Green Energy and Technology

Adriano Bisello
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Smart and Sustainable Planning for Cities and Regions

Results of SSPCR 2015

EURAC research

ISOCARP Knowledge for better Cities

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Green Energy and Technology

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Foreword

Beyond Urban Liveabilty: Terrestrial Habitability and the Rise of Intelligent Environments

Cities are lived-in technology. Like swallows, termites, and other fellow species of the global fauna, the human animal *Homo sapiens*, too, constructs her own habitat. The original Paleolithic caves and Neolithic huts evolved into ubiquitous products of a massive global industry, and merged into one of the most fascinating phenomena of this planet: cities. Throughout their histories, cities have morphed from communal shelter clusters into time-management machines, sources and objects of war, mass work houses, places of despair and suffering for some, and settings of liberation and liberty for others.

The medieval adage, *Stadtluft macht frei* meant that the city offered hope to liberated serfs but also served as a great equalizer, stripping away previous personal burdens. But the liberating city air soon also emerged as a focus of medical concern: cities were also massive waste machines, air polluters, and cesspools, dead ends for the poor, burgeoning squats, and, consequently, places of often-misguided ideas about social, ethnic, spatial, and environmental cleansing, of political reform, and of revolution.

But cities also evolved into complex and connected systems of movement, communication, culture, control, and command—their political economies are inseparably intertwined with technological change. Over the ages and across different levels of wealth, cities epitomized Gordon McGranahan's thesis of the cycles of environmental stress: from escaping local pollution hot spots to becoming trapped in a global carbon bubble, in the greatest Faustian dilemma of all times, i.e., heavenly progress bought through hellish energy sources such as uranium and coal, oil, and gas. The global fossil fuel supply chains and hydrocarbon-combustion-based development helped turbocharge rising megacities and global urbanization worldwide.

Each year, urban liveability indices rank cities and their lifestyle valuations. This important conference and its wonderful documentation begin pointing in the direction that is so desperately needed to avoid the rise of an urban *habitability* index, as cities, one by one, become uninhabitable, due to heat, drought, and inundation. Unthinkable? Think again. Fossil fuel and climate wars, historically interlinked with religious strife, political domination, and state terror, have already led to the elimination of urban communities across entire nations from the list of habitable, let alone, liveable cities: Aleppo, Bagdad, Basra, Benghazi, Erbil, Falluja, Gaza City, Damascus, Homs, Mosul, Sirte, and Tripoli. The list goes on.

Cities are both our own worst enemies and greatest hope for redemption. Buckminster Fuller's Spaceship Earth referred to the only habitable place we have ever known and yet the so-called smart money—the founders of Tesla, Amazon, and Virgin—has joined the growing ranks of governments (from China, France, Germany, India, Iran, Italy, Japan, and Russia to the United States) as well as the brilliant European Space Agency in the grotesque paradox of seeking to escape Spaceship Earth by investing massive capital extracted from its demolition, into deep-space exploration for the purpose of building extraterrestrial colonies, presumably to flee the very rampage that funded the escape, to fulfill the madcap destiny prescribed for humankind in the science fiction genre.

However, the actual task at hand is more immediate, more urgent, less glamorous, but equally heroic. The most important challenge of space exploration and planetary habitability is right here under our feet: to build cities as spatial, technical, financial, and societal systems so that they not only sustain themselves in the short term, but, more importantly, they protect and heal natural planetary systems through the very acts of smart and sustainable building, undoing harm and regenerating environments. Nurturing civil harmony, health, access, prosperity, and community vitality by: strengthening the existential essentials of renewable energy proliferation; greenhouse-gas sequestration in soils, wetlands, wood, and biochar; biodiversity protection; and organic food production. In this way, we pursue the most essential criterion for good urban design—specified by Christopher Alexander—but with a far more profound meaning for species' resilience and survival: to leave places better off than we found them.

This important conference volume brings together leading scientific minds and practitioners from around the world, all working today on the "smart and sustainable" cities of tomorrow, experts in renewable energy, information technology, water, urban agriculture, climate change mitigation, community health, social and cultural connectedness, peace, demilitarization, the political economy of sustainability, and regenerative infrastructure. Together, their messages provide the tools to help build *intelligent cities*: intelligent enough to halt and reverse the dramatic decline in terrestrial habitability.

Prof. Peter Droege
Liechtenstein Institute for Strategic Development
Berlin, Vaduz

Preface

Why do We Need a Smart and Sustainable Planning for Cities and Regions?

In an increasingly urbanized world, with over 50 % of the global population living in cities, smart and sustainable city planning represents an emerging topic both in the scientific and in the more general cultural debate.

The need for smart planning arises from our constant acceleration towards an information-mediated world experience and is driven by factors such as the current global financial crisis, global climate change, global population growth, and cultural globalization.

Smart and sustainable planning makes our cities and regions more liveable and competitive places, consistent with both our inspirations and our aspirations.

Transforming existing settlements into smart cities, de facto, means to couple their ICT potential with human factors—innovation in building and energy technology, people's engagement in participatory processes, environmental resources preservation, and the exploitation of new business models.

A uniquely coherent definition of the meaning of smart city has still to be established: academics, decision makers, and industries approach this topic from different perspectives, delivering multiple solutions often hard to replicate. Nonetheless, smart city projects are currently spreading worldwide, comprising a more diverse, and so far relatively unexplored, galaxy.

Therefore, a discussion on smart and sustainable cities and regional planning should, first of all, have the effect of providing guidance to all experts—researchers, politicians, public officials, and managers—entering into this innovative field. Spatial planning is traditionally a complex discipline, founded on multidisciplinary knowledge, requiring various skills, and pursuing multi-objective goals. Nowadays, it is clear that for tackling "smart and sustainable planning" challenges a holistic approach—going beyond solutions to single technicalities—is required.

The aim of this work is to provide a comprehensive outlook on the latest research paths taken by various branches of science in the field of smart and sustainable planning, stimulating a proactive dialogue and engendering a broad knowledge exchange. Some relevant theoretical findings are gathered here, together with already implemented lighthouse projects, to show how research results may be translated into real-word applications.

Lessons from pioneering practical implementations offer a great opportunity for follower cities and regions to improve their forthcoming plans and to researchers to define new technical procedures and methods. In these works, the various research themes are explored by adopting a crosscutting approach, mixing the contributions of authors from various fields under a few selected umbrella topics, trying to establish a shared baseline onto which to graft innovative development ideas.

The opportunity to gather a wide number of scientists and practitioners in the field of urban planning was offered by the first occurrence of the international conference on Smart and Sustainable Planning for Cities and Regions. This conference, shortly SSPCR 2015, took place during November 19–20, 2015, in Bolzano (Italy), organized by the Institute for Renewable Energy of the European Academy of Bolzano/Bozen (EURAC), with the support of the International Society of City and Regional Planners (ISOCARP). The SSPCR 2015 (http://sspcr2015.eurac.edu) focused on innovative planning methodologies, tools, and experiences aimed at supporting the transition of our cities and regions towards smarter and more sustainable dimensions, by touching on diverse scales, environments, and perspectives. EURAC and ISOCARP decided to couple the two words "smart" and "sustainable" in the conference title specifically to highlight that, only through the combination of the two concepts, is would be possible to achieve a better quality of life and well-balanced low-carbon development. To offer a comprehensive overview of this topic, the SSPCR 2015 was designed around four thematic sessions, flanked by a fifth session on real and practical experiences, as well as some plenary sessions introducing and synthesizing the debate.

Among our keynote speakers, we hosted: Prof. Peter Droge (University of Lichtenstein) with his contribution on intelligent and regenerative city regions; Prof. Jürgen Breuste (Paris, Lodron, University of Salzburg) discussing urban green areas and climate change; Prof. Ezio Micelli (University IUAV of Venice) suggesting innovative ways to recycle the cities' building stocks; Dr. Nora Mzavanadze (University of Manchester) presenting the EC Horizon 2020 project COMBI on operationalizing the multiple benefits of energy efficiency in Europe; Pietro Elisei (ISOCARP) presenting participatory governance approaches for urban decision-making; and, finally, former ISOCARP President Milica Bajic Brkovic asking delegates the question "will planning save the cities?".

Both EURAC and ISOCARP representatives provided productive topics for the discussions: Dr. Wolfram Sparber, Head of the EURAC Institute for Renewable Energy, introduced participants to new heating and cooling systems for smart cities, and Dr. Richard Stephens, ISOCARP President, discussed megatrends, black swans, and game changers, employing examples also from U.S. planning approaches.

The volume replicates the structure of SSPCR 2015: Part I presents the papers discussed under the topic “Energy and Climate”, Part II those under “Governance”, Part III concerns “Costs and Benefits”, while Part IV treats “Technologies”. The last part, Part V, takes a closer look at “Demonstration and cooperation projects” in the field of smart and sustainable planning.

Part I concerns “energy planning for cities and regions” and investigates in four papers how to couple energy–climate goals with the development or renovation of energy infrastructures and how to tackle vulnerabilities due to climate change. An integrated approach beyond sectorial infrastructure management is suggested, as well as the integration of renewable sources in existing networks. The relevance of energy issues also emerges in developing a renovation scenario on the urban scale, as well as a collaboration scheme to undertake energy efficiency development at regional scale.

In Part II, three meaningful examples are given on how “smart and sustainable technologies” involve challenges and opportunities for urban and regional planning. Applications are broad: buildings and other architectural features may act as environmental displays; mobility management may become more on-demand; and geospatial tools may help predict and prevent sprawl phenomena.

Within Part III, “benefits, costs, and opportunities of urban transition”, toward a more smart and sustainable dimension, are explored and discussed. Four different contributions report case studies or methodological approaches to assess values and trade-offs within decision-making processes. The topic is investigated looking at co-benefits of large-scale smart-district projects, urban-regeneration experiences, urban-transport projects, and spatial-planning methods. This section also includes an invited paper by Prof. Ezio Micelli (University IUAV of Venice) on innovative financial schemes in the construction sector to facilitate the refurbishment of existing buildings.

Part IV explores new ways to deal with an effective “governance for smart and sustainable growth” with five contributions fostering place-based policy-making, active and effective stakeholders’ participation, collaboration in development-path design, and public-private partnerships. This section also includes an invited paper by Prof. Ekaterina Domorenok (University of Padua) focusing on new governance tools for innovation and sustainable development in EU cities.

Part V embraces “cooperation and demonstration projects” that play an essential role in enabling the adoption of new approaches and technologies towards the development of win-win solutions. Six different reports on cutting-edge smart energy initiatives, currently under development or already achieving outstanding results, are presented. The section provides examples at various scales, from small rural villages to large urban communities. It also analyzes various contexts, from industrial clusters and SMEs to a metropolitan aviation hub. Finally, this section offers some relevant figures on European funding allocation on the smart city topic.

We would like to thank all the SSPCR 2015 speakers for their brilliant research contributions, inspiring a multidisciplinary debate among delegates. During the two conference days, we had 42 oral presentations and a poster session from academics, researchers, and experts coming from various countries such as Austria, Egypt,

Finland, Germany, Greece, Italy, Kenya, Nederland, Poland, Saudi Arabia, Serbia, Sweden, and Switzerland. As a result, the SSPCR 2015 constructively merged theoretical insights and findings with empirical evidence from case studies to deliver the worldwide context. Only conference papers that successfully passed the peer-review process have been collected in this volume. Thus, we are grateful to all the reviewers and the members of the scientific committee for their efforts in helping us to achieve such a high level of scientific output. We also wish to thank the EURAC Meeting Management team for contributing to the successful organization of the SSPCR 2015 conference. We hope that this event was instrumental in sustaining peer-to-peer knowledge exchange and in strengthening mutual learning among cities and communities.

Bolzano/Bozen, Italy — Adriano Bisello
Bolzano/Bozen, Italy — Daniele Vettorato
The Hague, The Netherlands — Richard Stephens
The Hague, The Netherlands — Pietro Elisei

Invited Talks

Milica Bajic Brkovic—ISOCARP
Architect and urban planner, Milica Bajić-Brković, has dedicated her professional life to the built environment. A former Full Professor of Urban Planning and Design at the University of Belgrade and BPTT Chair in Planning and Development at the University of the West Indies, she has also taught at other universities in her home country and abroad. Her recent research is in the area of climate change with respect to planning theory and methodology. Milica served as President of ISOCARP 2012–2015 and is a member of the UN SG HLAG on Sustainable Transport 2014–2016. Professor Bajić-Brković delivered the presentation "Will planning save the cities? Managing responses to climate change": "planning will likely bear the bulk of responsibilities in coping with climate change and making cities resilient and liveable. As the conventional planning interventions appear limited and often weak to meet these objectives, there is a need for a shift that will reinforce the capability of planning and make it climate-change responsive."

Jürgen Breuste—University of Salzburg
Jürgen Breuste holds a professorship for Urban Ecology at Paris-Lodron-University Salzburg, Austria, and at East China Normal University, Shanghai, China, and is an honorary professor at Capital Normal University, Beijing, China. He is member of several scientific boards and president of the International Society of Urban Ecology (SURE). Professor Breuste's presentation focused on "How can urban green help to adopt to climate change? The example of Linz, Austria": "The increase of the summer air temperatures will be most notable in urban areas, where the heat island effect emerges. Due to their climatic ecosystem services, urban green areas can play an important role in this process. Therefore, urban planning departments have to develop adaption strategies in order to be able to limit negative effects of the climate change on their citizens."

Ekaterina Domorenok—University of Padua
Ekaterina Domorenok is an associate professor of Political Science at the University of Padua, where she holds lectureships in European public policies and governance

of local development. She has been involved in several research projects on EU regional policies, multi-level governance, territorial development, environmental sustainability, and climate change. She focused on "New governance tools for innovation and sustainable development in EU cities": "Community Led Local Development (CLLD) and Integrated Territorial Investments (ITIs,) have been designed to encourage an integrated use of the EU Structural Funds for territorial development at national, regional, and sub-regional level. These tools are particularly relevant for the implementation of integrated actions for sustainable urban development that is among core priorities of the EU Territorial Agenda."

Peter Droege—University of Lichtenstein
Peter Droege is an international expert on advanced urban design, planning, and renewable infrastructure development. Professor Droege holds the first Chair for Sustainable Spatial Development at the University of Liechtenstein, and a Conjoint Professorship at the University of Newcastle's School of Architecture and Built Environment. He spoke about "Intelligent and regenerative city regions (IRCRs)—a research, development and action mandate": "Cities, regions and city regions are undergoing a renaissance in this globalized world, re-emerging as vital domains of collective life and sources of cultural identity. In this new world of information, communication, and energy technologies (ICET), resilient renewable-energy systems can evolve, supporting community health and security—and producing substantial value-added benefits."

Pietro Elisei—ISOCARP, Urbansofia
Pietro Elisei, Town and Regional Planner, is currently working in Bucharest as an independent researcher in Urban Policies and Managing Director of USPACE (http://www.urbasofia.eu), a company providing services and consultancy in strategic planning. He is external research collaborator at Dipartimento di Management e Diritto (Università degli Studi di Roma 'Tor Vergata', Roma) on topics related to Urban Regeneration (Urbact Project Re-Block). Currently consultant for the Croatian Ministry of Regional Development (Regeneration of Small Towns). He is co-author of the UNECE regional report contributing to the HIII Global Report (Quito, 2017). He edited in 2014 the book *Strategic Territorial Agendas for Small and Middle-Sized Towns and Urban Systems*. Pietro Elisei's presentation focused on "Consistent Decision-Making in Urban and Metropolitan Areas Based on Participatory and Multi-actor Governance": "Strategic tools for towns and cities in transition, especially developed and applied at the local level, have to provide operative, efficient, and effective solutions for counteracting problems related to market labor, social inclusion, cultural activities and heritage, environmental and landscape protection and valorization, use and design of public space, and mobility."

Ezio Micelli—University IUAV of Venice
Ezio Micelli is currently Associate Professor in real estate valuation at the University IUAV of Venice. His research focuses on the economic feasibility of real-estate projects and on the public/private partnership at the urban scale. He has

been member of the “Urban Regeneration” team of the Italian Ministry of Infrastructures and Transportations (2014). Professor Micelli focused on the theme “Recycling the City”: “It is necessary to recognize the structural social and economic changes occurring and the necessity of a major shift in order to hold together, within a new perspective, profitability and sustainability, consensus and development. For instance considering low—or absent—economic growth, the existing real-estate stock enables an interesting convergence between economy and ecology.”

Nora Mzavanadze—University of Manchester
Nora Mzavanadze is a research associate at the Center for Urban Resilience and Energy (CURE), the University of Manchester, UK. She is an economist and environmental scientist and is responsible for the assessment of air pollution and the social-welfare-related co-benefits of energy efficiency in the Horizon 2020 sponsored project “COMBI”. Nora has been part of the Global Environment Outlook-5 (GEO-5) authors’ team and will be contributing to the GEO-6 report. Nora Mzavanadze will talk about “The H2020 COMBI project”: “COMBI stands for Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe. It is funded by European Union’s Horizon 2020 research and innovation program, and it aims at quantifying the multiple non-energy benefits of energy efficiency in the EU-28 area.”

Wolfram Sparber—EURAC Research
Wolfram Sparber is heading the Institute for Renewable Energy at EURAC Research since its foundation in 2005. He is Vice President of the Board of the European Technology Platform for Renewable Heating and Cooling (ETP RHC), and, since 2011, he is Chairman of the Executive Board of ALPERIA, a regional energy utility group including over 30 companies active among others in the fields of renewable-electricity production and district heating. Mr. Sparber focused his talk on “Heating and Cooling for Smart Cities”: “Heating and cooling is responsible for nearly 50 % of the final energy consumption in Europe. While electricity markets and developments are mainly a national competence, the energy consumption for heating and cooling depends in a relevant way on the development of our cities. In order to reach a more sustainable thermal energy consumption, massive building-refurbishment actions and heat-provision strategies have to go hand in hand.”

Richard Stephens—ISOCARP
Richard Stephens is an educator, consultant, and civic advisor helping to create meaningful and memorable places in over 25 countries. He is currently an adjunct instructor at Marylhurst University, Portland State University, and the University of Oregon. He is the president-elect of ISOCARP. Mr. Stephens introduced concepts such as “Megatrends, Black Swans and Game changers”: “We are at the crest of an information tidal wave in which data is ubiquitous and omnipresent. Information everywhere all the time offers unique challenges and opportunities for urban planning as the environment, economy, and society search for a new equilibrium.”

SSPCR 2015 Scientific Committee

Peter Droege, University of Lichtenstein
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Wolfram Sparber, EURAC, Italy
Daniele Vettorato, EURAC, Italy
Adriano Bisello, EURAC, Italy

Contents

Part V Demonstration Projects

Part I
Climate-Energy Planning

Optimization of Load Flows in Urban Hybrid Networks

Thomas Kaufmann, Dominik Bothe, Wolfgang Gawlik and Karl Ponweiser

Abstract A sustainable supply of energy in urban regions requires an adequate infrastructure and operation. At present, the different energy sources (i.e., electricity, gas, district heating) are used separately without any connection to each other. To increase the flexibility of energy supply, the usage of energy hubs is a possible way. Energy hubs are connection points between the energy sources that comprise the key elements of so-called hybrid networks. Using the energy/hub approach, surpluses and power shortages from a specific energy network can be avoided. The hubs offer various technologies of energy conversion and can include electrical and thermal storage. Thus it is possible to convert electrical into thermal energy (heat pump, electric heating), chemical (gas) into thermal (furnace), or electrical energy (micro gas turbine) into, respectively, thermal and electrical energy (combined heat and power) depending on the used technology. The correct operating strategy for these energy hubs is an essential factor in order to minimize CO_2 emissions of urban energy systems. Therefore, a simulation model was developed in MATLAB®. The minimization of CO_2 emissions is based on a mixed-integer linear optimization of the overall system, consisting of the supplying infrastructure, energy hubs, and thermal/electric loads. First results have been obtained by a case study for an urban region supplied by three different energy carriers (gas, electricity, and district heating).

Keywords Multi-energy system · Hybrid network · Energy hub · MILP · Power flow calculations

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1 Introduction

Current developments in the European energy markets are influencing the operational strategy of energy suppliers. In particular, providing electricity and heat for urban regions faces new challenges regarding economic and ecological aspects. The energy turnaround (Ekardt 2014) requires innovative approaches and methods to achieve a sustainable supply of energy. Increasing energy demand as well as a growing number of intermittent renewable-energy sources and storages result in new requirements for current energy-supply structures. One possibility to reach a sustainable supply of energy is to model hybrid networks by using the energy-hub approach (Geidl et al. 2007). In this way, it is possible to react more flexibly to constantly changing requirements for supplying energy. Thereby, a hybrid energy and infrastructure system for urban regions is developed here. The term hybrid describes the interaction between different energy infrastructures.

2 Methodology

For analyzing a hybrid-energy infrastructure system, a mixed-integer linear programming (MILP) model is implemented in MATLAB® and solved by Gurobi Optimizer (Gurobi Optimization 2015). In the following subsections, the used-power flow calculation for the electricity grid, hydraulic calculations for natural gas networks, thermal-hydraulic calculations for thermal networks, coupling of infrastructures with energy hubs, and the overall optimization problem will be discussed.

2.1 Electricity Network

The model of the power grid describes a medium-voltage grid in an urban area. Power-flow calculations are usually executed by iteratively solving a nonlinear system of equations. The use of this method in a linear optimization problem requires some simplification in the power-flow equations, which are achieved by the DC-power-flow method (Wellssow 1986). The linear characteristics of the DC-power flow have the advantage that the calculation method can be directly implemented as a constraint in a linear optimization problem. Results from this method are the active power transportations in the considered electric grids. Voltage levels on nodes, transported reactive power, and transmission losses are not calculated. Loss estimation is possible by evaluating the quadratic relationship between losses and line current. In urban areas, short line-lengths and high load-densities are characteristics of electric grids. Therefore, voltage issues and line losses are negligible.

2.2 Thermal and Gas Networks

In the field of hydraulic simulation of fluidic networks, it is possible to use various steady-state methods for calculating pressures and velocities in the considered network. The choice of available methods depends on the structure of the district heating network (DHN). DHN designs are basically split into two groups, radial and meshed networks. The hydraulic properties of radially structured systems can be determined directly by consideration of the boundary conditions. The handling of meshed networks requires an iterative procedure. In Vldimarsson (2014), typical and popular approaches like the Hardy Cross method are presented. Stevanovic et al. (2007) present a method for calculating hydraulic characteristics based on the loop model of the network and the method of square roots for solving the system of linear equations. Ellis and Simpson (1996) investigated the Linear Theory Method (LTM), the Newton-Raphson method, and a hybrid method combining both, the LTM and Newton-Raphson method in terms of efficiency.

The hydraulic simulation of the gas network and district heating network is based on the Linear Theory Method. Additional to a hydraulic analysis, the thermal behavior of the district heating network can also be examined. For this purpose, a combined thermo-hydraulic calculation method is applied.

The hydraulic calculation of the district heating system works as for the gas network and serves as input for the thermal calculation, which is based on the discretization of the pipe network with the Finite Volume Method. In this way, a transient and detailed simulation of the thermal network is possible (see Fig. 1).

2.3 Energy Hubs

For the coupling of energy network infrastructures, energy hubs have to be defined. This will enable an interface between the grid infrastructures (electricity, natural gas, and heat) to be determined. Figure 2 shows an exemplary structure of an

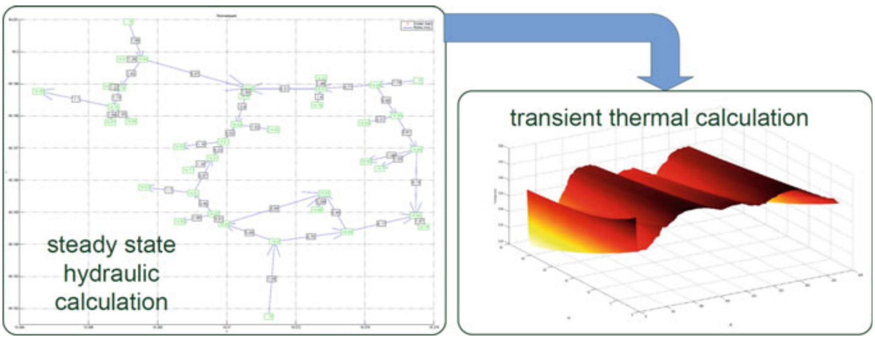

Fig. 1 Combined thermo-hydraulic simulation

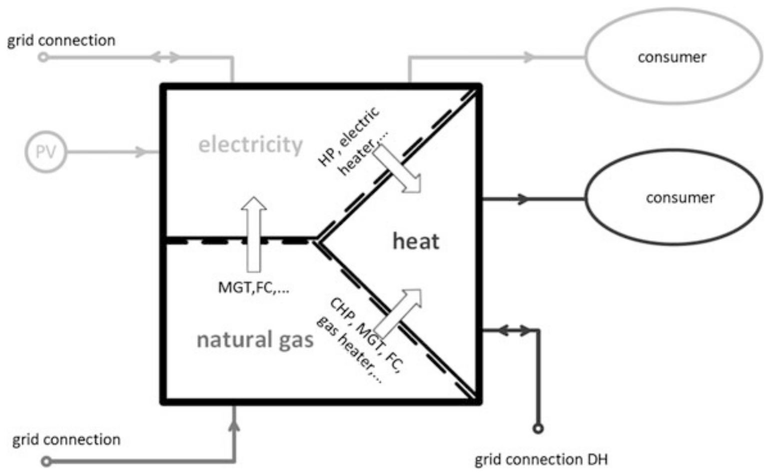

Fig. 2 Schematic illustration of an energy hub

energy hub. A Matrix, which is populated by the efficiency factors of the conversion technologies, provides an interface between different energy infrastructures. Additionally, storage technologies and renewable-energy sources can be integrated. The number and placement of energy hubs in an urban area depend on connection points that are defined by spatial proximity between different energy infrastructures. Energy hubs can be used for different applications, for example:

- Industry (refineries, steel industry),
- Complexes of buildings (airports, hospitals, shopping center),
- Limited geographical spreads (urban areas) and
- Island grids (plane, train, ship).

From a systemic point of view, the energy-hub approach has some advantages compared to conventionally separated energy supplied infrastructures, namely, improved reliability, more flexible loads, and optimization potential (costs, emissions, availability).

2.4 Optimization

The optimization problem is implemented in the YALMIP (Löfberg 2004) toolbox for MATLAB®. YALMIP expresses the defined constraints, decision variables, and objective function in canonical form before solving with Gurobi. Combining storage technologies and piecewise linearization creates a MILP optimization problem. Power-flow equations for calculations in electrical grids can be directly formulated as constraints. Due to quadratic velocity-terms in hydraulic networks, equations for flow calculations have to be linearized using piecewise linearization methods before being included as constraints in the optimization problem. The input vector of the energy hub is defined as a decision variable, so the optimization determines the optimal input powers for each energy hub depending on the current objective. The objective function can be selected in order to, for example, minimize line utilization in power grids, minimize pressure losses in thermal networks, and minimize costs. In this paper, the objective function minimizes the CO_2 emissions for load supply to consumers. A case study in the next section shows an implementation of this optimization model in an urban area.

3 Case Study

The area around the location of the TU Wien serves as a case study for the simulations. The multi-energy system consists of an electrical, a thermal, and a natural-gas network. Additionally, two energy hubs with different energy conversion technologies are taken into account.

3.1 Networks

GIS data of the networks represent the basis of the applied method. Therefore, the networks of the case study were generated with the software tool QGIS which enables it to locate the infrastructure elements like feed-in points, consumers, and the route of the cables and pipes of the considered area (see Fig. 3). The blue lines indicate a medium voltage segment with two segments and seven load points. The used operational data of the electrical network in an urban region originates from a statistical survey (Otto 2012). The orange-colored gas network has low-pressure behavior and one feed-in point. The red coloured lines present a section of a primary district heating network with two feed-in points.

3.2 Load and Production Profiles

The load profiles of the electrical- and thermal-energy demand of the case study are given for 1 week with an interval of 15 min (672 values). These profiles are split into two groups, one for households and one for industry. Energy hubs in the case study were defined either as industrial consumers or as households.

Thermal-load profiles are based on the standardized daily consumption generated with the Sigmoid-model. This model uses a direct dependency of the heat demand on the daily mean temperature. For the case study, a daily mean

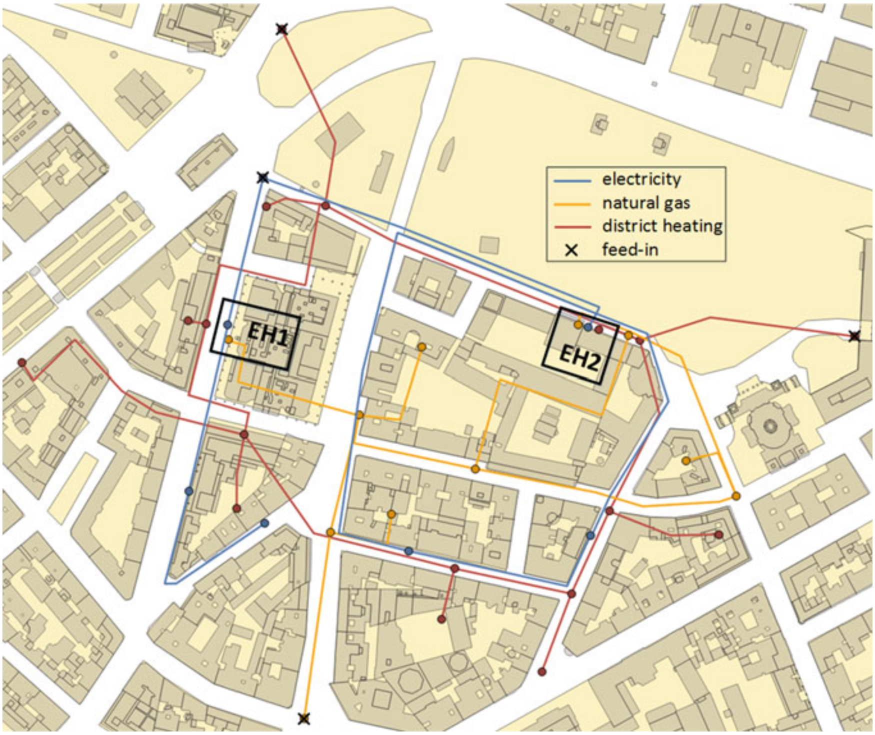

Fig. 3 Model of an urban hybrid network

temperature of 10 °C was chosen. The electrical load profile corresponds to the VDEW standard load profile H0 for households and G1 for industrial usage. Production profiles of the photovoltaic systems consider sunny and variably cloudy days, which are distributed over 1 week.

3.3 Definition of Energy Hubs

The energy hubs used in the case study have several connections to energy-supply infrastructures and are equipped with different coupling technologies to satisfy thermal and electric consumption. Energy Hub 1 is connected to the electric and natural-gas grid. By using a heat pump and gas heating, the thermal load can be supplied by two different technologies. Additionally, a thermal storage is included. Energy Hub 2 has connection points to all energy supply infrastructures (electric, thermal, and natural gas). The heat exchanger (HE) supplies the thermal load from a district heating infrastructure. The used combined heat and power (CHP) station generates electricity and heat simultaneously to cover electric and thermal loads. As in Energy Hub 1, a thermal storage is included that can be charged by CHP, HE, or immersion heaters shown as direct heating in the energy hub. Immersion heaters are used to store surplus energy from photovoltaics in contrast to cutting off feed-in power to prevent high line utilization in the electric grid. Figure 4 shows the used energy hubs.

Conversion efficiencies of the used coupling technologies are defined in Table 1. In the performed optimization, converter efficiencies are included as constants. Therefore, partial load behavior of converters is not considered.

3.4 Scenarios

With the introduced method for optimizing load flows, the effects of different energy conversion systems and supplying methods of electrical and thermal energy on the CO_2 emissions and the loads of the energy networks are examined. In Table 2, the eight analyzed scenarios are listed. Scenario "status quo mix" represents the reference scenario where the energy infrastructure disposes of neither

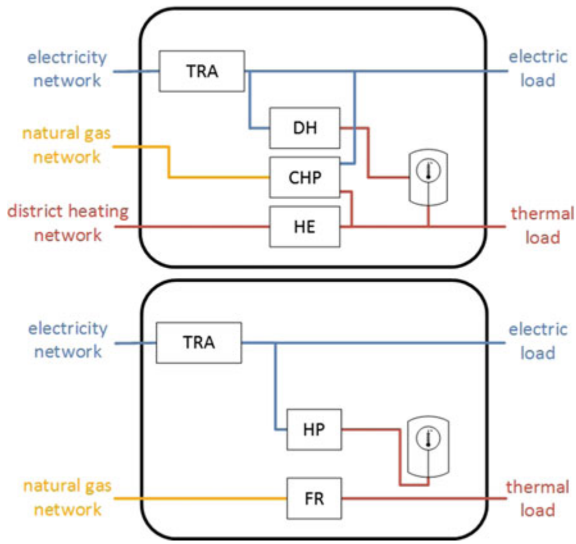

Fig. 4 Energy Hub 1 (*bottom*), Energy Hub 2 (*top*)

Table 1 Conversion efficiencies of used coupling technologies

Technologies	Efficiency
Transformer	99 %
Heat pump	COP = 2.5
Gas furnace	80 %
Immersion heater	100 %
CHP	η_{el} = 40 %, η_{therm} = 40 %
Heat exchanger	95 %

Table 2 Description of simulated scenarios

Scenarios	Energy hubs	Storage and renewables	Origin of electricity
Status quo mix	No	No	Power mix
Status quo eco	No	No	Eco power
Status quo mix pv	No	Yes	Power mix
Status quo eco pv	No	Yes	Eco power
Scenario mix energy hub	Yes	No	Power mix
Scenario eco energy hub	Yes	No	Eco power
Scenario mix all	Yes	Yes	Power mix
Scenario eco all	Yes	Yes	Eco power

energy hubs nor storages nor feed-in of renewable energy. The other scenarios differ in terms of the existence of energy hubs with thermal storages and the possibility of using renewable energy (photovoltaic).

All data used in the case study for CO_2 emissions is from ESU-services (2012). The kind of electric energy production is expressed in grams of CO_2 emissions per kWh electric energy. Thus, there are two different sources of electricity. The first one is a mixed generation with CO_2 emissions of 550 g/kWh ("power mix"), and the second is an absolutely ecological generation with CO_2 emissions of 40 g/kWh ("eco power"). For the valuation of the impact of the thermal energy consumption, CO_2 emissions of 260 g/kWh for the thermal energy provided by natural gas and 80 g/kWh for the thermal energy provided by district heating are assumed.

4 Results

All results shown in this section are based on the scenarios defined above. Optimal power flows in energy networks with respect to line utilizations in electrical grids, node pressures in gas networks, and node temperatures in district-heating networks are calculated. The objective function minimizes the CO_2 emissions in the energy hubs. In Table 3, the resulting CO_2-emission reductions based on the reference scenario "status quo mix" are listed. It can be seen that taking green electricity instead of a power mix can reduce the emissions by about 40 %—without using any renewables or energy hubs. Using renewables without energy hubs does not lower emissions in the case of green electricity use. The reason for this is that the thermal load, as the major part of the total load, is being supplied by natural gas or district-heating systems. Using energy hubs and green electricity, without considering renewables in energy hubs, quarters emissions compared to the reference scenario. When using energy hubs and photovoltaic, emissions come to one tenth of the emissions compared to the reference scenario. Further reduction is not possible due to load flow limitations in the supply infrastructures.

Afterwards, results from "scenario mix all" are described in detail. This means energy hubs and renewables (photovoltaic system) are used, and electric energy

Table 3 Resultant CO_2 emissions for various scenarios

Scenarios	CO_2 emissions (%)
Status quo mix	100
Status quo eco	59
Status quo mix pv	66
Status quo eco pv	56
Scenario mix energy hub	67
Scenario eco energy hub	23
Scenario mix all	24
Scenario eco all	10

comes from a power mix. Resulting input powers of the energy hubs, as well as their storage utilization, are shown in Fig. 5. It can be seen that for Energy Hub 1, electric energy is used most of the time to satisfy load requirements, because of lower emissions from heat pumps compared to gas furnaces. Natural gas is needed only when maximum line utilizations of electric lines are reached. This is the case when high thermal and electrical loads occur and no feed-in of renewable energy is available.

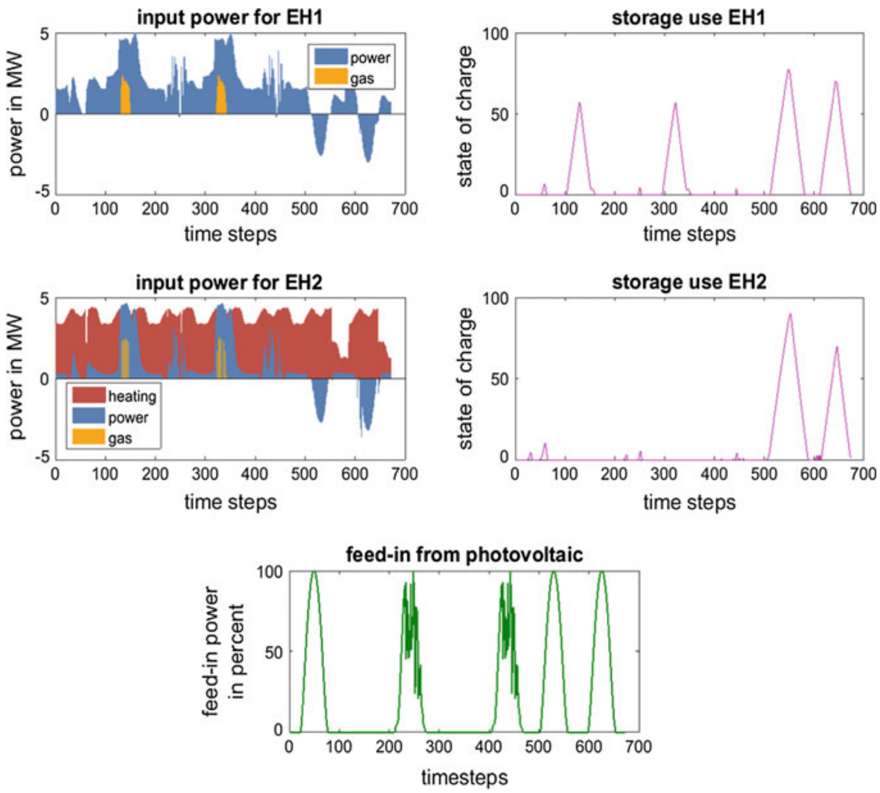

Fig. 5 Input powers for energy hubs and storage utilization

Input powers from Energy Hub 2 show roughly the same behavior. On days without feed-in from renewables, natural gas and electric power from energy networks are used based on consideration of line utilizations and node pressures. For better traceability of these results, Fig. 6 shows the used energy infrastructures

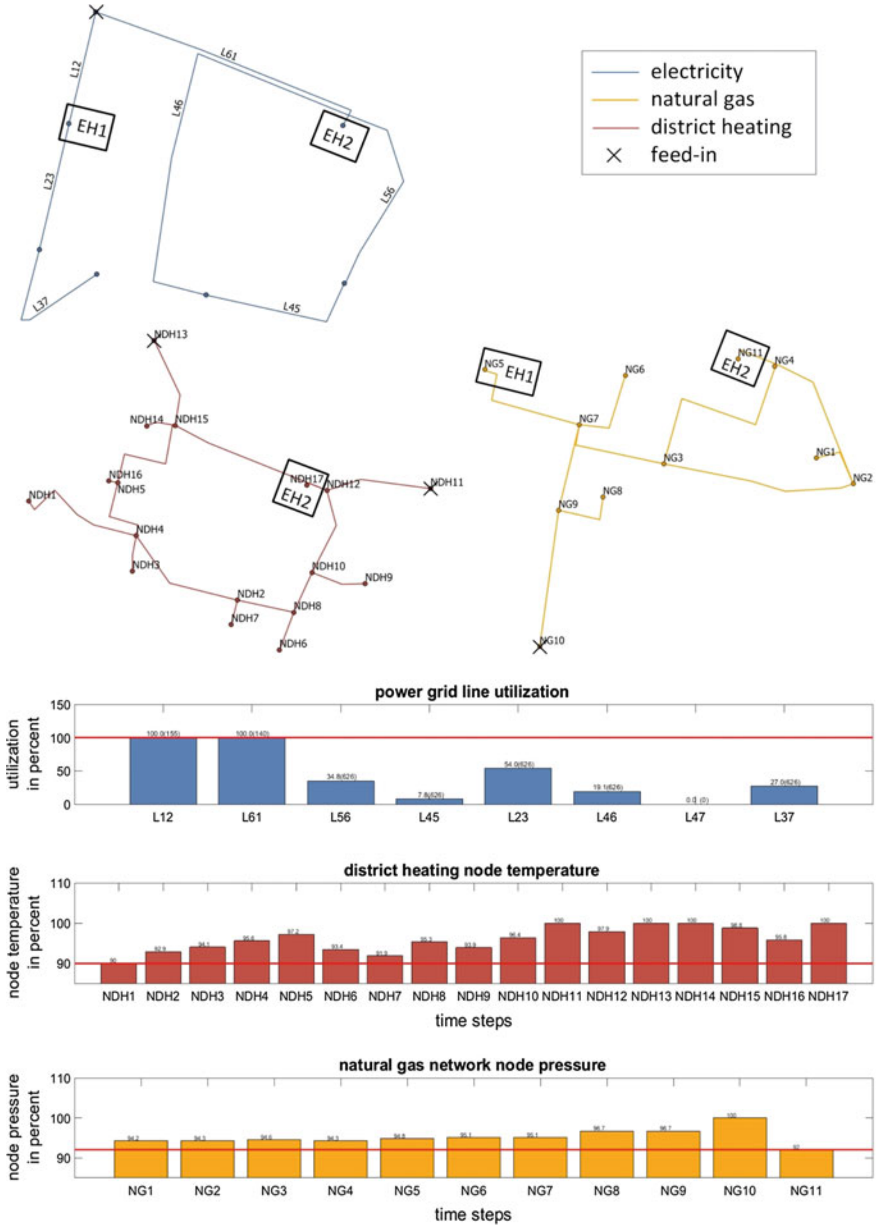

Fig. 6 Utilization of the electrical, gas, and thermal network

isolated, with energy hubs as interconnection points and line utilizations, node pressures, and node temperatures with designated limits.

