8.43 and 8.44). These jalousies are angled at 15° for the best airflow and least rain penetration. Gray tinted glass reduces glare. Fixed louvers called "monsoon louvers" are integrated in the facade at the patient bed height to provide minimum air exchange even during heavy rains. Sunshades over the windows protect patients from direct glare and act as light shelves that re-direct the light toward the ceiling to enhance the brightness of the rooms and reduce energy use. In the private inpatient units, fixed screens are incorporated in the facade to modulate direct sunlight and glare. These screens are angled to maximize views and provide maximum shading. Appropriate glazing with high visible light transmittance value and a high cooling index is selected.

In response to the tropical climate, natural ventilation is optimized in the eleven 32-bed subsidized wards as the key to patient comfort. These wards contain 352 beds in a combination of five 5-bed and six 10-bed ward units and 22 isolation rooms. Thirty-five percent of the building is designed for optimal natural ventilation, reducing the requirement for mechanical ventilation in those areas by up to 60 percent and hence reducing energy consumption. By orienting the ward tower to "capture" the prevailing northerly and southeasterly winds, an optimal wind speed of at least 1.98 ft./s (0.6 m/s) is achieved through natural means, providing adequate thermal comfort for the patients.

A 142-bed private ward tower includes mechanical cooling for a combination of private rooms and 4-bed accommodation. Operable windows are provided to give the patients the option for natural ventilation. The room's mechanical air conditioning unit automatically cuts off when windows are opened for natural ventilation. Ceiling fans in all private bed wards further improve air circulation. Fan coil cooling units are provided for individual control and operational flexibility; they can be switched off for the natural ventilation option or during periods of nonoccupancy.

Figure 8.43 Private patient ward facade. *Source: CPG Consultants Pte Ltd.*

Figure 8.44 Subsidized patient unit ward facade. *Source: CPG Consultants Pte Ltd.*

Figure 8.45 Daylit rooms designed for comfort. *Source: CPG Consultants Pte Ltd.*

Figure 8.46 View of subsidized ward patient room. *Source: CPG Consultants Pte Ltd.*

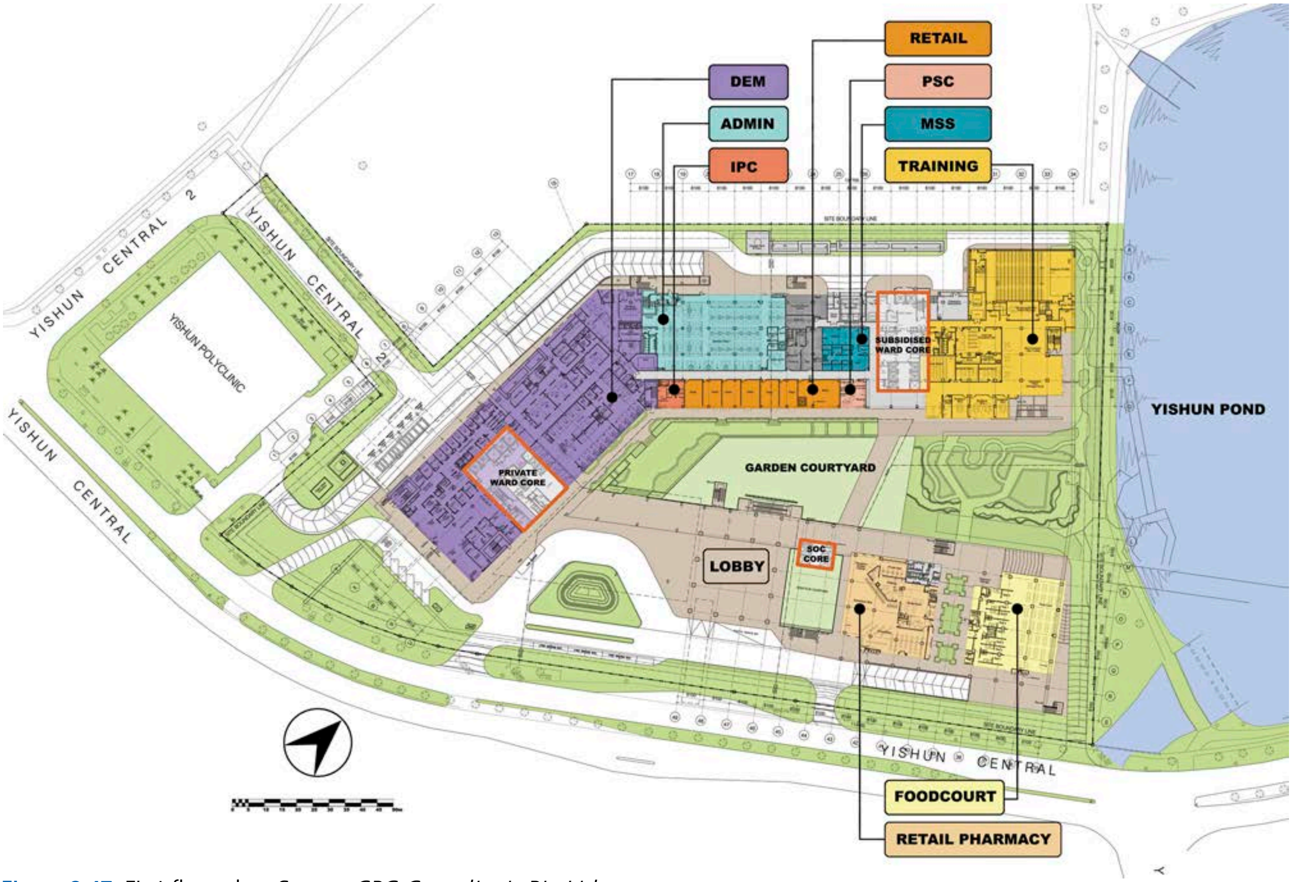


Figure 8.47 First floor plan. *Source: CPG Consultants Pte Ltd.*

For diagnostic and emergency areas that require mechanically controlled environments, equipment is carefully sized and selected to cater specifically to the cooling load and profile requirements of the specific uses. Variable drives and setback controls allow the building to modulate performance to volumes.

The hospital utilizes solar vacuum tubes to produce hot water. The solar thermal system coupled with solar heat pumps generates all of the hospital's hot water—about 5,500 gal (21,000 L) per day—resulting in an operational savings of approximately 781 kWh/day of electricity, and the capital cost savings associated with the cost and space of hot water boilers. KTPH includes a 13,735 sq. ft. (1,276 sq. m) photovoltaic system to offset a portion of grid-supplied electricity with clean energy sources and to educate the public on environmental sustainability.

In 2009, Khoo Teck Puat Hospital was awarded a Green Mark Platinum rating, the highest level of certification granted by the Building and Construction Authority (BCA) Green Mark, the Singapore government's sustainable building benchmark. It has influenced the next generation of hospital buildings in Singapore and the greater southeast Asia region.

Source: CPG Consultants Pte Ltd.

Case Study 27: Portadown Health and Care Centre

Portadown, Northern Ireland

OWNER: Southern Health & Social Care Trust

PROJECT TEAM:

Architects: Avanti Architects with Kennedy Fitzgerald & Associates

Mechanical and Electrical Engineers: Cundall/ Taylor & Fegan

Structural Engineer: RPS Consultants

Landscape Architect: Soltys Brewster Consulting

Contractor: H&J Martin, Belfast

TYPE: New Community Ambulatory Care Center

SIZE: 66,198 sq. ft. (6,150 sq. m)

EUI: 48 kBtu/sf/yr (153 kWh/sm/yr)

COMPLETED: 2010

PROGRAM DESCRIPTION: A multidisciplinary base for primary and community care services including General Practitioners, Health Visitors, Social Services, Nurses, O.T.s, Physiotherapists, Speech and Language Therapists, Podiatrists, Visiting Specialists, Orthopedists, and Family Planning

RECOGNITION: Winner: Building Better Healthcare Awards—Future Concept Award 2006; Highly Commended Sustainable Design: International Design and Health Awards 2011; NEAT Design Stage Assessment: "Excellent"

BIOME: Temperate Humid

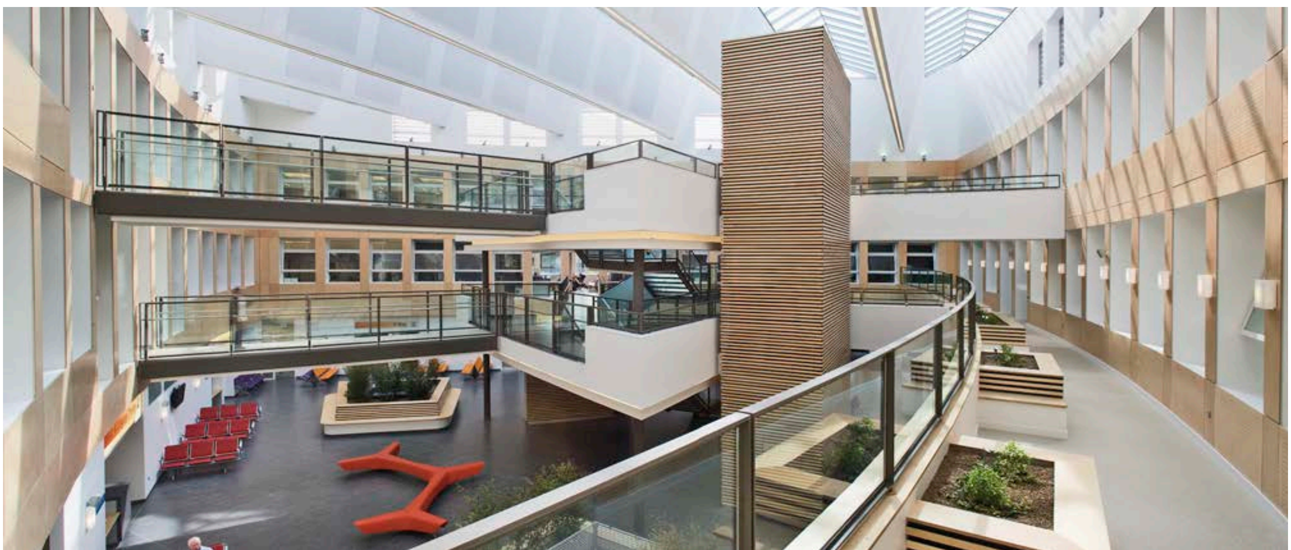
CLIMATE ZONE: Marine West Coast

PRECIPITATION: 29 in. (750 mm)

Figure 8.48 Portadown Health and Care Centre. *Source: Copyright © Paul Tierney Photographer*

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia*: Siting prioritizes views of river and landscape
- *Innovative Parking:* Staff parking below building and atrium
- *Energy Responsive Facade:* Atrium provides passively conditioned temperate space to reduce exposed facades; operable windows specifically designed for natural ventilation
- *Innovative Source Energy*: Ground source heat pump system for atrium conditioning; with wells located under surface parking lot; thermal labyrinth preconditions atrium ventilation air
- *Innovative Energy Distribution*: Hydronic heating
- *Natural Ventilation:* Operable windows in medical practice areas and atrium; night flush cooling equipped
- *Renewable Energy:* Biomass boiler
- *Healthy Materials:* Materials selected using Environmental Profiles Methodology 2008 and Green Guide to Specification
- *Civic Function:* Community services on-site
- *Adaptability:* Forecourt accommodates mobile specialist care unit
- *Acoustics:* Atrium space has acoustic absorbing panels (plasterboard and perforated birch plywood)



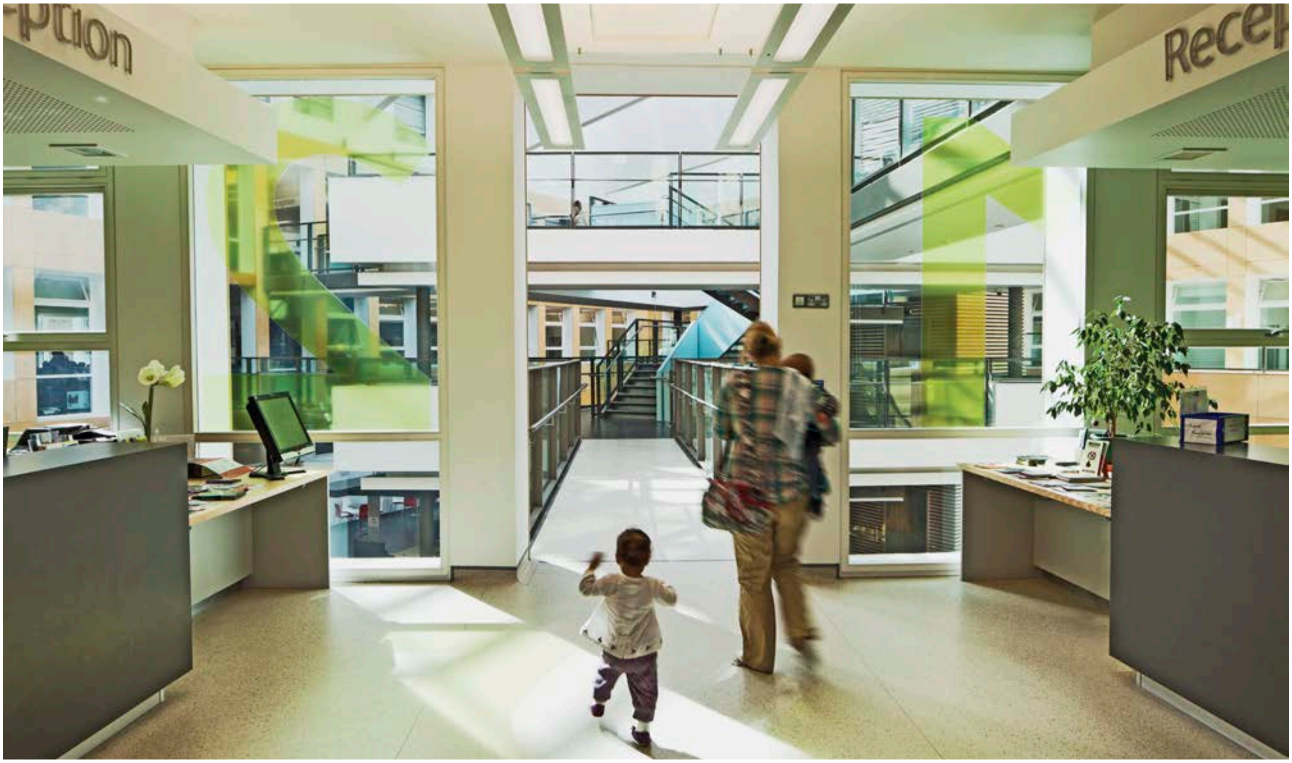


Figure 8.49 Second floor reception toward atrium. *Source: Avanti Architects*

As one of a new generation of the UK National Health Service's community based facilities that aggregate broad community services alongside primary healthcare, Portadown Health and Care Centre demonstrates a unique approach to innovative passive system strategies in order to reduce energy demand while creating a comfortable, destination civic building. It redefines the large atrium from being an energy intensive design feature to become part of an overall energy demand reduction strategy (Figure 8.48).

CONTEXT

The Southern Health & Social Care Trust set out to provide a new building, capable of providing for both their current and future needs and reducing demand on Craigavon Acute Hospital. The provision of community services as well as primary healthcare facilities make Portadown Health and Care Centre a community focal point—the building includes a pharmacy, Citizen's Advice Bureau and a drop-in cafe. With an increasing elderly population, convenient delivery of a range of primary and home-based healthcare services becomes essential infrastructure for maintaining independent living.

The building is intended to act as a local landmark but is modest and approachable in appearance. The triangular form is derived from the physical context—it responds directly to its site on the curving Meadow Lane and the gentle curves reduce the apparent size when seen in perspective. On the boundary between the town and the river, the building is designed to be viewed both from close up and from a distance.

The large forecourt provides a new public space that terminates Clonavon Avenue. This space has views across the river meadows and makes a connection between the town center and the River Bann, a link that enhances a specific sense of place and identity. Space is provided on the forecourt to bring in a mobile medical unit, which can be plugged into the building to facilitate specialist clinics. To lessen the impact of the Centre's requirement for extensive car parking, staff car parking is located under the building. The public surface parking is generously landscaped.

SITE AND BUILDING

With a capacity of up to 30 practitioners, Portadown is a compact triangular building with a triangular atrium space at the center to reduce the apparent scale of the building and improve navigation and traffic flows within and around it. The arrangement also allows for the size and number of departments to be changed in the future, both by re-planning the perimeter accommodation and by relocating the bridges, two of which on each floor are movable. Internally, the building is dynamic, able to respond to ever-changing patient needs and functionally fit for purpose. This arrangement provides easy public access to many separate departments without the need to use corridors or to pass by one department to reach another (Figures 8.49, 852, and 8.53).

The detailed design and integration of the building's structure and services provide a high degree of flexibility and create an energy efficient, sustainable facility. Detailed daylight, natural ventilation, and thermal modeling were used to develop the environmental strategy.

Mechanical ventilation has been designed out of the project where possible and is retained only where there is a clinical imperative for its use. The great majority of examination, office, service, and waiting rooms in the building are naturally ventilated. Multiple operable window configuration strategies were studied to determine the optimum ventilation approach. An exposed concrete slab ceiling in naturally ventilated rooms provides passive cooling. Automated upper operable window sections are controlled via the Building Management System, and are designed for daytime natural ventilation. The night purge ventilation is not used at present, but is a strategy that can be implemented in the future should the external environment change significantly. A 200kW biomass boiler (manufactured in Enniskillen) using wood pellets provides winter heating energy via integrated ceiling mounted radiant panels, fan convectors and radiators. This reduces reliance on natural gas.

The atrium has independent ventilation systems. Underfloor heating is supported by a ground source heat pump system with closed loop wells located under the surface parking lot. An underground thermal labyrinth beneath the underground parking provides fresh, tempered air to the atrium and to the naturally ventilated rooms overlooking the atrium. The labyrinth is constructed of two 164 ft. (50 m) long concrete tunnels in contact with the earth on three sides with integral baffles to increase air path and contact time between the fresh air and the labyrinth. Ventilation flow in the atrium is controlled by automatic high-level louvers around the edge of the atrium rooflight; the atrium is a key element of the night-flush cooling system (Figures 8.50 and 8.51).

Light levels in the atrium have also been carefully calculated to ensure that adequate daylighting is achieved in the rooms facing the atrium. The atrium rooflight is a particularly important feature of the design. In addition to its dramatic appearance from inside the building, access for cleaning and maintenance at roof level has been carefully integrated.

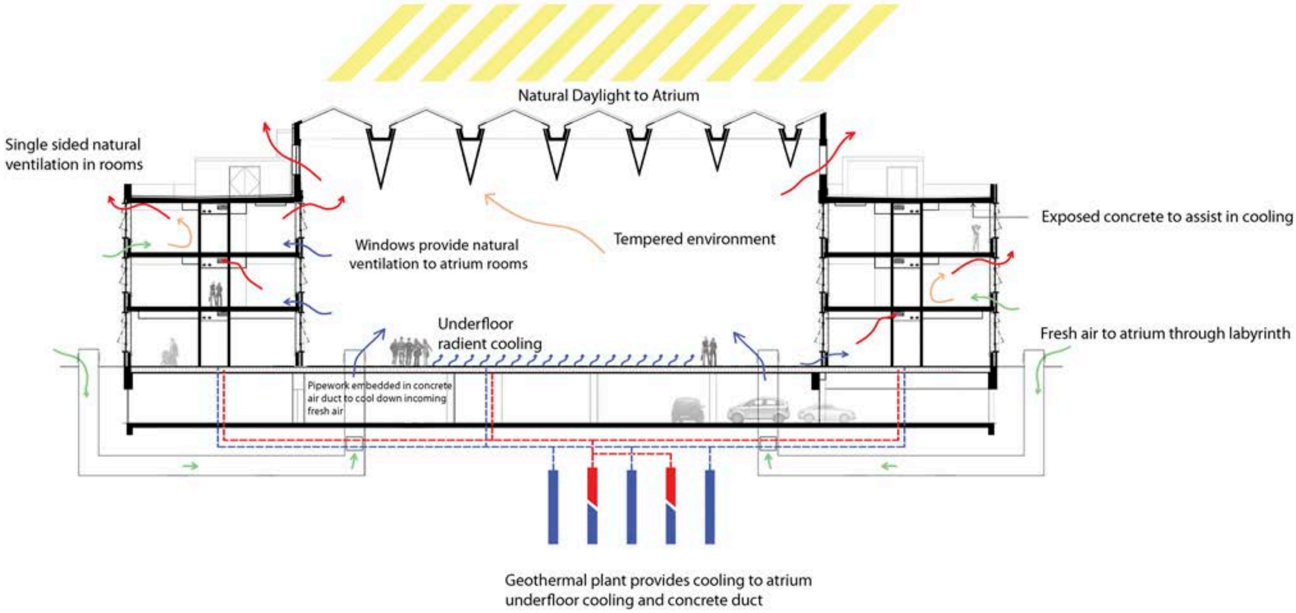


Figure 8.50 Building system diagram. *Source: Avanti Architects*

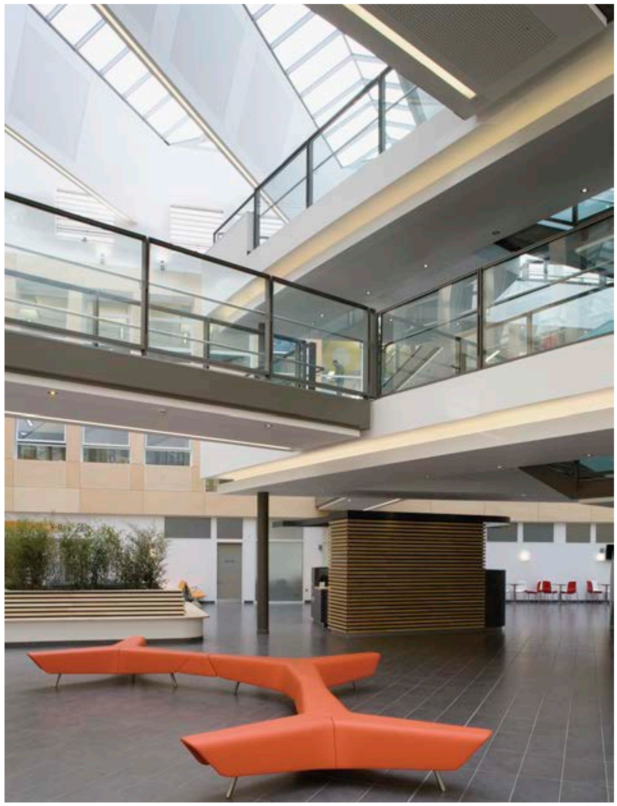


Figure 8.51 Atrium view from ground floor. *Source: Copyright © Paul Tierney Photographer*

With its many sustainable features—including a biomass boiler, ground source heat pumps, high-efficiency lighting, and thermal labyrinth—the building is expected to consume some 30 percent less energy than building regulation requirements and achieve a carbon performance of approximately 42 kg/year/sq. m.

The Green Guide to Specification was used to evaluate materials, which integrates the Environmental Profiles Methodology 2008 to assess impact using the thirteen categories of environmental damage. The Environmental Profiles Methodology is a standardized method of identifying and assessing the environmental effects associated with building materials over their life cycle—that is, their extraction, processing, use, and maintenance and their eventual disposal.

Source: Avanti Architects

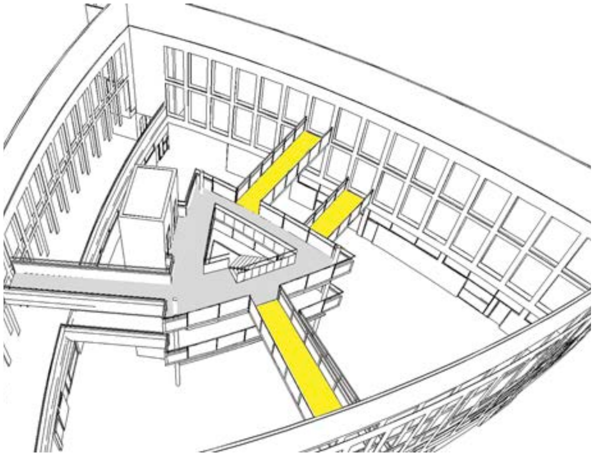


Figure 8.52 Atrium circulation, initial bridge locations.
Source: Avanti Architects

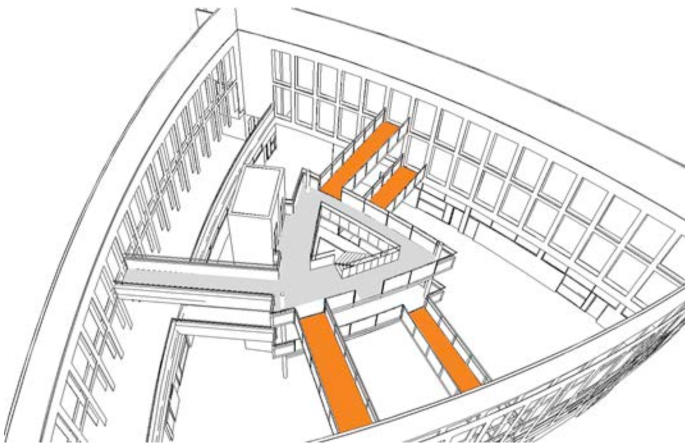


Figure 8.53 Atrium circulation, future bridge locations.
Source: Avanti Architects

Figure 8.54 Ground floor plan.
Source: Avanti Architects

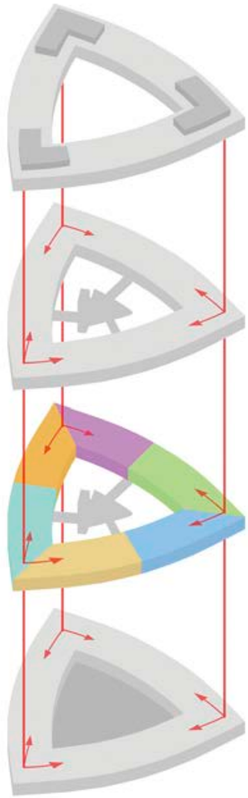


Figure 8.55 Mechanical services organized for vertical distribution.
Source: Avanti Architects

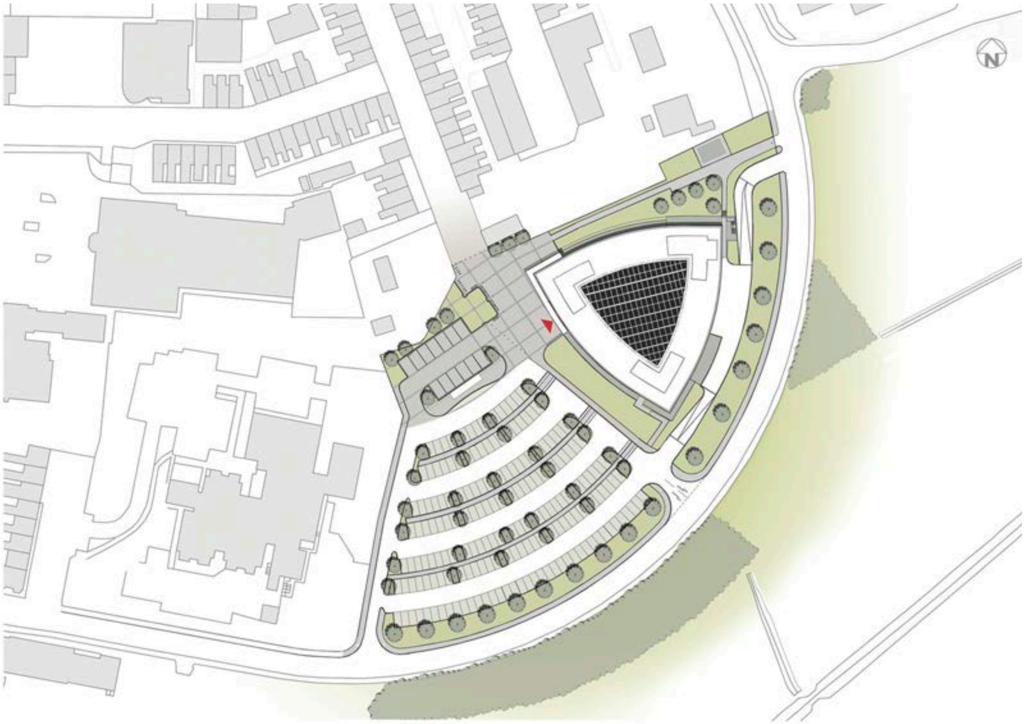


Figure 8.56 Site plan. *Source: Avanti Architects*

Figure 8.57 View from river. *Source: Copyright © Paul Tierney Photographer*

Case Study 28: REHAB Basel Centre for Spinal Cord and Brain Injuries

Basel, Switzerland

OWNER: REHAB Basel AG

PROJECT TEAM:

Architect: Herzog & de Meuron

Structural Engineer: Ingenieurgemeinschaft ARGE Pauli Frei Zachmann

Energy: Sulzer Energieconsulting Landscape: August Kunzel

Construction Manager: Hardegger Planung & Projekt management

TYPE: New Rehabilitation Hospital

SIZE: 246,386 sq. ft. (22,980 sq. m); Site: 6 acres (2.4 ha)

EUI: Not Available

PROGRAM DESCRIPTION: 92-bed private inpatient and outpatient spinal cord and brain injury rehabilitation clinic on a site that includes double and single patient rooms, a day clinic, exam and therapy rooms, a gym and swimming pool, and overnight accommodations for visitors

COMPLETED: 2002

BIOME: Boreal Humid

CLIMATE ZONE: Humid Continental, warm summer

PRECIPITATION: 30 in. (770 mm)

Figure 8.58 REHAB Basel Centre for Spinal Cord and Brain Injuries. *Source: Perry Gunther*

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Patient rooms located around the perimeter of the second story open to wood decks via sliding glass doors; wide decks accommodate rolling beds
- *Habitat Restoration:* Building sited to minimally disturb native landscape
- *Innovative Parking:* All parking on level under building
- *Narrow Floor Plate:* Series of 9 enclosed courtyards reduce apparent depth of large floor plates; skylights in patient rooms eliminate electric lighting needs in daytime
- *Energy Responsive Facade:* Combination of fixed and retractable solar shading reduces heat gain
- *Green Roof:* Intensive green roof, viewable from third-story conversation areas, filters rainwater and reduces heat gain
- *Innovative Energy Distribution*: Hydronic heating and no mechanical cooling (except at auditorium)
- *Natural Ventilation:* User-controlled passive ventilation through large, operable windows and sliding doors
- *Low Embodied Energy Materials:* Untreated oak, larch, ironwood, and waxed pine used for exterior cladding, *brise-soleils*, and interior wall and ceiling paneling; sealed oak floors throughout

REHAB Basel remains the most important healthcare building of the 21st century to date as a radical transformation of hospital typology. Through its extraordinary attention to connection to nature, daylighting, and patient experience, REHAB Basel fundamentally redefines healing environments as buildings built by people for people while remaining an efficient and effective environment for the rehabilitation of patients with traumatic brain injury and spinal cord injuries. It seamlessly integrates passive sustainable design strategies throughout, and through its careful sequencing of interior courtyards, transforms a seemingly deep floor plate building to a perforated, legible, easy to navigate, unforgettable experience (Figure 8.58).

CONTEXT

Located in northwest Switzerland where the French, German, and Swiss borders meet, REHAB Basel is a private facility for highly specialized treatment and rehabilitation of paraplegics and traumatic brain injury patients, drawing from both Switzerland and globally. Basel is Switzerland's second largest urban area, where temperature varies from a low of 29°F (–4°C) in winter to 76°F (24°C) in summer. There are approximately 121 days of rain or snow per year.

The private REHAB Basel blends into the residential scale of the suburban Basel neighborhood and prioritizes patient privacy. The building is low rise and organized with all beds on one floor to make it easier for patients in wheelchairs to get around; elevators connect all three stories. As a place where patients learn how to cope with life changes after a severe injury, the clinic functions as a treatment facility while fulfilling patients' diverse, long-term needs. In addition to the main building, the site includes extensive hippotherapy (including a stable) and running/exercise track.

Because patients may stay for as long as 18 months, the building is organized like a small town, connecting indoors and outdoors with separation between residential/private and social/public spaces. It is a multifunctional, diversified building with streets, plazas, gardens, public facilities, and more secluded residential quarters where people take different paths to move between destinations. Daylight permeates the building. Space is ample and flexible, with many nondedicated areas where patients can spend free time, linger between treatment sessions, or meet family and friends.

SITE AND BUILDING

The complex is conceived from inside out: instead of an arrangement of structures, courtyards are placed in a large rectangle. They serve as orientation and allow daylight to penetrate the entire interior. One enters the complex through an outdoor space. From the main lobby, various inner courtyards provide orientation: one is filled with water, another is clad entirely in wood, and the therapeutic pool ("bathhouse") is placed in a third. Patient rooms are focused on large windowpanes and views of the landscape, with a seamless transition between inside and outside. Other rooms, however, are entirely inwards in orientation; the most obvious example is the bathhouse, placed in one of the central courtyards like an erratic block wrapped in black rubber (Figures 8.61 and 8.62). From the roof conversation areas, one can look back into the city or out into the expanses of the Alsace.

The architects emphasized noninstitutional ambiance created by materials in an untreated state. REHAB Basel is an open, permeable, breathing building. Wood of different kinds and uses is the predominant material on the facades and inside. It recalls pavilion or garden architecture. A continuous covered deck links patient rooms arrayed on the 100,000 sq. ft. (9,290 sq. m) second floor, deep enough to accommodate a patient bed. This deck provides continuous shading

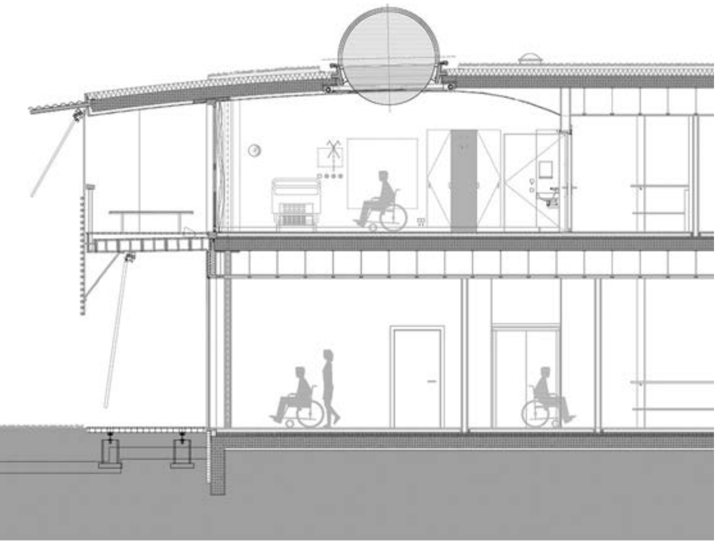


Figure 8.59 Section through patient room. *Source: Copyright © Herzog & de Meuron*

for the first floor glazing below, and creates an intermediate zone between the interior and the outdoors. A large, 6′-6″ (2 m) diameter skylight in each patient room eliminates the need for electric lighting in the daytime, while every occupied space includes operable windows and views (Figures 8.59–8.68).

To meet the Swiss energy code's high standards, the building capitalizes on savings achieved through passive solar techniques and natural ventilation. The vegetated roof minimizes heat gain, while fixed *brise-soleils* and retractable awnings provide control of light and heat through windows and courtyards. Retractable roofs can be extended across some courtyards, but are rarely engaged. There is no air conditioning except at the auditorium/conference center.

Source: Herzog & de Meuron Architects

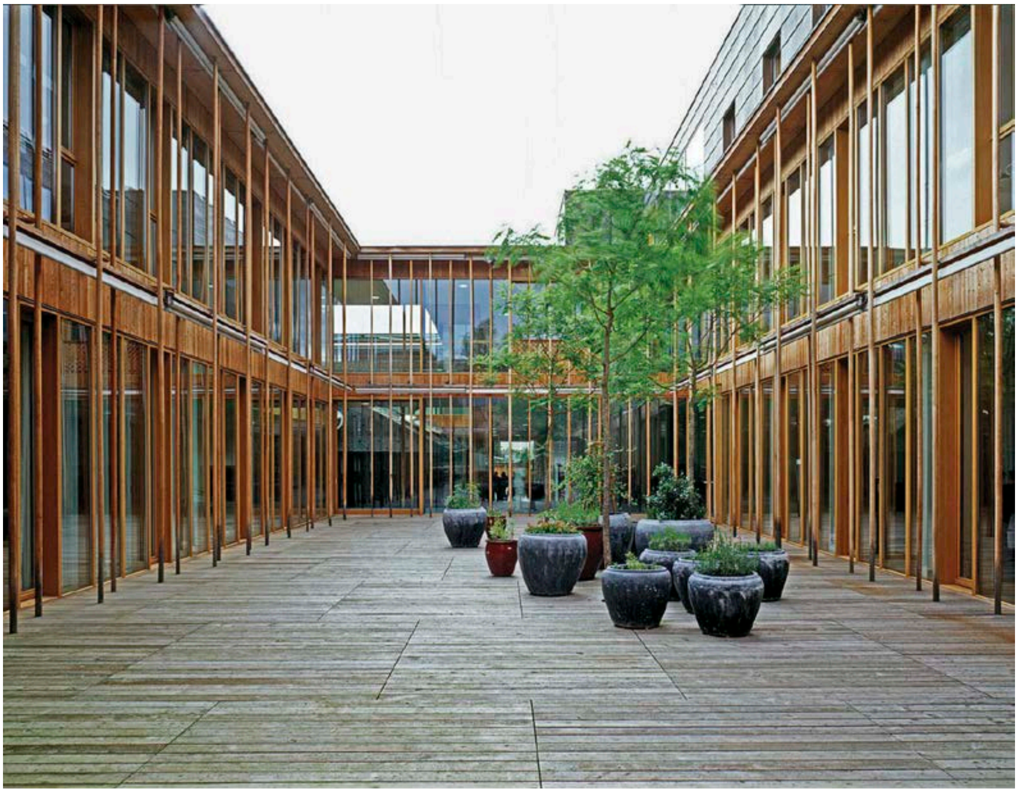


Figure 8.60 Courtyard with rocks. *Source: Copyright © Marguerita Spillutini*

Figure 8.61 Bathhouse roof in courtyard. *Source: Perry Gunther*

Figure 8.62 Bathhouse interior. *Source: Perry Gunther*

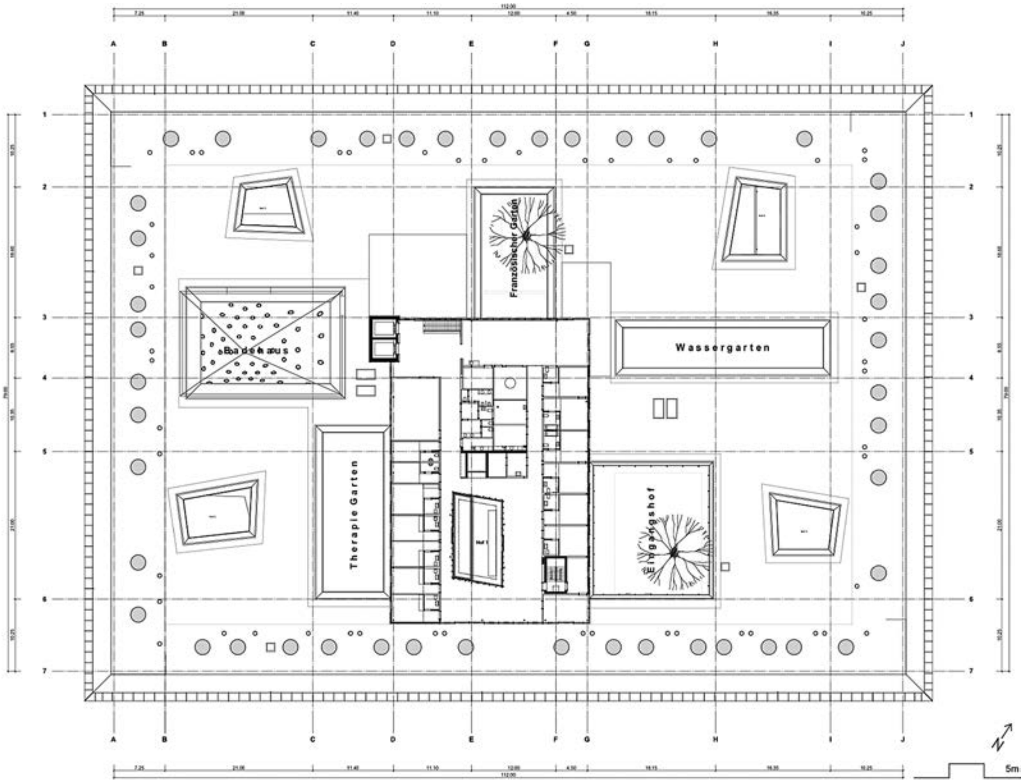


Figure 8.63 Roof plan. *Source: Copyright © Herzog & de Meuron*

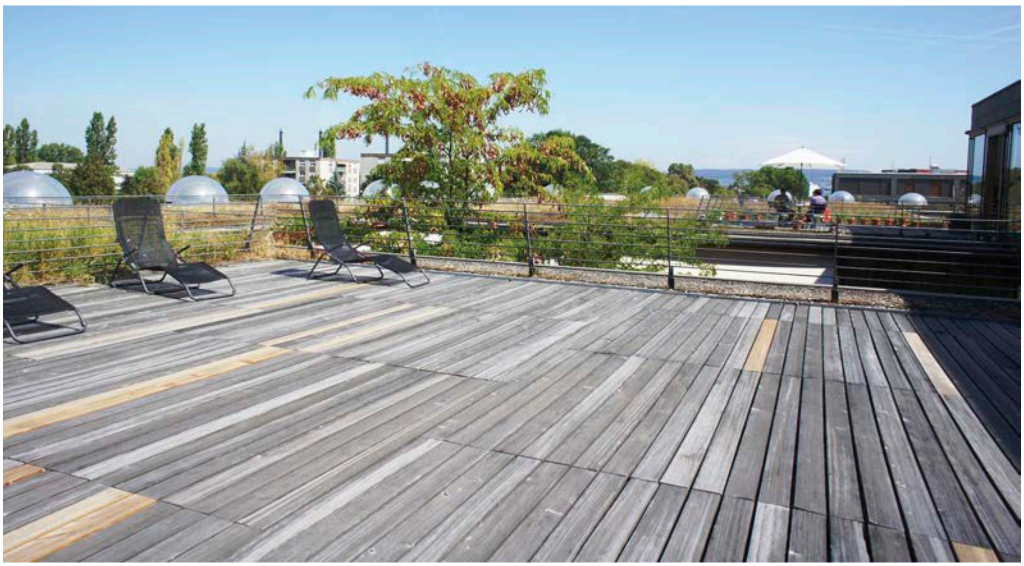


Figure 8.64 Roof deck with vegetated roof and patient room skylights. *Source: Perry Gunther*

Figure 8.65 Water courtyard. *Source: Perry Gunther*

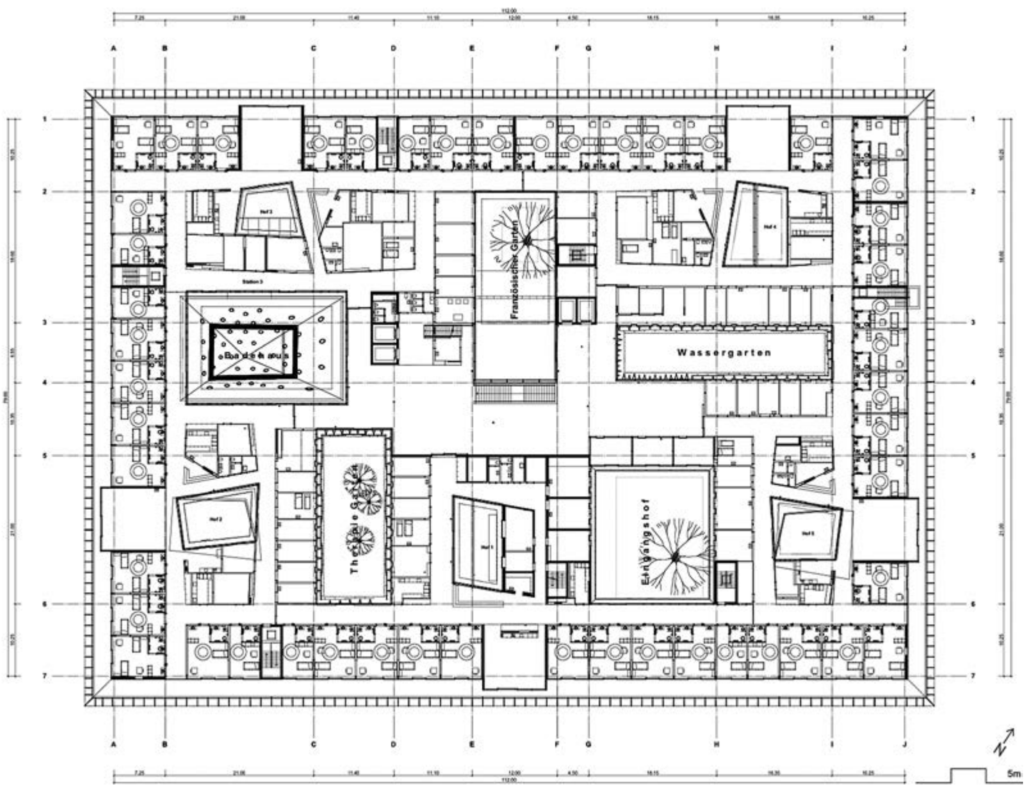


Figure 8.66 Second floor plan. *Source: Copyright © Herzog & de Meuron*

Figure 8.67 Sunflower courtyard.
Source: Perry Gunther

Figure 8.68 Patient room interior.
Source: Copyright © Marguerita Spillutini

Case Study 29: Reina Sofia Foundation Alzheimer Centre

Ensanche de Vallecas, Madrid, Spain

OWNER: Fundacion Reina Sofia with ownership transferred to the Spanish Government

PROJECT TEAM:

Architect: Estudio Lamela Arquitectos

Engineer: Valladeres Ingenieria

General Contractor: Grupo Rayet

Project Manager: Inteinco

TYPE: New Alzheimer In- and Outpatient Treatment and Research Center

SIZE: 138,962 sq. ft. (12,910 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: 138 rooms with maximum capacity for 156 residents; Day Centre with capacity for 40 patients; 4-level structure adjoining 18,245 sq. ft. (1695 sq. m) research center

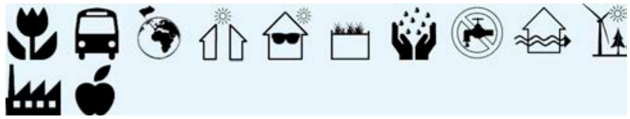
COMPLETED: 2007

RECOGNITION: Partner, European Commission GreenLight Programme

BIOME: Mediterranean Warm

CLIMATE ZONE: Steppe

PRECIPITATION: 17 in. (427 mm)



KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia*: Residential neighborhoods organized around landscaped courtyards
- *Climatic Design*: High thermal mass facade, green roofs, shading devices, orientation and courtyard form
- *Narrow Floor Plate:* Facilitates daylighting and natural ventilation of resident areas
- *Green Roof:* Extensive green roof for stormwater management and reduced heat island impacts
- *Rainwater Harvesting:* Irrigates gardens and green walls
- *Natural Ventilation:* Natural ventilation throughout utilizes operable windows in resident rooms and courtyards
- *Renewable Energy:* Solar thermal panels (hot water) and photovoltaic solar panels (electricity) reduce fossil fuel use by 60%
- *Low Embodied Energy Materials:* Simple, low energy, regional materials
- *Prefabrication/Modularity:* Prototype design features prefabricated, modular components
- *Energy Display:* Residents and staff view energy use display

Figure 8.69 Reina Sofia Foundation Alzheimer Centre. *Source: Estudio Lamela Arquitecto*

Figure 8.70 Night view of residential zone module. *Source: Estudio Lamela Arquitectos*

The World Health Organization estimates that 18 million people have Alzheimer's disease, projected to approach 34 million people by 2025. This compelling Alzheimer's treatment center prototype is a flexible, modular, bioclimatic inspired design that minimizes reliance on fossil fuel generated electricity in the context of a daylit, naturally ventilated, humanistic environment to enhance patient care and treatment (Figure 8.69).

CONTEXT

Through its Alzheimer's Project, the Fundacion Reina Sofia, founded in 1977, conceived of and funded this groundbreaking facility on a 46-acre (18.6 ha) site donated by the Madrid Regional Government. This winning design combines clinical care, research, and the training of medical professionals associated with this pernicious disease in a single facility. With its investment in research, the Centre makes a compelling statement about both disease prevention and discovering a cure.

The Centre was explicitly conceived as a prototype; the Fundacion intends to place similar facilities at other sites in Spain. As such, the design is based on a series of flexible, modular elements adaptable to specific programmatic, spatial, and capacity needs that can be combined in varying sequences. The prototype design informed key decisions: Shared spaces designed to accommodate 16 to 18 patients create easy-to-adapt living modules that can be modified for transfer to other locations, with flexibility based on economic context; architectural, material, resource, and system solutions are also exportable to other sites.

SITE AND BUILDING

The Centre's clearly differentiated public and private zones are distributed across four levels. The public area includes the Day Centre, Research Centre, caretaker training facility, and shared public spaces. A central lobby connects the public area with the private, residential zone, comprised of nine shared spaces including 144 rooms—120 singles and 18 doubles for married couples.

Bioclimatic design principles inform the building's orientation, geometry, and design to ensure low-energy, low-carbon benefits. Indeed, an overarching design principle was to minimize electrical consumption as a means to lessen carbon dioxide emissions. The building features a broad complement of climatic design strategies including green roofs, thick walls providing thermal mass, ventilated facades, solar shading, natural cross-ventilation, and light-reflecting roof and facade materials. These strategies reflect one of the architect's maxims: "It is easier to prevent overheating than to try to eliminate it once it is a fact within the building." In addition to energy demand reduction strategies, the integration of on-site renewable energy systems—both solar thermal for hot water and grid-connected photovoltaic power generation—reduces total fossil fuel energy demand by an estimated 60 percent.

Portions of the building's roof are planted with native plants that require minimal irrigation, and buffer the expansive horizontal plane from direct solar heat gain. Natural ventilation strategies significantly contribute to the Centre's low carbon goal. The building form facilitates cross-ventilation, with the intentional placement of windows across from each other. The interior patios, distributed throughout the building and inspired by traditional town plazas, freshen and filter the air as it crosses through the vegetated spaces.

Madrid is one of the driest cities in Europe, with less than 18 inches (457 mm) of average annual precipitation. The roofs of each of the buildings' 4,844 sq. ft. (450 sq. m) living units are designed to capture rainwater. The collected rainwater is stored in a tank, minimally treated, and used to irrigate the interior gardens, gardens between units, the green roof, and vegetated wall.

Large, 59 inch by 59 inch (150 cm by 150 cm) windows provide daylight, expansive views, and connection to the outdoors, with shading provided by the prefabricated slats. The nine living units, or shared spaces, are organized around interior patios that provide generous daylight, abundant throughout the building. The easily accessible interior patios offer the patients therapeutic garden-related activities, including both food production and floral plantings (Figures 8.71–8.75). To enhance accessibility, architectural barriers are removed; wide corridors provide ample space for patients to comfortably walk.