5 Conclusion

The introduced methodology of optimizing load flows in hybrid networks demonstrates the potential of increased flexibility for supplying electricity and heat by using energy hubs. In consideration of network infrastructures, conversion technologies, and the behavior of consumers, it is possible to optimize the operation of hybrid networks of a given urban area. The objective function of interest can vary from CO_2 emissions over costs to individual objectives, always under the constraint that no load exceeds the allowable values of the considered network.

The results of the case study show how energy hubs could be operated to minimize the output of CO_2 emissions to supply the demand of electrical and thermal energy by consumers. Further steps are the implementation of efficiencies depending on the part-load behavior of conversion technologies.

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Technical, Financial and Urban Potentials for Solar District Heating in Italy

Alice Dénarié, Marco Calderoni and Matteo Muscherà

Abstract AIRU, the Italian association of district heating, and the Department of Energy of Politecnico di Milano have tried to evaluate the economic, technical, and urban potential of solar district heating in Italy as an efficient and flexible system to spread the use of solar thermal energy in urban areas. This potential has been estimated with the analysis of five case studies of solar thermal integration in district heating networks in the north of Italy: three with a centralized solar plant in existing district heating, one with distributed solar in an existing network, and finally one of a new solar district heating network. These studies, realized in the framework of Solar District Heating Plus project, aim at verifying the technical and economic feasibility of this integration. Besides the more common economic and technical study, a critical analysis looking at the urban aspects of this technology is proposed in order to analyze local potentialities and barriers for this technology. Centralized solar thermal integration has had positive results, while distributed solar rooftop-plants integration turns out to be not economically sustainable. A need for heat planning and heat mapping in urban design emerges as needed to promote and simplify the spread of large-scale renewable-energy plants.

Keywords Solar energy · District heating · Case studies · Trnsys · Urban energy planning · Legal framework

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1 Introduction

District heating systems, DH, can be described as urban-scale centralized systems that distribute energy from the heating source to residential and commercial buildings over a wider area. This technology has been demonstrated to have great potential and an important role in increasing the efficiency of urban heat-distribution systems in Europe (Persson and Werner 2012). DH is in fact able to extensively use and efficiently distribute heat that would otherwise be wasted (Werner 2006) like cogenerated heat, waste to energy, industrial recovery heat, as well as renewable heat from biomass and solar thermal, reducing the primary energy consumption (Lund et al. 2010). In particular, solar thermal energy has successfully been integrated into existing and new district heating networks, especially in northern European countries like Denmark, Sweden, Germany, and Austria. (Nielsen 2014; SDH project partners 2008).

In Italy, this kind of integration has just started with the first integration of solar thermal collectors in the district heating network of Varese, in the north of Italy.

In the framework of European project on Solar District Heating, SDHplus, AIRU, the Italian association of district heating and the Department of Energy of Politecnico di Milano have tried to assess the feasibility of this kind of application in Italy in terms of technical, economic, and urban planning aspects through the calculations and analysis of several case studies. Two of the cases analyzed in this paper, A and D, have already been presented in Dénarié et al. (2015), plus technical data is available in SDHplus project deliverables on solar-district-heating.eu. At the conclusion of the project, thanks to the presentation of additional analyzed cases, the aim is to reach some consensus on the potential of this technology, in particular from the urban-integration point of view.

2 Opportunities for Solar District Heating—the Italian Framework

High efficiency DH and its integration with renewable-energy sources is a central research issue internationally recognized as an instrument to improve the financial and environmental sustainability of urban energy distribution (Connolly 2014; Lund et al. 2014). In particular, in Italy, the boundary conditions that characterize DH are forcing this system to face big changes, and this is definitely an opportunity for solar thermal energy.

Technical Framework: District Heating Energy Sources

DH systems risk losing their attractiveness in terms of energy efficiency, CO_2 emissions savings and financial profitability because of the current national energy context. First of all, the actual Italian DH networks are in great part fed by steam-cycle cogeneration plants (CHP) and internal combustion engines, which are much less efficient then modern steam-gas combined heat and power (GCC) plants

(AIRU 2014). In addition, actual networks are for the majority fed by fossil fuels with very little contribution from waste and renewable heat and almost no contribution from industrial heat recovery (see Fig. 1).

Secondly, electrical consumption has considerably decreased, 9.2 % from 2008 (Terna 2014), because of the economic crisis and efficiency measures, while the share of renewables in the electric grid has increased, and photovoltaic covers 7.5 % (Terna 2014) of electricity needs. All these conditions cause longer and longer periods of inactivity for CHP plants, in particular in summer, so that DH companies are forced to increase the use of their back-up gas boilers, which has a very bad impact on energy efficiency, environmental sustainability, and economic profitability. Consequently, DH utilities are looking for a more environmentally friendly and cheaper thermal source, and solar heat can definitely satisfy these requirements.

Political Framework: Legislation

European Directive 2012/27/EU, transposed in the Italian D. lgs. n. 102/2014, promotes "efficient district heating", a system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat, or 50 % of a combination of such energy and heat. Renewable-heat-sources integration in DH networks is now a real possible solution for utilities also because the diversity in heat supply options enables the use of the most suitable and favorable heat source depending on the market conditions and the heat costs. (Frederiksen and Werner 2013).

In addition to that, energy performance of new buildings and major renovations requirements have become increasingly ambitious. The promoters of this change are the European directives such as 2010/31/EC and the 2009/28/EC, both implemented in Italy, respectively, by D. lgs. 63/2013 and D. lgs. 28/2011.

The two directives give renewable energy a key role in achieving the goals of efficiency, requiring the introduction of an increasing share of renewable energy for heating and cooling in buildings. Solar district heating is an efficient way to meet these requirements, shifting the obligation of installing solar thermal from building

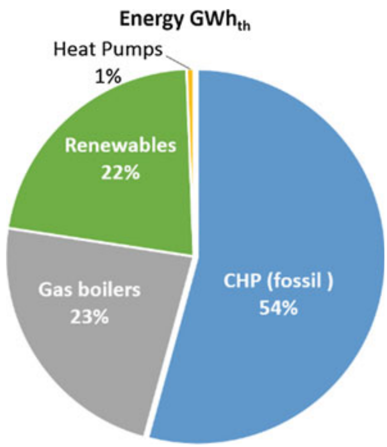

Fig. 1 Generation systems of Italian DH (AIRU 2014)

owners to DH utilities. Annex I of the 2010/31/EC also prescribes that the method of calculation of the energy performance of buildings, which defines their energy label, takes into account the presence of district heating for its primary energy-conversion coefficient. In the calculation of this coefficient, the heat sources feeding the DH network are considered, and the presence of renewable thermal energy has direct impact on this parameter.

On the other hand, successful Swedish examples (Dalenbäck 2012), suggest an opportunity for building owners that have already installed solar thermal to become *prosumers*. By connecting to DH networks, it is possible to avoid use of individual storage, to sell the excess solar-heat production to the DH networks, and to buy heat from this network instead of installing an individual back-up boiler.

Economic Framework: Incentives

Two parallel phenomena are happening that represent an opportunity for solar district heating (SDH).

Past incentives that supported the birth of DH plants fed by fossil fuels cogeneration systems, like *Green Certificates* D.M. (2008), *white certificates* (D.M. 2004) and *CIP 6* (CIP 1992), are expiring in the next few years, and consequently CHP systems risk being less economically interesting.

Meanwhile, the actual incentive system, *Conto Termico* (D.M. 2012), subsidizes solar thermal fields up to 1,000 m^2, making the integration of both large-sized centralized and multiple, distributed, medium- size solar thermal fields interesting. The revision of the same incentive schemes will support solar thermal fields up to 2,500 m^2 in future years (D.M. 2016).

After having analyzed some case studies in a previous paper (Dénarié et al. 2015), two of which are also mentioned in this paper, the subsidized surface of 1,000 m^2 seems to be too big for individual systems, but too small to have a big impact on DH plant size. Nevertheless, according to more experienced northern-country partners of the SDH plus project (Dénarié 2015), for a typical medium Italian network, a bigger-size solar field of at least of 5000 m^2 could be a really interesting solution in terms of energy output and economic profitability, benefitting from the cost reduction caused by the scale effect and even without incentive.

Local Framework: Urban Planning

From the experience gained and shared with involved utilities during the SDH project, urban aspects are crucial in the process of designing and building a SDH plant. In the design phase, while looking for space availability, and in the authorization phase, the DH utilities have to confront local authorities on urban issues. The legislative framework previously presented promotes the integration of renewables, but speaking about solar energy means speaking about available space that is not easy to find if not properly considered in the planning phase of an urban territory (SDH project partners 2015). For matters requiring a high-level legislative framework, national or regional, some urban tools are available to plan renewable energies. At the regional level, PEAR—Programma Energetico Ambientale Regionale is the strategic energy and environmental tool with which energy savings and objectives in the field of renewable energies development are defined by every region (L. 10/1991, January 9).

Moving to the lower local level, the PAES, Piano di Azione Energetica Sostenibile (SEAP Sustainable Energy Action Plan), is the planning and policy document for the reduction of greenhouse-gas emissions that the City Council has agreed to set up as part of the Covenant of Mayors. These tools define objectives and goals by implementing European directives, but, at the same time, they seem to lack consequent action measures, and they are not reflected in concrete indications nor requirements on how to reach these objectives from an urban point of view. The main focus of these plans is a buildings' efficiency, but they don't deal with urban energy issues (Zanon and Verones 2013).

At least in Italy, urban planning executive documents still do not have heat-and-energy-planning tools with clear indications on renewable energies. That implies that new SDH systems still have difficulties in the design and authorization phases because there is no clear reference to this kind of plant in urban planning documents or how the local utilities should deal with them. From the experience of the first SDH plant in Italy in Varese (Fidanza 2015), it's possible to conclude that this plant was built following a specific and singular authorization path that cannot be generalized. In order to reduce the weights of personal interests and political influence on the decisional process that leads to SDH plants, there's a need for legislative tools, instruments, and action guidelines to support the positive decision towards solar large-scale plants and to generalize the authorization procedure.

3 Methodology of the Analysis

In the framework of the just-ended European project SDHplus, the Energy Department of Politecnico di Milano with the support of AIRU has analyzed the potentiality of SDH in Italy from what concerns the energetic technical point of view, its economic feasibility, and the opportunities and barriers in the urban-planning field.

In particular, the elaboration of several case studies in collaboration with several utilities has given a concrete perspective to the analysis, raising issues and facing aspects that utilities have to deal with in implementing this kind of technology. From a technical point of view, cases A and D have already been presented in Dénarié et al. (2015). Here is the outline of the used methodology.

First, contacts with utilities are important to define the basic information required to start a preliminary project of integration in the solar field:

- motivation
- expected impact on the existing network
- space availability
- economic availability

Answering these questions raises some points and issues that can immediately expose the opportunities and barriers with which the Italian framework can consider this kind of plant.

Table 1 Characteristics of the analyzed DH networks

Case	Length (km)	Energy delivered (GWh_{th}/year)	Generation system		Temperatures (°C)	Type
			Technology	(MW_{th})		
A	26	45	Gas boilers	11.6	W 105–65 S 80–60	Existing
			Gas combined cycle (3rd party)	28.0		
B	20	49	Gas boilers	30	W 92–68 S 92–68	Existing
			Waste-to-energy plant	16		
C	4.4	5.8 heat 0.4 cold	Gas boilers	2.8	W 85–70 S 85–70	Existing
			Gas Cogeneration	0.75		
			Biomass-cogeneration recovery (3rd party)	0.8		
			Absorption chiller	0.4		
D	12.5	36	Gas boilers	29	W 115–65 S 85–65	Existing
			Gas Cogeneration	4		
			Biomass-cogeneration recovery (3rd party)	4.0		
E	–	13.8 heat 7 cold	Solar Thermal existing DH as backup		70–50	New

In particular, the choice of the location for the integrated solar field is an important factor, influenced by urban regulations, that deeply influences the installation technology and consequently the installation price and business model.

For the technical feasibility, DH-network monitoring data are collected from the utility and used to simulate the system in the energy-dynamic-simulation software, Trnsys. Thanks to the simulations performed, the solar heat production and the influence of the solar field on existing network temperatures and energy-plant production are evaluated during the whole year. After an optimization phase, the best solution is presented to the utility, which calculates the economic feasibility of the investment according to its own specific parameters.

In this analysis, five case studies have been analyzed: four regarding solar integration in existing networks and one of a new network fed by solar heat. Technical details of cases A and D are presented in Dénarié et al. (2015); Table 1 describes the four existing networks that have been investigated for solar integration.

4 The Case Studies of Existing District Heating Networks

4.1 Centralized Solar Thermal Field

The networks involved are experiencing a quite common situation for Italian networks because they are suffering the crisis of traditional CHP systems. Because of the situation previously described, the utilities look for an alternative heat source that enables increasing the share of renewables in the networks and for a cheaper alternative to gas boilers. Considering the requests, the previously mentioned incentives scheme and the availability (of all the utilities involved in centralized solar thermal integration) of a unused area of 2,500 m^2 around the generation plant, the solar integration proposed consists of a ground-mounted solar field of 1,000 m^2 integrated in the return line.

4.1.1 Case Study a—Solar Thermal + Natural Gas

The first case study concerns a medium network in the north of Italy that exemplifies a typical Italian DH network, which delivers 45 GWh/year and which recovers heat from a third party, gas, combined-cycle plant.

The solar plant is directly connected to the return line, using the network as storage (see Fig. 2).

4.1.2 Case Study B—Solar Thermal + Waste-to-Energy

The second case study deals with a utility of medium dimension similar to the previous one, which delivers 49 GWh/year, but with a different generation system: a waste–to-energy (WTE) plant. The utility is looking for a new heat source for potential future extensions (Fig. 3).

The WTE plant, however, changes the framework completely: Since the WTE plant has priority in feeding the electric grid, the plant operates during the whole year, also in summer. Cogenerated heat is usually in competition with a solar source, because increasing the return temperature reduces the efficiency of CHP. In this case, the integration is designed to reduce the amount of steam bled from the turbine, without affecting the heat recovery from condensation and the cooling process. The solar integration helps the electrical efficiency of the WTE plant with a double benefit: thanks to the incentive provided to electricity through the green certificates mechanism, thus reducing the pay-back time of the solar plant.

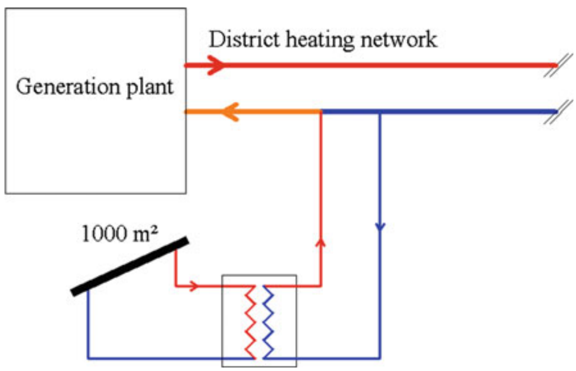

Fig. 2 Integration of the solar field in the network of case study A

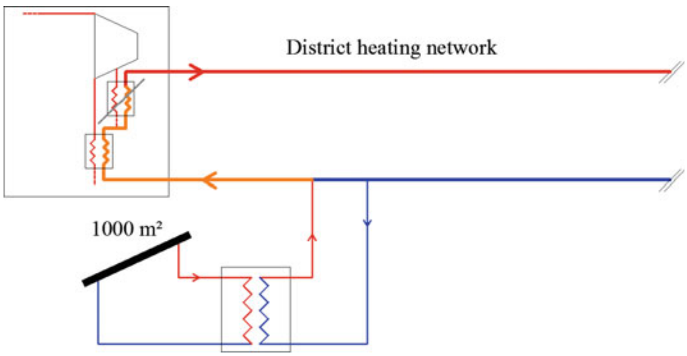

Fig. 3 Integration of the solar field into the network of case study B

4.1.3 Case Study C—Solar Thermal + Natural Gas Cogeneration + Biomass-Cogeneration Heat Recovery

The third case study analyzed has another different background in which the solar thermal source is foreseen among various different production technologies. It represents an interesting case of diversification of heat sources and the flexibility of the generation system, and it shows district heating is a crucial system for the energy transition, able to collect various and different kinds of heat that would otherwise be wasted (Frederiksen and Werner 2013). The DH system consists of a small network with extension planning fed by a natural-gas CHP and heat recovery from a third-party-biomass CHP plant on the return line. In addition to that, an absorption chiller feeds a small cooling network that needs 400 MWh of cooling energy cold per year. The solar field is foreseen again on the return line but feeding the supply line of the DH network, and placed in an empty nearby area surrounding the central plant location, and subsequent to the heat recovery for the third party biomass CHP plant located along the distribution return line. The generation systems consisting of solar integration is presented in Fig. 4. The solar pump is regulated to guarantee a supply temperature for the network (75–80 °C) in winter and 85° in order to feed the absorption chiller in the summer.

4.2 *Distributed Solar Thermal*

In the last analyzed case, the idea is to make peripheral users completely independent from the network during summer thanks to small fields of distributed collectors on building roofs: maintaining the temperature at a nominal level in distant peripheral branches, indeed, leads to high distribution losses, especially in summer when demand is lower (only for domestic hot water). In such conditions, distributed solar thermal installations are analyzed in order to evaluate the feasibility of this summer "disconnection" for some branches of the network, in order to

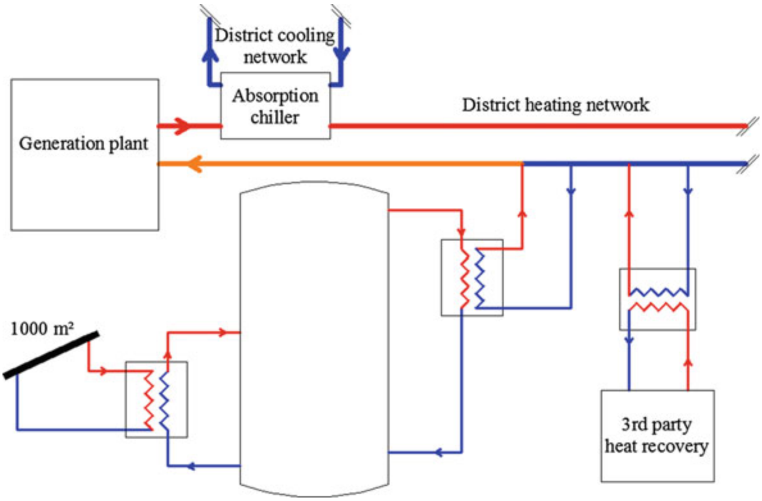

Fig. 4 Integration of the solar field in the network of case study C

reduce summer heat losses. It's not a solar integration though, but a case in which solar energy helps reducing DH losses and consequently fossil-fuel consumption. For every branch analyzed, the solar collector surfaces and storage volumes are dimensioned in order to fully cover summer loads, using district heating as a backup integrated in storage tanks (Fig. 5).

Fig. 5 Integration of the solar field in the network of case study D

Table 2 Solar energy performances

Case	Solar field (gross) (m^2)	Solar yearly yield (MWh)	Yearly solar fraction	Solar average efficiency
A	1,000	541	1.2 %	42 %
B	1,000	412	0.83 %	32 %
C	1,000	353	7.3 %	–
D	160 + 140 + 80 + 315	Tot. 180	0.5 % (av. ~50 % for single branches)	33 %

5 Energy Performances

Energy performances of the simulated solar integrations are described in Table 2.

The energy production for all the cases ranges between 300–500 kWh/m^2 per year.

It can be noticed that even with the same collectors' area and in the same climate conditions, the solar energy yield of case B is lower than the case A one because of the higher return temperature of the network and the consequent decrease of the collectors' performances. Looking at the solar fraction (SF) of case C, it is apparent that, considering the same convenience from the economic point of view of a collector surface of 1,000 m^2, the solar contribution here has much more impact because of the reduced network dimension and because of the absorption cooling system that enables better exploitation of solar energy. The "disconnection" of the buildings from the networks, thanks to the solar in case D, enables fossil-fuel savings for the district network: not only the amount for building needs, but also a big share of the network heat losses that these demands cause.

6 Economics of the Case Studies

Concerning the economic assessment of the case studies, the financial sustainability of solar integration in existing DH network (case A, B, C, D) is done by verifying the economic indicators: payback time, internal rate of return, and net present value of the investment (Duffie and Beckman 1992; Kandpal and Garg 2003). In order to reach more realistic results for these indicators, authors have asked utilities to perform the calculation of these indicators in order to be free to use their own internal and confidential parameters: fuel costs, customers' tariffs, and revenues for heat and power sold. Each utility has been given the solar costs:

- Incentive scheme: 55 €/m^2 of collector surface for 5 years, with a limit of 65 % of the investment cost (Conto Termico, Italian D.M. 2012).
- Collectors field: 350 €/m^2 aperture area for ground mounted; 700 €/m^2 aperture area for roof mounted (based on authors' experience and Nocera 2015; Fidanza 2015)

Table 3 Economic indicators of the foreseen solutions

Case	Load (GWh/year)	Solar field (m^2)	Cost of installation (€) (excl. incentive)	Payback time (years)
A	45	1,000	395,000 (solar field + ground)	~20
B	49	1,000	267,000 (solar field + pipes)	<10
C	5.8 heat 0.4 cold	1,000	352,000 (solar field + storage)	~10
D	36	160 + 140 + 80 + 315	536,500 (rooftop solar fields + storages)	>20

- Operation and maintenance costs: precautionary cost hypothesis of 1 % of the initial investment (Battisti 2013).

Considering a life time of 20 years, utilities involved the cases have calculated the previously mentioned indicators: payback time, internal rate of return, and net present value.

The results are summarized in Table 3.

Looking at the energy results and at the economic indicators for the centralized solar thermal cases, payback time results are shorter than 20 years, which is the solar collectors' lifetime. All the analyzed networks are fed by cogenerated heat, but because of the electricity market's adverse conditions, in particular in summer, solar heat enables reducing the use of gas boilers that are running instead of CHP, in the periods were the electricity price is too low. Case B has a particularly short payback time because, as mentioned before, the solar integration enables reducing the amount of steam bled from the turbine, with a double benefit thanks to the incentive provided to electricity through the green-certificates mechanism.

As can also be noticed, the need to buy the ground for the first case makes the investment much less interesting even if the payback time is shorter than the lifetime of the plant. On the other hand, looking at case study C, it is shown that the payback time decreases with the increase of the solar fraction: the utility has to face a higher investment cost, but the investment is much more interesting in terms of lifelong savings.

A negative consideration, looking at the energy results and at the economic indicators, is that the distributed solar fields' solution analyzed for case study D is not feasible in this particular case. Relatively high investment costs for small rooftop plants, and the fact that a certain heat price reduction for the customers must be applied as a reward for using building roofs, make the investment unprofitable, despite relatively high heat-loss savings along the analyzed peripheral branches.

7 New DH Network with ST

The last case study is about a feasibility case study of a new subnetwork. The heating company already operates an existing network, and it will serve a future neighborhood currently in a design stage in a city of the Lombardy region. The new area will be characterized by the presence of buildings with various intended uses: residential, offices, commerce, schools, etc. It is expected that the district will be at the forefront in terms of expectations for energy sustainability and energy performance for buildings, and consistent with the classes A (<29 kWh/m^{2}year) and B (<58 kWh/m^{2}year) (DR Lombardia n. 5796/2003).

With this background, solar heating can definitely be taken into account as a possible source of heat, being a technology that perfectly matches low-energy demand buildings with low-temperature heating systems and considering the surrounding, sloped, empty area of 20,000 m^2 that can be considered available for solar collectors. A second important reason for this choice is also in the outlook for networks in the future: the urban utility, like many other district heating utilities, looks to the future in order to fulfill the new directive requirement for efficient DH that affects the share of thermal renewables in district heating (2012/27/EU) (D. lgs. 102/2014).

7.1 Energy Load Estimation

In order to size the solar field and to simulate properly the hourly contribution of solar energy to cover new buildings' needs, the first step is the analysis of buildings' energy needs. An hourly energy-load profile is necessary: in order to obtain it, some simulations of "typical" buildings have been performed in Trnsys, and the energy results have been used to estimate the entire district-energy needs. The masterplan has provided preliminary information on buildings geometries and use zoning; some hypothesis on materials, properties, and internal occupations have been made in order to simulate energy performances in line with the labelling requirements (A and B), as it can be seen from Table 4.

Buildings simulations results follow:

- Heating needs: 7,000 MWh_{th}/year
- Cooling needs: 6,800 MWh_{cool}/year
- Domestic hot water needs: 7,000 MWh_{th}/year

Considering the needs and ground availability for solar collectors, the proposed solution is simulated with low temperature DH with 4,500 m^2 solar plant for heating purposes, space heating, and domestic hot water. The cooling loads are covered by individual chillers and consequently lie outside this work.

7.2 Case E—Solar DH—Central Plant 4,500 m^2

As mentioned in the previous paragraph, the solution proposed is to cover the heating needs of new buildings with a lower-temperature district-heating

Table 4 Hypothesis on buildings

Use	Gross floor area (m^2)	Average net height (m)	U_{opaque} (W/m^2K)	$A_{window}/A_{lat. env}$	U_{window} (W/m^2K)	Occupancy ($n°/m^2$)	Air change (m^3/h pers)	Internal gains (W/m^2)
Residential	185,626	20	0.22	35 %	1.40	0.04	40	10
Tertiary	62,132	25	0.28	45 %	1.40	0.07	40	15
Hotel	20,506	25	0.22	45 %	1.40	0.05	40	15
Commerce	105,500	10	0.32	20 %	2.00	0.13	25	30
Events	36,741	10	0.32	10 %	2.00	0.13	25	30

subnetwork (Olsen et al. 2014). After some preliminary analysis, the idea of using the "solar network" also for cooling purposes with reversible heat pumps was abandoned because of heat rejection predominantly in summer. A new DH subnetwork with a supply temperature of 70 °C, lower than the existing one, delivers heat for domestic hot-water production (produced at 60 °C to avoid Legionella risk in centralized storages) and low-temperature heating (radiant floor at 35 °C, fan coils at 50 °C, and AHU batteries at 50 °C). The subnetwork supply temperature is chosen in order to satisfy space heating and domestic hot-water production, being the last one the main design constraints. Lower temperature could have been considered in case of direct production of DHW without storage (Dalla Rosa 2012), different configuration than the one here analyzed. For cooling needs, each building is equipped with an air-cooled chiller.

A large solar-thermal plant is foreseen to maintain the subnetwork at 70 °C all year long. The existing DH network is used as a backup and is connected to the subnetwork through a heat exchanger in order to make the two networks independent of the hydraulic point of view. See Fig. 6.

The energy-performance results of the yearly simulation of the solar integration in Trnsys are:

- Solar energy yield: 2,100 MWh/year
- Solar average efficiency: 30 %

Considering the solar-energy production in the subnetwork and the share of renewable energy in the existing main district-heating network used as a backup and provided by waste and a heat pump, the total share of renewables in the subnetwork is 50 %.

The estimated cost of the solar integration is approximately €1.5 million.

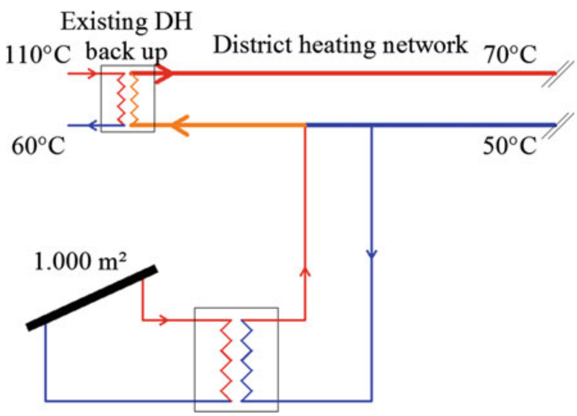

Fig. 6 Configuration for case E

8 The Urban Aspects of the Case Studies

As mentioned before, the main urban issues of a SDH plant is space availability and its characteristics: in the case of ground installations, the necessary area should be at list 2.5 times the collectors' area (Nielsen 2012) in order to enable proper distances and avoid shadow effects.

For all the cases analyzed which forecast centralized plants, some available space can always be found around the generation plant because of appurtenant tolerance of surrounding lands, enough to foresee the maximum incentivized surface of 1,000 m^2, but not enough to design a much bigger plant. In order to design a solar field with "Danish size" of several thousands of square meters, the utilities are often in the need of buying or renting surrounding land, often property of the local authority.

As for cases A and E: in both cases, a large free-ground surface surrounding the area concerned is available but owned by the local administration, so the estimated renting or buying investment can definitely have a negative impact on the payback time of the whole project. In both cases, from an urban legislative point of view, the surfaces are defined as non-constructible where only superficial excavation is possible because of the previously buried landfill. This makes them suitable places for a ground-mounted solar-thermal field, depending on how the local administration considers the construction of the solar plant. This is quite a common situation in Italian peripheral urban areas, often characterized by the presence of ex-industrial or ex-landfill land which are actually unused grass fields where no construction and no public green use is possible because of the pollution of the ground. Case B is interesting because it represents a common situation of the bad reputation of WTE and DH plants in the citizens' community. Thanks to the information collected in SDHplus through surveys circulated by Italian utilities, it is clearly evident that many utilities suffer from a bad reputation. The main causes are the generation systems, in particular, WTE incinerating plant or biomass burners, from antiquated technologies even if their systems have undergone big renovation and are currently in the best available technological configuration regarding gas emissions. The integration of "clean", zero emission systems as solar thermal is also considered by these utilities as a strategic integration to show their effort towards an environmental development that improves the reputation of their DH systems thanks to the green image of renewables.

Case D raises a complete different set of urban issues dealing with distributed solar integration.

In this case, roof mounting has been foreseen which implies private customer's relations more than urban issues, but nevertheless the possibility of installing solar systems on roofs is often subject to urban regulations on buildings.

Finally, case C is an interesting case of third-party heat recovery on the local territory. The utility recovers heat from a biomass CHP owned by a different actor. The same business model could be applied to solar thermal (Dénarié 2015) with a solar ESCO model.

Third-party heat recovery represents a great potential source of waste and renewable heat. In this process, heat planning and heat mapping could be useful tools to interject this kind of opportunity at the local level, identifying the territory of overlapping of heat demand and waste-heat recovery offer. An opportunity for local administrations to adopt this tool can be identified in 2012/27/EC and D. lgs. 28/2011 that ask the local community to perform heat planning and cost/benefit analysis of DH. In particular, georeferenced energy mapping is an important tool to identify energy synergy between generation and demand (Persson et al. 2014; Sansoni and Gussoni 2015).

9 Conclusions

The energetic and economic conditions of actual Italian district-heating systems, and the renewable-energy requirements and incentive schemes actually present, create a particular framework in which solar- thermal energy can see potential growth.

From the analyzed cases of integration of solar in existing networks, the incentivized maximum-solar surface of 1,000 m^2 has been considered for economic sustainability. Considering the high temperatures of the Italian DH networks, energy performances of simulated solar fields are in the range of 300–500 kWh/m^2 per year with collector's efficiency around 30–40 %. Payback-time values show that even when not so short, around 10 years on the average, they are positive and they decrease with the increase of the solar fraction. The case study on distributed-rooftop-solar plants turns out to be not economically interesting because of relatively high investment costs despite very interesting energy savings. In the case of new networks in newly constructed building areas, this is definitely an opportunity to find, starting from the master plan design phase, the proper location and space for solar thermal so that the DH network can be sized with lower temperatures.

The main urban issue of SDH plant is space availability. For all the cases analyzed that forecast centralized plants, some available space can always be found around the generation plant because of appurtenant tolerance of surrounding lands, enough to foresee the maximum incentivized surface of 1,000 m^2, but not enough to design a much bigger plant. In order to design bigger solar field and to have higher solar fractions, the utilities are often in need of buying or renting surrounding land, often property of the local authority.

What emerges after analyzing the urban legislative framework is that some urban tools from renewable-energy promotion are available in Italy, but they seem to lack consequent action measures, and they don't reflect concretely indications or requirements on how to reach these objectives.

Deeper heat planning and heat mapping is essential in urban design in order to promote and simplify the spread of large-scale renewable-energy plants.

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Building-Stock Analysis for the Definition of an Energy Renovation Scenario on the Urban Scale

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Abstract This paper describes the enhanced typology approach we developed as an operative tool for building-stock analysis and its implementation in two case studies. It is based on the outcomes of the IEE Project Tabula, which introduced the classification of residential constructions in reference typologies according to the architectural features and the construction period. These typologies compose the matrix, representing the whole building stock of a territory. The enhanced approach described in this paper is focused on analysis on the urban and inter-municipal levels, and enables estimations of the overall energy demand of the constructions, while associating with each real building the energy performance as calculated for the relative reference typology. Starting from the analysis of building stock, we developed renovation strategies with different levels of interventions (i.e., base, standard, and advanced) for the representative building typologies. Accordingly, we foresaw several energy-saving scenarios considering different renovation rates and levels of intervention for the building typologies, and we identified the most cost-effective renovation strategy on the whole building-stock level. The implementation of the approach on the urban level provides a general overview of the main energy-consuming typologies, identifying the buildings' needs for renovation and the potential savings. In this regard, the results could constitute effective support for defining tailored policies. We applied the approach within two preparatory studies to develop an integrated energy strategy on the inter-municipal

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level: the Rotaliana-Königsberg Valley Community and the Passiria Valley. The paper presents the main results of these applications, highlighting the different strategies for the data collection and approaches for the definition of the typologies according to the available sources of information and the main features of the building stock.

Keywords Building stock analysis · Renovation scenarios at large scale level · Energy strategies · Geographical information systems · Energy-efficient retrofitting

1 Introduction

In recent years, in order to reach the EU-target of reducing the GHG emissions to 20 % before 2020, several actions have been started on different scales (Atanasiu et al. 2013; I. E. Agency 2008). In particular, on the urban and regional levels, the Covenant of Majors proposed in 2010 the Sustainable Energy Action Plan (SEAP) (European Commission 2010), as a tool to promote energy-saving policies and measures to reduced GHG emissions by end users. Given that buildings account for 40 % of EU-energy consumption, they represent a strategic sector to be addressed in a SEAP, which can also promote specific measures to foster the building renovation process on urban level, both for public and private buildings. Nevertheless, in order to estimate reliably energy consumption of the building stock, to define energy saving potential and performance targets, and to determine robust technology renovation actions, detailed data as well as consistent and replicable methodological approach are needed.

In this regards, EURAC has started an internal research line intended to define renovation scenarios at building-stock level to develop strategies for both private and public single-owners and multiple owners. In particular, this paper is focused on the approach developed for the definition of scenarios for multiple-owners of building stock, represented by residential buildings.

There are several methods to evaluate the performance of a large number of buildings in order to define robust energy-conservation measures, and they can be classified into two main categories: on the one hand, the top-down approaches that enable determination of the energy performance of each building, starting from aggregated data and finding a relationship between statistical information on the features of the construction and the related consumption (Bentzen and Engsted 2001; Mastrucci et al. 2014). On the other hand, bottom-up approaches define the overall performance of stock starting from the evaluation on the single-building level. The information can be deduced through official statistics on actual consumption or by using energy performance certificates (Mangold et al. 2015) or through an engineering-based approach, defining the numerical model of a set of reference buildings representative of a whole building stock (Filogamo et al. 2014).

The approach adopting reference buildings to both scenarios on the national (Sartori et al., Dascalaki et al.) and urban scale (Caputo et al. 2013; Galante and Torri 2012) is the one most often applied. The method developed by EURAC is based on the typology approach defined within the IEE Project TABULA (Ballarini et al. 2011), which introduced the criteria for the definition of a set of reference buildings representative of building stocks on the national level.

Starting from those achievements, we developed a practical method, focused on the urban scale, to provide an operative tool for the definition of effective renovation strategies on the urban level. Therefore, the level of detail for the definition of the reference buildings is increased, and we introduced a structured and manageable approach for the data collection exploiting the information from different sources available for the territory (GIS maps, local statistics, on-site survey, and questionnaires). The data collection is preparatory for defining the baseline of energy consumption and the possible renovation scenarios, tailored on the specific needs of the local building stock, with an estimation of the potential saving on the urban level supported with the use of a GIS software.

The following sections present a detailed overview of the activities and assumptions for each phase of the typology approach considering the particular issues of the residential building stock. Moreover, the paper presents and discusses the main results of the building stock analysis approach to two case studies: the Rotaliana-Königsberg Valley Community and the Passiria Valley.

2 The Typology Approach

The building-stock analysis enables us to identify the most energy-consuming typologies and to define effective renovation strategies, so it represents a strategic support for a public authority to define policies and incentives for building renovation. In fact, starting from the definition of the baseline scenario for the energy consumption at large scale, we propose different tailored renovation packages for the identified target buildings and to evaluate the energy saving potential on the urban, regional or territorial level.

The typology approach encompasses four principal steps:

- definition of reference buildings;
- energy-demand modelling and baseline scenario;
- renovation packages: elaboration of strategies to renovate the identified reference buildings;
- renovation scenarios: definition of the targets after the implementation of the renovation packages and elaboration of different scenarios to assess the energy saving potential.

2.1 Definition of Reference Buildings

Following the approach developed within the IEE project TABULA (Tabula project team 2012), the aim of the first phase is to define the typology matrix that includes the set of reference buildings for the analyzed building stock. The choice of the base parameters for the definition of the matrix might vary with the scope of the evaluation and on the kind of buildings the analysis focuses on. For the residential constructions, which present homogeneous features in terms of thermal zone, indoor temperatures, internal loads and occupancy time, the two variables adopted (Ballarini et al. 2011; Filogamo et al. 2014) that also represent the axes of the matrix are:

- the *building-age class*, which affects the construction features (envelope and HVAC system); and
- the *building category*, which determines the geometry of the buildings.

In particular, the definition of the age classes should reflect the changes of construction methods over the last decades in the territory: the introduction of new building materials and techniques (e.g. reinforced concrete, prefabrication), the availability and costs of energy resources, as well as the definition of specific policies on energy savings that affect the architecture of buildings and the thermal features of the envelope. Therefore, the definition of the age classes is the key issue for an accurate determination of the baseline scenario, as well as to propose appropriate renovation strategies. For example, after World War II, buildings in Central Europe have been constructed mainly cost-effectively and quickly with the available material on-site. For that reason, buildings of this construction period usually do not meet the present requirements of thermal and acoustic insulation (Amtmann and Altmann-Mavaddat 2014). Another important milestone for the energy policies is the oil crises of the seventies, when energy conservation was becoming an important issue. Gradually reducing the maximum permitted limits for the heat loss, through legislation, influences the energy efficiency of the building envelope and thus the design and materials used. Therefore, the defined age classes should reflect mainly: evolution of policies, construction material and techniques innovation and historic events which effects on energy issues.

The second main variable, the building category, enables us to define the geometry of the constructions in order to determine heat losses through the thermal envelope (i.e. roof/top floor, external walls, windows, baseplate/basement ceiling) as well as the relation between surface of the thermal envelope and heated volume (surface-to-volume ratio), which is strongly connected to the specific-energy demand.

According to these two variables, the entire building stock is divided into different building categories which have similar characteristics in term of architectonical features such as size, shape, dimensions, surface-to-volume ratio and other energy relevant properties like the number of floors of housing units, presence of balconies, external or internal staircase, etc. Each reference building is described by a data set, containing all energy relevant information: geometry, thermal characteristics and building services.

The data collection phase is crucial for the determination of the building categories; in this regards, we decided to adopt firstly an on-site survey in the relevant area, in order to identify the main building features and typical construction methods. During the survey, a vast majority of buildings is photographed and, by means of a GPS, the images are georeferenced and integrated into the GIS map. In this way, it is possible to locate the images, to identify the documented buildings and to start the process of cataloguing and analyzing buildings according to their dimensional characteristics and architectural features. The photographic campaign enables on the one hand, to have a general overview of the building stock, and on the other hand, to collect and store specific information on the construction features (e.g. material used, amount of overhang, balconies, roof type, etc.) and the state of conservation.

According to the information gained during this process, it is possible to establish preliminary rough dimensional thresholds that determine the main building categories typical for the area of investigation (e.g. single-family house, semi-detached house, multifamily house, terraced house, block etc.). Table 1 reports the preliminary dimensional ranges adopted for Case Study 1 (described in more detail in Sect. 2.1).

Besides the on-site investigation, it is crucial to collect all useful energy relevant data about the buildings from statistical databases (such as national or regional institutes for statistics, historical maps, and development plans of municipalities), questionnaires for the users and, above all, to extract information from maps provided by GIS data sources/geoportals. In particular, in order to properly describe a building stock, five key parameters for each building are needed from the GIS database:

- the covered or built-up area
- the average building height (ideally including both the eaves and ridge height)
- the perimeter
- the building age
- the heritage-related legislation

Table 1 Building category and preliminary dimensional thresholds

Building category	Dimensional range
One/two-family house	Buildings with 1–2 floors (+0.5 for attic floor), with 1–2 housing units, mainly with saddle roof
Agglomerates/terraced house	<3 floors, apartments adjacent to others housing units, agglomerates/accumulation in historic centers, terraced houses
Small multi-family house	Building with 2–4 floors, <10 housing units
Large multi-family house	Building with 2–4 floors, >10 housing units
Block	>4 floors, high number of housing units and compact design (low shape ratio)

Starting from these base parameters, a series of other relevant data can be ideally recognized from the map, such as adiabatic-not-adiabatic walls, roof shape and orientation (for the integration of solar energy) or data that can be deduced, such as: net base area, net-floor area, net heated-floor area, gross-floor area, number of inhabitants and housing units, gross volume, heated volume, number of floors, surfaces of the thermal envelope (vertical: exterior walls; horizontal: baseplate/basement ceiling or roof/top floor ceiling), window surfaces, and shape ratio.

After the creation of a thematic map, integrating all relevant data from different sources into one GIS map, for each examined building we obtain a polygon feature linked to a series of data. From the data of the geographical map, a table is generated (1 building/1 row) and is subjected to a process of statistical analysis. The building stock can be divided into the identified age classes and, for each of them, a series of definitive thresholds for geometric characteristics are defined to fix the building categories.

The result is the division of the building stock into different typologies according to the two main variables: age class and building category. This information can be reimported into the GIS software and can be illustrated on the thematic map as shown in Fig. 1.

The key step of this first phase is the definition of the reference buildings that will be assumed as representative of each typology in terms of building features and thermal properties. According to the availability of data, it is possible to adopt three kind of references, with different levels of detail:

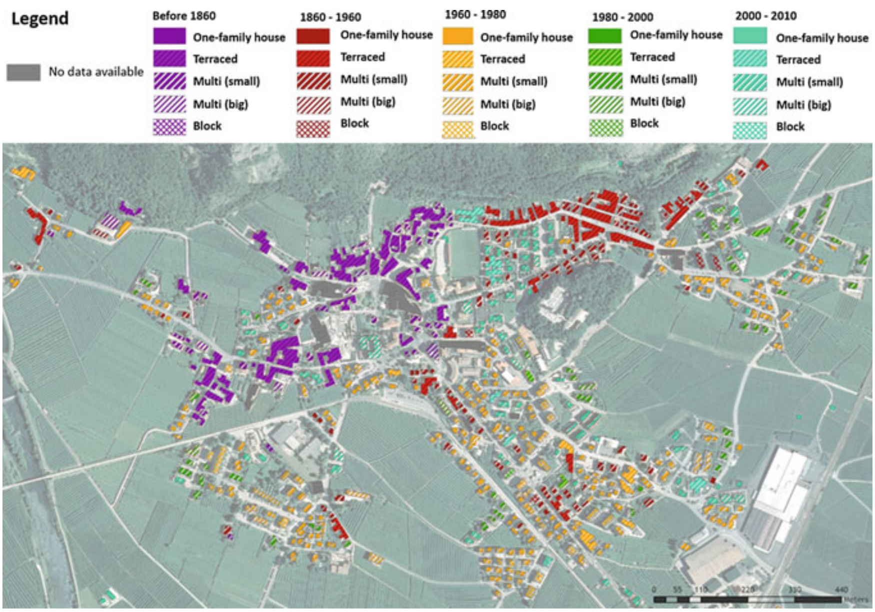


Fig. 1 Illustration of building typologies in the geographical map

- a real exemplary building defined according to on-site survey (*qualitative approach*)
- a real exemplary building that is close to the median geometrical features of each typology (*quantitative approach*)
- a model building that represents the median values of all the geometrical features (*detailed approach*)

Coupled to the geometrical features, for each reference building the thermal properties and the features of the HVAC system have to be determined. In particular, the properties of the envelope are deduced from catalogues of typical national or regional construction materials and methods (i.e. TABULA or AlpHouse project, UNI 11300, technical guidelines of regional energy certification etc.). In order to increase the reliability of the analysis, the results from literature research should be compared with former architects' drawings and on-site spot investigations of the reference buildings.

The data on the technical building systems for heat production, distribution and radiation are deduced as well from databases for existing heating plants. The assigned values, e.g. boiler efficiency, are dependent on the year of construction of the building and the building typology (UNI TS 11300-2 2014). For heat generation we usually choose the technology and energy source with the highest use, according to the respective building age and category in the area.

2.2 Baseline Simulation

The aim of the reference building definition is to determine a so-called "baseline" scenario that offers a picture of the current energy consumptions of the building stock. In this regard, it is possible to collect the actual energy consumption of the buildings or/and to evaluate the energy performance through energy simulations. The level of detail of the simulation determines the reliability of the analysis, nevertheless, the more detailed the simulations, the more time-consuming is the analysis. As an effective compromise, in order to evaluate the energy demand for heating, domestic hot water (DHW) and cooling, we adopted a steady-state energy balance according to the norm EN 832 which is based on a monthly method.

In order to determine the total energy consumption of the buildings in the investigated area, the calculated specific energy demand of the single building typologies (in kWh/(m^2a)) is projected to all the existing buildings (based on the calculated heated net surface), according to the age class and to the category of each building. The result is the illustration of the actual energy consumptions of the whole building stock according to all building categories in the different age classes. The knowledge of the trend and distribution of energy consumptions over the building stock is an essential basis and starting point to define effective energy-saving strategies, to identify most energy-consuming typologies and to develop tailored renovation measures.

The final step is the validation of the baseline scenario according to either actual consumption collected on building-stock level or specific consumption for the reference buildings (if real buildings are assumed as reference buildings, the validation for the performances of the specific building typology can be carried out applying the M&V Protocol or the IPMVP Protocol).

Although the validation represents an important step for the reliability of the baseline scenario and is crucial for an effective definition of the energy conservation measures and the potential energy savings, the lack of detailed and structured information usually does not allow proper completion of this phase.

2.3 Renovation Measures

The renovation packages include both improvements of the thermal envelope (insulation of facades, roof and baseplate, replacement of windows, improvement of air infiltration rate, etc.) and of the building services (replacement of boiler and increased efficiency of the plants). The aim is to reduce energy consumption and costs as well as CO_2 emissions, while improving the quality of comfort at least to comply with the legal minimum standard.

In particular, a set of different renovation packages tailored to the specific needs of the building typologies and to the current local standards are elaborated aiming to improve the thermal envelope and the building services.

As a general approach, we distinguish between interventions tailored to the requirements of historic buildings and renovation measures for non-historic buildings. Therefore, the proposed renovation packages vary according to the preservation requirements (listed buildings and protection of historic ensembles) present in the territory that have an impact on energy efficiency measures. These are the three different renovation sets that have been developed:

"**Conservative renovation**": minimal invasive renovation for listed historic ensembles under preservation order.

"**Standard**": renovation of the building elements to meet the minimum values required by law for the related climate zone.

"**Advanced**": renovation towards the nZEB target.

The information on the land-use plan of the municipalities and communities enables us to identify how many buildings are subjected to what kind of preservation constraints. Consequently, it is possible to attribute the different renovation packages and to perform the calculation of the potential energy savings for the building stock in the whole area.

The calculation of energy consumption "after-renovation" is performed for each reference building. To assess the impact of the renovation measures, the primary energy demand of the existing building is compared to the results of the renovation variants. Starting from the possible energy savings that can be obtained, the pay-back period for the renovation packages is evaluated in relation to each building typology.

2.4 Energy Saving Potential and Target Setting

Starting from the specific energy saving associated with each renovation package for the building typologies, the evaluation of the saving potential on the building-stock level requires assumption of a reliable annual renovation rate in a certain time frame (e.g. 20 years), in order to establish which is the surface which undergoes renovation each year. This value represents a strategic parameter that is affected by the renovation policies on national and local levels, thus usually a series of energy saving scenarios adopting different renovation rates on the building-stock level have to be performed to provide a comprehensive evaluation.

In particular, one of the scenario aims to evaluate the total percentage of energy savings achievable with the current average renovation rate of the last 20 years in the territory. A second scenario considers an increased and desirable rate of 3 %, which would correspond to the minimum value recommended by the campaign "Renovate Europe" at European level, to attain by 2030 the energy savings specified in the EU directive 2012/27/EU. When performing the scenarios, as described above, we assigned to the listed buildings the respective adequate renovation packages depending on the preservation regulations, while to the non-historical building we applied either the "Standard" or the "Advanced" package. Results show different percentages of energy-saving potential according to different renovation rates within a predetermined time frame. The elaboration represents the basis to formulate energy-saving targets in order to estimate reliably and adequately the renovation rates and to orient the energy-saving policies on the local level.

3 Results of the Building-Stock Energy Analysis

The enhanced typology approach was implemented in two areas in northern Italy: the Valley Community Rotaliana-Königsberg and the Passiria Valley.

3.1 Case Study 1: Rotaliana-Königsberg

Rotaliana-Königsberg is an Alpine valley located in northern Italy. The Community includes eight municipalities (Faedo, Lavis, Mezzocorona, Mezzolombardo, Nave San Rocco, Roverè della Luna, San Michele and Zambana) and forms a geographical unit oriented north-south along the bottom of the Adige valley. Data sources for the energy analysis of residential buildings and the consequent estimation of the potential energy savings were: municipality, community, Province of Trento and Department of Civil Environmental and Mechanical Engineering of the University of Trento.

3.1.1 Data Collection

Two different shapefiles were available for the investigated area: one from the geoportal of the province, with information on the building size, in terms of covered area, building height and perimeter; and another one elaborated by the University of Trento with information on the construction period. In addition, an on-site visit was conducted intended to capture typical building dimensions, particular architectonic features and building methods and to determine the prevailing building categories in the district. At the same time, a vast majority of building was photographically documented from the outside. Information about the preservation regulations have been collected manually from the land-use plan of the municipalities (% of listed building and ensembles under protection). The physical parameters or, respectively, the typical component assembly were taken from catalogues of national and regional building methods, as well as in part from the typology brochure of Italy from the TABULA project (Corrado et al. 2014), and not verified on-site. The information from the two shapefiles on building geometry and building age, as well as the images (by means of GPS), were integrated into one thematic map, which contained a relatively high level of information on every building and represented therefore a good starting point for the categorization of buildings and baseline calculation. In this case, the data on the actual energy consumption of the building stock are not available, and so it was not possible to validate the analysis.

3.1.2 Building-Stock Analysis/Typology Matrix

The building stock of the Rotaliana-Königsberg territory totals about 3,830 residential buildings and the analytical work considered 3,690 constructions, or about 96.5 % of the total stock. The analysis shows that almost 40 % of the analyzed residential buildings were built between 1960 and 1980, during the so-called Italian "construction boom".

Due to the results of the on-site inspection and the subsequent analysis of the catalogued photos, five building categories have been roughly determined; the prevailing building types in the area are: one/two-family dwellings, small and large multifamily houses, terraced houses/agglomerates and housing blocks. The building classes were then extracted from the whole building stock, by splitting up the statistical building data into a series of specific thresholds describing the characteristic dimensions and proportions.

For the definition of the reference buildings, we calculated a fictitious median building from the geometric data of every building category. The available data on construction periods enabled us to define five building age classes taking into account: two periods before and after the use of reinforced concrete (respectively <1860 and 1860–1960); and three periods, from 1960 and later, that reflect the introduction of the national legislations for energy efficiency in buildings (1960–1980, 1980–2000, >2000). Figure 2 shows the resulting typology matrix with the 25 reference buildings defined for the district.

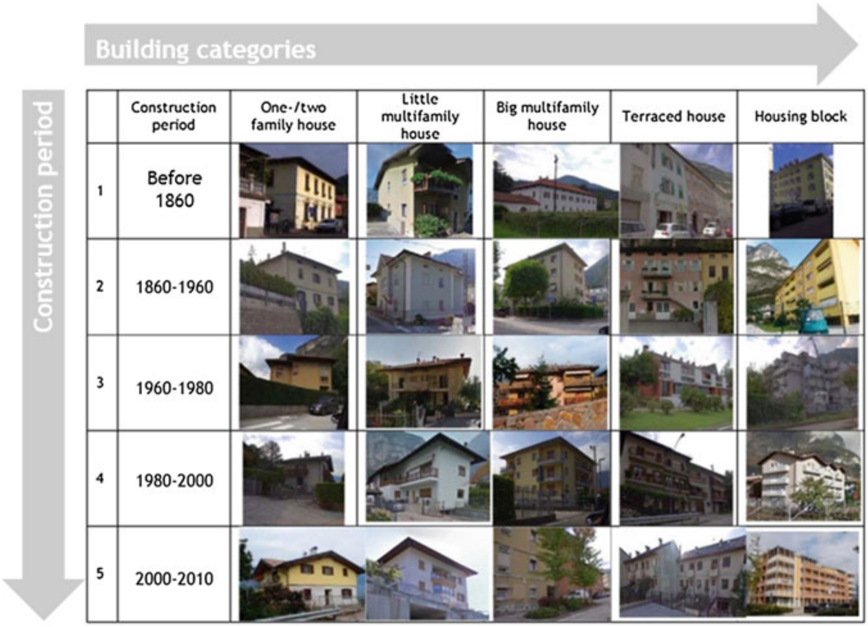


Fig. 2 Exemplary building typology matrix, indicating the two base parameters

The quantitative analysis show that most buildings of all typologies were built between 1960 and 1980. At around 1,100, the number of small multi-family houses stands out compared to the other typologies in all the age classes, but especially between 1960 and 1980, followed by the one/two-family houses of the same age class with approximately 220. The typology with the lowest number of buildings over all construction periods is the apartment block. The number of agglomerates/detached houses was constantly decreasing over the years. The total heated surface confirms the main trend: over all periods, the small multi-family house represents the largest fraction of the whole surface, here followed in the first age class (before 1860) by the agglomerates of the historic city centers. The largest part (around 700,000 m^2) of the heated surface was built from 1960 until 1980, but also the historic building surface totals around 510,000 m^2, while the remaining three age classes total around 300,000 m^2 each.

3.1.3 Renovation Measures

Due to the large portion of historic buildings, it was necessary to develop a tailored renovation package that addresses the special requirements of listed buildings and historic ensembles under preservation order. Following the renovation criteria of the Province of Trento that distinguishes between "Restoration" and "Conservative renovation", we developed solutions that have no impact on the aesthetic of the buildings (especially from outside). For listed buildings, we propose a minimum insulation of the roof and the installation of a new boiler, while, for less protected ensembles, we propose the insulation of roof/top floor ceiling and baseplate/basement ceiling, interior insulation of outer walls, enhancement of existing windows by implementing double glazing and improving their airtightness, and a new heating boiler.

For the large remaining part of multifamily houses from the 1960 until 2000, besides the standard solution, we proposed an advanced renovation package, which foresees approaching the target nZEB. In particular, special focus is devoted to large-dimension residential buildings like the multifamily houses and blocks that would have a higher impact on the energy savings at stock level. Furthermore, high energy-efficient solutions for the compact and standardized architecture of those multifamily houses and blocks from the last decades can be more replicable, cost-efficient and easier to apply. In detail we propose as “standard” package: renovation of the building elements to meet the minimum values required by law for the related climate zone by means of adding medium insulation to the whole building envelope, replacement of windows (double glazing), improvement of airtightness and installation of a new heating boiler. As “advanced” package: the same as standard, but increased energy efficiency of the components of the thermal envelope, e.g. triple glazing and the installation of a ventilation system with heat recovery (see Table 2).

Table 2 Detailed parameters of the four renovation packages

Refurbishment measures	Restoration	Conservative Renovation	Standard	Advanced
Thermal envelope	U-values (W/m^2K)	U-values (W/m^2K)	U-values (W/m^2K)	U-values (W/m^2K)
Insulation of exterior walls	–	0.38	0.34	0.16
Insulation of roof/top floor ceiling	0.43	0.22	0.30	0.17
Insulation of baseplate/basement ceiling	–	0.33	0.33	0.22
Replacement of windows	–	Glazing: 1.20 (g-value = 0.60)	Glazing: 1.70 (g-value = 0.7) Frame: 1.60	Glazing: 1.10 (g-value = 0.56) Frame: 1.00
Airtightness	n50 (h^{-1})	n50 (h^{-1})	n50 (h^{-1})	n50 (h^{-1})
Air change rate at press. test	2.0	1.5	1.5	0.6
Building services	Boiler efficiency normal output	Boiler efficiency normal output	Boiler efficiency normal output	Boiler efficiency normal output
Replacement of boiler (higher efficiency)	99 % (condensing boiler)	99 % (condensing boiler)	99 % (condensing boiler)	99 % (condensing boiler)
Installation of a controlled ventilation system with HR	–	Heat recovery efficiency 85 % 0.35 Wh/m^3	–	Heat recovery efficiency 85 % 0.35 Wh/m^3

3.1.4 Main Results: Baseline and Renovation Scenarios

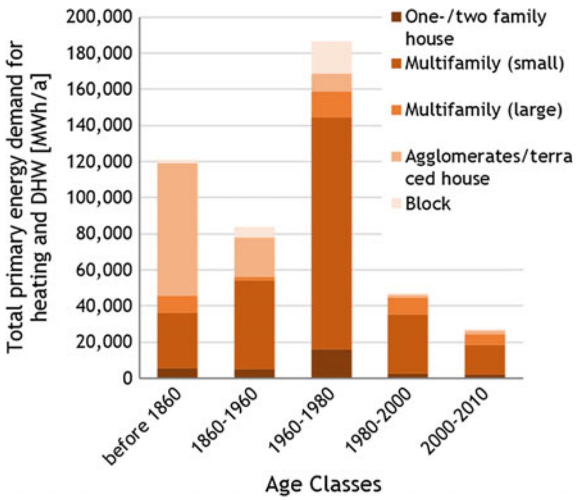
Considering the baseline scenario, the results of the analysis show that the single-detached buildings (one or two-family) present the highest specific primary-energy demand for heating and hot water (EP_{gl}) over all building periods. This is due to the higher surface-to-volume ratio, the relationship between surface of the thermal envelope and the heated building volume, compared to the other building typologies.

The average specific EP_{gl} of the building stock is around 215 kWh/(m^2a); whereas the lowest value is associated with the housing blocks of the recent construction period (2000–2010) accounting for 88 kWh/(m^2a), while the highest EPgl value is calculated for one/two-family houses built from before 1860—with 490 kWh/(m^2a).

Considering the total primary energy demand (MWh/year) for the building stock, the constructions of the age class 1960–1980 have the highest energy needs. Among them, the small multi-family houses are the highest consuming since this is the most frequent typology in the analyzed territory. The total primary energy demand of the whole district is 465,515 MWh/a, where of the small multi-family houses from 1960–1980 contribute for 128,213 MWh/a, which represents the 28 % of the total (Fig. 3).

One result from the energy simulations was that the potential savings of primary energy are greater for buildings built before 1980. In fact, for these buildings, thanks to an advanced refurbishment, the energy need would be reduced to a tenth of the current one. The payback time of refurbishment interventions, which was determined by a simple balance between the investment costs per intervention and the annually saved energy costs (calculated with the actual stable energy unit price), showed that typologies which are more compact (blocks of flats, big multi-family

Fig. 3 Primary energy demand for heating by building typologies and age classes before renovation



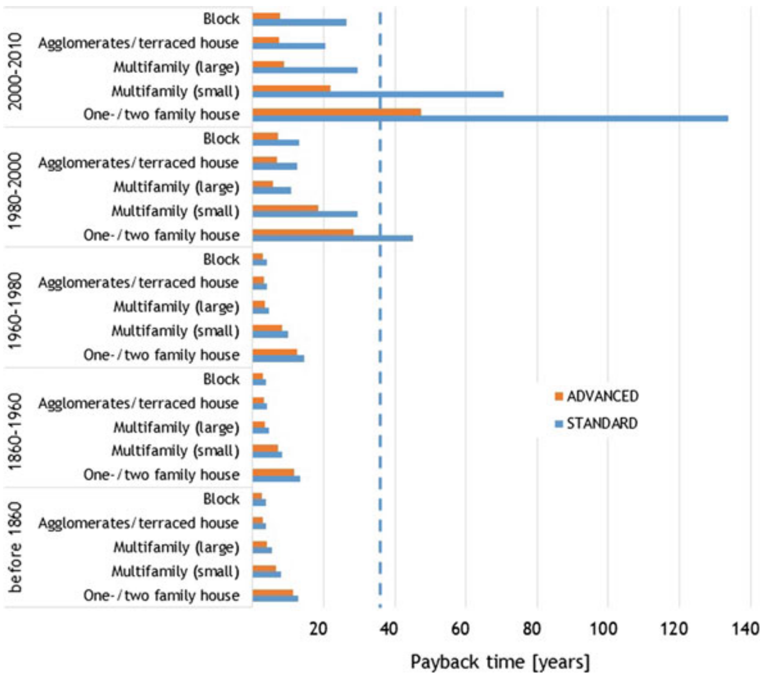


Fig. 4 Payback time by building typologies and age classes

buildings) and generally buildings built before 1980 have a lower payback time and therefore more benefits (Fig. 4). In the scenario with an annual refurbishment of 3 % of the existing residential buildings, by 2025 the total demand of primary energy would be reduced by almost 20 % with standard interventions and by 24 % with advanced refurbishment actions (Fig. 5). Due to their large number and diffusion, the small multi-family buildings would remain the typology with the highest impact on energy savings (Fig. 6).

3.2 Case Study 2: The Passiria Valley

The Passiria valley is a left tributary of the Adige, between the Alps of the Ötztal on west side and the Alps of Sarntal on the east side. For the sustainable-energy action plan (SEAP), in particular, the residential building stock of the municipalities of St. Leonhard, St. Martin and Moos were investigated. Data sources for the energy analysis of residential buildings and the consequent estimation of the potential energy savings were: municipalities, community, the Province of Bolzano, databases of national and regional institute of statistics (ISTAT and ASTAT), and questionnaires to the inhabitants.

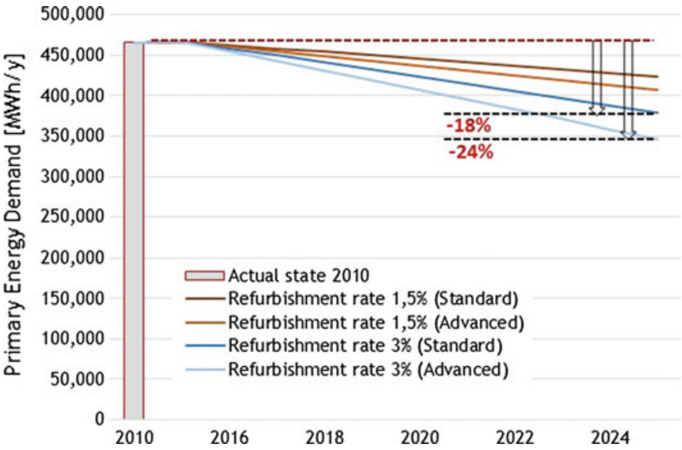


Fig. 5 Trend of primary energy demand for heating and hot-water generation according to different annual renovation rates (1.5 and 3 %) from 2010 until 2025

3.2.1 Data Collection

The two shapefiles, provided by the Consortium of Municipalities in the Province of Bolzano, included on one hand a polygon feature for every residential building and on the other hand shapefiles for all listed buildings. There was no more specific georeferenced data available with regard to additional geometric parameters or especially to the construction age. To complete the geometrical data of building typologies, the covered area and perimeter could be deduced from the shapefile of the GIS map, while the height was calculated from the number of floors (from photos) multiplied by an estimated floor height. It was not possible to gain information on the building periods from historic development plans archived by building authorities. Therefore, in order to obtain more energy relevant information, a detailed on-site inspection accompanied by photographic documentation of 80–90 % of the whole building stock was conducted, besides a survey amongst the inhabitants of residential buildings. The survey was answered by 189 households, which represented 6 % of the total of dwellings in the three municipalities. It showed that almost 70 % of the surveyed households live in brick buildings, 75 % use combined generation (heating and DHW) and that methane, together with biomass, are the most used fuels. Due to the low participation in the survey however and some clear discrepancies with the data from the national institute for statistics, the results of the survey were only used, together with literature, for the description of the reference buildings, but not for the inventory of each building typology and age. On the district level, data from the national institute for statistics

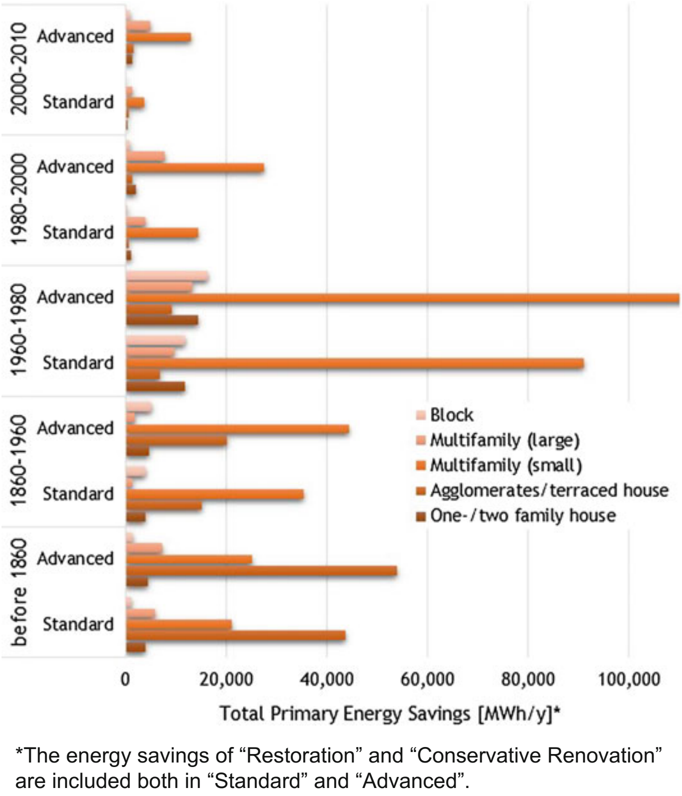


Fig. 6 Possible total primary energy savings after renovation according to building typologies and age classes

(ISTAT) was collected regarding number of dwellings per municipality, useful floor area, number of floors above ground, building material, type of fuel etc., as well as from the provincial statistics institute (ASTAT) concerning total the number of buildings and number of buildings by dwelling types. Besides ISTAT information about building materials and methods, data was taken from regional and national catalogues for typical component assemblies, especially from the project AlpHouse (Benedetti et al. 2013) and, in parts, from the typology brochure of Italy from the TABULA project (Corrado et al. 2014), but not verified on-site. Data on real consumption was provided by the energy suppliers and from a study on biomass use; nevertheless it was not adoptable for the typology approach since it was not structured, e.g. by the municipalities (three in this case).

3.2.2 Building Stock Analysis/Typology Matrix

According to the data of ASTAT, the residential-building stock of the three municipalities included, in the reference year 2010, a total of 1,691 buildings. 55.4 % of the residential buildings were constructed in the period from 1946–1991, which reflects the construction boom in Italy of the 60s–70s. The existing buildings from before World War II made up around 24 %. The percentage of buildings that have been built between 1992 and 2005 is about 17 %, which is comparatively high and approximately proportional to the period after the World War II (1946–1991). The distribution of the buildings in the different age classes is very similar for all municipalities.

According to the available data, only three typical building types were defined after a qualitative analysis of the documented buildings in terms of their dimensions and architectonical features. The investigated area consists of relatively small villages with a majority of small constructions, like one/two-family houses, semi-detached houses and a minority of (small-sized) multi-family houses. From the catalogued buildings for each category, one real building was selected, representative for the entire category in terms of size and proportions. The real building was recognized in the GIS map, and the geometric data was taken from the shapefile. The four building periods divide the building stock into constructions before World War II and after, until the introduction of the national laws beginning in 1991 (Italian Law n. 10/1991) and beginning in 2006 (311/2006) that required the enhanced use of thermal insulation. Table 3 show the resulting typology matrix with the 12 reference buildings defined for the district.

The distribution of the three building categories (one/two-family house, detached and multi-family house) over the four construction phases was determined from the photo documentation of the buildings. The total number of multi-family houses was

Table 3 Building typology matrix of case study 2

	Age class	One/two-family house	Multi-family house	Detached house
1	Before 1945			
2	1946–1991			
3	1992–2005			
4	2006–2010			

taken from ASTAT data (buildings with more than three units). A look at the development of the building stock related to building categories and age classes shows that the building type one/two-family-house of the construction period from 1946–1991 occurs most frequently and clearly stands out from the total number of buildings. According to statistical data, the total heated net area of the building stock is 300,685 m^2: 123,178 m^2 in St. Martin, 107,203 m^2 in St. Leonhard and 70,304 m^2 in Moos.

3.2.3 Renovation Measures

The proposed renovation packages for older one/two-family houses of the district were based on the specific interventions developed especially for historic envelopes typical for the Alpine space within the project Alphouse (Benedetti et al. 2013). To respond to the different requirements of listed and non-listed buildings, but also to consider different amounts of investment costs, three renovation packages were elaborated: A "base", a "standard" and an "advanced" refurbishment package. The base renovation foresees minimal invasive interventions (roof/top floor insulation and installation of a new heating boiler), the standard package respects again the minimum values required by law for the related climate zone and the advanced renovation anticipates the high-energy efficiency refurbishment towards the low-energy standard.

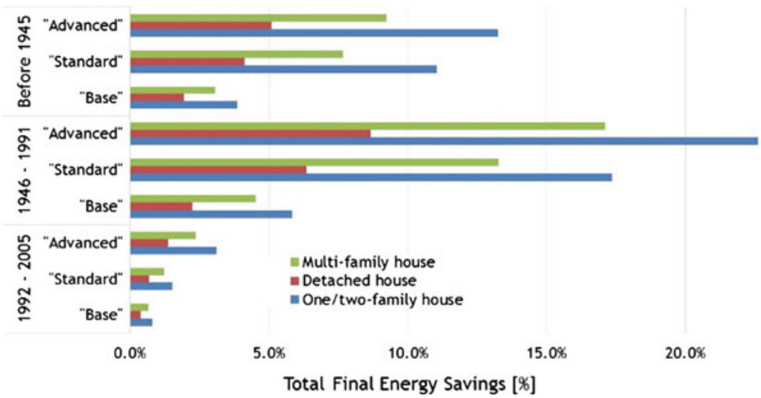
3.2.4 Main Results

Due to the fact that the municipality of Moos belongs to a colder climate zone because of its higher altitude above sea level, the specific primary energy needs for heating and domestic hot water of the building typologies tend to be higher than in the lower situated municipalities of St. Leonhard and St. Martin. In fact, the average primary energy demand of buildings in Moos was 291 kWh/(m^2a), while for buildings in St. Leonhard and St. Martin it was 254 kWh/(m^2a). The building type one/two-family house has, despite similar characteristics of the thermal envelope in the whole district and over all construction periods, the highest energy demand, especially in the first age class, before 1945, with 489 kWh/(m^2a). This is again due to the comparatively high surface-volume ratio. On the other hand, the multifamily and the terraced houses, which are characterized by a higher compactness, show reduced energy needs, especially the terraced houses from the most recent construction period (2006–2010) with 84 kWh/(m^2a).

Due to the lack of sufficient data, the net heated floor area distribution per building category and age class was estimated proportionally: the product of the number of buildings per building category and age class and the related typical net heated surface produced the percentage of one building typology of the total net heated area of the district. According to that, the one/two-family house of the second construction period (1946–1991) has the highest impact on energy consumption, with a share of around 35 %, followed by the same building type of the first age class (from before 1945), with around 19 %.

Applying the three renovation packages to the reference buildings, we can see, that with a "base" refurbishment which foresees insulation of the roof and installation of a new heating boiler, already one third of energy savings can be achieved at least for buildings of the first two age classes. In general, in both of these construction periods (before 1945 and 1946–1991), the highest energy savings can be achieved: through realization of the high energy efficient refurbishment, energy consumption can be reduced by factor 10. Regarding the payback time of refurbishment interventions, buildings built before 1991 have significantly lower amortization periods (Fig. 7).

Renovating 3 % of the buildings per year until 2020, with standard interventions, would reduce the energy demand by 15 % compared to current energy needs. Considering advanced interventions (toward the target of the low-energy standard) with the same annual rate, the final energy demand would be reduced by 18 % compared to the current one (Fig. 8).



Payback-time of interventions									
	Before 1945			1946-1991			1992-2005		
Payback-time [years]	Base	Standard	Advanced	Base	Standard	Advanced	Base	Standard	Advanced
One/two-family house	6.4	9.1	9.0	7.8	12.0	11.0	19.8	>30	23.3
Multi-family house	7.3	12.2	12.1	8.7	14.9	13.9	21.8	>30	29.4
Detached house	6.8	10.6	10.1	7.8	12.6	11.4	21.4	>30	22.9

Fig. 7 Possible energy savings after renovation and payback time of interventions according to building typologies and age classes

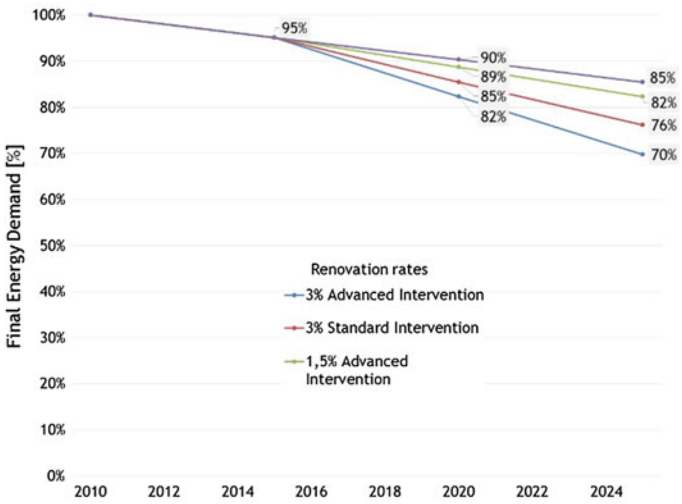


Fig. 8 Trend of final energy demand for heating and hot water generation according to different annual renovation rates (1.5 and 3 %) from 2010 until 2025

4 Conclusions

The paper shows that the developed methodology has a great potential both in considering the investigation phase, which enables us to have a general overview on the building stock, as well as in identifying the main needs of renovation and which are the sectors with the most energy consumption to be addressed by energy conservation measures. The results obtained show very well the possible energy reduction for every building typology combined with the information on which measures for what building type are cost-effective and which interventions on what building type have the highest impact on energy savings. The enhanced-with-GIS typology approach can therefore support public authorities during the decision-making process to choose among priorities and to define policies and incentives for building renovation, as well as to set precise energy targets within a specific time frame.

Nevertheless, the quality of the results is affected to a large extent by the availability of data on the urban level, in terms of georeferenced information on building geometry and construction period, as well as by the availability of energy consumption data. Even if GIS data are available from different sources, it is often not possible to integrate them because the shapefiles are not overlapping. The other main critical point is that often there is a lack of structured and detailed information on real energy consumption. If it is not possible to compare the simulated energy consumptions with real consumptions, the analysis cannot be validated. Energy consumptions in reality might be lower as the simulated ones, since the simulation foresees a standard temperature of 20° for the whole heated surface over all the time. Consequently, total energy savings might be reduced and the analysis may produce misleading results. Therefore, public authorities and energy suppliers are in demand to provide structured and interoperable data.

In general, the level of detail of the survey depends strongly on the specific question or on the specific target of the investigation. The more detailed the preceding inventory, the more accurate and reliable the results, but also the more time-consuming. At the beginning of the building stock analysis, the concrete question for the relevant district has to be clarified and the methodology has to be tailored to the specific conditions and the data availability. In any case, this methodology can be adapted and extended to the central issue of the investigation area: other energy types in terms of electric energy consumption or energy consumption for cooling can be considered; energy calculations can be done with dynamic energy simulations programs; and the integration of renewable energy production on-site can be taken into account in the energy balance. Also, the cost-benefit calculation can be enlarged and made more detailed, considering already existing subsidies and maintenance actions.

However, this methodology is a tool for preliminary estimates: already a quite rough investigation based on sufficient input data can provide effective renovation measures, identify intervention areas and deliver a useful and reliable estimation of energy saving potential, thanks to the enhanced-with-GIS typology approach.

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Collaboration in Regional Energy-Efficiency Development

Markku Mikkola, Ari Jussila and Tapani Ryynänen

Abstract Regional energy efficiency has become an increasingly popular topic in the discussion concerning sustainability and energy issues. Although energy production, renewable fuels and emissions have attracted more attention in the mainstream media, saving energy has become equally important. Additionally, issues such as sustainability and regional energy self-sufficiency are becoming increasingly important as drivers of change, alongside the traditional energy price factor. Balancing the system has an important role in the overall efficiency, and optimization requires close collaboration of all partners producing, consuming or transmitting energy. Traditionally, various stakeholders within a region have managed and developed their energy use or production independently. Utilizing, for example, the excess energy of other stakeholders in the region has been rather sporadic. From the system (i.e. regional) perspective, independent efficiency development in the sub-parts (e.g. individual companies) has its limitations and acknowledging this has directed attention to the opportunities of regional energy cooperation. This requires a new kind of collaboration between the stakeholders, from the identification of efficiency improvement opportunities to potential joint investments. The purpose of this paper is to study these potential regional collaboration opportunities between the stakeholders and the boundary conditions related to their implementation. One finding is that bilateral collaboration and development is already taking place, but broader cooperation is still somewhat modest. Furthermore, the stakeholders are usually well aware of the benefits of broader collaboration and have already identified some potential forms of cooperation. However, the long-term nature of the development of energy systems presents challenges for collaboration. It requires long-term commitment from the stake-

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holders, as well as a coordinating organization that has the aspiration and means to facilitate the collaboration over a long-time perspective.

Keywords Regional energy · Collaboration · Energy efficiency · Co-development · Innovation

1 Introduction

The topic of energy efficiency has gained increasing attention in the discussion concerning sustainability and energy. Although energy production, fuels and emissions have had more exposure in the mainstream media, saving energy has become equally important. Issues such as sustainability and energy autarky have also emerged as drivers of change alongside the traditional energy price. In energy systems, efficiency is not the only important criterion, but balancing the elements of the overall system also has an important role. In the regional energy system context, close collaboration between all partners producing, consuming or transmitting energy is required to optimize the system.