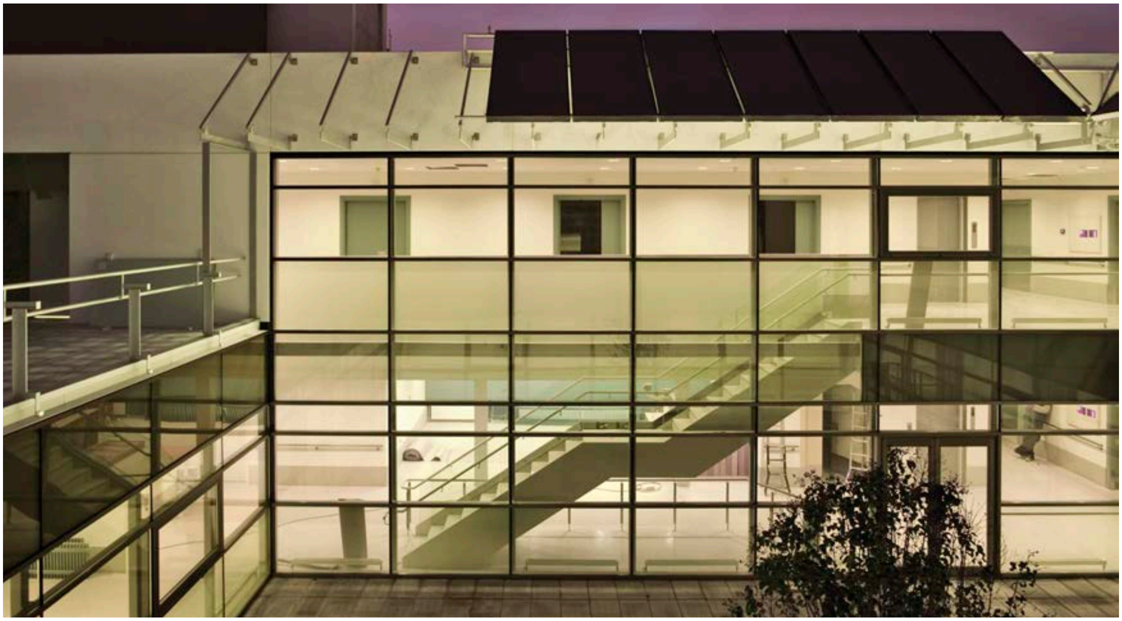


Figure 8.71 Night view of residential zone; solar thermal panels mounted on roof. *Source: Estudio Lamela Arquitectos*

Figure 8.72 Courtyard between residential modules. *Source: Estudio Lamela Arquitectos*

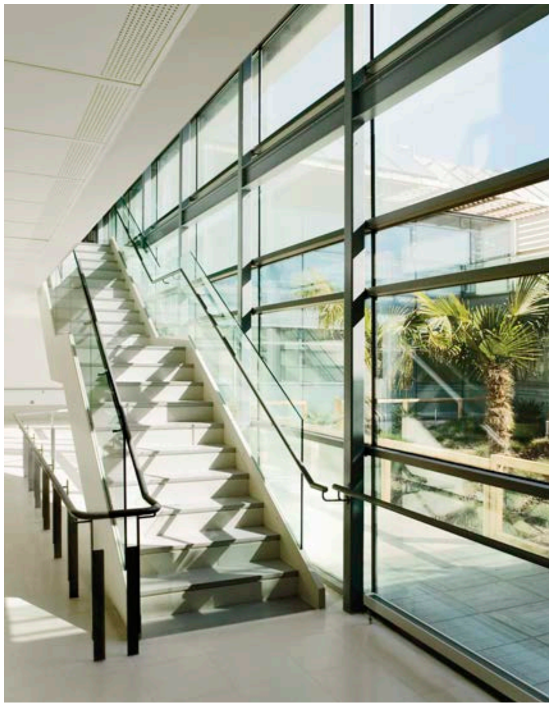


Figure 8.73 Communicating stair in residential unit. *Source: Estudio Lamela Arquitectos*

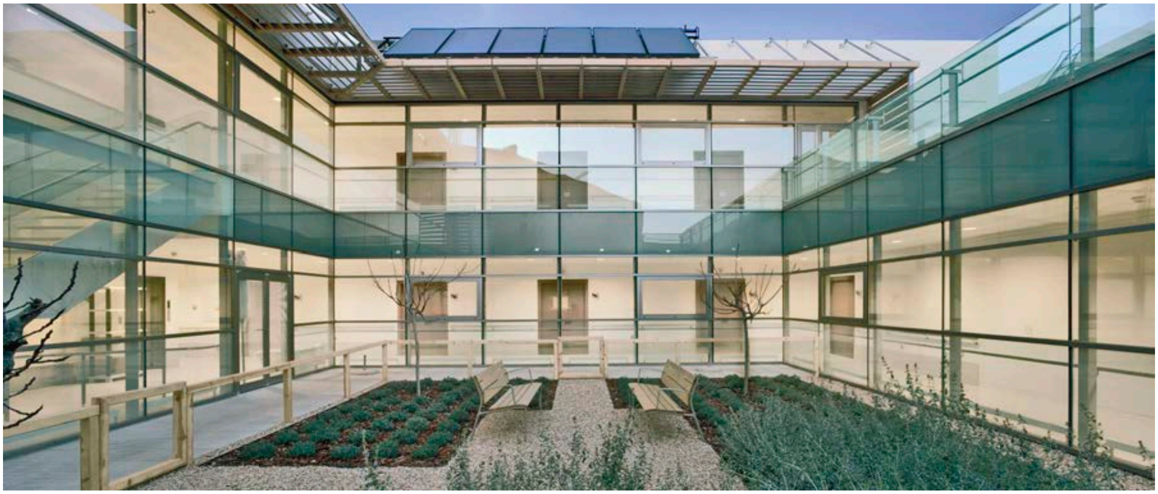


Figure 8.74 Daytime view of residential zone interior patio and therapeutic garden. *Source: Estudio Lamela Arquitectos*

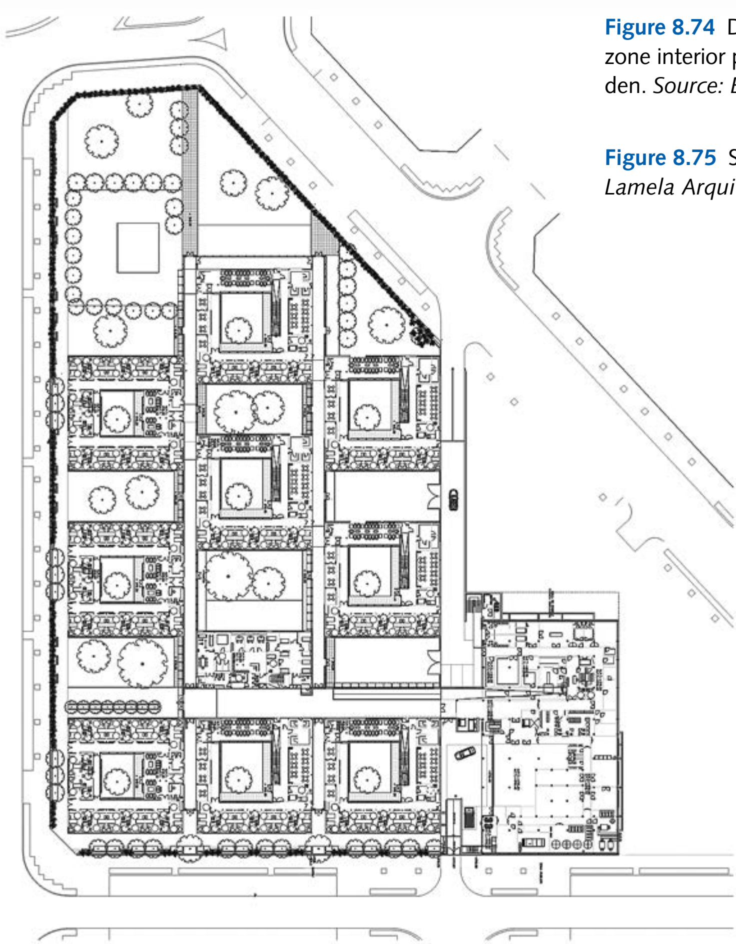


Figure 8.75 Site plan. *Source: Estudio Lamela Arquitectos*

Figure 8.76 Research center tower. *Source: Estudio Lamela Arquitectos*

Figure 8.77 Photovoltaic shading system on research center tower. *Source: Estudio Lamela Arquitectos*

Solar thermal panels fulfill most of the residential units' hot water needs, while electricity generated from the innovative 3,444 sq. ft. (320 sq. m) zinc-coated photovoltaic array mounted on the Research Center's southeast and southwest facades is sold to and feeds into the city's electrical grid (Figures 8.76 and 8.77). A logging monitor located inside the building displays the photovoltaic system performance indicating actual power generated (in kw), production accomplished (in kWh), and CO_2 emissions avoided (in kg).

Consistent with the prototype concept and to promote simplicity, the building is constructed of three basic materials: zinc, glass, and prefabricated elements, including window slats. Small wood elements introduce decorative variation; the entry floor is limestone quarried from nearby Zaragoza. Alabaster lighting on the building's wood paneling is the only "luxury" material.

Source: Estudio Lamela Arquitectos

Case Study 30: Royal Children's Hospital

Melbourne, Victoria, Australia

OWNER: Victorian State Government

PROJECT TEAM:

Architect: Joint Venture: Billard Leece Partnership and Bates Smart Architects, with HKS as international pediatric design advisors

Building Services (MEP) and Environmental Engineer: Norman Disney & Young

Structural Engineer: Irwin Consult

Contractor: Lend Lease

TYPE: Replacement Children's Hospital

SIZE: 1,776,000 sq. ft. (165,000 sq. m); Site 10 acres (4.1 ha)

EUI: 143 kBtu/sf/yr (450 kWh/sm/yr)

PROGRAM DESCRIPTION: 357-bed, 7-level, 4,000 staff replacement children's hospital and trauma center for pediatrics in Victoria, and a Nationally Funded Centre for cardiac and liver transplantation and hypoplastic left heart syndrome

COMPLETED: 2011

RECOGNITION: National Infrastructure Awards, Project of the Year 2012; Dulux Colour Awards, Grand Prix Winner 2012 and Commercial Interior Winner 2012

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 26 in. (650 mm)

KEY SUSTAINABILITY INDICATORS

- *Energy Responsive Facade:* High performance building envelope; fixed solar shading
- *Rainwater Harvesting:* 75% of roof area is catchment; collected rainwater used for landscape irrigation
- *On-site Wastewater Treatment:* Blackwater treatment plant recycles selected wastewater for use in toilet flushing, cooling plant, and irrigation
- *Innovative Source Energy:* Tri-generation system comprised of two 1,160-kW gas reciprocating engines contributes 25% base power, A/C chilled water from two absorption chillers and heating hot water, plus domestic hot water
- *Innovative Energy Distribution:* Active chilled beams provide radiant cooling in offices and consulting rooms
- *Natural Ventilation:* Thermal labyrinth and mixed mode ventilation to the "central street"
- *Renewable Energy:* 600 kW biomass boiler uses compressed timber pellets for fuel; solar thermal hot water
- *Low Embodied Energy Materials:* Local/regional material source and manufacture
- *Recycled Content:* Maximum fly ash content in precast concrete panels

Figure 8.78 Royal Children's Hospital. *Source: John Gollings*

With an aim to be the greenest hospital in Australia, the new Royal Children's Hospital (RCH) achieves a 45 percent carbon reduction through form and facade, innovative mechanical systems, and renewable energy. Its pioneering on-site water treatment and reuse system fulfills 20 percent of the hospital's water needs through non-potable, reclaimed water. Located in a region with increasing water scarcity and facing continued reliance on coal-fired electrical power generation, this hospital demonstrates that significant reductions in water and energy demand can be realized in complex acute-care environments for children (Figure 8.78).

CONTEXT

Known as "a hospital in a park" and "a park in a hospital," the new Royal Children's is located in Royal Park, adjacent to the site of the old hospital. Independently assessed to achieve a 5-star rating based on the Green Building Council of Australia's Green Star Healthcare pilot assessment tool, Royal Children's is influenced by evidence-based design and research that positively correlates exposure to nature with healing and an aim to be the greenest hospital in Australia.

Creating a welcoming environment for children and young people is a strong design driver. Equally important is stewardship of natural resources and environmental protection. The new Royal Children's Hospital employs a sophisticated, pioneering approach to establish an integrated blending of low- and high-tech appropriate technologies in response to the Victorian Government's targets to reduce energy, carbon dioxide emissions and potable water use, and the project brief's precedent setting sustainability criteria.

SITE AND BUILDING

A central "street" runs north/south, with 30 percent of the north-facing side and roof glazed, providing a warm, light, and airy circulation spine with views to the gardens, connecting the buildings with prominent place markers for ease of navigation. Energy-conscious design features are integrated throughout the building. RCH's north-facing facade orientation provides solar energy, ventilation, daylight, and views.

The facades for the east and west buildings are pressure equalized curtain wall using a double-glazed system with double low-e coating. This is overlaid with an armature of feature "leaves"—laminated glass on an acid etch surface with a graded colored frit pattern. The exterior skin of "leaves" function as building-integrated fixed sunshades that also serve as wayfinding elements, with colors and textures characteristic of the leaves and bark of eucalyptus trees in Royal Park: green petals identify the main entrance and red the emergency department entrance (Figures 8.79–8.81).

Roof-mounted louvers allow the street to be naturally ventilated; in good weather even the doors on the main floor can be opened to take advantage of the cooling breeze. Programmed areas are zoned with energy savings in mind: clinical areas operating 24–7 are grouped separately from support areas that operate only during core hours.

The new Royal Children's Hospital's interiors were established from the same concept of "hospital in a park" and "park in a hospital" to capture light, color, texture, and form, creating an ambiance of well-being. The hospital is flooded with daylight, with 34 percent of total floor area within 15.4 ft. (5 m) of perimeter windows/atrium. The inpatient unit in the north building consists of wedge shaped "fingers" that reach deep into Royal Park. Eighty percent of all patient rooms and all day medical chairs overlook and have a view of Royal Park; the other 20 percent of patient rooms have a view of courtyards or gardens. Innovative reflective surfaces installed on the side and top of the window frames offer children confined to their beds a "view" of the park.

The hospital embraces the importance to connect the young patients, staff, and visitors to the circadian rhythm—the natural cycle of the day—evidenced by changing patterns in light and the surrounding landscape. The region's natural history comes alive with a pedagogy reflecting Australia's flora and fauna, with each level visibly distinguished by a nature-based theme exhibited through generously placed artworks, graphics, and signage. A two-story aquarium stocked with 25 species of fish and a naturalized area that houses nine meerkats, developed in partnership with the Melbourne Zoo, extends the reality of a park-like setting inside, and provides welcome distraction for children, families, and staff (Figures 8.82–8.85).

The structural system is reinforced concrete on a standard 27′-6″ (8.4 m) square grid, utilizing 13′-9″ (4.2 m) floor-to-floor height on each level. A precast concrete facade system was used for the north building, utilizing a number of thicknesses and finish types for visual dynamism. At the lower levels, exterior panels are precast concrete with maximum fly ash content.

The Royal Children's Hospital's innovative water source and treatment systems directly respond to the dire drought conditions that have plagued Victoria and other parts of Australia over the last decade, with 2010–2011 reported to be the driest two-year period on record for portions of southeastern Australia. In response to this challenging water reality, the Project's brief required a minimum 20 percent of the facility's total water consumption—process and potable—to be sourced from nonpotable, reclaimed water sources. This requirement was fulfilled through an integrated approach to collect, store, and distribute nonpotable water sources and to reduce total water demand.

Figure 8.79 Detail—south–southwest facade shading. *Source: John Gollings*

Figure 8.80 Detail—bed tower shading. *Source: John Gollings*

Figure 8.81 Detail—principal facade shading recalls eucalyptus leaves. *Source: Shannon McGrath*

Royal Children's Hospital relies on water-efficient technologies to reduce water demand. Principal among these are Muller 3C Coolers that reduce annual potable water consumption by approximately 10.56 million gal (40 ML). By replacing conventional cooling towers with these innovative closed-circuit fluid coolers, the hospital's annual water consumption drops below 29 million gal (110 ML). This proved to be key to meet the goal to fulfill 20 percent of total water consumption with non-potable sources, 5.8 million gal (22 ML/year) or 15,850 gal/day (60 kL/day).

The building takes advantage of rainwater and sewage (blackwater) to meet its 20 percent nonpotable water target, with the majority fulfilled with the building's blackwater. Seventy-five percent of the building's roof area is designed to collect rainwater, with 52,800 gal (200,000 L) storage tanks sized to collect 85 percent of the run-off. Collected rainwater is used for landscape irrigation and, in the winter months when there is reduced irrigation demand, for the heat rejection system.

The building's sewage is processed in the on-site Blackwater Treatment Plant (BWTP) producing 47,500 gal (180,000 L) of treated blackwater per day. It includes a membrane bioreactor, filtration, and tertiary disinfection technologies. The resulting treated blackwater is used for heat rejection fluid coolers on the roof, selected toilet flushing and bedpan macerator flushing (excluding immuno-suppressed patient areas), and for interior garden irrigation. Additional nonpotable sources are wastewater from the haemodialysis water treatment plant, and fire test water (a closed system using the fire water storage tanks).

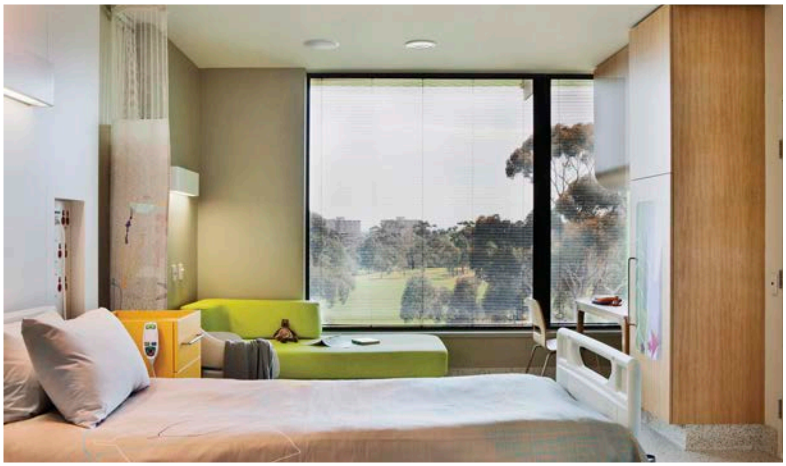


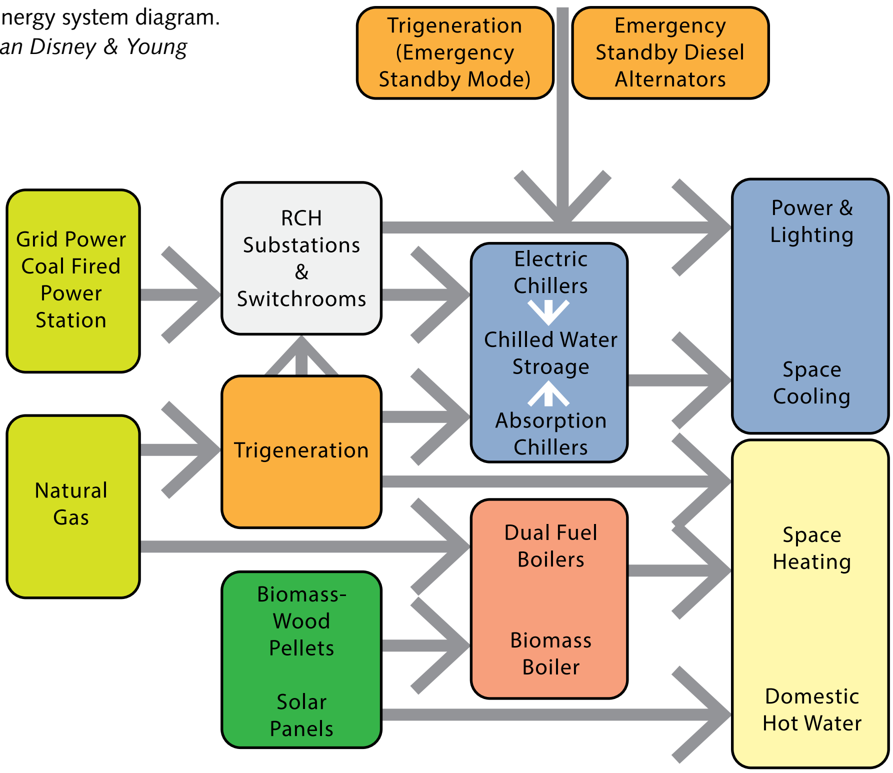
Figure 8.82 Patient lounge with view of Royal Park. *Source: Shannon McGrath*

Figure 8.83 Patient room. *Source: Shannon McGrath*

Figure 8.84 Two-story aquarium. *Source: Shannon McGrath*

Figure 8.85 Entrance level of central street. *Source: John Gollings*

Figure 8.86 Energy system diagram.
Source: Norman Disney & Young



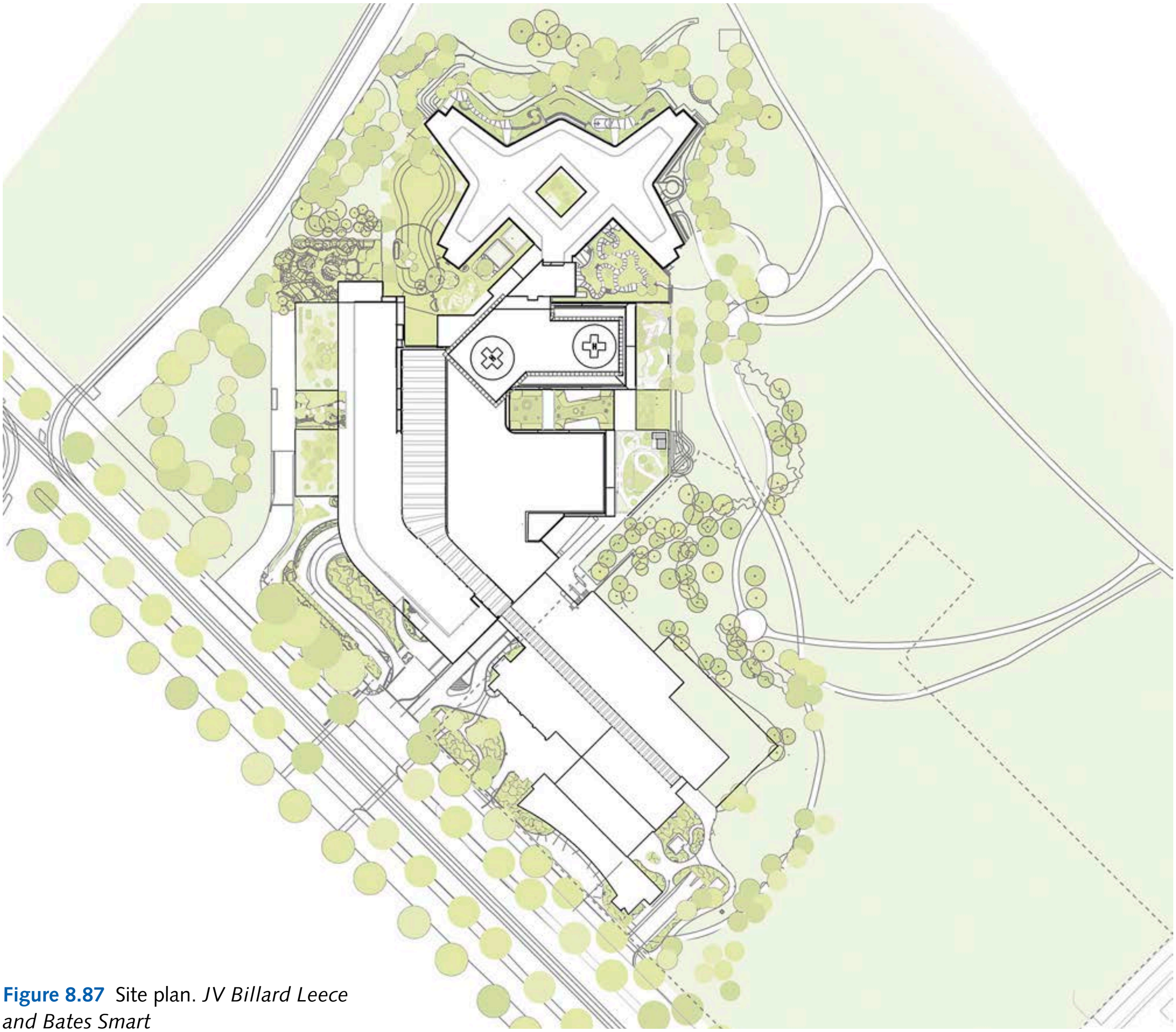


Figure 8.87 Site plan. *JV Billard Leece and Bates Smart*

The combined performance efficiencies of an on-site tri-generation plant, solar panels, and a biomass fuel boiler are estimated to result in a 45 percent reduction of greenhouse gas emissions. The 2.4-megawatt tri-generation plant, comprising two 1150 kW gas reciprocating engines, contributes 25 percent of the building's base power. The engines are fueled with natural gas, resulting in reduced greenhouse gas emissions and other pollutants compared to coal, thereby advancing the project's broader values of environmental protection. This is a significant departure from the customary dependence on local coal—with reserves in Victoria, Queensland, and New South Wales that provide about 85 percent of Australia's electricity generation. As with combined heat and power technologies, the heat resulting from generating electricity will be stored and used for the building's heating, cooling, and domestic hot water (Figure 8.86).

Air distribution systems include mixed-mode ventilation to the "central" street incorporating a labyrinth. Active chilled beams incorporate primary ducted ventilation, providing radiant cooling in offices and consulting rooms. The chilled beams' cooling ventilation flow is induced by the convection effect that occurs. Patient wards are provided with conventional ducted air conditioning, with terminal HEPA filters in Oncology wards. The decision to opt for conventional air conditioning in ward areas was client driven and motivated by a requirement for optimum operational flexibility. Similarly, operable windows were considered but eliminated on the basis of clinical and legal concerns.

Other renewable and high-performance energy technologies include roof-mounted solar thermal panels. They are sized to contribute about 40 percent of the patient ward areas' hot water needs. A 600-kilowatt biomass boiler fueled with timber pellets derived from logging residues from Australia's forestry industry provides space heating and is the first of its type in Australia.

Recognizing that the health of the environment and of people are inextricably linked, the new Royal Children's Hospital delivers a holistic approach to sustainability—environmental, emotional, physical, and psychological. It demonstrates that sustainability can and should be thought about in broad terms, not only reducing resource consumption, but also encompassing social responsibility and the creation of well-considered, welcoming environments for people. These considerations are central to the environmentally sustainable design strategy for the new Royal Children's Hospital.

Source: Bates Smart Architects, Norman Disney & Young

Case Study 31: Rush University Medical Center

Chicago, Illinois

OWNER: Rush University Medical Center

PROJECT TEAM:

Architect/Interior Design: Perkins+Will

Mechanical Engineer: ESD (Tower); IBC Engineering (Entry Pavilion)

Landscape Architect: Hitchcock Design Group (Tower); Hoerr Schaudt (Entry Pavilion)

Civil Engineer: Terra Engineering

Construction Manager: Valerie Larkin Power Jacobs Joint Venture

TYPE: Replacement Acute-Care Hospital

SIZE: 830,000 sq. ft. (78,039 sq. m)

EUI: 167 kBtu/sf/yr (526 kWh/sm/yr)

PROGRAM DESCRIPTION: 14-story hospital with 304 single acute and critical care patient rooms, 72 neonatal intensive care beds, 10 LDRs; houses the McCormick Foundation Center for Advanced Emergency Response

COMPLETED: 2012

RECOGNITION: LEED Gold–certified

BIOME: Temperate Humid

CLIMATE ZONE: Humid Continental

PRECIPITATION: 35 in. (889 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Extensive green roofs and rooftop landscaping connect occupants to nature in dense urban environment
- *Innovative Stormwater Management:* Rainwater capture and green roofs manage stormwater on-site
- *Innovative Parking:* Below grade parking
- *Energy Responsive Facade:* 40% window to wall ratio improves thermal performance
- *Green Roof:* Extensive green roofs for stormwater management
- *Rainwater/Condensate Harvesting:* Used for irrigation and cooling tower makeup
- *Potable Water Use Reduction:* 34% from low-flow plumbing fixtures
- *Heat Recovery*: For exhaust air streams
- *Healthy Materials:* PVC avoidance; low-emitting materials; used Perkins+Will Precautionary List
- *Recycled Content Materials:* 34% by cost recycled content
- *Construction Waste Reduction:* 94% diverted from landfills
- *Occupant Control:* Individual lighting and thermal comfort controls in patient and staff areas

Figure 8.88 Rush University Medical Center. *Source: Copyright © James Steinkamp, Steinkamp Photography*

Rush releases large, urban hospitals from the deep floor plate typology and all-glass facades. Its flexible, anticipatory design coupled with its compelling blend of evidence-based and sustainability attributes is distinctive for a U.S. hospital of such significant size. Its bold design strokes like the butterfly wings—affording patients and staff with essential access to daylight and views—integrating nature and green spaces throughout, prioritizing specification of green materials and curbing energy intensity and potable water use, are measurable expressions of Rush's commitment to environmental stewardship and protecting human health (Figure 8.88).

CONTEXT

Rush University Medical Center was initially conceived in the 1830s when the Illinois legislature granted a charter to establish a public medical center. Over the course of more than one and a half centuries, the center evolved and expanded. It was renamed Rush University Medical Center (RUMC) in 2006, coincident with a $1 billion "transformation" plan to refresh its 30.5 acre (12.3 ha) campus on Chicago's West Side into an environmentally compelling, humanistic environment for patients, staff, and the community.

Phase 1 was completed in 2009, including a new materials management and loading dock, central utility plant, orthopedic ambulatory building, and structured parking. The RUMC Tower project is Phase 2. With its distinctive form inspired by butterfly wings, the building has dramatically transformed the campus and surrounding community. As of its opening in January 2012, the 830,000 sq. ft. (78,039 sq. m) facility is the largest LEED Gold–certified healthcare building in the world. Its design was substantively informed by and benefited from engaging Rush's doctors, nurses, and other staff to provide design guidance early in the process.

SITE AND BUILDING

Known familiarly as "The Tower," the facility is comprised of a six-story base topped by a five-story tower. The base includes diagnostic areas, an emergency department, and three floors of operating and treatment rooms. These are intentionally designed to facilitate flexibility over time to accommodate changes in treatment modalities, program and function, and to quickly adapt to significant emergency conditions, such as a bioterrorist attack or pandemic. The building lobby rapidly converts into a triage and treatment center: as part of the quick-response conversion, outlets are embedded in the lobby's structural columns to provide electricity and medical gases.

The Tower's street level entry, the 40-foot tall Edward A. Brennan Entry Pavilion, is a bold gesture to bring the outdoors in and was initially conceived as a Living Building (Figures 8.89 and 8.90). Added as a subsequent phase project component, the Pavilion incorporates a number of strategies demonstrating Rush's commitment to sustainable design. Indeed, the three-story space is amply daylit by two large, circular skylights and dominated by a full-height planted terrarium that is open to the sky, providing a visual cue to the weather outside, whether rain or snow, sun or clouds. Furthering the theme of connection with the outdoors, the generously sized Shirley and Richard Jaffee Family Garden awaits building visitors who enter the building on the fourth level via the bridge from the parking garage. The roof garden offers alluring views to the Lobby and Tower and is complemented by the placid, landscaped environment (Figure 8.91).

Habitat restoration occurs in three additional areas: ground level (29,950 sq. ft. [2,782 sq. m]), the 9th floor terrace extensive green roof (3,703 sq. ft. [344 sq. m]), and the 16th (R1) floor rooftop extensive green roof (20,094 sq. ft. [1,867 sq. m]). The ground level is planted with a combination of native and adapted trees, shrubs, vines, and perennials, the 9th floor with a combination of trees and drought-tolerant perennials, and the rooftop with a combination of drought-tolerant perennials. In summary, the experience is transformational.

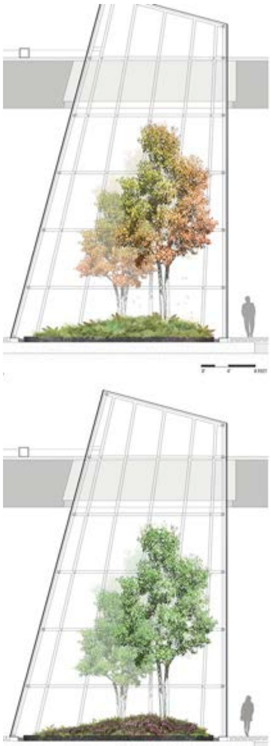


Figure 8.89 Terrarium section studies. *Source: Hoerr Schaudt Landscape Architects*

Figure 8.90 Edward A. Brennan entry pavilion with terrarium. *Source: Copyright © Steve Hall, Hedrich Blessing Photographers*

The pedestal base sits in stark contrast to the graceful butterfly-inspired patient bed tower that rests above it. The bed tower is characterized by four curved wings, evenly distributed around a central hub to provide patients and staff with ample access to daylight and views. In addition, the design minimizes the distance between patient rooms and nurses' stations, another key benefit of evidence-based design. The design prioritizes daylighting and access to natural light and views (Figures 8.92 and 8.93).

Beyond the daylight and nature connectivity, the Medical Center's commitment to sustainability is evidenced by an integrated approach to reducing its environmental footprint, including a broad array of water, energy, materials, and indoor environmental quality strategies.

The hospital is projected to reduce annual potable water use by 1.3 million gallons: air handler condensate is captured and redirected to irrigate the native plant landscape and to supply makeup water for the facility's air conditioning chillers; dual-flush toilets installed in all public bathrooms along with other low-flow fixtures result in 34 percent reduced indoor water use compared to baseline.

The building's two green roofs [9th floor green roof (3,700 sq. ft. [344 sq. m]) and 16th floor green roof (20,094 sq. ft. [1,867 sq. m]), a total of 23,794 sq. ft. (2,211 sq. m), function as absorptive surfaces, or "sponges," to reduce stormwater runoff into Chicago's overburdened sewer system. As in many cities, Chicago's sewer infrastructure is subject to overflows resulting in polluted water entering nearby streams, rivers, and lakes. Further mitigating stormwater runoff is a clever sidewalk detail that diverts stormwater running along the curb and redirects it to irrigate street trees and planters (see Figures 8.94 and 8.95).

SITE SELECTION	I RESPONSIBLE SITE SELECTION	
	II LIMITS TO GROWTH	
	III HABITAT EXCHANGE	1. Habitat preservation
ENERGY	IV NET ZERO ENERGY	2. IPV on skylights, south faces of bridges 3. Panels on atrium precast walls, atrium roof 4. Batteries stored in healing wall 5. Daylighting, stored solar for night 6. Displacement ventilation 7. Heat recovery system 8. Stack effect, double wall thermal chimeny 9. Radiant floor 10. Solar hot water heat for restrooms
MATERIALS	V MATERIALS RED LIST	
	VI CARBON FOOTPRINT	11. Alternatives to thin set epoxy terrazo 12. Calculations 13. Wood from demo projects / FSC wood 14. Local stone and wood
	VII RESPONSIBLE INDUSTRY	
	VIII APPROPRIATE MATERIALS RADIUS	
	IX CONSTRUCTION WASTE	

WATER	X NET ZERO WATER XI SUSTAINABLE WATER DISCHARGE	15. Rainwater for irrigation 16. Rainwater for toiletes 17. Divert rainwater from roofs into cisterns
IEQ	XII CIVILIZED WORK XIII SOURCE CONTROL XIV VENTILATION	18. Operable windows 19. Daylighting 20. Walkoff system 21. Double skin facade 22. Exhaust hot air from atrium via double skin cavity
BEAUTY	XV DESIGN FOR SPIRIT XV I INSPIRATION AND EDUCATION	23. Plant terrarium 24. Art mural 25. Historic artifacts exhibit 26. Energy performance LED screen 27. Exposed rainwater retention system 28. Permanent displays explaining features

Figure 8.91 Study for sustainable design features in entry pavilion. These strategies are compared against the Living Building Challenge imperatives. *Source: Perkins+Will*

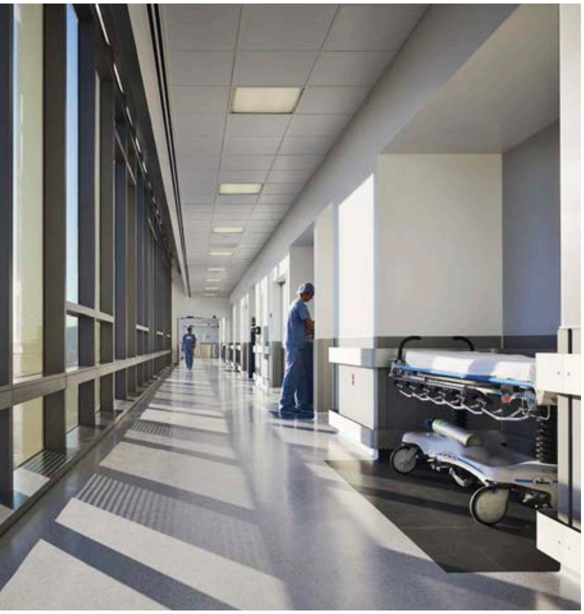


Figure 8.92 Daylit surgery corridor. *Source: Copyright © Steve Hall, Hedrich Blessing Photographers*

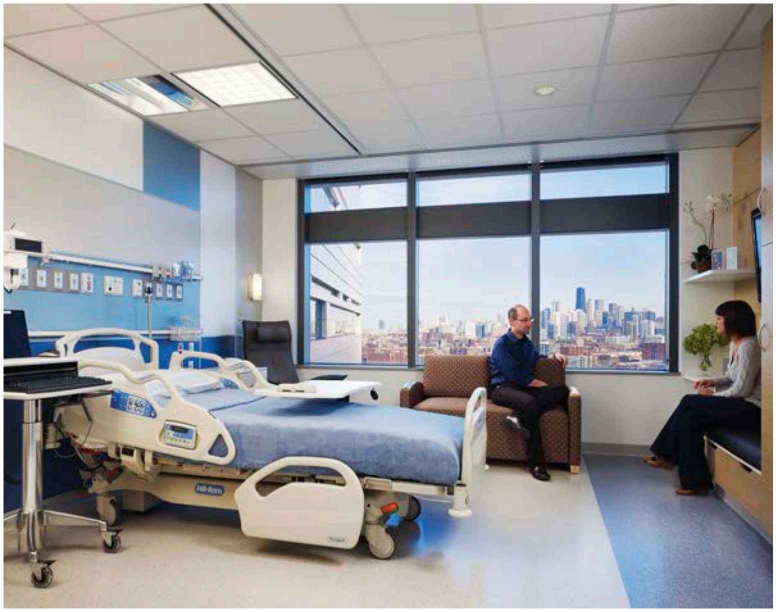


Figure 8.93 Patient room. *Source: Copyright © Steve Hall, Hedrich Blessing Photographers*

Figure 8.94 Aerial view of sidewalk planter. *Source: Perkins+Will*

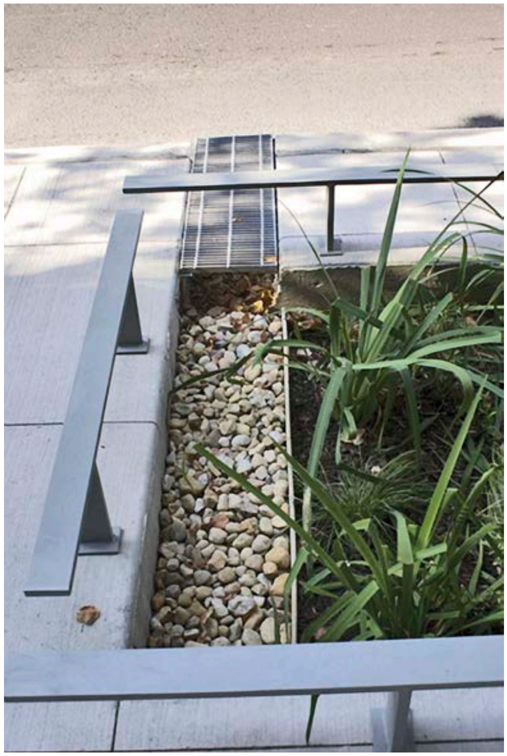


Figure 8.95 Planter detail to divert rainwater in street for irrigation. *Source: Perkins+Will*

The Tower's modeled energy performance is 20 percent below ASHRAE 90.1–2004, reflecting a complement of energy-efficient mechanical and lighting systems; white membrane and green roofs that, respectively, reflect light and enhance thermal performance; and generous daylight that reduces reliance on electrical light. Early facade studies and energy modeling led the design team to reject an all-glass curtain wall in favor of the Tower's 40 percent glazing/60 percent opaque wall system.

Creating spaces filled with daylight and providing unobstructed views to the outside for patients and staff is challenging for large, urban hospitals. With the new patient bed Tower hovering above other hospital functions, and its four narrow glazed wings extending out in different directions, the designers accomplished their goal to create a humanistic, healing environment with a lighter environmental footprint (Figures 8.96 and 8.97).

Source: Perkins+Will

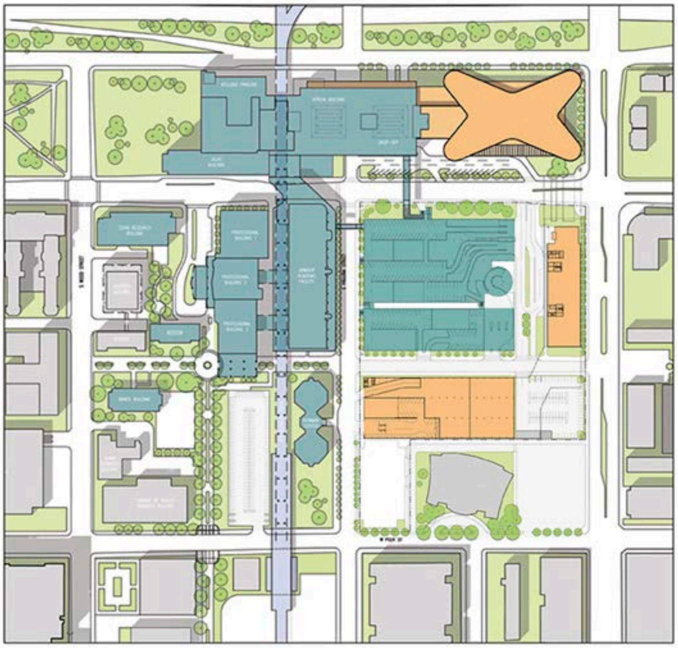
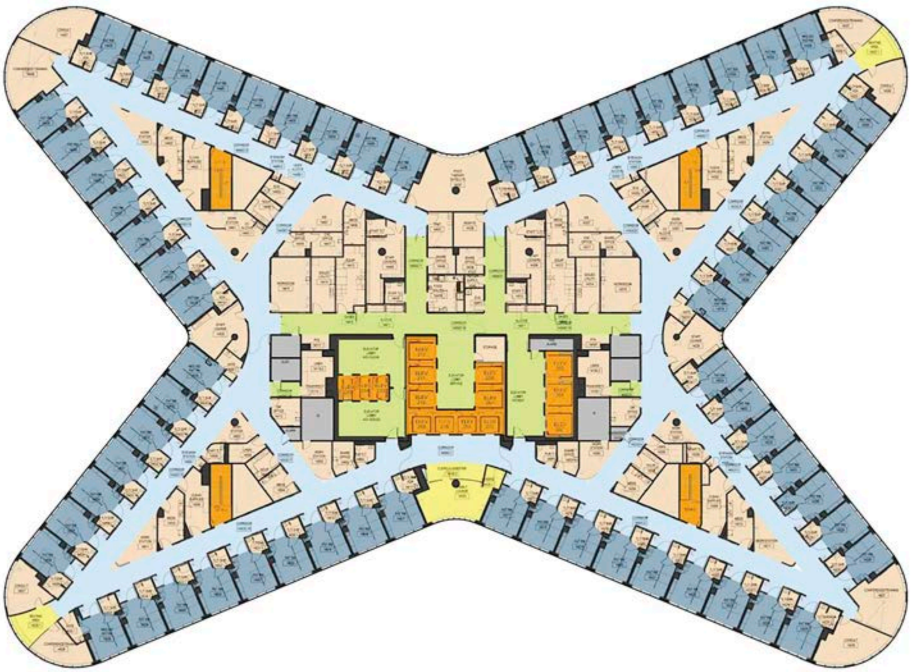


Figure 8.96 Site plan. *Source: Perkins+Will*

Figure 8.97 Patient Tower plan. *Source: Perkins+Will*



Case Study 32: Salam Centre for Cardiac Surgery

Soba (Khartoum), Sudan

OWNER: EMERGENCY

PROJECT TEAM:

Architect: Studio Tamassociati

Structural Engineer: Francesco Steffinlongo

Mechanical Engineer: Jean Paul Riviere and Nicola Zoppi

Site Engineer: Roberto Crestan and Alessandro Giacomello

TYPE: New Acute-Care Hospital

SIZE: 64,580 sq. ft. (6,000 sq. m); Site: 10 acres (4.1 ha)

EUI: Not Available

PROGRAM DESCRIPTION: Full service 63-bed adult and pediatric cardiac surgery hospital, including 3 operating rooms, 15-bed intensive care unit, 16-bed sub-intensive care unit, 48-bed patient wards, emergency room, outpatient clinics, catheterization laboratory, radiology and ultrasound, guesthouse for patients' relatives, pavilion for prayer and meditation

COMPLETED: 2007

RECOGNITION: 2010 "Best of Green Award" (Treehugger, USA); "Sustainable Architecture" Fassa Bortolo Prize; Italian Architecture Gold Medal 2009

BIOME: Desert Temperate

CLIMATE ZONE: Desert

PRECIPITATION: 10 in. (259 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia:* Planned around historic trees and traditional "hollow space"
- *Climatic/Bioregional Design:* Limited exterior fenestration and covered walkways minimize heat gain
- *Narrow Floor Plate:* Daylighting and natural ventilation in patient units
- *Energy Responsive Facade:* High-efficiency building envelope, high thermal mass cavity wall with extensive insulation, deep overhangs to limit solar gain
- *Innovative Energy Distribution:* Thermal labyrinth for air pre-cooling and fresh-air filtering technologies
- *Natural Ventilation:* Mechanical cooling of ORs and diagnostic areas; natural ventilation in patient areas
- *Renewable Energy:* On-site evacuated tube solar collectors for chiller energy
- *Low-Embodied Energy Materials:* Locally crafted bricks (sun baked); woven shading screens produced on site using traditional bed-making techniques

Figure 8.98 Salam Centre for Cardiac Surgery. *Source: Raul Pantaleo*

In a country with very low levels of technology, no underlying infrastructure and with harsh climate conditions, the key features of this project are simplicity, innovation, and a focus on bioregional and context-specific design solutions. This project demonstrates that with design innovation and low-cost technologies, the same level of high-quality, effective healthcare can be realized with minimal environmental impact. Such innovation is key to a resilient and reliable global healthcare infrastructure (Figure 8.98).

CONTEXT

Patients receive free, state-of-the-art cardiac healthcare in this advanced hospital setting, funded by individual European philanthropists. EMERGENCY's intention in developing a pilot "gem" project was to respond to the urgent healthcare needs of the country and surrounding region, and to set a precedent for a project that conceives of free healthcare as a fundamental right for all people. It also provides important medical education and training for nurses, anesthesiologists, and surgeons in Sudan.

Every detail of the building is aimed to make patients and caregivers comfortable and highlight the fundamental values of caring and preserving life. The details of the building are the "face" that represents these values—residing in the hospital makes the patients of any gender, race, color, or belief come together under the common roof of fundamental values such as cohabitation and hospitability. The design of the Salam Centre for Cardiac Surgery followed three guiding principles:

- The idea of a "hollow" space and a pavilion-based system;
- The choice of the best possible technology given the context;
- The search for an ethical language for this type of architecture.

SITE AND BUILDING

The hospital has been developed around a "hollow" space, physically occupied by two enormous mango trees, located at the center of the site (a plot of land on the banks of the Nile about 12.4 mi (20 km) from Khartoum). In line with traditional housing structures, the hospital is configured around this hollow space. The hospital buildings that embrace the courtyard have been designed as pavilions (Figures 8.105 and 8.106).

Sudan is a desert region where temperatures can range from a comfortable 84°F (29°C) to an extreme high of 113°F (45°C)—the challenge is to ensure the hospital is cool enough for the patients and staff. Beginning with passive technologies, the building features a high-performing 23 in. (58 cm) exterior wall made of two layers of bricks separated by an insulating air cavity, with small windows. The windows are high-performance, low-emissivity glass. Shrubs and trees shade the buildings from the heat and mitigate effects of the harsh climate. Traditionally crafted thatched roofs for paths, screens for outdoor corridors (Figures 8.99 and 8.100), and areas for rest are important from a practical and aesthetic point of view. The building was constructed using local, low-embodied energy materials and construction methods.

Sudan has dust storms that can cause significant dust infiltration when operable windows are employed. To alleviate this, a thermal labyrinth pre-cools and filters fresh outdoor air before it enters the air handlers or mechanically ventilated portions of the building. This design ensures that sand is captured as sediment in the labyrinth and does not

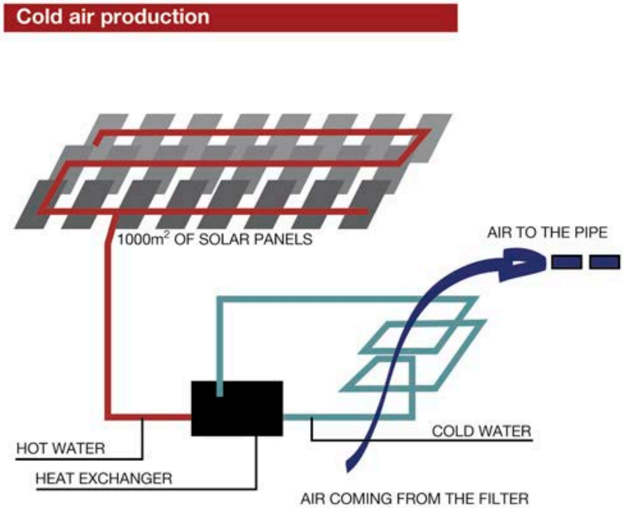
enter the hospital. As a final safety measure, water is sprayed at the entrance to the air conditioning units to ensure that any residual sand does not enter the equipment. The system requires little maintenance work—limited to cleaning the labyrinth structure—and allows the air to reach the conditioners filtered and 48°F (9°C) cooler than when it enters the system (Figure 8.102).

Even with these methods in place, the hospital still requires energy for cooling, particularly in operating rooms and diagnostic areas. Solar energy, collected by 288 evacuated tube thermal panels of approximately 9,688 sq. ft. (900 sq. m), produces 176–194°F (80–90°C) hot water that is the energy source for two chillers (Figures 8.103 and 8.104). Two boilers are alongside as backup for the solar.

Source: Studio Tamassociati

Figure 8.99 Traditional architectural screens at exterior corridors. *Source: Studio Tamassociati*

Figure 8.100 Local artisan weaving traditional screen. *Source: Studio Tamassociati*



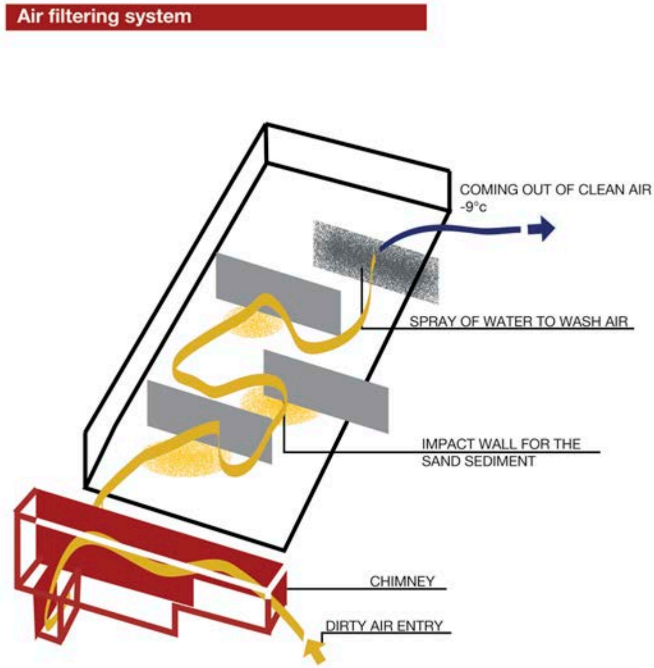


Figure 8.101 Solar water heating for chiller plant. *Source: Studio Tamassociati*

Figure 8.102 Thermal labyrinth filters and pre-cools outdoor air. *Source: Studio Tamassociati*

Figure 8.103 Evacuated tube solar collectors provide hot water for chillers. *Source: Studio Tamassociati*

Figure 8.104 Pumps convey water to the chillers. *Source: Studio Tamassociati*

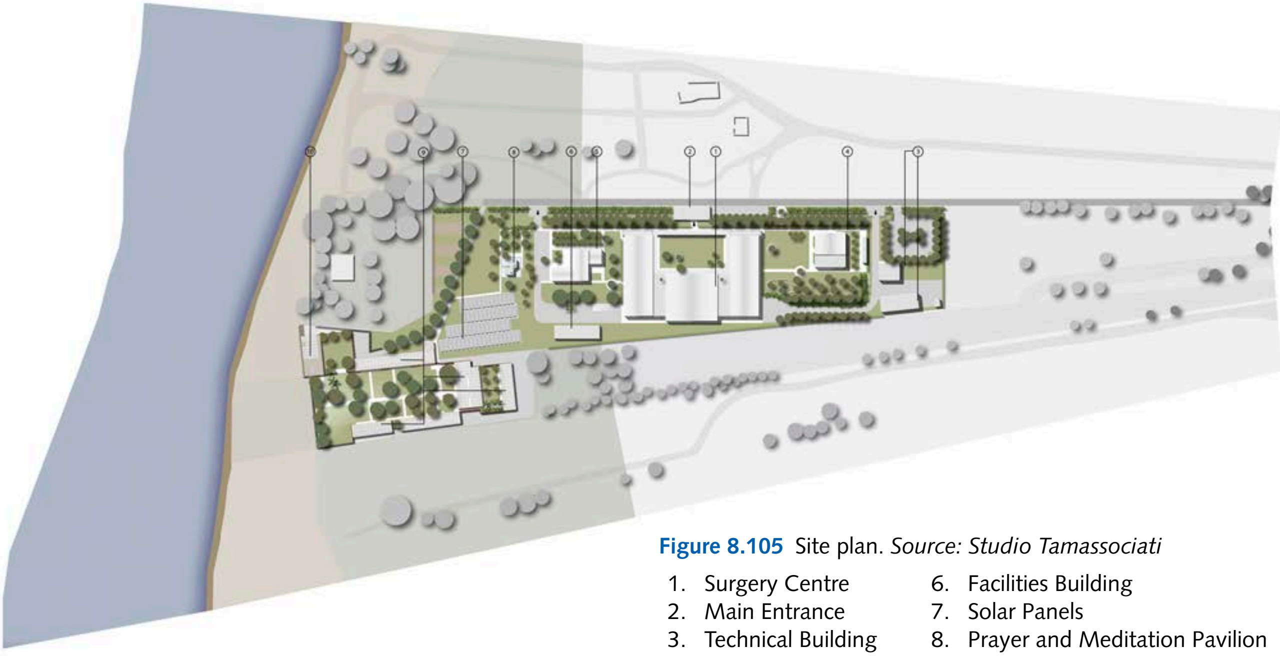


Figure 8.105 Site plan. *Source: Studio Tamassociati*

1. Surgery Centre
2. Main Entrance
3. Technical Building
4. Relatives House
5. Service Building
6. Facilities Building
7. Solar Panels
8. Prayer and Meditation Pavilion
9. Medical Compound
10. Cafeteria

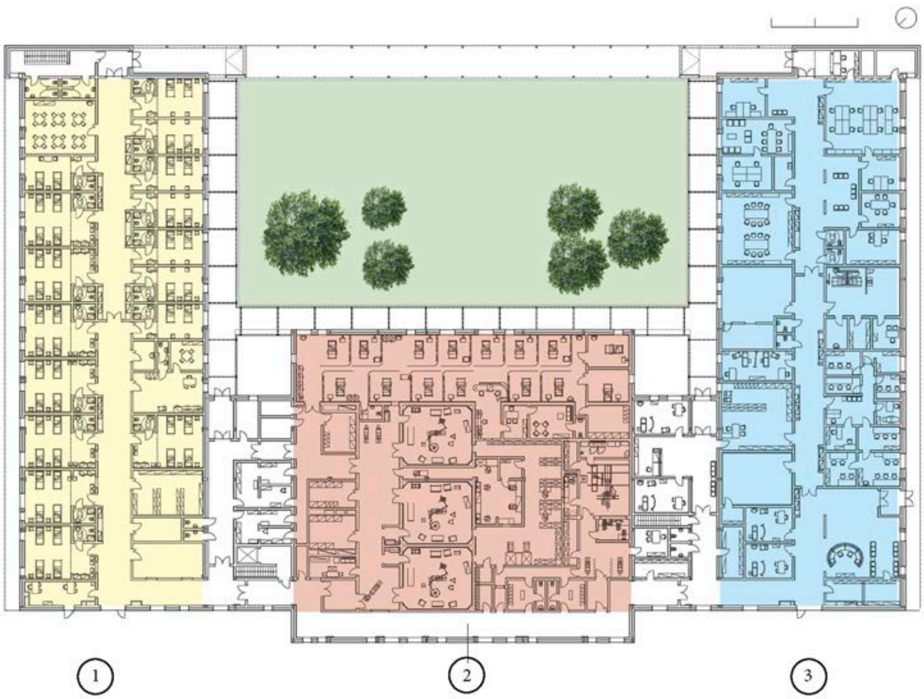


Figure 8.106 First floor plan of the surgery centre. *Source: Studio Tamassociati*

1. Surgery Block
2. Diagnostic and Administration
3. Ward

Case Study 33: Santa Lucia University General Hospital

Cartagena, Spain

OWNER: GISCARMSA, SAU

PROJECT TEAM:

Architect: CASA Solo Arquitectos SLP

MEP Engineer: JG Ingenieros Consultores de Proyectos SA

Civil and Structural Engineer: NB 35 SL

General Contractor: UTE Hospital Cartagena (FCC + Intersa)

TYPE: New Acute-Care Hospital

SIZE: 1,231,058 sq. ft. (114,369 sq. m)

EUI: 66.6 kBtu/sq. ft./yr (210 kWh/sq. m/yr)

PROGRAM DESCRIPTION: 630-bed teaching hospital, with complete medical services and community amenities including sports facilities, retail and leisure

COMPLETED: 2010

RECOGNITION: "@Aslan" 2011 award from the Asociacion de Proveedores de Sistemas de Red y Telecomunicaciones (Association of Suppliers of Network and Telecommunication Systems) for "cases of innovative success in Public Administrations and Agencies."