Traditionally, various stakeholders within a region manage and develop their energy use or production independently. Utilization of, for example, the excess energy of other stakeholders in the region has been rather sporadic. Regulatory policies driven by increasing energy costs and sustainability needs, for example, related to the use of renewable energy sources and energy efficiency, have also directed attention towards the opportunities of regional energy collaboration. This requires a new kind of innovative cooperation between the stakeholders.

From the innovation research point of view, the regional energy collaboration context provides insight into the challenges of facilitating innovation in loosely coupled business networks (Ritter et al. 2004; Dhanaraj and Parkhe 2006). By loosely coupled business networks, we mean company relationships that are not based on doing a particular business together (e.g. in a value chain) but there exists a different need for collaboration. In our case, the need is to take advantage of the improvement opportunities in regional energy efficiency.

Unlike in traditional supply chain collaboration, there is not a single common business target that guides the innovation activities in the context of regional energy efficiency development. The common denominator is that the companies and organizations reside in the same geographical region, but the businesses they operate may vary considerably. This has implications concerning the initiation of the innovation process, as well as for its management. Such a situation strongly emphasizes the learning approach: learning about each other, learning about differences and similarities and learning about mutual opportunities. One part of our study is to present an approach for promoting innovation in the context of collaboration in regional energy-efficiency development.

Concepts and approaches for collaborative innovation have traditionally been developed especially in the context of business networks, e.g. strategic alliances, supply chains etc. We suggest that theories of learning organization (see e.g. Argyris and Schön 1978) and co-innovation (see e.g. Chesbrough 2004) developed in these contexts could also be applied to loose networks of regional stakeholders.

Considering innovation activities from an organizational learning perspective, we base our approach on the following concepts. Dixon (1999) emphasized the importance of collective meaning and presented an organizational learning cycle involving four steps: (1) widespread generation of information; (2) integration of new/local information into the organizational context; (3) collective interpretation of information and (4) having the authority to take responsible action based on the interpreted meaning. Collins and Ison (2010) interpreted social learning as one or more of the following processes: (1) Convergence of goals: understanding each other's goals, criteria, and knowledge, leading to more realistic mutual expectations and building relational capital; (2) Process of co-creation: By gathering many perspectives, a collective knowledge creation is developed that provides insight into the causes of and means required to change a situation; (3) Behavioral change and actions: understanding something through action. Additionally, our approach is based on the idea of co-innovation, where new ideas and approaches from various internal and external sources are integrated within a platform to generate new organizational and shared values (Lee et al. 2012).

Concerning innovations in the context of developing sustainable regional energy systems, Müller et al. (2011) proposed a concept of energy autarky. This was conceptualized as a situation in which the energy services used for sustaining local consumption, local production and the export of goods and services are derived from local renewable energy resources. They proposed a process for implementing energy autarky, which is theoretically guided by the innovation-decision model of Rogers (2003). In order to implement energy autarky, the process needs to be initialized, and preliminary preparations should be made. Second, a series of analyses must be carried out in order to provide the basis for the adoption or rejection decision. Third, strategic decisions, concerning the general configuration of the energy subsystem, should be made. Fourth, operative planning and the subsequent implementation are carried out (implementation stage). In a fifth step, evaluation and monitoring activities are conducted.

Jönsson et al. (2012) studied energy efficiency development in an industrial cluster case in Sweden. The companies first formulated a joint vision for their collaboration. Jönsson et al. (2012) argued that, in order to be implemented fully, the vision requires well-developed cooperation between various actors, the implementation of new technologies and efficient technical system solutions, and overcoming of a number of non-technical barriers. They also concluded that the challenges related to realizing the vision are of three types: (1) technical (implementing efficient technical-system solutions and adopting new technologies); (2) organizational (organizing for change and collaborative work); and (3) business (adapting existing business models to new areas of business). Park and Behera (2014) also studied industrial symbiosis in a South-Korean industry park. They focused on four indicators, one being an energy consumption indicator proposed by the World Business Council for Sustainable Development. They aim to provide a framework as a tool to promote symbiotic transactions and persuade decision makers.

Sharma and Kearins (2011) conducted a study on inter-organizational collaboration for regional sustainability, which is contextually close to the theme of energy efficiency. Their findings suggest that, through collaborating, members can develop a better understanding of the economic, social and environmental issues affecting their region's sustainability and challenging their organizations' legitimacy. By sharing experiences and expectations of sustainable development, members can also develop better relationships and respond to various pressures for sustainable development. However, the ideological foundations of sustainable-development philosophy can make such collaboration an extremely tense and political process (Sharma and Kearins 2011). While exploring solutions that integrate environmental, economic and social sustainability dimensions in the local and regional context, the members may also strive to preserve or enhance their organizational interests. Ultimately, they may compromise on rather easy or abstract solutions that can build their organization's reputation and legitimacy rather than serve the wider remit of sustainable development (Sharma and Kearins 2011).

The purpose of this paper is to study the potential opportunities for collaboration on regional energy-efficiency development between stakeholders, and the boundary conditions related to their implementation. First, the research approach and method are presented together with short case descriptions. Then the main findings from the case studies and their comparison are considered. Finally, key conclusions are discussed and summarized.

2 Case Descriptions and Methods

Regarding the development of energy efficiency in a region, our conceptual idea is to utilize the existing and new energy-production technologies within the region more efficiently by matching the regional energy demand and supply more intelligently. The two major challenges are typically that the various stakeholders within the region manage and develop their energy use/production independently and the regional energy-efficiency viewpoint is usually not included in the decision making and planning. To improve the situation, collaborative decision processes between stakeholders are required, e.g. relating to the management of energy resources, investing in the required technologies and managing the energy delivery (Fig. 1).

2.1 Case Descriptions

The two case regions are located in southern Finland near a metropolitan area. The first, case A, is a medium-sized municipality where energy-related stakeholders also include a few large energy-intensive industrial companies. The thermal power plant

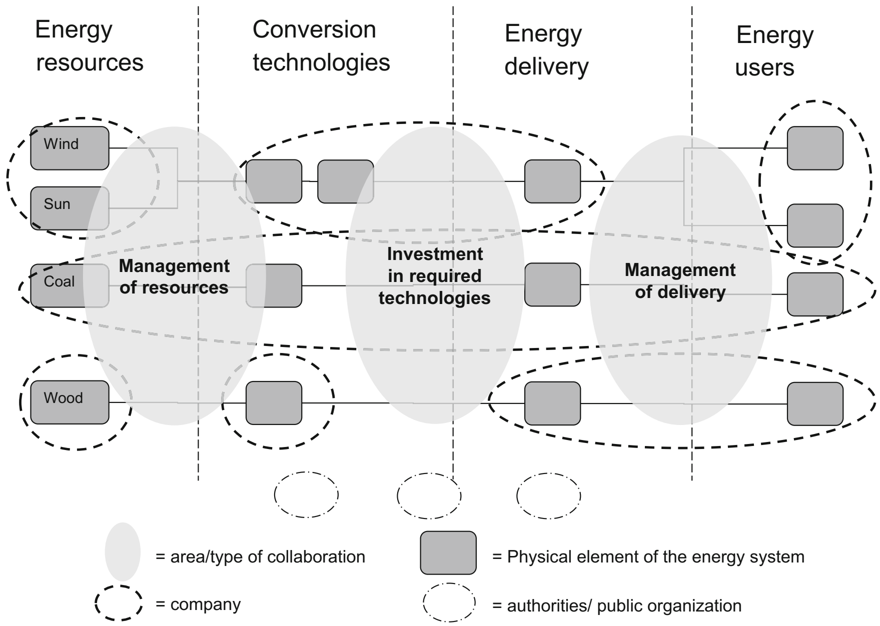

Fig. 1 Regional energy collaboration context (Jussila et al. 2014)

providing district heating for the region is owned by the municipality. One of the energy-intensive factories is also connected to the district heating system and is able to provide excess heat to the system if needed. The other similar kind of factory has the potential to do the same, but the company has not yet implemented the technology. Some of the factories are so large that they are part of the national electricity-grid control system.

The second, case B, is a region which covers three medium-sized municipalities (later referred to as B1, B2, and B3) that are about equal in population but differ in land area and industrial structure. The energy system that crosses all these municipalities forms a multifaceted system of various kinds of ownership and management structures. One of the municipalities (B1) has its own energy company, which owns and operates a combined heat and power plant (CHP). The second municipality (B2) has a district heating contract with a privately owned and commercial CHP located in its area. The third municipality (B3) has no power plants in its area. Its district heating network is part of the regional network covering both B1 and B3 municipalities and is mostly owned by the private energy company running the CHP in B2. Overall, in case B, there are only a few energy-intensive companies and they are more in need of cooling than heating, thus making them potential excess heat providers to the district heating network. However, this would require additional investments since they are currently not connected to the district heating network.

In both cases, bioenergy fuels such as wood chips are used in the CHP plants. The smaller units which are used to cover energy demand during the peak hours also use other types of fuel such as natural gas, but the operating hours of these plants are short. For covering the peak hours, bilateral trading of heat between the energy companies takes place in case B. Trading also takes place with external district heating providers outside this case area. Both fuel selection and heat trading provide tools to control emission levels in both cases.

2.2 Methods

In our approach, we applied the theories of learning organizations and co-innovation presented in Sect. 1. The approach (depicted in Fig. 2) has three main phases, and it is extremely important that all key stakeholders are included in the process from the very beginning: (1) joint analysis of the current situation, identification of development opportunities and setting mutual targets; (2) joint planning and experimentation of solutions to achieve the targets; and (3) establishing workable solutions in everyday practice. This report focuses on the findings of the first step.

The research was carried out as a case study that was combined partly with participatory observation. The primary data-collection methods included semi-structured stakeholder interviews, in both cases, and a regional collaboration

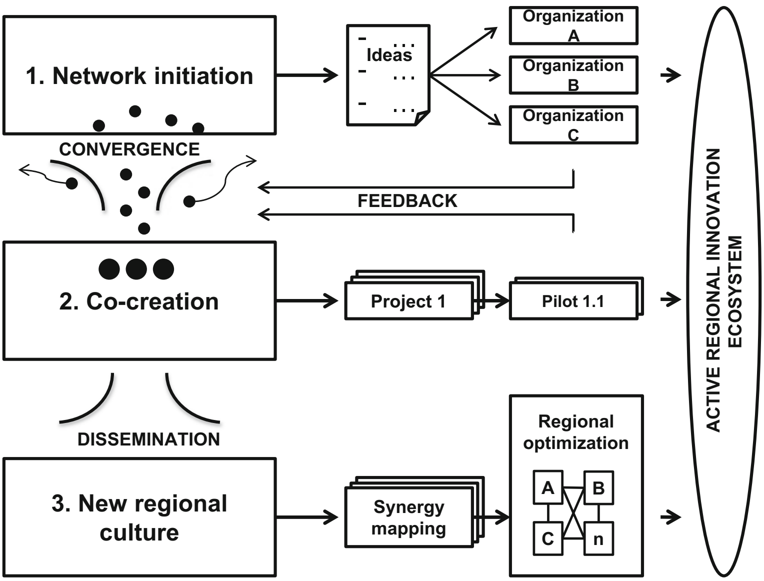

Fig. 2 Developing a collaborative approach to regional energy-system development (Jussila et al. 2014)

workshop in case A. The main themes of the stakeholder interviews included current energy solutions, development plans for the energy system, drivers and barriers of development, needs for potential energy efficiency services and regional cooperation in energy issues. In addition, in case B, particular emphasis was placed on inter-municipal cooperation and related challenges. Six different stakeholders were interviewed in both case areas. These included municipalities, energy companies and industrial energy users.

In case A, a regional energy cooperation workshop was also arranged. The data gathered during the interviews was used as source material in the workshop. Participating stakeholders were the region's industrial energy users, energy companies (municipal and private), key municipal actors and energy consultants (altogether 22 participants including researchers). The workshop included three parallel work group sessions facilitated by the researchers. These group works focused on four topics: (1) mutual understanding of the factors affecting regional energy efficiency; (2) major challenges to the achievement of community level energy efficiency targets (past, current, and future); (3) ideation of how these challenges could be solved and how to promote regional development; and (4) ideation of potential regional energy-efficiency services.

The data for the analysis consists of the interview notes and the material generated in the workshop discussions and group works. The data was analyzed using the thematic analysis method applying the following six main steps suggested by Braun and Clarke (2006): (1) familiarize yourself with your data; (2) generate initial codes; (3) search for themes; (4) review themes (5); define and name themes; and (6) produce the report.

3 Findings

The findings of the cases are presented first in the separate Sects. 3.1 and 3.2. After that, the comparison of the case findings is discussed in Sect. 3.3.

3.1 Findings from Case A

The case A findings are based on the interviews of major energy users and producers within the municipal area and the material created in a single collaboration workshop including these actors. The interviews clearly indicated that the municipality has a much broader set of goals related to energy issues than the other stakeholders. These goals included the preservation of jobs and employment in the region through moderate and reasonable energy prices. Furthermore, regional energy self-sufficiency was a goal. The municipality also emphasized the environmental aspect, i.e. abandoning the use of fossil fuels, preservation of ground water and reduction of greenhouse emissions. The other stakeholders interviewed were rather energy-intensive industrial companies and a municipality-owned power producer. In contrast to the municipality's goals, these other stakeholders were mostly driven by their internal development targets to have more efficient production processes and the emissions regulations set by the national authorities. However, from the collaboration perspective, it should be noted that the local power producer has had several activities on bilateral energy-system development with these various industrial companies, e.g. to utilize the excess energy of the factories.

In case A, we were able to proceed to the first phase of a regional energy-efficiency workshop during the research project. As described earlier, the companies and organizations in the case's region were operating over a wide variety of businesses. Thus, their interests and aspirations varied significantly, although they all had a general interest to be more energy efficient. The joint workshop provided a platform to get together to have a first exchange of ideas on the common opportunities. However, in order to achieve common understanding of the situation and development opportunities, merely gathering together and discussing is not enough. Basic information and data are required to ground the joint development and discussions in feasible solutions and opportunities. Utilizing third party expert organizations to gather and analyses the base data is a viable solution to obtain this kind of unbiased base information. On this foundation, a joint master agenda and development scenarios can be built. The workshop concluded that there is a need to reach mutual understanding on the following factors affecting regional energy efficiency:

- Energy use patterns (residents, public sector and industrial users)
- Energy technologies (e.g. geothermal heat) and fuel selection (e.g. an optimal mix between bio and fossil)
- Market conditions such as energy price, subsidy policies and taxation issues
- Waste-energy reduction/utilization
- Current regional infrastructure and future city-planning.

Starting the broader collaboration from zero also means that it will take time and many meetings to reach the first joint conclusions on collaborative energy-efficiency activities. This means that there has to be an actor who is facilitating the process in the long-term. For example, our research project had a limited time span and researchers could only have a limited time to facilitate the process. The researchers soon came to the conclusion that a long-term facilitator is required. Our current understanding is that the most suitable actor would be some municipal organization that naturally has a long-term interest in developing the region.

The first energy-efficiency workshop also listed the following major challenges to collaboration to achieve community level energy efficiency targets:

- Long-term commitment and motivation
- Size difference of the various stakeholders
- Foreseeing future energy supply and demand
- Predictability of energy-related policies and regulations
- Regional structure and planning issues.

3.2 Findings from Case B

Case B included only initial interviews with the main stakeholders in the region. The joint workshop had not been organized at the time of the writing of this paper. In case B, common to all interviewed organizations is that they are interested in energy efficiency and energy topics in general. Furthermore, they all have positive attitudes towards collaboration, although there are not many joint activities in energy issues. However, the resources for the collaboration are limited, one reason being that in-house energy efficiency investments and projects are preferred in comparison to external ones. Furthermore, the energy consumption of the major stakeholders within the region is relatively low (e.g. compared to case A), thus reducing the potential of energy savings in absolute terms. One implication of this is that the main focus of municipalities is on the energy efficiency of buildings, public buildings in particular. They usually carry out the efficiency-improvement activities by themselves or in cooperation with an outside partner, such as an energy company.

Findings concerning cross-municipal collaboration opportunities in the development of the energy system were twofold. On the one hand, municipalities have ongoing collaboration in other areas such as land-use planning, environmental management and waste management. This suggests that collaboration in general has been found to be feasible in these areas. On the other hand, they also have a competitive position among each other to attract businesses and inhabitants to their own premises, thus leading them to compete in promoting their own interests for example in regional planning.

From the private-sector viewpoint, one of the region's larger energy users considers that it is currently still most feasible for it to focus on developing the energy efficiency in-house, utilizing e.g. new technologies in its processes. Nevertheless, they also have a concept to utilize their excess energy by connecting to the nearby district heating pipeline, but this is still an early-phase idea, and possible only to be realized in the distant future.

One positive factor on which to build the collaboration is that personal-level relationships are good between the energy companies in the region. For example, many of the people in the various energy companies have been colleagues at some point in their earlier careers. The energy industry also has common research and development activities and networks, which is another supporting factor for the regional collaboration in energy efficiency development. One interesting notion brought up by one of the energy company interviewees was that the energy companies focus on the energy-production side (energy production, distribution and storage) of efficiency development, whereas the municipalities usually focus on the consumption-side efficiency. No actor focuses on the integrated system perspective.

3.3 Comparison of Case Findings

Table 1 presents a comparison of the key findings of both cases regarding the case-specific and common factors that either support or hinder collaboration in regional energy-efficiency development. Some interesting findings can be highlighted.

First, good personal-level relationships were brought up in both cases. It appears that people working in a specific region and in a specific domain can form a grass-root-level foundation on which to build organizational collaboration. However, there is lack of resources to be allocated for the collaboration from the organization's perspective.

Second, due to the energy systems being very long-term of investments compared to typical business operations, it is very challenging for individual companies to commit themselves to long-term joint energy-system solutions.

Third, the collaboration activities require continuous coordination and leading. Finding such a leading organization also appears to be a challenge. Our studies suggest that it should be an organization that has a long-term interest in the region. In the Finnish context, one potential source of leading organizations are the municipality-owned development companies, which aim to promote a particular region or urban economic activity.

Table 1 Common and specific supporting and barrier factors for collaborative regional energy-efficiency development

	Case A	Case B
Case-specific supporting factors	• Bilateral development of energy systems between stakeholders exists	• Collaboration activities exist in other areas between municipalities
Case-specific barrier factors	• Size difference of the different stakeholders (in energy use) • Different planning horizons of the different stakeholders	• Municipalities often focus on the efficiency of energy utilization, whereas energy producers would like to extend the focus to the production side too (i.e. the whole energy system) • Competition between municipalities • Stakeholders' energy consumption relatively low, not enough potential savings appeal
Common supporting factors	• Energy efficiency is a common goal for all stakeholders • Good relationships between personnel in different organizations	
Common barrier factors	• Limited resources to initiate and maintain active collaboration • Internal energy-efficiency-development activities dominate external activities • Energy efficiency is only one of many goals • Lack of leader organization for the collaboration • Competing long-term commitments • Lack of commitment to joint long-term initiatives	

Considering the potential differences in the development of regional energy-efficiency solutions, we can identify some background factors. First, rather obviously, if the region crosses the boundaries of many municipalities, it requires higher-level collaboration than in the case of a region situated within a single municipality. Thus, a corresponding management level for the collaboration must be introduced. Second, if the region has heavy energy users, it may be possible for the region to reach its targets for energy-efficiency development if a single large user makes an improvement investment to its operations independently.

4 Conclusions

Multilateral regional energy collaboration between several local actors is rather uncommon, at least in the Finnish context. In this paper, we presented conceptual models for such collaboration and an approach to facilitate it. These models and concepts can be utilized especially by the actors and authorities who have a strong interest in regional development, e.g. municipal development offices and organizations. These concepts can also be applied to other loosely-coupled collaboration networks focusing on, for example, regional renewable energy utilization or similar broad-scale regional infrastructure development.

Regional collaboration between several actors requires coordinated long-term planning. Especially in the case of long-term heavy investments such as district heating, where infrastructure can have life cycles of over 50 years, the collaboration must be continuous and built into the organizational structures and processes. The long-term perspective also highlights the importance of the leading organization. The innovation network requires systematic management that is able to adapt to the regional context and its special requirements. Without a leading operator, the process will come to a halt, as various stakeholders easily revert to using only traditional in-house development. In general, in order to make joint efforts happen in a loosely-coupled network, there must be some party who takes the lead and tightens the loose couplings.

Heavy emphasis should also be placed on developing and implementing profit- and risk-sharing models, since this kind of cooperation requires a high level of commitment that is easier to achieve if all partners feel that there is a fair balance between benefits and disadvantages.

Our case studies so far have covered only the starting phase of the collaboration in regional energy-efficiency development. It has become evident that in this context the progress of collaboration takes time. Although the organizations engage in the collaboration rather out of curiosity in the early phase, and then learn the value of sharing experiences and ideas, considerable efforts appear still to be necessary to reach agreement on concrete collaborative actions.

Considering the future research requirements a long-term follow-up, and even extra interventions are required in order to obtain knowledge about how the collaboration evolves and how it can be supported further. This calls for long-term research collaboration models and activities.

Collaboration in regional energy efficiency issues is related to many other areas of cooperation, such as regional planning in general and public services (e.g. health care and education). Further research could also focus on finding and comparing successful cooperation experiences in these fields and identifying ways to transfer these models to the regional energy-efficiency context (and vice versa).

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Part II
Innovative Technologies

Lighting up the Landmarks with Information About the Environment

Matija Brković and Višnja Sretović Brković

Abstract In order to ensure sustainable development of our cities, we all have to do our part. There is a growing awareness about environmental problems, and citizens want to be informed and find the information about the environment relevant for all, not just for those who are making decisions. Many communities want to have a role in making their cities attractive and livable. However, the public cannot always easily perceive the causes of environmental problems—e.g., neighborhood or city-level energy consumption, air and water pollution, or noise levels. Making such information easily accessible and understandable to all is the challenge this paper addresses. This paper argues for the use of public buildings and local landmarks as a means for communicating information about the quality of the environment by employing their existing illumination systems as a medium for transferring and disseminating the respective information. Instead of using one color or randomly changing colors (as is a case employed on many public buildings nowadays), the proposal this paper advocates for is to connect the light color to the corresponding environmental parameter, and, in this way, convey the information. For instance, if CO_2 is taken as a relevant parameter, when the emissions go above a certain level, the building could glow red. The intensity of color or a choice of color corresponds to the parameter that is measured. This is an informative, non-invasive, simple, and inexpensive solution that can help in raising awareness about the environmental problems and, at the same time, make the public informed. The information presented in this way is easy to understand, it is visible to a large number of people and "glanceable". Furthermore, it could support the involvement of a community in coping with the environmental issues by spurring a bottom-up action and making the community one step closer to the ideal of making their cities sustainable and resilient. The approach in developing this system is embodied in the

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concept of smart cities. It is also viewed as a contribution to smart solutions and the use of technology in a smart way, as well as a way that contributes to the public good. In addition to presenting and justifying this proposal that is based on several parameters of sustainability, the paper will also discuss the potential benefits of the system for raising the public awareness, and will reflect on the relationship between community involvement and urban planning.

Keywords Environment · Illumination · Landmarks · Pro-environmental behavior · Glanceable information

1 Introduction

In order to ensure sustainable development of our cities, we all have to do our part. Given the increasing environmental problems, sustaining pro-environmental behavior is becoming a more important and necessary task. The media play an important part in introducing and sustaining this change as today's information channels have made it easy to exchange and disseminate information and to extend influence over the public domain. This is reinforced by better education and growing awareness among the citizens regarding the environmental concerns, as well as their increasing interest in being better informed and getting access to information about the quality of the environment of the places where they live. Many are willing to take an active role in making their cities livable and better places for all.

However, many environmental challenges cannot be easily perceived by the public—e.g., city-level energy consumption, concentrations of greenhouse gases in the air, or water pollution, especially if the changes are happening slowly or the environment is not yet affected to the extent that the consequences are directly perceivable. Making such information visible, easily accessible, and understandable is the challenge this paper addresses.

The idea presented here is to use the existing public buildings and landmarks by employing their illumination system as a glanceable display to provide information on the environmental factors in a simple-to-understand and easy-to-catch way. Presented in this way, they create a new public good domain that is very important in building environmental awareness and, consequently, contributing to the pro-environmental behavior. This system can also act as a support system for citizens' involvement in solving the environmental problems or for the bottom-up actions, thus making cities and towns one step closer to the ideal of sustainable development. The approach in developing this system is embodied in the concept of smart cities. It is also viewed as a contribution to the smart solutions in using technology in manner that is smart and contributing to the public good.

2 Lighting up the Landmarks

2.1 Glanceable Information

"Glanceable information" is known by different terms (ubiquitous technology, informative art, ambient information systems, etc.). It is a kind of information channel embedded within the existing surroundings that utilizes unused physical and visual aspects of tangible objects to communicate certain information. It is used to display information that is important but not critical, and can be easily ignored when there are more pressing matters that require attention (Hazlewood et al. 2008). It is used to display various kinds of information, from the weather forecast, stock market prices, electric energy consumption, unread e-mail counts, etc. In general, one object is used to display only one kind of information (Pousman and Stasko 2006).

The size of the objects that are used to convey the information ranges from small, ball-shaped desktop items (Ambient Devices, no date) to fountains (Mensvoort, no date) or even to large buildings. The size of used objects depends on the goal of how many people we want to serve. Small objects are used to inform one or two people, while a large building can inform many more.

Given the goal of informing the public, the object used to convey information should:

- Be clearly visible from a close proximity to a faraway distance;
- Have the capacity to inform many people simultaneously;
- Can be used in the urban context.

The choice of the existing public buildings and local landmarks is effective primarily because of their visibility—they often occupy the prime locations in cities making them clearly visible from many points in the city and are passed by a large number of people every day.

There are multiple ways to convey information via tangible objects, using the light, sound, shadows, movement of water, etc. (Pousman and Stasko 2006). Illuminating an object with various colors is a frequently used option. Regarding the public buildings and landmarks they are usually somehow illuminated. Continual developments in LED technology, leading to the continuous fall of manufacturing costs and increases in their energy efficiency, have made LED lighting an increasingly popular choice for the illumination of buildings (Sade 2014). In some cases, the built-in LED lighting is also capable of changing colors. Most of the time, this functionality is not used (the colors do not change), or it is used in a way that does not convey any information (the colors change randomly). Instead, colored lighting has only decorative or aesthetic relevance.

Objects that use this kind of lighting are the best candidates to convey information because they require the least intervention and investments. Instead of using one color or randomly changing the colors, the idea we are advocating for is to connect the light color to the corresponding environmental parameter, e.g. the building glows red when the CO_2 level rises above a certain level. The intensity of

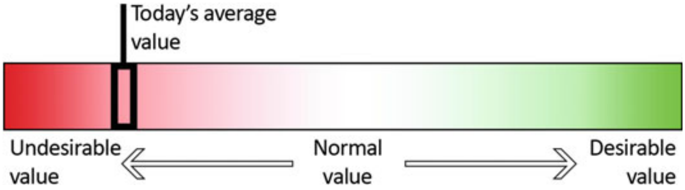

Fig. 1 Mapping the environmental parameters to the color spectrum

color or a choice of color corresponds to the parameter that is measured. Mapping the values of the environmental parameters to the corresponding parts of the color spectrum enables the observers to "read" the information by simply glancing at the object (Fig. 1).

The color spectrum that ranges from red via yellow to green ("semaphore" colors) may provide a responsive and good choice because it is something people are already familiar with. However, in the case of the "semaphore" colors, illuminating the buildings with only the chromatic colors may not be the most desirable option, so a modification of the "semaphore" lighting in which the white substitutes the yellow is possible. Other options are possible as well, depending on the parameters that are measured and the effects that are desired.

Such a technology is informative, non-invasive, simple, and inexpensive, which can help raise awareness about the environmental problems and make the public informed. The information presented in this way is easy to understand and visible to a large number of people.

In building and exploring this idea of employing glanceable information systems, we investigated the state of the art in the field and looked for similar examples or already existing case studies. Herewith are the examples of the projects that have been already realized. They all share some common traits with our work and are presented here to illustrate how the system works in practice.

2.2 Examples

2.2.1 D-tower

The D-tower is an interactive sculpture/installation erected in 2004 in Doetinchem, the Netherlands, that reflects a measure of the happiness of the inhabitants. It is a 12-m-high blob-like structure resting on four columns, designed by the NOX art and architecture office, which is connected to a website used to survey the emotional lives of the citizens. The emotions are "measured" daily by an online questionnaire developed in collaboration with Q.S. Serafijn, a Dutch artist. The four identified “feelings” (hate, love, happiness, and fear) are than mapped to the four corresponding colors illuminating the structure (green, red, blue, and yellow) (Fig. 2).

2.2.2 Rogier Tower

The Rogier Tower, formerly known as the Dexia Tower, is a 137-m-tall skyscraper located in the middle of Rogier Square in Brussels, visible from several major traffic arteries in the city. The building is designed in partnership between Jesper-Eyers architects and Philipe Samyn and partners, while the lighting installation was designed by Lab[au]. Four thousand two hundred of its 6000 windows are equipped with red, green, and blue LEDs. When lit up, the whole tower acts as a huge

Fig. 2 D-Tower in Doetinchem (D-toren by Hugo—https://www.flickr.com/people/hugosimmelink/. Licensed under CC BY ND 2.0 via Flickr)

Fig. 3 Rogier Tower (Lab [au]: Spectr|a|um by Marc Wathieu—https://www.flickr.com/people/marcwathieu/. Licensed under CC BY 2.0 via Flickr)

colorful display that is being used to inform the citizens about the weather forecast for the following day or other pieces of information on special occasions (Fig. 3).

2.2.3 Breast Cancer Awareness Month

Breast Cancer Awareness Month is an annual international health campaign held each October. Among other activities, on one particular day in October, landmark buildings are illuminated in pink in order to raise awareness of breast cancer (Fig. 4).

Not all countries observe this on the same date. For example, joining this initiative, the Republic of Serbia proclaimed 20 March as a National Day against Breast Cancer, symbolically choosing the first day of spring to mark the day (Fig. 5).

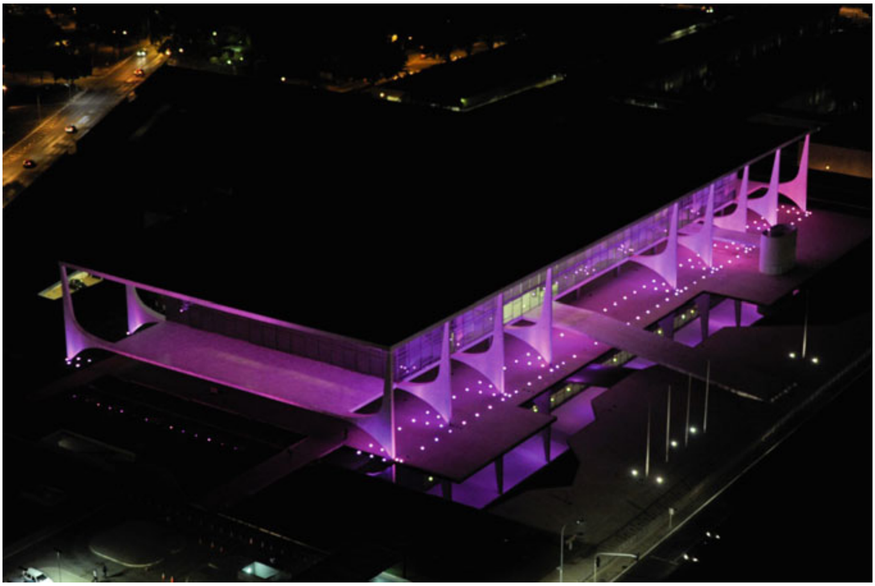

Fig. 4 Palácio do Planalto (The President's Palace) in Brazil illuminated in *pink* (Outubro Rosa by Senado Federal—https://www.flickr.com/people/agenciasenado/. Licensed under CC BY 2.0 via Wikimedia Commons)

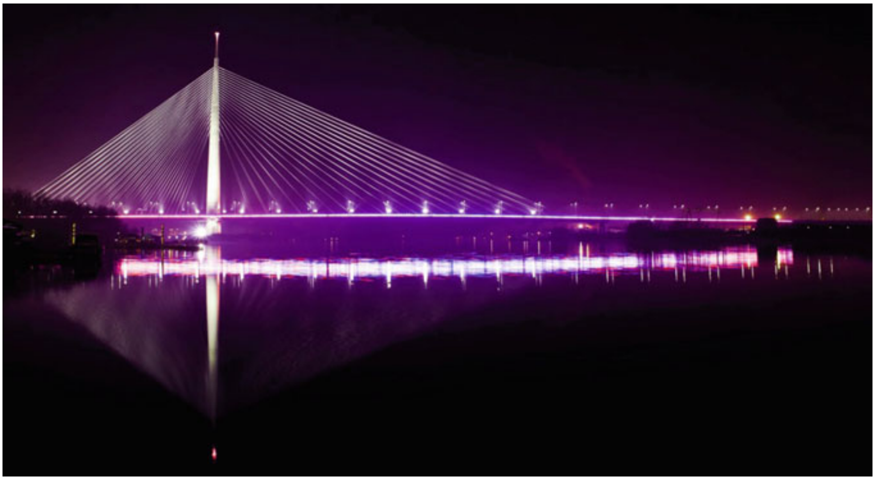

Fig. 5 Bridge in Belgrade illuminated in *pink* (The Ada bridge by Vojislav Vujanić—www.bud3.net/. Licensed under CC BY NC SA 2.0 via Flickr)

3 Choosing an Environmental Parameter

A choice of an environmental parameter to be monitored and displayed is very important, and it depends on the several factors:

- Technical considerations and available equipment (such as which sensors will be employed);
- The issues that should be focused on and the awareness raised about (e.g., the usual air quality indicators are sulphur dioxide, nitrogen dioxide, and PM10 particulate matter concentrations in the air, while the water quality indicators are completely different);
- The desired effect that depends on the scale of the parameter and its fluctuations.

The large-scale parameters (such as the air-pollutant concentration or electricity consumption) have relatively stable, slow, and predictable fluctuations, in which daily fluctuations are minor compared to the annual ones under the normal circumstances. The individual contribution to these parameters is almost negligible, making a collective contribution or sudden change in the environment beyond our ability to influence dominant factors in the fluctuations (e.g., wind that causes reduction in air pollution or annual differences in daylight hours). The predictable fluctuations under the normal circumstances and presence of the negligible individual contribution make these parameters good candidates for:

- Raising awareness about a certain environmental issue by making it visible;
- Encouraging the people to acquire more information in cases of a sudden change of color (a study conducted by Hazlewood et al. (2008) showed that individuals often reacted when a sudden change of color happened);
- A kind of a warning alert (for example, about a sudden rise in the air pollutant concentration), preferably coupled with an appropriate public announcement.

The small-scale parameters differ from the large-scale ones because the individual's contribution is much more likely to be felt on this scale. Furthermore, these parameters often fluctuate more during the day. These are usually the local-level parameters, for example, a noise level at a certain intersection in the neighborhood or the neighborhood's electricity consumption. The fluctuating values and the perceived individual contribution make these parameters good candidates for:

- Raising awareness about a certain environmental issue by making it visible, this time possibly by highlighting the individual contribution;
- Encouraging people to inquire more information about the issue and its causes;
- Motivating people to take an action—since the individual contribution can be felt, it can also be visualized, thus creating a potential feedback mechanism that can serve as positive reinforcement.

4 Being Smart

There is no one definition for a smart city. It is a broad term that encompasses different issues, such as information technology, infrastructure, environment, entrepreneurship, business innovation, education, creative industries, communities, governance, etc. The term is sometimes used synonymously with cyber, digital, wired, knowledge-based cities, e-government, etc. (Hollands 2008; Nam and Pardo 2011a; Anthopoulos 2015). The aim and purpose of the smart initiatives can be very different from city to city, and it depends on the underlying notion of the term "smart", governance agenda, and specific local context.

The smart-city initiatives can fall into various application domains. According to Anthopoulos (2015) and Neirotti et al. (2014), these are:

- Natural resource management and utilization, optimizing the primarily "hard" infrastructure issues such as smart electricity grids, street lighting, waste management, etc.;
- Transportation and mobility that addresses the logistics, information, and people's mobility in cities;
- Buildings and physical structures that include facility management, housing quality, etc.;
- e-government services, i.e., issues of the transparency and administration efficiency;
- Economy, such as entrepreneurship or business incubators;
- Social inclusion, connectivity, and the digital-divide issue; and
- Quality of life—the domain that is taken as a general framework in our case and which is discussed in this paper. This domain addresses the initiatives that are concerned with, for example, education, safety, healthcare, and pollution control.

While there is a general consensus among the researches (Hollands 2008; Neirotti et al. 2014) that smart cities usually involve technology for the purpose of improving the economic, social, and environmental sustainability of a city, it should be also noted that the technological innovation is just one of the resources in the smart initiatives, smart projects, and smart approaches to urban planning.

Some initiatives are more technologically driven (e.g., "hard" infrastructure optimization, cables, technology), the others are driven by information and human networks (e.g., applications to academic knowledge and/or business innovations), while some of them emphasize human capital (e.g., skills, education, creativity) (Hollands 2008).

Regarding the use of technology in smart systems, Neirotti et al. (2014) identified two ways it is used. The first one uses technology in a centralized way to gather and process data in order to optimize various urban processes (e.g., transportation, waste management, energy production and distribution). In this case, the focus is more on the "hard", tangible infrastructure. The second type uses technology to aid the citizen-led bottom-up approaches by making data available and easily accessible to all. In this case, the focus is more on the "soft", intangible infrastructure and the support for citizen participation, while technology is used as an enabler and complementary support system.

As Neirotti et al. (2014) previously hinted, it is necessary to view smart-city initiatives not as a single technological feature, but as a complete stack that takes into account multiple facets of innovation. A successful smart-city innovation is comprised of (Nam and Pardo 2011b):

- Technology—development and application of innovative tools with the aim to improve service;
- Organization—development of organizational capacities to effectively use technology and manage innovations; and
- Policy innovation—to address the institutional and non-technical urban problems and create an enabling environment for a smart city.

At the same time, it must take into account a specific local context in terms of the economic, physical, technological, governmental, cultural aspects, etc. A successful smart-city initiative addresses all of these levels.

In the case this paper is focused on, the emphasis is on the environmental problems and on informing the citizens about them, so technology is used to help raise awareness. Yet, the key drivers in triggering a change are people. In order to succeed, this initiative would have to be accompanied by matching support by the organizations that are involved and the respective city policies.

5 Effects and Where to Go from Here

Potentially, several positive effects can be achieved by communicating the information about the environment via the landmark and building illumination. First, these could help raise awareness about environmental problems and issues. The citizens become aware of certain problems or results of their actions simply by being continuously informed in a way that is simple to get and understand. Consequently, they may seek more information in order to inform themselves about the causes or severity of the effects it may generate. In the best-case scenario, the increasing awareness can lead to a change in their behavior, or in their acting towards the local governments by demanding that the city authorities do something, i.e., through direct or indirect action, as defined by Kollmuss and Agyeman (2002). Additionally, there is a potential for using this newly-created feedback mechanism to help sustain its positive effects (Fig. 6).

However, in making the system work, there are many challenges and open questions still needing to be addressed. The challenges this paper emphasizes are:

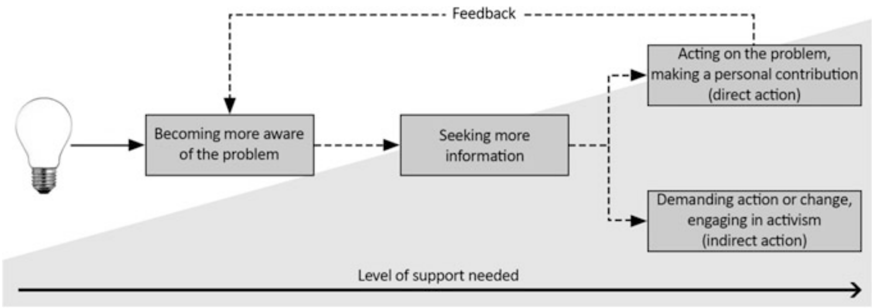

Fig. 6 Potential benefits and feedback mechanism (Lightbulb image by George Hodan—http://www.publicdomainpictures.net/browse-author.php?a=8245. Licensed under CC0 1.0 Public Domain)

- A support system: development of support system;
- The implementation: development of the landmark-selection criteria and solving the technical issues;
- The environment: environmental costs.

Using glanceable displays to raise awareness about environmental problems means reaching people in their daily routines and continuously informing them "in the background". However, exactly how effective glanceable displays are is very hard to measure, as shown by Hazlewood et al. (2008), because such technology relies on a proper integration into the everyday surroundings where it can deliver information "in the background". Several studies have been conducted aimed at determining and measuring how aware people are of the information presented to them, while, at the same time, not being distracted in their routine (Matthews et al. 2009).

If the information is received clearly, this can help raising awareness about a problem. However, awareness does not necessarily equal action. The researchers agree that the environmental knowledge and awareness are only partially responsible for the pro-environmental behavior, and that at least 80 percent of the motives for the pro-environmental behavior stems from factors other than environmental awareness and knowledge (Kollmuss and Agyeman 2002). Therefore, raising awareness about problems should be viewed as only one of the elements needed to nurture the pro-environmental behavior.

The realization of the benefits of this proposal in terms of direct and/or indirect action depends on the factors that extend beyond technology. As previously mentioned, smart-city innovation needs support in terms of the organization that will manage the innovation and the policy that creates the enabling environment for a change (Fig. 6). A change in organization or a policy requires much larger effort compared to only the illumination of landmarks. Urban policies are linked to a larger environmental context (social, political, economic, cultural, etc.) (Nam and Pardo 2011b). The creation of the environment that will enable citizens to seek more information and spark demand for an action, and/or involvement in the

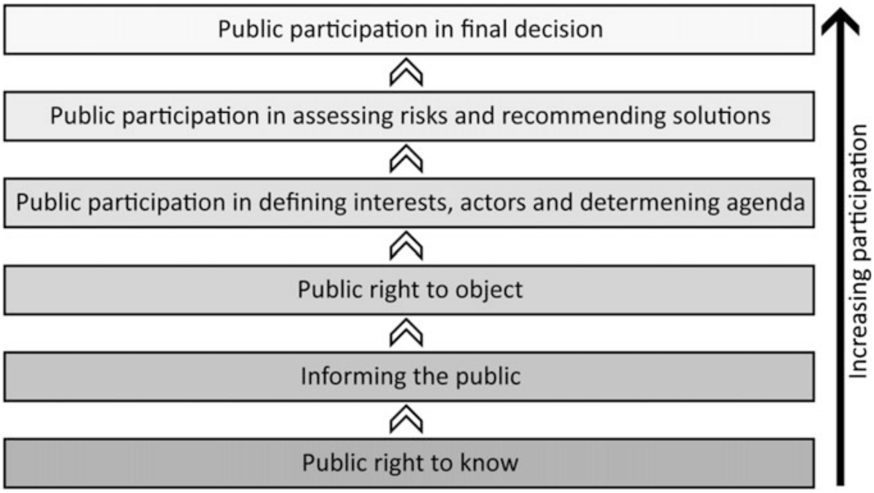

Fig. 7 Public participation ladder (Carver and Peckham 1999)

bottom-up action both directly correspond to the participation level citizens can achieve (Fig. 7).

As regards the implementation challenges, it is very important to carefully analyze each object and/or landmark on a case-by-case basis in order to determine whether it is suitable for implementing the system. The issues of technical implementation (using LED technology, available sensors, etc.), the visibility of a landmark from different points in space, their aesthetic requirements (as the illumination can/does change the appearance of the object), and their effects on the image of the city are among the critical ones to be addressed throughout the process and may very well affect some aspects, for instance, the color choice. The effect on local identity is important (Zielinska-Dabkowska 2014), given the role the landmarks have in developing local identity and because of the effect the displayed message (information about the environment) has on the medium (in this case the landmark), and vice versa.

The design of visualization is also a relevant question. The biggest challenge refers to the ways and means of delivering a key for understanding what the visualization displays. The various solutions have been used—placing a sign table next to a landmark that is visible only from close by, using newspapers or other media, using the Internet and social networks, etc. The visualization cannot exist by itself, as it needs support to be understood.

Finally, there are the environmental issues. This aspect has been only partially touched on here due to the specifics in choosing the medium objects. In this paper, the emphasis is on the existing public buildings and landmarks that are already illuminated in one way or another. Therefore, their environmental footprints in terms of energy consumption, light pollution, or other environmental effects may not change considerably. Notwithstanding the case explored and presented in this paper, there is a general rule that the environmental costs should be taken into account in each particular case.

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Taxi of the Future: Big Data Analysis as a Framework for Future Urban Fleets in Smart Cities

Susanne Schatzinger and Chyi Yng Rose Lim

Abstract Smart city needs smart mobility—travel should be made as convenient as possible through sustainable urban transport solutions. Transportation systems in many parts of the world are facing unprecedented challenges in the 21st century as increasing population, urbanization, and motorization growth continue to pressure these systems. Hence, cities need smart planning for a sustainable future, and this calls for greater governance across all levels of transportation decision making. Reimagining the role of information technologies (IT) and connectivity in today's cities enables us to realize the promise of smart mobility through the Internet of Things (IoT) which provides interlinking of vast networks, devices, and data which have thus far never been linked. As such, one of the strategies for smart cities to overcome the urban-mobility challenge is to spearhead the technological leap with big data. Within the frame of smart cities, leveraging big data and IoT is considered to be a key enabler for transforming urban mobility system towards higher flexibility and better integration with existing transport modes, as well as providing smart and sustainable mobility solutions such as sharing concepts, electric vehicles, and autonomous driving. However, the prerequisite for taking advantage of big-data analytics is to first address the issues of data availability and accessibility. Hence, by highlighting the need for urban data, this paper aims to draw attention to the taxi as an essential part of future urban fleets in smart cities for the shift towards sustainable mobility. Taxis solve a niche in the urban-mobility system as they provide to the general public flexible, door-to-door services. Such a semi-private character enables full-area coverage to better support travel demands, and thus the taxi industry has a significant function in the mobility system. However, compared to other transport modes, the taxi is often overlooked and receives little attention from planners and policy makers. So what does the taxi of the future look like? The project "*Future Urban Taxi*" rethinks the taxi from bottom up. It focuses on how

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the taxi: (1) as a vehicle, has to adapt to user demands and specific urban contexts; and (2) as a system, can be integrated into the mobility web of a city in a more effective and sustainable way. This is one of the sub-projects under the initiative "*Ambient Mobility Lab*" which is supported with funding by the Ministry of Finance and Economics of the federal state Baden-Württemberg in Germany.

Keywords Big data · Internet of Things · Smart cities · Smart mobility · Sustainable mobility · Taxi

1 Introduction

The "*Ambient Mobility Lab*" is a joint initiative between the "*Mobility Innovation Lab*" at the Fraunhofer Institute for Industrial Engineering (IAO) in Germany and the "*Senseable City Lab*" at the Massachusetts Institute of Technology (MIT) in the United States (U.S.) aiming to shape the future of urban mobility through the development, evaluation, and application of sustainable mobility concepts—including innovative and cutting-edge technologies such as autonomous driving, electric vehicles, sharing solutions, and new drive concepts—for existing and future urban systems.[1] This initiative intends to improve the quality of life in cities while setting a course for sustainable mobility (Jacob 2015).

Within the "*Ambient Mobility Lab*", the taxi is the focus for two of its sub-projects. Firstly, the project "*HubCab*" led by MIT analyzed 150 million taxi trips within the city of New York in order to identify mobility patterns as well as better understand travel behaviors and habits. The result of this big-data analysis led to a visualization of the city's taxis shareability networks, showing about 40 % of the New York taxi trips could be shared (Santi et al. 2014). This implies the potential of ridesharing—in this case, sharing of taxi rides—in contributing to shorter travel times, less congestion, increased resource efficiency with smaller environmental impact, or even gaining more urban spaces as a result of optimizing mobility options. These positive effects are not only good news for the users and policy makers, but service providers can also benefit with lower unit prices and higher all round prices.

Next, building on the big-data analysis of "*HubCab*" and using it as a framework, the project "*Future Urban Taxi*" is led by Fraunhofer IAO with the focus to gain further insights into the taxi as a mobility system within a specific city. Urban systems are highly contextual considering that cities are unique and so complex in their characteristics, thus the context plays a crucial role in order to adequately understand any such systems. In the case of "*Future Urban Taxi*", the context is determined by selecting a specific city where the taxi will be studied in the light of its urban-mobility system.

[1]See http://www.ambientmobility.org.

In view of the above, this paper takes on mobility—one of the cornerstones of a smart city—with a focus on the taxi and considers how we need to look at it differently in the smart-city age because the taxi forms an essential part of the future urban fleets. The paper first discusses the need for urban data by focusing on context—a highly relevant issue when studying urban systems—thus the necessity to select cities. The adopted methodology for assessing the overall urban data availability of a city is then described in detail and includes an evaluation system based on performance indicators to make comparisons across cities. Next, key findings are presented and discussed. Finally, drawing upon insights from big data and IoT, this paper concludes with a discussion on big-data analytics for smart mobility in the light of megatrends, game-changers, and black swans, as well as providing an outlook for the future with a vision of the future urban taxi.

2 The Need for Urban Data

The need for urban data is compelling because, if harnessed using the power of the Internet, it can result in a ripple effect that benefits everyone—from improving public-private interactions, business operations, and efficiencies across the spectrum to the quality of products and services, as well as the quality of life in general. Moreover, if data is made open by governments or businesses, it also helps grow sectors. This way, government can better respond to its citizens' needs, businesses are better prepared to target resources and compete in global markets, and the communities can share ideas (Starks 2015). However, most federal-/state-level data are too general—especially in the case of the project "*Future Urban Taxi*" where rich data is needed to perform a detailed analysis of the taxi systems—partly attributing to the conventional methods of data collection such as censuses and household travel surveys. Hence, cities hold great potential in offering rich urban data through their extensive deployment of sensors and networked technology which enable them to generate big data (Svítek 2015).

Cities are both the key domain for a sustainable future and the critical arena to address sustainability issues such as sustainable urban mobility (Frantzeskaki et al. 2015). In this instance, urban data can be used to create new economic and social values as well as innovative urban services to improve mobility options for the city's residents, businesses, and visitors (Go Boston 2030 undated). Furthermore, in the context of Germany, taxis are bound within the city borders—an issue of national legislations[2]—thus cities are not only relevant but also serve as a key unit of analysis if one wants to conduct research on the taxi such as is pursued in the project "*Future Urban Taxi*".

[2]Para. 39 and Para. 51 of the Passenger Transportation Act (PBefG) as well as Para. 51 subpar. 1 nr. 6 of PBefG and Para. 37 sub-par. 3 phrase 6 of the Regulation on the operation of motor vehicles companies for passenger services (BOKraft) (BMJV 1961, 1975).

2.1 Comparative Approach: Selection of Cities

The cities were selected on the basis of providing a regional overview as well as a local overview of Germany to compare how each city fares according to their overall urban data availability. The selection of the cities was based on two key criteria—size of the city and its population—that derived two main categories: big cities which have an area of more than 200 km^2 and a population size of more than 500,000 inhabitants, and medium-sized cities which have an area of less than 200 km^2 and a population size between 100,000–500,000 inhabitants. As such, a total of 13 cities were selected and they include:

- Three international big cities namely Boston (U.S.), London (Europe) and Singapore (Asia) were selected to represent regional forerunners of urban data; and
- 10 German cities were selected to geographically represent Germany. The selection of German cities comprises five big cities—Berlin, Frankfurt, Hamburg, Munich, and Stuttgart—and five medium-sized cities—Bochum, Freiburg, Halle (Saale), Moers, and Ulm.

2.2 Methodology

The research methodology adopted to analyze the cities is based on four steps for assessing the availability of urban data in a city (see Fig. 1). The iterative approach of performing both quantitative and qualitative searches closes the data gap and provides a holistic overview of the availability of urban data in any specific city (see Fig. 2). Furthermore, an evaluation system developed within the project "*Future Urban Taxi*" provides a basis for assessing the overall urban data availability of a city through a quality index. This enables comparisons to be made based of each city's performance on this index (see Fig. 3).

2.2.1 Combining Quantitative and Qualitative Aspects of an Approach

On the one hand, a quantitative online search for urban data of a specific city is performed to provide a first impression of urban data availability in the city. To keep the data search consistent and manageable, the scope of this quantitative search is delineated to include data from three city sectors deemed as most relevant to the central focus on taxis in the project "*Future Urban Taxi*":

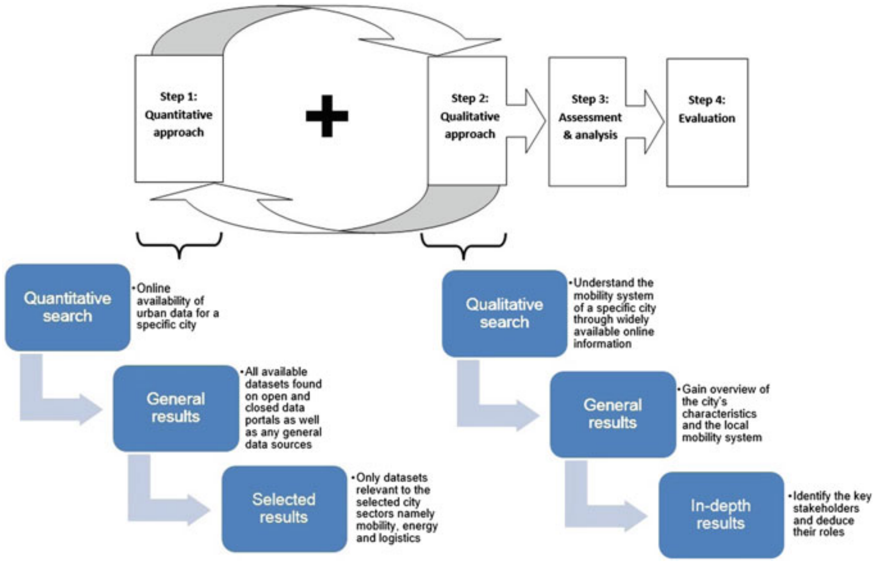

Fig. 1 Overview of the methodology

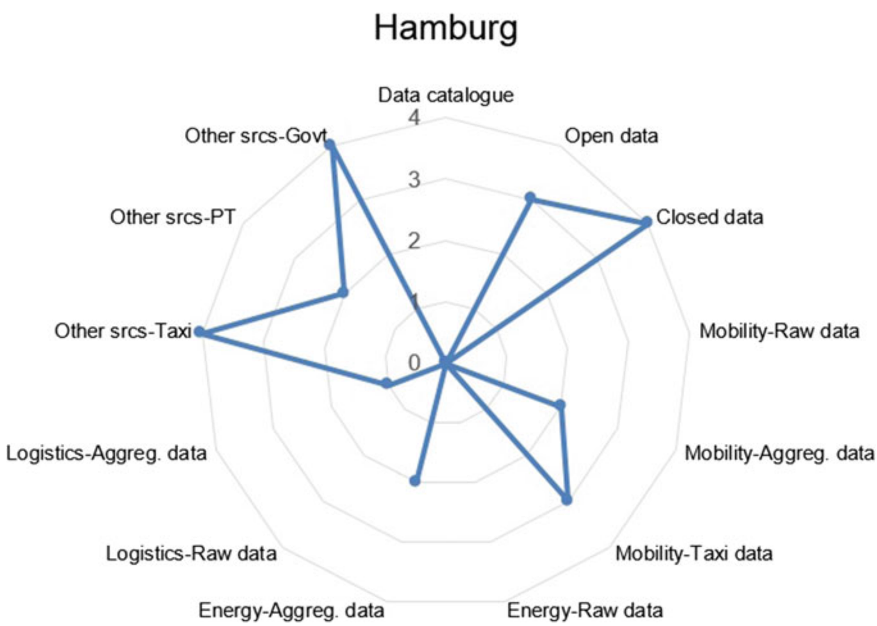

Fig. 2 Hamburg—best performer on the quality index among the ten German cities—is selected as the German model city to be used as case study for the second phase of the project "*Future Urban Taxi*"

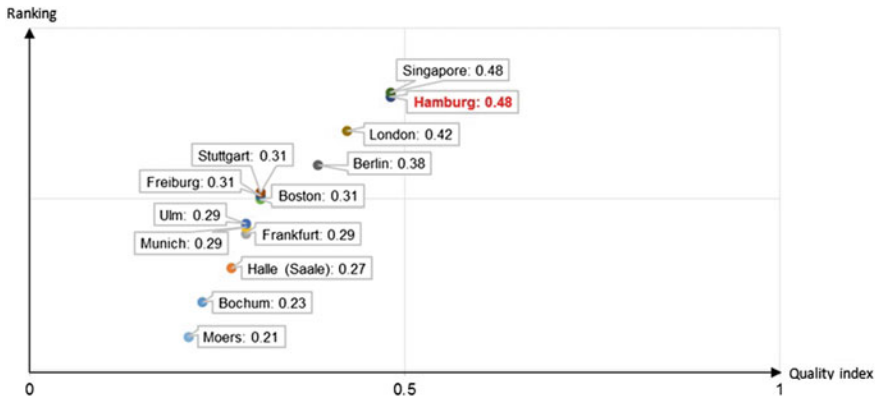

Fig. 3 Performance on the quality index for selected cities where comparisons were made

- Mobility-related data is needed to better integrate taxis into the mobility system of a city;
- Energy-related data is needed given the increasing shift towards electrification of taxi fleets, thus highlighting the interrelation between urban mobility and energy efficiency; and
- Logistics-related data is needed to better integrate taxis into the city's mobility system as one of the future logistics service providers.

On the other hand, a qualitative online search for other relevant sources in a specific city is performed to provide an indication of the network of potential data providers, as well as to gain a better understanding of the city's individual characteristics and its mobility system. Likewise, to keep the search consistent and manageable, the scope of this qualitative search is delineated to include conventional sources where data can be acquired from regular data providers, which are categorized as follows:

- Taxi-related sources refer to taxi companies and call centers;
- Public transport-related sources refer to local public transport companies and associations; and
- Government-related sources refer to local government agencies.

2.2.2 Deriving Performance on the Quality Index

Each indicator can be given a value of 0 (lowest value, in view of poor data unavailability) to four (highest value, in view of excellent data availability). For comparison of each city's performance on a quality index, the total given value of each city is first derived by summing up the respective values given to all its 13 indicators (see Table 1).

Table 1 The 13 indicators used to measure a city's performance on a quality index

General urban data availability	
Indicator 1	Data catalogue
Indicator 2	Open data
Indicator 3	Closed data
City sector: mobility-related data availability	
Indicator 4	Mobility-raw data
Indicator 5	Mobility-aggregated data
Indicator 6	Mobility-taxi data
City sector: energy-related data availability	
Indicator 7	Energy-raw data
Indicator 8	Energy-aggregated data
City sector: logistics-related data availability	
Indicator 9	Logistics-raw data
Indicator 10	Logistics-aggregated data
Availability of other relevant data sources	
Indicator 11	Taxi-related sources
Indicator 12	Public transport-related sources
Indicator 13	Government-related sources

- TGV refers to the total given value of each city
- V_{i1}, V_{i2}, $V_{i(n+1)}$, …, V_{i13} refers to the given value of the respective indicator

$$TGV = \sum V_{i1,} V_{i2,} V_{i(n+1),} \ldots, V_{i13}$$

The comparative value of each city is then derived by dividing its total given value against the maximum achievable total value of 52.

- MATV refers to the maximum achievable total value
- T_i refers to the total number of indicators = 13
- HV refers to the highest value which can be given to each indicator = 4

$$MATV = T_i \times HV$$

- CV refers to comparative value, and it indicates each city's performance on the quality index

$$CV = \frac{TGV}{MATV}$$

3 Key Findings and Discussion

All selected cities, except Munich and Stuttgart, have an open data portal. In terms of mobility data available on these cities' respective open data portal, the city of Bochum is the only one which does not provide mobility data on its portal. Furthermore, only three cities—Boston, Singapore, and Hamburg—provide some taxi data on their open data portal. Since not all cities have an open data portal and the data available on these portals are mostly limited and poor, data on closed data portals such as DataMarket and Statista were also considered. Hence, in terms of the overall data availability for the three selected city sectors:

- Aggregated[3] mobility data are available in all selected cities, but raw[4] mobility data are available only in Boston and Berlin.
- Aggregated energy data are available in all selected cities, except Bochum and Moers. Raw energy data are available only in Boston.
- Aggregated logistics data are available in all selected cities, except Moers. Raw logistics data are unavailable in all selected cities.

As the taxi is the central focus of the project "*Future Urban Taxi*", the availability of taxi data is thus highly relevant yet extremely lacking in view of the findings yielded by quantitative means through the access to open and closed data portals. In this instance, the qualitative approach is able to reveal some interesting findings:

- While taxi companies and call centers in most German cities collect data—include global positioning system (GPS) data—for the purposes of their business operations, these taxi data are often either not stored at all or only stored for a certain period of time and then destroyed.
- On the contrary, the city of Hamburg actively collects and stores a huge amount of taxi data—mainly for fiscal purposes—through the fiscal taximeter. As a result, the city is able to generate more tax revenues, thus undermining the mechanics and effects of illegal taxi operations. The fiscal taximeter is a tax-control device that not only aids city authorities in carrying out fiscal management of the taxi industry, but it is also a vital tool for taxi companies to manage their fleets by integrating multiple functions such as auto billing, invoice printing, mileage-info collecting, and data storage.
- In Germany, the legal obligation to use the fiscal taximeter will become binding by November 2016 and all cities across the country are then obliged to introduce fiscal taximeter for their taxi industry.[5] In view of this, Hamburg's commitment to being the first German city that already uses the fiscal taximeter has earned

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[3]These are analyzed data which are collected, stored and processed for a certain purpose(s).

[4]These are unanalyzed data which are (covertly) collected and stored in their initial state. Such data can be a result of the digital trace (e.g., social media accounts, email accounts, credit cards, mobile phones, etc.) left behind from our interactions with computing systems, digital infrastructure, and services.

[5]See http://taxipedia.info/fiskaltaxameter.

acceptance and trust from its local taxi companies. As such, the city authorities and local taxi companies share a good and mutually-beneficial relationship which, in turn, also benefits other parties such as research institutes since the former two are rather open to cooperation on relevant topics of interest.

The key results above therefore suggest that in order to better integrate taxis into cities' mobility systems and transform the taxi into a more sustainable mode of transportation, cities would need to be more proactive in collecting, storing, and making taxi data available and accessible. Moreover, while open data portal may be a good platform to promote urban data sharing and provide data access to support researchers and developers in creating economic and social values as well as innovative urban solutions, not every city views this the same way—a significant amount of resources and manpower is foreseen for the set-up and maintenance of an open data portal—mostly due to limited capacities but also having to deal with the delicate issue of data privacy. This means that failure to account for the changing nature of data collection, usage, and access can lead to undesirable outcomes such as missed economic opportunities and unintended erosion of privacy rights (OECD/ITF 2015a; Starks 2015). For instance, the German federal privacy laws force the local transport authorities to develop their own mobile applications (apps). However, the authorities are not allowed to collect back the data from their users, and this essentially puts them at severe disadvantage because, despite having access to the data generated from apps which they have invested time and effort to develop, the local transport authorities are unable to use these valuable data due to privacy laws (Erez 2015). Finally, it should be noted that although taxi services are very similar around the world, taxi industries are regulated in very different ways (Aarhaug and Skollerud 2014)—even within the same national boundary, legal obligations may vary across cities and regions as seen in the German context. Hence, taxi systems need to be analyzed in context by taking into consideration other interconnected system components (e.g., legislative framework, governance processes and structures, existing infrastructure, and demographics), because the context is highly relevant for the varying attributes of how taxi systems function.

4 Conclusion and Outlook

4.1 Big Data Analytics and the Promise of Smart Mobility

In the light of megatrends[6] such as demographic patterns—growing world population and rapid urbanization—and climate change—increasing motorization rates—where resource and environmental stress stem, planning for urban mobility is thus an

[6]These trends are predictable global challenges that exist today and will become acuter as well as gain much greater momentum in the future. They are the larger forces shaping policy choices of the public authorities for dealing with emerging, long-term issues which are projected to have

increasingly complex and demanding task to overcome the shortcomings of transportation systems, such as inefficiency and unsustainability. Regardless of regions, national/city territorial sizes or prosperity levels, megatrends are relevant worldwide. However, the pressures on transportation systems caused by these trends will necessitate varying changes—each region or city will need to determine the degree of relevance and the impact that these megatrends have in the local context so as to respond proactively/accordingly with necessary changes in policies, regulations, and/or programs (e.g., infrastructural, social) (NIC 2012; KPMG 2014; Svítek 2015).

Furthermore, enabling technologies such as new data-collection mechanisms based on ubiquitous digital devices, immensely-enhanced storage capacity, and computing power, as well as advanced sensing and communication technologies enable massive amounts of data to be used and transmitted in almost real-time. Such acceleration in both the growth and speed of exploitable data—even more optimally with open data—will trigger significant and disruptive changes across sectors, including the mobility sector (OECD/ITF 2015a). In this instance, technologies (i.e., boosting economic productivity and solving the problems caused by megatrends through technological advancements) and governance (i.e., governments and institutions being fast enough to adapt and to harness change or be overwhelmed by it) are two key game-changers[7] that will largely determine what kind of transformation we will see in the urban mobility systems of the future (NIC 2012).

In view of the above, there are important consequences to be addressed when the "known"-megatrends meet the "unknown"-game-changers. For instance, relevant for our discussion in this paper are the consequences of enabling technologies such as big data or autonomous vehicles that blur the boundary between private and public (in terms of data and mobility options) as well as the transformations in the mobility system such as the rise of the sharing economy (KPMG, 2014: 23). The equation gets even more complicated when the "unknowable unknowns"-black swans[8] turn up, which will drastically alter the magnitude and impact of these consequences. An example would be unanticipated cyber-attacks that cripple key IT infrastructure which, in turn, will have domino effects on other interconnected smart systems thus causing a large-scale disruption. This inherently means that long-term—both urban and regional—planning is a real challenge considering the intricate combinations of these meta-forces.

Amid the manifold dynamics of the meta-forces, big-data analytics open new pathways towards the understanding of highly complex systems such as cities and their infrastructure and emerges as a useful framework for analyzing and modeling

(Footnote 6 continued)

relevance for at least 20 years and thereby also shaping the role of public authorities well into the future (NIC 2012; KPMG 2014).

[7]Similar to megatrends, game-changers are transformational but their occurrence – where and when, as well as their magnitude and impact – is filled with uncertainty thus unpredictable (NIC 2012).

[8]These are discrete, unanticipated events which have profound and devastating consequences (NIC 2012).

complex systems (Offenhuber and Ratti 2013: 14). For instance, a compelling case to demonstrate the value of big data analytics is intelligent transport where visualization and analysis of the real-time use of transport networks are made possible (Santi et al. 2014; OECD/ITF 2015a). In this sense, the promise of smart mobility—one "that anticipates future change and takes advantage of new opportunities" (Buscher et al. 2014: 3)—can thus be realized through big-data analytics which is a proactive and holistic approach to better understand mobility-related big data for improving mobility planning and management.

As an integral component of the smart-city concept, smart mobility refers to a transport infrastructure that is not only digital technology-enabled and intelligent but also more sustainable. Hence, smart mobility entails the capability to alter the way people use mobility services by equipping them with more and better information as well as to promote the efficient use of transport infrastructure. However, technologies and services that enable smart mobility rely on vast amounts of—mostly or near real-time mobility-related—data (Buscher et al. 2014). In view of this, smart mobility can leverage the catalytic power of IoT which simplifies smart cities through ubiquitous sensing processes, as well as active and large-scale data collection.

Lying at the heart of both the power of IoT and smart cities is thus the collective power of completely disparate elements to generate the big data needed to enable smart mobility. Big data is considered as:

- An opportunity because when used wisely, it "can enable improved system functionality, environmental sustainability, traveler experience and new economic value" (Buscher et al. 2014: 21); and
- A challenge in terms of its management and governance because public authorities must critically evaluate where and how new or newly available/accessible big data are collected to meet what purposes and for what uses so as to avoid any breach of data privacy (OECD/ITF 2015a).

With new technologies becoming increasingly embedded within everyday objects and parts of objects, it means that IoT is also rapidly increasing in scale and reach, whereby its effect is both cumulative and potentially transformative. This implies a dramatic impact on the dynamics of urban systems and lifestyles which will see a change from conventional data collection, analysis, and reactive approaches, to real-time interchange of sensing and proactive responses across a very wide spectrum of city operations and activities. As such, IoT will enable people, places, things, devices, networks, and processes to interconnect in new ways that promote a more responsive urban experience (McClelland 2015).

As Buscher et al. (2014: 3) pointed out, "the need to treat mobility as one tool to enhance economic, social and environmental well-being", and Svítek (2015: 3) later reiterated a similar point that "urban mobility is progressively becoming a decisive factor for the further sustainable development of cities", yet the adverse side-effects of urban mobility—such as congestion, pollution, and accidents resulting from increasing urban traffic—are directly affecting the cities' attractiveness and competitiveness. Therefore, mobility is given highest priority on top of the political agenda for planners and policy makers. In view of this—and especially crucial within the frame of smart cities—cities need to leverage big data and IoT since these are considered to be key enablers for transforming urban systems towards a sustainable future. As such, making key urban data available and accessible as well as keeping them up-to-date and interoperable will not only facilitate big-data analytics for realizing the promise of smart mobility, but it will also imply how a city fares globally in the long-term transitions towards sustainable urban development and the smart city of tomorrow.

4.2 Future Urban Fleets: Taxis in Smart Cities

A cornerstone of the smart city is sustainable urban mobility that aims to maximize usage of all available operational, information, and telecommunication technologies for leveraging rich and reliable data generated by the city infrastructure and urban community. This not only facilitates urban planning and management, but it will also allow close integration of various sectors such as mobility, energy, and logistics, which in turn will lead to improved synergies that help enhance the quality of life in cities (Buscher et al. 2014; Svítek 2015). As such, in the smart city age, cities need to start thinking about big data differently and act on them so as to come up with "a holistic response to urban mobility [that] optimizes both supply and demand solutions to facilitate more sustainable outcomes" (Buscher et al. 2014: 2). The planning for urban mobility will need to consider the active collection and strategic exploitation of large datasets—that is, big data—whereby the processing of these large volumes of data can reveal mobility patterns which, in turn, provides space to rethink the role of taxis in smart cities as well as how taxis can be efficiently and sustainably integrated into the urban-mobility system of specific contexts.

As urban mobility systems continue to face great challenges while on their way to becoming more efficient and environmentally-friendly, an issue that remains contentious and confounding is the position of cars within the evolving sustainable mobility paradigm—"the value proposition offered by the automobile—comfort, convenience, utility, safety, security, flexibility—is likely to remain compelling [...]" (Borroni-Bird 2012: 334; Driscoll et al. 2012). Yet through new forms of transport and integrated mobility options made possible by smart IT solutions[9] and infrastructures, the mobility paradigm is blurring between the flexible, comfortable private transport and the high capacity, environment-friendly public transport which will never be individualized as its main focus is mass transit.

In view of the taxi's semi-private character for being favorably positioned between the public and private transport systems—thereby having the capacity to

[9]Such solutions can help to improve the efficiency of the mobility system by redistributing demand across modes, routes, and time, which in turn provides a wider spectrum of mobility options (Miller 2013; Buscher et al. 2014).

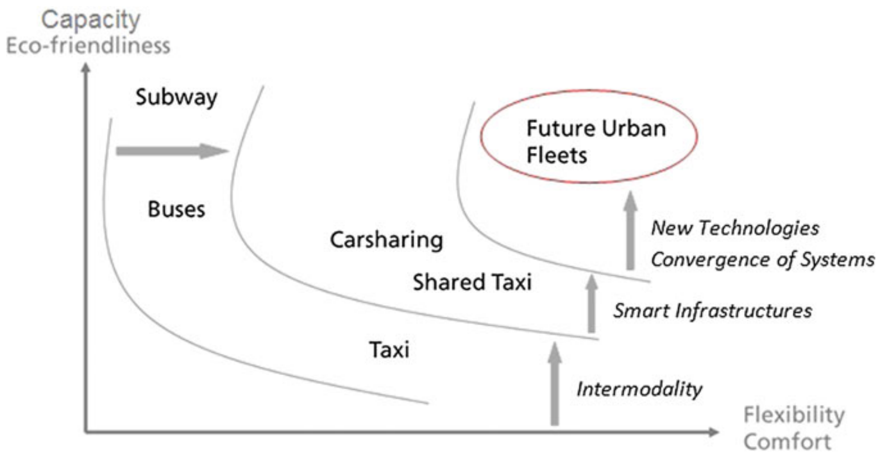

Fig. 4 Overcoming the mobility paradigm based on the theory developed for trade systems by Ahlert and Kenning (2007)

merge the gap between these two classic systems by making possible flexible, intermodal combinations—the potential of the taxi within the sustainable mobility paradigm to offer relatively individualized yet environment-friendly mobility options such as ridesharing, electric or autonomous vehicles is often overlooked (Aarhaug and Skollerud 2014). Moreover, the taxi industry has long been neglected as a field of scientific research (Szell and Groß 2013: 32), yet it encompasses tremendous potential to overcome this paradigm (see Fig. 4). This potential is still inadequately explored since there has not been much scientific work or a holistic approach in the field dedicated to analyzing taxi systems. In addition, even with the promise of big-data analytics to provide a systemic understanding of taxi systems, the potential of taxis cannot be fully evaluated due to a severe lack of taxi data as supported by our key findings. In this instance, assessments—which can benefit key decision makers such as planners and policy makers—of the technical and economic feasibility of introducing innovative future urban fleets into mobility systems cannot be made. In summary, taxis are an essential part of future urban fleets in smart cities, but its potential to contribute towards sustainability is understated.

Finally, four big drivers, namely: electro-mobility, autonomous driving, shared mobility and convergence of cities' systems,[10] are going to fundamentally change urban mobility systems worldwide. On the one hand, as cities around the world discuss the future design of sustainable mobility, electro-mobility continues to dominate this discussion and reinforce its established place for becoming the future mode of transport in urban mobility systems. On the other hand, autonomous driving, as a technological game-changer coupled with the rise of sharing economy,

[10]Cities are complex ecosystems and, therefore, innovations in one subsystem will have direct and/or indirect effects on various others.

will also play a key role in driving the transformation of the future urban-mobility system. Indeed, the current mobility landscape is already on the edge of disruption, and what this essentially means for transport remains speculative yet promising. While the rapid development of autonomous vehicles is accelerating the acclaimed entry of these vehicles into the mainstream, on-demand mobility solutions such as ride sharing (e.g., Uber, Lyft), car sharing (e.g., car2go, Zipcar) and bike sharing (e.g., nextbike, Smoove) are also picking up pace in shaping the future of urban mobility. As such, the potential social, environmental, and economic impacts from the coupling of autonomous vehicle technologies and shared mobility are already anticipated to be positive and profound (Shaheen and Christensen 2015). For instance, a study led by OECD/ITF (2015b) showed that by coupling the benefits of both these systems, autonomous shared fleets can make a significant impact leading to a safer, more sustainable, and efficient urban mobility system. Hence, future urban fleets comprising integrated shared fleets of autonomous vehicles that roam the streets of a city will usher in a new era of mobility.

In view of the above, the four drivers will have huge impacts on the taxi and also other vehicle fleets. Adopting new technologies introduced through these drivers, vehicle fleets such as taxis, corporate fleets, or car-sharing fleets will realize the greater potential to improve operational efficiency and mobility management for meeting travel demands in the most effective and sustainable way. As such, a vision for taxis of the future is one that is shared, electric, and—at least in some parts of a city—autonomous, embedded within the convergent urban systems.

Within the project "*Future Urban Taxi*", a data-oriented approach is adopted to build the ideal transformation scenarios of shared, electric, autonomous, and convergent taxi systems in a specific city—Hamburg—using an intelligent combination of the four drivers based on big-data analytics to:

- Evaluate the potentials of mobility concepts—taxi ridesharing, electrification, and automatization of taxi fleets—in a convergent taxi system;
- Develop a parametric model of a taxi system to be embedded within the case-study city; and
- Conceive appropriate business models for the future urban fleets.

This way, it will take us one step closer to realizing the aforementioned vision—one that is similar to what Miller (2013: 305) envisioned, "a seamless multimodal transportation system that is sufficiently flexible and robust […]" combined with "[…] data streams [that] are fused, interpreted and made available in a virtual environment with tools for human engagement and shared decision making".

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Modeling Future Land Use and Land-Cover Change in the Asyut Region Using Markov Chains and Cellular Automata

Hatem Mahmoud and Prasanna Divigalpitiya

Abstract The Asyut region in Upper Egypt is often considered as one of the most appealing regions in Upper Egypt for its importance as a medical, educational, and commercial center. As a result of these factors and regarding its location, which is surrounded by agriculture land, the available land area is quickly decreasing. However, the government has established New Asyut city to absorb the urban growth outside the Nile Valley. Yet the region's importance and the increasing population have led to significant urban growth, which has led to increasing loss of agricultural lands within the Nile Valley. Modelling spatially the dynamic change is important for innovative planning strategies. This study's main aims are to characterize the past urban growth process and to investigate a future scenario intended to help decision-makers in redrawing their policies for sustainable development to save the agriculture areas by absorbing the urban sprawl towards the new cities outside the Nile Valley. Satellite-derived Land Use and Land Cover (LULC) maps of the study area from 1990, 2003, and 2015 were processed. The explanatory driving forces were quantified and ordered using an analytical hierarchy process. The outputs were then processed within a framework of the Markov-cellular automata, and a multi-criteria evaluation (MCE) was used to produce the future suitability model. The model was verified using ROC and Kappa statistics. The study concluded that combinations of diversified driving forces exist during different periods. It found that the current urban development process is in a critical stage where urban and rural areas will face unprecedented stress on agriculture areas over the next 15 years. The present policies cannot deal with the future challenges regarding the direction of urban development. However, the study

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suggests that differentiated policies, based on the investigated scenario, should be considered to guide reasonable urban expansion; these have important implications for urban planning and management in Egypt.

Keywords Remote sensing · Scenario modelling · Urban development · Land cover land use change · Egypt

1 Introduction

1.1 Background

Urban sprawl in Egypt is one of the main problems that reduce the limited but highly fertile lands in the Nile Valley of Egypt (Belal and Moghanm 2011). Egypt's uncontrolled population growth and migration into urban areas represents the main reasons for urban sprawl. It suffers from unbalanced distribution of its population, as 95 % of the total area of Egypt is uninhabited land. The majority of the population is concentrated on the banks of the Nile. The encroachment of urban settlements onto agricultural lands may result in dire consequences. The ever-increasing population decreased the agricultural-land area, per capita, from 0.12 ha in 1950 to 0.06 ha in 1990 (Ghar et al. 2004). Rapid urban sprawl has caused agricultural lands to be decreased by 36 % or about 1.5 million acres (6300 million m^2) (Rageh 2007). Since the 1970s, the Egyptian government has formulated plans and policies to save the agricultural lands and redistribute the population horizontally through establishing new urban settlements across the desert areas outside the Nile Valley; this is intended as a way to reduce the urban pressure on long-standing agricultural land. However, these policies have failed, especially in the Upper Egypt region. Thus decision makers in Egypt face unprecedented challenges with regard to governance, urban planning, and land-use management. As a consequence, knowledge concerning spatial-temporal LULC change and predicted changes that might be occurring have played an important role in the decision-making process. Monitoring growth helps to develop an understanding of past trends and growth patterns, while urban-prediction models provide insights into possible future developments. Both approaches are necessary for implementing appropriate strategies regarding the urban planning decision-making process (Moghadam and Helbich 2013). In this study, the status of LULC of the Asyut region was mapped using multi-temporal data from satellite images, and the future of LULC change was then predicted using Markov-cellular automata (Markov-CA).