BIOME: Temperate Semi-Arid

CLIMATE ZONE: Steppe

ANNUAL PRECIPITATION: 13 in. (339 mm)

KEY SUSTAINABILITY INDICATORS

- *Climatic/Bioregional Design:* Building orientation, architecturally integrated external openings and double-skin facade introduce natural ventilation and temper solar heat gain
- *Energy Responsive Facade:* Extensive taut fabric mesh brise-soleil and orientation-specific shading solutions reduce heat gain on facades and roofs
- *Rainwater Harvesting:* For landscape irrigation, toilet flushing, and outside cleaning operations
- *Reclaimed Water Reuse:* Toilets flushed with collected/filtered greywater from washbasins, showers, sinks
- *Water Use Reduction:* Indoor water conserving fixtures include automatic sensor taps in showers and washbasins; dual flush toilets; low-flow showerheads
- *Innovative Energy Distribution:* Chilled beams and displacement ventilation in administrative and inpatient areas
- *Natural Ventilation:* In inpatient units
- *Renewable Energy:* 400 solar thermal panels generate 65 percent of sanitary hot water; grid-connected photovoltaics with installed output of 341,200 Btu (100,000 W) peak
- *Low Embodied Energy:* Locally sourced stone, aggregates
- *Civic Function:* Indoor pool, gym, outdoor running track for staff and general public use

Figure 8.107 Santa Lucia University General Hospital. *Source: Copyright © Joachin Zamora*

With the vision that "good architecture is self-sustainable," Santa Lucia is a compelling, integrated, futuristic hospital. Emphasizing quality and effectiveness of patient care, prevention, and health promotion, Santa Lucia blends a humanistic design with a complement of climatic design and renewable energy strategies including natural ventilation and extensive daylight. The water reuse and efficiency strategies employed at Santa Lucia offer a roadmap for an integrated approach to water demand reduction and harvesting of on-site resources to offset reliance on municipally treated potable water (Figure 8.107).

CONTEXT

Santa Lucia University General Hospital is large, requiring skillful attention to form, orientation, circulation patterns, and an integrated approach to resource management. Protection of health is an important part of the hospital's mission—an ethic that prioritizes prevention. Santa Lucia includes health-promoting amenities for sports and leisure, offering opportunities for the community to take advantage of the hospital as a place that nurtures health and wellness by offering resources to encourage active lifestyles and enhance public health.

SITE AND BUILDING

The building form is defined by strong connections between indoor and outdoor spaces. Outpatient and diagnostic facilities are arrayed on two floors along the main axis parallel to the highway, accessed from a major vehicular drop-off. Directly above these floors and below the bed towers, an interstitial mechanical floor includes air handling equipment that draws its intake air from the courtyards between inpatient wings, reducing intake temperatures. Six narrow floorplate inpatient wings are arrayed above this two story landscaped plinth, providing unobstructed views to the natural landscape and surrounding hills and daylight as well as ample outdoor space for patients. As with traditional buildings in hot arid climates, usable interior courtyard patios function both as light wells and as outdoor respite areas for patients and staff—the resulting building is daylit in all regularly occupied spaces, despite the depth of the plan.

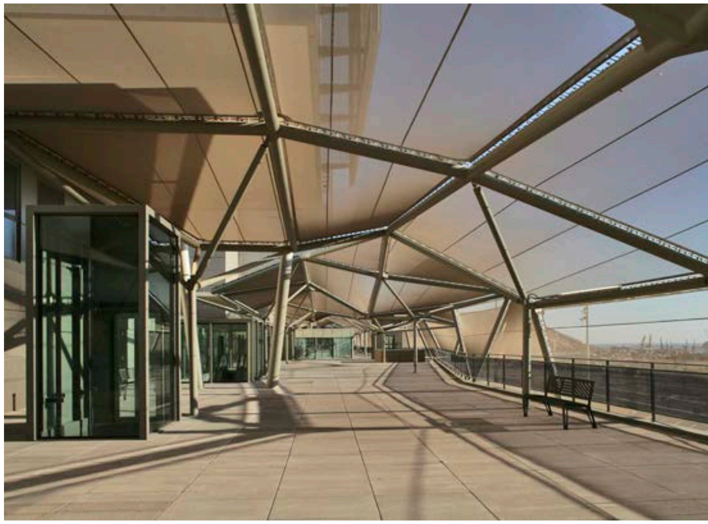
Energy efficiency is achieved through careful integration of climatic design and passive features, including building orientation, solar protection, and natural ventilation complemented with renewable energy and high performance mechanical systems. The building envelope takes advantage of materials with low energy transfer coefficient. Ventilated system facades are composed of aluminum, cor-ten steel, and local natural stone, coupled with high performance insulation and low-e double-glazed windows. On the building's principal west facade (the arrival side), a distinguishing taut fabric mesh extends over a metallic tubular structure, creating a tensile form that provides effective solar shielding, reducing the building's thermal load and reliance on the mechanical cooling system. The mesh vertically cuts across the middle of the building, and is a visual gesture to the surrounding mountains (Figures 8.108 and 8.109).

The covered parking spaces for patients and the axis "boulevard" are designed to be fully naturally ventilated, precluding the need for mechanical ventilation and thus eliminating electrical demand, associated maintenance and carbon emissions. It also connects and gives free cooling to transition and entrance areas into different parts of the building. The same solar shielding is used to protect the corridor's west-oriented curtain walls (Figure 8.109).

All patient room windows are south oriented to provide excellent views. Patient wings are single-loaded corridors to optimize natural ventilation and designed so that their individual outboard bathrooms shade the room from west sun, a further demonstration of the skillful integration of design and function. In addition, medium- to low-occupancy spaces, such as the patient rooms and administrative zones, are conditioned using inductive, active beam systems designed so that the induced air mixes with ventilation air, increasing ventilation air three to six times. This approach requires no preventive maintenance, reduces electrical use, noise, and Legionnaire's disease risk, while improving thermal comfort.

Additional energy demand reductions are achieved through efficient fluorescent lamp lighting and a variable air volume distribution system that optimizes energy use by taking advantage of outside air and heat recovery sections from the output air of the extraction systems. Recognizing that the hospital's energy demands fluctuate through a 24-hour cycle and seasonally, the centralized building energy management system adapts power production and distribution based on real-time requirements, thus substantially reducing energy consumption.

Both site-installed solar thermal and photovoltaic systems offset reliance on fossil fuels, reducing the hospital's carbon footprint. Sixty-five percent of the hospital's domestic hot water requirements are fulfilled by the solar thermal installation, comprised of 400 solar panels covering a 10,764 sq. ft. (1,000 sq. m) area; the balance is produced through a heat recovery system on the building's cooling plant. The facility's 341,200 Btu (100,000 W) photovoltaic plant, with a mirror surface area of 8,396 sq. ft. (780 sq. m), generates medium voltage electrical power delivery to the urban network. The grid-connected system reflects the utility structure that pays a higher price for renewably-generated energy



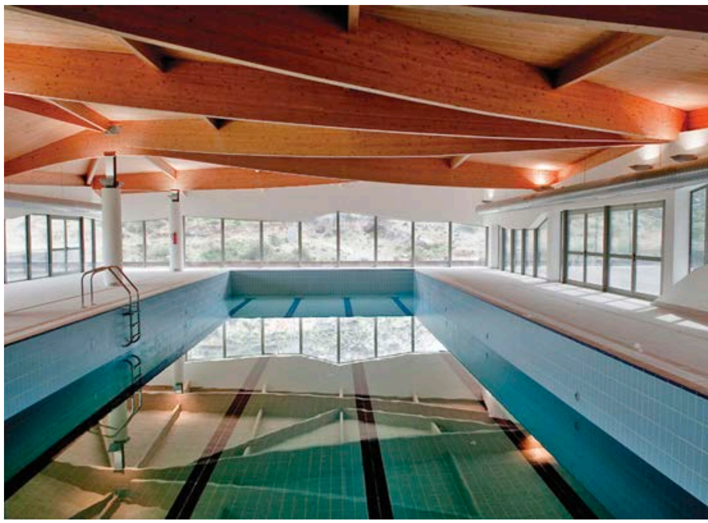


Figure 8.108 View of entrance. *Source: David Pernas*

Figure 8.109 West-facing two-story principal facade is deeply recessed and shaded. *Source: David Pernas*

Figure 8.110 Public swimming pool on retail and community use promenade. *Source: UTE Nuevo Hospital de Cartagena* fed into the central grid than purchasing it from the grid, creating a profitable arrangement for the hospital.

As with many parts of the world, sustained drought conditions have forced significant changes in water dependency. In 2012, Spain experienced the driest winter ever recorded. Murcia is a region in Spain very conscious about water supply due to its climatic conditions. Given this context, water conservation and management is another area where Santa Lucia has undertaken impressive steps.

Santa Lucia collects and reuses rainwater for irrigation and outdoor cleaning, and greywater for toilet flushing. Rainwater is collected from the building's 258,334 sq. ft. (24,000 sq. m) upper roof, and is piped through a dedicated plumbing network to cisterns with a capacity of 100,000 gal (375,000 L), enabling sufficient storage to accommodate the region's fluctuating rainwater pattern. The collected rainwater is filtered with an ultra-filtration system and then fed into a 31,700 gal (120,000 L) tank where it is stored until needed. Greywater—wastewater derived from the inpatient units' showers, washbasins, and sinks located on the building's second to fifth floors—is also piped through a dedicated plumbing network and stored in a 48,000 gal (180,000 L) storage tank.

Infection control is an essential consideration when using greywater, especially in a hospital setting. As with the rainwater, the collected greywater is subject to an ultra-filtration system prior to reuse. It is also chlorinated, a filtration provision beyond that required for the rainwater. The treated greywater is stored in a 25,000 gal (95,000 L) tank, and directed through the dedicated plumbing system to flush toilets, urinals, and bedpan washers. It is estimated to fulfill 94 percent of total water used for these fixtures.

Taken together, the hospital demonstrates the power of place-based, climatically responsive architecture for health. Through conscious focus on energy and water demand reduction, coupled with investments in renewable energy and reclaimed water sourcing, Santa Lucia demonstrates that large-scale healthcare in hot, arid regions can be delivered with reduced resource demands.

Source: CASA Solo Arquitectos SLP

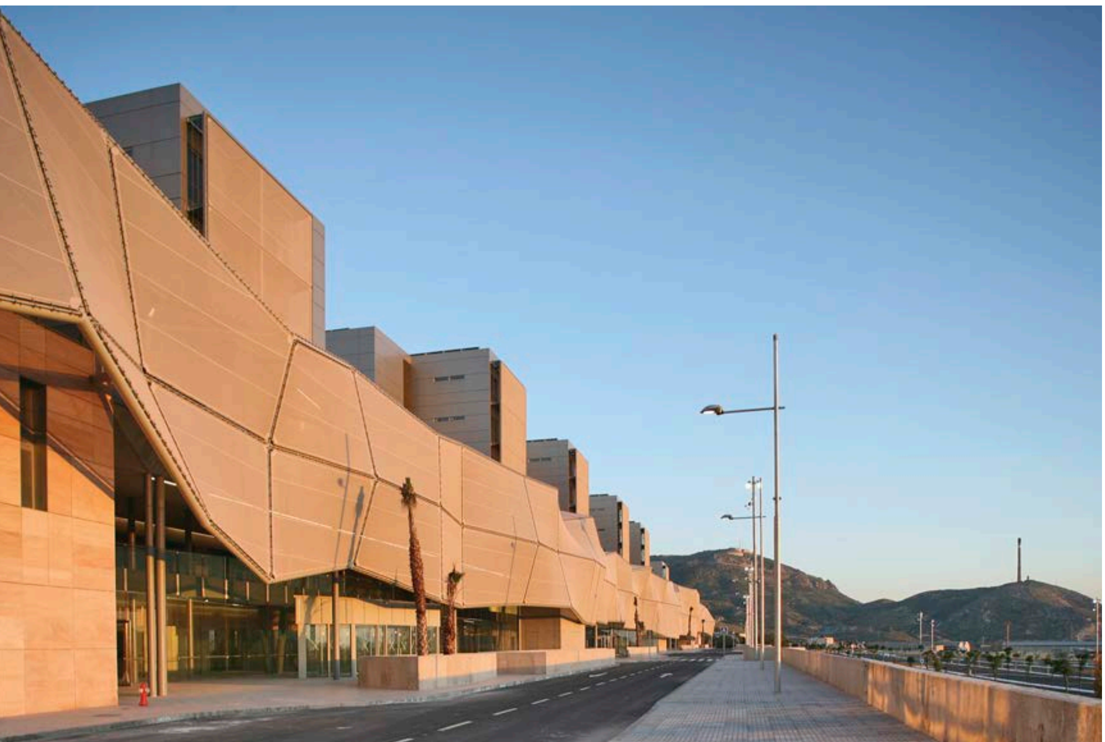


Figure 8.111 Mesh system wraps roof deck to provide continuous shading. *Source: David Pernas*

Figure 8.112 Aerial view of complex. *Source: UTE Nuevo Hospital de Cartagena*

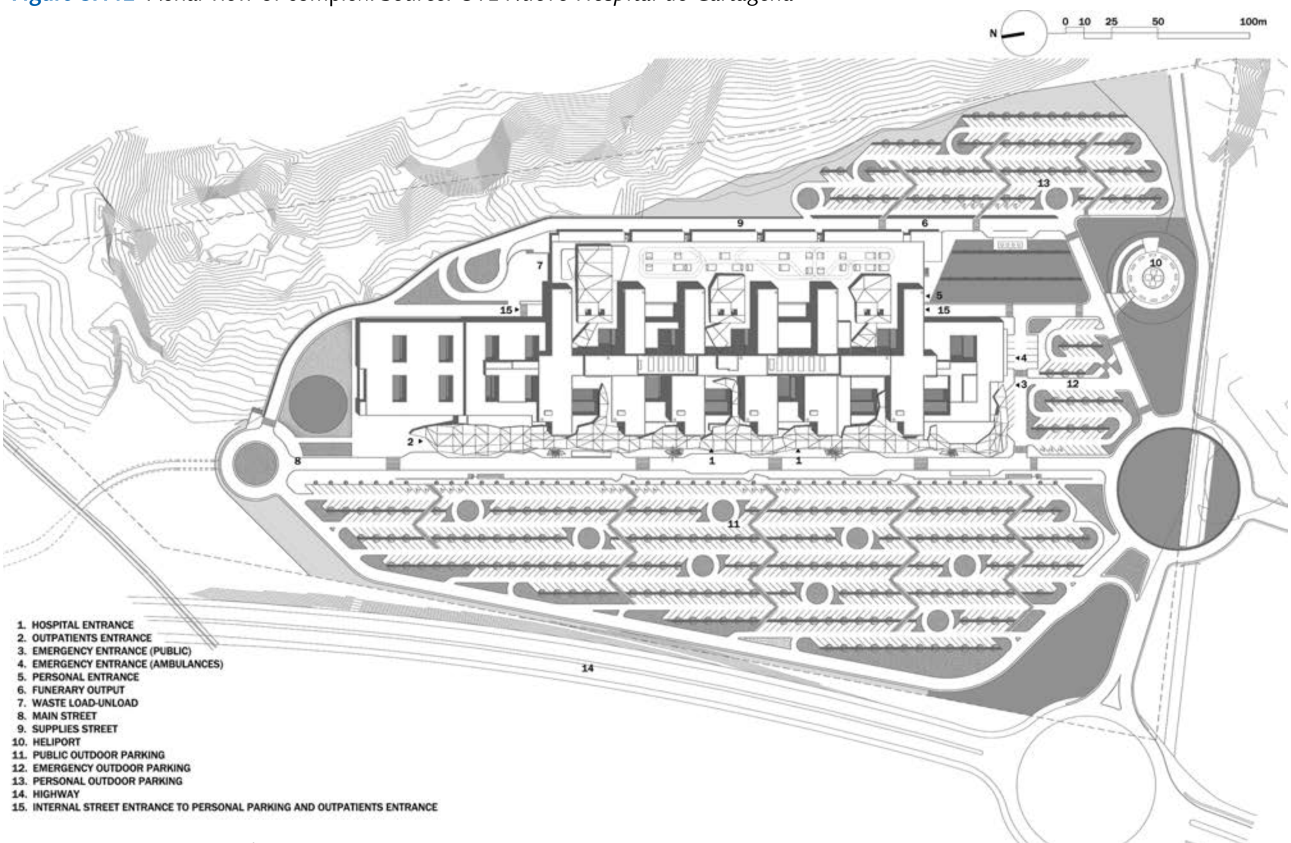


Figure 8.113 Site plan of complex. *Source: CASA Solo Arquitectos SLP*

Figure 8.114 West facade detail at bed towers. *Source: Copyright © Joaquin Zamora*

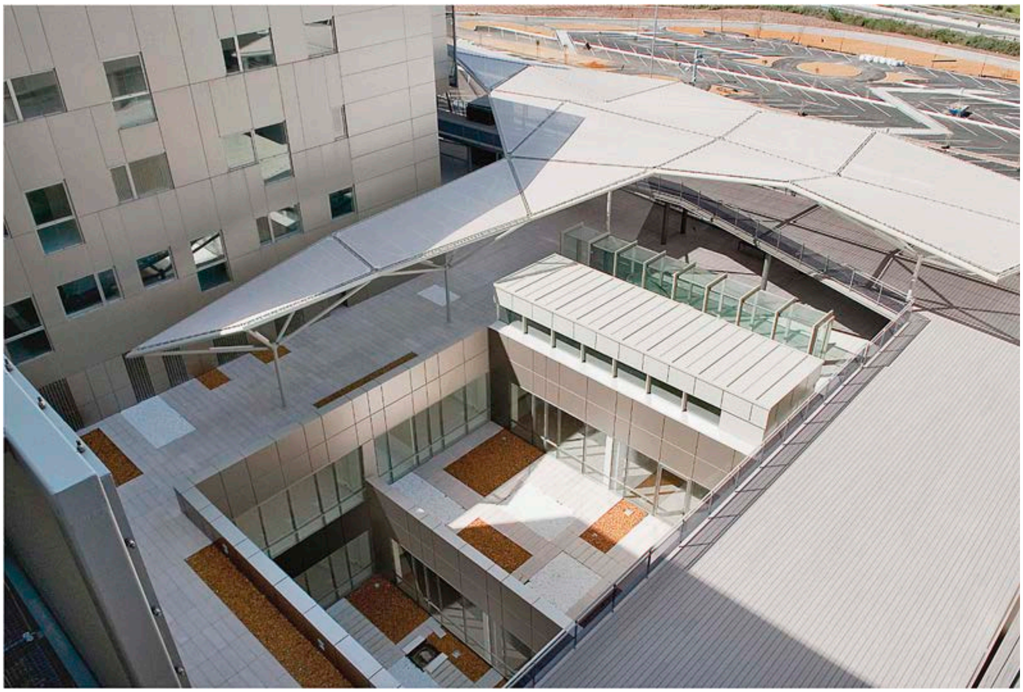


Figure 8.115 Detail of courtyards between bed towers. *Source: Copyright © Joaquin Zamora*

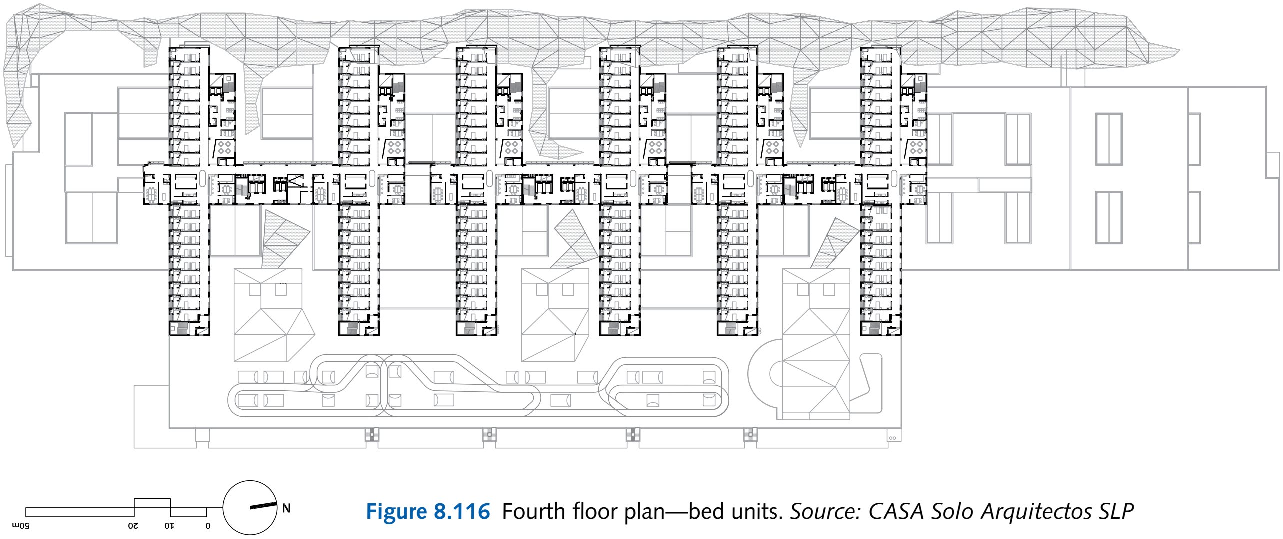


Figure 8.116 Fourth floor plan—bed units. *Source: CASA Solo Arquitectos SLP*

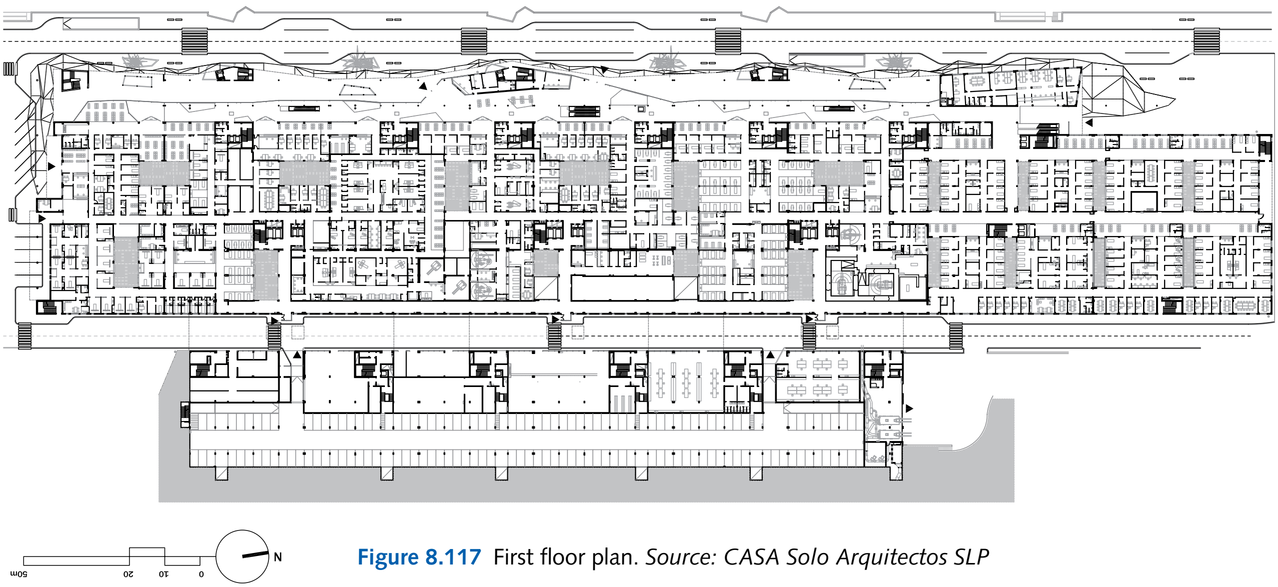


Figure 8.117 First floor plan. *Source: CASA Solo Arquitectos SLP*

Case Study 34: St. Bartholomew's and The Royal London Hospitals

London, England

OWNER: Capital Hospitals PFI (Innisfree, Skanska, Dutch Infrastructure Fund), National Health System Trust (NHS)

PROJECT TEAM:

Architect/Design Team Leader: HOK

Services Engineer: DSSR (Royal London)

Services Engineer: Troup Bywater and Andersie, (Bart's)

Structural Engineer: Skanska Technology (Bart's)

Healthcare Planner: Health Care Partnership

Construction Team Leader: Skanska

TYPE: New and Renovated Acute-Care Hospitals on Two Sites

SIZE: Total Floor Area: 2,988,000 sq. ft. (277,650 sq. m). St. Barts: 645,800 sq. ft. (60,000 sq. m) new; 71,600 sq. ft. (6,650 sq. m) renovated. The Royal London: 1,550,000 sq. ft. (144,000 sq. m) new; 183,000 sq. ft. (17,000 sq. m) renovated.

EUI: St. Bart's: 188 kBtu/sf/yr (593 kWh/sm/yr). Royal London: 174 kBtu/sf/yr (549 kWh/sm/yr)

PROGRAM DESCRIPTION: St. Bartholomew's (Bart's), a 300-bed Cancer (Phase 1) and Cardiac Center (Phase 2) and The Royal London Hospital, an 800-bed quaternary care facility

COMPLETED: 2011 (Royal London Phase 1); 2015 (Royal London Phase 2); 2010 (Bart's Phase 1); 2014 (Bart's Phase 2); 2016 final completion

RECOGNITION: NEAT "Excellent" rating

BIOME: Temperate Semi-arid

CLIMATE ZONE: Marine West Coast

AVERAGE ANNUAL PRECIPITATION: 23–29 in. (580–740 mm)

KEY SUSTAINABILITY INDICATORS

- *Site:* No additional land expansion; all construction on previously developed sites
- *Energy Responsive Facade—Royal London*: High performance envelope with 30% window to wall ratio, external shading and solar control glazing; automated external solar blinds
- *Natural Ventilation:* Cooling only provided in new construction and in specific parts of the renovations where summer temperatures are expected to surpass comfortable levels
- *Innovative Energy Distribution:* Active chilled beams (4,500 total)
- *Healthy Materials:* BRE, A-rated materials prioritized; toxic chemical avoidance based on Skanska *Restricted Substances List*
- *Construction Waste:* Project diverted more than 96% of construction waste; Returnable Transit Packaging (RTP) eliminated 40,000 cubic meters of cardboard packaging waste
- *Prefabrication:* Modular elements constructed off-site in a purpose-built Skanska facility with extensive recycling infrastructure
- *Civic Function—Bart's*: Restoration of pedestrian path and historic square, building facades

Figure 8.118 St. Bartholomew's (St. Bart's). *Source: HOK*

This single National Health Service project consists of expansion and renovation of two central London hospital campuses. Together, St. Bart's and The Royal London form the largest teaching, research, and care facility in Europe. The projects demonstrate that large, complex urban healthcare campuses can be programmatically transformed and incorporate a range of sustainable system strategies. The goal of this project is to create modern hospitals that are functional, energy efficient and promote healthy indoor environments. St. Bart's and The Royal London also demonstrate the role of healthcare in urban regeneration, while preserving the historic and cultural fabric of the surrounding communities.

CONTEXT

The Bart's and Royal London Trust project consists of 2.2 million sq. ft. (204,000 sq. m) of new construction on two campuses. The project was delivered under the largest single Private Finance Initiative (PFI) ever undertaken by the National Health Service. Capital Hospitals is responsible for designing, building, redeveloping and maintaining the hospital buildings until 2048; the NHS Trust will continue to be responsible for managing healthcare services and the hospital buildings will revert to NHS ownership following the contract.

The hospitals are managed by the Bart's and The London NHS (National Health Service) Trust, and annually care for over 700,000 people. Bart's Hospital is situated in central London, and the Royal London Hospital is in Whitechapel, East London. Prior to the redevelopment, the hospitals were in acute need of modernization and expansion following several decades of insufficient investment. The complex, phased redevelopment work began in May 2006; the final renovation phases of both the Bart's and The Royal London hospitals are scheduled for completion in 2016. Both major medical campuses consist of many disparate structures and major infrastructure elements that have been seamlessly integrated in the new facilities (Figure 8.123).

St. Bartholomew's: The redeveloped Bart's Hospital is a single building addition that replaces two dilapidated wings. The facility houses cancer and cardiac facilities. Its modern architecture blends with the hospital's historic Georgian buildings. Patients in the new hospital enjoy unobstructed views of St. Paul's Cathedral. The new construction reestablishes a major pedestrian access that at one time connected the 11th century portal through an 18th century courtyard to the public face of the site from which one views the dome of St. Paul's Cathedral. The new building, clad in Portland stone to blend into the historic surroundings, connects to the existing fourth side of the 18th century courtyard and creates an organizing atrium axially behind it. The courtyard will be permanently closed to vehicles and restored to a pedestrian plaza to enhance the Smithfield Conservation Area (Figures 8.118–8.122).

The Royal London: The redeveloped Royal London Hospital is a cluster of two inter-connected 17-story and one 10-story landmark glass towers. The hospital houses London's leading trauma and emergency care center and one of Europe's largest renal units, together with London's Air Ambulance. The site planning establishes a new axis that organizes all entries to the multiple hospitals on the site. In a gesture to link the history of the Whitechapel site, the axis originates in the landmark historic Georgian building that was the first Royal London Infirmary. Reconfiguration of extensive underground infrastructure included construction of a network of service tunnels for supply chain management (Figures 8.124–8.126).

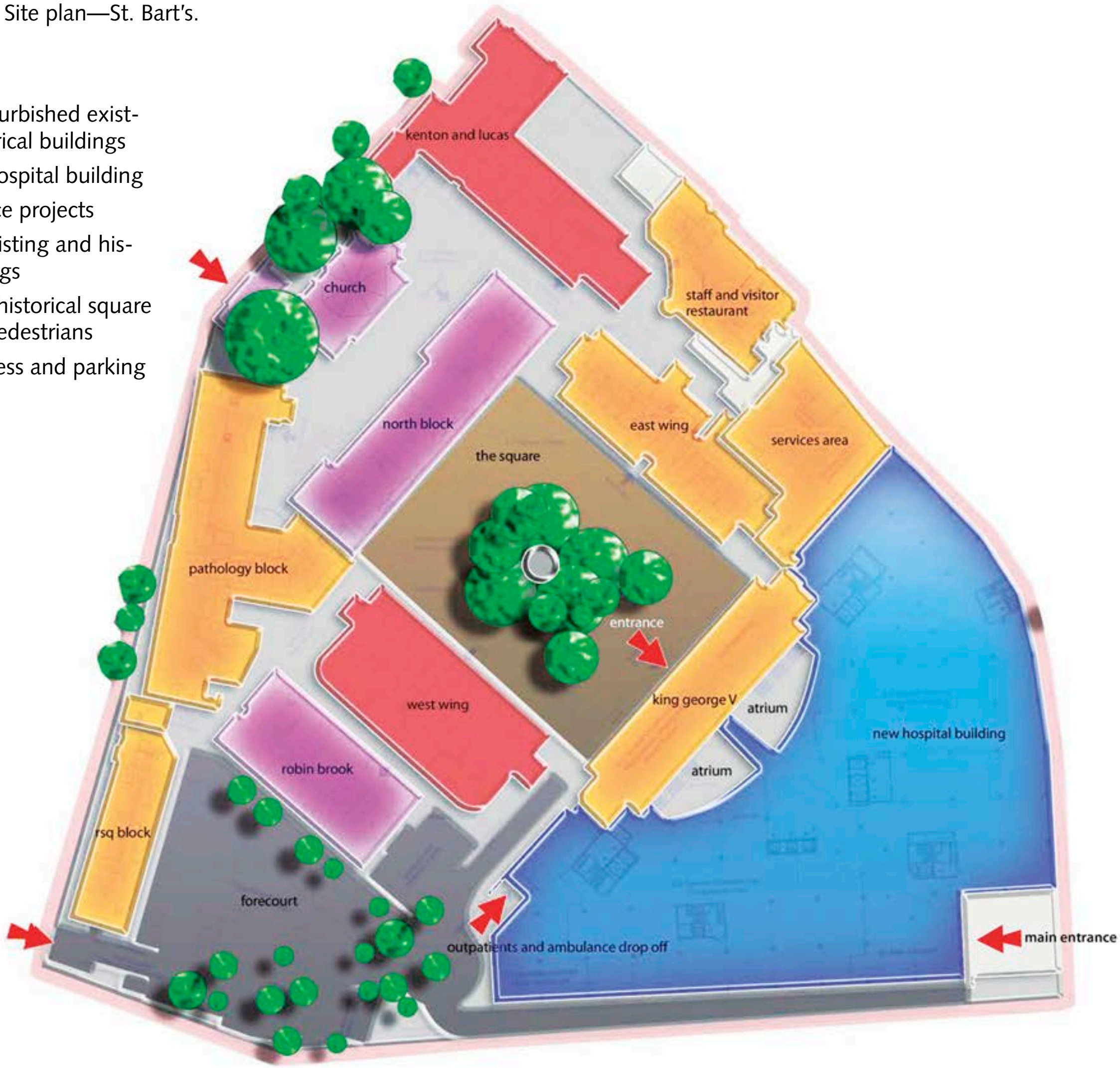


Figure 8.119 Site plan—St. Bart's.
Source: HOK

Key

Orange—Refurbished existing and historical buildings

Blue—New hospital building

Red—Advance projects

Pink—Key existing and historical buildings

Brown—The historical square returned to pedestrians

Arrows—Access and parking

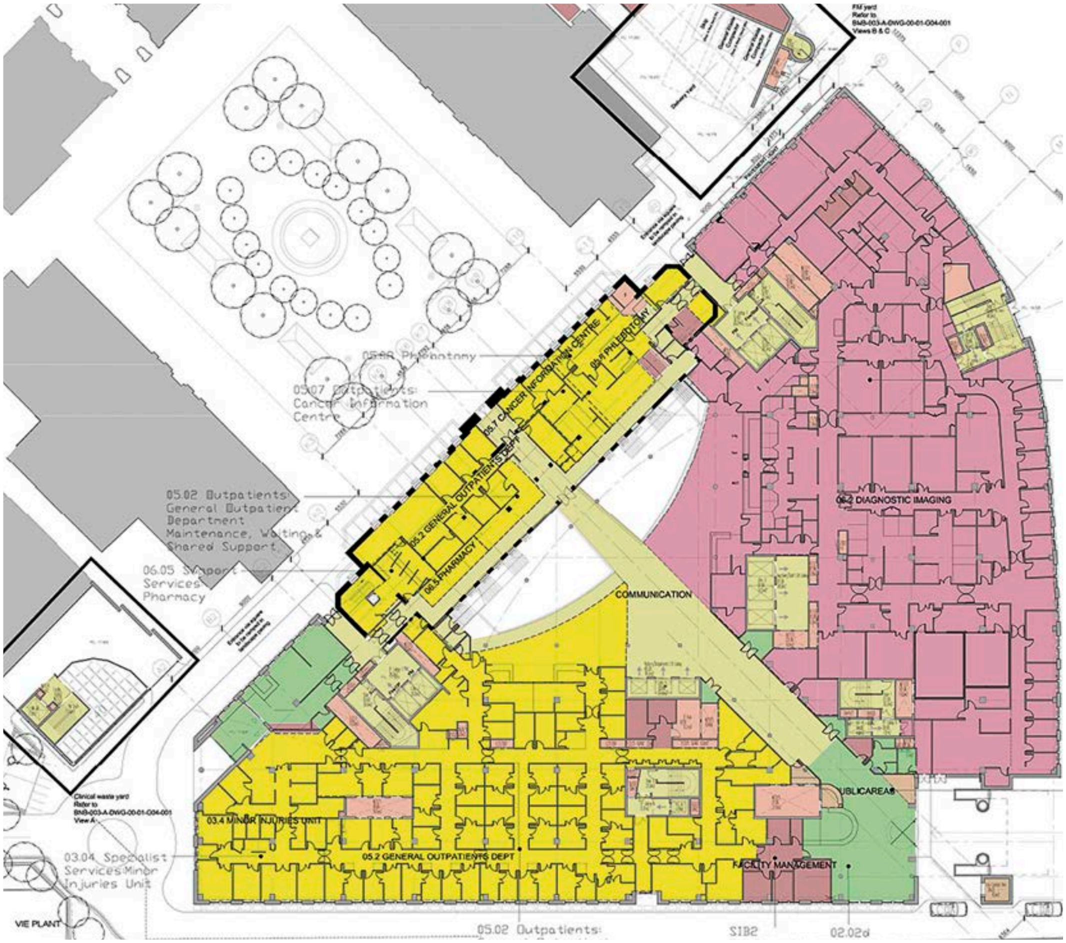
The hospital planning arranges wards alongside relevant diagnostic and treatment facilities in discrete "zones." The design is intended to facilitate patient transfer and access to relevant facilities while sufficiently separating patient areas and treatment facilities to minimize noise and disturbance. Over 40 percent of hospital beds are single rooms, with the remainder in large four-bed bays. Men and women will have separate facilities; relatives are accommodated in adjacent overnight stay facilities.

SITE AND BUILDING

The project is constructed to meet the NHS Environmental Assessment Tool (NEAT) Excellent rating, which requires the incorporation of sustainability into every stage of building design, construction, commissioning and management. The project was used in the development of BREEAM for Healthcare and has already received numerous sustainability-related awards.

►Figure 8.120 Street facade—St. Bart's. *Source: HOK*

►►Figure 8.121 Interior atrium at night—St. Bart's. *Source: HOK*



Key

Yellow—Outpatient

Pink—Diagnostic & Treatment

Green—Public waiting/ reception

Light yellow—Primary circulation

Figure 8.122 First floor plan—St. Bart's. *Source: HOK*

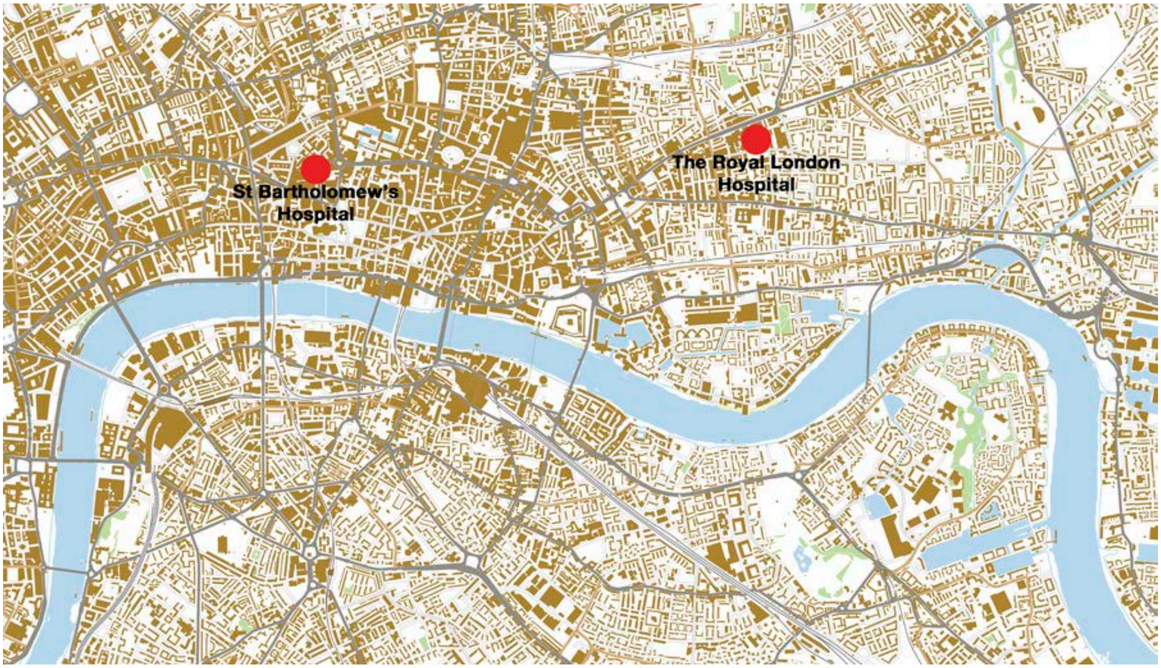


Figure 8.123 Map of central London with campus locations. *Source: HOK*

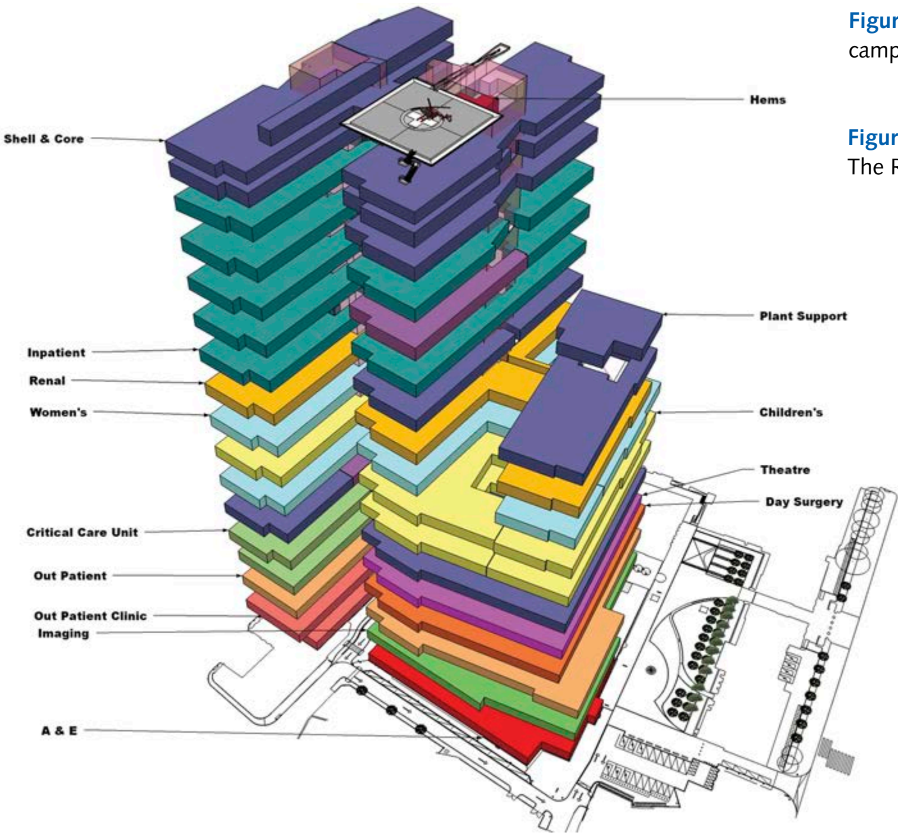


Figure 8.124 Functional stacking diagram—The Royal London. *Source: HOK*

All new buildings are being constructed on previously developed sites within the hospital grounds; no adjacent communities are being disturbed. The project consists of demolishing dilapidated buildings, restoring existing historic buildings, landscaping areas and enhancing pedestrian access.

The dense urban sites and requirement to maintain continuous operation on both campuses dictated a set of innovative construction management practices. A total of twelve 6-story buildings, one 7-story building and several low-rise structures were "deconstructed" to facilitate the replacement structures on both campuses. Systematic waste management processes and the creation of an offsite Construction Consolidation Center to minimize and manage the on-site delivery congestion led to 96 percent construction waste recycling.

Energy efficient systems include separation of ventilation and conditioning, with chilled beams as the primary innovative energy distribution system. Heat recovery systems reduce waste heat, while efficient ventilation fans, low-energy lighting and variable speed drives ensure that energy use better follows demand. Energy efficient medical equipment is installed throughout. New buildings have a high-performance envelope: improved insulation, external shading and solar control glazing reduce the need for cooling in the summer.

A focus on prefabricated materials included 1,200 external cladding panels and 1,000 pipe modules that carry up to nine services, such as duct work, oxygen, nitrogen, water and cable trays. The prefabricated materials were manufactured in a purpose-built Skanska factory with excellent recycling infrastructure. Returnable Transit Packaging (RTP) was used to transport mechanical and electrical products, such as 30,000 light fittings. RTP uses robust plastic crates that can be collapsed and returned to suppliers for reuse. The technique reduced cardboard packaging waste by approximately 8 tons and reduced damaged goods.

All new wood used on the project is certified by the FSC (Forest Stewardship Council) or the PEFC (Program for the Endorsement of Forest Certification).

The redeveloped hospitals are designed to create indoor environments that promote patient healing and enhance the experience of both employees and visitors. The wards are light and airy and have large windows and glass atria to allow natural light into the buildings. The buildings are fully air conditioned. Incoming air is filtered to ensure that pollutants from the surrounding city do not compromise the sterile hospital environments.

Skanska required each supplier to identify any high VOC (volatile organic compound) or toxic materials at the project planning stage, resulting in the early elimination of potentially harmful substances. Non-toxic and water-based substances, such as floor adhesives, were used to improve indoor air quality. Skanska developed their UK Restricted Substances List during the course of the project.

Together, these projects demonstrate that large-scale, dense urban hospital replacement projects can achieve aggressive energy efficiency goals and enhance the communities within which they provide medical care. The total transformation of these two inner-city London hospitals demonstrates the importance of focusing on innovative construction practices in the context of sustainable building goals.

Source: HOK

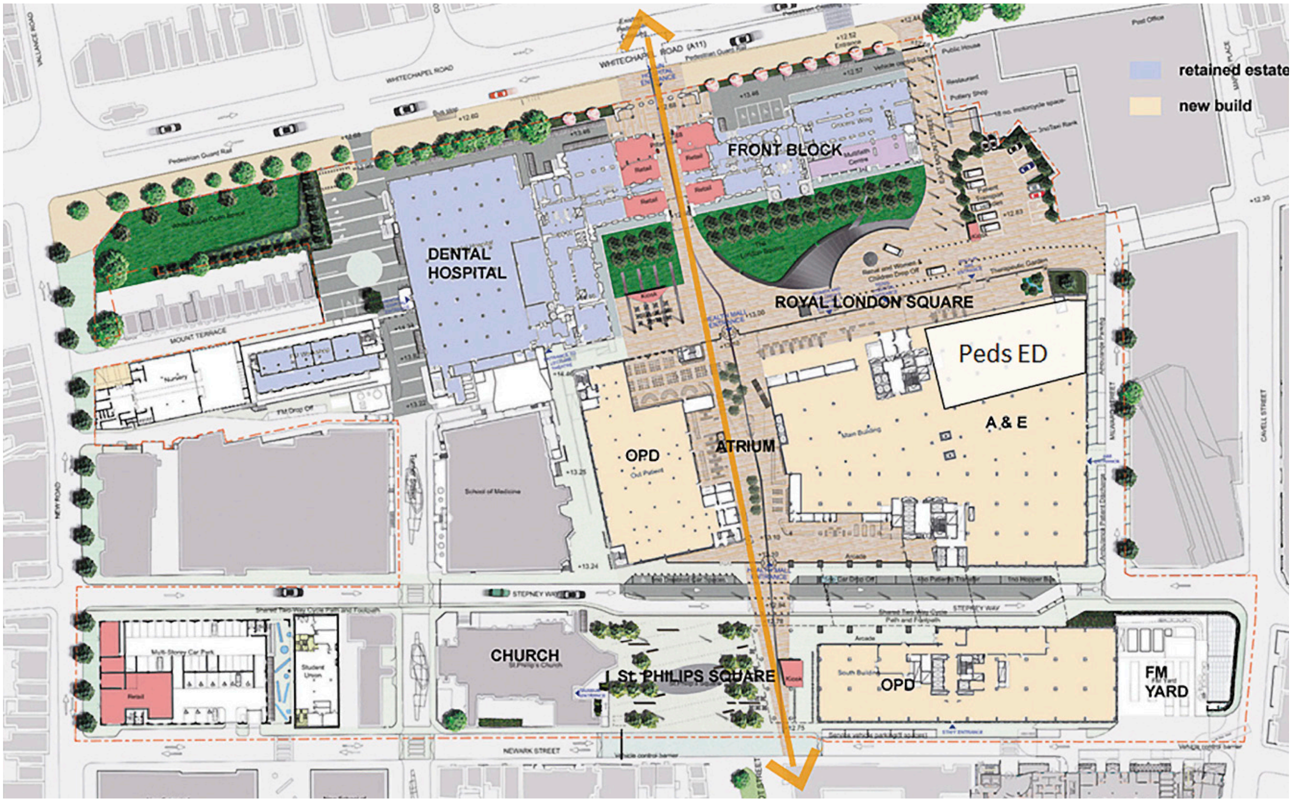


Figure 8.125 Site plan—The Royal London. *Source: HOK*

Figure 8.126 The Royal London on the London skyline. *Source: HOK*

Case Study 35: Swedish Medical Center

Issaquah, Washington

OWNER: Swedish Health Services (hospital) and Hammes (medical office building)

PROJECT TEAM:
Architect: CollinsWoerman
Civil Engineer: Coughlin Porter Lundeen
Landscape Architect: Brumbaugh & Associates
Mechanical Engineer: CDi Engineering
Electrical Engineer: Sparling
General Contractor: Sellen Construction

TYPE: New Acute-Care Hospital and MOB Campus

SIZE: 377,982 sq. ft. total/353,173 sq. ft. (35,115/ 32,810 sq. m) occupied hospital/Central Utility Plant (CUP); Site: 12.5 acres (5 ha)

EUI: Hospital: 114 kBtu/sf/yr (333.9 kWh/sm/yr) Campus: 95 kBtu/sf/yr (315 kWh/sm/yr)

PROGRAM DESCRIPTION: Comprehensive medical campus (588,528 sq. ft. [54,676 sq. m]) comprised of a 210,546 sq. ft. (19,560 sq. m) medical office building, and hospital (opening with 80 beds, expanding ultimately to 175 beds); with both surface and 50,688 sq. ft. (4,710 sq. m) structured parking; rental retail and community functions

COMPLETED: 2011

RECOGNITION: *Contract Magazine*, 33rd Annual Interior Award for Healthcare, 2012

BIOME: Temperate Humid

CLIMATE ZONE: Mediterranean

PRECIPITATION: 57 in. (1,447 mm)

KEY SUSTAINABILITY INDICATORS

- *Innovative Parking*: Underground parking reduced impervious area by 50,700 sq. ft. (4,710 sq. m)
- *Green Roof:* 16,212 sq. ft. (1,506 sq. m) vegetated roof
- *Low EUI*: Hospital: 114 kBtu/sf/yr (333.9 kWh/sm/yr) Campus: 95 kBtu/sf/yr (315 kWh/sm/yr)
- *Innovative Source Energy*: Energy system utilizes a heat recovery chiller (HRC) to recover heat from exhaust air and chilled water loads, process loads and meets up to 80% percent of building heating and domestic hot water requirements
- *Innovative Energy Distribution*: Hydronic heating used in atrium and MOB; low pressure and low velocity air handling units utilizing multiple supply and return fan arrays reduce fan energy
- *Salvaged Materials*: Finish cladding of exposed public elevators constructed of 10,500 LF (3,200 LM) of Douglas fir wood reclaimed from gymnasium upgrade projects
- *Construction Waste:* 93 percent of construction waste diverted from landfills for recycling and reuse
- *Civic Function:* Campus includes 16,000 sf of destination retail services for staff and patients; cafeteria is full-service restaurant featuring local and organic food choices

Figure 8.127 Swedish Medical Center, Issaquah Campus. *Source: Benjamin Benschneider/OTTO*

Swedish/Issaquah demonstrates how high performance goals considered alongside a compelling design vision can yield an exceptional healing environment. As of its opening, the daylight infused facility in a breathtaking setting appears to be the most energy-efficient operational hospital in the U.S.

CONTEXT

Part of the Providence Western Washington Region System, Swedish is the community medical campus serving the population of the New Urbanism community of Issaquah and immediate surrounds. Located in the Issaquah Highlands just inside the Seattle urban growth boundary with amazing views of the Sammamish Plateau, Olympic and Cascade Mountains, the campus abuts state forests and preserves. The hospital is located on a previously cleared land parcel, which meant that no trees were removed for its construction. Underground parking further reduces the development footprint.

The key element of the project is its energy performance. Funding provided by Puget Sound Energy Custom Grants enabled the team to exceed energy code and industry standards. The initial hospital energy goal was set at 150 kBtu/sf/yr; as the systems were modeled in design, it became clear that the hospital building would exceed this target. The energy model, as developed by the design team, predicted an EUI of 135 kBtu/sf/yr. As of one year of its initial operation, the hospital is operating at 114 kBtu/sf/yr. The MOB is operating at 75 kBtu/sf/yr, and the combined campus total is operating at 95 kBtu/sf/yr.

SITE AND BUILDING

The hospital and MOB are distinct building elements aggregated in a single structure connected by an atrium, with a single public elevator core. A separate Central Utility Plant (CUP) provides mechanical infrastructure for the campus. The hospital component is organized around a large courtyard garden, reducing lighting loads and providing daylight and views of the wooded mountains to all inpatient rooms. The courtyard includes a ramp to the lower level, which brings both daylight and nature to below-grade support service areas, accommodates air intakes, and supports active design goals.

Figure 8.128 The central courtyard. *Source: CollinsWoerman*

Thirty percent of the aggregate building envelope is composed of high-performance insulating glass; the balance is a highly insulated cementitious rainscreen system. Roof assemblies combine high-reflectance and vegetated systems with R-30 insulation, 42 percent above code minimum. The building employs a combination of orientation specific overhangs, shading devices, massing, and orientation to reduce solar gain.

The atrium lobby includes a working fireplace and woodclad central elevator tower. Old-growth Douglas fir elevator tower wood was salvaged from reclaimed bleacher inventories obtained from schools in Chicago and North Dakota. Key community elements include a ground floor retail complex focusing on the needs of pregnant women, new moms and babies, a large selection of post-operative garments as well as private prosthesis fittings provided by specialized staff. A walking trail encircles the site and connects to the community-maintained trail system. Parking is a combination of surface and below-grade garage.

The restaurant serves locally sourced, healthy food. All deep-fat fryers have been removed from the kitchen in favor of healthier options. The restaurant has also eliminated soft drinks in an effort to demonstrate its commitment to helping families and staff select healthier options.

Key energy features include an advanced heat recovery system that captures abundant waste heat from the hospital's chilled water system and uses it for building and water heating needs (i.e., heat recovery chiller) coupled with variable-air-volume multiple fan array air handling units. Coupled with better duct pressure controls, this yields tighter ventilation control and larger energy savings. The hospital's new low-static pressure

Figure 8.129 The central atrium. *Source: Benjamin Benschneider/OTTO*

Figure 8.130 Main entrance. *Source: Benjamin Benschneider/OTTO*

duct system, with larger diameter ducts and lower air speeds, also reduces energy consumption because fans don't have to work as hard. This system is similar to one of the options modeled in the University of Washington *Targeting 100* study (see Chapter 5).

In the complex's five-story medical office building, owned by Hammes and leased to Swedish, a new high-efficiency gas hydronic space heating system substantially reduces energy demand. While the hydronic system had a higher initial cost and 16-year payback, a PSE grant reduced payback to less than one year.

Another key hospital feature is an innovative operating room (OR) setback system. Standard control system setup is "unoccupied," reducing air changes from 20 to 8 per hour. OR clinical staff tap a simple touch screen to set the occupancy duration, in hours, for each room. Thirty minutes prior to shutdown, the room control panel blinks to alert staff; occupancy sensors prevent the room from shutting down while a case is in progress. Additional energy conservation measures include LED exterior lighting and daylighting controls for all corridors and daylit public spaces.

Impressive energy savings are accruing: an estimated 4.12 million kWh and 361,000 therms a year in the hospital itself, for projected annual savings of $533,000. With the medical office building saving an estimated 1.52 million kWh a year, Hammes will recoup a projected $83,000 annually. Continued adjustments in building systems and operations carried out by the Swedish engineering staff may ultimately reduce hospital energy use to as low as 100 kBtu/sf/yr—more than 60 percent less than the 250 kBtu/sf/yr average for Northwest hospitals and meeting the 2030 Challenge for 2015.

These sustainable design accomplishments—alongside its innovative program that combines retail, ambulatory, and acute care—have led to this resounding accolade: "This is not just a hospital, it's the new way of providing healthcare."

Source: CollinsWoerman and Swedish/Issaquah

Table 8.1 CO_2 Emissions Reduction

CO_2 Emissions Equivalent	Average Seattle Hospital	Swedish Issaquah	Difference per Year	Environmental Benefits of Reduced Energy Consumption
Metric tons CO_2	10,846	4,141	6,705	Less metric tons CO_2
Barrels of oil	25,223	9,630	15,593	Less barrels of oil
# of homes electricity use	1,352	516	836	Less # of homes electricity use
# of homes thermal energy use	939	359	580	Less # of homes thermal energy use
Railcars of coal burned	59	23	36	Less railcars of coal burned
Equivalent passenger vehicles	2,127	812	1,315	Less equivalent passenger vehicles
Gallons of gasoline consumed	1,215,919	464,238	751,681	Less gallons of gasoline consumed

Source: Jeff Grinzel, Swedish/Issaquah
www.epa.gov/cleanenergy/energy-resources/calculator.html#results

TEN LESSONS LEARNED

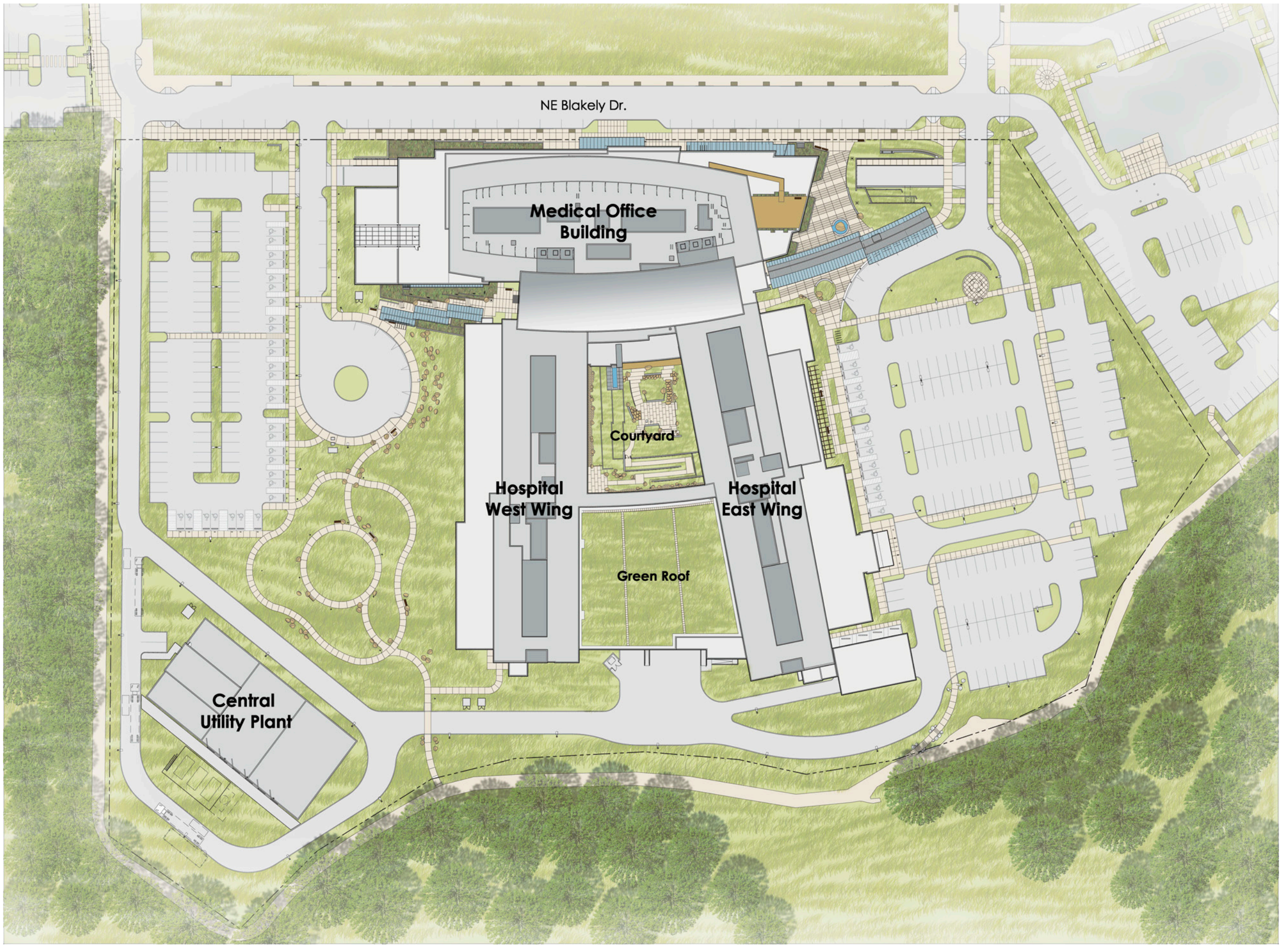
1. Invest in glazing and building envelope design to exceed current energy code standards. Commission the envelope to maximize performance.
2. System commissioning must extend throughout a full round of seasonal variations—i.e., one full year of operation.
3. Occupant psychology is an important consideration during design. Perceptions about comfort are major influences in the energy use once the hospital opens. In general, occupants are supportive of energy conservation as long as they are not inconvenienced. People don't want to be told to either put on a sweater, or work in an environment that they perceive is too cold.
4. Larger ducts for reduced air velocities and low static pressures are a good design practice where achievable. Mechanical and architectural consultants must agree to work together on this.
5. Zoning of air handling systems has a major impact on HVAC energy use, particularly regarding reheat. Key lessons learned: consider nursing unit core zoning, taking care to separate nursing stations from equipment/support rooms such as medication/nourishment, etc. Do not zone departments with disparate cooling loads together.
6. Procedure rooms for endoscopy/bronchoscopy, C-Section, and the like should be supplied with air from surgery AHUs. If these spaces are zoned with other spaces, the discharge temperature must be set too low for other uses, driving needless reheat energy use.
7. Watch pressurization; spaces such as Central Sterile Supply (CSS) that are pressurized should be designed with air locks at entry points to reduce energy waste.
8. Consider separating stationary reception positions from spaces such as ED and Imaging waiting areas with air exchange rates as high as 12 ACH, or add radiant floor or ceiling panels. Can we expect people to be comfortable and not complain about excess air noise?
9. Limit occupant lighting controls in public areas or corridors. If the lighting is on automatic or daylight control, limit the ability for staff to override it. All it takes is one staff person who insists on turning on all the lights because of their individual perception.
10. Engaging engineering staff in high-performance operations and maintenance is essential but challenging. High-performance designs, with their Building Automation Systems and more advanced control sequences, tend to be complicated, while most staff want things to be simple to understand and operate. A high-performance building requires human intelligence to operate.

"The best approach is to make the systems operate so well that the staff and patients rarely notice. You can't make everyone happy but if the systems are working efficiently and they can be comfortable then you can have a high performing hospital."

Source: Jeff Grinzel, Swedish/Issaquah

Figure 8.131 Lobby features café at right and reclaimed woodclad public elevators beyond. *Source: Benjamin Benschneider/OTTO*

Figure 8.132 Site plan. *Source: CollinsWoerman*



Case Study 36: Ysbyty Aneurin Bevan (Aneurin Bevan Hospital)

Ebbw Vale, Blaenau Gwent, Wales

OWNER: Aneurin Bevan Health Board

PROJECT TEAM:

Architect: Nightingale Associates

MEP & Structural Engineer: ARUP

Contractor: BAM

TYPE: Replacement Acute-Care Community Hospital

SIZE: 137,240 sq. ft. (12,750 sq. m); Site: 12.9 acres (5.2 ha)

EUI: Not Available

PROGRAM DESCRIPTION: Two-level public community acute care hospital; 96 inpatient beds, 11 mental health beds; includes Mental Health Unit day center, outpatient, therapy, radiology, minor injury and birthing facilities

COMPLETED: 2010

RECOGNITION: NEAT Excellent; "A" rated Energy Performance Certificate; Exemplary Scheme by Secured by Design

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

AVERAGE ANNUAL PRECIPITATION: 44 in. (1112 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia:* Courtyard connections and variety of outdoor spaces and activities
- *Habitat Restoration:* Local landscape and biodiversity plan
- *Brownfield:* Site of former Corus Steelworks
- *Climatic Design:* Building form optimizes daylight, views, shade, and natural ventilation
- *Energy Responsive Facade:* External solar shading on southeast and southwest facade reduce heat gain
- *Natural Ventilation:* User-operated mixed-mode ventilation in patient areas
- *Innovative Energy Distribution:* Hydronic heating
- *Renewable Energy:* Biomass boiler generates heat, hot water, and underfloor heating
- *Recycled Content:* Project incorporates materials salvaged from former steelworks
- *Civic Function:* First major development of former Corus Steelworks
- *Occupant Control:* Individual thermal control allows patients to control natural ventilation/mechanical ventilation options

Figure 8.133 Ysbyty Aneurin Bevan. *Source: Charlotte Woods*

Named for the founder of the UK's National Health Service, Aneurin Bevan Hospital is the first public hospital in Wales to have exclusively single patient rooms. Constructed on a brownfield—the site of a former steelworks—great care was taken to remediate and regenerate the contaminated site. Consistent with climatic design principles, the extensively vegetated hospital is designed in a distinctive zig-zag shape to optimize daylight, views, shade, and natural ventilation (Figures 8.133, 8.138, and 8.139).

CONTEXT

Ysbyty Aneurin Bevan (Aneurin Bevan Hospital) is named after Aneurin Bevan, an Ebbw Vale resident who started work as a coal miner at age 14, later becoming a Member of Parliament from 1929 until his death in 1960. As the postwar Minister of Health, Bevan spearheaded the creation of the National Health Service, which provides point-of-care health services to all Britons free of charge. The NHS's 60th anniversary in 2008 coincided with the start of the hospital's construction process.

Ebbw Vale, an early rural settlement, was transformed by the Industrial Revolution. The Ebbw Vale Iron Works opened in 1778; in the 1930s–1940s, the steelworks was the largest in Europe. In the 1960s it employed more than 14,000 people, but by the turn of the century the industry had collapsed. In 2002, it closed. Demolition of the former buildings began in 2003, followed by a five-year remediation initiative. A large regeneration process has begun: the vision for the site is for a high-quality, vibrant mixed-used development comprising commercial, residential, health, education and leisure facilities.

Ebbw Vale's unemployment rate is among the highest in the United Kingdom; economic revitalization is a key priority. Located on the site of the former Corus Steelworks, Ysbyty Aneurin Bevan is the first public building completed on the remediated brownfield site. It is part of a larger development initiative to regenerate the industrial site. Future plans include locating 720 new homes next to the hospital and other public and private enterprises with the goal of creating approximately 2,000 new local jobs.

SITE AND BUILDING

Ysbyty Aneurin Bevan is part of the Welsh Assembly's "Designed for Life: Building for Wales" procurement framework. The intent of the private room model is to improve infection control, patient privacy, and patient control of lighting and thermal comfort, thereby improving patient recovery rates and nursing flexibility. Recognizing the therapeutic value of connections with nature, patients have direct access to landscaped courtyards, gardens and views (Figure 8.134). As the former steelworks use resulted in degradation of site ecology and chemical contamination that required remediation, site preparation included substantial cut and fill. Site work was carefully undertaken to preserve as much of the earth materials as possible, particularly along the slope.

The hospital's layout is a distinctive zig-zag pattern that orients and connects the three 32-bed wards, each with four eight-bed clusters, to a central spine. This building form, selected after evaluating other options including hub and spoke, linear, and radial, provides each room with optimum orientation for daylight, views, and natural ventilation. The spine, constructed from steel recovered from the remaining industrial buildings, provides a material connection to and continuity with the sites' former activities.

The main entrance addresses a public square along the former steelworks' central communication spine. The hospital is designed with two distinct sides: the eastern face offers a public, urban edge with formal detailing and materials that link to the site's industrial

Figure 8.134 Plan enclosed courtyards. *Source: Charlotte Woods*

heritage. The more domestically scaled western face houses inpatient and staff programmed areas oriented toward natural and landscaped areas, with terraces providing patients with direct access to a sheltered outdoor area (Figure 8.135).

The three 32-bed wards are each named after a Welsh river—Ebbw, Sirhowy, Tyleri. The winning entries from a photography competition bring the rivers inside, connecting patients, staff and visitors to those identifiable environmental markers, with photographs of the rivers placed at entrances to the wards and integrated into other elements of the interior design (Figure 8.136).

Building orientation, along with integrated shading features, high-performance mechanical systems and a sophisticated approach to ventilation substantially reduces energy demands. A brise-soleil shades the southeast and southwest facades. Its ability to prevent overheating was tested and verified using an Integrated Environmental Solutions thermal modeling system.

From its conception, sustainability considerations were at the forefront of the facility's planning: a local landscape and biodiversity management plan, travel plan, and sustainable energy strategy were developed early in the planning phase. Numerous well-integrated sustainability features were realized as a result of strate-

Figure 8.135 View of balconies from courtyard. *Source: Charlotte Woods*

Figure 8.136 Private patient room. *Source: Charlotte Woods*

gic planning decisions early in design addressing site, energy, indoor environmental quality, and materials selection. The project earned a NEAT "Excellent" rating (with a score of 76.6%). In addition, the hospital earned an "A" rated energy performance certificate (with a score of 20).

A biomass-fueled boiler fulfills heating, hot water, and underfloor heating demand for different parts of the building. A building management system ensures that zoned areas are conditioned appropriately to account for the unique seasonal adjustments required in this location, with more or less energy used to match actual conditions. In conjunction with the envelope efficiency measures, annual CO_2 emissions are estimated to be 22.6 kg CO_2/sq. m/yr.

Clinical areas benefit from mixed-mode ventilation that primarily allows the user to control the level of natural ventilation, with background mechanical support where required for specific clinical purposes. The aggregated performance of these features results in an air permeability rate of 3.3 $m^3/h.m^2$ at 50Pa, meeting the UK Building Regulations requirements, and confirmed by air leakage tests conducted by the Contractor at the end of construction.

The patient controls large operable windows connected to the individual patient room controls. Generously sized glazing is strategically placed to ensure maximum daylight for patient and multi-occupant spaces, and views to the outside landscape areas in the valley and the landscaped courtyards and gardens.

The facility's materials strategy prioritized recycled content, recyclable and reused, with some materials derived from the industrial buildings remaining on the site. The timber is FSC-certified. Addressing the material cycle, construction-generated debris was minimized with emphasis on waste reduction and recycling, and the building's space planning ensured that adequate area was provided to support an effective operational recycling program (Figure 8.137).

This project demonstrates how a commitment to economic vitality and health can place healthcare in the center of a new dialogue on civic responsibility and presence. This hospital now anchors the steelworks urban revitalization efforts, and demonstrates that sustainable building can and should be a foundation for the next generation of development.

Source: Nightingale Associates

Figure 8.137 Exterior massing at the entry drive provides view of natural and salvaged material palette. *Source: Charlotte Woods*

Figure 8.138 Site plan. *Source: Nightingale Associates*

Figure 8.139 Concept sketch. *Source: Nightingale Associates*

PART 4

VISIONING THE FUTURE

CHAPTER 9

TOWARD A NEW LANGUAGE OF FORM

> The hospital as a machine for healing has become an anachronism. As a building type, the hospital remains a curious amalgam, with medical technology often pitted against humanist concerns.... There is little doubt that architecture can, and should, play a crucial role in humanizing the hospital. At first glance, this seems rather unlikely. How can architecture contribute to revolutionizing healthcare?
>
> STEPHEN VERDERBER

INTRODUCTION

If "architecture is the clothing we put on our institutions" (Guenther 2006), what is the shape of the medical delivery system that determines the current fashion of healthcare buildings? What aspects of the medical delivery system have informed current design archetypes? What is emerging in medicine's relationship to ecology that will inform the delivery system and shape the healthcare system—and its buildings—in the future? Architectural historian Stephen Verderber postulated a near-term challenge to create a "sustainable health architecture" based on a new aesthetic—"one in which the dominant and depressing parking garage no longer symbolizes an unquestioning acceptance of the role of the automobile in our lives" (Verderber and Fine 2000). As public health and medical practitioners postulate the role of the automobile in chronic disease, possibilities for new hospital archetypes emerge.

This chapter explores the typology of architecture for health—both its historic evolution and ideas about its future. The case studies in this book demonstrate key differences between the typologies of international and North American healthcare buildings—differences based on fundamentally different responses to the relationship between the built environment and the natural world.

North American hospitals have become completely uninhabitable without massive inputs of electric lighting and mechanical ventilation—a permanent "life support" infrastructure—for the sake of efficiency and technological accommodation. Elsewhere in the developed world, building regulations requiring access to daylight and operable windows in occupied buildings have ensured that hospitals remain fundamentally "habitable" without these artificial inputs. Medical technology and processes are accommodated within the definition of a habitable building. The European hospital building becomes, to North Americans, a demonstration of "the road not taken."

In energy resource–constrained settings where building regulations are limited, there is no choice except to design and construct climatically tuned, passive hospital buildings that are inherently "habitable" without reliance on external energy inputs. Indeed, the lesson of Butaro Hospital, Butaro, Rwanda (Case Study 22, Chapter 8), is that virulent forms of tuberculosis incubate in poorly maintained, under-resourced, mechanically ventilated hospital buildings—a cautionary tale. Butaro Hospital architect MASS Design Group notes that by moving circulation and waiting rooms to covered outdoor patios and providing robust natural ventilation, infection control is dramatically improved.

The differences in building typology, which have profound implications for resource consumption, must be acknowledged, debated, and resolved. For much of the developing world, the creation of a medical service delivery structure is just beginning. The forms of those systems, and the buildings that partner in care delivery, have yet to be designed. The biggest challenge is also the biggest opportunity: how to evolve bioregionally appropriate, human-scaled healthcare building typologies that reflect twenty-first-century realities of climate change and ecological stewardship and, by doing so, resist exporting a single model reliant on an unsustainable ecological footprint. The first path encourages innovation and entrepreneurial creativity to flourish, with the promise to bolster local economies and enhance human, community, and ecosystem health. Continuing to enable the latter will further exacerbate economic and social inequities and ecological distress.

THE DEVELOPMENT OF THE MODERN HOSPITAL

> The mega-hospital was conceived in strict opposition to nature . . . . The triumph of minimalism and high technology was everywhere to be found in the modern hospital: the lack of natural ventilation, the shrinkage of the window aperture and a diminution of the total amount of glazed area, adoption of the hermetically sealed building envelope, dependence on artificial lighting over natural daylight, the rise of the block hospital and its rejection of courtyards and other green spaces for use by patients, and a de-emphasis on overall patient amenity were but a few technologically driven modern developments.
>
> —Verderber and Fine (2000)

The twentieth-century hospital, in its quest to accommodate rapid and chaotic changes in urbanization and suburbanization, medical care delivery, and medical and construction technologies, relegated a vision of healing, wholeness, and connection to nature to the past. While originally conceived of as "places of hospitality," almshouses for the poor, or hostels for pilgrims, by the early nineteenth-century rapid development, urbanization, and industrialization had transformed these "spiritual" care places to secular repositories for serving both medical needs of patients and the science and education of physicians and surgeons.

The earliest hospitals grew from religious acts of mercy; many were associated with monasteries. For the most part, care was directed at the classes who lacked social or economic support. By the early seventeenth-century, large, formally symmetrical ward buildings arranged around courtyard gardens, such as the Ospedale Maggiore in Milan, could be found throughout Europe.

By the late eighteenth-century, lack of utilities and sanitary infrastructure amid growing urbanization was beginning to be recognized as a major issue for the health of Europe's citizens. Clean air and water were also seen as essential in hospital settings. Florence Nightingale reinforced this point of view in her *Notes on Hospitals*, published in London in 1859, in which she outlined prescriptive design measures (including dimensions for a ward and sizes of windows) to provide for abundant daylight and fresh air in patient care areas. To deprive the sick of pure air "is nothing but manslaughter under the garb of benevolence," she wrote. To respond to this vision, hospitals had to be reconfigured, which led to the development of the "pavilion hospital."

As the name implies, pavilion hospitals were often situated on large land parcels far from the dense urban environment. Here, abundant light and clean air and water were readily available. Initially, pavilion designs were limited to about three stories and featured narrow, high-ceilinged multi-bed open wards traversed by nurses. These facilities provided highly efficient, naturally lighted and ventilated patient wards in buildings arranged in a formal symmetrical relationship to nature. As urbanization continued throughout the nineteenth and twentieth centuries, however, many of these hospitals were eventually engulfed by the cities from which they had escaped.

By the late nineteenth-century, advances in diagnosis, anesthesia, and infection control were transforming the disciplines of medicine and surgery. At the same time, environmental issues, such as lighting and ventilation, still governed much of the physical arrangement in hospitals. Architect Ernest Flagg, for example, placed an operating theater with natural lighting over a chapel to form the centerpiece of New York's St. Luke's Hospital, a pavilion hospital begun in 1896. In addition, he deliberately staggered adjacent inpatient pavilion floors by a half-story to prevent potential cross-contamination of patient rooms. During this period, another, albeit short-lived, advantage of the pavilion plan came to light: As medical specialization emerged, pavilions could be designated for different purposes—such as obstetrics or pediatrics—making it easier to respond to the particular medical needs of patients.

The Monumental Block Hospital

By the second decade of the twentieth-century, a better understanding of bacteria had resulted in dismissal of the earlier assumption that elaborate natural ventilation systems were needed for asepsis. In addition, the increase in specialty medical and surgical services led to an expansion in facilities for paying patients, which increased the need for private-patient accommodations. Given the narrow footprint of early pavilion buildings, converting open-ward buildings proved challenging.

In addition, the proliferation of innovative and expensive medical technology, including inventions like the X-ray machine, concentrated medical knowledge in the hospital and gave rise to diagnostic and treatment departments that required the movement of bedridden patients across larger campuses. One-story pavilion hospitals necessitated long travel distances. Efficiency of patient movement to and from diagnostic departments demanded adjacency; travel distance analyses optimized deep floor plates and vertical arrangements. The frenzied speed of change in medical technology also forced hospitals to place greater emphasis on specialization. Medical services—from anesthesia and surgery to emergency medicine and trauma treatment—were emerging and changing faster than buildings could be constructed.

By 1910, it was clear that the increasing specialization of medicine, coupled with real estate pressure, necessitated the development of a skyscraper or block hospital typology. By 1920, flexibility was consistently emphasized to allow for expansion and response to scientific discovery (i.e., medical technology). Educator and cultural critic Neil Postman (1992) once noted, "Technology was to be the weapon with which disease and illness would be vanquished." Coupled with the pervasive twentieth-century notion of progress, the provision and accommodation of ever more complex and challenging medical technology came to define the twentieth-century hospital.

Vertical plans became possible with the advent of improved vertical transportation systems. The 1930s' urban block-plan hospital rejected courtyards and green spaces used by patients as the building height precluded direct connection with the ground plane for large numbers of patients. With this, the hospital ceased once and for all to be concerned with celebrating the connection between nature and healing. In *Medicine & Culture*, journalist Lynn Payer (1988) summed it up: "The once seemingly limitless lands gave rise to a spirit that anything was possible if only the natural environment . . . could be conquered. Disease could also be conquered, but only by aggressively ferreting it out diagnostically and just as aggressively treating it, preferably by taking something out rather than adding something to increase the resistance."

The proliferation of medical subspecialties and the emergence of the technology-driven hospital also led to specialization in the field of architecture. Prior to the twentieth-century, generalist architects designed the hospital building. By 1930, "hospital design" firms had formed to consolidate the technical knowledge required to manage the requirements of increasingly complex processes and equipment, and hospital-specific codes and standards.

At the same time, larger and deeper horizontal floor plates were made possible as mechanical ventilation systems emerged in the 1950s and 1960s. Postman (1992) continues, "Like some well-known diseases, the problems that have arisen as a result of the reign of medical technology came slowly and were barely perceptible at the start. Through it all, the question of what was being undone had a low priority if it was asked at all." Industrial systems thinking applied to hospital design led to a detailed assessment of travel distances, adjacencies, and the emergence of the discipline of medical planning as maximum "plan efficiency" was pursued for each functional building component.

At the same time, declining air and water quality in urban environments, increasing concerns about respiratory illnesses linked to pollen and dust, and the advent of more sophisticated air filtration systems for medical environments created the perception that outdoor air was, in fact, less healthy than the conditioned indoor air. The response was to separate the natural world, with its particulates, insects, and dirt, from the clean, aseptic hospital environment.

Across North America, the "hospital as machine for healing" generated ever larger, more modern hospitals. The most notable of these endeavors is McMaster University Health Sciences Center (1972) in Hamilton, Ontario. Each floor plate of this hospital comprises 10 acres, the mechanical system is expressed, and the circulation is organized around a major atrium. Critics questioned the overwhelming scale and lack of "humanity" in the expressive machine form of the facility. These massive buildings, they argued, were a physical manifestation of the centralization of power in hospital-based healthcare.

Redefining Healing Environments

By the end of the twentieth-century, a body of research had begun to appear supporting the importance of nature in healthcare settings. In particular, early studies demonstrated the therapeutic importance of views of nature. Related work on "wayfinding"—the concept that architecture can help individuals find their way through a building or complex—showing that contact with the exterior can help orient occupants of a building, gave additional credence to the notion that healthcare facilities should increase their connection with nature.

A *New York Times* feature article on health in September 2004 exclaimed: "If there is one universal truth about hospitals, it is that they are drab, dismal places . . . not at all designed to soothe and heal" (Alvarez 2004). Why? In a talk to the American Institute of Architects (AIA) Academy on Architecture for Health barely one month later, architect Paul Hyett, principal at Ryder HKS in the United Kingdom, summarized the problem this way: "New technologies in modern architecture produced new building forms—high rise, deep plan, sealed environments—that are inappropriately low in thermal mass and too heavily dependent on artificial systems" (Hyett 2004).

Bellevue Hospital in New York, one of the first hospitals in the United States, demonstrates this transformation as it evolved on its Manhattan site overlooking the East River. In the late 1800s, McKim, Mead & White developed one of the last pavilion master plans for the site—a plan that was never fully realized. By the 1970s, a twenty-two-story block tower with approximately 1.5 acres per floor replaced all the acute-care functions in a one-million-square-foot sealed high-rise (see Figure 9.1).

While this example may be extreme, the prevalent typology of North American hospitals, which places deep floor plate diagnostic and treatment (D&T) bases below towering inpatient units, has evolved into completely artificially lit and conditioned spaces. That *New York Times* writer contrasted the "drab, dismal" state of North American healthcare with the Rikshospitalet-Radiumhospitalet Medical Centre (see sidebar) in Oslo, of which architect Tony Monk (2004) said, "The philosophy that permeates throughout the scheme is to create an environment for people, like a living beautiful town where the different functional activities fuse together and every opportunity is exploited to stimulate interesting spatial experiences." Monk captures a fundamental shift in healthcare-building design: the reemergence of buildings designed with a focus on people rather than technology. In describing the Rikshospitalet, Knut Bergsland (2005), of SINTEF Health Research, straightforwardly describes "a building designed by human beings for human beings."

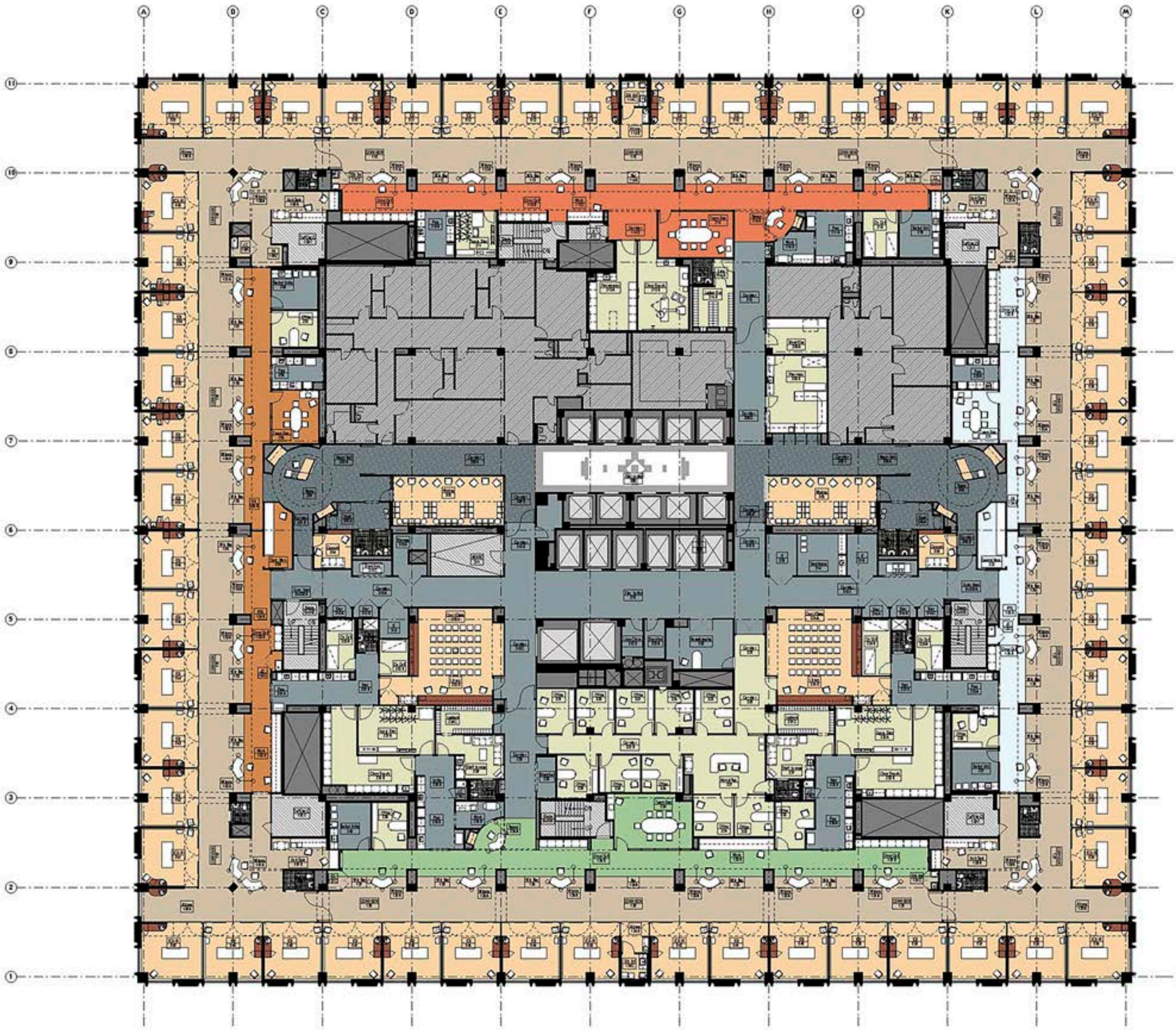


Figure 9.1 Bellevue Hospital in New York City, a high-rise, deep-plan, sealed building, is typical of many 1970s block-plan buildings. Originally designed with 6-bed rooms, this floor has been converted to 56 single intensive care beds. *Source: Courtesy of Perkins+Will*

Rikshospitalet-Radiumhospitalet Medical Centre

Owner: University of Oslo/Norwegian Statsbygg (Directorate of Public Construction and Property)

ARCHITECT: MEDPLAN ARKITEKTER NORWAY

Located on a landscaped suburban site with views of the city of Oslo and the nearby fjord, the new 2,027,000 sq. ft. (192,500 sq. m) Rikshospitalet was heralded by the press as a new model hospital design upon its opening (Figure 9.2). The hospital appears low rise but contains as many as seven levels in some areas; it is built into the bowl-shaped site to keep the hospital's profile at a more human scale.

Figure 9.2 *Source: Rikshospitalet-Radiumhospitalet Medical Centre*

Christian Brynildsen, project manager for Medplan Arkitekter Norway, says, "The objective was to keep the building in scale with the adjacent historic landmark psychiatric hospital—and more generally, to keep the building no taller than a tree." The state construction and real estate ministry managed the construction project.

Based on the idea of humanizing the hospital, the design considers the individual's confidence and security as well as the functional requirements of building and treatment. A striking glazed internal street studded with balconies, greenery, and glass bridges provides overall organization; D&T and inpatient units are located perpendicular to this main atrium. Parallel organization minimizes vertical circulation travel time. The offsets in the axis create framed events along the concourse (Figures 9.3–9.5). The hospital houses Norway's largest public art collection outside of a museum.

Initiated in the mid-1990s, the project predates explicit sustainable design initiatives in the healthcare sector. Designers were primarily interested in a design supportive of individual comfort and healing, focusing on daylight and art within the space. Energy use has been higher than expected—in 2003, a three-year plan to reduce consumption by 34 GBtu/hr (10 gigawatt hours) annually was implemented. While the plan successfully reduced building thermal energy consumption, new energy-intensive surgical equipment keeps actual total energy consumption essentially static. The hospital treats almost twice the number of patients assumed in its design and those figures are still rising; this also contributes to higher than expected energy use.

Sources: Medplan Arkitekter Norway; Brynildsen (2006); Rikshospitalet-Radiumhospitalet Medical Centre

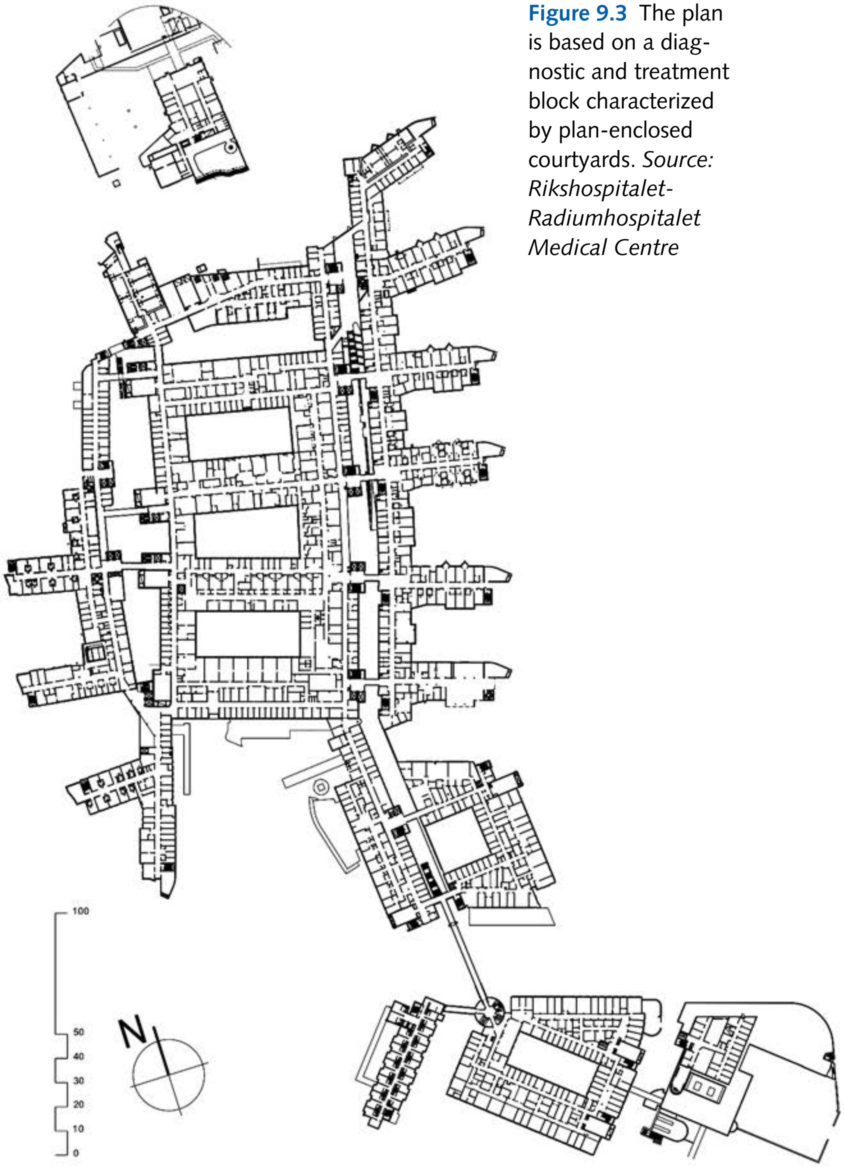


Figure 9.3 The plan is based on a diagnostic and treatment block characterized by plan-enclosed courtyards. *Source: Rikshospitalet-Radiumhospitalet Medical Centre*

Figure 9.4 The central street (detail). *Source: Rikshospitalet-Radiumhospitalet Medical Centre*

Figure 9.5 The central street bisects the hospital, with diagnostic and treatment blocks to the left and inpatient units to the right. *Source: Rikshospitalet-Radiumhospitalet Medical Centre*

Rikshospitalet-Radiumhospitalet Medical Centre's influence on contemporary European hospital building is evident in the Global Survey case study projects featured in Chapter 8. Neighboring Akershus University Hospital (Case Study 21, Chapter 8) represents the next generation of low-energy Norwegian hospitals that have adapted the Rikshospitalet typology. Deventer Ziekenhuis (Case Study 23, Chapter 8) converts the axial street to an outpatient and public rotunda space accessed off a central arrival courtyard. Santa Lucia University General Hospital (Case Study 34, Chapter 8) converts the interior street to a vehicular spine with decentralized entrances, and while the bed units actually sit atop the diagnostic chassis, courtyards between the bed units penetrate the base with daylight. The relatively small-scale Ysbyty Aneurin Bevan (Case Study 36, Chapter 8) demonstrates yet another variant on this typology.

There are, essentially, two typological directions in contemporary healthcare design—the narrow floor plate (single or double loaded corridor) nursing unit alongside the narrow floor plate diagnostic block and the deeper racetrack nursing unit alongside or atop the deep diagnostic block. Europe has largely embraced the former; North America, the latter. The University of Washington's Integrated Design Lab, in their Targeting 100 research, responded to these two typological options (see Chapter 5). The former seeks to place medical programs in essentially nature-infused, habitable structures; the latter is a single purpose–built, fundamentally uninhabitable structure without reliance on massive artificial lighting and ventilation inputs.

The first group of case studies in this chapter explores these typological differences in some detail. The first, Martini Hospital, Groningen, the Netherlands (Case Study 37, this chapter), is an aggressive narrow floor plate solution—a single loaded, 52 feet (16 m) deep inpatient unit strategy based on the optimum depth of residential structures. The structural aperture and exterior skin are standardized; in fact, the building can be converted to a school, office building, or 250 units of housing across an anticipated forty- to fifty-year life span. Its double skin facade and prefabricated interior elements offer maximum flexibility for revising the layout and interior arrangement without impacting the exterior design. An extensive demountable and prefabricated interior partition system is employed, including prefabricated operating theaters.

Arras Hospital, Arras, France (Case Study 38, this chapter) continues this exploration with a typological solution that separates the "residential," "technical," and "administrative" buildings in a series of uniquely configured narrow floor plate structures. The residential bed wing houses 560 beds in a large, rectangular building structure penetrated by three large courtyards and features, like Martini, a double-skin facade for energy reduction—an elegant solution that provides a unified facade solution to a building with outboard toilet rooms. The technical wing, which houses surgery, imaging, and the like, is also punctuated with multiple smaller plan-enclosed courtyards, reflecting more critical adjacency needs.

A radical solution for a dense urban site, the Pediatric and Cardiac Centre of the Innsbruck University Clinic, Innsbruck, Austria (Case Study 39, this chapter) is a long, relatively narrow children's hospital floor plate that connects a series of existing campus structures and provides a distinctive, colorful unifying street facade. The three floors of inpatient units are essentially a racetrack typology placed above public and outpatient space but feature interior courtyards piercing their cores. A motorized facade shading system that reduces solar gain and mitigates nighttime heat loss facilitates the large expanses of floor-to-ceiling glazing that maximize views and daylight.

At a much smaller scale, Helsingor Psychiatric Hospital, Helsingor, Denmark (Case Study 40, this chapter) takes a radical approach to nesting the narrow, daylit building into the landscape. Through skillful use of courtyard penetrations and landscaped roof, the psychiatric hospital prioritizes the lake views for its patients without compromising lake views for the patients in the medical campus beyond. Its snowflake form is reminiscent of radical hospital forms of the 1970s, but motivated by climatic and contextual conditions.

In many instances, provision of daylight is legislated for building occupants. In the Rhine Ordinance Barracks Medical Center, Kaiserslautern, Germany (Case Study 41, this chapter), all regularly occupied spaces must have windows to the outdoors, a requirement that drives the building's narrow, curvilinear form. This daylight requirement also facilitates the inclusion of operable windows in both the Administration Tower and Medical Services Center. Likewise, at Ng Teng Fong General Hospital and Jurong Community Hospital, Singapore (Case Study 42, this chapter), the building form is derived from the design goal for each patient in a multi-occupant room to have both direct access to daylight and views as well as an operable window for improved thermal comfort in a naturally ventilated building. The highly articulated facade, with orientation-specific solar shading systems, is a direct result of daylight and ventilation studies.

In his essay "Doubling Daylight," architect Ray Pradinuk proposes a typology for healthcare that restores the relationship between the built environment and the natural world, transforming the experience of the hospital building for its occupants and surrounding community in the process. Drawing on the extensive research linking daylight and views to improved patient outcomes and staff productivity and well-being, as well as new European hospitals (some of which are featured as case studies throughout this book), Pradinuk forcefully argues for a fundamental change in healthcare culture and architecture. In the Nanaimo Regional General Hospital Emergency Department and Psychiatric Emergency Services Addition, Nanaimo, British Columbia, Canada (Case Study 43, this chapter), the Stantec design team successfully introduced plan-enclosed courtyards in the midst of a critical Emergency Department environment, fundamentally transforming the hospital experience.

DOUBLING DAYLIGHT

Ray Pradinuk, MBAIC

At the Healthcare Design Conference in 2003, Boston surgeon and author Dr. Richard Selzer marveled during his keynote address at the selfless commitment of a nurse who had worked her entire career in a windowless post-op recovery area without ever treating a conscious patient. His single plea to the assembled design professionals was for daylight and views for staff, in the operating room and beyond. In his 1979 essay, "An Absence of Windows," Selzer wrote,

> I have spent too much time in these windowless rooms. Some part of me would avoid them if I could.

Healthcare architects have been talking to each other at conferences about designing healing environments filled with daylight since about the time that Selzer penned his lament, yet a "window that opens" remains the most asked for, least delivered characteristic of the caregiver work environment in North American hospitals. While North American design teams continue to struggle to add more daylight to their deep plan diagnostic and treatment blocks (D&Ts), European architects continue to add the same sophisticated care processes and technologies to intrinsically habitable daylit buildings (Figure 9.6).

Figure 9.6 A courtyard at REHAB Basel introduces daylight and nature to the interior of the Diagnostic and Treatment blocks. *Source: Ray Pradinuk*

CURRENT DAYLIGHTING LEVELS AND THE EVIDENCE FOR MORE

Because windows are code required for inpatient rooms in North America, the percentage of daylit space on the inpatient unit (IPU) is higher than on the D&T block, but it is often *only* the patient rooms on IPUs that have windows. So staffers in North American hospitals continue to spend the majority of their workdays in artificially lit spaces, and many do not experience daylight for hours, or in midwinter, even days at a time. While the negative impact of the absence of daylight on patient well-being in outpatient or D&T areas of the hospital may not extend beyond their relatively short visit, evidence and common sense suggest the effects on the staff working in those many small rooms all day long, day after day, are detrimental.

The effect of daylight on patient outcomes is becoming more widely understood, primarily through the evidence-based research compiled by the Center for Health Design. Researchers Ulrich and Zimring (2004) reference several strong studies linking daylight to reductions in depression, agitation, and drug use. They report on an Italian research group's finding that patients with unipolar and bipolar disorder randomly assigned to eastern rooms exposed to direct sunlight in the morning had a mean 3.67-day shorter hospital stay than patients in west-facing rooms (Benedetti et al. 2001). In a study that merits replication with much larger sample sizes and other patient categories, researchers in Bangladesh found that both the always-available access to views from outboard beds and single rooms and the lux level of the daylight received at the patient's bed substantially reduced post-cardiac surgery patient recovery time (Joarder et al. 2010). Seemingly, it not only matters that you get your dose of views and sunlight, it matters how much and when in the day you get it.

Possibly because there are so few daylit hospital staff work environments in North America to study, there is correspondingly less North American–focused research linking daylighting to staff well-being and performance. Might daylight deprivation be linked to medical error? Nurses in an Alaskan study reportedly made twice the errors in the darker months (Ulrich and Zimring 2004). The Canadian Adverse Events Study (Baker et al. 2004) reported that 40 percent of adverse events in Canadian hospitals were preventable; preventing that proportion of the adverse event deaths attributed to medical error would save close to 5,000 lives each year. While the benefits of daylight on caregiver attentiveness and productivity may be difficult to measure in the field, it is unimaginable that the presence of the most desired characteristic of their work environment would not impact positively on caregiver performance.

Conversely, the absence of natural light in the nursing station, report room, office, treatment room, and operating theater must be considered a likely contributor to preventable medical error. Heschong Mahone Group's much-referenced study of 21,000 students in school districts throughout California, Washington, and Colorado found a 20 percent and 26 percent difference in math and reading test score results, respectively, between students in the worst and best lit classrooms. As more evidence linking daylight deprivation to medical error and productivity loss comes in, it is not unlikely that the performance of caregivers in windowless workplaces will be found alarmingly similar to that of students in windowless classrooms leading North American healthcare providers to concede that the benefits of increasing daylight in staff spaces will extend to their patients. Indeed, under the precautionary principle, the existing evidence identifying the impact of daylighting—or its absence—on medical outcomes and patient well-being, combined with the general research on daylight's effect on knowledge-worker productivity, would by now be considered sufficient to warrant a significant increase in daylighting in North American healthcare facilities.

WHY ARE HOSPITALS SO LIGHT DEPRIVED?

When and why did daylight lose significance as a hospital form generator? Daylight has been undervalued in North America since the advent of air-conditioning in the 1960s, with the massive footprint of New York's Bellevue Hospital's tower, constructed in 1988, (Figure 9.1) demonstrating "the triumph of conditioned compact utility over fresh air and daylit habitability in health care facility design" (Verderber and Fine 2000).

With daylight expectations so low for so long, programming and design teams readily succumb to forces compacting the D&T plan (Figure 9.7). Urban hospitals over-program confined sites and are compelled to retain existing buildings during the construction of their replacements. On suburban sites, clinicians all want to be on the main floor and planners want the rest of the site for surface parking. In cities and suburbs, and even when site area is virtually unlimited, big, deep-plan D&T blocks predominate. On inpatient units, the ubiquitous racetrack layout continues to deprive caregivers of daylight at their workstations. Regardless of the racetrack's shape—square, rectangular, or triangular—patient rooms monopolize the daylit perimeter, leaving staff corralled in the support core in the middle along with the utility and equipment rooms.

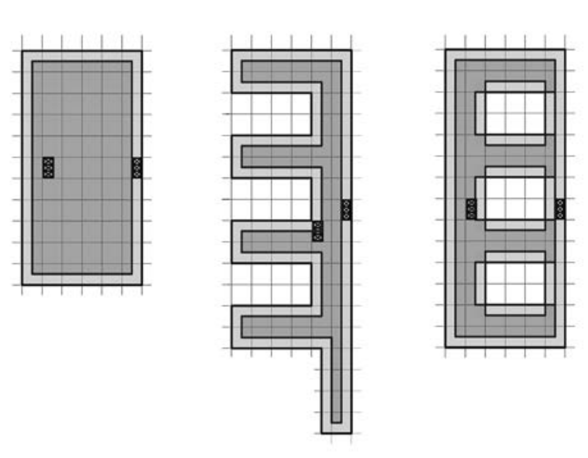


Figure 9.7 All three diagnostic and treatment (D&T) plans are 59,400 sq. ft. (5,518 sq. m). Less than one-quarter (24.2 percent) of the deep plan D&T's area is within 15 feet of its perimeter. Just over half (51.5 percent) of both narrow-plan D&Ts are daylit spaces, but only the plan-enclosed courtyard (right) retains operational efficiency and flexibility. *Source: Stantec Architecture*

CATALYSTS TOWARD DAYLIGHT

Of late, the deep-plan D&T has been exposed to renewed criticism by North American healthcare architects encouraged by mounting evidence from clinicians' research, the sustainable design movement's interest in daylight, and by a growing awareness of the substantially higher quantity of daylighting that continues to be achieved by European hospitals. Of these, it may ultimately be close scrutiny of buildings in Europe—if not forays by European architects into the healthcare design sector here—that will most influence the hospital configuration paradigm in North America.

Among the most compelling of the newest generation of European hospitals are: Oslo's New Rikshospitalet University Hospital by Medplan Arkitekter (see sidebar, earlier in this chapter) and Herzog & de Meuron's REHAB Basel Center for Spinal Cord and Brain Injuries (Case Study 28, Chapter 8).

After meeting with clinicians, first-time healthcare architects Herzog & de Meuron prescribed "daylight, nature and space" for REHAB Basel (Case Study 28, Chapter 8). The memory of the beauty of how REHAB Basel's five smaller within-care-area courtyards imbue each care area with daylight and nature inspired Stantec not to fill in the space between the charting stations in the urgent/emergent care pods at Nanaimo General Regional Hospital's new ED (Figures 9.8 and 9.9).