Cellular automata (CA) may be defined as discrete models, useful in complexity science, to understand the spatial dynamics of change over time (Vaz 2012). CA, applied to urban growth, relies on the iteration of a given dimensional cell, based on supporting socio-economic and geographical data, to change into urban or non-urban form within a given time frame (Vaz 2012). The simplicity of this model in dealing with complex variables, has attracted use in many studies in recent years, which employ it as an effective tool to study urban dynamics in rapidly growing cities, to predict urban scenarios for sustainable growth, and as an effective decision-making tool for planners and governments. CA for urban growth usually maintains similar frameworks regarding assembly, testing, validation, and calibration. However, in this study, Markov-CA was used. It is a combination of CA, Markov chain, multi-criteria, and multi-objective land allocation (MOLA) with land cover prediction procedures that add an element of spatial contiguity as well as knowledge of the likely spatial distribution of transitions to Markov-chain analysis. A Markov-CA is capable of simulating temporal and spatial dynamics of LULC change by integrating remote-sensing and GIS-based data with bio-physical and socioeconomic data (Sayemuzzaman and Jha 2014). This technique has not been applied in Egypt. This study is the first study in Egypt to predict future urban sprawl in a region using the CA technique. It aims to characterize the past urban growth process and expects to use the predicted future-growth pattern during the next

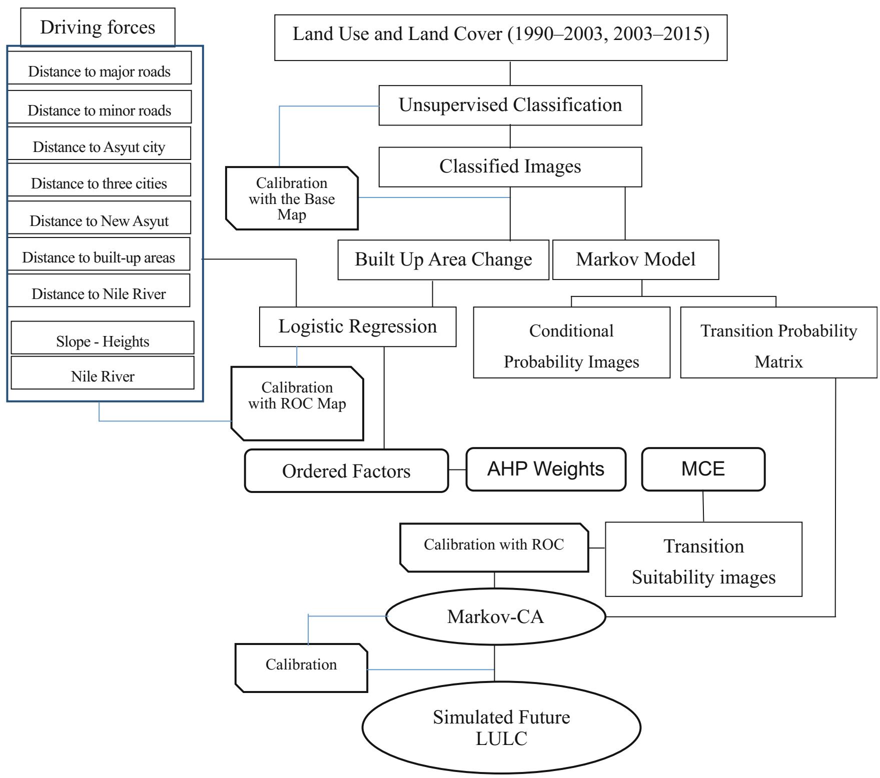

Fig. 1 The study flow chart

15 years as a tool for better land-use planning. The case study is considered a typical case in the Upper Egypt region, so the results can be applied to the whole Upper Egypt region. The study introduces an approach for the Egyptian case that enables choosing the best strategic development to help in the decision-making process when using a quantitative analytical approach. The study methodology is well represented in the flow chart in Fig. 1.

2 Materials and Methods

2.1 Study Area

It has been a challenge to determine appropriate spatial detection boundaries. Asyut center and its connection to the new Asyut city were chosen as a case study because this region is often considered as one of the most appealing because of its importance as a medical, educational, and commercial center in Upper Egypt. Moreover, the urban growth pattern of this region has never been analyzed. The study area contains three administrative centers and a new city; Asyut center consists of its capital city—Asyut—and seven local units “villages and followers:” El Fath center, its capital Elwast, and six local units; and Abnoub center which includes its capital Abnoub city and four local units. Abnoub and El Fath were administrative centers and were separated in 1998; it also contains New Asyut city “NAc.” Asyut city is one of the biggest and most important cities in Upper Egypt, located on the west bank of the Nile, 375 km south of Cairo (Fig. 2). This affected urban planning and led to fast and uncontrolled urban expansion. Asyut is one of Egypt’s medium-sized cities with a population of 509,156 (Asyut Governorate

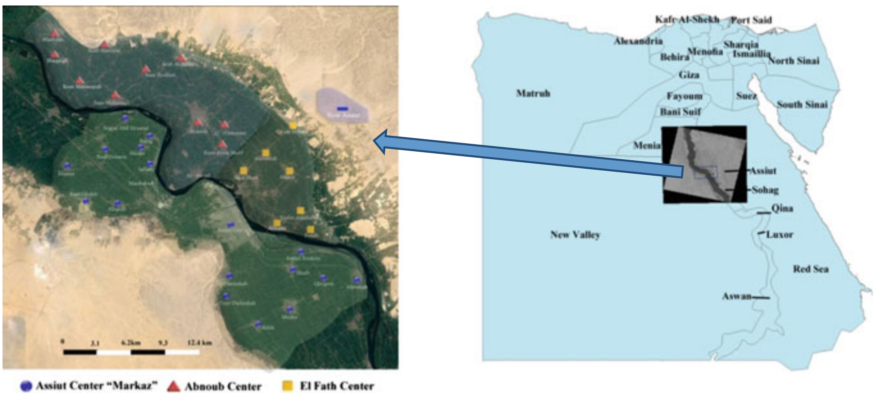

Fig. 2 **a** The study area: three administrative centers “Markaz:” Asyut, Abnoub, Elfath (Adapted from Google Earth 2015). **b** Egypt governorates map and the study area. *Source* Adapted from General Organization for Physical Planning (2015)

Information Center AGIC 2015). As of 2015, the study area had a total population of 1,732,931 and total area of 171,083 acres. It was possible to provide population statistics for the study area for the years 2015, 2004, 1996, and 1986. Based on the population growth ratio in the Asyut governorate in 1986–1996 and 1996–2066, which were 2.24 % (AGIC 2015) and 2.12 % (calculated) respectively, the population in 1990 and 2003 were calculated (see Table 1). The study area coordinates are (Min X 300495, Max X 341745, Min Y 2996895, and Max Y 3026805—reference system UTM 36 N-).

2.2 Data and Pre-processing

The acquired data of the study area were processed and analyzed using remote sensing, TerrSet software, and GIS techniques to collect information on urban growth from 1990 to 2015. The temporal satellite images were collected for use in the current case study from Landsat satellite imagery (USGS 2015) which was helpful in providing efficient support for the study-area analysis. The following Landsat time stamps were gathered for spatio-temporal mapping: 1990, 2003, and 2015. A projection to the UTM zone 36 North, as well as resampling to a common spatial resolution of 30 m was necessary, to provide a homogenous time series.

2.3 Extraction of Land-Use Data for the Model

In order to detect, quantify, and analyze the changes, unsupervised classification ISODATA were used for the years 1990, 2003, and 2015. The LULC was generated (Fig. 3). The factors affecting the urban sprawl in the study area were tested and considered (Mahmoud and Prasanna 2015), which determined the CA-transition rules. The rules for this study are defined as Euclidean distance from major roads, minor roads, existing built-up areas (including the three cities in the

Table 1 Study area statistics

Name	Population 2015	Area in acres	Area in km^2	Population in 2003	Population in 1990
Asyut center	1,007,332	53,897	218.11	774,525	576,489
El Fath center	302,997	38,093.76	154.16	231,323	145,305
Abnoub center	392,602	46,293.2	187.34	301,863	189,616
New Asyut	30,000	32,800	132.74	–	–
Total	1,732,931	171,083.96	692.35	1,307,711	911,410

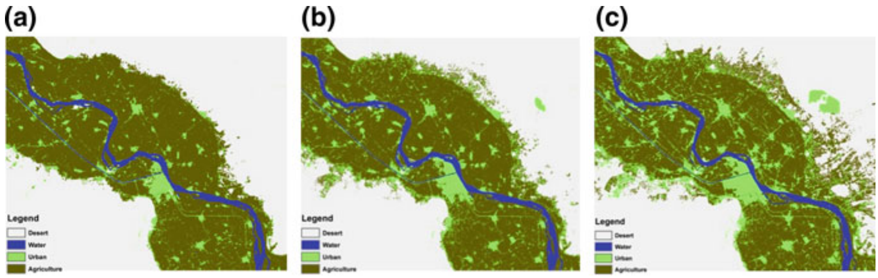

Fig. 3 Extracted land use maps **a** 1990, **b** 2003, **c** 2015

study area), Asyut city, New Asyut city, the Nile River, the border between the Nile Valley, and the deserts. For example, the area closer to Asyut city has a higher probability of development, whereas areas farther away from main roads are less prone to development. The transition matrices were constructed from the change/no-change matrices obtained in the change-detection analysis and the modeling processes implemented using algorithms supplied with the TerrSet software. The model calculated the change between 2003 and 2015 and thus predicted the LULC 2015. According to the predicted and generated LULC 2015, the model was validated. Finally, a prediction of LULC 2030 was undertaken using Markov-CA, incorporating the above mentioned parameters.

2.4 Results

The classification process resulted in three land-use maps that discriminated among the following four land-use categories: desert, water, urban (built-up areas), and agriculture. To assess the results, a file of point locations was also produced. One hundred points were created according to a stratified random-sampling scheme. This scheme works by dividing the area into a rectangular matrix of cells. It then chooses a random location within each cell. The accuracy of the system classification compared to the real LULC was 88 % for the 1990 data; 93 % for the 2003 data; and 84 % for the 2015 data.

In order to understand the changes in LULC, the gains and losses for each class were calculated as described in Table 2 and Fig. 4. In the first period (1990–2003), most land conversion was attributed to the replacement of agricultural lands with urban areas. About 8,428 acres had changed to built-up areas, with 6,125 acres (72.6 %) being former agricultural lands. However, there was partial compensation of agricultural lands; 4,235 acres of desert land were converted to farming. For the period between 2003 and 2015 after the establishment of New Asyut city (NAc) in 2000, a very rapid build-up of development of more than 12,496 acres was observed to have occurred, with approximately 9,020 acres (72.2 %) of the urban sprawl encroaching onto agricultural lands. Moreover, the rate of land development

Table 2 Urban land expansion in the study area from 1990 to 2015

Year	Area (acres)		Change rate %		2003	2015	Growth rate %	
	1990	2003	−	+			−	+
Urban	13482.44	21911.1	0	38.47	21911.1	34084.06	0.22	36.46
Desert	166062.88	159525.04	4.18	0.25	159525.04	143009.5	11.05	0.58
Agriculture	117156.43	115258.70	5.58	4.03	115258.70	120280	9.46	13.21
Water	8180.25	8185.13	0	0	8185.13	7506.38	17.95	10.54

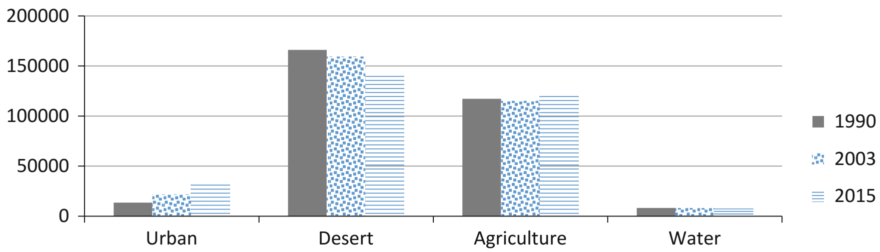

Fig. 4 Temporal changes of land use classes (in acres)

in the study area outstripped the rate of population growth. Despite the fact that most of the urban sprawl occurred on agricultural land, thus decreasing the latter by 9.46 %, there was an increase in new agricultural land, especially in the eastern desert area, next to the NAc. The increase in agricultural areas more than compensated for the loss due to urban sprawl, even resulting in an increase in the total agricultural areas in this period by encroachment onto agricultural lands; however, the new extensions towards the new city succeeded in creating a good environment for agricultural sprawl.

3 Markov Chain Land-Use Simulation

After extracting the land-use model, a Markov chain "MC" model was used to quantify transition probabilities of several land-cover categories for discrete time steps. The model focuses on quantity in predictions for land-use changes, and the model's spatial parameters are weak (Nejadi et al. 2012). The MC model analyzes a pair of historic land-cover images and outputs a transition probability matrix, a transition area matrix, and conditional probability images for each category of classified land uses (Sayemuzzaman and Jha 2014). The first step in applying the MC model is comparing the historic land-use maps for two periods: from 1990 to 2003, and from 2003 to 2015, to produce images for the categorical pattern of changes between the maps of the two dates in each period (Fig. 5). The transition

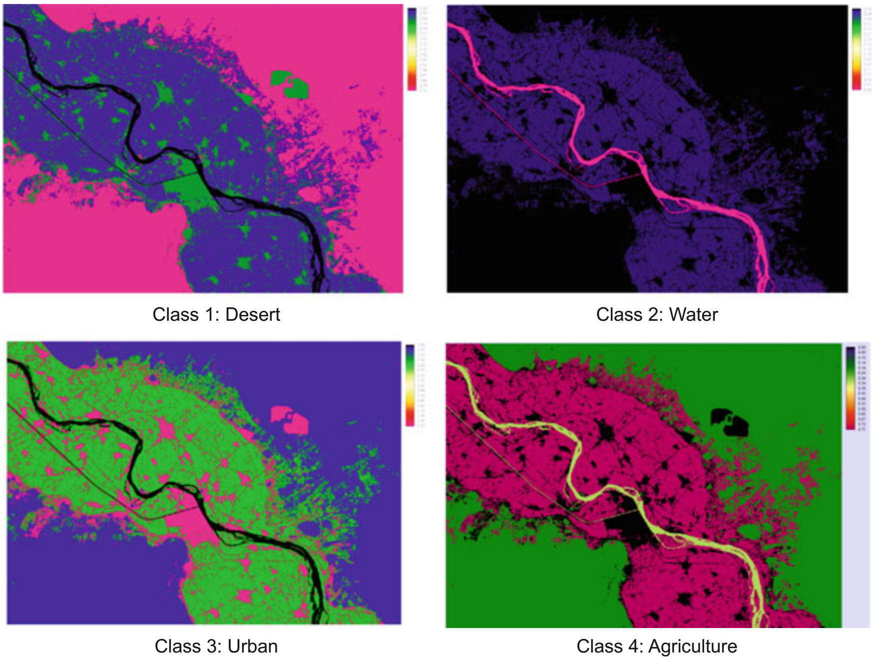

Fig. 5 Conditional probability images based on projection date 2030

Table 3 Markov transition probability

	1990–2003				2003–2015			
	Desert	Water	Urban	Agriculture	Desert	Water	Urban	Agriculture
Desert	0.8364	0.0000	0.0540	0.1096	0.7509	0.0001	0.0460	0.2029
Water	0.0000	0.8700	0.0000	0.1300	0.0000	0.6769	0.0008	0.3222
Urban	0.1300	0.0000	0.8700	0.0000	0.1318	0.0000	0.8676	0.0006
Agriculture	0.0109	0.0002	0.1639	0.8251	0.0236	0.0165	0.1919	0.7680

probability matrix is then calculated according to the projection date 2015 for the first period and 2030 for the second period (Table 3). The predicted image for 2015 was compared with the base map of 2015 for validation.

3.1 *Standardization and Weighting of Main Driving Forces*

The evaluation of the driving forces that shape urban expansion and affect land use transition probabilities was executed within the Analytical-Hierarchy-Process (AHP) framework. The relative importance of each criterion was determined by applying the logistic regression model on them in a previous study (Mahmoud and

Prasanna 2015). The individual weights are listed in Table 4. Driving forces with higher weights are statistically more important. The consistency ratio was calculated to verify the logical consistency of the selected weights. The suitability of the defined weighting schema was confirmed, because the value was 0.03 which is below the critical value of 0.1 (Malczewski 1999).

3.2 *Predicting Future Urban Expansion*

The multi-criteria evaluation (MCE) (Eastman 1995) and extracted weights of urban driving forces that cover the natural and socioeconomic variables were used to generate the group of suitability images for 2015 and 2030 (Figs. 6 and 7). The suitability images for each land cover establish the inherent suitability of each pixel for each land-cover type in a specified time period (Eastman 2006). The suitability images for urban change for 1990–2003 were validated using the relative operating characteristic (ROC) test (Swets 1986), an excellent instrument to evaluate the degree of certainty of the transition suitability images. ROC values range from 0 to 1, where 1 indicates a perfect fit and 0.5 indicates a random fit. In our study, the initial result within 10 % of the sampling test. It was performed by comparing the suitability image of 1990–2003 (to predict 2015) with the image derived from the actual 2015 map. The value of ROC was 0.9168.

Although probabilities of land-use transition are provided on a per-class basis by the MC model, the spatial distribution of occurrences within each land-use class was lacking in the analysis (Belal and Moghanm 2011). Thus, the integration of cellular automata by using the Markov-CA model is required. For validation purposes, the transition probabilities for the period 1990–2003 and its suitability image were used in the model to predict the known map for 2015. Validation was conducted to ensure accuracy and an applicable simulation that represented effective predictions. The predicted image for 2015 was compared with the classified satellite-derived image on the Kappa statistic. The Markov-CA's overall simulation

Table 4 Extracted weights based on AHP

No.	Driving force name	Relative weights	
		1990–2003	2003–2015
1	Distance to New Asyut city	0.3313	0.3337
2	Distance to urban heart	0.2307	0.2302
3	Distance to border	0.1572	0.1568
4	Distance to minor roads	0.0509	0.1056
5	Distance to water	0.0327	0.0707
6	Distance to three cities	0.0477	0.0475
7	Distance to Asyut city	0.1059	0.0326
8	Distance to major roads	0.0236	0.0230

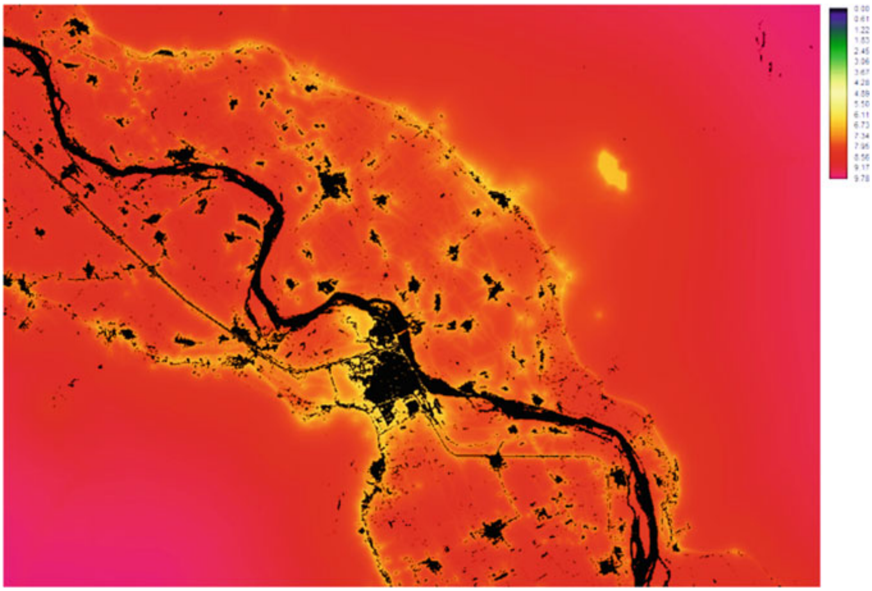

Fig. 6 The suitability images 1990–2003 to predict 2015

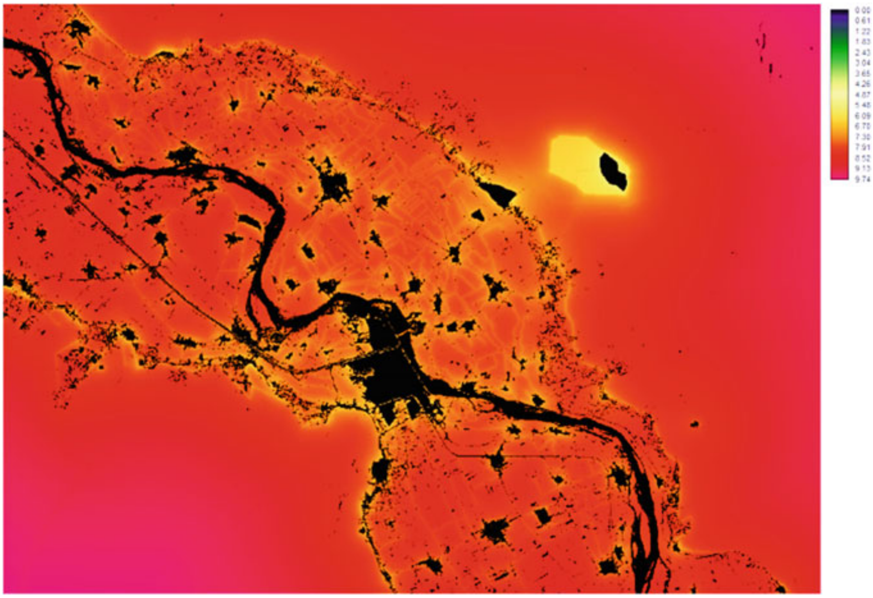

Fig. 7 The suitability image 2003–2015 to predict 2030

Fig. 8 2015 base map

success is 77.235 % which means a "substantial" degree in the level of agreement (Landis and Koch 1977). It was difficult to increase the simulation success due to the nature of the study area as most of the growth is informal growth. For the simulation of the 2030 LULC map, a similar procedure described for the 2015 simulated map was carried out, specifying 15 cellular automata iterations based on (1) the 2015 LULC base map (Fig. 8), (2) the 2015 transition potential maps, and (3) the 2003–2015 transition area matrix.

3.3 The Results

After extracting the simulated LULC for the year 2030 (Fig. 9), the changes in LULC, the expected gains, and the losses for each class were calculated. According to Table 5, Figs. 10, and 11, most land conversion will be attributed to the replacement of agricultural lands with urban areas. About 22,137 acres from agricultural lands will change to built-up areas. Thus the net growth rate of built-up areas is expected to be about 42.16 %. Despite the fact that the main aim for building New Asyut city was to absorb the urban sprawl from the agricultural lands, most of the urban sprawl will occur on agricultural land, thus agricultural lands may lose 18 % of their current extent. However, there was an increase in new agricultural land, especially in the eastern desert area, next to NAc. The increase in agricultural areas is more than compensated for by the loss due to urban sprawl, and even results in a very small increase in the total agricultural areas of 2.33 %.

Fig. 9 Simulated LULC change for the year 2030

Table 5 Urban land expansion in the study area from 2015 to 2030

Year	2015	2030	Growth rate %	
			−	+
Urban	34084.06	59240.18	−0.72	42.88
Desert	143009.5	114738.29	−19.94	0.72
Agriculture	120280	123821.69	−18.44	20.77
Water	7506.38	7079.82	−6.17	0.52

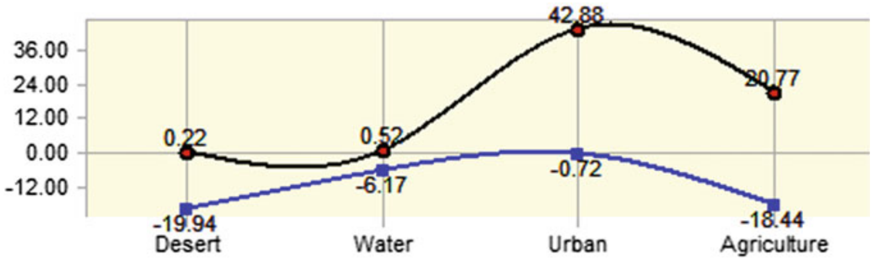

Fig. 10 Gains (*red*) and losses (*blue*) in land-use classes 2015–2030 (percentages %)

Looking at the spatial patterns of land change in the future, the evidence shows that the rate of conversions from non-built to built-up areas is quite rapid, with scattered patches of urban development in agricultural areas characterizing the urban sprawl in the Nile valley. The simulated future LULC changes indicate

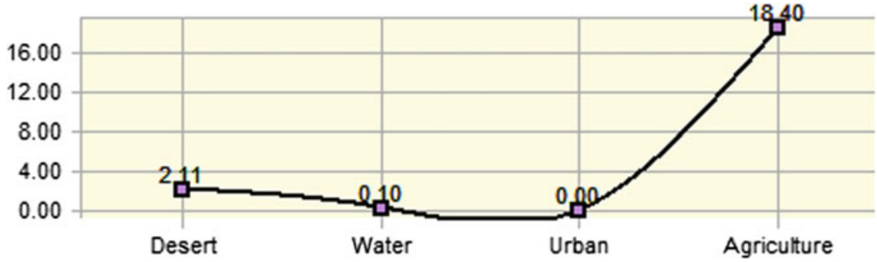

Fig. 11 Contributions of each land-use class in urban growth 2015–2030 (% change)

increasing pressure on agricultural lands (one of the most important resources in Egypt). Socioeconomic conditions and the roads network have played important roles in producing these spatial patterns. Spatial diffusion of built areas spreads outward from the core of existing built-up areas along with the roadways. This is mainly because of road expansion and weak regulation over increasing the population; citizens have no strong motivations to move outside the valley towards the new city.

4 Conclusion

The urban growth of Asyut region make it one of the fastest growing urban regions in Egypt, and this growth has unprecedented effects on LULC changes. However, no research had previously addressed the simulation of future urban growth of the Asyut region. In this respect, the Markov-CA model in combination with socio-economic and natural urban driving forces was used to predict the future LULC changes during the next 15 years (until 2030).

Strong evidence suggests that urban expansion will continue to occur in the Asyut region throughout the next 15 years. The temporal mapping of built-up areas and simulation models for the next 15 years indicate that the projected urban expansion will be directed mainly near to New Asyut city, existing built-up areas, and the agricultural-lands border. The main swap in land use will occur between urban and agricultural lands; however, it should occur between urban and desert lands. This problem is mainly because of (a) the relative location of these agricultural lands being near to existing built-up boundaries, (b) the lack of regulations that ensure protecting the agricultural lands, and (c) New Asyut city is not able to absorb all of the urban expansion. Thus, it is clear that the decision-makers should act strongly on other urban development driving forces than are used in this study, whether natural or socioeconomic, to control future urban growth.

The outcome of the LULC study investigated here will provide decision-makers and urban planners with the basic information necessary for the integrated assessment and management of future urban growth in the study area. It will inform them of the extent of growth that can be expected so that they can adapt their policies to the expected situation.

Urban areas are responsible for the majority of resource consumption, thus instigating an increasing need to create smarter management for the future, which provides greener and more sustainable urban dynamics. In this study, the combined approach, using remote sensing and future modeling, is a powerful and productive direction for achieving improved understanding, and representing future urban data; such an approach will help in better planning the future and conserving natural resources, because it is vital to ensure cities are made greener and more sustainable.

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Part III
Benefits, Costs and Opportunities

Recycling the City New Perspective on the Real-Estate Market and Construction Industry

Ezio Micelli and Alessia Mangialardo

Abstract Themes related to the conservation of the existing city recently became a relevant issue in national and international public policies. One of the challenges that European Union and Italian authorities seek to pursue is sustainable-cities development on energetic, social and economic levels, discouraging urban sprawl, and promoting reuse of the existing real-estate stock. City reuse instead of its expansion onto greenfields has then become in Italy a priority for the construction industry. The aim of the paper is to point out the potential radical change of the construction industry in Italy and the new perspectives the industry can pursue in the future. Existing city reuse can be undertaken in two ways: through demolition and reconstruction or retrofitting the existing real-estate stock. The preference between the two options depends by real-estate market dynamics and by zoning rules made by local authorities. In the majority of Italian cities, retrofit operations appear to be the true challenge because real-estate market values are not capable of supporting radical city transformations through demolition and reconstruction. Market figures make clear that the shift towards reuse is already under way, with a significant growth of the reuse-segment over the span 2008–2014. Nevertheless, the major costs for reuse and the limited budget of Italian families represent relevant issues standing in the way. So the construction industry confronts a new challenge: innovating reuse technology—with reduced costs and increased effectiveness—and finding new sources of value to support the investment choice. The Dutch Energiesprong case study shows that highly-industrialized retrofit processes and the conversion of the energy bill into a financial source to support stock refurbishment represent the pillars of a disruptive and effective strategy.

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Keywords Urban renewal · Construction industry · Real estate market · Retrofit · Energiesprong

1 Introduction

In recent years in Italy, with the advent of the global financial crisis, the demand for conservation of urban and environmental quality assumed a key role in the city development. The reuse of the existing city has become a central theme at the national and international levels, with important implications in city management. The significant slowdown in the construction industry and in new urban expansion investments have led to a radical change of perspectives on the urban development along with a new social, cultural, and economic interest to recover the existing city especially for brownfields.

Rather than focus on a new urban expansion, perspectives are centered on reusing the existing city to achieve multiple objectives: containing the land use, redeveloping existing urban areas to preserve and to increase the green areas on one hand, making sustainable cities and protecting the environment, and limiting both the energy consumption and pollution on the other.

Urban renewal has become a strategy that public authorities pursue to recover, revitalize, and innovate the city through technological interventions along with social measures, supporting citizenry to care for their territory. Retrofitting operations in existing buildings and regenerating parts of the city represent new key options for a sustainable development.

The European Union and also Italian Authorities promote the reuse of the existing city by means of economic incentives and provisions that discourage new construction. That's why in recent years a new demand emerged, based on re-use and re-cycle the existing city, to which experts, professionals, and construction companies must respond. The construction industry overturned its field of action, drastically reducing the construction of new buildings and increasing interventions to recover the existing city, through retrofitting or demolition and reconstruction operations. Representing one of the leading Italian economic industries, construction companies must find strategies for innovating, thus recovering from the crisis and providing simultaneously more economic and durable interventions.

The paper aims to illustrate the new side of the construction industry in Italy, employing retrofit operations to retrofit existing buildings, presenting also the advanced Dutch experience called Energieprong. This case study represents an excellent example of the construction sector, ensuring sustainable, economic, durable, and also attractive interventions on existing obsolete real-estate assets.

The paper is divided into four parts. The first one illustrates the current situation of the real-estate market and of the construction industry in Italy. The second one analyzes the possible solutions to regenerate the existing housing stock, which are retrofitting or demolition and reconstruction operations. The third one shows the Dutch case of Energiesprong. Finally, the fourth one highlights some considerations and defines some future research fields.

2 A Market Moving Toward the Retrofitting of the Existing Stock

Despite some recent signs of recovery, the Italian economy is still notable to grow. The country is going through a difficult situation of uncertainty, which continues in all areas of the economy and indicates medium-term stagnation in GDP. The International Monetary Fund (IMF), comparing the GDP of the various countries of the European Union, describes Italy as particularly fragile, putting it in the last place for increase in GDP in absolute terms at constant prices compared to other European countries (Fig. 1).

The construction industry has significant dimension, contributing almost a tenth of GDP, especially for residential buildings, its most relevant segment. Real-estate assets represent two-thirds of household wealth. The economic crisis has significantly depleted the Italian population especially of the younger generations who find it increasingly difficult to buy a house. Insufficient income and a greater difficulty in accessing bank loans are two of the main elements causing the downturn of the real-estate market.

Qualified studies (ANCE 2014) depict the difficult national context in the construction field, with a new demand side emerging compared to the pre-crisis market, and a significant drop in real-estate-values, especially for the residential sector.[1] The ANCE report on the construction industry[2] summarizes the data referring to the Italian real-estate sector characterized by strong instability. From 2008 to 2014, the decline in investment in the construction industry amounted to 31.7 %, dropping about 58 Million Euros, returning to a level comparable to the year 1967 (Fig. 2). New residential buildings represent the segment hit hardest, with a decline over the span 2008–2014 of 58.1 % in value (ANCE 2014).

Related to the investment decline in the construction sector is the sharp decline of building permits issued by local authorities for new dwellings. Istat statistics show the number of permits issued by municipalities to build new houses or to significantly modify existing ones (Fig. 3). After a major peak detected in 2005 (305.706 permits), building permits decreased from 2006 to 2013 by 81 %,

[1]Between 2010 and 2014, houses prices have been characterized by a net decrease of 13.6 %. In detail, the new residential construction marked a reduction of 1 %, the existing building of 18.8 %.

[2]Osservatorio Congiunturale sull'Industria delle Costruzioni, July, 2014.

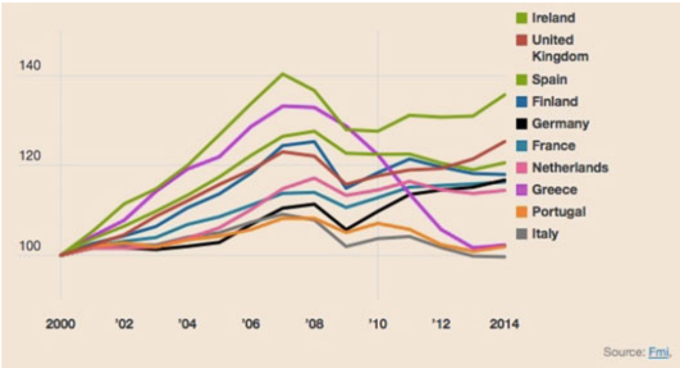

Fig. 1 A country with no growth, Italian GDP 2000–2014

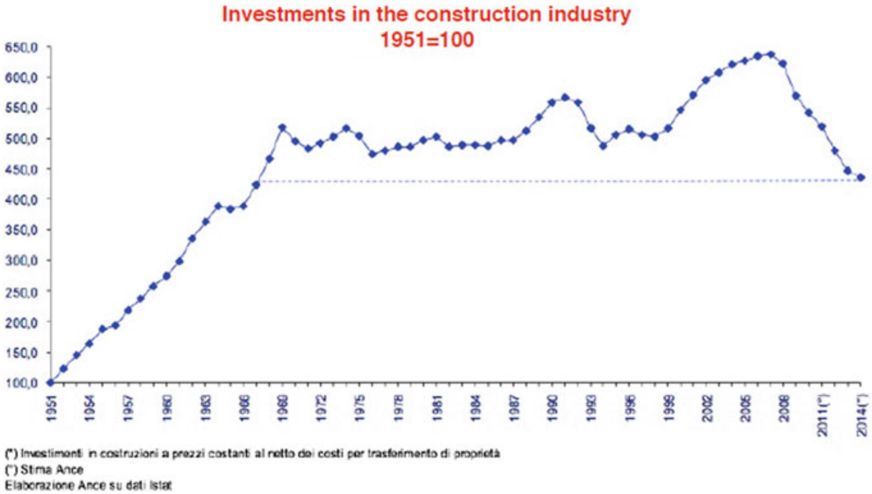

Fig. 2 Investments in the construction industry long-term trend: back to the 60s

returning to a situation similar to 1936, excluding the years of World War II (Fig. 4).

Although in Italy the housing demand remains high thanks to an increase of 1.6 % in the number of resident families, in just 7 years the number of newly built homes fell by 59 % (2008–2014).

Some figures point out where the market is moving, providing useful elements to draw a scenario for the future. Refurbishment of the existing residential stock partly counterbalances the decrease of investments in new buildings (Fig. 3), and, in 2014, investments in refurbishment amounted to 50,225 million Euros and since

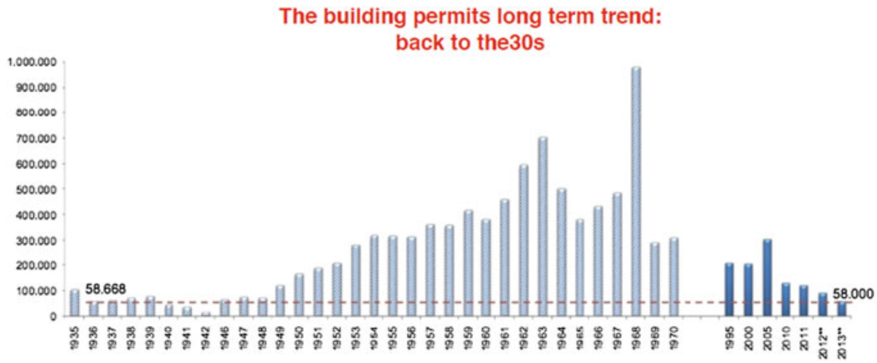

Fig. 3 The building-permits long-term trend-back to the 30s

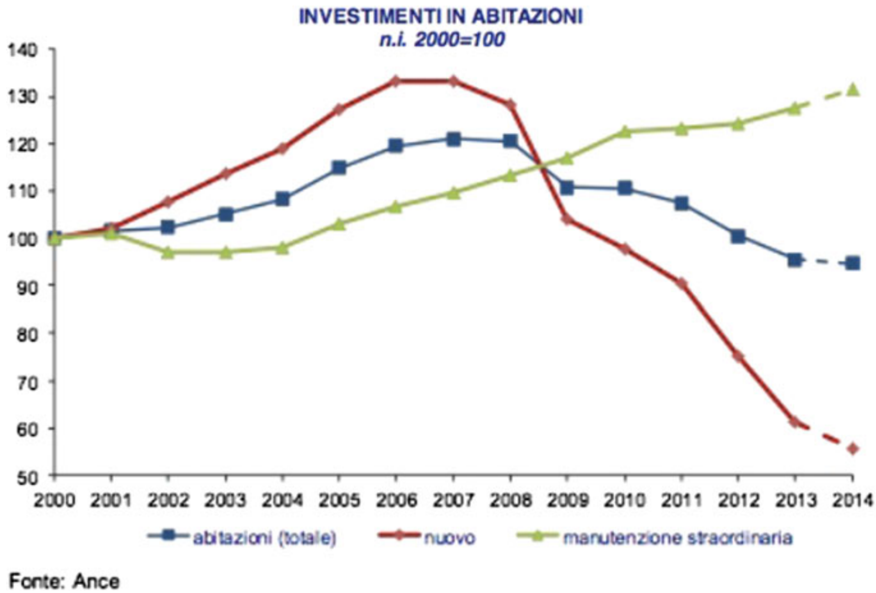

Fig. 4 The existing trend and the relevance of the refurbishment

2008 marked an increase of 20 %, representing the sole positive figure in the construction industry.

Retrofitting operations now account for 40 % of the interventions in the industry, representing its most promising segment. Recent European and Italian public policies also incentivize urban reuse by means of norms that focus, in particular, on fiscal benefits. Graph 3: New building development: the building permits' long term trend. Recent standards, still under discussion, are likely to state that new land consumption is allowed only where no alternatives on already

Table 1 The housing stock in Italy

STOCK	30.038.200	100%
di cui:		
Prima del 1919	3.893.567	55,4%
1919 - 1945	2.704.969	
1946 - 1960	4.333.882	
1961 - 1971	5.707.383	
1972 - 1981	5.142.940	17,1%
1982 - 1991	3.324.794	11,1%
1992 - 2001	2.161.345	7,2%
Dopo il 2001	2.769.320	9,2%

urbanized areas can be undertaken.[3] In recent years, Italian public authorities supported retrofit and reuse investments in the existing dwelling stock by enabling cost recovery through tax credits.

Focusing on urban redevelopment represents a new opportunity to renovate the construction industry. Over 50 % of Italians (Table 1) lives in dwellings designed and built before 1971. Much of the Italian housing stock is more than 40 years old, and it is now obsolete, being responsible for the consumption of a vast amount of non-renewable energy and for a significant fraction of urban pollution. The new horizon of the construction industry is then represented by interventions on the existing building stock within the wider frame of a more sustainable and wealthier city.

3 Demolition/Reconstruction Versus Retrofitting: Two Options to Regenerate Cities

Recovery of the existing asset, the reuse of brownfields, the containment of land use, and the energy performance improvement of buildings are just some of the goals that public policies at a global level aim to achieve to implement sustainable territorial strategies.

Recently the issue related to re-use and re-cycling became a central topic for public policies, to limit the harm to the environment for the future habitability of the planet. The overbuilding of lands not yet urbanized recall problems not only related to GHG emissions, but also to a collective-costs perspective (Talen 2011). About

[3]D.D.L. Containment of soil consumption—approved on 12th of May 2016.

70 % of the European population lives in urban areas. Therefore, the European Union issued a directive to reduce at least 20 % of the emissions causing global warming by the year 2020. Existing buildings represent an extraordinary resource: with appropriate energy policies for the existing stock, we can significantly reduce CO_2 emissions compared to other sectors such as agriculture, transports, or industry (Dowson et al. 2012).