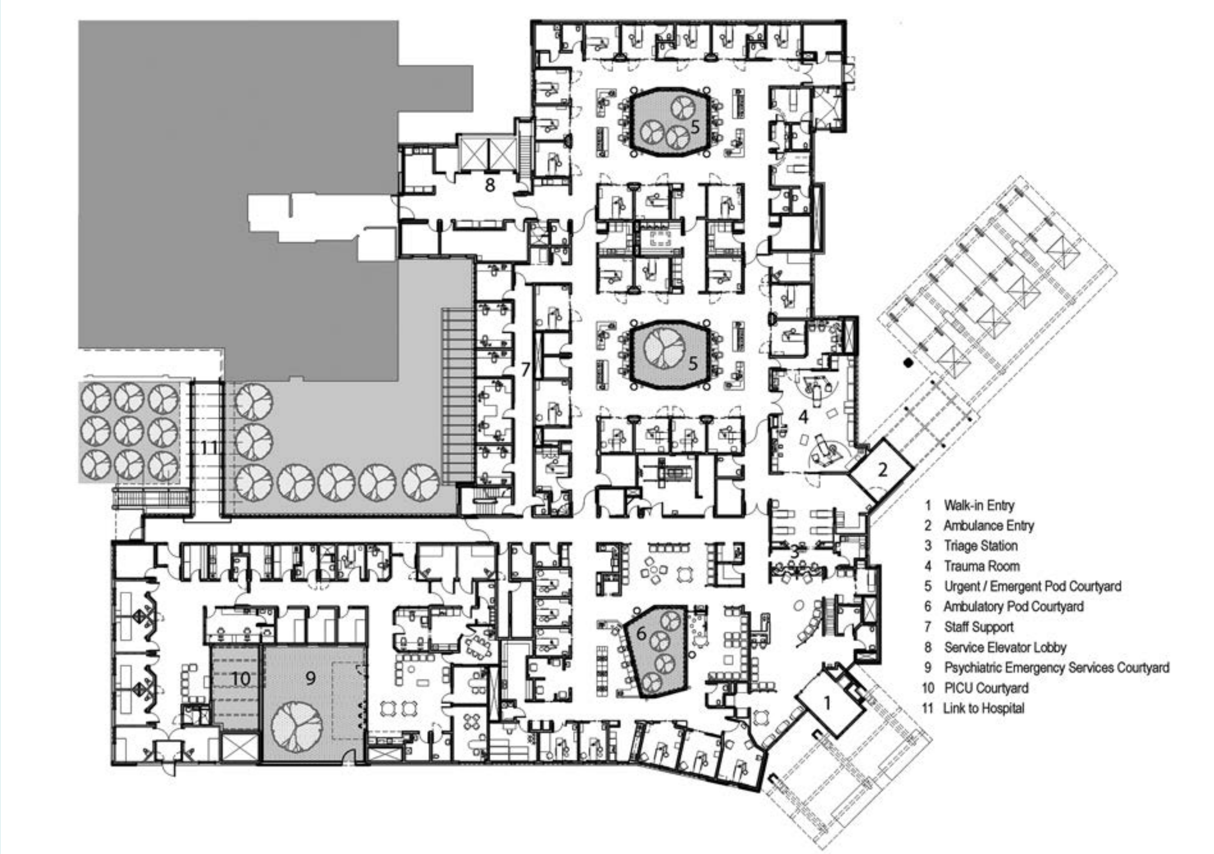


Figure 9.8 Nanaimo Regional Emergency Department plan, where small within-care-area courtyards, inspired by REHAB Basel, bring daylight and nature views to care-givers and their patients. *Source: Stantec Architecture*

Figure 9.9 View of courtyard in relation to treatment positions. *Source: Stantec Architecture*

THE COSTS AND BENEFITS OF DAYLIGHTING

Increasing daylighting in any building increases capital costs. Doubling the daylit area in the D&T and providing daylight for virtually all staff workstations on the inpatient unit will add to the cost of constructing an acute care hospital for the increased perimeter wall and window alone. Additional costs might include courtyard landscaping, automatic operable windows and exterior solar shading. Since the courtyards within a daylit D&T are typically 20 percent of its gross floor area, the overall floor plate will increase, or on confined sites, the building will expand vertically, requiring an additional floor's worth of stairs and elevator and service shafts. The energy saved by daylighting and daylight-responsive artificial lighting controls will make a significant contribution toward reducing the building's overall energy consumption.

However, even where energy costs are highest, energy savings can only contribute a fraction to the return required for a ten-year payback on an investment in more perimeter wall and window. Savings in recruitment and training alone will likely exceed energy's contribution, but the opportunity to recoup the additional capital investment in daylighting would mainly arise from a combination of not insignificant cost avoidances (error reductions) and productivity gains.

First, with regard to error, realizing all of the achievable 40 percent reduction in medical error the Canadian Adverse Events Study estimates would avoid substantial—and in the United States non-reimbursable—healthcare costs. Daylighting's potential contribution to error reduction is currently speculative at best, and costs associated with errors are highly variable. With regard to productivity, a mere 2 percent productivity increase in just the additional daylit area of a healthcare facility would pay for the *additional* wall and window a daylit plan would provide in less than five years.

While configuring hospitals to increase face-to-face communication within and between care teams can be achieved at relatively low cost, the investment that will be required to implement advanced healthcare information and communications technology will dwarf that required for improved indoor environmental quality in healthcare facilities. All three sets of improvements are essential. Once a line appears in healthcare construction accounting practice for care-delivery benefits, additional daylight will be viewed as self-financing. Eventually, we too may come to design for daylight without having to think much about it, as is the case now in Scandinavia. As Knut Bergsland put it when speaking about the extraordinary daylighting of Oslo's Rikshospitalet: "It's just the way we do it—no cost/benefit required" (Bergsland 2005).

CONFIGURING FOR DAYLIGHT

The plan-enclosed courtyard has been the building plan strategy of choice in European cities to achieve both density and daylight for centuries. In a hospital, plan-enclosed courtyards allow a simple overall D&T plan shape to be retained; allow departments to ebb and flow around their corners, front and back; and allow treatment and service spaces to be shared at the back-of-house of departments. Most caregivers spend most of their time working in a relatively small area along relatively short but well-worn work paths. A matrix of sixty-foot wings in a multi-courtyard plan would accommodate most caregiver work paths with a minimal amount of added travel for caregivers (Figure 9.7). If on average 20 percent of caregiver travel is cross-hospital to the cafeteria, meeting spaces and the like, and if 20 percent of total work time is travel, then a 20 percent increase in the hospital footprint would affect overall caregiver time by less than 1 percent. A useful byproduct of caregiver travel is an increase in opportunities for chance encounters with fellow caregivers. As we learn how better to configure hospitals to increase opportunities for face-to-face communication between as well as within care teams, a modest increase in cross-hospital travel may be seen as a useful contributor to overall hospital culture.

While plan-enclosed courtyards provide contained views—ideally a tree-filtered view of a beautiful wall and a slice of sky—in North America, the longer the view the better. North Americans are unfamiliar with courtyard typologies and are predisposed to criticize the most effective strategy for increasing D&T daylight as too costly to build and maintain and certain to reduce patient care time by adding to caregiver travel.

To otherwise significantly increase daylight in the D&T, the only alternative to plan-enclosed courtyards is the surprisingly ineffective articulated plan (Figure 9.7 center). But the articulated plan can't come close to providing the access to daylight that plan-enclosed courtyards can provide without seriously impacting the functionality of the plan. The more daylight provided, the more the articulated plan replicates the highly inflexible "alphabet" pavilion plans of the early twentieth century that trapped departments up dead-end corridors, giving them nowhere to grow but the front-of-house and leaving no possibility of any backdoor sharing of support and treatment spaces. Clearly, the plan-enclosed courtyard is the only viable means of significantly increasing D&T daylighting.

For inpatient units, daylight for staff and family spaces is best achieved by revisiting the double-loaded corridor plan that the racetrack unit replaced (see Santa Lucia University Hospital [Case Study 34, Chapter 8], Ysbyty Aneurin Bevan [Case Study 36, Chapter 8]). As the evidence from clinicians suggests, by distributing caregiver workstations and support rooms within single-room, double-loaded corridor wings more bed heads will be seen with each nurse step so more patients will be in view as they stir to rise from their beds and fewer will be untended and at risk of falling. With supplies at hand and fewer unnecessary trips, nurse travel time will drop from the 25 percent range, toward 15 percent. Families will have more opportunities to meet and support each other. Coincidently, it will be found that these re-minted, daylit L- and T-shaped nursing units will join together rather well around courtyards. When patient rooms face into fully plan-enclosed courtyards, ideal conditions are established for the hybrid natural ventilation of inpatient rooms, thereby engaging all of the senses in the cherished patient/world relationship. Juhani Pallasmaa (2005) writes in *The Eyes of the Skin, Architecture and the Senses,* that:

> The most essential auditory experience created by architecture is tranquility. [. . .] Architecture emancipates us from the embrace of the present and allows us to experience the slow, healing flow of time.

QUALITIES OF LIGHT

Once hospital construction budgets have been adapted to accommodate increased daylighting, qualitative design issues will need to be addressed, particularly those addressing working and convalescing around courtyards. Looking out a courtyard window, the building that is enclosing the viewer is seen, so the facade—not just the interior of the hospital—is present in the patient experience, putting Heidegger's "critical lack of nearness" (Frampton et al. 1999) in modern architecture back on the healthcare architecture agenda. While some walls, materially, merit close viewing more than others, more than details are at issue. The simultaneity of being sheltered while seeing the building providing that shelter magnifies the psychological and social dimensions of dwelling: the room is situated in the building; its occupant is situated in the building community; and the hidden labyrinth of corridors and stairs that choreographs the connection among its members is imagined.

In the design of these courtyard hospitals, would use influence character? Could a certain courtyard be perfect for staff offices and lounges, for example—maybe a greenhouse courtyard with meeting balconies? Could tree branches provide just the right filtering of views between examination rooms in another? Will orientation influence materials where light will bounce across from walls that see the sun? How will soundless air handling be achieved? How will the landscape be maintained and the wildlife accommodated? The beauty of the world and our happiness within it are intertwined—as patients, caregivers or designers. A new architecture of the healthcare courtyard with building systems to match awaits.

Bioregionalism

Increasingly, global markets for goods and services homogenize hospital design both nationally and internationally. Architectural historian Cor Wagenaar characterized the adoption of the International Style in healthcare design as expressing progress and modernity. However, as healthcare assumes a more prominent role as the new civic architecture, and notions of climate-responsive, place-centered design become more understood, a new bioregionally based design language may emerge.

Sustainable design challenges the standardization of building typology by recognizing:

- *Bioregional differences in climate:* Temperature, wind, and moisture require unique, climate-responsive architecture.
- *Indigenous materials:* Using locally and regionally sourced materials supports distinctive architectural typologies, strengthens local economies, and safeguards the environment from the burdens of long-distance transport.
- *Buildings connect people to place:* By constructing buildings using local resources, people recognize the familiar and are more keenly aware of place.
- *Biophilic response is universal and operative in times of stress:* The unique function of hospital buildings—occupied in times of impaired health and stress—demands a typology that recognizes the spiritual and psychological dimensions of the encounter.

Architects Tye Farrow and Sean Stanwick, Farrow Partnership, are creating bioregionally responsive healthcare design solutions in North America and beyond. Farrow and Stanwick (2008) assert that healthcare buildings need to be synchronized with their environment and grow from their communities, celebrating the local culture and becoming enmeshed in the local economy:

> To enhance their meaning and relevance to an increasingly diverse population, and to minimize their environmental footprint, hospitals can no longer afford to operate as isolated facilities with tenuous connections to the community. Instead, they should be like natural habitats: areas full of energy, life, and diversity, fostering relationships between the land and the water and embracing their role as comprehensive resources for healing at all levels. In this light, sustainability should be considered part of a larger symbiotic paradigm in which appropriate technological solutions are responsive to the cultural identities intrinsically linked to local geography, environmental attunements, and essential cultural values. This way of thinking—and doing—begins to address the debate between the often-polarized forces of universalizing technology and localizing place identity.

Farrow and Stanwick's work in Canada demonstrates these principles in action. They point to the work of McMinn and Polo (2006) who wrote, "[T]o be truly sustainable, buildings need to remain relevant and functional to the community they serve. Energy-efficient buildings that fail to address cultural needs and values may suffer premature obsolescence and invite major modifications or outright demolition or replacement." In parts of North America, reflecting the historical economic association with the great forests, wood has the power to drive and sustain local economies, to generate tourism dollars, and even promote the generational succession of woodworking trades by giving new life to an old and reborn method of construction. Both at Thunder Bay Regional Health Sciences Centre, Thunder Bay, Ontario (Figures 9.10 and 9.11), and the Carlo Fidani Peel Regional Cancer Centre at Credit Valley Hospital, Mississauga, Ontario (Figures 9.12 and 9.13), their pioneering use of large-scale timber in healthcare structures is unprecedented.

> *When adopting green design principles, we must embrace the duty of stewardship bestowed upon us as designers and create a cohesive system of wellness for the environment and the people who inhabit its spaces. Returning to the notion that concern for human values is of the utmost importance to the care of the sick, a regionally inspired architecture that bridges the gap between science and nature has the capacity to uniquely connect people to place in the service of healing.*
>
> —Tye Farrow and Sean Stanwick (2008)

Figure 9.10 This conceptual sketch of the wood-structured main concourse at Thunder Bay illustrates the layering of the facade and structural elements. *Source: Farrow Partnership*

Figure 9.11 The photograph captures the completed building shown in sketch in Figure 9.10 at dusk. *Source: Farrow Partnership*

There are many inspiring Case Studies in this book that demonstrate bioregional principles in action. The Farrow Partnership, in collaboration with Okpanum Architects and Clark Nexsen, designed the winning competition entry for Protea Health (see Chapter 3), a prototype community health facility in South Africa. Among the Chapter 8 Global Survey examples, Butaro Hospital, Burera District, Rwanda (Case Study 22) and Santa Lucia General Hospital, Cartagena, Spain (Case Study 34) demonstrate bioregional principles in action at very different scales.

Seattle Children's Bellevue Clinic, Bellevue, Washington (Case Study 44, this chapter) demonstrates the importance of bioregional and climatic design principles to influence form. While it is not a narrow floor plate building, the combination of moving surgical activity to a lower acuity, non-hospital setting, combined with an innovative facade shading system, produces a bio-regionally appropriate, inspired solution. And, although it is a totally sealed building, its form suggests an emergent North American trend toward climatic influence and engagement with nature. Inclusion of outdoor program spaces is an important innovation.

In the developing world, bioregional and climatic design solutions are emerging as important indicators of the future of healthcare typologies. At Pictou Landing Center Mi'Kmaq Community Health Center, Trenton, Nova Scotia (Case Study 45, this chapter), traditional First People's boat-building techniques merge with a local workforce to produce a unique community health and resource center that connects to the community it serves. The community and the design team took the stance that health and cultural renewal were directly related issues, and that the building should serve as a catalyst for cultural renewal as well as a community center. The ground-source heat pump system linked to hydronic heating recalls the hot stone radiant heating of traditional longhouses in this cold climate.

By contrast, the Kenya Women's and Children's Wellness Center, Nairobi, Kenya (Case Study 46, this chapter) exists in a climate that prefers a higher quantity of externalized spaces, single-loaded corridors, and smaller, narrow 46 ft. (14 m) floor plates that take advantage of daylight and natural ventilation. The climate suggests that the types and complexity of mechanical systems present in the more extreme climates of the northern and southern hemisphere need not be present in high plateaus of East Africa. The resultant hospital structure is a porous, naturally ventilated structure that benefits from orientation to prevailing breezes and controlled sun shading.

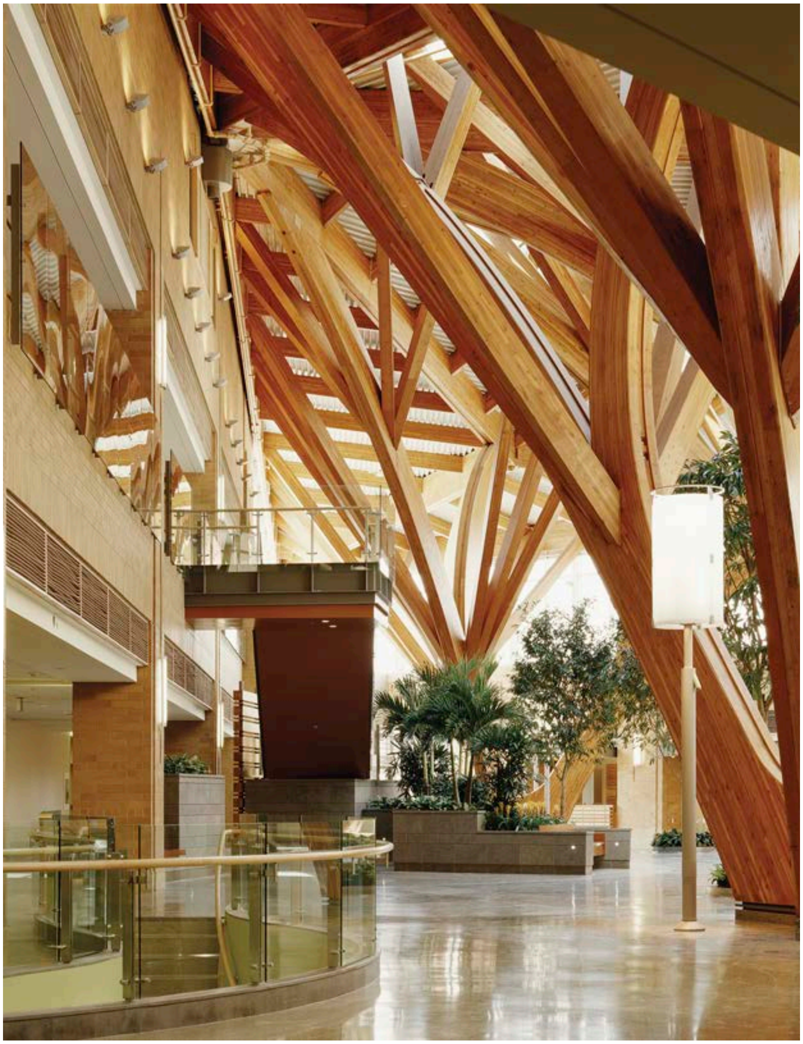


Figure 9.12 The Carlo Fidani Peel Regional Cancer Centre atrium was conceived as a "village gathering place." The building has a direct connection to nature and to its occupants' inner social lives. Wood materials were selected to humanize, personalize, and demystify the healthcare experience. *Source: Copyright © Peter Sellar, Klik Photography*

Figure 9.13 The design of the structural forms mimics nature. *Source: Farrow Partnership*

In Kolkata, India, the Tata Medical Centre Cancer Hospital (Case Study 47, this chapter) is a series of linked, narrow floor plate pavilions oriented to harness prevailing breezes, while glazing is deeply recessed to limit solar gain and monsoon rain deluge penetration. While the facility is equipped with mechanical cooling in a climate that often exceeds 100°F (38°C), it also includes operable windows to accommodate patient preference.

Finally, CBF [*Centre pour le Bien-etre des Femmes*] Women's Health Centre, Ouagadougou, Burkina Faso (Case Study 48, this chapter) demonstrates that significant architectural solutions can be constructed locally and with minimal resources. This health center exists in an area devoid of any planning regulations or basic infrastructure, and was constructed with the most basic materials—sun-baked bricks, corrugated aluminum, and translucent fiberglass. Solar panels provide electricity for electric lighting and medical devices. This project is clearly an example of the power of health-promoting architecture to generate social and cultural vibrancy as well as improve the underlying conditions for health.

One of the key learnings from projects in the developing world is that construction methodologies have long been modeled on the experience of the developed world. In Africa and Southeast Asia, many of the project delivery methods are modeled on the practices of former colonizers. Hence, these projects represent a significant break by reconnecting to indigenous culture and local building principles. Collectively, these projects connect a sense of bioregionally inspired design and construction realities with twenty-first-century healthcare delivery in new and innovative ways.

Conclusion

Sustainable design considerations are influencing hospital building typologies around the world. In the developing world, a focus on bioregional-appropriate solutions is bringing forward innovative, low-resource healthcare buildings that are in turn influencing less resource-intensive typologies in more developed regions.

As buildings become more climate-responsive, bioregional influences will create distinctive, signature design elements—imagine "the hospital as a machine" replaced by "the hospital as a flower." Connecting healthcare buildings to the communities they grow from within can provide a powerful pattern language. European and other global hospital buildings, with their continued reliance on natural ventilation, daylight, and passive heating and cooling, can inform this new language of form. While there is no single typology, a series of related themes are emerging—narrow floor plate, natural light, access to ventilation. The case studies included here and throughout the book offer provocative glimpses into different approaches that reveal what is possible.

Case Study 37: Martini Hospital

Groningen, the Netherlands

OWNER: Martini Hospital Foundation

PROJECT TEAM:

Architect: SEED Architects

Project Management: AT Osborne

M&E Consultants: Deerns Consulting Engineers; Royal Haskoning

Interior Design: Vos Maupertuus and SEED Architects

Building Physics Consultant: Peutz

TYPE: New Regional Acute-Care Hospital

SIZE: 645,835 sq. ft. (60,000 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: 570-bed regional tertiary hospital, 17 operating rooms, diagnostic and outpatient departments, burn unit

COMPLETED: 2007

RECOGNITION: IFD demonstration award, shortlisted World Architecture Festival Barcelona 2008

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 29 in (734 mm)

KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management:* Stormwater management is landscape feature
- *Community Connectivity:* Access to transit; bike and walking paths on site
- *Narrow Floorplate:* Daylighting enhanced by narrow, 52.5 ft. (16 m) footprint
- *Climate Responsive Facade:* Double skin facade; operable windows throughout
- *Innovative Source Energy:* Underground Long-Term Energy Storage (LTES) system for passive heat and cold storage
- *Low Embodied Energy:* Most materials manufactured within approximately 100 miles (150 km)
- *Healthy Materials:* Focus on natural wood, linoleum
- *Prefabrication and Adaptability:* Large-scale IFD (Industrialized, Flexible, Demountable) prefabrication to reduce waste, time and improve adaptability over time
- *Acoustics:* Exterior glazing system enhances sound attenuation
- *Civic Function:* Health-related community functions in building

Figure 9.14 Martini Hospital. *Source: SEED Architects*

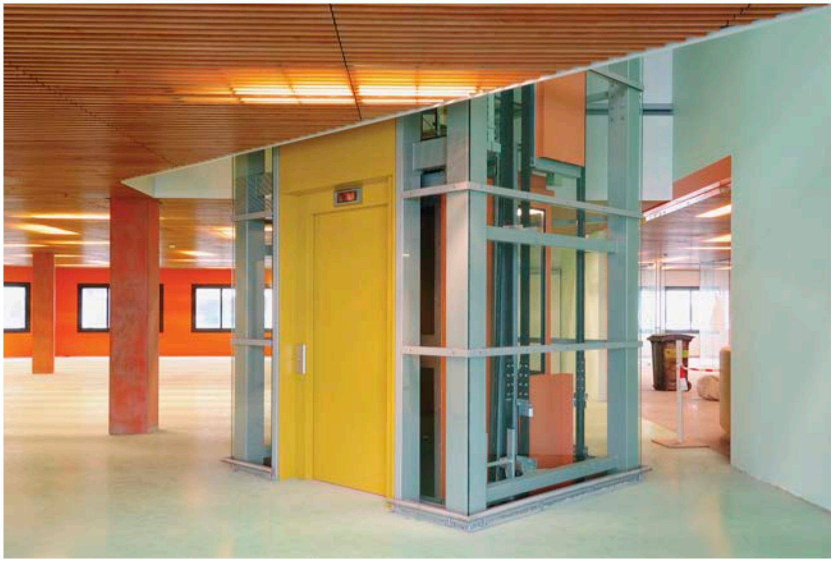


Figure 9.15 Public circulation spine. *Source: Copyright © Rob Hoekstra*

Figure 9.16 Patient room. *Source: Jan Buwalda*

Figure 9.17 Glass-enclosed elevators are located at the nodes. *Source: Derk Jan de Vrie*

From project inception in 2004, the major design goals were to use industrialized prefabricated building components, provide adaptable interior spaces, and to develop a demountable kit of parts to be used interchangeably as functional needs evolve over time—a system known as IFD. A key innovation is the use of a narrow, 52.5 ft. (16 m) bay depth in lieu of the typical 82 ft. (25 m) typology. This allows for significantly more daylight penetration and for the complete reconfiguration of the internal floor plans as needs evolve (Figure 9.14).

The exterior facade is a layered demountable double-skin panel system. The outer skin is a regular grid of low-emissivity glass. The inner skin consists of demountable, moveable screens and panels that accommodate window apertures of varying proportions and locations. Exterior windows are operable throughout, in thin horizontal bands that span the length of the building. The interstitial space is 2.62 ft. deep (80 cm). The double-skin panel system acts as a thermal buffer and presents a uniform appearance while the inner skin responds to particulars of program. No heating apparatus is required at the exterior wall, enhancing usable floor area and flexibility. The randomly placed boxes in the glass facade and the dynamics of the sunshades lend dynamism to the building, recalling the changing nature of health care in the twenty-first century (Figures 9.15–9.17 and 9.19).

Stephen Verderber eloquently described the plan as resembling "two chromosomes that touch at junction points." The nodes house vertical circulation and service spaces. The undulating bands offer varying view orientations from within, and reduce the apparent length and scale from the exterior. The plan is divided into 6 blocks of approximately 10,764 sq. ft. (1,000 sq. m, or 60 m by 16 m) and two blocks (60 m by 22 m) that house the core diagnostic departments of the hospital; each block can respond to functional use changes independently.

Given its dramatic undulating shape, it is surprising that the Martini Hospital is located on an existing hospital site in a long-established residential neighborhood within the city center of Groningen (Figure 9.18). Site development includes a prominent man-

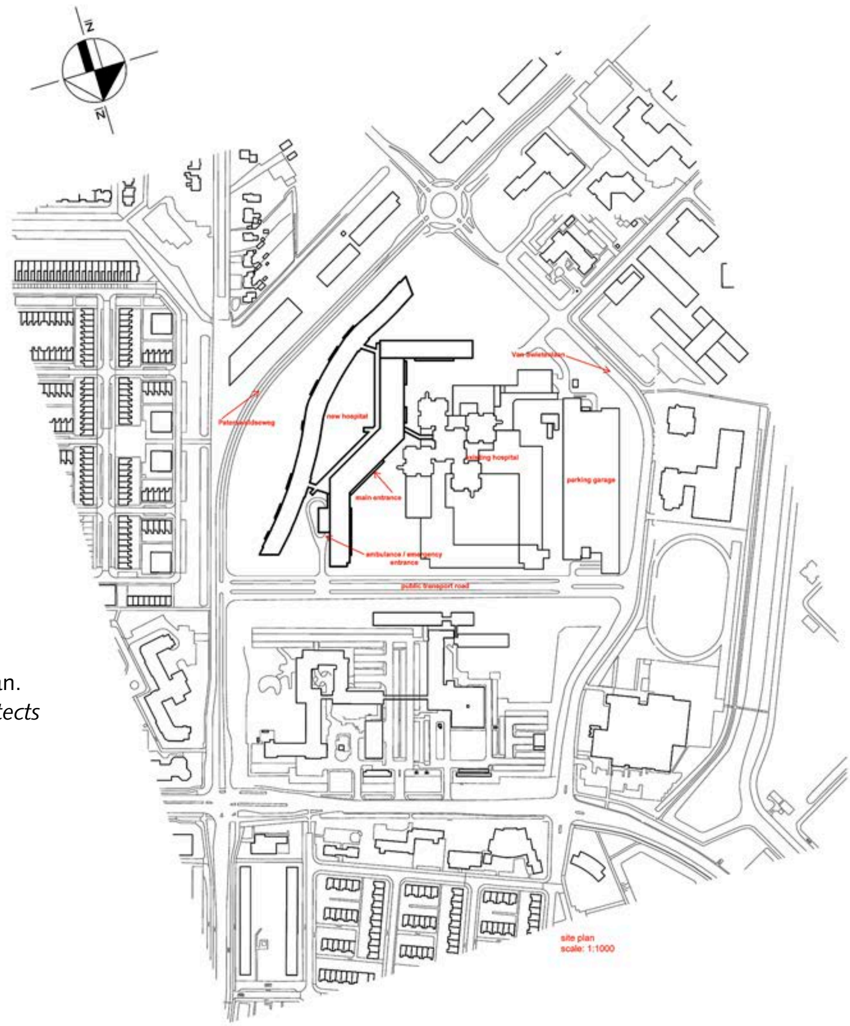


Figure 9.18 Site plan.
Source: SEED Architects

Figure 9.19 Principal facade. *Source: Copyright © Rob Hoekstra*

made stormwater detention pond and a community pocket park, features that encourage physical activity and outdoor socializing and interaction. The hospital houses a number of health-related commercial enterprises, encouraging community engagement. The existing hospital has been retained on the site for administration and ancillary functions.

The energy system for the Martini Hospital is based on Long Term Energy Storage (LTES). Below ground wells provide thermal storage for heating and cooling energy. Energy is stored at relatively low temperatures in hot and cold wells—the cold well at an average of 46.4°F (8°C) and the hot well approximately 60.8°F (16°C). In winter, heat pumps harvest the heat from the hot well into useable warmth. Free cooling from the cold wells is used as much as possible in summer; when required, heat pumps will provide additional cold water. In order to maintain maximum flexibility and adaptability, distribution is largely via ducted air systems, with modulating VAV/reheat equipment.

The Martini Hospital remains unsurpassed in its exploration of IFD principles in large-scale healthcare structures. It is an important glimpse into a future where building design decisions are framed with consideration of long-term, life cycle impacts of the resources that are used to construct them.

Source: SEED Architects, DEERNS Consulting Engineers, Verderber (2010)

Case Study 38: Arras Hospital Centre

Arras, Nord-Pas-de-Calais, France

OWNER: C.H. of Arras

PROJECT TEAM:

Architect: groupe-6

MEP Engineer: Jacobs France

Landscape Design: Pierre-Yves Jorcin

Project Management: Aeprim/Oger International

TYPE: Replacement Acute-Care Hospital

SIZE: 807,300 sq. ft. (75,000 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: Replacement 587-bed acute-care hospital, including inpatient beds, emergency services, surgery, general medicine, obstetrics, pediatrics and geriatric care

COMPLETED: 2008

BIOME: Temperate Semi-Arid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 25 in. (645 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Landscape courtyards and view toward park
- *Innovative Stormwater Management:* Water court
- *Energy Responsive Facade:* Double skin ventilated facade with automated openers to improve thermal performance
- *Green Roof:* Extensive green roof at courtyards
- *Innovative Source Energy:* Hospital uses district energy (natural gas fired co-generation) for heating and cooling energy
- *Natural Ventilation:* All patient rooms and inpatient units naturally ventilated
- *Low Embodied Energy:* Recycled concrete and local manufacture
- *Healthy Materials:* Linoleum flooring throughout

Figure 9.20 Arras Hospital Centre. *Source: Copyright © groupe-6*

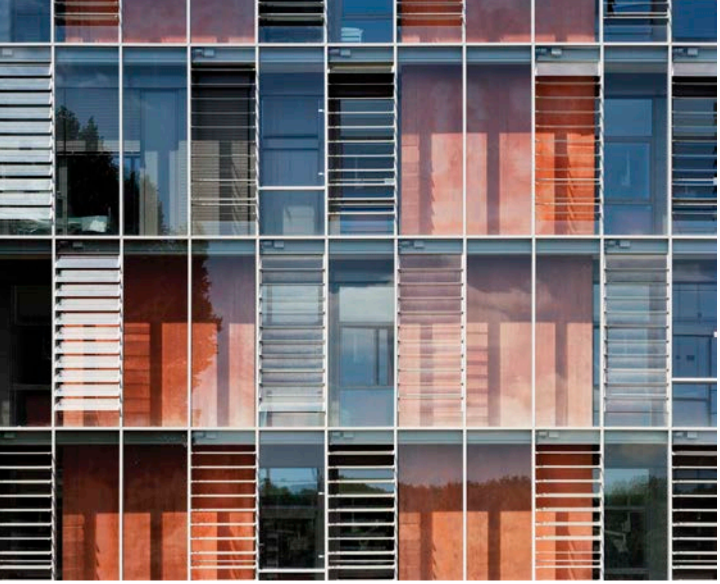


Figure 9.21 Facade detail. *Source: Copyright © groupe-6*

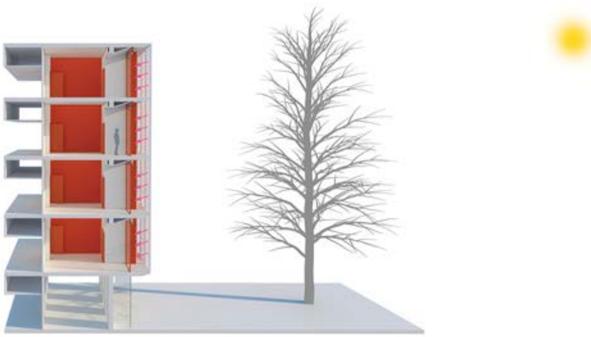
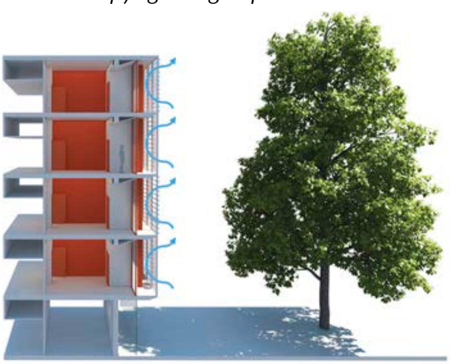


Figure 9.22 Facade section in winter. *Source: Copyright © groupe-6*

Figure 9.23 Facade section in summer. *Source: Copyright © groupe-6*



The Arras Hospital Centre serves a regional population of 230,000 on a site strategically located at the outskirts of the historic city of Arras. Prior hospital site development had turned its back on the historic downtown; this major expansion and replacement re-engages the city as the new bed wing faces the historic city center across a landscaped park. Designed using *Haute Qualité Environnementale* or High Environmental Quality Approach (HQE®), a standard for green building in France, the building is the first low-energy hospital constructed in France, and incorporates a range of sustainable building strategies (Figure 9.20).

The new hospital is composed of three modular buildings: one building for lodging (the inpatient bed wing); a technical center (the diagnostic and treatment chassis); and the refurbished existing building for administrative and ancillary functions (Figure 9.24). Each building has a unique architectural expression; the buildings are connected by a series of transparent bridges with landscaped and water pool courtyards between (Figure 9.25). Distributed public and mixed use spaces are filled with natural light, reinforcing the definition of the hospital as living space.

The inpatient building provides the symbolic identity and the signature expression of sustainable design: a large glass box set forward and placed in the park. The 53,820 sq. ft. (5,000 sq. m) double-wall glass facade blends with the environment by reflecting the landscape, while it provides an important thermal buffer between the inside and outside of the building (Figures 9.21–9.23). Outboard toilets create a rhythm of solid and fenestration that is mitigated by this much larger, unifying facade gesture; operable windows in the patient rooms take advantage of the tempered winter air. Lounges and public spaces, set back from the exterior for shading, punctuate the continuous glass planes. A flat roof floating over the architectural massing accentuates lightness, openness, and transparency.

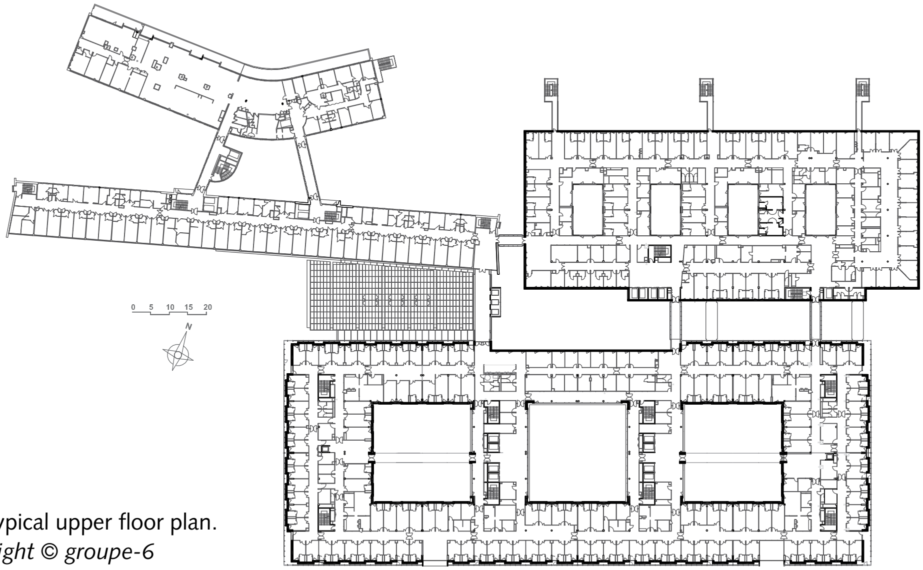


Figure 9.24 Typical upper floor plan.
Source: Copyright © groupe-6

The double skin facade incorporates automated operating vanes. In the winter, the vanes are closed; cold air is warmed in the cavity and exhausted at the top of the building, effectively buffering heat loss. In summer, the vanes are opened to ventilate the inner facade and prevent excess heating. Patient rooms are naturally ventilated; three large landscaped courtyards in the center of the inpatient wing provide for cross ventilation and bring the park inside the building. Each large floor plate is a modular plateau, incorporating centralized support and logistics.

By contrast, the technical wing is primarily opaque, with a series of inset windows for view. It is fully mechanically ventilated. The hospital relies on the City of Arras' district co-generation system for hot water and steam.

The Arras Hospital Centre is the first of a new generation of hospitals focused on architectural, spatial, environmental, and social values—combining modernity and humanity. It focuses on creating a high performance healing environment, bringing together significant technology, innovative planning, and sustainable design to provide a new standard for care.

Sources: groupe-6; Arras Hospital Centre

Figure 9.25 Reflective pool courtyard between bed wing and technical wing. *Source: Copyright © groupe-6*

Case Study 39: Pediatric and Cardiac Center of the Innsbruck University Clinic

Innsbruck, Austria

OWNER: TILAK—Tiroler Landeskrankenanstalten GmbH

PROJECT TEAM:

Architect: Nickl & Partner Architekten AG

HVAC: JMP Jaeger, Mornhinweg + Partner; A3 Ingenieurbüro Jäger/Plasil

Electrical Engineer: A3 Ingenieurbüro Jenewein GmbH

Landscape Architect: UGC Schrankenmüller

TYPE: Acute-Care Hospital Addition

SIZE: 187,300 sq. ft. (17,400 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: 150 Pediatric day hospital and cardiac acute-care beds (single, semi-private and 4-bed) and Pediatric Oncology bed unit, Neonatology, Emergency, post-anesthesia care and intensive care unit, 2 OR + 2 birth-OR, administration, cafeteria, meditation space, lecture halls and seminar rooms (ground floor)

COMPLETED: 2008

BIOME: Boreal Humid

CLIMATE ZONE: Humid Continental, Cool Summer

PRECIPITATION: 34.7 in. (883 mm)

KEY SUSTAINABILITY INDICATORS

- *Innovative Parking:* 2-story underground parking is planned for the second phase
- *Connection to Nature:* Outdoor gardens, loggias and courtyard places of respite
- *Narrow Floor Plate:* Narrow building with plan enclosed courtyards
- *Energy Responsive Facade:* Automated shading system improves thermal performance
- *Innovative Source Energy:* Heating and power supplied by a campus-wide district co-generation system
- *Innovative Energy Distribution:* Public space utilizes hydronic heating; balance of building radiators with individual thermostat controls
- *Natural Ventilation:* All building windows are operable; in areas with infection and particular pressurization demands (e.g., oncology) windows are locked and areas are mechanically cooled and ventilated
- *Healthy Materials:* Rubber flooring in common spaces, wood parquet in patient areas

Figure 9.26 Pediatric and Cardiac Center of the Innsbruck University Clinic. *Source: Stefan Mueller-Naumann*

This addition to the Innsbruck University Clinic is a bold, dynamic, confident and natural addition to the urban streetscape. Nickl & Partner won a 2002 design competition to commence the expansion and eventual replacement of the multi-building complex; this first building, arrayed along the street front, connects multiple clinic buildings dating from the 1970s and earlier. In order to facilitate future developments and to retain the focal point of the complex, this horizontally and vertically connecting addition is situated to the north of the planned clinic. The concourse, expressed as the grey element on floors 1 and 2, is the main artery of the building: It incorporates waiting areas, rest areas, and areas for children to play or paint, with the magnificent scenery of the surrounding mountain landscape always in the background (Figures 9.26, 29). Above this plinth are four floors of inpatient units, including Pediatric Oncology. On the interior, a simple palette of rubber flooring and oak floors present a clean, light and natural feel (Figure 9.27).

Innsbruck, Austria is an internationally renowned winter sports center, with temperatures ranging from 11°F (–20°C) to 87°F (31°C). Winters are cold (colder than most European cities) and snowy—average annual snowfall is 38 in (98 cm). Key to the building's energy performance and design identity is the dynamic automated facade shading system. The facade was developed using more than 200 screens comprised of several layers of 13 ft. (4 m) -tall folded and sliding perforated aluminum plates [each hinged section is up to 11 in. (300 mm) wide], with their side faces painted in red, orange, and yellow. The shading system is controlled by a building management system; it responds to sun, rain and wind (by heat-, rain- and wind-detectors) (Figure 9.28). Additionally building occupants can manually control the shading

Figure 9.27 Nurses' station. *Source: Stefan Mueller-Naumann*

Figure 9.28 Facade detail. *Source: Stefan Mueller-Naumann*

Figure 9.29 Entrance pavilion. *Source: Stefan Mueller-Naumann* system (the automatic system takes over again after a determined time period, e.g., 1.5 hours). The facade design is somewhat reminiscent of an accordion; "it is a functional facade that makes you curious."

Between the inner and outer layers the facade reveals a lively and playful combination of material and color. This "second skin" provides protection from solar gain and privacy for building occupants (glazing is close to full height) while optimizing transparency and connection to the view of the mountains. Even when the facade is fully closed, the 28 percent openness factor of the perforations maintains unobstructed views.

The narrow floor plate building maximizes natural light and views through both overall form and introduction of a series of plan enclosed courtyards and roof gardens (Figure 9.30). On the south side of the building loggias integrated into the climatic envelope mark the transition from private to semi-private to the public space of the street and allow building occupants to experience the outdoors and direct outside air. The clinics' inward orientation creates a strong sense of comfort, privacy and safety.

Source: Nickl & Partner Architekten AG

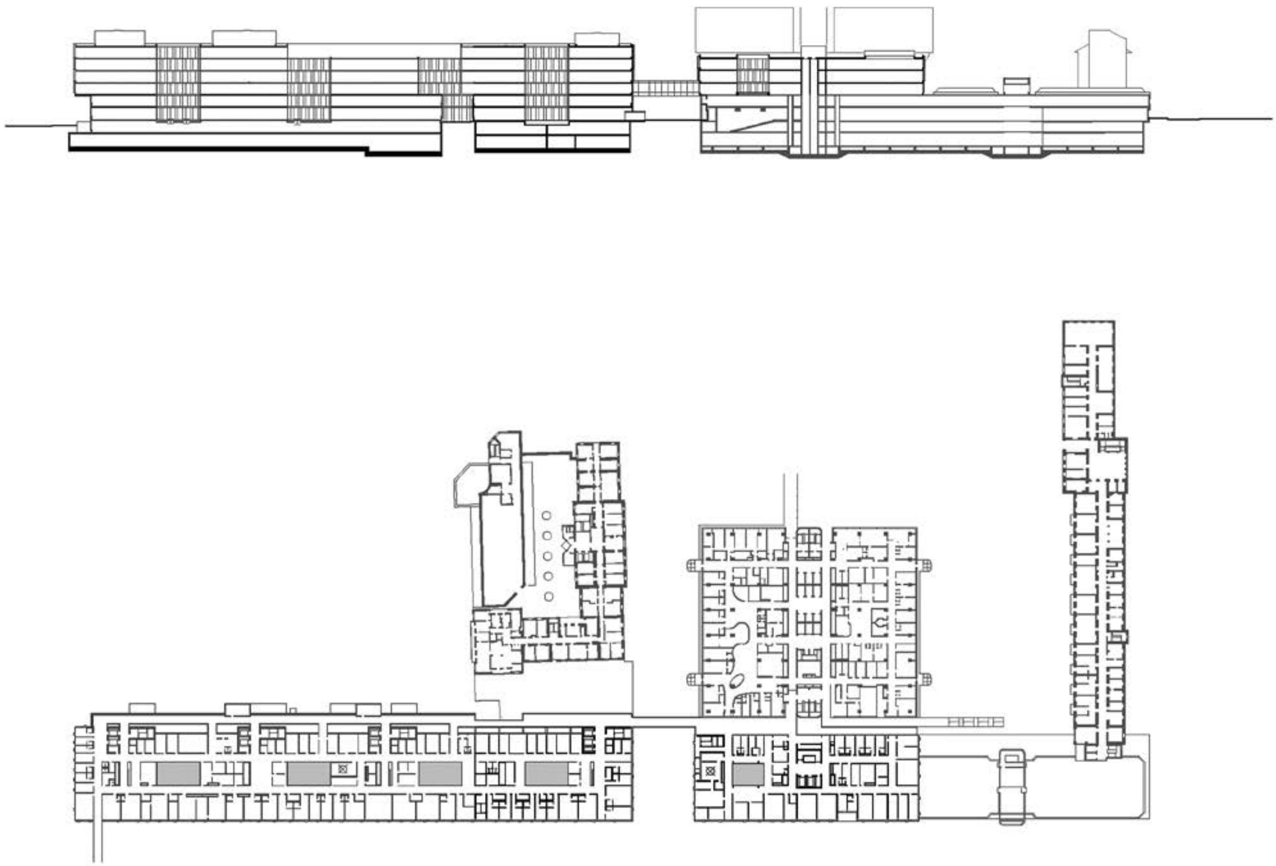


Figure 9.30 Section through addition and second floor plan (bridge level). *Source: Nickl & Partner Architekten AG*

Case Study 40: Helsingør Psychiatric Clinic

Helsingør (Elsinore), Denmark

OWNER: Frederiksborg County, Helsingør Hospital

PROJECT TEAM:

Architect: PLOT = BIG + JDS

Structural Engineer: Moe & Brøsgaard

Landscape Architect: Schonhere Landskab

Contractor: NCC Construction Denmark

TYPE: New Psychiatric Hospital

SIZE: 64,580 sq. ft. (6,000 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: Public inpatient and outpatient psychiatric hospital including 48 beds, treatment areas, outpatient clinics and day hospital

COMPLETED: 2005

BIOME: Temperate Humid

CLIMATE ZONE: Humid Continental, Cool Summer

PRECIPITATION: 24 in. (612 mm)

KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management:* Extensive permeable paving
- *Narrow Floorplate:* Natural daylight and direct access to the landscape is provided from all parts of the building
- *Energy Responsive Facade:* Hospital is built into the landscape to buffer heat loss; roof captures heat
- *Green Roof:* Extensive vegetated roof
- *Low EUI:* No mechanical cooling
- *Climatic/Bioregional Design:* Operable windows, overhangs, natural ventilation, and orientation to minimize energy demand
- *Innovative Source Energy:* Supplied by district system
- *Innovative Energy Distribution:* Hydronic heating system
- *Natural Ventilation:* Throughout
- *Healthy Materials:* Simple, honest material palette

Figure 9.31 Helsingør Psychiatric Clinic. *Source: Peter Sorensen*

This unique design solution for a residential psychiatric program, which has become a best-practices model of healthcare design, demonstrates a keen integration of landscape and building in a cold-dominated climate. Located on the northeast coast of the island of Zealand in eastern Denmark, temperatures range from winter lows of 33°F (0°C) to summer highs of 68°F (20°C). This free-standing building is connected via bridge to an existing hospital campus, but its form completely departs from both the context and traditional planning typologies (Figure 9.31). The landscape has been both cut and bermed to preserve views from the adjacent hospital, providing protection from harsh exposure while maximizing daylight and views.

The clover-shaped structure organizes the residential program to orient each patient's room toward unique landscape views—two sets of rooms face the lake, and one set of rooms faces the surrounding hills. The intimate living program has been folded into the landscape, level with the lake. Between the residential functions a new collective space emerges, populated by small courtyard patios (Figures 9.32–9.34). The plan effectively and rationally minimizes walking distance, and at the same time provides individual sections with identity, autonomy and intimate spaces where occupants can feel almost at home.

On the upper level, the treatment program is placed level with the existing hospital and is organized as five individual pavilions, combined into a snowflake structure. The day treatment program, outpatient clinic and departmental offices cluster around the arrival points. All parts of the building are fused at one single point, right above the center of the clover structure. One of the treatment center's galleries breaks off as a bridge to the existing hospital.

Figure 9.32 Green roof punctuated by courtyards. *Source: Peter Sorensen*

Figure 9.33 Activity area courtyard. *Source: Esben Bruun*

Figure 9.34 Residential corridor punctuated by courtyard. *Source: BIG*

Operable windows and narrow, courtyard-punctuated footprint reduce the need for mechanical ventilation systems. Dark roof surfaces absorb heat year round. No mechanical cooling is required. At places where the building is half underground the landscape slips over to become the roof, integrating the building with the surrounding landscape (Figures 9.35–9.38).

The building demonstrates a unique approach to minimal material use. All materials retain their natural surfaces. Cast concrete floors are tinted with lively colors and walls are made of glass, wood and concrete (Figure 9.34).

Sources: BIG (Bjarke Ingels Group); Moe & Brøsgaard

Figure 9.35 Aerial view in summer. *Source: Esben Bruun*

Figure 9.36 Aerial view in winter. *Source: Dragor Luftfoto*

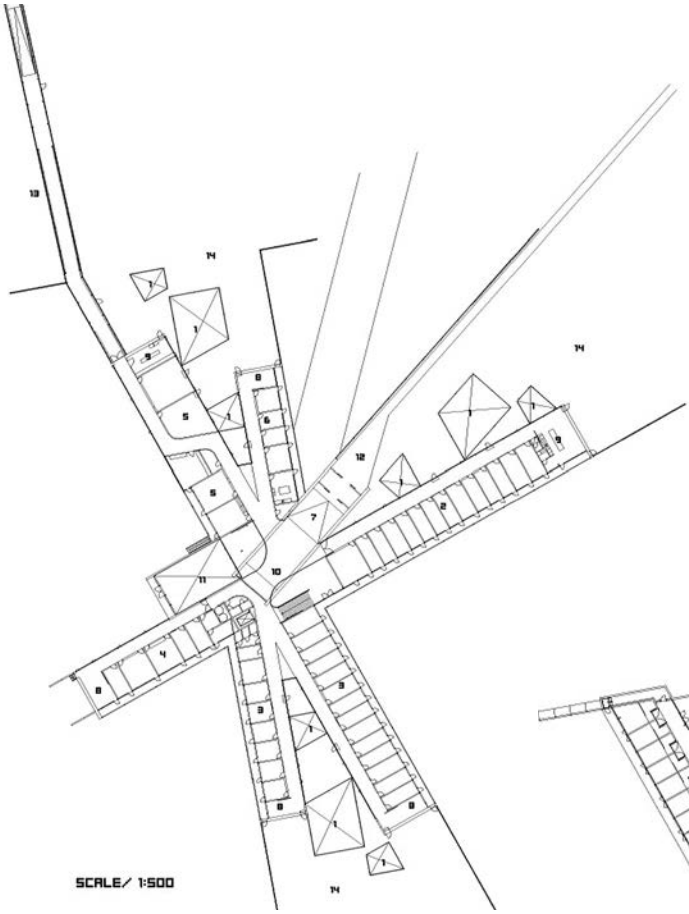


Figure 9.37 Upper level plan (bridge to hospital top). *Source: BIG*

Key:

1. Courtyard (Atrium)
2. Day Treatment
3. Mental Health
4. Conference
5. Education
6. Administration
7. Main Entrance
8. Meeting Room
9. Kitchen
10. Central Atrium
11. Gymnasium/Sports
12. Entrance Path
13. Connection to Hospital
14. Landscape Roof of Lower Level

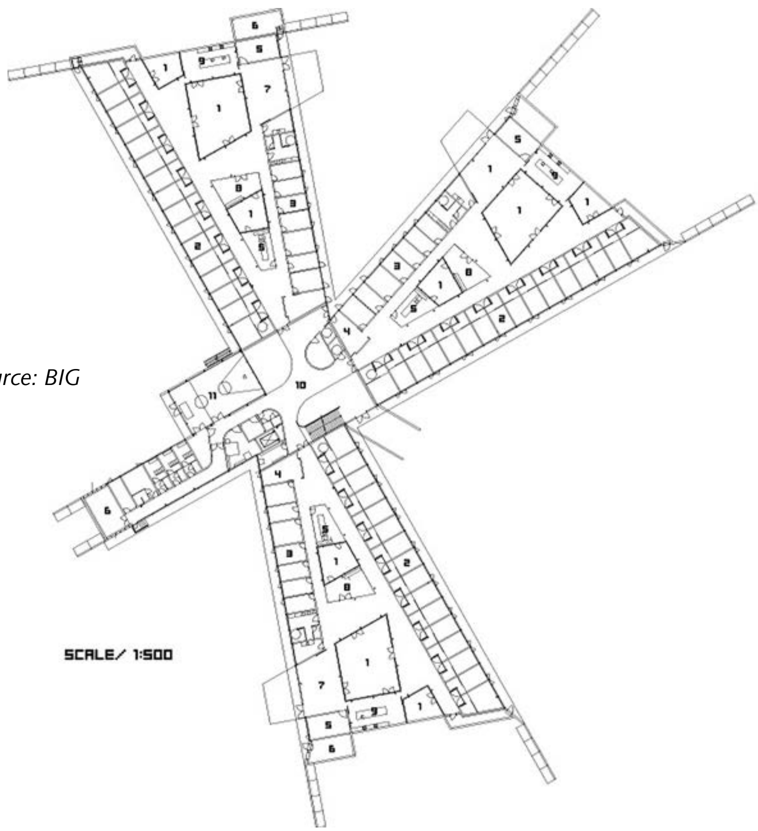


Figure 9.38 Lower level plan. *Source: BIG*

Key:

1. Courtyard (Atrium)
2. Resident Room
3. Office
4. Unit Reception
5. Meeting Room
6. Mechanical/Technical
7. Dining
8. Meeting Room
9. Smoking Room
10. Central Atrium
11. Gymnasium/Sports
12. Staff Changing/Locker

Case Study 41: Rhine Ordinance Barracks Medical Center Replacement

Kaiserslautern, Germany

OWNER: U.S. Army/State of Rheinland Pfalz

PROJECT TEAM:

Architect: HOK in collaboration with HWP Planungsgesellschaft

MEP Engineer: Affiliated Engineers, Inc. in collaboration with GTB-Berlin

Civil Engineer: CDM Smith

Landscape Architect: HOK

TYPE: New Replacement Acute-Care Hospital and Ambulatory Clinic

SIZE: 985,479 sq. ft. (91,554 sq. m)

EUI: 159 kBtu/sf/yr (501 kWh/sm)

PROGRAM DESCRIPTION: Comprehensive military in- and out-patient medical center serving wounded warriors and more than 36,000 active and retired military personnel and their families with in- and out-patient services

COMPLETED: 2020 (anticipated)

RECOGNITION: Targeting LEED for Healthcare Silver (minimum)

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 19 in. (477 mm)

Figure 9.39 Rhine Ordinance Barracks Medical Center Replacement. *Source: HOK/HWP*

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Minimal tree removal; places of respite provided by courtyards, green roofs, gardens, and walking trails
- *Habitat Restoration:* Protected wetland and habitat for protected species
- *Innovative Stormwater Management:* 100% infiltration; strict water quality standards
- *Narrow Floorplate:* Access to daylight for all regularly occupied spaces
- *Energy Responsive Facade*: High-performance glazing, walls and roof
- *Rainwater Harvesting:* 100% irrigation water demand
- *Innovative Source Energy:* Central utility plant with water-to-water heat pumps
- *Innovative Energy Distribution:* Chilled beams, heat exchange and energy exchange loops
- *Natural Ventilation:* Operable windows in Administration Tower and Medical Service Center
- *Healthy Materials:* Avoid halogenated organic compounds, phthalates and flame retardants, replaced vinyl flooring with porcelain tiles, linoleum, and rubber flooring

Figure 9.40 Central atrium. *Source: HOK/HWP*

Figure 9.41 Outpatient entrance. *Source: HOK/HWP*

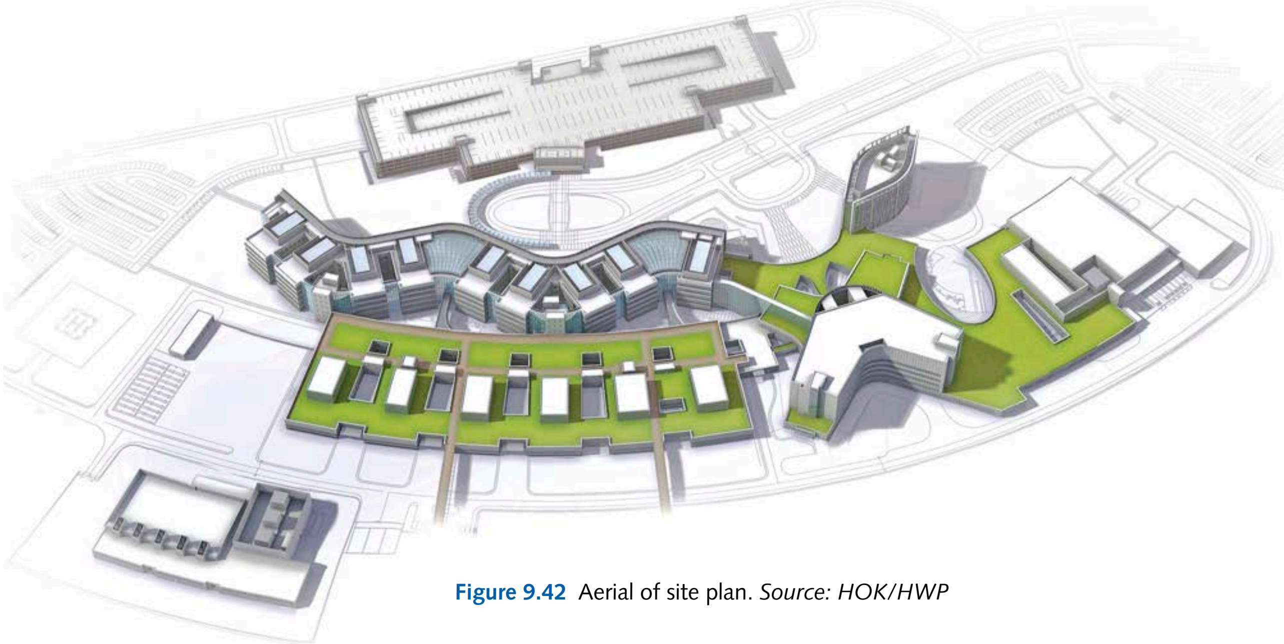


Figure 9.42 Aerial of site plan. *Source: HOK/HWP*

Kaiserslautern is a city of about 100,000 people, located in southwest Germany and bordering the Palatinate Forest. Since the mid-1950s, Kaiserslautern has been home to a major NATO installation with approximately 50,000 military personnel living in the area—the largest community of U.S. military personnel outside of the U.S. including components of the U.S. Army and Air Force.

The Rhine Ordinance Barracks Medical Center Replacement will function as a first response facility to wounded warriors, and provide in- and out-patient clinical services to active and retired military personnel and their families living in the region. The aim is to create a world-class hospital inspired by clinical innovation that recognizes the substantive healing benefits that can accrue from integrating sustainable and evidence-based design strategies. Reflecting this commitment, the project will meet both U.S. and German building guidelines and regulations, including a requirement to achieve a minimum LEED for Healthcare Silver certification (Figure 9.39).

The project has a strong commitment to energy efficiency, with a schematic design that achieves 38 percent energy savings below ASHRAE 90.1–2007 (not including process energy) and 14 percent improvement over the German 2009 energy code. The project is designed to fulfill at least 50 percent of both building heating and cooling needs with renewable energy sources. Ventilation is provided with a variable air volume system integrated with active chilled beams to fulfill U.S. and German energy requirements. The ventilation system is designed to both meet the German requirement of 2.7 air changes per hour for medical spaces, and increase to 4 air changes per hour as appropriate.

The central utility plant incorporates a sophisticated integrated system based on water-to-water heat pumps that move reject heat from cooling loads to heating loads and vice versa. Energy exchange loops transfer heat from equipment loads to heat air and water, and heat pumps are used to generate cooling via pre-heat water for sterilizer and other pre-heat systems. The air handler also incorporates air-side heat and cooling recovery loops. The envelope's effective thermal performance is another integral factor to overall building energy performance, with attention to high performance glazing, walls, and green roofs.

The Rhine Ordinance Barracks Medical Center is designed to provide outdoor views to 100 percent of regularly occupied spaces along with ample daylight throughout to comply with German workplace requirements. Its narrow curvilinear form enables this; it is constructed of white pre-cast concrete, metal panels and glass on a forested site (Figures 9.40–9.43). Both the Administration Tower and Medical Services Center have operable windows. And, with an eye to the future, the hospital's physical elements are designed in modules to facilitate flexibility and growth over time.

Source: HOK

Figure 9.43
Outpatient entry.
HOK/HWP

Case Study 42: Ng Teng Fong General Hospital and Jurong Community Hospital

The Republic of Singapore

OWNER: Singapore Ministry of Health

PROJECT TEAM:

Architect/Structural/Civil: CPG Consultants Pte Ltd.

Design Consultant and Medical Planning: HOK

Green Mark Consultant: ZEB Technology Pte Ltd., Singapore

Mechanical & Electrical: Parsons-Brinkerhoff

TYPE: New Public Acute-Care Regional and Community Hospital Campus

SIZE: 1,946,440 sq. ft. (180,830 sq. m) Site Area: 13.3 acres (5.4 ha)

EUI: 70 kBtu/sf/yr (220 kWh/sm/yr)

PROGRAM DESCRIPTION: Specialist Outpatient Clinics (SOC)—335,100 sq. ft. (31,133 sq. m); 699-bed Regional Hospital (RH)—877,300 sq. ft. (81,504 sq. m); 402-bed Community Hospital (CH)—231,300 sq. ft. (21,485 sq. m); shared support services—330,710 sq. ft. (30,724 sq. m)

COMPLETED: 2014—CH and SOC; 2015—RH

RECOGNITION: Targeting Green Mark Platinum

BIOME: Tropical Humid

CLIMATE ZONE: Tropical Savanna

PRECIPITATION: 79 in. (2000 mm)

KEY SUSTAINABILITY INDICATORS

- *Narrow Floorplate:* More spaces with low-glare daylight; windows for every patient in communal wards
- *Energy Responsive Facade*: Solar shading customized for orientation; massing responds to prevailing winds
- *Green Roof:* Extensive green roofs and gardens
- *Natural Ventilation:* Natural ventilation and passive cooling 70% of beds
- *Rainwater Harvesting:* For landscape irrigation
- *Reclaimed Water Reuse:* Municipal reclaimed water for toilet flushing in SOC and landscape makeup water
- *Innovative Energy Distribution:* Heat pumps for precooling of outside air
- *Renewable Energy:* Solar thermal system heats 100% domestic hot water (heat pump backup); grid-connected solar PV system of 100 kWp
- *Natural Ventilation:* Natural ventilation and passive cooling for majority of beds
- *Heat Recovery:* Heat pumps; heat exchangers with run around coils for the ORs, precooling of all fresh air units
- *Healthy Materials:* Low VOC and Singapore Green Label products
- *Resilience:* Hospital is ground zero emergency preparedness center
- *Civic Function:* Community park within the hospital premise

Figure 9.44 Ng Teng Fong General Hospital and Jurong Community Hospital. *Source: CPG Consultants Pte Ltd/ Studio 505*

Ng Teng Fong General Hospital and Jurong Community Hospital is slated to be a next-generation healthcare hub in Singapore, comprising a regional hospital (RH) and community hospital (CH) as well as extensive specialty outpatient care (SOC) (Figure 9.44). The two hospitals operate symbiotically, with the RH providing advanced medical and general support services to the CH and the latter receiving the former's stabilized, recovering patients. The site features a large park for patients and the community, complete with a jogging track, stage for events, and comprehensive rehabilitation facilities.

The 1,968 ft. (600 m)-long campus development is part of the Urban Redevelopment Authority plan. It integrates the Elevated Pedestrian Network on the second level, enabling safe and protected passage for users coming from the nearest Jurong East MRT station. This level contains public dining and retail facilities, as well as a public thoroughfare from public transit to adjacent shopping and offices. Three distinct buildings are linked with elevated bridges as well as two common below-grade levels where shared parking and support service facilities are located.

The Regional Hospital (RH) is 16 stories including administration offices, training and teaching facilities, isolation wards, Emergency Department equipped with Civil Emergency capabilities, Intensive Care units, Endoscopy, Day Surgery, Operating Theatres, Staff welfare and amenities, single- and 4-bed private patient rooms and fully subsidized 6- and 12-bed wards. The Community Hospital (CH) is a 12-story building including administrative offices, retail, training, single and 4-bed private patient rooms, fully subsidized 6- and 8-bed wards, specialized outpatient clinic and inpatient/outpatient rehabilitation centers. Unlike most older

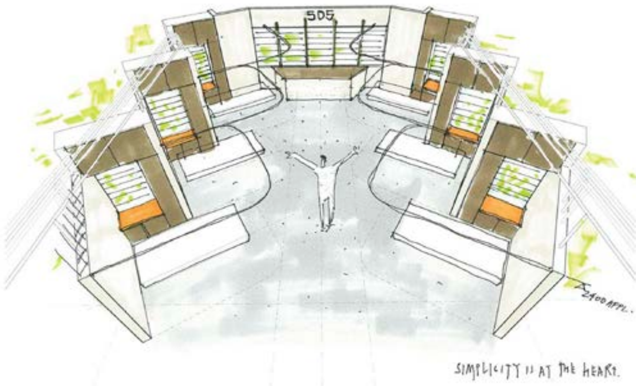


Figure 9.45 Innovative ward room design. *Source: CPG Consultants Pte Ltd/Studio 505*

Figure 9.46 Facade detail. *Source: CPG Consultants Pte Ltd/Studio 505*

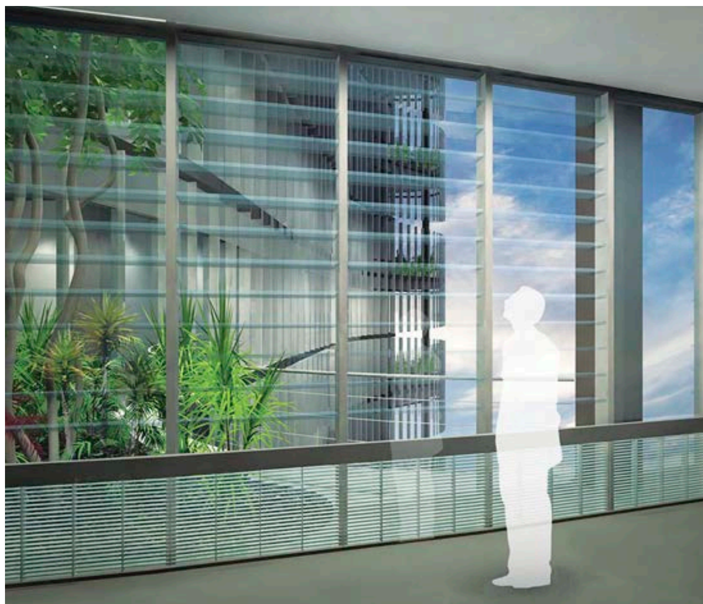


Figure 9.47 Interior corridor with operable jalousie. *Source: CPG Consultants Pte Ltd/Studio 50*

Figure 9.48 Ambulatory SOC building. *Source: CPG Consultants Pte Ltd/Studio 505*

public hospitals in Singapore, an innovative herringbone concept ensures that "every patient has a window," providing direct views outside, lowering the chances of cross-infection while allowing generous spaces for clinical bedside care (Figure 9.45). All wards are designed for flexible conversions between service classes.

The hospital is projected to achieve more than 30 percent energy savings in comparison to a baseline hospital, and more than 40 percent savings from a minimum code compliant hospital. Passive strategies are the foundation of the design. Aggressive design analysis and computer modeling assisted the design team with optimizing building form, daylighting, solar control, acoustics, and natural ventilation. The facade system is unique to every orientation; shading design provides at least 60 percent shading for the critical facades and 40 percent for the other facades (Figures 9.46 and 9.47). There are three levels of shading protection: primary shading consists of exterior shading devices above the windows and projecting slab edges to protect against solar gain and help to direct stormwater runoff. Secondary shading consists of vertical louvers in selected glazed areas to protect against low angle morning and evening sun. Tertiary shading is provided by plantings; these protect against both overhead and low angle sun.

A solar thermal system backed by heat pumps provides 100 percent of domestic hot water needs. High efficiency mechanical systems include extensive run-around heat recovery in ORs and heat pumps for pre-cooling of outside air. Natural ventilation and passive cooling is employed for 70 percent of the overall bed total of both the CH and RH; operable windows are interconnected to the Building Management System. Finally, a grid-connected 100 kWp solar photovoltaic system reduces peak electrical demands. The building incorporates occupancy sensors and sleep-mode features for elevators and escalators, and monitoring and control systems for daylighting and general equipment.

Innovative water conservation features include use of collected rainwater and municipal reclaimed water (NEWater) for irrigation throughout as well as toilet flushing in the ambulatory (SOC) building. Very low cooling loads significantly reduce the process water required in comparison with conventional buildings. Building materials feature Singapore Green Label Products, and prioritize low-VOC solutions. In summary, Ng Teng Fong General and Jurong Community Hospital advances the principles pioneered in Khoo Teck Puat (Case Study 28, Chapter 8) in an innovative next generation hospital campus (Figure 9.48).

Source: CPG Consultants Pte Ltd/HOK

Case Study 43: Nanaimo Regional General Hospital Emergency Department Addition

Nanaimo, British Columbia, Canada

OWNER: Vancouver Island Health Authority

PROJECT TEAM:

Architect: Stantec Architecture Ltd.

Mechanical and Electrical Engineer: Stantec Consulting Ltd.

Structural Engineer: Read Jones Christoffersen

Landscape Architect: HB Lanarc

LEED Coordination: Advicus

General Contractor: CMF Construction Ltd.

TYPE: New Emergency Department Addition to Existing Acute-Care Hospital

SIZE: 68,850 sq. ft. (6,396 sq. m)

EUI: 197 kBtu/sf/yr (621 kWh/sm/yr)

PROGRAM DESCRIPTION: Emergency department with trauma, urgent and non-urgent care, offices, emergency psychiatric care and adjacent Psychiatric Intensive Care Unit with staff education, lounge with unprogrammed office space, plant rooms and thermal labyrinth on lower level

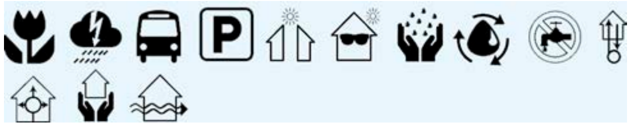
COMPLETED: 2012

AWARDS AND RECOGNITION: Targeting LEED Gold certification

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 44 in. (1,110 mm)



KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia:* Plan enclosed courtyards provide views to nature in all public and clinical areas
- *Innovative Stormwater Management:* Stormwater collected in tanks below courtyards
- *Innovative Parking:* Electric vehicle charging stations installed
- *Narrow Floorplate:* The L-shaped addition ensures daylight provided to all public and clinical areas
- *Energy Responsive Facade:* Automatically controlled exterior sun shades protect glazed areas from direct solar radiation; operable glazed walls in some spaces open to courtyards
- *Rainwater Harvesting/Reclaimed Water Reuse:* Collected rainwater and diverted renal backwash filter water from a hemodialysis unit used for landscape irrigation
- *Innovative Energy Distribution:* Thermal labyrinth precools supply air in summer and shoulder seasons; prewarms air in winter; in combination with displacement ventilation eliminates needs for mechanical cooling
- *Natural Ventilation:* Operable glazed walls naturally ventilate psychiatric emergency and intensive care waiting, staff offices, and education spaces lounges

Figure 9.49 Nanaimo Regional General Hospital Emergency Department Addition. *Source: Stantec*

Nanaimo Regional General Hospital's new Emergency Department, an L-shaped two-story structure at the north corner of the existing hospital, has been configured for functionality, indoor environmental quality and sustainability (Figure 9.49). The ambulance and walk-in entries and all clinical functions are on the second level, matching existing grade and the hospital's Main Level. The addition is set apart from the existing hospital to preserve existing building windows and to provide daylighting to staff work areas lining the inside of the L-shape on both floors. The hospital's four values underlie the Addition's design principles: timely, respectful, quality care and a place people would want to come to work.

The Addition's primary design goal is to reduce caregiver and patient stress by providing daylight and views of nature in all public and clinical areas. Each of the five patient care zones focuses on a plan-enclosed landscaped courtyard, bringing beauty, calm, and life-world connection to these high-stress environments (Figures 9.50 and 9.51). Operable glazed walls in the psychiatric emergency and intensive care lounges fold open to courtyard gardens. The remaining upper level courtyards extend down to the lower level, increasing daylight to future office type functions. A staff respite courtyard lies in the gap between the existing hospital and the ED addition (see earlier plan, Figure 9.12).

Figure 9.50 Courtyards punctuate the addition. *Source: Stantec*

The project's small courtyards, benefiting from immediate and unanimous clinician support, are landscaped with lush vegetation, inspired by the small courtyards in Herzog & de Meuron's REHAB Basel (Case Study 28, Chapter 8). Abundant rainfall will be channeled from the roof to stormwater retention tanks located below the staff and psychiatric courtyards and used to irrigate courtyard plantings and other landscaped areas. The tank will also collect diverted renal backwash filter water from an adjacent hemodialysis unit.

The ED's lower level below-grade perimeter is lined with building service rooms and a thermal labyrinth that will provide significant pre-cooling of supply air in the summer and shoulder seasons, and pre-warming in winter. The labyrinth can be operated in three modes: active, storage, and flushing. All-directional air grills on a wind tower can be controlled to open only on the windward side for intake or only on the leeward side in reverse-flow flushing mode, reducing fan energy when the labyrinth is in use. In summer flushing mode, cool night air pooled above the building's high albedo roof is drawn down through one of the courtyards and then backward through the labyrinth and out of the tower, usually using only stack-effect and wind.

Glazing is protected from direct solar radiation by automatically controlled exterior sunshades, allowing the use of displacement ventilation. In the Nanaimo climatic context, the labyrinth delivers the higher supply temperature required for displacement, eliminating the need for mechanical cooling.

Figure 9.51 View of courtyard from ED interior. *Source: Stantec*

Figure 9.52 The staff courtyard separates the addition from the existing hospital. *Source: Stantec*

As with all new healthcare projects in British Columbia, LEED Gold certification is mandatory, as are yearly payments for offsets to achieve carbon neutrality as required by Bill 44–2007: Greenhouse Gas Reduction Targets Act. This innovative and radical solution moves beyond prevailing typologies to transform the care experience, work environment, and environmental performance of this high-stress, energy-intensive hospital component (Figure 9.52).

Source: Stantec

Case Study 44: Seattle Children's Bellevue Clinic

Bellevue, Washington

OWNER: Seattle Children's Hospital

PROJECT TEAM:

Architect: NBBJ

Engineers: AEI Affiliated Engineers Inc. *(mechanical/electrical);* ABKJ (civil); PCS Structural Solutions (structural)

Commissioning: Keithly Barber Associates

Landscape: Site Workshop LLC

General Contractor/Sustainability: Sellen Construction

TYPE: New Pediatric Ambulatory Surgery Center

SIZE: 80,000 sq. ft. (4,432 sq. m) and 107,000 sq. ft. (9,940 sq. m) structured parking

EUI: 162.7 kBtu/sf/yr (513 kWh/sm/yr)—includes garage lighting and fans

PROGRAM DESCRIPTION: Pediatric ambulatory care, outpatient surgery, imaging, urgent care, and more than 15 specialty services

COMPLETED: 2010

AWARDS/RECOGNITION: LEED-NC Gold Certification; Modern Healthcare Design Awards: Honorable Mention

BIOME: Temperate Humid

CLIMATE ZONE: Mediterranean

PRECIPITATION: 38 in. (972 mm)

KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management:* Bioswales and on-site retention pond
- *Innovative Parking:* Tuck-under parking to preserve open space: plaza level vehicle entry with a green roof covering parking spaces below
- *Daylighting:* Skylights on second floor and full expanse windows at end of corridors bring daylight deeper into plan
- *Energy Responsive Facade:* South-facing entry elevation utilizes metal-mesh panels that make a shaded zone with covered outdoor spaces.
- *Green Roofs:* Patients, staff can view green roofs on second floor
- *Community Uses*: Accommodates a planned city-wide walking/running/bike path on an abandoned railroad
- *Low Embodied Energy:* 25% materials extracted/manufactured locally

Figure 9.53 Seattle Children's Bellevue Clinic. *Source: Copyright © Benjamin Benschneider/OTTO*

Figure 9.54 Solar shading protects full-height glazing from unwanted heat gain. *Source: Copyright © Benjamin Benschneider/OTTO*

Figure 9.55 Exterior terraces inhabit facade shading system. *Source: Copyright © Benjamin Benschneider/OTTO*

Seattle Children's created this expanded ambulatory services clinic to reduce patient load at its core hospital and to provide care closer to families living in eastern King County (Figure 9.53). Although green design was not a high priority for the client at the start, it became increasingly important during the design and construction process. By the time the building opened in 2010, it had earned LEED-Gold certification and Seattle Children's had committed itself to the 2030 Challenge of creating low-carbon facilities.

Through a conscientious effort at increasing room efficiency and minimizing travel distances, the design effort achieved a 28 percent space savings, fitting 110,000 sq. ft. (10,219 sq. m) of program into 80,000 sq. ft. (7,432 sq. m). Adopting a dual-circulation model improved efficiency for the staff while offering a healthier, more pleasant experience for the patients. A series of public amenities that empower wellness takes advantage of daylight and nature connection, including a café, a 2,500 sq. ft. (232 sq. m) athletic facility, and a playroom where children can interact before and after surgery.

An integrated process brought the local utility to the table during the early design stages with grants and incentive programs, allowing the team to implement energy conserving measures that lower energy costs by more than $117,000 each year. By orienting the building to the south and shading this glazed facade with metal-mesh panels, the architects were able to bring daylight into a public corridor running the length of the building's second floor while protecting it from too much sun (Figures 9.54 and 9.55). High-efficiency envelope measures (including high-performance glazing), green roofs, and sun-shading devices reduce energy demand while providing visually engaging indoor and outdoor spaces. Optimized heating and cooling systems, including a variable speed chiller, high-efficiency boilers, and variable air volume air handling units, daylighting, and occupant lighting controls further reduce energy demand. In its first year of operation, actual annual energy use of 13,028 MBtu (3,818 mWh) was within 1.5 percent of the predicted 12,834 MBtu (3,761 mWh).

Site planning features include structured parking to reduce heat-island impacts, bioswales, and an on-site stormwater retention pond. Landscaping features extensive native plantings—a theme brought indoors through interior artwork that features Pacific Northwest flora and fauna. In summary, the project demonstrates sophisticated and seamless integration of indoors and outdoors, a climate-responsive facade, and extensively daylit interiors—all in the service of transforming the clinical experience for patients, families, and caregivers.

Source: NBBJ/Pearson (2012)

Case Study 45: Pictou Landing Mi'Kmaq Community Health Centre

Trenton, Nova Scotia, Canada

OWNER: Pictou Landing Mi'kmaq First Nation

PROJECT TEAM:

Design Architect: Piskwepaq Design Inc.

Architect of Record: Peter Henry Architects

Structural Engineer: BMR Structural Engineering

Mechanical Engineer: CBCL Limited

Contractor: Higgins Construction

TYPE: New Ambulatory Clinic and Community Centre

SIZE: 1,292 sq. ft. (120 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: A 2-story medical clinic and community center

COMPLETED: 2008

RECOGNITION: World Architecture Festival 2008–Shortlisted

BIOME: Temperate Humid

CLIMATE ZONE: Humid Continental, Cool Summer

ANNUAL PRECIPITATION: 46.4 in. (1,178 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature*: Site includes medicine garden with indigenous stone wheels and plants traditionally used for healing
- *Climatic/Bioregional Design:* Building built into earth and traditional building methods. Design based on traditional Mi'Kmaq precedents for instrumental and harmonious qualities
- *Innovative Source Energy:* Geothermal/ground-source heat-pump provides heating and cooling from a local de-commissioned municipal well water system
- *Innovative Energy Distribution:* Hydronic heating
- *Natural/Enhanced Ventilation:* Height and slope of cross section allows for efficient capture of return air and heat recovery ventilation
- *Innovative Construction:* Community sawmill constructed as part of the project to train local workers in building the trusses and provide a local source of sawn wood in an economy largely based on fishing
- *Low Embodied Energy:* Sourced locally available un-sawn wood in the round, bent into arched forms while green and flexible to maximize strength and minimize embodied energy

Figure 9.56 Pictou Landing Mi'Kmak Community Health Centre. *Source: Paul Toman*

The Pictou Landing Health Centre is located in an indigenous Mi'kmaq coastal fishing community. Incidents of health problems within the community have historically been much higher than that of the surrounding non-native population—attributed to nearby industrial pollution, chronic poverty, and inadequate access to health care and health education. The community and the design team agreed that the building should maximize the use of local intelligence, material, and skills, while minimizing operating costs and environmental impacts (Figure 9.56).

The structural and environmental strategies for the building are based on principles of traditional Mi'kmaq building (Figure 9.57). Traditional wood use by Algonquin tribes involves working with the wood grain and the use of tension and shear connections. Local small-diameter trees, bent into arched forms while green and flexible, maximize structural capacity. Using the wood without sawing it ensures that it is in its most efficient possible configuration: end-to-end fibers stacked in concentric cylinders. The truss system was developed after studying traditional Mi'kmaq construction by building traditional lodges and longhouses in collaboration with Mi'kmaq elders, which in turn required training of local Mi'kmaq workers. A community sawmill was constructed to provide a local source for sawn wood for the Health Centre and future community projects.

Traditional Mi'kmaq longhouses and lodges used the earth for thermal storage, by placing heated rocks in holes in the ground. Average temperatures range from 12°F (–11°C) in winter to 76°F (13°C) in summer, with significant snowfall. Built into a hill, the thermal mass of the Health Centre building at the lower level retains heat, and an interior earth plastered wall helps to regulate interior humidity. Ground source heat and cooling systems provide conditioning in this heating dominated climate. As in traditional

Figure 9.57 The building structure during construction. *Source: Richard Kroeker*

Figure 9.58 Interior. *Source: Paul Toman*

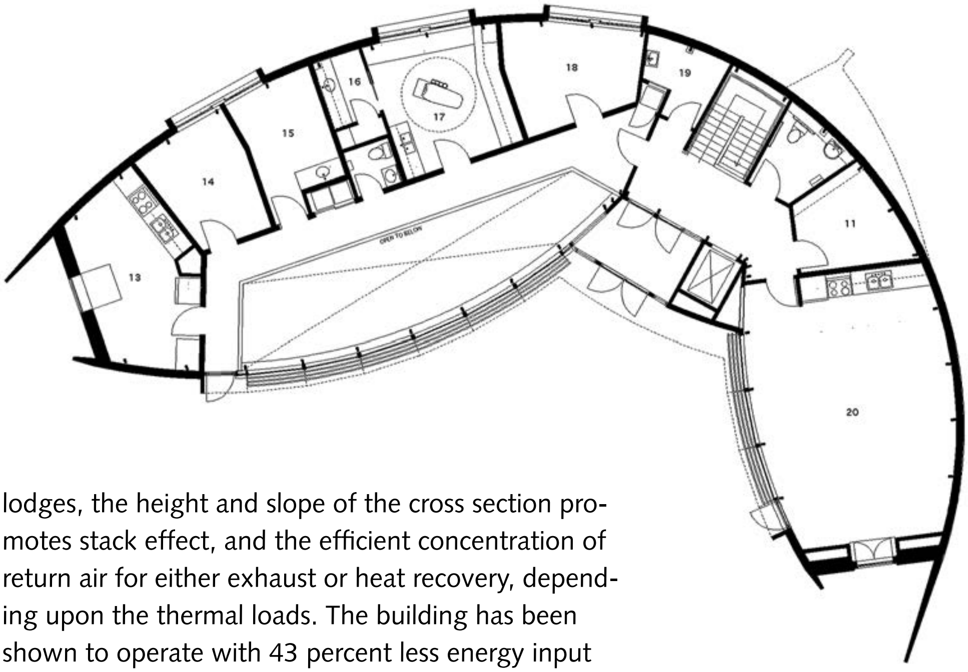


Figure 9.59 Upper level plan.
Source: Richard Kroeker

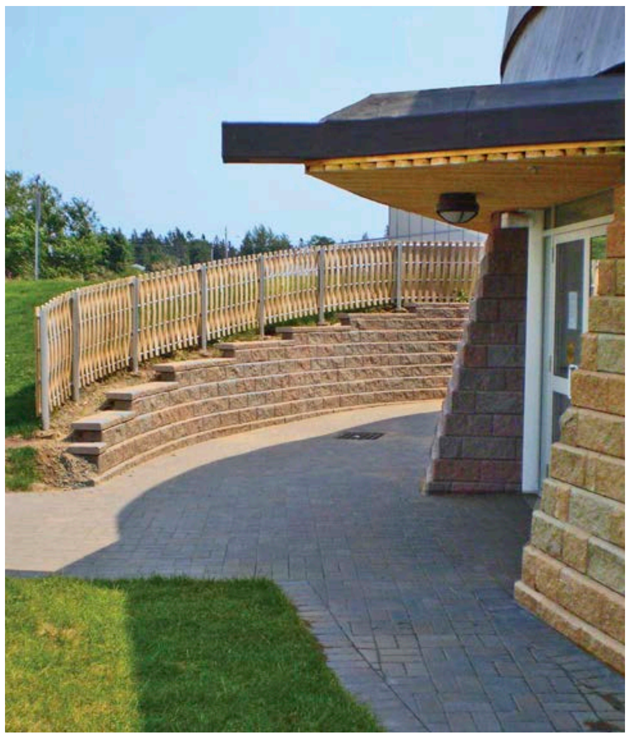
lodges, the height and slope of the cross section promotes stack effect, and the efficient concentration of return air for either exhaust or heat recovery, depending upon the thermal loads. The building has been shown to operate with 43 percent less energy input than a conventional building of the same size.

The spaces within the building are materially articulated, visually interconnected, and naturally lit. Curving sunlit spaces with their connecting views and expression of natural materials are intentionally part of the healing process (Figures 9.58–60). Spaces are shaped to provide for many forms of social interaction, with distinct views into the surrounding community and landscape. The building embraces a circle in the center of the community that houses both traditional stone medicine wheels and an active medicinal herb garden (Figure 9.61).

The building has become a source of local pride and provides material evidence that this ancient culture has much to contribute to the world from within its own history. First Nations communities and elders throughout the region view the building as important testimony to the possibility for building cultural continuity and health in the future.

Source: Richard Kroeker

Figure 9.60 Lower level entry.
Source: Richard Kroeker



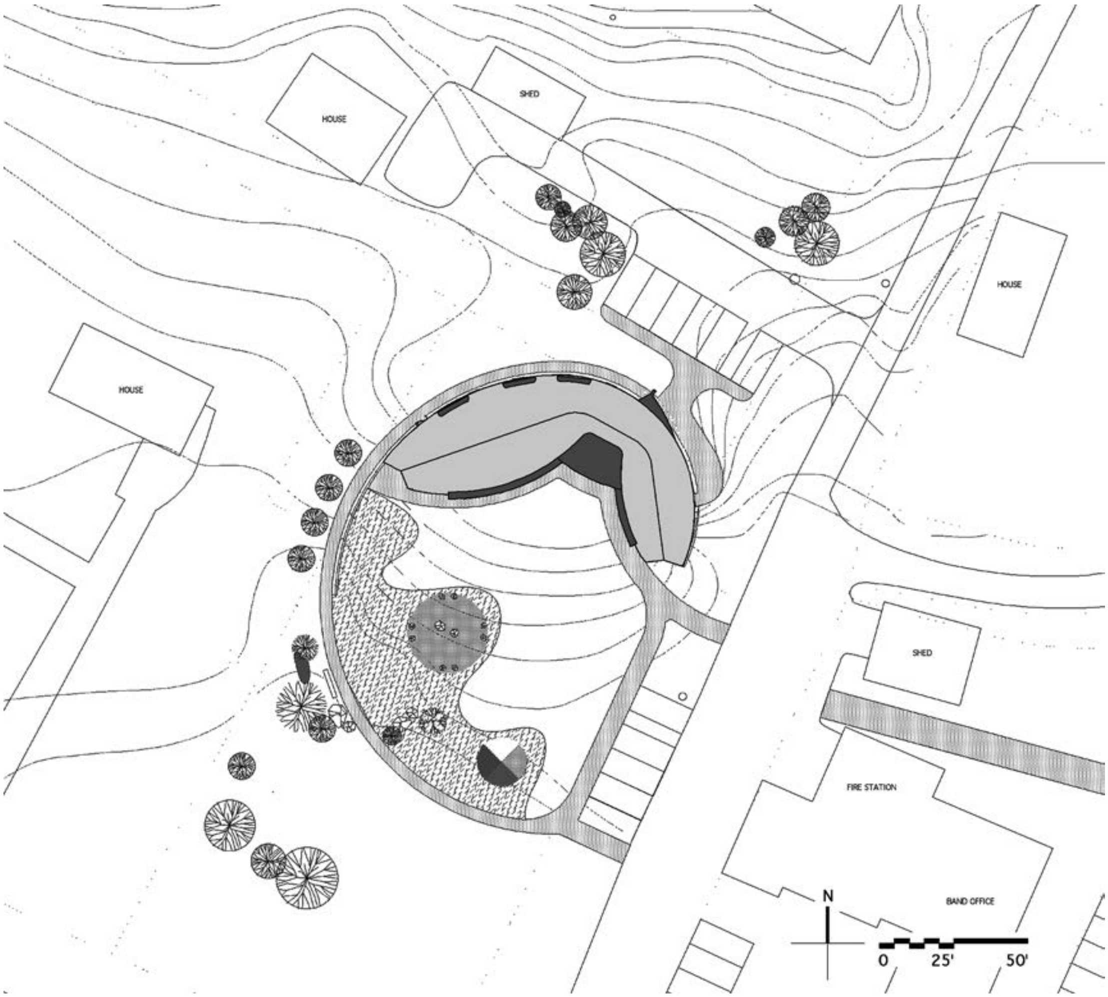


Figure 9.61 Site plan with medicinal garden. *Source: Richard Kroeker*

Case Study 46: Kenya Women's and Children's Wellness Centre

Nairobi, Kenya

OWNER: James R. Jordan Foundation

PROJECT TEAM:

Architect: Perkins+Will; Triad Architects, Kenya

Civil/ Structural Engineer: EngPlan

Mechanical/Electrical Engineer: EAMS Ltd.

Quantity Surveyor: Barker and Barton, Kenya

TYPE: New Acute-Care Healthcare Campus

SIZE: 446,700 sq. ft. (41,500 sq. m); Site area: 10 acres (4.04 ha)

EUI: Not Available

PROGRAM DESCRIPTION: 170-bed inpatient hospital, outpatient clinics for women and children institute of learning, Gender Violence Recovery Center, family hostel and a forensics lab

COMPLETED: Estimated 2016

BIOME: Tropical Humid

CLIMATE ZONE: Tropical Savanna

PRECIPITATION: 30 in. (750 mm)

KEY SUSTAINABILITY INDICATORS

- *Reduced Site Disturbance:* Construction follows natural site contours to minimize cut and fill
- *Narrow Floorplate:* Prioritizes daylight and natural ventilation
- *Climatic Design:* East and west facades have porches to buffer interior space against low sunlight angles; passive cooling strategies
- *Rainwater Harvesting:* For landscape irrigation and toilet flushing
- *Reclaimed Water:* For toilet flushing in Wellness Centre
- *Water Use Reduction:* Low-flow fixtures
- *Energy Responsive Facade:* Overhang provides fixed level of control from sunlight
- *Renewable Energy:* Solar PV for on-site electrical production; solar thermal for hot water production
- *Low Embodied Energy:* Local and natural materials with low-energy manufacture
- *Civic Function/Community Engagement:* Incorporates on-site hotel; engages communities, providing resources, support and motivation for women

Figure 9.62 Kenya Women's and Children's Wellness Centre.
Source: Copyright © Rhett Koo

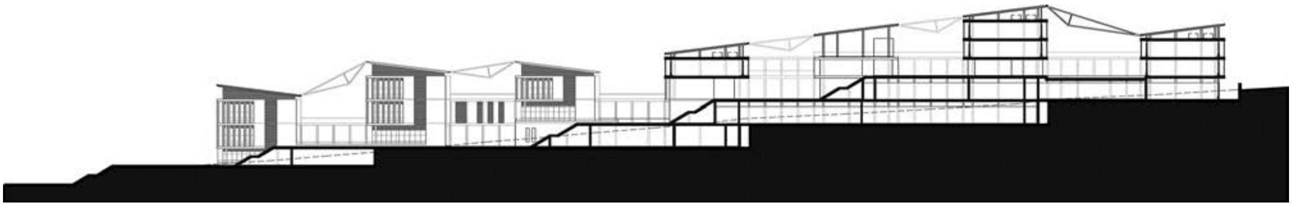


Figure 9.63 Inpatient courtyard. *Source: © Perkins+Will*

Figure 9.64 Inpatient balcony. *Source: © Perkins+Will*

Figure 9.65 Section through site. *Source: © Perkins+Will*

The vision of the Chicago-based Jordan Foundation is to provide a twenty-first-century, state-of-the-art wellness village for the women and children of Kenya. Located on the campus of United States International University (USIU), the facility will provide services to the surrounding communities, the city of Nairobi and beyond (Figure 9.62).

At approximately 6,000 ft. (1,829 m) above sea level, Nairobi benefits from an ideal year-round climate—temperatures vary from 50°F (10°C) to 78°F (25°C) throughout the year. With its location on the equator, the sun remains high overhead throughout the day and throughout the year. The effective solar yearly radiation in Nairobi provides ample opportunities for solar power, solar hot water and daylighting, but also requires thoughtful design strategies to reduce solar gain. In addition, the high cost and unreliable source of electrical power from the government-owned utility requires provision of multiple alternative sources of power for reliability. The buildings take advantage of the site, stepping the building into the site and providing views to the north and buffering highway noise from the south (Figures 9.63 and 9.65).

Constant throughout the entire building perimeter, a 6.5 ft. (2 m) overhang provides a fixed level of control from the sunlight. In addition, a louvered screen system optimized to its particular orientation further diffuses the sunlight. The long north and south facades are substantially protected from direct solar radiation while the short east and west facades have porches to help buffer the interior spaces against the low sunlight angles (Figure 9.64).

The width of the building, fixed at 46 ft. (14 m) including the overhangs, plays an important role in both daylighting and the collection of rainwater. The Wellness Centre uses rainwater to supplement landscape irrigation and as the source for greywater for toilet flushing. Understanding the local design approach guided the selection and sourcing of materials. The roof enclosure was specifically designed to have a flat concrete slab system with a secondary standing seam sloped system to prevent infiltration of rainwater. In summary, the project reflects the Jordan Foundation mission: compassionate global care tailored to local climate, culture, and need.

Source: Perkins+Will

Case Study 47: Tata Medical Centre Cancer Hospital

Kolkata, India

OWNER: TATA Healthcare Group

PROJECT TEAM:

Architect, Interior Design: Cannon Design

General Contractor: Tata Consulting Engineers

TYPE: New Inpatient Cancer Hospital

SIZE: 300,000 sq. ft. (27,870 sq. m); 14 acres (5.7 ha)

EUI: Not Available

PROGRAM DESCRIPTION: 150-bed comprehensive cancer center includes clinical care and support services, research, outpatient ambulatory facility

COMPLETED: 2011

RECOGNITION: Award of Excellence in the International category, Society of American Registered Architects (2012); Honor Award, New Construction, AIA Western New York (2012)

BIOME: Temperate Semi-Arid

CLIMATE ZONE: Tropical Rain Forest

PRECIPITATION: 60 in. (1,520 mm)

Figure 9.66 Tata Medical Centre Cancer Hospital. *Source: Cannon Design*

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature/Biophilia:* Central landscaped interior courtyard; vegetated site connects patients/staff to nature
- *Transit Access:* Site accessible by public transportation
- *Climatic/Bioregional Design:* Building oriented to capture prevailing winds for ventilation
- *Energy Responsive Facade:* Overhangs and deep recessed windows shield building from summer sun and monsoon rains; double-walled system protects building from natural elements on the south and west
- *Rainwater Harvesting:* Rainwater stored in tanks, used for irrigation
- *Natural Ventilation:* Operable windows installed in waiting areas; mechanical system designed to accommodate open windows
- *Low Embodied Energy Materials:* Extensive use of indigenous stone for facade
- *Civic Function:* 50 percent of patients provided free services

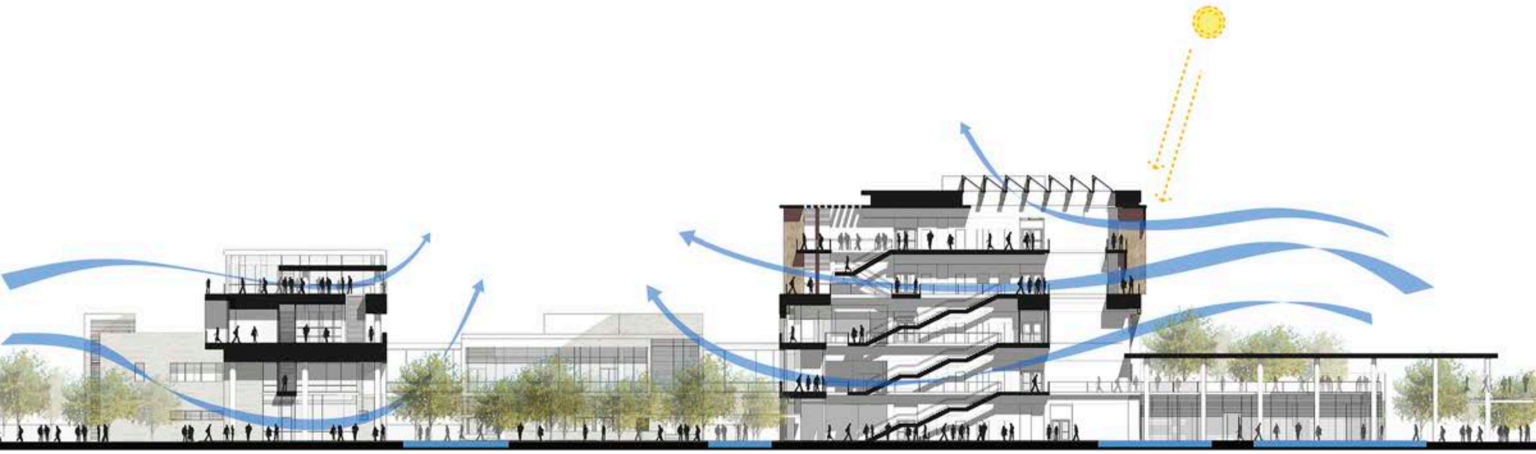


Figure 9.67 Section encourages natural ventilation. *Source: Cannon Design*

The mission of Tata Medical Center is to promote prevention as well as treatment of cancer patients, including rehabilitation and palliative care. Located in Kolkata's Rajarhat area, the Center responds to India's need for specialized treatment facilities to care for more than three million underserved residents living with cancer. This project is the first phase of an 800,000 sq. ft. (74,322 sq. m) master plan. The Center's building and landscape is health promoting while fulfilling a social mission—50 percent of services are offered free of charge. More than 1,000 local residents were involved with constructing the Center, marrying knowledge of local materials and construction skills with a sophisticated medical center to create an iconic landmark that honors health and healing (Figure 9.66).

The human-scaled campus is composed of a series of separate, linked structures built of simple materials: natural stone and concrete. The buildings are grouped around a central courtyard, imbuing both a connection to nature and creating a calming, serene environment for patients, families, and staff.

The Center was artfully designed with appropriate orientation and climatic strategies that lessen dependence on external resources, especially important given a pattern of summer temperatures exceeding 100°F (38°C), and extreme monsoon rains between June and September each year. Shifting from eight months of minimal rainfall to the four-month monsoon season, rainwater is collected and stored in underground tanks and used to irrigate the extensive landscaped areas year-round.

Building orientation takes advantage of prevailing breezes to provide ventilation and enhance human comfort; windows are primarily placed on the north facade and are recessed; deep overhangs protect the building from direct solar gain and from the deluge of the monsoon rains (Figures 9.67–9.69). A double-walled "jali" screen system is installed on the buildings' south and west facades to protect them from natural elements. Although the building is fully air conditioned, operable windows are installed in some waiting areas, understanding that some patients and visitors prefer natural over mechanical ventilation.

Source: Cannon Design

Figure 9.68 Courtyard. *Source: Cannon Design*

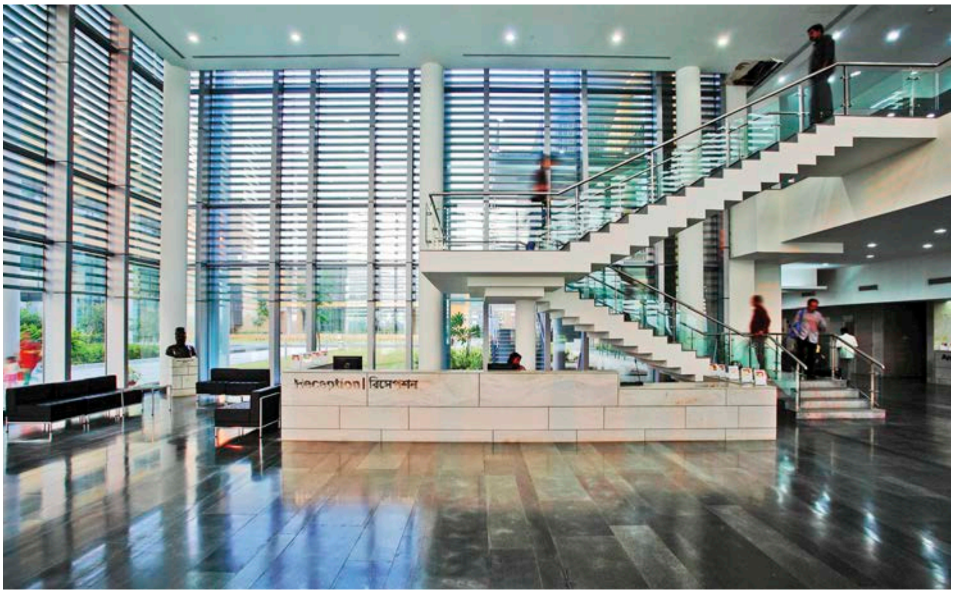


Figure 9.69 Lobby. *Source: Cannon Design*

Case Study 48: CBF [*Centre pour le Bien-être des Femmes*] Women's Health Centre

Ouagadougou, Burkina Faso

OWNER: AIDOS [*Associazione Italiana Donne per lo Sviluppo*]

PROJECT TEAM:

Architect: FAREstudio

Project Management: AIDOS with Voix de Femmes

Construction Services/Funding: Partito dei Democratici di Sinistra, European Commission

TYPE: New Women's Outpatient Health Center

SIZE: Covered surface: 5,381 sq. ft. (500 sq. m); Site area: 17,222 sq. ft. (1,600 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: Outpatient Health complex with examination, training and counseling

COMPLETED: 2007

RECOGNITION: Zumtobel Award for Architecture 2009; International Architecture Prize 2009; Gold Medal for Italian Architecture 2009

BIOME: Tropical Semi-Arid

CLIMATE ZONE: Tropical Rain Forest

PRECIPITATION: 31 in. (792 mm)

KEY SUSTAINABILITY INDICATORS

- *Habitat Restoration:* Western and Sub-Saharan Africa tree species provide shade and promote the return of native vegetation
- *Climatic/Bioregional Design:* Natural and passive ventilation strategies, raised platform protects from dust and mud; provides passive cooling
- *Energy Responsive Facade:* Building oriented to reduce effects of hot winds
- *Rainwater Harvesting:* Sloping tarpaulin is part of a system that collects and stores rainwater to irrigate the garden
- *Renewable Energy:* Photovoltaics installed along perimeter wall
- *Natural Ventilation:* Mechanical air conditioning only in medical exam rooms; extensive use of operable windows
- *Low Embodied Energy:* Building walls are constructed using compressed, sun-baked clay bricks made on site using earth, cement, and water
- *Civic Function:* Focuses on providing education services, information and awareness about women's sexual and reproductive rights

Figure 9.70 CBF Women's Health Centre. *Source: Copyright © Sheila McKinnon*

The CBF is the first "real" building to be constructed in Sector 27, one of the poorest suburbs in Ouagadougou. This semi-rural area is defined by a multitude of small, spontaneously constructed mud huts entirely devoid of any planning regulations or basic infrastructures. The design is approached as a typological model with clearly defined architectonic characteristics derived from climatic, environmental, technical and economic considerations and is flexible and adaptable to any possible site (Figure 9.70).

The design concept is based on two pavilions that provide distinct programmatic separation of the primary activities performed by the CBF into two distinct, though closely related buildings: a Training Centre dedicated to activities of awareness-building and the administration and management of the CBF and a Consultancy Centre, used for medical visits, legal assistance and psychological counseling. The two buildings are set atop a single raised reinforced concrete platform that creates a unified sense of place and ensures protection against dust, mud, and humidity. The buildings are covered by corrugated aluminum and translucent decking that allows natural light to filter into the interior, reducing the need for artificial illumination. The two buildings are protected against rainfall and, above all, direct sunshine, by a lightweight waterproof velarium supported by an independent structure of steel "trees" (Figures 9.71 and 9.72).

The space between the steel roof and the velarium and the open cavity beneath the platform, together with the exterior openings fitted with operable glass fins, improve the natural ventilation of interior spaces and virtually eliminate the need for mechanical cooling (Figure 9.73).The modular configuration of the structure allows for future expansion. Walls are constructed using compressed dry stacked BTC—sun-baked clay bricks made on site using a rough mixture

Figure 9.71 Entrance View. *Source: FAREstudio*

of earth, cement, and water. This introduces local, alternative, and sustainable technologies within a context that is otherwise tied to standardized, nonoptimized building practices and the widespread importation of foreign building materials.

Given the lack of water and power in the area, the Center is fully grid-independent. Water is provided by a dedicated well and photovoltaic cells provide power. Air conditioning is limited to medical rooms in order to assure filtered air. The sloping tarpaulin is part of a system that collects and stores rainwater to irrigate the garden.