There are two ways to pursue the sustainable reuse of the existing city. First, the replacement of obsolete real-estate asset or retrieving it through retrofitting operations (Della Puppa 2012; Micelli 2014). These two scenarios are different in implementation methods, but they result in a more compact and liveable city (Antoniucci and Marella 2014; Antoniucci et al. 2015; Gordon 1997). Both ensure a better quality of private and collective life, enhancing the existing social capital and providing greater durability in the performance of existing buildings (Fusco Girard et al. 2011; Micelli 2000).

The two models may appear equivalent, but, from an economic point of view, the difference between demolition-reconstruction operations and the reuse of existing buildings is significant. The first scenario takes place normally in locations where a property can draw a considerable economic advantage, extracting value from the potential rent related to the development opportunity set by the zoning instruments and by the real-estate market. If such conditions are not verified, the second scenario is the only option, and it is then necessary to proceed to upgrade the existing assets (Micelli 2014).

To reuse buildings, optimizing their intrinsic energy and economic value requires other finance sources different than the potential rent contained in the property. Deep retrofitting can actually be financed by energy bills, diverting the stream of revenues currently allocated to the energy payments to finance retrofit interventions and so extracting the maximum value from properties and taking a conservationist attitude with respect to the energy stocked in buildings (Johnson et al. 2014; Power 2008).

In Italy, the economic preference between the two urban reuse models assumes a specific geography. In high-density urban areas, with a high development potential, often with better—present or planned—infrastructural facilities, the demolition and reconstruction option should maximize the property value assuming relevant real-estate market opportunities and a coherent zoning set of rules. On the contrary, in cities with reduced market pressure, as characterized by a normally populated urban territory with low building density and valuable buildings, policies should focus on retrofitting existing buildings.

This is the case of the first suburbs built-up between the World War II and the economic boom of the last century, representing the majority of real-estate assets in Italy. In such contexts, the potential rent does not match the existing assets value, and, if public authorities and investors are determined in regenerating the stock, in the absence of specific subsidies, it is necessary to provide requalification and enhancement operations on existing real-estate assets (Micelli 2014).

4 How to Combine Successfully Energy Value and Stock Retrofitting: The Energiesprong Case Study

The regeneration of the existing real-estate stock represents an important priority at the international level.[4] In Italy, retrofit operations are still relatively sporadic and insufficient to guarantee the European requirements. The relevance of real-estate-stock regeneration is remarkable: more than 17 million residential units are obsolete with poor energetic performances and in need of renewal. But, the retrofitting of obsolete buildings, even when generating positive returns for energy bills, appear to be a controversial investment (Rovers 2014; Konstantinou et al. 2015).

The scarce economic resources from public and private entities are one of the most important factors for which public policies must provide. Considering the difficulty to access public resources, private resources are considered the other main solution. For example, ESCo (Energy Service Company) societies finance interventions with private funding, assuming the risks of the venture and recovering expenses through the energy-bill savings. The commitment to repay the intervention is linked to the building and not to the homeowners. After having invested significant economic resources, from the first year of the intervention, funders and private investors gain from these investments by more than 7 %.

In the UK, the Green Deal[5] provides for a similar strategy. The method is based on implementing the energy-efficiency performance in the existing buildings without initial expenditure by homeowners—the total operation cost will be recovered from the energy bills—managed by a public-private consortium of ESCo. In Italy, the interventions supported by ESCo are yet uncommon, because these initiatives need public incentives and anticipated infusion of private capital.

Since 2010 in the Netherlands, an independent non-profit team formed by some real-estate developers and 27 social-housing associations (HLM's) proved to provide a significant solution for this issue (2015). This team started by considering that the real competitors for builders are the energy companies, founding a virtuous funding mechanism without the need for public or homeowners' economic resources, using the energy-bill savings to finance the retrofit interventions.

The main purpose of this project was to refurbish with Net-Zero-Energy levels—a building producing as much energy as it consumes—for residential buildings. Energiesprong worked up a market-development program for refurbishing 111,000 houses (Munckhof and Erck 2015). Initially for social housing, today this project

[4] At the European level, Germany promoted the Passivhaus standard, instituting an energy-efficiency program for all buildings built before 1984 (more than 40 million houses) by 2050. In the UK, the so-called Energy Act, approved in 2011, established some urgent measures for improving energy efficiency in 7 million houses by 2020. Similar to these are the Empty-Home agency in Ireland and the project 2ndSkin—BTA in the Netherlands.

[5] To learn more about the Green Deal, please refer to the official decree, available at this website: https://www.gov.uk/green-deal-energy-saving-measures/.

deals with the real-estate private sector, also expanding to the UK and France. Especially in the social housing sector, the tenants pay directly to the manager of the social housing, instead of paying energy bills to the energy provider. In this case, the manager of social housing uses this money to invest in new retrofit operations. In the private sector, it works in almost the same way: homeowners pay a higher mortgage rate, but they save on energy bills.

The goals of this team are very ambitious: the drastic reduction of costs and time for refurbishments, along with a long-life performance guarantee. In 2010, Energiesprong retrofitted the first home in Rosendaal with Euro 130,000. In 2013, during another retrofit intervention in Arnhem, they reduced costs by two third, arriving at just Euro 40,000, for the same type of refurbishment (2015). These lower transaction costs for deep retrofit operations ensure, at the same time, a high level of energy-performance guarantee after the completion, on the order of about 40 years (2015).

As well cost reductions, also time spans required for refurbishment were greatly reduced. Retrofit operations last about 10 days and, at the maximum, 2 weeks, so the inhabitants' disturbance is limited to a few days, reducing noise and dust to a minimum. To reduce refurbishment time spans, it is necessary to undertake prefabrication of the main refurbishment components. In this way, through a preliminary analysis, the construction companies prepare the components, so the elements constructed on site are reduced to the minimum, ensuring less operative time in situ.

Specific technologies are necessary for monitoring and measuring the relevant dimensions of houses with great precision, like 3D scanning techniques. The measurements captured are fed into a computer program that creates a model. In the final step, these technical drawings directly produce components with the packages then ready to be transferred in situ. Prefabrication also provides for comfortable and attractiveness internal and external spaces for living, improving the quality of occupants' life and the aesthetic level of the houses.

These temporal and cost benefits introduce an innovation technology for the building sector, transforming the construction industry in industrialized and not project-based solutions. In this way, Energiesprong has managed to reduce significantly costs and time spans for the refurbishment of the buildings.

Extracting value form the existing stock is possible: new technologies enable processes radically more effective and more efficient, thus exploiting the opportunities of the digital manufacturing revolution. The funds currently destined for energy bill can then by the financial source for retrofitting.

5 Conclusions

Urban regeneration and land-use containment represent priorities of the territorial policies, in Italy and in a wider international context. The statistics of the Italian construction industry reveal a profound crisis in recent years for the traditional real-estate field. The low real-estate market demand discloses that the new residential construction sector has dropped dramatically. The re-use and re-cycling of the existing buildings, without subtracting unbuilt territory, is the new perspective to create a sustainable city. The urban-reuse processes are quite different: demolition-reconstruction or retrofitting operations. The regeneration processes based on the demolition and reconstruction of the assets are expensive and destined to require a modest fortune in the absence of major public support, while retrofitting interventions seem to be only one option in the majority of Italian cities.

The recent acceleration of upgrading the energy-efficiency programs of real-estate assets requires raising substantial financial resources. Based on its primary role of intermediary between the supply and the demand side, considering the actual economic crisis, the new commitment that the construction industry must take is combining major urban renewal with the shortage of private and public financial resources. The existing assets are likely to be subject to a process of deep retrofitting at much more competitive costs than their current values suggest. Energiesprong demonstrated that, by coordinating the various stakeholders, it is possible to activate a virtuous funding mechanism without other sources of economic resources. On the basis of this project, the strategy is to convert energy bills into an energy plan to pay for the investment, while considering also some actual industrial issues related to the construction industry: major energy performance guarantees, shorter times for delivery, and the affordability and the attractiveness of the renewed buildings. Energiesprong provided for all these matters: reducing by two-thirds retrofitting costs, decreasing the time for refurbishment (10 days), guaranteeing 40 years of energy performance, and also improving the aesthetic internal and external quality of the houses (2015).

Future research could analyze whether, and under what conditions, an urban-regeneration process will be able to take place, and consistent with preserving Italy's cultural heritage, a country with a significant downturn in the housing market, in terms of the development of the city and also of the possible social polarization.

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Co-benefits of Smart and Sustainable Energy District Projects: An Overview of Economic Assessment Methodologies

Adriano Bisello, Gianluca Grilli, Jessica Balest, Giuseppe Stellin and Marco Ciolli

Abstract The concept of "co-benefit" is commonly adopted to define any additional positive impact of a policy, program, or project, arising alongside the desired primary goal. Co-benefits relate to human health and well-being, as well as environmental, economic, and social aspects. The concept, investigated beginning in the 1990s, is recognized today, as supported worldwide by several notable organizations, to provide a better grasp of the economic value of foreseen or applied measures. Nevertheless, given the complexity of achieving complete pictures and understanding many interrelations or cascade effects, co-benefits are often only analyzed locally or measured qualitatively. Therefore, the aim of this paper is to provide an overview of the methodologies for economic assessment that are applicable to the monetization of co-benefits related to Smart and Sustainable Energy District Projects. Starting from a previously defined framework of expected co-benefits, we analyzed the various techniques, identifying the most appropriate with respect to target stakeholders and expected outcomes. As a result, we obtained a clear and comprehensive assessment model, tailored to a specific project type, and operationally applicable. This model would sustain the funding, public acceptance, and political commitment of Smart and Sustainable Energy District Projects, enabling the various stakeholders to better understand the entire economic value of a project, in addition to energy saving and greenhouse gasses reduction.

Keywords Co-benefits · Smart and Sustainable Energy District Projects · Cost-benefit analysis · Economic assessment · Stated and revealed preferences

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1 Introduction

Policies, programs, and projects are usually designed to deliver one or more specific desired changes (outcomes), through the development and completion of certain measures and activities (outputs). Positive changes are intended as benefits by the people or organizations (stakeholders) effecting the outcomes. Furthermore, the project's outputs achievements may lead, whether or not intentionally, to other additional positive impacts (co-benefits) or conversely to negative changes (co-costs). The concept of co-benefits, related to the low-carbon sector, has emerged beginning in the early 1990s in parallel with the release of the first IPCC assessment report on climate change (Davis et al. 2000). Nowadays the relevance of incorporating co-benefits into the decision-making process, to have a better grasp of the total welfare value of foreseen or applied policies, is recognized and worldwide supported by several notable organizations (IEA 2014b; Pachauri and Meyer 2014; US EPA 2011).

Nevertheless, given the complexity of achieving the whole picture and clearly understanding the interrelations or cascade effects, co-benefits are often analyzed locally within various branches of science, e.g., medicine environmental sciences. One of the most investigated sectors concerns the co-benefits of policies for the mitigation of greenhouse gasses (GHG) (Davis et al. 2000), where the widely investigated co-benefits are human health, industrial productivity, poverty alleviation, and the employment effect (Ürge-Vorsatz et al. 2014).

Conversely, the co-benefits related to projects primarily aimed at reducing GHG emissions within the urban environment, by achieving relevant energy saving in buildings, are mostly qualitatively measured and seldom monetized. For example, since the early experiences in devising and implementing the European Union (EU) initiative CONCERTO, it was well recognized that the district-wide approach of such projects could provide additional relevant positive impacts (Lützkendorf et al. 2013a; Di Nucci and Spitzbart 2010). At the same time, the relevance of improving the understanding of co-benefits by decision makers began to be clear (Immendoerfer et al. 2014) and therefore to be able to properly evaluate the increase in people´s welfare arising out of such projects. Actually there is still a need to raise the discourse level and to recognize their full impact on the quantitative decision-making framework, because in such projects "*the absence of co–impacts (co-benefits and adverse side effects) is probably the exception much more than the rule*" (Ürge-Vorsatz et al. 2014).

Starting from these premises, the present contribution aims to provide an overview of suitable economic assessment methodologies, creating a framework for evaluating the key urban co-benefits recognized by Smart and Sustainable Energy District Projects (SSEDPs) funded by the EU. The projects taken into consideration refer to the CONCERTO and the later ongoing "Smart Cities and Communities" programs, i.e., the two main European initiatives of energy refurbishment on a district scale funded during the latest decade. Therefore projects are here analyzed and assessed as temporary endeavours, aimed at achieving unique objectives by the performance a series of activities and tasks, within certain specifications and under funding, time, and resource constraints (Kerzner 2013).

The paper is organized as follows: Sect. 2 provides a brief exposition of the background of cost-benefit analysis. In Sect. 3, the starting point of the research is explained, and in Sect. 4 the research methodology is illustrated. Section 5 provides the results of co-benefit-assessment methodologies. In Sect. 6, the main findings, shortcomings and further steps are analyzed and discussed. Section 7 concludes the paper, summarizing the procedures and results.

2 Cost-Benefit Analysis Background

According to the Kaldor-Hicks criteria (Hanley et al. 2009), while evaluating public policies, a decision maker should assess the provided changes in people´s welfare, then choose the one with the higher welfare increment. For this reason, including not only the main outcomes but also the co-benefits within this assessment, enables a better identification of the welfare changes of various programs and projects. The most common tool for welfare evaluation in applied economics is the cost-benefit analysis (CBA), through which all the costs and benefits of a project are compared in order to estimate its net benefit (Pearce et al. 2006). While this tool is applied both in the private and public sector, in the second case it is sometimes called social CBA, because it aims at evaluating costs and benefits for the entire society (Ürge-Vorsatz et al. 2014). CBA is applied to the decision-making framework by quantifying in monetary terms all the positive effects (benefits) as well as the negative (costs) and then calculating the Net Present Value (NPV); if the NPV is positive, then the alternative is said to be welfare increasing. Other feasibility calculations, typically adopted for building-retrofitting projects, are the internal rate of return (IRR) or the discounted payback period (DPBP) (Boeri et al. 2011).

A critical point of such analysis is that not all co-benefits are evaluated in monetary terms, so non-market techniques have to be applied to price them. Such techniques investigate the consumer preferences starting from individual purchasing habits (revealed preferences) or asking them directly their preferences (stated preferences). Whenever original studies are unaffordable, as often occurs in policy analysis, "taking economic values from one (geographical) context and applying them to another" (Pearce et al. 2006) may be the second-best option (benefit transfer). Together with the cited methods, there are also a family of evaluation techniques called "non-demand approaches", based on the calculation of the costs. The idea behind these techniques is that if people are willing to cover some costs for a non-market good, e.g., to improve the environmental quality of a site, then the site has at least the same worth as the sustained cost. Within this framework, there are multiple techniques, such as market-price approaches, opportunity costs, replacement costs, and defensive expenditures; for a detailed description of these methods, see Bateman and Turner (1993). Although being widely applied in practice, non-demand approaches are often criticized by economists, because they only approximate the value and are not capable of really describing the welfare change provided by the non-market good in question. Despite such criticism, non-demand approaches may be used to demonstrate the importance of some non-market goods and services.

A second critical aspect emerges mainly because people are often uncertain when pricing goods and services that are considered to be priceless. In particular, in the health sector, it is quite inconvenient and maybe even unethical to assign a price to human lives and health. In the environmental field, opponents to non-market methods argue that pricing nature may encourage equating environmental services with artificial substitutes, thus leading to a depletion in the environmental quality. Moreover, people's preferences for some environmental goods may not reflect their ecosystem importance, but simply be related to the common perception. Jacobsen et al. (2008) proved that people show higher interest in conserving large mammals and iconized species, while neglecting many insects, arachnids, reptiles, and other species, because they are thought to be scary and repugnant, although being much more important in the ecosystem. For this reason, often conservation projects focus on attractive "flagship" or "umbrella" species (e.g. the panda bear, elephant, gorilla, and whale) that are used as Trojan horses to protect less appealing species that are the main target (Clucas et al. 2008; Hunter et al. 2016).

Nevertheless, non-market valuation is broadly applied because it is the only solution to assess welfare changes in a comprehensive way. In addition, methodologies have been studied for many years in order to reduce potential biases, and nowadays the procedures and estimates are widely accepted in economics. In any case, regardless of the methods chosen, it should be remember that CBA is "about value, rather than money. Money is simply a common unit and as such is a useful and widely accepted way of conveying value" (Nicholls et al. 2012). Indeed, CBA applied to SSEDPs must necessarily convert welfare changes into money, because this is a tool to make explicit and ease the debate, and not because the final aim is to monetize everything.

3 Framework of Key Urban Co-benefits

The starting point of our research was a previous work done by Bisello et al. (2015) on co-benefits related to Smart and Sustainable Energy District Projects (SSEDPs), where the key urban co-benefits were identified. Regarding the two main objectives of the study, they defined SSEDPs as "European international co-funded cooperation projects, applying outstanding energy technologies within urban settlements, involving multiple stakeholders and including the local authority into the consortium", while co-benefits as "positive impacts arising beside the desired primary project goals". Therefore, both CO_2-emission-reduction and energy savings, as primary SSEDPs goals, were not considered. It is worth mentioning, that such benefits are precisely measured by projects and therefore can be evaluated by their values, according to current energy and carbon prices. Although these values may have quite unexplained and considerable, they change over time: for example, the EU ETS allowance ranged from 30 €/tCO_2 in mid-2008 to less than to 5 €/tCO_2 in mid-2013 (Koch et al. 2014). Or, as energy prices, they can be country specific, ranging in 2012 from close to 12 €c/kWh inc. taxes in Sweden to less than 3 €c/kWh in Romania (European Commission 2014).

In Bisello et al. (2015), 19 key urban co-benefits of 36 SSEDPs were first related to three main groups of the projects' activities: (i) intervention on buildings and infrastructures at district level; (ii) actions on stakeholders; and (iii) project design and management. It is worth noting, as displayed in Table 1, that the majority of co-benefits relate to the core activities of such demonstration projects, i.e., housing intervention and implementation of new technologies in new or existing buildings, as well as in energy infrastructures.

Table 1 Co-benefits related to intervention on buildings and infrastructures at district level, adapted from Bisello et al. (2015)

Definition	Short description
Better environmental resources management	Project activities can reduce negative effects and impacts on abiotic as well as on biotic components, improving the sustainability conditions and reducing environmental footprint
Building life-cycle-costs reduction	Efficient technologies can yield lower maintenance, repair, and operation costs, as large-scale interventions and integrated design can enable reduction of construction costs
Changes to local taxes revenue	Taxation of additional jobs and activities can have positive effects on local public balance
Energy services establishment	Neighborhood approach can stimulate the development and testing of ESCOs or new energy schemes
Enhancement of neighborhood identity	The district approach can create a better image and sense of place in the neighborhood
Health and well-being increased	The district approach can create a better image and sense of place in the neighborhood
Increased assets value	The buildings' energy refurbishment and the adoption of high-quality materials and technologies, as well as design criteria, can enable better indoor thermal comfort and living conditions
Innovation in technology development and adoption	Frontrunners in adoption of innovative solutions can have an advantage over their competitors, whether they are other companies or other cities
Local air quality improved	Shifting heat and power production from fossil fuels to renewables, or decreasing energy demand can reduce other air-pollutant emissions, in addition to CO_2
Local energy-supply-chain development	Energy production from former by-products or waste heat can produce additional income from energy sales and management-cost reduction

(continued)

Table 1 (continued)

Definition	Short description
Resilience of energy infrastructures increased	Better response to faults or to interruptions, up to the ability to prevent them, can increase efficiency and safety in energy systems
Easier loan conditions	Large-scale interventions financially supported by the European Union can be interesting for banks and other investors and therefore can help to negotiate better financial conditions
Stimulation of local jobs' market	Project's management and implementation can lead to the creation of new direct, or indirect, job positions
Tackling fuel poverty	Reducing energy expenses to an affordable level, even for low-income people, can lower the number of excess winter or summer deaths attributable to indoor thermal shocks
Territorial attractiveness increased	An exemplary smart and sustainable district can attract visitors like institutions, professionals and researchers interested in innovative and green solution, as well as green tourists

Table 2 Co-benefits related to actions on stakeholders, adapted from Bisello et al. (2015)

Definition	Short description
Professional skills development	Increased knowledge and know-how of innovative processes and energy technologies can help to face the challenge of an effective intervention on the construction markets
Users' awareness on energy-related issues increased	Educational and communication activities can change positively stakeholders' and residents' energy behaviors and solutions' acceptance

Table 2 reports the co-benefits related to a second relevant field of action of such projects, given by technical training to professionals (architects and engineers) or practitioners (building workers or craftsmen), coupled with awareness creation in end users.

The last group of co-benefits, as shown by Table 3, concerns tasks and activities related to the development of the project's concept, as well as the day-to-day management of partners' relationships.

Co-benefits were finally assigned to the seven components of the ideal smart city: (i) smart natural environment, (ii) smart services, (iii) smart community, (iv) smart governance, (v) smart economy, (vi) smart built environment, and (vii) smart mobility. The list is not exhaustive, but considers the most recurrent (i.e., the key) co-benefits. Single projects may encompass additional ones.

According to Mosannenzadeh and Vettorato (2014), a smart natural environment is mainly related to natural non-living, chemical and physical, components; two co-benefits are considered within this component. Smart services mainly include citizens' health and safety; one single co-benefit strictly related to this is here

Table 3 Co-benefits related to project design and management, adapted from Bisello et al. (2015)

Definition	Short description
Innovation in processes and decision making	Participating at a SSEDP promotes exchange of experiences, introduces innovation in processes and can positively improve the quality and effectiveness of decision making
Institutional relationship and networks created	To get in touch with existing, or creating new, associations can offer the opportunity to learn and to adapt experiences from other cities and partners and to improve the effectiveness in next calls for funding

investigated. Three co-benefits are recognized within the smart community, which encompasses people and neighborhoods in terms of cohesion, welfare, and behaviors. The same quantity deals with smart governance, where the administrative, organizational, and institutional aspects of the city are considered. The component of the smart economy that addresses the economic domain of the city and its local labour market has seven related co-benefits. The smart built environment, which concerns buildings, facilities and technology infrastructures representing the physical aspect of the city, has the last three of them. Indeed, no recurrent co-benefit has been found connected with the smart mobility component, defined as networks and transportation systems enabling exchange of data, people and goods.

4 Measurement and Monetization Techniques

Starting from this co-benefits framework, we performed a literature review to identify the most appropriate indicators that are suitable to capture each one of the co-benefits. According with OECD (2003), an indicator is defined as “a parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value”, i.e., appropriate indicators selection enables one to reduce the number of measurements necessary to precisely describe a situation (OECD 2003). Common indicators on well-being are suggested by OECD (2011) and are more specific for the assessment of cooperation programs by the EU (2013). Other detailed qualitative and quantitative indicators, adopted for the measurement of socio-economic and environmental performances of SSEDPs, are found in Di Nucci and Spitzbart (2010) and additional ones related to technical aspects in Lützkendorf et al. (2013b). Moreover, Ürge-Vorsatz et al. (2014) provide a useful list of physical indicators based on a recent review of approaches to the measurement of climate-change mitigation co-impacts. Co-benefits from energy efficiency, clean-energy-sources exploitation, or GHG mitigation policies are often investigated singly or by specific areas. Therefore we looked at several studies that cover all three of the main groups of SSEDPs’ activities, reporting positive impacts on air quality (Bell et al. 2008; Chau et al. 2008, 2010; Joyce et al. 2013; Williams et al. 2012; Kim et al.2003), assets value (Bonifaci and Copiello 2015; Chapman et al. 2009; Deng et al. 2012; Eichholtz et al. 2010; Fuerst and McAllister 2009; Hoffman and Henn 2008; Howden-Chapman et al. 2012; Johnson Controls 2011; Popescu et al. 2012), energy infrastructures (Schweitzer and Tonn 2002), tax revenues (Joyce et al. 2013), jobs and investments (Janssen and Staniaszek 2012; Joyce et al. 2013; Tirado Herrero et al. 2011; UNEP/ILO/IOE/ITUC 2008; Ürge-Vorsatz et al. 2010), fuel poverty (Bone et al. 2010; Tirado Herrero et al. 2011; Ürge-Vorsatz et al. 2010; Williams et al. 2012), other environmental resources (IEA 2014a, b), stakeholders' skills and awareness (Beurden 2011; Borgatti 1998; Brandon and Lewis 1999; EEA 2013; Gill et al. 2010; Hori et al. 2013; Khandker et al. 2010; Lewis e al. 2013; Painuly 2001; Rae and Bradley 2012; Sorrell et al. 2004), neighborhood quality, and urban appeal (Campbell 2012; Lee 2008).

Some of these studies approach a specific topic by different perspectives: e.g., Kim et al. (2003) translate the benefits of reduced air pollutant in the Seoul metropolitan area as a change in housing market prices, while Pollicino and Maddison (2001) estimate the cost of air pollution as a damage to buildings. In contrast, Bell et al. (2008) consider the benefits of outdoor air-quality improvement from the perspective of human health, while Chau et al. (2008) derived them from improving indoor-air quality.

Works of different authors, such as Joyce et al. (2013) or Tirado Herrero et al. (2011), cover the multiple benefits from sectorial interventions. For example, the first relates the energy-efficient renovations of the buildings of the EU to energy savings, job creations, tax revenues, health benefits, and air pollution. The second quantifies the implications of employment, energy security, and fuel poverty arising from retrofitting the Hungarian building stock. Additional references are used to explain the importance of social and human capital (HC) in measuring a project's co-benefits (Borgatti 1998; Franceschetti et al. 2015; Jones et al. 2009; Krishna and Shrader 2000; OECD 2001). Particularly, Dagum (2006) provide an analysis of three different methods of estimating the monetary value of HC: (i) prospective, (ii) retrospective, and (iii) latent variable-actuarial (LV-A). A literature review of measurement methodologies and monetization methods is also found in Nosvelli (2009).

On the basis of such references, we suggested which economic assessment methodologies are applicable to translating measured co-benefits into economic values. Generally speaking, co-benefit monetization is possible by employing several techniques that are related to specific categories: existing market analysis, revealed preferences, stated preferences, and transferring results. The first existing market is applicable when a direct data collection of market prices of goods or services and close substitute of goods or services can be eventually adjusted for distortionary factors (so-called shadow prices). Another market-based technique is the cost of illness (COI), even if it is slightly different from the direct market-price approach. COI aims at estimating the amount of cost caused by a disease or the net gain that could be obtained if the disease is eradicated. The others are techniques used in the economic literature to evaluate non-market goods. Table 4 provides an overview of the various typologies of non-market techniques.

Table 4 Non-market evaluation techniques

Group	Typology	Technique	Welfare measures
Indirect methods	Revealed preferences	Travel cost	CS
	Revealed preferences	Hedonic pricing	CS
Direct methods	Stated preferences	Contingent valuation method (CVM)	CV/EV (WTP/WTA)
	Stated preferences	Choice experiment (CE)	CV/EV
Second best	Stated/revealed preferences	Benefit transfer (BT) Value-function transfer	CS/CV/EV

In particular, revealed-preference methods assess the economic value of a good or service through market data, using the consumer surplus (CS) for that good or services as a measure of welfare change (Champ et al. 2003). The two most common techniques in this framework are the travel-cost method and the hedonic price. Travel cost is usually applied for the value of recreation, since it derives the value of a site by assessing the number of trips and the distance travelled by tourists. Hedonic price assumes that the value of a good is given by its attribute, so the objective is to decompose the good into its relevant attributes and to evaluate them separately.

When market data are not available, welfare changes may be estimated through stated-preference methods, applied by creating a hypothetical scenario and asking people how they would behave if that scenario were real (Champ et al. 2003). Contingent valuation (CVM) and choice experiments (CE) are the methods used for this purpose. CVM is carried out creating a scenario and asking people their willingness to pay (WTP) or to accept (WTA) a compensation for that scenario (Mitchell and Carson 1989). On the other hand, CEs are based on the characteristics theory of value (Hanley et al. 2009). The goods or services are decomposed into their attributes, and each attribute is associated with several levels. The combination of attributes and levels creates multiple scenarios, which are proposed to respondents iteratively. Within the stated-preferences context, welfare changes are estimated through two different measures: compensating variation (CV) and equivalent variation (EV). CV is the maximum amount of money that people are willing to pay for an increase in the level of that good or service. EV is the minimum amount of money people would accept as compensation for a lower level of provision of that good or service. A second-best approach to non-market valuation is the benefit transfer (BT) or value-function-transfer method, through which the value of a good is derived by analyzing similar studies carried out in different contexts and transferring the welfare measure (Boyle and Bergstrom 1992; Navrud and Ready 2007). The choice of the technique for valuing non-market goods depends on the nature of the good itself, as well as on the suitability of the approach to understanding the nature of the benefit flow (tangible or not tangible, use or non-use value).

Through the application of these techniques, we argued it is feasible to incorporate co-benefits into a broad CBA of a SSEDP, making clear to the wide public how relevant welfare changes are, and what they are worth. Examples of how a cost-benefit assessment is heavily influenced when taking into account also some intangible benefits, for instance measuring the social return of investments (Nicholls et al. 2012), are already available. Similarly, the vastness of the co-benefit concepts, beyond the traditional notion of "externality", is well known, at least in the debate about climate and energy policies (Ürge-Vorsatz et al. 2014).

5 An Overview of Methodologies for the Economic Assessment of Co-benefits

Linking co-benefits with indicators and techniques for monetization has been done through the review of literature mentioned in Sect. 4 and experts-knowledge elicitation (Ford and Sterman 1997). Five brainstorming sessions took place between September and October 2015 among an urban planner, an environmental economist, and a sociologist to share and debate findings.

As result of our investigation, we linked each co-benefit with one or more indicators and techniques that are able to provide us with a monetary measurement of expected welfare changes. References to the existing literature enabled us to define at least one evaluation indicator for each co-benefit. In a few cases (specifically: users awareness on energy issues, loans conditions, and assets value), we detected multiple options and related assessment methodologies.

Concerning monetization techniques and approaches, we have been able to discern three different quality levels of the information. The best concern studies suggesting monetary estimations of the co-benefit magnitude. An intermediate level deals with references pointing out methodologies used for the economic assessment of a specific co-benefit (or one of its relevant details). The lowest includes estimations or approaches suggested by the authors by analogy to reference literature, i.e., we found a confirmation of the possibility to assign an economic value to the co-benefit, but a specific study on this topic has never been published yet, to our knowledge.

Table 5 explains how our investigation fits the framework: for six SSEDPs' co-benefit (improved local air quality, better environmental resources management, health and well-being increased, territorial attractiveness increased, stimulation of local jobs' market, and increased assets value), at least one value (V) has been found, while for five (tackling fuel poverty, increase in users awareness on energy related issues, positive changes to local taxes revenue, softer loans conditions, and reduction in buildings' life-cycle costs) only related monetization techniques (T) are known. The remaining eight co-benefits (enhancement of neighborhood identity, innovation in processes and decision making, institutional relationship and networks created, local energy-supply-chain development, energy services establishment, innovation in technology development and adoption, professional skills development, and resilience of energy infrastructures) are lacking direct studies, and therefore techniques have been suggested by analogy (S). For detailed results, see the Appendix.

Table 5 Techniques for co-benefits monetization

Smart city component	Co-benefit	Techniques for monetization						Human capital
		Existing markets		Revealed preferences		Stated preferences		
		Direct market value or shadow prices	Cost of illness	Hedonic prices	Travel costs	Contingent valuation	Choice experiment	
Smart natural environment	Local air quality improved		V			T	T	
	Better environmental resources management	V		T		S	S	
Smart services	Health and well-being increased		V			T	S	
Smart community	Tackling fuel poverty		T					
	Users awareness on energy related issues increased	T				S	S	S
	Enhancement of neighbourhood identity					S	S	
Smart governance	Innovation in processes and decision making							S
	Territorial attractiveness increased	T			V			
	Institutional relationship and networks created					S	S	
Smart economy	Positive changes to local taxes revenue	T						
	Softer loans conditions	T						
	Stimulation of local job's market	V						
		S						

(continued)

Table 5 (continued)

Smart city component	Co-benefit	Techniques for monetization						Human capital
		Existing markets		Revealed preferences		Stated preferences		
		Direct market value or shadow prices	Cost of illness	Hedonic prices	Travel costs	Contingent valuation	Choice experiment	
	Local energy supply chain development							
	Energy services establishment	S						
	Innovation in technology development and adoption	S						
	Professional skills development							S
Smart build environment	Increased assets value	V		V				
	Buildings life cycle costs reduction	T				S	S	
	Resilience of energy infrastructures increased	S						

V = Estimated values reported by reference literature
T = Techniques or approaches assumed by reference literature
S = Techniques or approaches suggested by the authors by analogy to reference literature

6 Discussion

In this section we sum up the strengths and shortcomings of the co-benefits consideration in a CBA, applied to SSEDPs. Indeed, we start by recalling our approach aimed at considering such projects as more than physical urban-refurbishment intervention. Then we move through the co-benefits discussion and criticisms. For each point, we comment on our results and main findings, highlighting activities requiring further research. We conclude by participating in the general debate around the appropriateness of the CBA to value the benefit of urban-energy projects at district scale.

In our work, we consider the SSEDPs not only with respect to the "hard measures" implemented, but within the whole perspective of a knowledge-creation environment. This means that projects are temporary endeavours, where a consortium of partners is established to achieve a specific goal in a cooperative way, in contrast with business as usual activities (Kerzner 2013). Therefore, new attitudes, knowledge, and social networks, mainly related to the "soft measures", are likewise as important as the physical interventions. Consequently, we propose indicators for the measurement of the quality and the quantity of these variables, with the aim to estimate the capacity of a city to be effective in reaching a project's goals, and we provide in Table 5 an overview of monetization techniques to define the overall value of welfare changes.

We suggest that a SSEDP appraisal should consider both tangible (i.e., basically outputs as physical equipment) and intangible assets, such as outcomes implying wider changes in different kind of resources available to a community, a group, or a person. Although the former are the most visible, the latter are particularly important because they can substantially contribute to the accomplishment of the project's objectives (Franceschetti et al. 2015). Moreover, co-benefits may derive from a combination of practical and socio-cultural activities, e.g., innovation requires changes in materials and involves institutional and relational aspects (Rodima-Taylor et al. 2012), thus both sides of the coin should be known. In this context, our research shows how unexplored are the SSEDP's assessment of the data concerning the social capital and human capital, although positive outcomes in these fields are often pointed out. Although tools for their analysis are available, monetization techniques need to be further investigated. Conversely, for the majority of other co-benefits, it is more of a fine-tuning effort, to contextualize well-known economic assessment methodologies. Therefore, we argue that the key urban co-benefits consideration within a CBA of a SSEDP is feasible and needed.

It is obviously crucial, even before defining the assessment methodology, to establish appropriate indicators, capable of grasp magnitude of each co-benefit at the urban level, and possibly its flow over time. Assessment experiences of previous projects may suggest coherent references. This introduces at least four relevant issues in co-benefits appraisal. The first concerns the quality and reliability of the input data: are these both enough precise and trustable? Co-benefits accounting encounters various challenges related to possible interactions and synergies, double counting, context dependency, and distributional issues. Therefore we suggest to keep the list concise. The second considers the probability of occurrence: is the co-benefit absolutely certain would it only likely be present? An option could be to distinguish between “real” co-benefits and co-opportunities. The third aspect deals with the effort of scientific investigation of co-benefits, compared with their relative value: is it worth it? Generally speaking, the adoption of different indicators or techniques will probably lead to various estimates for the same co-benefit, and for the less relevant the benefit transfer method could be the most cost effective solution. Finally, the heterogeneity of impacts is also a matter of concern. They can arise on the individual to sectorial level and range from local to international dimensions (IEA 2014b): how to satisfy the need to consider, according to Ürge-Vorsatz et al. (2014), “the relevant groups of stakeholders at an appropriate scale”? As the local authority should ensure within the decision-making process adequate welfare balance to the whole community, and not only to the project’s consortium or actively involved citizens, we point out the urban dimension as the adequate reference scale for SSEDPs co-benefit assessment.

Cities are the governance level closest to citizens, therefore the right place to implement low-carbon strategies and to translate into practice the international agreement on climate change, although, given that positive effects of GHG mitigation measures occur globally, quite independently from the context where they are implemented, it can be hard to provide necessary incentive to the local community to participate in the effort. In some cases even the pure energy savings can be insufficient to justify high investments in urban regeneration. Therefore is necessary to find and demonstrate in a robust way that other more local and quickly immediate co-benefits are achievable. If this can be framed within the smart-city debate, now at the top of the agenda, instead of the quite outmoded sustainable-development paradigm, successful results may be expected. Even though there are criticisms of the CBA, such a methodology is extremely useful for understanding the monetary impacts of projects, where not only monetary outcomes are considered. Ürge-Vorsatz et al. (2014) argue that “for the assessment of the co-impacts (…), social cost-benefit analysis is the preferred appraisal tool because it measures costs and benefits as variations in human well-being”. Therefore, monetizing co-benefits could be a promising strategy for evaluating the total impact of comparable projects, such SSEDPs, and effectively supporting their diffusion.

7 Conclusions

The present contribution has established a framework for evaluating the co-benefits of Smart and Sustainable Energy District Projects, i.e., the additional positive impacts delivered by the execution of projects primarily aimed at reducing GHG emissions within the urban environment through energy saving in buildings.

Starting from a list of 19 key urban co-benefits, provided by a previous review of the ongoing and accomplished European projects, the most appropriate evaluation indicators have been selected and associated to each one.

Next, direct monetary indicators or non-market techniques have been identified, with regard to the existing scientific literature. Through brainstorming, they have been filtered and finally suggested to translate each co-benefit within a cost-benefit analysis (CBA), providing examples of their potential magnitudes in monetary terms.

By defining an urban framework and linking them with the various seven smart-city dimensions, we introduced (for the first time, to our knowledge, in a well ordered way) the co-benefit concept, with respect to pioneering projects such SSEDPs, into the smart-city debate. This result can positively contribute to solve the primary question whether co-benefits are so relevant that they can largely offset the cost of project development and implementation, or if they are so small that can be safely ignored, simplifying a complex project assessment (Krupnick et al. 2000). We argue that studying additional outcomes of such projects is paramount to realize their total impacts on human environment. At the same time, estimating their economic value enables researchers to evaluate welfare effects and to foresee the effectiveness of public interventions aiming at contributing to smart-city development. OECD (2011) itself is promoting this to decision makers and pressing for the adoption of well-being indicators at the regional and national scales. Going beyond the pure gross domestic product (GDP) measurement to assess individuals changes in the quality of life (Stiglitz et al. 2009) constitutes a crucial change in the approach to public economics and a momentous occasion for a paradigm shift.

The next step in research is replicating the same approach to investigate the hidden costs not directly reported in SSEDPs budget, although faced by project stakeholders or occurring beyond the intended beneficiaries (Ürge-Vorsatz et al. 2014). This will lead to the completion of the framework for project CBA within an urban-welfare perspective.

It is worth mentioning that the increase in people´s welfare is not the only objective that should be achieved by any public policy, since other considerations are also important, in particular when talking about the environmental impact. For this reason, in the presence of alternative objectives, other evaluation techniques, such as multi-criteria analysis or life-cycle assessment should be explored to evaluate the attractiveness of projects. Nevertheless, looking at the smart-city approach, where usually the main objectives are to ensure a better quality of life and to assure urban sustainability, the risk of depleting the environment seems to be less likely than in other sectors, and, consequently, a CBA approach is appropriate to evaluate the benefits.