Source: FAREstudio

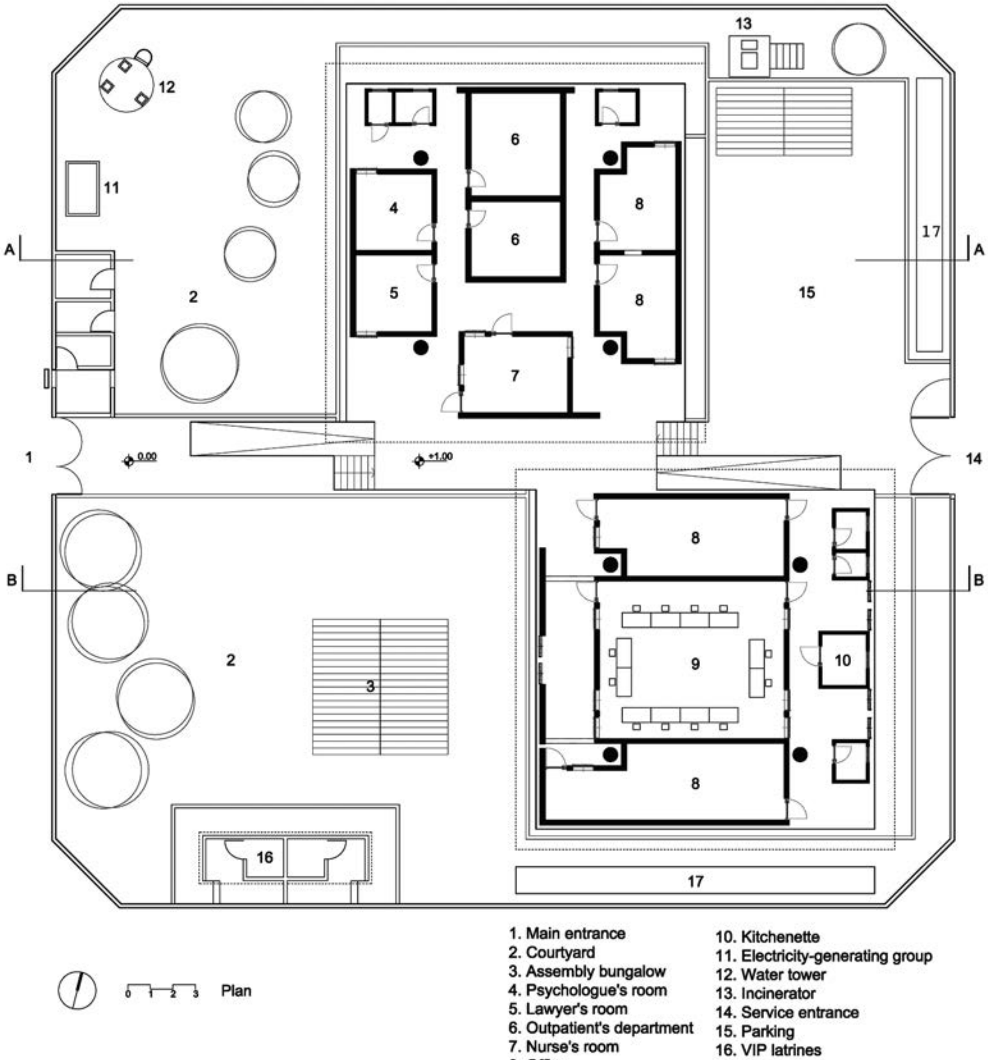


Figure 9.72 Plan. *Source: FAREstudio*

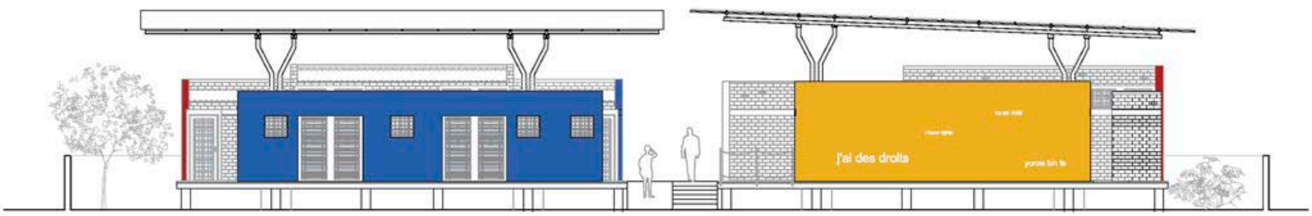


Figure 9.73 Elevation. *Source: FAREstudio*

CONTRIBUTORS

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Ray Pradinuk is co-leader, Healthcare Research and Innovation for Stantec Architecture, and a principal of the Vancouver Integrated Healthcare Design Studio. He applies sustainable design and evidence-based research to the design of a wide range of healthcare and interdisciplinary research projects with Stantec colleagues and collaborators from around the world. He tries to visit the most outstanding new hospitals.

BIBLIOGRAPHY

Alvarez, L. (2004). Where the healing touch starts with the hospital design. *New York Times,* September 7.

Bergsland, K. (2005). Keynote address, annual HealthCare Design Conference, Scottsdale, AZ, November 6–9.

Farrow, T., and S. Stanwick (2008). Humanism and the Art of Sustainable Healing. In *Sustainable Healthcare Architecture,* R. Guenther and G. Vittori. Hoboken, NJ: John Wiley & Sons, Inc., pp. 340–342.

Guenther, R. (2006). How should healthcare lead? Panel discussion at CleanMed Conference, Seattle, April 20.

Habraken, J. N. (1998). *The Structure of the Ordinary: Form and Control in the Built Environment.* Cambridge, MA: MIT Press.

Hyett, P. (2004). New developments in the healthcare estate in England. Presentation at the AIA Academy of Architecture for Health Conference, Washington, DC.

Kendall, S. (2008). Open Building: Healthcare Architecture on the Time Axis—A New Approach. In *Sustainable Healthcare Architecture,*R. Guenther and G. Vittori. Hoboken, NJ: John Wiley & Sons, Inc., pp. 353–359.

McMinn J., and M. Polo (2006). 41° to 66°, Regional Responses to Sustainable Architecture in Canada. Museum exhibit. Cambridge, Ont.: Cambridge Galleries.

Monk, T. (2004). *Hospital Builders.* London: Academy Press.

Payer, L. (1988). *Medicine & Culture: Varieties of Treatment in the U.S., England, West Germany and France.* New York: Penguin.

Postman, N. (1992). *Technopoly: The Surrender of Culture to Technology.* New York: Knopf.

Pearson, C. (2012). Seattle Children's Bellevue Clinic. *Greensource,* March, 2012. http://greensource.construction.com/green_building_projects/2012/1203-bellevue-washington.asp.

Stephens, S. (2005). REHAB Center for Spinal Cord and Brain Injuries. *Architectural Record* (June).

Verderber, S. (2006). Hospital Futures: Humanism Versus the Machine. In *Architecture of Hospitals,* ed. C. Wagenaar. Rotterdam: NAi.

Verderber, S., and D. Fine (2000). *Healthcare Architecture in an Era of Radical Transformation.* New Haven: Yale University Press.

Wagenaar, C. (2006). Five Revolutions: A Short History of Hospital Architecture. In *The Architecture of Hospitals,* ed. C. Wagenaar. Rotterdam: NAi, p. 35.

DOUBLING DAYLIGHT—RAY PRADINUK

Baker, G. R., P. G. Norton, V. Flintoft et al. (2004). The Canadian Adverse Events Study: The Incidence of Adverse Events among Hospital Patients in Canada. *Canadian Medical Association Journal,* 170(11).

Benedetti, F., C. Colombo, B. Barbini, E. Campori, and E. Smeraldi (2001). Morning Sunlight Reduces Length of Hospitalization in Bipolar Depression. *Journal of Affective Disorders,* 62(3):221–223.

Bergsland, K. (2005). Keynote address, annual HealthCare Design Conference, Scottsdale, AZ, November 6–9.

Frampton, K., T. Grajewski, and A. Eggleton (1999). Counting the Cost of People and Materials Movement within Hospital Buildings. Unpublished research report, Cardiff University, Wales.

Green Guide for Health Care [GGHC] (2004). Best Practices for Creating High Performance Healing Environments, Version 2.0 Pilot. www.gghc.org.

Joarder, A. R., A. Price, and M. Mourshed (2010). *Access to Daylight and Outdoor Views: A comparative study for therapeutic daylighting design;* World Health Design, January 2010.

Pallasmaa, J. (2005). *The Eyes of the Skin: Architecture and the Senses.* Hoboken, NJ: John Wiley & Sons, Inc.

Selzer, R. (1979). An Absence of Windows. In *Confessions of a Knife.* East Lansing: Michigan State University Press.

Ulrich, R. (1984). View Through a Window May Influence Recovery from Surgery. *Science,* 224:420–421.

———. (2001). Effects of Interior Design on Wellness: Theory and Recent Scientific Research. *Journal of Healthcare Design* (November): 97–100.

Ulrich, R., and C. Zimring (2004). The Role of the Physical Environment in the Hospital of the 21st Century: A Once in a Lifetime Opportunity. Report to the Center for Health Design. www.healthdesign.org/research/reports/physical_environ.php.

Verderber, S. (2010). *Innovations in Hospital Architecture.* New York: Routledge.

Verderber, S., and D. Fine (2000). *Healthcare Architecture in an Era of Radical Transformation.* New Haven: Yale University Press.

CHAPTER 10

CREATING THE TWENTY-FIRST-CENTURY HOSPITAL

> The fatal metaphor of progress, which means leaving things behind us, has utterly obscured the real idea of growth, which means leaving things inside us.
>
> G. K. Chesterton

> Of course, there is no such thing as the twenty-first century either. It is only a name, and we have no reason to suppose that how we have thought or behaved in the twentieth century need be, or will be, different because the Earth made another turn around the sun. But it is a name we use to foster hope, to inspire renewal, to get another chance to do it right.
>
> —Neil Postman

INTRODUCTION

Educator Neil Postman postulates that imagined futures are more about where we have been than where we are going (Postman 2000). In a sense, buildings are manifestations of the past: what we were thinking about when they were designed—whether that was five or fifty years ago. The challenge for all of us is to look back at history but envision the path ahead. There is no question that our future depends on this vision.

The challenges ahead are daunting: carbon neutrality, water balance, PBT elimination, and zero waste (see Chapter 5). While this may seem beyond the reach of an industry with so many fundamental economic, occupational, regulatory, and safety challenges, healthcare leaders worldwide are nonetheless embarking on this journey.

Rapidly developing nations, like China and India, are contemplating construction equal to or greater than the total U.S. hospital infrastructure in the next ten years, both in response to explosive population growth and to enhance care technologies. What models will they use? Will they achieve these ambitious sustainable building goals? Will they construct low-energy sustainable hospitals modeled on examples in the European Union, or energy-intensive buildings modeled on a prior generation of U.S. facilities?

Sustainability is now firmly rooted in the vocabulary of contemporary healthcare design. Architect and educator Stephen Verderber, author of *Innovations in Hospital Architecture* (2010) states, "The very first requirement of a hospital is that it shall cause neither human nor ecological harm." He continues: "A hospital can no longer think of itself as an island, or for whatever reasons exempt from its urban (or) ecological context." Verderber articulates this challenge:

> This is the challenge—to first and foremost promote community health through design and ecological responsibility . . . . What good to (the poorest, most remote) would-be patients is it for their local hospital to be noise-free, aesthetically superior, afford a high level of privacy, be safe of medical and staff errors, and so on, if they lack access to it?

Globally, the green building movement is evolving from conceiving of buildings as resource consumers toward "restorative and regenerative" buildings designed with inherent capability to become net resource producers. This translates to moving beyond doing "no harm" to a built environment that "heals"—a perfect metaphor for the healthcare sector. Restorative and regenerative design offers a global vision for a healthcare delivery system that contributes to a stronger, fairer, and cleaner world economy based on one simple truth: We will not have healthy people on a sick planet.

What is necessary is a cohesive roadmap toward a true sustainable future—a roadmap postulated in Figure 10.1. This diagram suggests that "green" initiatives today, however well intentioned, are focused on reducing negative impacts—using "less" fossil fuel and water, avoiding persistent bioaccumulative toxic chemicals (PBTs). Strategies and systems that "do no harm" are theoretically "sustainable"—i.e., capable of continuing indefinitely with no adverse impacts to human or natural systems over time. On a planet with finite resources where degradation is already threatening the long-term viability of life, "restorative" systems and initiatives are aimed at both sustaining the status quo and restoring or regenerating some of what has been lost. Increasingly, our very survival may depend on embracing such restorative systems.

This final chapter postulates that the healthcare industry is in a pivotal position to lead this twenty-first-century transformation—reintegrating environment, health, and sustainability in service of restoration and healing. By critically reinventing the hospital as an accessible, restorative place of healing, marshaling purchasing power, and modeling health and wellness behaviors within global societies in critical need of alternatives to fast food and retail culture, the healthcare industry can signal a new relationship to healing and health.

The question before us is how to create this future. How can the healthcare sector move beyond a focus on doing "less harm" to a future that positively contributes to the conditions that foster individual, community, and global health? Can healthcare create restorative service delivery models and supply chains? If architecture is the clothing we put on our institutions, then the key visible manifestation of this transformation is the physical structures of the twenty-first-century healthcare delivery system—from hospitals to ambulatory clinics.

This chapter examines four catalysts that form the foundation of a regenerative healthcare system that "heals" and examines their role in the emergence of healthcare as the new civic architecture and restorative healthcare design. Collectively, these four ideas are reshaping twenty-first-century healthcare in the service of planetary survival and health.

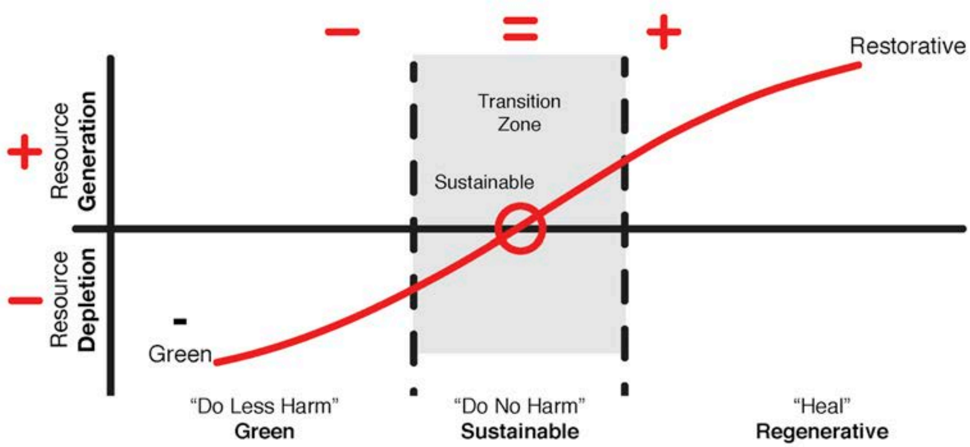


Figure 10.1 Green practices offer improvements over conventional practice, sustainable practices connote "net zero-impacts," restorative practices assist in evolution of subsystems, and regenerative practices actively co-evolve human and natural systems. *Source: Robin Guenther*

TWENTY-FIRST-CENTURY HEALTHCARE

These four ideas will be pivotal in transforming twenty-first-century healthcare from resource depletion to resource generation—from "green" to "restorative":

- Prevention and health promotion
- Community connectivity
- Transparency
- Resilience

At the intersection of these four ideas resides an emerging definition of healthcare as restorative, and the buildings that house healthcare activities at the center of a new civic architecture and restorative/regenerative design dialogue.

Prevention and Health Promotion

Medical sociologist Aaron Antonovsky (1979) coined the term "salutogenesis" to describe a medical approach focusing on factors that support human health and well-being, rather than on factors that cause disease. Analyzing U.S. epidemiological data, Antonovsky concluded that at any one time, "at least one-third and quite possibly a majority of the population of any modern industrial society is characterized by some morbid condition." In contrast to a pathogenic, medical approach that asks, "Why do people get this or that disease?"—Antonovsky suggested that it is only when we ask why people stay healthy that we begin to search for factors that can promote health despite the "ubiquity of pathogens—microbiological, chemical, physical, psychological, social and cultural." Salutogenesis seeks to describe and explain factors that move people toward the healthy end of a health continuum.

As healthcare expands from a narrow focus on disease management and treatment to a broader role in prevention and health management, how will the facilities alter to respond to this new mandate? As healthcare services are reconfigured to work within social frameworks and ecological limits, what does a truly "sustainable" healthcare system look like? Kaiser Permanente asked this fundamental question in its Small Hospital Big Idea Competition and the United Kingdom's NHS undertook this exploration in its Route Map for Sustainable Health (see Chapter 7). For both of these healthcare provider and insurer organizations, the answer entailed a redefinition of a hospital from a "sick care" environment to a "total health" environment supporting a reimagined care delivery system spanning from the home to acute-care settings. For the NHS, it included shifting economic resources from sick care to prevention and health management. In the emergent developing world with limited healthcare infrastructure, projects featured in Chapter 9 such as Pictou Landing (Case Study 45), Kenya Women's and Children's (Case Study 46), and CBF Women's Health, Burkina Faso (Case Study 48) point to bioregionally appropriate care delivery solutions that address health access, education, prevention, and early treatment as intrinsic to a holistic, comprehensive approach.

The entire body of work termed "salutogenic design," coined by Professor Alan Dilani (2008) of the International Academy of Design and Health, focuses on the design of health-promoting healthcare structures. Salutogenic design provides a basic theoretical framework for psychosocially supportive design that supports health and well-being. In this book, virtually every Case Study of sustainable buildings include salutogenic elements—connection to nature, daylighting, enhanced ventilation; many go beyond this to psychosocial or cultural connectivity that supports community. Protea Health (Chapter 3) is an example of a winning competition entry aimed at making visible a healthcare environment that is health-promoting by definition.

Community Connectivity

The NHS Route Map for Sustainable Health explicitly supports the need for paradigm shift from a system that is institution led, to a community-based system that provides for the future of society and the environment, informed and in partnership with patients and communities in a more open decision-making system (see Chapters 3 and 7). Recent U.S. healthcare system reform, the 2010 Patient Protection and Affordable Care Act, has set in motion the transformation of healthcare with regard to community engagement, mandating that nonprofit hospitals become "accountable care organizations" and produce periodic Community Health Needs Assessments. These requirements are likely to create the "stickiness factor" for three related community-based initiatives: commons healthcare, health districts, and anchor institutions. Commons healthcare examines the organization of healthcare service provision relative to a community and population; health districts connect large-scale planning decision-making to healthy communities; and anchor institutions' initiatives encompass how hospitals and healthcare organizations use their purchasing decisions to support their local economies.

A new dialogue, rooted in Elinor Ostrom's Nobel–prize-winning work on commons management, can be termed "Commons Healthcare." In *The Case for Commons Healthcare*, activist Jamie Harvie (2012) suggests that community-based social structures must manage their "commons"—a set of agricultural, energy resource, educational, and health systems that are required to sustain a population in a given geographic area:

> Commons healthcare also requires changing the current rationale for a healthcare system. In fact, the community-centered philosophy inherent in primary prevention approaches reinforce that a new model will necessarily be community informed and directed. No longer should filling their beds and keeping their labs, operating rooms and diagnostic and therapeutic machinery humming reward healthcare institutions. The incentives need to change. Moreover, a commons healthcare system would recognize, promote and preserve health-promoting activities and institutions such as farmers markets, community gardens, better food access, and increased farmland, clean air, and clean water.

In his seminal article *The Cost Conundrum*, physician Atul Gawande (2009) points out that U.S. communities that spend more per capita on healthcare do not produce better results: "Americans like to believe that, with most things, more is better. But research suggests that where medicine is concerned, it may actually be worse." The article examines low-cost communities such as Rochester, Minnesota (home of Mayo Clinic), Seattle, Washington (home of Swedish and Providence), as communities that provide quality care at low price points. One of the key factors in controlling costs is defining a "healthcare commons"—i.e., crafting a care delivery system tailored to meet the specific health needs of a defined community of people, locally and responsibly. In some instances, it includes organizing teams of healthcare professionals to target "hot spots," that is, a high-cost panel of patients that require consistent, cross-discipline medical and social support to manage their health.

Physicians Christine K. Cassel and Troyen Brennan (2007) believe that a commons framing offers distinct advantages for both healthcare cost and quality: In fact, single payer systems, by definition, create a healthcare commons. While U.S. medical care today is a marketplace, not anything resembling a commons, Cassel and Brennan suggest the creation of "virtual commons mechanisms" to encourage physicians to operate within a framework of "group responsibility." Quoting from their article, activist and writer David Bollier (2008) suggests such a virtual commons in U.S. medical care could create "a sound ethical framework for effective resource management linked to high-quality care." It would limit cost shifting, take responsibility for all the care of a population, focus on public health and prevention, and move away from a per-unit reimbursement system for services.

The Congress for New Urbanism (CNU) Health Districts Initiative integrates community-based planning strategies for healthcare facilities, grounded in the knowledge of the health impacts associated with sedentary lifestyle and automobile-oriented communities. Defined as neighborhoods or districts that contain one or multiple health facilities, Health Districts are seeking to advance urban design and planning criteria for promoting healthy built environments that benefit patients, staff, and families. This initiative builds directly from the public health evidence base described in Chapters 2 and 3. Strategies such as locating farmers' markets on hospital campuses, connecting hospitals to mass transit expansion or development initiatives, and adaptive reuse of hospital campuses are in fact reflections of health district considerations. Health districts can be viewed as a physical manifestation of a healthcare commons—expanding to managing inpatient care, outpatient treatment, home care, and health promotion within the district.

Health impact assessments (HIAs) are another manifestation of community health becoming a more pivotal public policy consideration. A health impact assessment uses an array of data sources and analytic methods, and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and the distribution of those effects within the population (NRC 2011). Assessments provide recommendations on monitoring and managing those effects, and help decision makers make choices about alternatives and improvements to prevent disease/injury and to actively promote health. The World Health Organization (WHO) believes HIAs have the potential to dynamically improve health and well-being.

Coined in 2002 by Harvard Business School professor Michael Porter, "anchor institutions" are defined as named industries anchored to a place—nonprofit centers for education or health, whose name and history tie them to a city. Increasingly, major U.S. cities and mega-regions are focusing on tying development and economic revitalization efforts to anchor institutions. In U.S. healthcare, strategies focus on leveraging the economic power of healthcare organizations to produce targeted community benefits. Many hospitals are affiliated with large health systems that cover multiple states or mega-regions that, in turn, purchase significant amounts of food and medical commodities through large national group purchasing organizations. While aggregated purchases through system-wide and national group purchasing contracts may achieve some economies of scale for health systems, this system of purchases often does little to support the local economy. Moreover, as the scale of healthcare operations and purchasing expands, hospitals realize less economic benefit from such large aggregated purchasing—local economic benefit is increasingly seen as equally important. The Henry Ford Hospital, Detroit, Michigan, provides incentives to managers to hire locally and has set in place a policy to pay local vendors in advance to provide working capital. The hospital expanded this initiative in 2010 by partnering with two other local anchor institutions, Detroit Medical Center and Wayne State University, and has already seen an impact of $400,000 in redirected annual purchasing to local businesses. The Cleveland Clinic has sponsored local urban farming businesses to supply year-round produce for its food service operations (community-wealth.org).

Transparency

Transparency, as used in a social context, implies openness, communication, and accountability. There is no doubt that global business has entered an era of transparency, fueled by the Internet. In a cover story titled "Leadership in an Age of Transparency," the Harvard Business Review (Meyer and Kirby 2010) reported that corporate leaders are increasingly taking responsibility for their environmental and social impacts and externalities (Figure 10.2). They are taking ownership of those impacts directly traceable to their organizations, such as fos sil fuel emissions or campus planning and siting impacts;

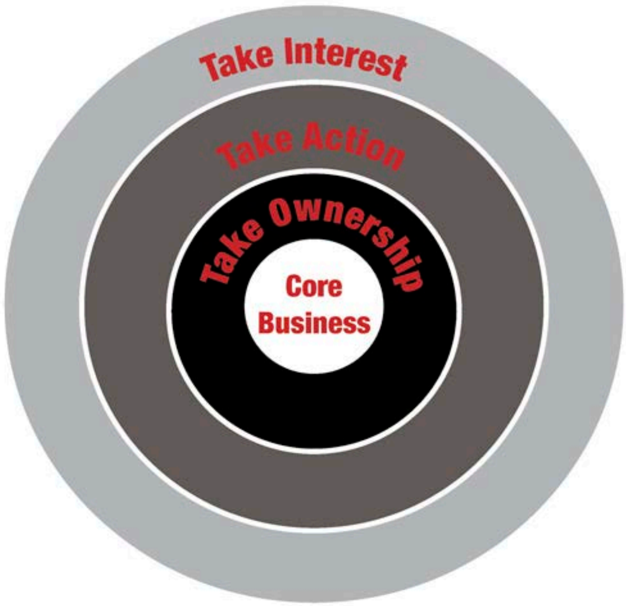


Figure 10.2 Business leaders in an age of transparency are taking ownership, action, and interest in the ripple effects of their environmental impacts. *Source: Meyer and Kirby (2010)*

taking action on those impacts they contribute to and have some "problem-solving competence" to deal with, such as supply chain environmental impacts and healthy food procurement; and taking interest in the ripple effects of their actions, where they have no special competence to directly address them, such as social justice issues associated with supply chains or waste streams. But in order to take responsibility, an organization has to understand and quantify its externalities—open access to information is at the core of "transparency."

Environmental impacts associated with the healthcare services sector are as varied as the components that comprise it. The UK National Health Service, for example, researched, quantified, and published its carbon emissions across building energy, transportation, and supply chain (see Chapter 7) and "took ownership" of many of those impacts. Environmental law and policy advocates Marian R. Chertow and Charles Powers (1997) note three important services sector areas from which to leverage environmental improvements:

> The environmental footprint of services extends into manufacturing, agriculture, and other natural resource industries since all are connected by the value chain which begins with extraction and manufacturing and ends with reuse or disposal. The tremendous impact of service companies on the environment can be divided into three basic categories: upstream leverage, where the service company influences its suppliers and others up the value chain; downstream influence, where the service company influences its customers toward the end of the value chain; and environmentally responsible production, which requires us to consider how the "production" of services can be done more efficiently.

As the purchasing agents for millions of healthcare consumers, healthcare organizations and their group purchasing organizations have tremendous leverage over their suppliers. This book contains multiple examples of healthcare organizations employing upstream leverage—note Kaiser Permanente's focus on moving markets (Chapter 7), and the myriad innovators and leaders who have purchased emerging products and technologies in support of more environmentally responsible solutions and to continue to drive socially and environmentally responsible research and innovation. Whether in search of better building products or organic food, the healthcare industry is exerting upstream leverage on manufacturers and suppliers. In the building industry, manufacturers are transforming the design, packaging, shipment, and end-of-life management of products based on healthcare-system advocacy.

Downstream influence is subtler. Chertow and Powers (1997) maintain that service industries play a key role in both satisfying and creating consumer preferences for goods and services, including their environmental dimensions. When a hospital serves patients local and organic food as part of their treatment, patients and families gain a new awareness of the importance of healthy eating. Likewise, patients experiencing a green building leave with a better understanding of the importance of sustainable architecture on occupant, community, and global health.

The healthcare industry is poised to take a leadership position in informing other services sectors about an explicit, health-based approach to sustainable building technologies and operation. The UK's National Health Service's ownership of its carbon footprint has been a key element in moving large U.S. healthcare systems such as Partners HealthCare, Kaiser Permanente, and Gundersen Health System to do the same (see Chapter 7). Who better than the healthcare sector to lead a health-based approach to sustainable building?

Finally, the concept of environmentally responsible production recognizes that services must also be "produced," often through complex operations requiring prodigious energy use and generating voluminous waste streams. If, in fact, Gawande is correct that higher cost healthcare includes "overprescribing" of healthcare services, how can healthcare systems "see" the impacts of this activity and reduce such waste? How do healthcare organizations develop tools that make the impacts of healthcare services production more transparent?

Daniel Goleman (2009) suggests that ecological intelligence in large, complex organizations like healthcare is based on distributed intelligence among many players. In centralized systems, like the NHS, this distributed intelligence may be centrally collected and acted upon.

Because U.S. healthcare is decidedly less centralized, operating through myriad for-profit, nonprofit, and government healthcare systems and independent entities, the distributed intelligence is more akin to a "swarm" of insects, in which individual organizations follow simple "swarm rules" that work together in countless ways to achieve self-organizing goals. In fact, campaigns such as the Healthier Hospitals Initiative in the U.S. and the Global Green and Healthy Hospitals Network internationally are organized around these principles. Goleman's three simple swarm rules are excerpted here; he continues:

> Swarm intelligence results in an ongoing upgrade to our ecological intelligence through mindfulness of the true consequences of what we do and buy, the resolve to change for the better, and the spreading of what we know so others can do the same. If each of us in the human swarm follows those three simple rules, then together we might create a force that improves our human systems. No one of us needs to have a master plan or grasp all the essential knowledge. All of us will be pushing toward a continuous improvement of the human impact on nature.

SWARM RULES

1. Know your impacts.
2. Favor improvements.
3. Share what you learn.

Source: Daniel Goleman (2009)

Resilience

Ecological economist C. S. Holling (1973) developed the concept of "resilience" in his study of ecosystem health and transformation. Why did some ecosystems seem unaffected by external human development pressures while others collapsed? Through this work, resilience has been defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks" (Walker et al. 2004). Resilience thinking is a framework applied to social-ecological systems that looks at the capacity of social systems to continue in the face of both abrupt disruption and gradual change. Resilience thinking examines healthy ecosystems to understand the factors that increase resilience to external challenges, and their applicability to social systems.

> *Human societies have never been more globally interconnected and technologically efficient, and less resilient: less able to handle, physically and psychologically, the disruptive changes we will likely face as we encounter planetary tipping points in the decades ahead.*
>
> —Thomas Fisher (2013)

U.S. healthcare service delivery increasingly lacks resilience to many of the ecological, economic, and social challenges of our time. Clayton Christensen and colleagues (2008) suggest that U.S. healthcare is increasingly vulnerable to major "disruptive innovation"—i.e., lower cost service delivery innovations that undercut established markets, as it remains highly centralized, expensive, and its specialized "disease" focus is increasingly irrelevant to large numbers of consumers. Hurricanes Katrina and Sandy have demonstrated that our acute-care healthcare infrastructure is vulnerable to extreme weather events, which has rendered it incapable of providing care in intense times of need.

Thomas Fisher (2013) describes our current "fracture-critical" design reality, in which centralized infrastructure, from power grids to hospitals, are larger, more complex, increasingly dependent on massive amounts of increasing ongoing maintenance, and often vulnerable to failure of a single element. Unlike ecosystems, in which resilience is assured through redundancies, affluent societies have based definitions of efficiency on eliminating redundancy. U.S. healthcare exemplifies this notion: Operable windows were eliminated once mechanical ventilation came into use; electrical lighting replaced daylighting; windows

Figure 10.3 Spaulding Rehabilitation Hospital, located on the Boston waterfront, includes building design strategies that improve passive survivability in extreme weather and future sea level rise. *Source: Perkins+Will; Partners HealthCare*

themselves were perceived as redundant. Now, loss of backup emergency electrical power renders hospitals completely uninhabitable—and the size and complexity of backup systems have increased to the point that they are financially difficult to afford and adequately maintain.

The "passive survivability" of healthcare infrastructure is essential to its sustainability—the concept, coined after Hurricane Katrina, that buildings be designed to survive loss of essential services, such as electricity, water, and sewage, as a consequence of a natural disaster, utility outage, or terrorist attack (Wilson 2005). On-site renewable energy, daylighting, and passive ventilation are examples of strategies that contribute to extending the critical services of a healthcare facility in the event of major ongoing utility disruptions. For mission-critical systems, it is imperative to provide multiple independent and redundant ways of supplying necessary services, and locate those services out of harm's way. Hospitals that incorporate renewable energy onsite, for example, have a second option when grid infrastructure is unavailable. If their spaces are daylit, they have even more resilience through extended loss of services. On the Boston waterfront, Spaulding Rehabilitation Hospital (Case Study 16, Chapter 7 and Figure 10.3) demonstrates resilience thinking.

Fisher (2013) sums it up: "Humans have, for most of our history, created our world this way, built with what was readily available, fueled by renewable resources. . . and conceived of as multi-functional and quickly adaptable to the unforeseen circumstances that await us. We have come to see those older ways of living as primitive or impoverished. But we need to see the work of our ancestors anew, not as more rudimentary than our own, but quite the contrary as more resilient and resourceful, and more flexible and dependable than the extremely fracture-critical world that we have since created."

Contrast Fisher's remarks in the sidebar that follows with this quote from Kenneth Langone, chairman of the board of NYU Langone Medical Center, who was a patient there at the time Hurricane Sandy forced an evacuation and two-month closure. "We believed we had the machines, we believed the machines would work, and we believed everything we were told about the scope and size of the storm," Langone said in an interview (Armour et al. 2012).

And, going forward, good design and planning should start with the assumption that nothing will work as intended—or even at all. We should, in other words, take nothing for granted and act as if we have only those within our community and that within our control to depend on. . .it is the only way to achieve the real optimism of knowing that we can survive, and indeed thrive, regardless of what may happen. We are at our best when we have imagined and accounted for the worst.

—Thomas Fisher (2013)

Healthcare as the New Civic Architecture

An awareness of prevention, community engagement, transparency and resilience is growing throughout the healthcare sector globally. The Case Studies in this book attest to the myriad ways these new relationships and change agents are transforming the built environments of hospitals and healthcare facilities. As healthcare grows in scale and influence, its ability to act as a model for physical development that embodies these elements becomes more critical. If not healthcare, where will these models emerge?

The U.S. services sector—from real estate to retail, fast food to healthcare—accounts for more than 79 percent of its economic activity and 80 percent of employment (Economy Watch 2010). As of 2010, healthcare alone accounts for just over 18 percent of total U.S. GDP—more than 20 percent of the services sector's economic activity (Jones 2012). As one of the largest and fastest growing sectors of the global economy, healthcare is an increasingly important sector throughout developed and developing nations.

Hence, it should come as no surprise that healthcare buildings are viewed as the new civic architecture. Dell Children's Medical Center of Central Texas (Case Study 1, Chapter 5) located on a remediated brownfield parcel, providing an important economic anchor for 700 acres of sustainable urban mixed-use development and the surrounding residential neighborhoods. Ysbyty Aneurin Bevan (Case Study 36, Chapter 8) is situated on the site of Ebbw Vale's former steelworks, the largest regional employer for over 200 years—today, the UK National Health Service is the nation's largest employer.

The sheer scale of healthcare, coupled with the emerging focus on prevention and health promotion, are catapulting healthcare buildings from self-contained, separated campuses to vital definers of urban fabric and place-making. Improving access to healthcare, an important factor in reducing system costs and enhancing public health, requires a new focus to ensure community centered, convenient locations. In addition, the large number of staff, visitors, and patients aggregating on major healthcare campuses can, in and of themselves, generate necessary volumes for public transit investments. Together, these factors support an expanded role for healthcare as central to healthy communities.

The New Karolinska Solna Hospital (Case Study 9, Chapter 5) includes a completely new public transportation hub below a major urban plaza as a significant aspect of its design program. First People's Shunde (Case Study 24, Chapter 8) catalyzed a new public transit system to facilitate patient, staff, and visitor travel. London's St. Bartholomew's (Case Study 34, Chapter 8) reintroduced a significant historic pedestrian pathway through a dense urban site. The reconstruction of St. Olav's Hospital, reintroduces the formerly interrupted street grid by replacing the former multi-building mega-hospital campus with a series of below-grade and bridge-connected independent buildings (Figure 10.4). As a group, these projects demonstrate the new "civic" focus of large-scale urban healthcare.

Shifting scales, community-based healthcare is also a powerful civic typology, as illustrated in Case Studies in this chapter. For The Ubuntu Centre, Zwide Township, Port Elizabeth, South Africa (Case Study 49, later in this chapter), this first community clinic in the area is physically located at a busy intersection and designed to allow the well-worn pedestrian pathways from the township to the bus stop to continue uninterrupted through the plan. It demonstrates restorative principles by blending time-honored climatic design principles, traditional craft, and the important civic function of normalizing HIV treatment. The naturally ventilated, passive heated

Figure 10.4 An aerial view illustrating the overall plan for a series of courtyard buildings that comprise the more than 2 million sq. ft. (230,000 sq. m) replacement campus and reconstructed urban street grid on the site of the former hospital mega-campus. *Source: Team St. Olav*

and cooled building is constructed of simple concrete forms, while its design—open at the ends—is welcoming to all who pass by, reinforcing the sense of connection that "Ubuntu" inspires.

In London, the UK NHS co-located a public library with a primary care center at Gardens Health Centre and Library (Case Study 50, later in this chapter), responding to a need to improve Ealing Borough's health services and modernize its library service. The co-location of two normally disparate public services in a single facility captures synergies between health, well-being, and lifestyle, projecting a civic presence. The health services provide extra "foot traffic" for the library and the library improves available access to information on health and well-being. Feedback from users in the first year of operation confirms that the benefits anticipated are being realized and there is a genuine sense of ownership by the local community.

In Portland, Oregon, the expansion of the Old Town Recovery Center (Case Study 51, later in this chapter) transforms a vacant downtown corner fast-food restaurant into a verdant, light-filled healing oasis for Portland's homeless population. Adjacent to the existing medical clinic, the project expands social and behavioral health services, brings those services to the street in spaces that encourage clients to enter, interact, and learn, and proposes future housing for the homeless above reinforcing urban density and ensuring that needed social and medical services are located near residences.

Finally, Waldron Health Centre (Case Study 52, this chapter) demonstrates how a replacement clinic on a dense, urban site redefines a sense of civic architecture and connects to community. In fact, architects Henley Halebrown Rorrison believe that the overarching urban response took precedence over the program brief for the replacement building, a two-wing phased structure that creates an important town square for pedestrian traffic moving between the metro station and downtown retail and residential areas. The local community traverses the public lobby to access a set of shared garden allotments that remain.

Restorative and Regenerative Design

Restorative and regenerative design represents the culmination of this transition to a built environment capable of sustaining life and health, and repairing or restoring some of what has been degraded or lost. Regenerative design, as defined by architect and professor Ray Cole (2012), refers to:

> [A]pproaches that support the co-evolution of human and natural systems in a partnered relationship. It is not the building that is "regenerated" in the same sense as the self-healing and self-or-

> ganizing attributes of a living system, but by the ways that the act of building can be a catalyst for positive change within the unique "place" in which it is situated. Within regenerative development, built projects, stakeholder processes and inhabitation are collectively focused on enhancing life in all its manifestations—human, other species, ecological systems—through an enduring responsibility of stewardship.

Building on the seminal work of architects Bill Reed and Sim Van der Ryn over the past two decades, the principles of restorative and regenerative design align the ecological profile of the built environment with the core mission of healthcare—that is, healing—in a building that delivers all necessary building services abundantly while supporting broader ecosystem services (Figure 10.5). Restorative design ties together health promotion, community engagement, transparency, and resilience in a cogent manner.

There are many global examples of healthcare organizations embracing "restoration" of health and community. As Gary Cohen, Executive Director of Health Care Without Harm notes, "hospitals can situate themselves within the ecology of their communities and act as a force for healing" (see Chapter 3). The UK National Health Service suggests that in the future, the notion of progress will be redefined in new, more restorative and regenerative terms (see Chapters 3, 7, and sidebar here).

REDEFINING PROGRESS

- Economic and social resilience prioritized over growth
- Quality of life is the key goal
- People value meaningful work, low-impact lifestyles, and their community
- Healthy living is a high priority
- Care is delivered through friends, families, and charities

Source: UK NHS Route Map

Resilience—related to extreme weather events and pandemic diseases—is also beginning to transform the healthcare built environment. Remarkable examples of social and climate resilient healthcare buildings are emerging in response to lessons learned from extreme weather events and natural disasters, anchoring community health and restoration. Kiowa County Memorial Hospital (Case Study 5, Chapter 5), reconstructed after a devastating tornado leveled Greensburg, Kansas, is totally powered by on-site and off-site wind turbines with the goal of increased resilience. First People's Shunde (Case Study 24, Chapter 8) features both on-site renewable energy and specific programmatic responses to infectious disease outbreaks as a response to the 2002 SARS outbreak.

Mirebalais National Teaching Hospital, Mirebalais, Haiti (Case Study 53, later in this chapter), is a 320-bed comprehensive public teaching hospital that replaces a

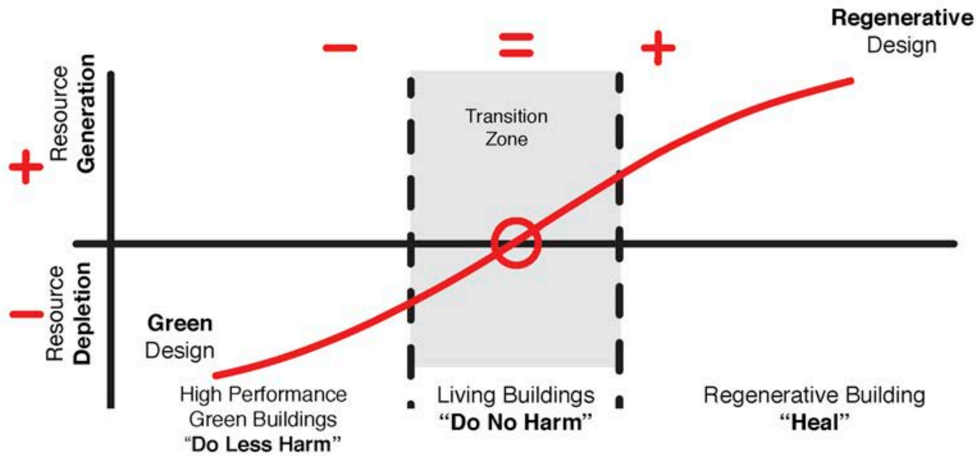


Figure 10.5 The principles of restorative and regenerative design offer an opportunity to align the ecological profile of the built environment with the core mission of healthcare. *Source: Robin Guenther*

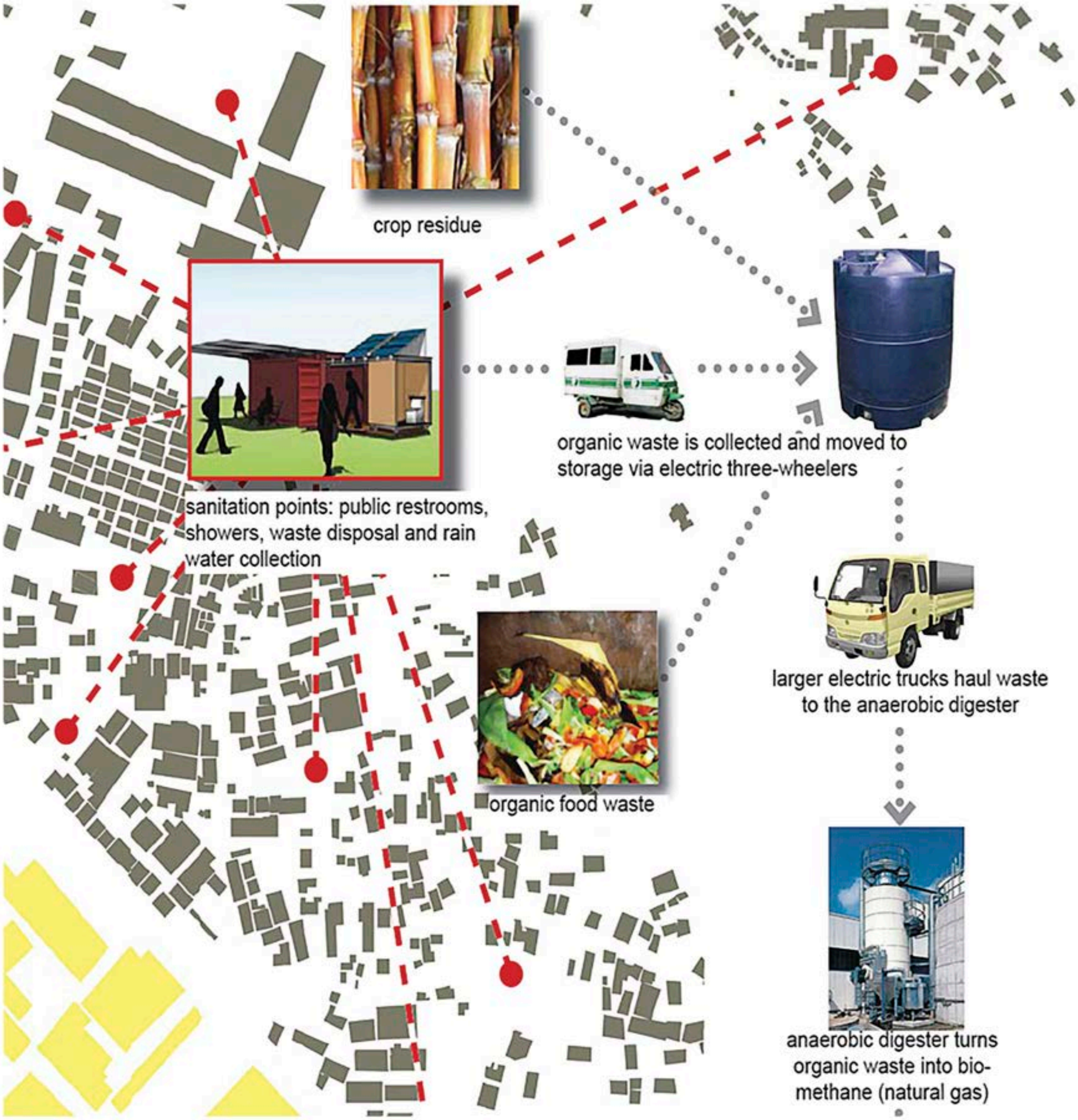


Figure 10.6 The Embassy Medical Center energy solution includes a system for community pickup of organic waste for digesters, linked to provision of potable water to the community in "hubs." *Source: Perkins+Will*

hospital destroyed in the 2010 earthquake. With the devastation of Haiti's healthcare infrastructure, Partners in Health, an international nonprofit established in 1987 dedicated to provide "a preferential option for the poor in health care," accelerated its plans for a new community hospital in Mirebalais, about 35 miles northeast of Port-au-Prince as a model of resilience, with both grid-connected utility services as well as on-site solar photovoltaics and a self-contained, modular on-site wastewater treatment facility. The emphasis is on producing a facility that can remain operational when community infrastructure fails.

The design proposal for Embassy Medical Center, Colombo, Sri Lanka (Case Study 54, later in this chapter), responds to the reality of limited infrastructure and climate vulnerability—the Sri Lanka coastline is vulnerable to both typhoons and coastal tsunamis. The project program emphasizes the need for a range of civic functions and to provide a "safe haven" during and following extreme weather events. The design proposal ensures that the facility can remain operational off-grid, using methane from the local Colombo landfill as well as the hospital organic waste as the primary energy sources. An on-site digester is linked to the blackwater treatment system, where conveyance water is recirculated for toilet flushing (Figure 10.6). A biogas-fired co-generation plant (with natural gas backup) provides on-site electrical generation; rooftop solar supplements this system. On-site well water is treated for potable use at the hospital, and for the broader community. Systems are complementary and completely independent, ensuring continued operation should external conditions render any one system inoperable.

A Model for the Future

If the healthcare industry can reinvent itself around prevention and health promotion, community connectivity, transparency, and resilience, what a model of optimism it would be to the broader society! If people experience hospitals that promote health and foster ecological restoration, they will demand schools and homes and office environments that do the same. In the quote excerpted here, environmental advocate Bill Walsh postulates how healthcare can support sustainable building to further this mission.

> *If we come to expect healthy hospitals, then we might soon come to expect school buildings that help students learn better, offices that stimulate creativity, and factories designed to increase workers' productivity, as well as their job satisfaction and even their personal health.*
>
> *Indeed, how long will it be before we expect our buildings to be living buildings that are net contributors to the communities they populate, generating their own energy with renewable resources, capturing and treating all of water used on-site, and using all materials efficaciously to maximize the health and beauty of our world?*
>
> *Not long. This is the tectonic shift in public policy toward health and the environment that is reflected by the trailblazers, strategies, and case studies that you have encountered in this book. The penultimate lesson is this: healthy building practices do not compromise the essential missions of our most important institutions; they further those missions. There is no downside to a hospital that heals, a school building that increases adolescent attention spans, or a building that does not just stand, but rather "lives" in its community.*
>
> —Bill Walsh, Healthy Building Network

The book's final case study, All Ukrainian Health Protection Centre for Mothers and Children (Case Study 55, later in this chapter), demonstrates how combining these aspirations in a single project can produce a transformative architectural solution. Designed as a "dacha in the woods" this nature-inspired 250-bed hospital is located in a forested area and will be open to children from throughout Ukraine. Like Protea Health (Chapter 3), the Kaiser Small Hospital Big Idea competition (Case Study 20, Chapter 7), and Embassy Medical Center (Case Study 54, this chapter), these prototype facilities signal fundamental shifts in hospital typology. With their focus on community, health, resource conservation, and resilience they foreshadow an optimistic future.

Guiding This Transformation

The global healthcare industry is redefining itself in the service of ecological health. Visionary healthcare leaders, like those profiled in this book, are beginning this journey. Collectively, they represent a set of organizations that, according to physician and public health advocate Ted Schettler, MD, MPH, "are informed by the inextricable link between environment and human health and are moving beyond both compliance and monetary savings with a long-term plan to reduce environmental footprint" (2001).

Sarah Network of Hospitals Principles

Everything we do and practice rigorously follows these principles:

- Create a specialized healthcare center that treats the patient as a human being who is not merely the object upon which techniques are applied, but rather, is the agent of that action.
- Participate actively in society and work at the prevention of disability and deformity while at the same time combating prejudice against the physically disabled; after all, life is characterized by infinitely varied forms that change with time.
- Defend the principle that no human being should be discriminated against for being different in his or her physical form or way of performing an activity.
- Freedom from technological dependency by rejecting a passive attitude in the face of consumerism and imitation and by utilizing our culture's creative potential.
- Develop a critical attitude toward imported standards, be they techniques or conduct.
- Simplify technique and procedures in order to adapt them to the genuine necessities born of Brazil's contrasting economies and regions. Simplification is the critical synthesis of the most complex systems and processes: one cannot simplify that which one does not understand.
- Appreciate innovative initiative and the exchange of experience, in education and research, stimulating the creativity of persons and groups; "the individual is the institution," and each person represents it, answers on its behalf, and dedicates his or her life to it.
- Live for health instead of merely to survive illness.
- Transform each individual into an active agent responsible for his or her own health.
- Work so that the utopia of this hospital is educating for health until each individual, protected from illness, no longer needs it.
- The community bears the primary responsibility for this work, whose purpose is the fulfillment of the community's will. It is everyone's duty, then, to demand of this institution the commitment consolidated here today.

www.sarah.br (Do Couto 2006)

The Sarah Network of Hospitals, operating throughout Brazil, offers a unique set of principles that guide their organization. Excerpted here, they form a fitting close to the discussion of twenty-first-century healthcare. Their facilities continue to influence and inspire this generation of healthcare buildings (Figures 10.7 and 10.8).

The coming years are likely to bring a flurry of renewed global policy initiatives linked to climate change and carbon, waste, and toxics reduction. Can the healthcare industry shed its culture of compliance in favor of informed environmental leadership and begin to shape environmental health policy direction? What leadership position might healthcare hold on behalf of the broader ecological sustainability agenda? How can a culture predicated on prevention and precaution elevate the public discourse on climate change, toxification, and waste? Can healthcare insist that prevention and health promotion, community connectivity, transparency, and resilience are embedded in public policy initiatives in the future?

CONCLUSION

In an era of chronic disease, the global healthcare industry is shifting its focus from treating disease to creating the conditions for healthy people and communities. It is engaging with the communities it serves in new and innovative ways in the service of health and well-being. Leading healthcare organizations are embracing transparency and taking ownership of their environmental impacts, exerting both upstream leverage on supply chains and downstream influence on employees and patients.

As climate change alters weather patterns and disease vectors, it will become more important to invest in and produce a resilient infrastructure to meet expanded healthcare delivery challenges. Aligning our built environments with restorative and regenerative design thinking will help us meet this future—and in the process, reinvent our hospitals. By fully embracing principles of restorative design, healthcare organizations demonstrate more than a commitment to high-quality patient care—they demonstrate a commitment to saving lives and improving health without undermining ecosystems or diminishing the world.

Figure 10.7 Invented by Lima, the camamaca (literally "bed stretcher") or mobile bed facilitates patient movement, enabling them to comfortably move between interior and exterior spaces during their rehabilitation. *Source: Courtesy of the Sarah Network and João Filgueiras Lima*

Figure 10.8 The Centro de Reabilitação Infantil, Rio de Janeiro, provides generous daylight in its physical therapy areas, using prefabricated building elements designed to maximize daylight while minimizing solar gain and facilitating natural ventilation. *Source: Courtesy of the Sarah Network and João Filgueiras Lima*

Case Study 49: The Ubuntu Centre

Zwide Township, Port Elizabeth, South Africa

OWNER: Ubuntu Education Fund

PROJECT TEAM:

Design Architect: Field Architecture (Stan Field, Jess Field)

Project Manager/Local Architect: John Blair Architects, NOH Architects

Structural Engineer: ILISO Consulting

Contractor: SBT Construction

TYPE: New Multipurpose Health and Education Center

SIZE: 21,000 sq. ft. (1,950 sq. m)

EUI: Not Available

PROGRAM DESCRIPTION: A free community social services facility including Pediatric HIV & TB testing and counseling clinic, career guidance and computing center, health resource library, multi-purpose hall for community events and occasional shelter

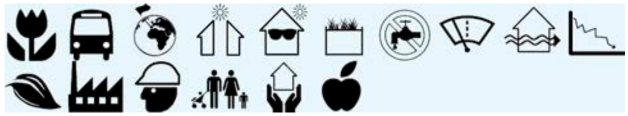
COMPLETED: 2010

RECOGNITION: South African Institute of Architects' 2012 Award of Excellence; 2011 Regional Award for Architecture; *Architect Magazine*'s 2009 Progressive Architecture (P/A) Award, Honor; San Mateo Chapter American Institute of Architects' 2008 Honor Award

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 24 in (610 mm)



KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Native vegetation provides a psychological and emotional connection to local heritage
- *Energy Responsive Facade:* Optimized orientation; daylighting reduces lighting loads; Gum-Pole "Izibonda" shading screen shields high angle summer sun and allows low angle winter sun
- *Low EUI:* Passive heating and cooling used as primary systems, with mechanical systems for backup
- *Natural Ventilation:* Operable windows are strategically placed on building's narrow profiles
- *Low Embodied Energy:* Regionally sourced and fabricated materials; rapidly renewable Gum Pole timber
- *Safe Construction Practices:* Concrete Institute of Southern Africa assisted with labor development and training to produce highest-quality concrete and invest in future jobs for newly skilled workers
- *Civic Function:* Community training space for schools, clinics, NGOs; theater; meeting space
- *Food:* Rooftop gardens part of large network of community gardens throughout Zwide; vegetables grown supplement nutritional content of daily lunches for children in need

Figure 10.9 The Ubuntu Centre. *Source: Jess Field*

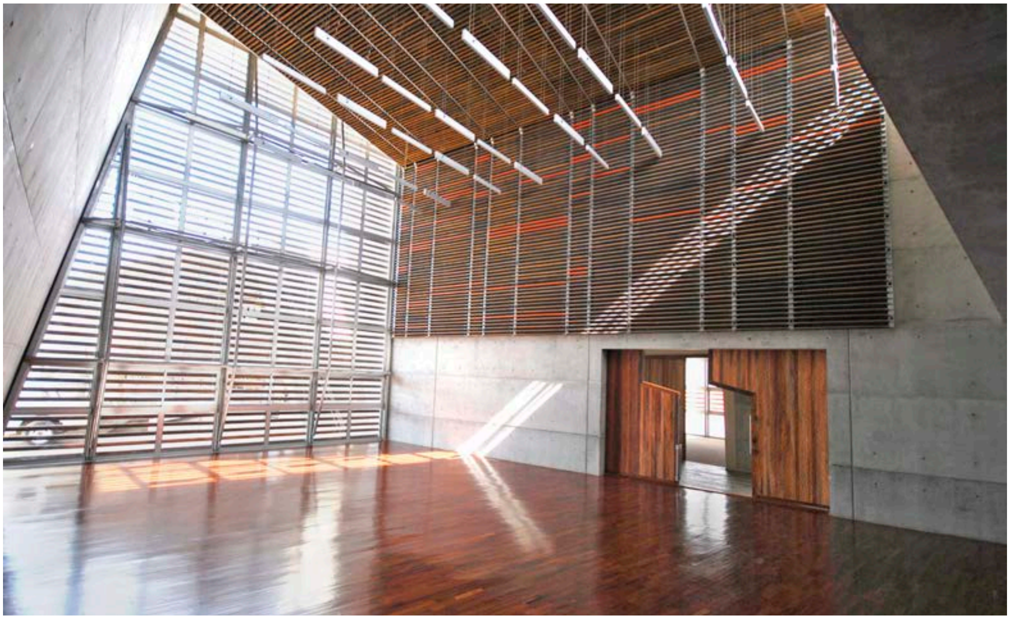


Figure 10.10 Community space. *Source Copyright © Jon Riordan*

Physically located at a busy intersection in the South African township Zwide, the Ubuntu Centre demonstrates restorative principles by blending time-honored climatic design strategies, traditional craft, and the important civic function of normalizing HIV treatment. The naturally ventilated, passive heated and cooled building is constructed of simple concrete forms, while its design—open at the ends—is welcoming to all who pass by, reinforcing the sense of connection that "Ubuntu" inspires (Figure 10.9).

The word "Ubuntu" references an African ethical philosophy that relates to people's relationships with each other: "I am because you are." This phrase, originating from South Africa's tribal languages, appropriately depicts this new health and education center located on the site of a former post office destroyed as a symbol of apartheid. Designed with the active engagement of community representatives who communicated their vision of the new center through drawings, the building is a physical manifestation of the owner's request: "a building that has never been done before." Located on a central intersection in Zwide Township, the building intentionally uses its public visibility to mesh with people's everyday lives and normalize HIV treatment (Figure 10.12). The process and resulting building demonstrate the powerful outcomes that can result from collaborations between nonprofit organizations and architects.

Poured-in-place folded concrete forms organized in five individual volumes comprise the basic roof and wall materials. The building form is a metaphor for people caring for each other, as the panels lean on, and are supported by, other panels. The solid concrete forms exude permanence; open on both ends, they also provide a sense of openness. Climatic design principles inform orientation: the five volumes optimize thermal performance and daylight. They feature large window walls that allow daylight to flood interior spaces. A curtain made of a local gum tree, "Izibonda," celebrates a culturally significant, indigenous thatch craft and is strategically located to block the high summer sun and provide shade and security (Figure 10.10). Translucent interior walls allow daylight into the interior rooms. Together, these materials and methods create a visually rich juxtaposition of permanent and open, modern and traditional. They support passive heating and cooling, including strategically located operable windows, with active systems employed as back-up. The building is "solar ready," able to accommodate on-site solar technology in the future.

The program extends beyond clinical functions to include community spaces, broadening the view of a health center from a place that treats illness to one that educates, promotes health and enlivens the civic experience. The Centre's organic rooftop garden is part of a network throughout Zwide that collectively feeds more than 2,000 children each day, providing important nutrition and engendering self-sufficiency and empowerment for the township's residents (Figure 10.11).

Source: Field Architecture

Figure 10.11 Rooftop vegetable garden. *Source: Copyright © Jon Riordan*

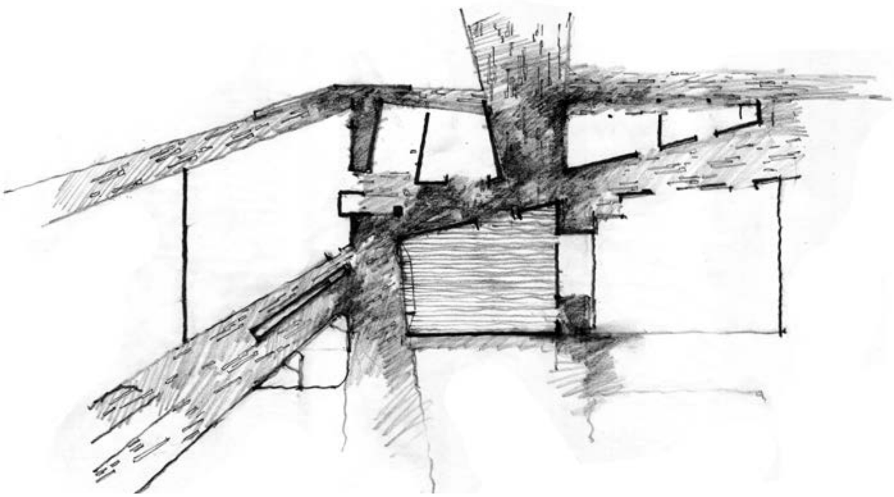


Figure 10.12 Plan sketch showing pedestrian path through building. *Source: Jess Field*

Case Study 50: Jubilee Gardens Health Centre and Library

Ealing, London, England

OWNER: Ealing Council and Ealing Primary Care Trust

PROJECT TEAM:

Architect: Penoyre & Prasad

Engineer: Cundall Johnston LLP (Services)

Contractor: Willmott Dixon Construction Ltd

TYPE: Primary Care Health Center and Public Library

SIZE: 22,600 sq. ft. (2,100 sq. m)

EUI: 70 kBtu/sf/yr (221 kWh/sm/yr)

PROGRAM DESCRIPTION: General primary care, treatment rooms, minor surgery, audiology, and district nurse services as well as public library and community meeting rooms

COMPLETED: 2010

RECOGNITION: NEAT "Excellent" Score: 79.96

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 30 in. (750 mm)

KEY SUSTAINABILITY INDICATORS

- *Brownfield:* Located on former brownfield site
- *Habitat Restoration:* Landscaped areas increase the ecological value of the site and help protect local plant and animal species
- *Narrow Floorplate:* At least 2% average daylight factor in occupied areas
- *Energy Responsive Facade:* Building form, mass and planning optimize passive systems and natural ventilation; utilizes night-flush cooling
- *Water Use Reduction:* Low-flow fixtures throughout
- *Innovative Source Energy:* Biomass boiler system
- *Natural Ventilation:* Building primarily naturally ventilated
- *Low Embodied Energy Materials:* At least 80% (by area) major materials low embodied energy: overall "A" Green Guide rating
- *Innovative Construction Practices:* Monitor, report, and set targets for CO_2 and energy related to construction activities
- *Civic Function:* Integrates community public library and meeting space

Figure 10.13 Jubilee Gardens Health Centre and Library. *Source: Copyright © Nick Kane*

Figure 10.14 First floor library. *Copyright © Nick Kane*

Figure 10.15 Clinic waiting areas. *Copyright © Nick Kane*

The new Jubilee Gardens Health Centre and Library is the result of a partnership between Ealing Council and Ealing PCT, creating a unique combination of healthcare services and a local community library on a single site. The PCT brief required a flexible building that would support different operating conditions for each program while allowing flexibility to change and adapt usage over time.

The building, constructed on the former 1930s library site, is situated to respond to Jubilee Gardens, the adjacent park, allowing large feature windows to the library on the ground floor. The entrance is clearly legible from both the park and adjacent neighborhood, with an entry expressed by a projecting bay, faced in metal panels (Figures 10.13–15).

The building is constructed with an in-situ concrete frame on the lower two floors, with exposed concrete soffits as part of the thermal mass/natural ventilation approach. The upper floor and roof are formed in steel frame to create the distinctive roof form and emphasize the "lighter weight" of this element.

Natural ventilation is Jubilee Gardens' key environmental strategy. The windows are carefully designed to deliver daylight, ventilation, night cooling, and security. This allows daytime natural ventilation and night flush cooling of the exposed structure.

A 50 kW biomass boiler provides 20 percent of the total annual energy use via a renewable energy source; it is sized to provide the building's base heating/hot water load to ensure that operation is generally at peak output for the majority of the year. The boiler is installed in a modular arrangement with two conventional gas-fired boilers that provide the peak heating/hot water requirement as well as backup resilience. The boiler plant and pellet storage is located in the top floor mechanical penthouse, with delivery of wood pellets (4 deliveries per year) blown via fill pipes from ground floor to the 25 cubic meter storage location. The building achieved a NEAT "Excellent" rating.

Source: Penoyre & Prasad

Case Study 51: Old Town Recovery Center

Portland, Oregon

OWNER: Central City Concern

PROJECT TEAM:

Architect and Interior Design: SERA Architects Mechanical, Electrical, Plumbing Engineer: Interface Engineering

Structural Engineer: KPFF Consulting Engineers

Landscape Architect: Atlas Landscape Architecture

General Contractor: Walsh Construction Company

TYPE: New Addition to Ambulatory Community Health Clinic

SIZE: 45,000 sq. ft. (4,181 sq. m)

EUI: 34 kBtu/sf/yr (107 kWh/sm/yr)

PROGRAM DESCRIPTION: Three-story community health clinic integrating outpatient primary care with behavioral mental healthcare services for primarily homeless, uninsured and Medicaid patient population providing more than 80,000 patient visits per year

COMPLETED: 2011

AWARDS/RECOGNITION: LEED Gold–certified (New Construction); Contract Magazine Healthcare Environment Award for Ambulatory Care Facilities, 2012; Recognized by Robert Wood Johnson Foundation for "Exemplar Practice" for Effective Ambulatory Practices, 2012

BIOME: Temperate Humid

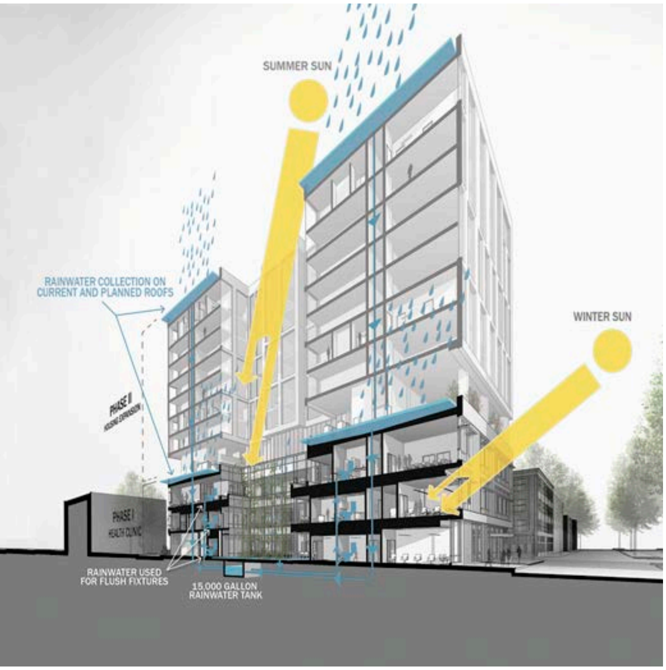
CLIMATE ZONE: Marine West Coast

PRECIPITATION: 38 in. (950 mm)

KEY SUSTAINABILITY INDICATORS

- *Connection to Nature:* Landscaped open-air courtyard and tree-lined streets provide patients, staff and visitors with views of nature
- *Innovative Stormwater Management:* Extended curb line to create a vegetated bioswale to reduce stormwater runoff
- *Energy Responsive Facade:* High performance exterior wall construction prototype thermal-break brickwork support system
- *Water Use Reduction:* 77% reduced potable water use
- *Rainwater Harvesting:* Rainwater from roofs/courtyard collected in 14,000 gallon below-grade retention/detention tank; collected rainwater is filtered and UV treated and used for toilet flushing
- *Low EUI:* 34 kBtu/sf/yr (107 kWh/sm/yr) modeled performance based on ASHRAE 90.1–2007; designed to meet Architecture 2030 Challenge
- *Low-Embodied Energy/Healthy/Recycled Content Materials:* Local/regional-sourced and manufactured materials including local FSC-certified wood; low-VOC and low-toxic materials; high recycled content
- *Civic Function:* Provide health, health management and social care services to 4,000 primarily homeless, uninsured, and Medicaid patient population

Figure 10.16 Old Town Recovery Center.
Source: SERA Architects



Old Town Recovery Center is an urban success story, transforming a downtown corner fast-food restaurant into a verdant healing oasis for Portland's homeless population (Figure 10.16). Located adjacent to the Old Town Clinic, the revitalized lot enables the local nonprofit owner, Central City Concern, to expand its current outpatient primary care services to include behavioral counseling, acupuncture, and community spaces to provide yoga and exercise classes, kitchen, showers and laundry—all designed to develop the patients' social and domestic skills. Future plans to construct 120-units of low-income housing atop the clinic will further strengthen Portland's downtown social fabric (Figure 10.17).

Portland's temperate climate provides an ideal context to meet the Architecture 2030 Challenge, with a target to reduce building energy use by 60 percent over the national average. This is achieved through integrating envelope and mechanical systems, including advanced mechanical and lighting systems, daylight controls, exhaust air heat recovery, high-performance glazing, and an innovative exterior wall system. Portable water use is dramatically reduced through low-flow plumbing fixtures and a 14,000-gallon rainwater collection storage system that provides water for toilet flushing. The clinic's healthy interior environment reflects specification and installation of non-toxic, low-emitting materials. In addition, local and regional sourced and manufactured materials, including local FSC-certified wood, dominate the building's interior and exterior, and measurably reduce the material palette's embodied energy.

Old Town Recovery Center's transformation from a blighted, former fast-food restaurant site to "clinic as sanctuary" is achieved in part with a glass side-walled central staircase to promote active living and a welcoming open air interior courtyard landscaped with bamboo and river rocks as focal points. Both bring the outdoors in, complement the building's daylight and views strategies, and affirm biophilia—humans' intrinsic need to connect to nature—as essential to the healing process (Figures 10.18–21).

Source: SERA Architects

Figure 10.17 Rendering with final housing addition. *Source: SERA Architects*

Figure 10.18 Section showing courtyard. *Source: SERA Architects*

Figure 10.19 Communicating stair in clinical area. *Source: Copyright © Michael Mathers*

Figure 10.20 Street entry to community education space. *Source: Copyright © Michael Mathers*

Figure 10.21 Floor plans. *Source: SERA Architects*

Ground Floor:

1. Clinic Reception
2. Waiting Area
3. Sub Waiting Area
4. Living Room/Community Programs
5. Community Kitchen
6. Future Housing Entry
7. Loading Area

Second Floor:

1. Exercise/Yoga Room
2. Reception Area
3. Sub Waiting Area
4. Nursing/Injection
5. Medical Assistant
6. Mental Health Group Meeting Rooms

Case Study 52: Waldron Health Centre

Lewisham, South London, England

OWNER: Lambeth, Southwark and Lewisham LIFT; Amersham Vale Practice

PROJECT TEAM:

Architect: Henley Halebrown Rorrison

Structural Engineer: Price & Myers

MEP Engineer: Ramboll

Contractor: Willmott Dixon Construction Ltd

TYPE: New Community Health Center

SIZE: 64,895 sq. ft. (6,029 sq. m)

EUI: 63 kBtu/sf/yr (200 kWh/sm/yr)

PROGRAM DESCRIPTION: Community Clinic

COMPLETED: 2010

AWARDS/RECOGNITION: NEAT* Excellent performance rating Building Better Healthcare Awards (CABE), Best Primary Care Design, 2008; Design & Health International Academy Awards, International Health Project, 2011

BIOME: Temperate Humid

CLIMATE ZONE: Marine West Coast

PRECIPITATION: 30 in. (750 mm)

Figure 10.22 Waldron Health Centre. *Source: Copyright © Nick Kane*

KEY SUSTAINABILITY INDICATORS

- *Habitat Restoration:* Brown/living roof to restore and support Black Redstart habitat
- *Narrow Floorplate:* Windows in all habitable spaces; interior courtyards enhance natural ventilation
- *Energy Responsive Facade:* Exposed concrete soffits are used as thermal mass and generous open windows for ventilation; solar shading responsive to orientation
- *Low EUI:* Low energy intensity based on passive systems, night flush cooling and energy responsive facade
- *Natural Ventilation:* All spaces use operable windows and natural ventilation
- *Healthy Materials:* BREEAM A–rated major construction materials
- *Civic Function:* Incorporates public community functions, including a new town plaza

The Waldron Health Centre is located in the London Borough of Lewisham, just north of London's South Circular inner ring road. Physically, the area has been blighted by twentieth-century development in which housing estates and tower blocks populate a fragmented landscape. The site lies at the west end of a local pedestrian route, Douglas Way, and a string of local community facilities, public buildings, and public open spaces.

The new center replaces an anonymous single-story health center with a significant urban development that shapes the fabric of the locality and forms a backdrop for public activity. The building occupies the site's northeast and southwest quadrants and frames two contrasting public spaces: the existing community garden allotments and a new square in the northwest quadrant that opens up a diagonal route to the train station. The building rises from two stories in the northeast to four in the southwest. Each wing accommodates two clinical clusters, one accessed directly from the foyer, the second along a cloister—a corridor that runs parallel to the wing bypassing the first. Garden courts, into which both clusters' waiting spaces look, separate the cloister and wing and are integral to the facility's natural ventilation strategy. In the interiors, scale, proportion, natural light and views all play a role in orientation.

Exposed concrete soffits provide thermal mass; generous operable windows allow for a predominantly naturally ventilated building. Louvers on east and west elevations, acting both as solar protection and acoustic baffles, are fabricated from the same timber component as the rain-screen cladding. The plan layout, windows, and cladding are based on the same 3.9 ft. (1.2 m) module. Rooms are generally 10 percent larger than NHS minimum standards, improving interchangeability

Figure 10.23 View from New Cross Station. *Source: Copyright © Nick Kane*

Figure 10.24 View from allotments. *Source: Copyright © Nick Kane*

Figure 10.25 Central hall. *Source: Copyright © Nick Kane* of use. Over its life the building can be re-planned with ease and the size of the clusters renegotiated within the wing.

The Waldron Health Centre was one of the first two NHS buildings to achieve a NEAT* "Excellent" performance rating. No renewable energy systems were incorporated; however, the building was designed to minimize energy demand through such features as heat recovery, high efficiency condensing boilers, and efficient electrical lighting. The electrical lighting scheme was designed in accordance with "Achieving Energy Efficiency in the NHS" and incorporates occupancy lighting control. Occupant comfort is improved with high levels of daylight and thermal zoning, aided by natural ventilation. The site is also equipped with bicycle storage, recyclable waste storage, and accommodates shared community facilities. A brown/living roof provides a habitat for insects and bird life, in particular the Black Redstart. Some of the material from the demolished pre-existing buildings on the site was recycled as the brown (earthen) roof.

Credit: Henley Halebrown Rorrison Architects

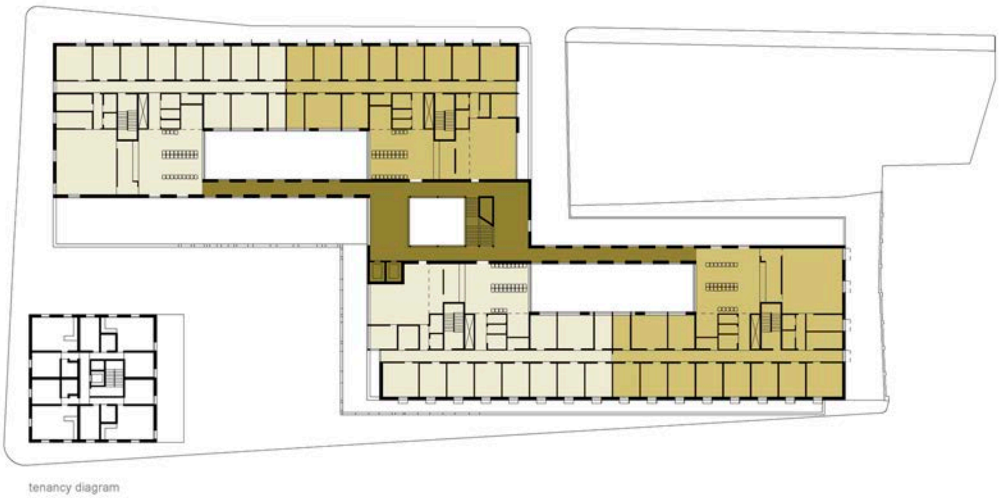


Figure 10.26 Tenant plan. *Source: Henley Halebrown Rorrison*

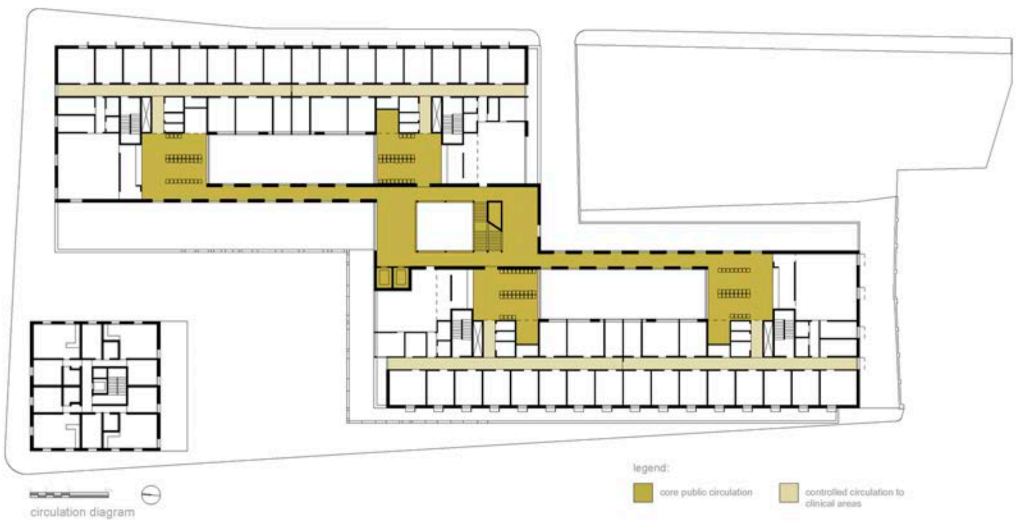


Figure 10.27 Public circulation. *Source: Henley Halebrown Rorrison*

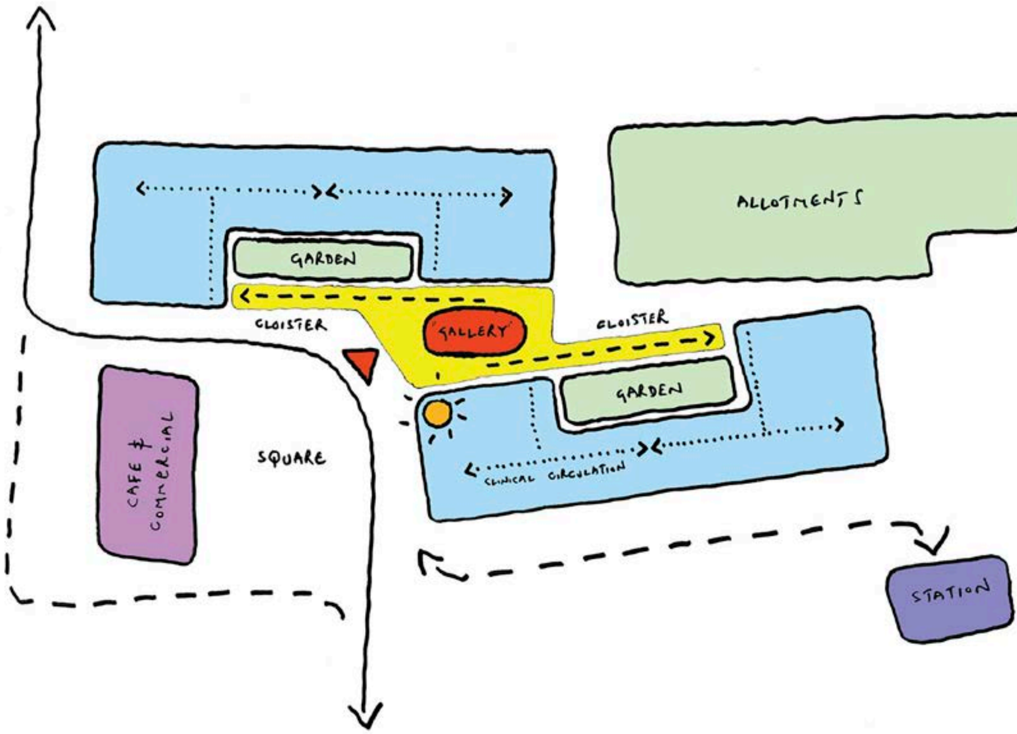


Figure 10.28 Concept sketch for public circulation. *Source: Henley Halebrown Rorrison*

Case Study 53: Mirebalais National Teaching Hospital

Mirebalais, Haiti

OWNER: Haitian Ministry of Health, Partners In Health (PIH), and Zanmi Lasante

PROJECT TEAM:

Architect: Nicholas Clark Architects Ltd., Ann Clark Architects LLC with PIH Design Team

Engineers: JML Engineering (structural); Cannistraro (HVAC-Plumbing Engineer); John Penney & Associates/Jason D'Antona (electrical)

Landscape Architect: Paul Kurtz

General Contractor: COAMCO (site and building shell) with PIH and SDC (including carpentry, finish, landscaping, HVAC, wastewater treatment plant)

TYPE: New Acute-Care National Teaching Hospital

SIZE: 180,000 sq. ft. (17,187 sq. m); Site: 13.5 acres (5.5 ha)

EUI: Not Available

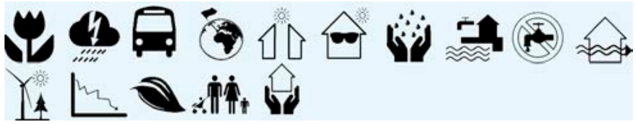
PROGRAM DESCRIPTION: 320-bed comprehensive public teaching hospital including 79-bed women's health unit, labor/delivery and neonatal intensive care unit; 110 internal medicine/pediatric care beds, surgery suite with 6 operating rooms, tuberculosis isolation ward, outpatient and community health clinics, pharmacy, and community meeting room

COMPLETED: 2012

BIOME: Tropical Humid

CLIMATE ZONE: Tropical Rain Forest

PRECIPITATION: 53 in. (1,353 mm)



KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management:* Ponds integrated into garden courtyards to capture stormwater runoff
- *Climatic/Bioregional Design/Orientation:* Building oriented for breeze/solar access
- *Narrow Floorplate:* Narrow pavilion patient wards provide access to daylight for patients and staff
- *Energy Responsive Facade:* Operable windows, light colored walls promote natural ventilation and reflect solar radiation
- *Rainwater Harvesting:* Collected rainwater used for landscape irrigation
- *On-site Wastewater Treatment:* On-site modular aerobic, biological treatment wastewater treatment system
- *On-site Renewables:* 1,800 panel, 475 kW solar photovoltaic system installed on roof produces maximum 95kW
- *Natural Ventilation:* Operable windows throughout patient units
- *Low-Embodied Energy Materials*: Locally sourced, manufactured materials; minimal finishes
- *Healthy Materials:* Low-VOC materials
- *Civic Function*: Community meeting room available to public; local economic development opportunities associated with recycling and composting; trains future medical professionals

Figure 10.29 Mirebalais National Teaching Hospital.
Source: Rebecca E. Rollins, Partners in Health

Figure 10.30 Exterior circulation rings courtyards. *Source: Ann F. Clark*

Haiti is the poorest country in the Western Hemisphere, with just over half of its 9.8 million residents living in densely populated urban areas. In January 2010 a devastating magnitude 7.0 earthquake erupted in the capital city Port-au-Prince, killing an estimated 300,000 people and leaving about 1 million people homeless; most of the city's infrastructure including hospitals and clinics were destroyed in its wake. The largest reconstruction project completed since the earthquake, Mirebalais National Teaching Hospital opened in 2012 with approximately 900 staff, providing an unprecedented level of care to the public, and an inspiring educational environment for Haiti's future medical professionals.

The hospital is conceived as a physical manifestation of a healthy environment: oriented to provide for abundant daylight; naturally ventilated with high ceilings it provides infection control; expansive waiting areas open to the outdoors. Designed as a series of seven simple, connected white-painted concrete pavilion structures to facilitate construction methods, manage costs, and enhance navigability, patient wards surround three verdant healing gardens, providing calming views and a place for patients and families to relax and recuperate.

Attention to resource efficiency is visible throughout. An innovative modular on-site aerobic, biological wastewater treatment system uses sewage-eating bacteria to treat the facility's wastewater; treated water is disinfected with chlorine before discharge to a tributary of the Artibonite River. Captured rainwater fulfills irrigation needs; low-flow fixtures are installed throughout, and education is provided on how to use indoor fixtures, especially toilets.

Low-energy natural ventilation strategies in patient units, augmented with ceiling fans, reduce energy use intensity. Electricity is supplied through an 1800 panel, 475 kW solar photovoltaic system, producing 95kW maximum. Patient spaces are daylit, supplemented by efficient light fixtures.

Mirebalais's inspired operational practices, from procuring locally sourced food, to on-site recycling and composting, and community enterprises to service the building's operations, provide enduring education and community benefit and a legacy of public health.

Source: Ann Clark Architects LLC

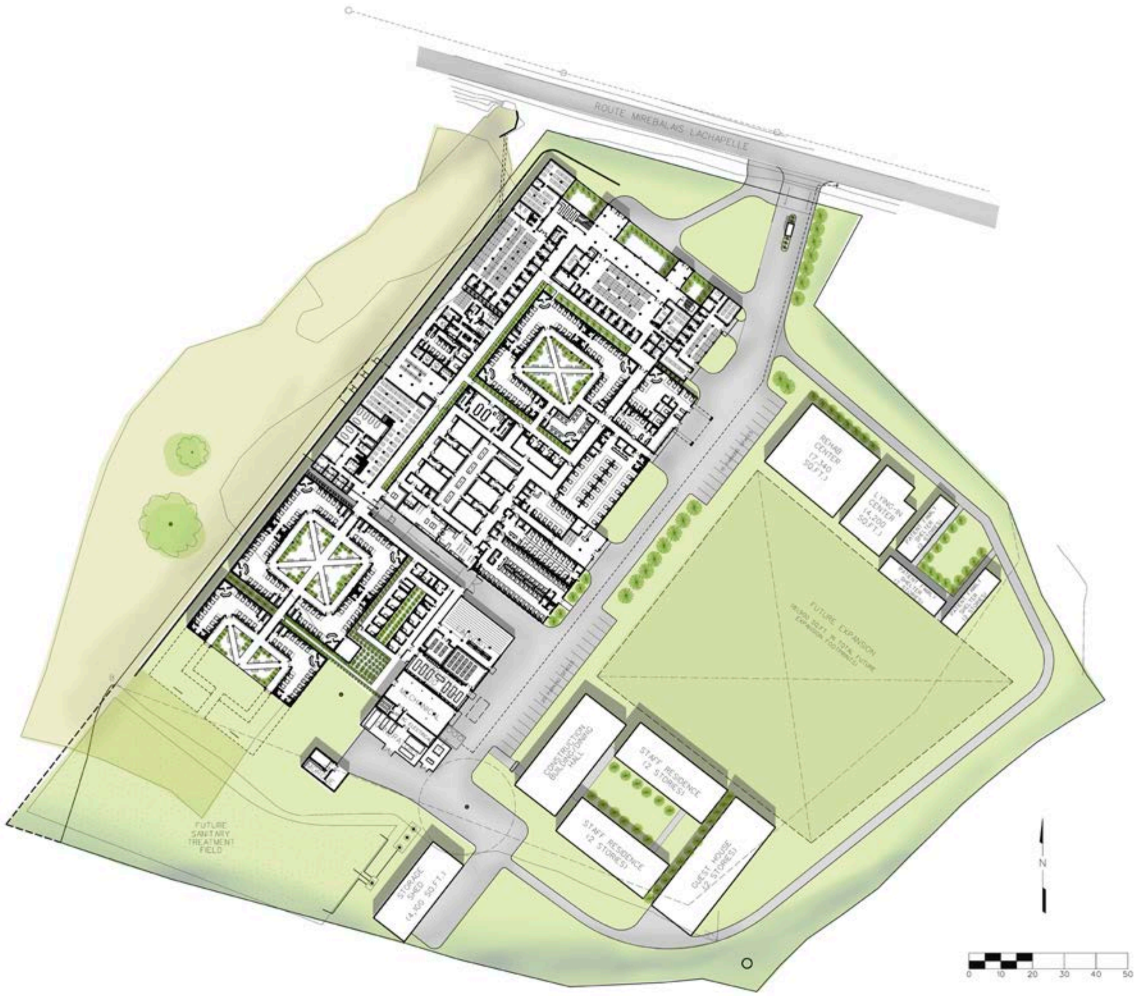


Figure 10.31 Site plan. *Source: Ann Clark Architects LLC/Nicholas Clark Architects Ltd.*

Case Study 54: Embassy Medical Center

Colombo, Sri Lanka

OWNER: Embassy Medical System

PROJECT TEAM:

Architect: Perkins+Will

TYPE: New Acute-Care Hospital Campus

SIZE: 500,000 sq. ft. (46,450 sq. m); Site: 11.8 acres (4.77 ha)

EUI: 120 kBtu/sf/yr (378 kWh/sm/yr)

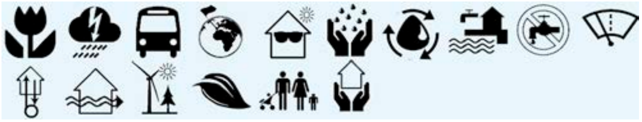
PROGRAM DESCRIPTION: 180 acute-care beds, emergency, oncology, surgery and cardiology, obstetrics, pediatrics, outpatient clinics, diagnostic and treatment, a hotel, staff housing, education center

COMPLETED: Project on Hold

BIOME: Tropical Humid

CLIMATE ZONE: Tropical Rain Forest

PRECIPITATION: 88 in. (2,230 mm)



KEY SUSTAINABILITY INDICATORS

- *Narrow Floor Plate:* For daylight, connection to nature and natural ventilation efficiency
- *Energy-Responsive Facade:* Orientation-specific facade shading systems
- *Rainwater Harvesting:* Collect and store 60–90% of rainwater in tanks and ponds
- *Innovative On-site Wastewater Treatment:* Treat and recycle 100% of wastewater
- *Reclaimed Water Reuse:* Collect condensate water for reuse
- *Innovative Source Energy:* Anaerobic system to integrate organic waste treatment and energy production; co-generation plant; ground-source heat-pump system
- *Innovative Energy Distribution:* Thermal labyrinth (earth tubes) for pre-conditioning of incoming air
- *Resilience:* Provide back-up water supply through on-site wells; on-site power generation; fuel source municipal organic waste
- *Food Production:* Greenhouse for food production
- *Community Jobs:* Anaerobic digester process will generate as many as 100 full-time jobs

Figure 10.32 Embassy Medical Center.
Source: Perkins+Will

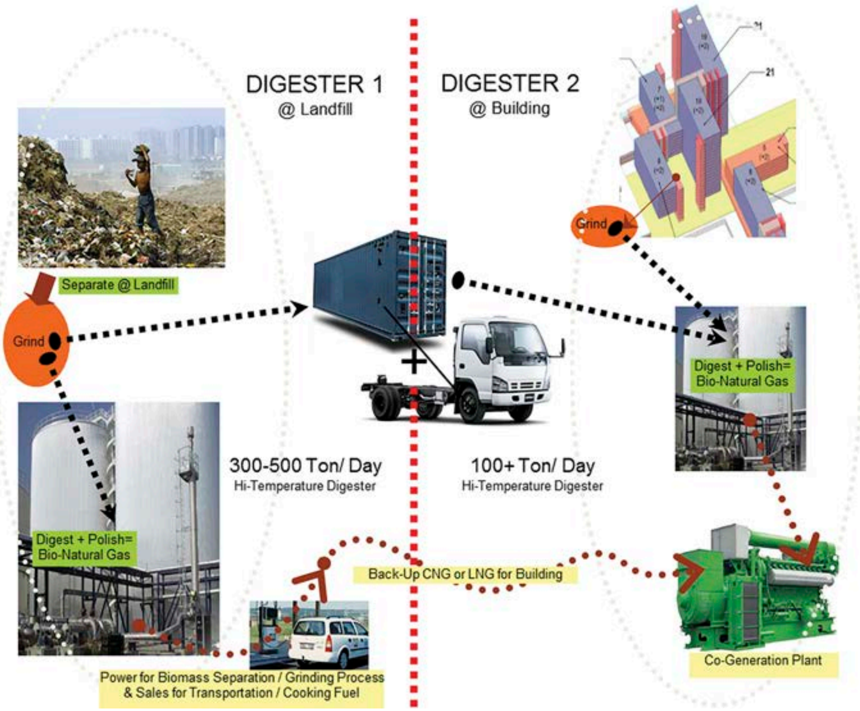


Figure 10.33 Two digesters, one at the landfill and one at the hospital, provide the hospital's energy source. *Source: Perkins+Will*

This design proposal for a new private acute-care hospital facility is located near the New Kelani River Bridge in the northern suburbs of Colombo, Sri Lanka. With the amazing natural resources, climate, and economic growth, Sri Lanka's population is rapidly expanding. Existing urban transportation, healthcare, and cultural infrastructure are unable to support the emerging needs of daily life. At the same time, the devastation of the 2004 tsunami has raised the importance of buildings' resilience in the wake of typhoons and extreme weather events. The surrounding community will use the hospital for both civic functions and as a "safe haven" in addition to healthcare.

Colombo is located 6.93 degrees above the equator. The sun's angle remains consistently overhead, with about eleven to thirteen hours of sunlight throughout the year. Year-round temperature ranges from 72–91°F (22–33°C). While rainfall is abundant in this tropical "wet zone," water storage is required to meet water needs during extended dry periods.

Functional program components are organized into discrete definable architectural building blocks so that the type of construction, structural systems, bay spacing, fenestration patterns, and infrastructure systems can be optimized to the unique needs of the clinical service. Each program component can be initiated or expanded independently, yet are functionally linked. By elevating all critical support areas and services above the second floor level, the building is designed for resilience in catastrophic events such as hurricanes, tsunamis, and earthquakes.

The goal is to have the facility function off-grid, using grid-sourced electricity and natural gas (if available) only as back-up. The site's wind power potential is low and solar photovoltaic technologies are space consuming at the scale required for this facility. Therefore, a primary goal was to use as little electricity as possible, relying on renewable sources of heat (solar thermal and biomass) as the main energy drivers (Figure 10.33).

Early in the design process, a unique energy source emerged to provide carbon-neutral, renewable energy: the digestion of organic municipal waste and sewage. Colombo has limited water and sanitation infrastructure; thus, the facility relies on community level "sanitation hubs" for exchanges of household waste for water and toilet facilities (Figure 10.34). On-site and off-site (landfill located) high-temperature anaerobic digesters that produce conditioned bio-methane are the primary thermal energy technologies, coupled with an on-site solar water heating system. On-site digestion supports the installation of blackwater treatment for toilet flushing, reducing potable water demand. Biomass feedstock goals are: 1/2 to 3/4 sewage and 1/2 to 1/4 agricultural residue and organic garbage. Sewage and organic garbage will be collected from the hospital and the surrounding community. Electricity will be generated on-site using a CNG-fired co-generation plant.

Source: Perkins+Will

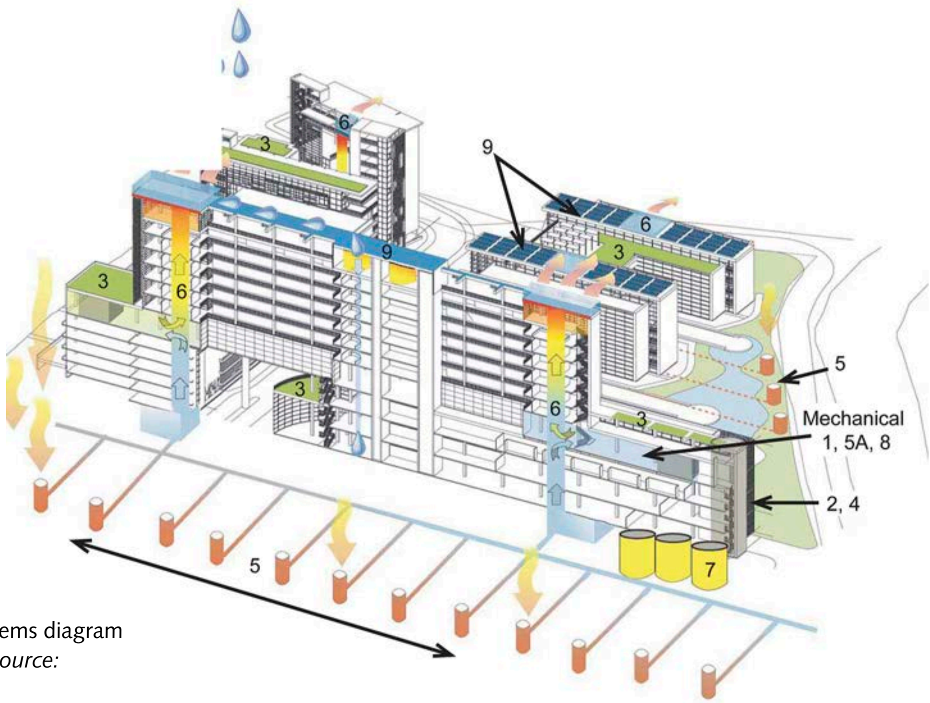


Figure 10.34 Systems diagram of the proposal. *Source: Perkins+Will*

1. Absorption Chiller—Utilizes Very Hot Water to provide Chilled Water for Cooling.
2. High Temperature Anaerobic Digester for Bio-Methane with conversion to pipeline grade Natural Gas. The Anaerobic Digester will also act as the "Sewage" Treatment plant for the facility.
3. Solar Hot Water Panels provide High Heat Hot Water for the Absorption Chiller and Domestic Use. Use Natural Gas from Digester to boost water temperature if needed.
4. Co-generation Plant—Generates Electricity with steam heated by natural gas from Digester. Hot Condensate is then sent to Absorption Chiller.
5. Ground Contact Earth Tubes—Pre-cool and Pre-Dehumidify fresh air for final touch-up and filtering by the Mechanical System.

5A. Desiccant Dehumidification using hot water or natural gas as an energy source will touch-up the fresh air after exiting the Earth tubes.

6. Thermal Chimney used to "pull" air through the Earth tubes for delivery to the Mechanical System. Use Mechanical System to boost "pull" if needed.
7. Cisterns for collection of rainwater—Used for flushing toilets and as feedstock for Domestic Water Filtration System. Cisterns can be used as "Overnight" Solar Hot Water storage.
8. Domestic Water Filtration System—Nonchemical.
9. Living Roof Area(s)—Pre-Filtration for Rainwater heading to Cisterns.
10. Stormwater Ponds for retention and filtration. Use water for Irrigation and as feedstock for Domestic Water Filtration System if Cisterns run low due to an extended dry period.

Case Study 55: All Ukrainian Health Protection Centre for Mothers and Children

Kiev, Ukraine

OWNER: Ukraine 3000 International Charitable Foundation

PROJECT TEAM:

Architect: BDP with groupe-6 and Budova Center 1 (Kiev)

Civil, Structural, and Building Services Engineer: BDP

TYPE: New Children's Hospital

SIZE: 570,487 sq. ft. (53,000 sq. m) on 24.7 acre (10 ha) site

EUI: <150 kBtu/sf/yr (<35 GJ/100 cubic meters)

PROGRAM DESCRIPTION: 250-single patient room children's hospital including general pediatrics and surgery, oncology, hematology-oncology, and a peritoneal center with five-story diagnostic and treatment building and five three-story patient wards and outpatient clinic

COMPLETED: Project on Hold

RECOGNITION: Finalist, Bentley Be Inspired Awards (2009)

BIOME: Temperate Semiarid

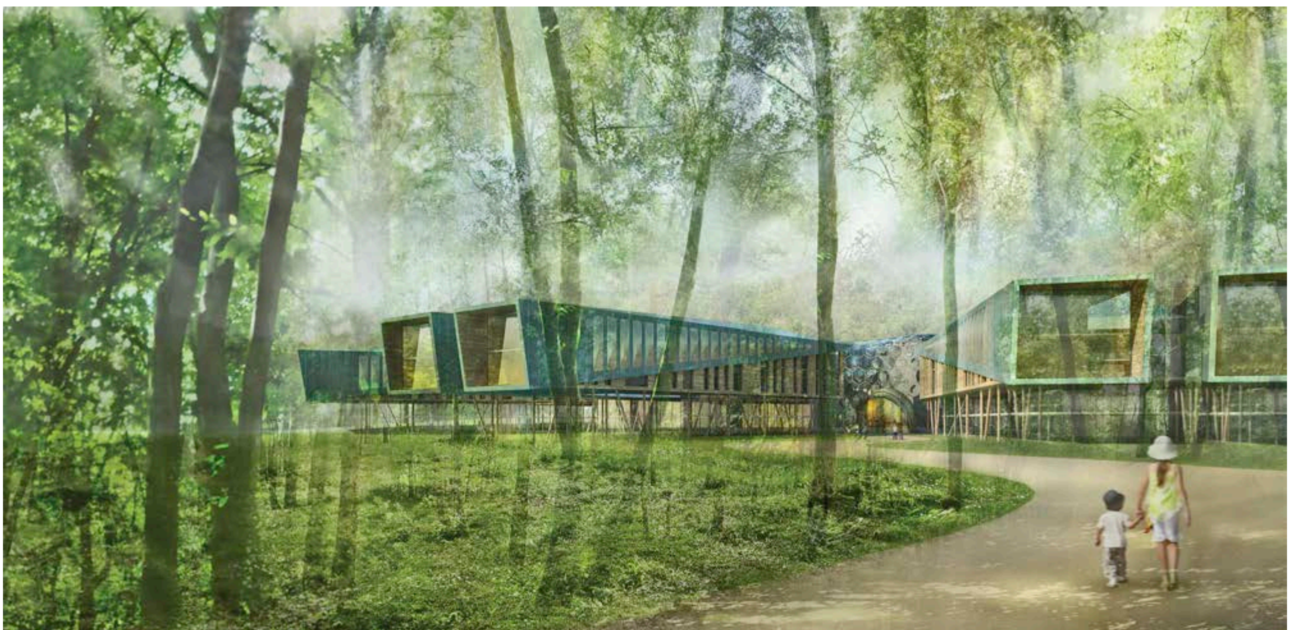
CLIMATE ZONE: Humid Continental, cool summer

PRECIPITATION: 24 in (619 mm)

KEY SUSTAINABILITY INDICATORS

- *Innovative Stormwater Management:* Stormwater captured in lake
- *Climatic Design:* Passive design including thermal mass/earth berms to control temperature swings; orientation takes advantage of prevailing breezes for natural ventilation
- *Energy Responsive Facade:* Patient room windows shaded from summer sun
- *Reclaimed Water Use:* Reclaimed stormwater/greywater reused for toilet flushing
- *Innovative Source Energy:* Dual fuel biomass/diesel tri-generation combined heat and power system (dependent on availability of biomass), chilled beams as primary method for space cooling; buried concrete earth tubes cool incoming air; solar thermal panels for water heating
- *Natural Ventilation:* Mixed-mode ventilation including natural ventilation during spring and autumn, with operable windows
- *Low-Embodied Energy Materials:* Locally sourced materials; low-VOC and low-toxic materials; PVC avoidance
- *Community Integration:* Publicly accessible trail system through the forest

Figure 10.35 All Ukrainian Health Protection Centre. *Source: Kiev BDP/Groupe6*



The result of an international competition, this new children's hospital located on the outskirts of Kiev—the capital of Ukraine and its largest city with about 2.6 million people—responds to the economic, social, and environmental challenges facing that country that have adversely affected children's health to unacceptably high levels, evidenced by an increase in child mortality in recent years. Designed as a "dacha in the woods" this nature-inspired 250-bed hospital is located in a forested area and will be open to children from throughout the country. To imbue a sense of connection with nature, the forest is preserved in its natural state, with minimum tree removal; the forest floor serves as the basis of the landscape rather than introducing grass. The building's passive, climatically responsive design is fitting for the climate—cold and damp during the winter, and hot and humid in the summer (Figure 10.35).

An overarching low carbon strategy influenced building orientation, design, and mechanical systems. A mixed-mode ventilation system allows for natural ventilation during spring and autumn, enabled by operable windows. A dual-fuel biomass/diesel tri-generation combined heat and power system, using bio-diesel when available, will provide resiliency to the hospital's on-site energy center, and be the primary source of electrical and thermal energy. Chilled beams will be the primary source of space cooling, with potential to link to a ground loop. Solar thermal panels will produce hot water. Passive design features offset reliance on air conditioning and include thermal mass, naturally ventilated bedroom pods with shading to block the summer sun, and an atrium "winter garden."

To provide an optimal healing and home-like environment, all bedrooms are single occupancy with room for family members, and are physically and visibly separated from the diagnostic and treatment block. Each playroom is placed at the end of ward "fingers" that extend from the sinuous atrium, with generous windows that create a sense of immersion and comfort in the surrounding forest (Figures 10.36 and 10.37). *Source: BDP Architects*

Figure 10.36 Site model. *Source: Children's Hospital of the Future, Kiev BDP/Group6*

Figure 10.36 Playroom at the end of wards. *Source: Children's Hospital of the Future, Kiev BDP/Group6*

Bibliography

Antonovsky, A. (1979). *Health, Stress, and Coping.* San Francisco: Jossey, Bass.

Armour, S., S. Pettypiece, and M. F. Cortez (2012). *Hospital Evacuation in NY Exposes Outdated Power Backup*. Bloomberg. www.bloomberg.com/news/2012–10–30/new-york-hospital-evacuates-patients-as-sandy-hits-power.html.

Bollier, D. (2008). Treating Healthcare as a Commons. *Commons Magazine (*October 7). http://onthecommons.org/treating-health-care-commons.

Cassel, C., and T. Brennan (2007). "Managing Medical Resources: Return to the Commons?" *Journal of the American Medical Association (JAMA)*, vol. 297, no. 22, June 13, 2007, pp. 2518–2520.

Chertow, M., and C. Powers (1997). Industrial Ecology: Overwhelming Policy Fragmentation. In *Thinking Ecologically: The Next Generation of Environmental Policy,* eds., M. Chertow and D. Esty. New Haven, CT: Yale University Press, 19–36.

Chertow, M., and D. Esty, eds. (1997). *Thinking Ecologically: The Next Generation of Environmental Policy,* New Haven: Yale University Press.

Christensen, C., J. H. Grossman, J. Hwang (2008). *The Innovators Prescription: A Disruptive Solution for Healthcare.* New York: McGraw-Hill.

Cole, R. (2012). Regenerative Design and Development: Current theory and practice. *Building Research and Information,* 40(1):1–6. London: Routledge.

Dilani, A. P. D. (2008). Psychosocially supportive design: A salutogenic approach to the design of the physical environment. *Design and Health Scientific Review,* 1(2): 47–55.

Economy Watch (2010). USA (United States of America) GDP, October 14, 2010. www.economywatch.com/gdp/world-gdp/usa.html.

Everson, M. (2005). Testimony before the House Committee on Ways and Means. 109th Congress. 1st sess. May 26. www.nacua.org/documents/Hearing_TaxExemptHospitals.asp.

Fisher, T. (2013). *Designing to Avoid Disaster: The Nature of Fracture-Critical Design,* New York and London: Routledge.

Gawande, A. (2009). The Cost Conundrum. *The New Yorker:* June 1, pp. 36–44.

Goleman, D. (2009). *Ecological Intelligence: How Knowing the Hidden Impacts of What We Buy Can Change Everything,* New York: Random House.

Harvie, J. (2012). "The Case for Common Healthcare." *Explore* (January/February): pp. 59–63. http://download.journals.elsevierhealth.com/pdfs/journals/1550–8307/PIIS1550830711003053.pdf.

Heinberg, R. (2004). *Powerdown: Options and Actions for a Postcarbon World,* Canada: New Society Publishers.

Holling, C. S. (1973). Resilience and Stability of Ecosystems. *Annual Review of Ecology and Systematics.* Vol. 4:1–23.

Jones, N. (2012). Healthcare in America: Follow the Money. NPR shots, *Health News (*March 19). www.npr.org/blogs/health/2012/03/19/148932689/health-care-in-america-follow-the-money.

Meyer, C., and J. Kirby (2010). Leadership in the Age of Transparency, *Harvard Business Review,* April 1, 2010.

National Research Council [NRC] (2011). *Improving Health in the United States: The Role of Health Impact Assessment.* Washington, DC: The National Academies Press.

Pine, B. J. II, and J. H. Gilmore (1999). *The Experience Economy: Work Is Theater and Every Business a Stage,* Boston: Harvard Business School Press.

Porter, R., and E. Teisberg (2006). *Redefining Health Care: Creating Value-Based Competition on Results.* Boston: Harvard Business School Publishing.

Postman, N. (2000). *Building a Bridge to the 18th Century: How the Past Can Improve Our Future,* New York: Vintage.

Schettler, T. (2001). Environmental challenges and visions of sustainable health care. Paper presented at CleanMed Conference, Boston, May 4. www.sehn.org/Sustainable_Health_Care.html.

Verderber, S. (2010). *Innovations in Hospital Architecture,* New York and London: Routledge.

Viana Do Couto, J. L. (2006). A Brazilian Model of Medical Care. OhmyNews International. http://english.ohmynews.com/articleview/article_view.asp?no=315378&rel_no=1.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig (2004) Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecology and Society.* 9(2): 5. www.ecologyandsociety.org/vol9/iss2/art5/.

Walsh, B. (2008). Design and Stewardship: How the Design of Facilities Helps Create Better Neighborhoods and Communities. In *Sustainable Healthcare Architecture,* R. Guenther and G. Vittori. Hoboken, NJ: John Wiley & Sons, Inc., pp. 389–391.

Wilson, Alex (2005). *Environmental Building News.* December 2005.

INDEX

C

D

H

N

R

T

U

V

W

Y

Z

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