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Appendix

Smart natural environment				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Local air quality improved	Air pollution emissions of SO_2, NOx, and small particle matter (PM)	Value of reducing the harmful effect of air pollution: cost of illness (COI); willingness to pay (WTP) methods quality-adjusted life year (QALY) value of a statistical life (VSL)	The value of health benefits from air pollution decrease, achievable through the retrofitting of EU building stock and related energy-consumption reduction (both electricity and thermal), has been recently monetized as four to six billion EUR of annual gross benefit at EU level by Joyce et al. (2013) Bell et al. (2008) provides an overview on several approaches applied in scientific studies for economic valuation of averted health consequences Reduction of pollutants like PM10, So_x, NO_x, CO and, O_2 is defined in the indicators set up by Di Nucci and Spitzbart (2010) for CONCERTO projects Moreover, Chau et al. (2010) included the air-quality improvements within the set of attributes for a CE	Although urban air pollution-related health impacts are one of the most investigated co-benefits (Williams et al. 2012), and multiple studies provide strong evidence about their economic relevance (Bell et al. 2008), they remains underestimates, due to other unquantified or underestimated endpoints
	Cost of cleaning and conservation of cultural heritage	CV: WTP for avoiding damages to building materials	Pollicino and Maddison, cited by Ürge-Vorsatz et al. (2014), performed a CV study on the WTP for an increase in the frequency of a hypothetical cleaning cycle of the UK's Lincoln cathedral: "Estimates of mean willingness to pay range from £15 to £23 per household per annum for those living in Lincolnshire" which in aggregate	Although the first goal of better air-quality measures is the improvement of human health, other avoided or reduced harmful effect of air pollution on building materials (like corrosion, stonework erosion, and blackening), especially on materials used in cultural monuments and historical buildings, should be taken into

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Smart natural environment				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			suggests an annual damage to the cultural monument valued between £0.4 m and £0.6 m (Pollicino and Maddison 2001)	account at urban level (Aunan et al. 2004; Tidblad et al. 2012; Ürge-Vorsatz et al. 2014)
Better environmental resources management	Water consumption and sewage production	CV: Willingness to pay for reducing impact on environmental resources, such as water (consumption and treatment) CS: Hedonic Price model may identify the share of price premium for green buildings exceeding monetary savings related to water usage	Deng et al. (2012) adopt a hedonic pricing model on transactions involving green and non-green residential units in Singapore. Results suggests substantial economic returns for green buildings, reaching specific energy- and water-efficiency requirements Economics of “green” buildings have been widely analyzed by Eichholtz et al. (2010) Hoffman and Henn (2008) present economic benefits for green buildings recooping capital costs: referring to Capital E Analysis, they report a NPV over a 20-year life cycle equal to US $0.51/sq. ft. for reduced water use in green buildings In another example, the operating cost reductions in water, wastewater, and energy expenditures is around 10–30 % lower in ENERGY STAR certified buildings (Johnson Controls 2011)	Hoffman and Henn (2008) point out that, despite the measurable benefits, individuals perception of green buildings is affected by cognitive biases that negatively impact their awareness of environmental impacts

Smart services				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Health and well-being increased	Reduced number of visits to general practitioners, hospitalizations, days off school, days off work declared by households leaving in retrofitted houses	Value of health and well-being can be measured by: cost of illness (COI); willingness to pay (WTP) methods quality-adjusted life year (QALY) value of a statistical life (VSL)	Health benefits from improved indoor climate are evident, although uncertain to clearly assess. A study concerning the deep energy-efficient renovation of EU building stock estimate them (including a rebound effect of 20 %) close to 88 billion EUR annual gross benefits at EU level: i.e., more health benefits than savings from lower energy bills, which are estimated as 75 billion EUR per year (Joyce et al. 2013). Other studies report that, for private sector, such benefit may amount to the same order of magnitude as the energy-related benefits (Jakob 2006) Di Nucci and Spitzbart (2010) identified an appropriate indicator for CONCERTO projects assessment as the indoor-comfort improvement in buildings Several approaches for economic valuation of averted health consequences are reported by Bell et al. (2008) and Williams et al. (2012)	Well-being measurement, according to OECD (2011), should include indicators dealing with quality-of-life and material living conditions, such as health status, life satisfaction, social connection, income and wealth, etc. Here only health status is considered, to avoid co-benefits double counting Additionally, looking at the working conditions in green buildings, it has been found how they can lead to relevant productivity gains (Johnson Controls 2011; Lovins 2004), as well as better performances of users in public and commercial buildings, such as offices or schools (Ürge-Vorsatz et al. 2014). Lovins (2004) argues that in efficient buildings "labour productivity typically rises by about 6–16 %. Since office workers in industrialized countries cost ~100× more than office energy, a 1 % increase in labour productivity has the same bottom-line effect as eliminating the energy bill"

Smart community				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Tackling fuel poverty	Reduced number of excess winter deaths attributable to cold housing Reduced number of excess summer deaths attributable to hot housing Changes in number of households spending more than 10 % of their income in energy bills	Economic evaluation of mortality impacts may be related to reduced lifespan due to premature mortality	Severe thermal stress due to cold homes in winter, as well as heatwaves in the hot season, can even cause death; therefore the borderline between heath benefit and fuel poverty can be set as passing from morbidity to mortality. In Hungary, more than 1,000 fuel-poverty-related excess winter deaths per year have been recently reported, affecting mostly seniors over 60 years old (Ürge-Vorsatz et al. 2010). Bone et al. (2010) reports that a radicalization of summer climate conditions is expected in the next year in UK, where during the 2003 summer, characterized by intense heatwaves, over 2,000 extra deaths occurred A cost-benefit analysis of a randomized trial on retrofitting low-income communities in New Zealand with insulation is reported in Chapman et al. (2009) According to US EPA, as cited in Williams et al. (2012), the economic valuation of mortality impacts should include: • the value of reduced lifespan due to premature mortality; • medical expenditures (e.g., for hospitalizations, medicines); the value associated with pain and suffering	To avoid double counting between "tackling fuel poverty" and "health and well-being increased", here only extreme events, leading to death, related to the inability to ensure adequate indoor termal conditions should be measured
Users awareness on energy-related	Number of end users who received training in the field of SSEDPs and	HC approach can provide a monetary estimation of knowledge gained through	From a quantitative point of view, an UK study estimates that "energy-efficiency behaviors" account for 51, 37, and 11 % of the variance in heat, electricity, and water consumption,	As argued by Lewis et al. (2013) training activities are often cost-effective, because they can result in significant financial savings

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Smart community				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
issues increased	number or hours of training	training or courses participation	respectively, between dwellings" (Gill et al. 2010) Assessment of training effectiveness can be done by applying several models, as the Kirkpatrick's four-level evaluation model (reaction, learning, behavior, results) and consequently it is possible to measure the return on investment (Roi) in human resources development (Votta 2012) Di Nucci and Spitzbart (2010) identify as appropriate indicators for CONCERTO Projects assessment the awareness creation about energy topics, the changes in energy consumption behavior, and the willingness to invest in energy saving measures or to pay more for RES/EE/green electricity	Schweiker and Shukuya, cited by Rae and Bradley (2012), demonstrate the effectiveness of users' education, suggesting how "technological and behavioural improvements should go hand in hand"
	Energy behavior's changes based on different kind of feedbacks	Direct monetary value	The European Environment Agency (EEA 2013) reports successful experiences in changing consumer behavior (up to 20 % energy savings) through direct and indirect feedback, where the first include information provided directly to consumers' ICT devices or in-home displays. The latter concern increases in energy-bill frequencies or inclusion of historical and/or comparative information To measure the energy behavior's changes Hori et al. (2013) propose the following variables: (i) Energy saving behavior, (ii) global warming consciousness, (iii) environmental behavior and (iv) social interaction	Studies on barriers to energy efficiency (Sorrell et al. 2004) or to renewable sources penetration (Painuly 2001) identify the social, cultural, and behavioral mechanisms as a relevant category. Within this category, remarkable elements are identified, such as: unknown product, resistance to change, and inadequate or imperfect information Feedback can be proposed in various forms and can have positive impacts on household energy behaviors (Brandon and Lewis 1999)

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Smart community				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			Moreover, methods of impact evaluation of feedbacks on energy behaviours are in Khandker et al. (2010)	
Enhancement of neighborhood identity	Social support, in terms of frequency of contacts and perception of possibility to count on someone else	CV: WTP for better social support CE technique can help to identify positive changes to neighborhood's key attributes defining its identity	The Organisation for Economic Co-operation and Development uses the term of social support as fundamental element to measure the quality of life (OECD 2011). People count on social support for spending time with others and being more satisfied with activities. Furthermore, contacts can increase neighborhood identity Lee (2008) defined a conceptual model to investigate neighborhood quality of life (QOL) in Taipei, including identify and related variables and Di Nucci and Spitzbart (2010) assessed the improvement of the sense-of-place and communities' social well-being as well as the perception of the demo site of selected CONCERTO projects Population living in areas with integrated urban-development strategies is also an indicator suggest by EU (2013) for projects assessment	The district approach that characterizes the SSEDPs, upgrading the whole living area or community instead of a single building, effects a great impact, that results in a neighborhood's image enhancement OECD (2001) recall how "investment in individual and group identity can lead to the creation of dense social networks and ultimately better economic and social outcomes"

Smart governance				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Innovation in processes and decision making	Number of people with increased professional capacity due to their participation in interregional cooperation activities in the field of SSEDPs Human capital and social learning Social capital in arena of decision maker. Acceptance of process and outputs	HC approach can provide a monetary estimation of increased professional capacity	According to Borgatti (1998), in innovation and decision-making processes, involved parties draw their needs, values, and expectations. In smart governance, the innovative process also involves participants in social-learning processes, in increasing human capital, and in creating new networks of social capital that are able to promote local contacts	The SSEDP environment, as a temporary organization and new system of relationships, forces actors to step away from their usual way of doing, the so-called comfort zone (Beurden 2011), and results in enhancement of motivation, knowledge, and skills
Territorial attractiveness increased	Number of learning exchanges undertaken to demo sites and offices or departments involved in the SSEDPs	Direct monetary value CS estimated with travel cost methods	Maabjerg "BioEnergy" (ECOSTILER project), one of world's largest biomass plants, received 5,000 international visitors in 2012 (IEA 2014a); the "Fossil Fuel Free Växjö" district (SESAC project) has become an attraction with at least 100 visiting delegations per year. Within the SORCER project, a scientific conference with more than 100 participants was organized Campbell (2012) quantifies per each delegation 7-person team staying for 4 nights, with an	Transforming an existing city district into a (or developing a new one) smart and sustainable district means developing an attractive location for households and business from outside, and additionally a demonstration site for interested in innovative and green-solution visitors (institutions, professionals, students, etc.) Moreover improving the smart and sustainable image of the city increase green tourism

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Smart governance				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			average local expenditure of US$ 800 per capita EU (2013) suggests to consider as an indicator the increase in expected numbers of visits to supported sites and attractions, and this could be explored with the travel cost method Additionally, Di Nucci and Spitzbart (2010) identify assessment of the increased visibility of the case-study area as an appropriate indicator for CONCERTO projects	
Institutional relationship and networks created	Social capital in and between cities (trust, reciprocity, cooperation) Number affiliations in national, international networks or groups SNA considering: number of nodes and number of relationships between nodes; diversity of nodes (e.g., in terms of kind of institutions and project's objectives); social capital surplus or deficit (in terms of competences of nodes); reputational power of leader	Investigating the influence of social capital through a social network analysis (SNA) on the WTP for new energy efficiency technology	Through the involvement in projects, institutions develop social capital that means networks, values, norms, and viewpoints. Such elements facilitate the cooperation between the involved institutions in exchanging resources, reaching project's results, and participating in new calls for projects funding, becoming more competitive (Franceschetti et al. 2015). For further resources, see Borgatti (1998), Franceschetti et al.	Territorial attractiveness concerns more dissemination and the target groups are public, students, or other projects that want to learn from you; but networking is learning together and its target groups are governors and international networks Valuing social capital is a very complex task, creating a reliable hypothetical scenario may be very hard

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Smart governance

Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			(2015), Krishna and Shrader (2000), and OECD (2001) EU (2013) suggests to consider as an indicator the number of research institutions and enterprises involved or the number of enterprises cooperating with research institutions To our knowledge, a WTP study in this topic has never been published yet. However, Jones et al. (2009) carried out an evaluation of the interaction of social capital and WTP in the environmental field, which could be applied in the networking field	

Smart economy				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Positive changes to local-tax revenue	Local income tax or labor income tax revenues	Direct monetary value	An estimation of effects in investments and tax revenues, related to an extent and deep renovation of the European building stock, concludes that public finances at EU level will benefit from an annual net improvement of € 6 billion due to reduced outlay on subsidies, although balanced by an equal loss of tax revenues from energy taxation (Joyce et al. 2013). Nevertheless, due to increasing economic activity, a positive impact on EU GDP of € 291 billion is expected, generating additional revenues: e.g., from corporate income tax or labor income tax, VAT (Joyce et al. 2013)	At local level, the change in tax revenues is expected to be positive per Immendoerfer et al. (2014): "Thinking the actual installation and maintenance of renewables, new buildings and retrofitting measures, the required work is typically undertaken by local professionals". Usually, at least part of labor and corporate tax remain at local level, instead of VAT, excise, and tax paid on energy, that are harvested at regional or governmental level
Easier loans conditions	Financing formulas and private investment	Direct monetary value	In the US some banks and other lenders recently started to offer energy-efficiency or green loans with special financing conditions (Hoffman and Henn 2008) Di Nucci and Spitzbart (2010) identify the payback period length as an appropriate indicator for CONCERTO projects assessment Moreover, private investment matching public support to enterprises (grants) and in innovation or R&D projects are indicators suggested by EU (2013)	Tirado Herrero et al. (2011) argue that even if large-scale renovation programs are costly, especially on the upfront cost side, some interesting financing formulas are suitable, e.g., pay-as-you-save, where the state provides interest-free loans

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Smart economy				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
	Additional funds drawn	Direct monetary value	Immendoerfer et al. (2014) point out that although "CONCERTO funding (was) very small in comparison to total capital cost (it) was enough to stimulate other investment". Involved municipalities "mobilised their own resources to subsidise projects further or drew on regional or national funding pots. These often came from urban renewal schemes or environmental funds"	Considering additional funding sources and revenues from feed-in tariffs "the picture would look very different for many projects" (Immendoerfer et al. 2014)
Stimulation of local job's market	Number and value of full time employment (FTE) positions created for: the implementation of the project (construction sector, design, etc.); planning and development of the project (management)	Direct monetary value	A recent report by Janssen and Staniaszek (2012), commissioned by the Energy Efficiency Industry Forum (EEIF), analyzing several reputable studies, concedes that, on average, 19 new direct local and non-transferable jobs in the construction sector for each € 1 million invested in energy efficiency refurbishment of EU building stock can be expected. This result is particularly relevant, because building renovation activities are much more labor-intensive than other types, such as road infrastructure (Ürge-Vorsatz et al. 2010) At EU level, the investments in a large-scale refurbishment program of existing building stock could generate annual employment opportunities: due to	A broad global overview on the possible impact of the various low-carbon economy sectors on the creation of new green jobs, with adequate working conditions and wages, is discussed in UNEP/ILO/IOE/ITUC (2008)

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Smart economy				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			the actual time of economic underperformance, for 760,000–1,48 million job opportunities, equal to a benefit to EU GDP of €153–291 bn depending on the level of investments (Joyce et al. 2013) Number of job opportunities created in course of project activities and the number of new business created in project area are considered within the indicators defined by Di Nucci and Spitzbart (2010) for CONCERTO Projects assessment	
Local energy-supply chain development	Avoided cost of by-products disposal (e.g., urban waste, sewage, or animal slurries)	Direct monetary value	An overview of investment costs and benefits related to a very large-scale biomass plant in Denmark, able to cover the demand for district heating in 5,000 homes and power consumption of 12,000 homes, are reported in IEA (2014a). In this example a socio-economic value of 1 bn DKK over 20 years is declared, including avoided CO_2 emissions and animal-slurries disposal Increase in local control of energy supply and in local energy production are defined in the indicators set up by Di Nucci and Spitzbart (2010) for CONCERTO projects assessment	Since the exploitation of local renewable-energy sources is usually mentioned as a main SSEDP goal, the revenues generated by selling clean energy, as well as feed-in tariffs and avoided fossil-fuel consumption, should not be considered. The same for avoided CO_2 emissions

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Smart economy				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Energy services establishment	Number of ESCOs developed during the project and expected revenues	Direct monetary value	In the last decades, ESCOs have founded $20-billion-worth of projects worldwide, about $4-billion in the US, more than a quarter of which is intended to design, install, operate, and maintain energy-efficiency measures in buildings (UNEP/ILO/IOE/ITUC 2008) Stimulation of local economy is defined in the indicators set up by Di Nucci and Spitzbart (2010) for CONCERTO Projects assessment	The SSEDPs' neighborhood approach can offer up options for financing solutions other than direct investment (Immendoerfer, et al. 2014). Larger scale may provide better conditions due to the dimension of the intervention itself and multiple implementable measures
Innovation in technology development and adoption	Incomes from additional sales of the involved firms after the adoption of new technologies	Direct monetary value	EU (2013) suggests to consider as an indicator the number of enterprises supported to introduce new-to-the-market products According to Damm and Monroy (2011), innovative joint activities might sustain product or process innovation, therefore generally increasing revenues. Ahearne et al. (2013) propose a Technology Performance Usage Model (TPUM), to look for usage levels that lead to optimum effect on sales performance. This work was applied to 131 firms of various sectors, when focusing on the co-benefit effect this model could be replicated by surveying the effects on the local firms involved in the project	

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Smart economy				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Professional skills development	Number of professionals who received training in the field of SSEDPs and number or hours of training	HC approach can provide a monetary estimation of knowledge gained through training or courses participation	Providing analyses of three different methods of estimating the monetary value of HC can be done following techniques suggested by Dagum (2006) and by Nosvelli (2009) Assessment of training effectiveness can be done by applying several models, as the Kirkpatrick's four-level evaluation model (reaction, learning, behavior, results) and consequently, it is possible to measure the return on investment (Roi) in human-resources development (Votta 2012) Number of training activities/courses offered is considered by Di Nucci and Spitzbart (2010) for CONCERTO projects assessment and the number of participants in joint education and training schemes is suggested by EU (2013)	Tirado Herrero et al. (2011), analyzing three different retrofitting scenarios for the Hungarian building stock, found that in the deep retrofitting scenario the crew composition should be on average 30 % architects/professionals, 47 % skilled workers, and 23 % unskilled workers. These figures show how marginal is the involvement of unskilled workers. Cam (2012) stress how crucial are capacity-building programs, delivering highly-skilled professionals and technicians, to ensure an adequate design and operation of active design solution in buildings. It is therefore clear how knowledge development, which is a dominant part of HC (Dagum 2006), support the high-technology economy and building sector (Hanushek 2002)

Smart built environment

Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
Increased assets value	Number of households with improved and certified energy performances	CS: Hedonic price model may identify the share of price premium for certified buildings exceeding monetary savings related to energy efficiency	Economics of green buildings has been widely analyzed by Eichholtz et al. (2010) A recent review on US green-buildings-market analysis reports an increased resale value from 5.8 to 35 % and increased rental rates from 2 to 17 %, coupled with an higher occupancy rates from 2 to 18 % (Johnson Controls 2011) Bonifaci and Copiello (2015), studying the Italian residential market, found that there is a positive gap between building-price premium and the achievable monetary savings given by reduced energy consumption. In the upper class "A", the incidence of capitalized savings on average market value, with reference to worst class "G", is 13.3 %, where the market price premium is 21.9 % Di Nucci and Spitzbart (2010) define the increase in	Energy performances of buildings are certified, therefore energy costs predictable. Building's sustainable certification contributes to rent premiums according to (Fuerst and McAllister 2009). Nevertheless, consumers appreciation has high variability in different territorial contexts and countries (Bonifaci and Copiello 2015; Johnson Controls 2011; Popescu et al. 2012)

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Smart built environment				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			real-estate and flats values as an appropriate outcome indicator for CONCERTO projects, while EU (2013) suggests to consider the number of households with improved energy-consumption classification	
	Price of houses in the surrounding of demonstration site (not directly interested by refurbishment measures) where renewable energy sources are adopted	CS: Spatial hedonic price model	Won Kim et al. (2003) measured the benefits of air-quality improvement in Seoul metropolitan area applying a spatial hedonic approach to the housing market. They found that where SO_2 pollution levels are higher than standard, they had a significant impact on housing prices: the marginal willingness to pay (WTP) per 4 % SO_2 mean—concentration reduction is about $2,333, i.e., 1.43 % of mean house value	
Buildings life-cycle costs reduction	Life-cycle costs of refurbished green buildings (except for energy expenditures)	CV: WTP for reducing the need of intervention, spare parts, and replacement hassles	As reported by (Hoffman and Henn 2008) construction cost for green buildings, like LEED certified, are today slightly	In buildings retrofitting, especially social housing, the containment of the cost for interventions, as well as

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Smart built environment

Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			higher than conventional buildings on average on the order of 2 %, or even lower. For example, citing Lockwood, they declare savings in construction costs per retail branch by building to LEED standards around US$ 80,000 Moreover, introducing energy-efficient technologies reduces maintenance, repair, and operation costs: e.g., longer lifetimes of hard-to-reach fixtures reduces the need of spare parts and replacement hassles (Ürge-Vorsatz et al. 2014). Nevertheless, to our knowledge, a WTP study in this topic has never been published yet According to Immendoerfer et al. (2014), the SSEDPs approach of tackling retrofitting at neighborhood scale has the potential for standardizing the approach,	management and maintenance, up to demolition costs, deserves careful consideration (Boeri et al. 2011)

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Smart built environment				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			leading to economies of scale, due to similarities in buildings typologies	
Resilience of energy infrastructures increased	Avoided cost of blackout interruption Physical intervention of maintenance workers	Direct monetary value	Schweitzer and Tonn (2002) analyzing non-energy benefits of The National Weatherization Assistance Program for low-income houses in the US, report, as service provision benefits, a transmission and distribution-loss reduction estimated in a NPV of US$ 33–80 per participating household. This is because efficient dwellings need less electric power, and consequently less energy has to be transported. Similarly, regarding thermal services, they recognize how, avoiding emergency calls, utilities save staff time and resources, which constitute a monetary benefit having NPV from $77 to 394 Reduction of energy costs is defined as appropriate	Achievement of more resilient systems is needed to prevent damage and blackouts acting on soft and hard components. This can be done by coupling predictive solution-and-metering systems, to prevent or manage demand peaks, with physical changes in the architecture of the system and diversification of supply systems and sources

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Smart built environment				
Co-benefit	Evaluation indicators	Monetization techniques or approaches	Reference literature	Strengths/shortcomings
			indicator for CONCERTO Projects by Di Nucci and Spitzbart (2010) EU (2013) suggests to consider as an indicator the number of additional energy users connected to improved energy systems (i.e., smart grids)	

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Assessing Socio-Economic Sustainability of Urban Regeneration Programs: An Integrated Approach

Marta Bottero and Giulio Mondini

Abstract Traditionally, the assessment of urban and territorial transformation scenarios has been based on the application of economic analysis, such as cost-benefit analysis. Many authors have highlighted the limits of economic analysis in addressing urban and territorial transformation decision problems; these limits are mainly related to a reductionist approach that does not enable consideration of the overall complexity of the system, and to the impossibility of including stakeholders in the decision-making process. For these reasons, methods belonging to the family of Multicriteria Analysis have become more and more important, even if drawbacks related to the use of non conventional procedures and to the difficulties of conducting the analysis have been put in evidence. The paper explores the use of a hybrid approach based on the combination of economic analysis and multicriteria analysis for supporting decision-making processes in the context of urban regeneration processes. In particular, the article investigates the construction of an integrated evaluation model able to consider both qualitative and quantitative information and both economic and extra-economic data in order to provide a socio-economic rating of alternative regeneration projects or strategies. Starting with a real case study related to a social housing estate located in Northern Italy, the paper illustrates the proposed integrated approach for rating four different strategies for the regeneration of the site.

Keywords Social benefits · Urban regeneration · Socio-economic rating · Stakeholders · Strategic assessment · Energy retrofit operations

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1 Introduction

The problems related to cities are assuming more and more importance in the policy-maker's agenda during the last years. In this sense, it is possible to highlight that, in 2010, 50 % of the world's population lived in urban areas, and this figure is forecast to rise to 75 % by 2050 (UN 2008). Due to this increase in urban population, governments are required to figure out how to create spaces for the citizens in the future. In this sense, it is also necessary to think about the future quality of life in cities.

An emerging approach in the context of urban systems is related to the concept of smart cities, which can be defined as those cities that utilize information-and-communication technologies (ICT) with the aim to increase the life quality of their inhabitants while providing sustainable development.

According to the scientific literature (Centre for Regional Science 2007), six axes exist for the creation of a smart city; these axes can be described as follows: (1) smart governance, (2) smart economy, (3) smart people, (4) smart living, (5) smart environment, and (6) smart mobility. Moreover, cities should base their smart-city models on three main pillars: infrastructure, human capital, and information (Fig. 1).

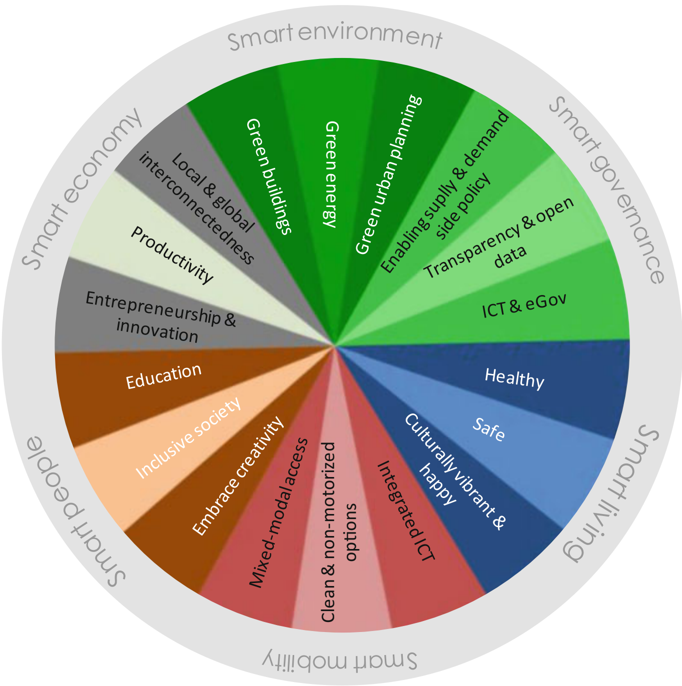

Fig. 1 The concept of smart city represented by the "Smart City Wheel" (elaboration from Cohen 2013)

Recently, some authors put into evidence the fuzzy nature of the concept of smart city. According to these authors, the smart city can be summarized by the following elements (Caragliu et al. 2009; Holland 2008):

1. Use of networked infrastructure (e.g., business services, housing, leisure and lifestyle services, and ICTs, including mobile and fixed phones, satellite TVs, computer networks, e-commerce, internet services, etc.) to improve economic and political efficiency and enable social, cultural and urban development (Coe et al. 2008);
2. Emphasis on business-led urban development;
3. Strong focus on the aim to achieve the social inclusion of various urban residents in public services, with specific reference to public participation, e-democracy, and e-governance;
4. Stress on the crucial role of high-tech and creative industries in long-run urban growth, following the ideas of Florida (2002);
5. Profound attention to the role of social and relational capital in urban development;
6. Social and environmental sustainability as a major strategic component of smart cities.

In the light of the aforementioned issues, in order to face the future problems related to city, a very important topic is connected to the reduction of soil consumption (Bottero et al. 2014). According to this approach, a crucial role is played by urban regeneration operations, meaning not only building-restoration operations, but also programs aiming at eliminating social decline, increasing the quality of life of the inhabitants, supporting the valorization of cultural resources, protecting the environmental system, bringing economic development, and so on. In fact, as mentioned by Roberts (2000), urban areas are complex and dynamic systems, reflecting the processes that drive physical, social, environmental, and economic transition and generating themselves important changes. Taking into consideration this complexity, it is of particular importance to provide the decision makers with integrated evaluation tools, able to consider the multiplicity of objectives and values when dealing with urban regeneration processes and to include the opinions and the needs of the different stakeholders involved.

The paper explores the use of a hybrid approach based on the combination of economic analysis and Multicriteria Analysis for supporting decision-making processes in the context of urban regeneration processes. In particular, the article investigates the construction of an integrated evaluation model able to consider both qualitative and quantitative information and both economic and non-economic variables in order to provide socio-economic ratings of alternative regeneration projects or strategies. The proposed methodology is applied on a real case study concerning an urban regeneration operation.

After the introduction, the rest of the paper is organized as follows: Sect. 2 provides an overview in the domain of evaluation approaches for supporting urban regeneration processes; Sect. 3 illustrates the integrated methodology proposed in the study; Sect. 4 presents the application of the methodology on a real case; finally, Sect. 5 discusses the main results of the research and summarizes the conclusions of the study.

2 Urban Regeneration Programs: A Taxonomy of the Evaluation Approaches

As already mentioned, urban regeneration processes are multidimensional concepts which includes socio-economic, ecological, technical, and ethical perspectives. Decision problems in the domain of urban regeneration processes represent “weak” or unstructured problems that are defined as problem which contains mostly qualitative parameters with no objective model for their aggregation (Moshkovich et al. 2005). Moreover, unstructured problems are characterized by multiple actors, many and often conflicting values and views, a wealth of possible outcomes, and high uncertainty (Prigogine 1997; Simon 1960). Under these circumstances, the evaluation of alternative projects is therefore a complex decision problem where different aspects need to be considered simultaneously, taking into account both technical elements, which are based on empirical observations, and non-technical elements, which are based on social visions, subjective preferences, and perspectives (Bottero 2015; Bottero and Mondini 2009).

In this context, many evaluation techniques and tools are available, depending on the phase in which the evaluation takes place (i.e., before, during, or after the construction of the project) (Table 1).

Table 1 Taxonomy of the evaluation approaches (elaboration from Bezzi 1998)

	Ex-ante	In-itinere	Ex-post
WHY	To formulate the project	To control if the project meets the initial objectives, putting in evidence the unexpected effects	To learn from past experiences and to inform public authorities and population
WHEN	Before the preparation of the project	During the construction phase	After a reasonable period of time
WHAT	Strategy and tactics	Tactics with reference to the strategy	Mostly the strategy, then the tactics
HOW	Scenario building Experts judgments Cost-benefit analysis Discounted cash-flow analysis Multicriteria analysis	Performance indicators Documents analysis Monitoring data	Surveys Analysis of the effects Econometric models

In the *ex-ante* phase, the evaluation tools are necessary to support the formulation of the project, providing information both on the strategies (that are represented by the objectives that the project is likely to pursue) and the visions (that are the actions that the project will implement in order to reach the objectives).

The *in-itinere* phase is mostly related to controlling that the project meets the initial objectives, putting in evidence the unexpected effects, while in the *ex-post* phase the evaluation process can help to make a final balance of the experiences and to inform the decision makers and the stakeholders about the final results that the project has attained.

3 Methodological Approach for the Proposed Integrated Evaluation Framework

A very well-known approach for the evaluation of urban regeneration operations refers to the method of cost-benefit analysis (CBA). However, it has been noticed that the CBA approach is subject to some limitations due to the problems arising in the economic measurement of intangible costs and benefits. In fact, only in some cases can the output of urban regeneration activities be evaluated using market-based data. In other cases, as for example in the valuation of the environmental quality, it is necessary to apply specific evaluation methods, such as the contingent valuation method (Carson 2000), that can result in time-consuming, complex-to-apply analysis and require a great cognitive effort (Tyler et al. 2013). For these reasons, the methodology proposed in the present study combines two evaluation approaches: the discounted cash-flow analysis and the multicriteria analysis in order to support decision problems in the context of urban regeneration processes. In fact, both the methodologies present negative points (Beria et al. 2012). For example, economic analysis is not able to manage intangible and extra-economic impacts and thus is not useful for providing a measure of urban quality of life. Conversely, multicriteria analysis is difficult to implement, and it is based on non-conventional evaluation procedures. For these reasons, the joint use of the two methodologies could overcome the limitations, providing a coherent approach for assessing both the efficiency and the effectiveness of urban regeneration programs.

The present study aims at investigating the use of an integrated model able to take into consideration the economic-financial aspects of the problems as well as the social benefits provided by the interventions under examination. An original model is proposed for the assessment of the socio-economic rating of alternative projects.

3.1 Discounted Cash-Flow Analysis

Feasibility analysis aims at answering the question "will it work?" for a specific project proposal. In principle, the method is based on the identification of the full range of costs and outcomes of the project in order to enable the investor to understand if the minimum objectives will be achievable.

According to the scientific literature (Oprea 2010), feasibility analysis is iterative and continuous and it involves the following eight steps: (1) assessing the physical and legal aspects of the site; (2) estimating demand for the space; (3) analyzing competitive space; (4) estimating costs of acquisition, construction, or rehabilitation; (5) estimating the cost and availability of borrowed funds; (6) estimating absorption rates; (7) developing cash-flow schedules; and (8) evaluating the estimated cash flow in terms of acceptability of the expected outcome.

A very important part of the overall feasibility study is related to the financial analysis, which normally can be addressed through discounted cash-flow analysis (DCFA). Particularly, this technique is used to derive economic and financial performance criteria for investment projects (French and Gabrielli 2004) in the form of synthetic and easy-to-interpret indicators that enable the decision maker to understand if the project should be accepted or rejected. The most used project-performance criteria are net present value (NPV) and the internal rate of return (IRR).

Let X be a project with real benefits B_{Xt} and real costs C_{Xt}, in $t = 0,1,\ldots, T$ years from now and r the discount rate. The NPV of the project can be defined as in Eq. 1:

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} \tag{1}$$

It has been noticed that: (i) If NPV = 0, it means that the discounted benefits are equal to the discounted costs, and then we should be indifferent in the decision whether to accept or reject the project; (ii) If NPV > 0, it means that the discounted benefits are larger than the discounted costs, and then we should accept the project; (iii) If NPV < 0, it means that the discounted benefits are smaller than the discounted costs, and then we should reject the project.

With reference to the internal rate of return (IRR) of the investment, the value can be derived by finding the rate of return such that the project breaks even. This means to find the rate of return that makes the present value zero as represented in the Eq. (2):

$$\sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = 0 \Rightarrow r = \mathrm{IRR} \tag{2}$$

It is possible to affirm that the project is acceptable if IRR > r (i.e., rate of return exceeds opportunity cost).

3.2 Multicriteria Analysis

Multicriteria analysis (MCA) (Roy and Bouyssou 1993; Figueira et al. 2005; Bouyssou et al. 2006) is a valuable and increasingly widely-used tool to aid decision making where there is a choice to be made between competing options. It is particularly useful as a tool for sustainability assessment and urban and territorial planning, where a complex and inter-connected range of environmental, social, and economic issues must be taken into consideration and where objectives are often competing, making trade-offs unavoidable (Huang et al. 2011). In fact, MCA has been regarded as a suitable set of methods to perform sustainability evaluations as a result of its flexibility and the possibility of facilitating the dialogue between stakeholders, analysts, and scientists (Cinelli et al. 2014).

MCA consists of a group of approaches that enable one to account explicitly for multiple criteria, in order to support individuals or groups to rank, select and/or compare different alternatives (e.g., products, technologies, policies) (Belton and Stewart 2002).

Various theories exist within the context of MCA methods that can be described as follows:

(a) Utility function theory: the utility-based theory includes methods synthesizing the information in a unique parameter (also called performance aggregation-based approaches), as introduced during the 1970s by Keeney and Raiffa (1976);
(b) Outranking relation: the outranking-relation theory involves methods based on comparisons between pairs of options to verify whether “alternative a is at least as good as alternative b” (also called preference aggregation-based approaches) (Roy and Bouyssou 1993);
(c) Sets of decision rules: the decision-rule theory originates from the artificial-intelligence domain, and it enables deriving a preference model through the use of classification or comparison of decision examples (Greco et al. 2001).

Many applications of MCA exist in the field of sustainability assessment, and a broad overview can be found in Munda (2005) and Huang et al. (2011).

3.3 Socio-Economic Rating

As mentioned in the introduction, the appraisal of urban regeneration projects and plans should be based on all relevant impacts, which depend on the type and size of the project being considered. Some of these impacts can be assessed in the moment, and thereby it is possible to include them in a decision model, as for example the DCFA model. However, there are other relevant impacts such as new services for the inhabitants, quality of the environment, etc. that hold a potential for improving the actual decision support based on the assessment, if they are treated properly. These non-monetary impacts should instead be assessed using MCA.

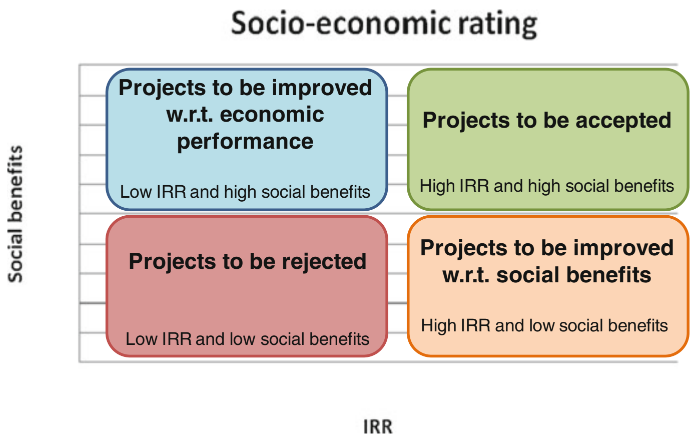

Fig. 2 Integrated framework for the evaluation of the socio-economic rating (elaboration from SINLOC 2014)

The idea behind composite-modelling assessment is to use in tandem the results of the cash-flow analysis and the multicriteria analysis in order to produce a more comprehensive type of appraisal as often demanded by decision makers by including these 'missing' decision criteria of relevance for the actual assessment task.

The results of the combined model are represented in a scattered plot where the x axis represents the financial performance of the project under examination (i.e., the value of the IRR) and the y axis represents the overall value of the project with reference to the production of social benefits (i.e., the priority of the project according to the MCA evaluation) (SINLOC 2014) (Fig. 2).

As a result of this evaluation, the project can be classified according to the following categories:

- low IRR and low social benefits: it means that the project should be rejected;
- high IRR and low social benefits: it means that the project should be improved from the point of view of the creation of social benefits in order to be accepted;
- low IRR and high social benefits: it means that the project should be improved from the point of view of the economic convenience in order to be accepted;
- high IRR and high social benefits: it means that the project should be accepted.

4 Application

4.1 *Description of the Case Study*

The case used for the experimentation with the proposed method is related to a real-world operation. In particular, the application considers the requalification of a social housing district located in the Province of Trento (Northern Italy).

The district is made by nine buildings that are owned by the Local Social Housing Authority (LSHA). The district is actually composed by 229 apartments which are rent-controlled. In order to meet the demand of the LSHA for an increase in the number of apartments in the districts and for an overall requalification of the district, four alternative strategies have been considered. The alternative options have been evaluated by means of the proposed evaluation framework in order to analyze their performances both from the point of view of the financial-economic aspects and from the point of view of the social-benefits generation. The alternative strategies are illustrated in Table 2 (Saraniti Pettinato et al. 2014).

4.2 Estimation of the Economic Performance

Following the methodology described in Sect. 3.1, a discounted cash-flow analysis (DCFA) has been developed for the evaluation of the alternative projects.

In the performed evaluation, the costs are represented by the investment cost of the transformation while the incomes are related to the rents produced by the project. As far as the building costs are considered, it is important to highlight that the unitary construction costs were appraised following the comparative-unit method, which is used to derive a cost estimate in terms of euro per unit of area or volume based on known costs of similar structures. In this case, the construction

Table 2 Description of the four alternative strategies under investigation

Alternative strategies	Description
Strategy 1	This project considers the construction of two new storeys on the top of the existing buildings in order to expand the current supply of apartments. The first new floor will be dedicated to social housing apartments while the second one is for ordinary apartments. The strategy also considers energy-retrofitting operations for the existing buildings by means of traditional technologies (insulation and substitution of windows). The ground floor of the buildings will be renovated and new common spaces for social aggregation will be created. Moreover, the project consider the requalification of the external areas of the buildings and the creation of new parking
Strategy 2	This strategy is similar to the first strategy but the project considers more ordinary apartments and less social housing apartments with respect to strategy 1
Strategy 3	This project only considers the construction of two new storeys for the creation of new apartments that will be entirely dedicated to social housing
Strategy 4	The strategy considers the construction of the two new storeys that will be entirely dedicated to ordinary apartments. The project also takes into account the development of energy-retrofitting operations and building-requalification interventions on the existing blocks by means of innovative technologies (e.g., prefabricated elements for energy retrofit). The renovation of the external areas and of the common spaces on the ground floors is minor in comparison with strategies 1 and 2

cost was estimated as 1,335 €/m^2 for new residential buildings. As far as the incomes are concerned, the analysis of the local property market conducted produced an average rent of 350 €/month for social housing apartments and of 500 €/month for conventional apartments. The general costs (which represent the cost of the investment process, including the expenses related to offices, particular consulting services, company formation, etc.) and the technical costs (which refer to the costs for the design and the management of the project and of the supervision of the construction works) were 2 and 8 %, respectively, of the total construction cost, while the annual maintenance cost were 0.5 % of construction costs. Moreover, it has to be mentioned that the analysis estimates the feasibility of the project for a potential developer assuming that the project is financed by bank borrowing. Under this assumption, the bank agrees to lend money to the developer at a "passive" (debit) rate while the bank will apply an "active" (credit) rate if the account is in credit (French and Gabrielli 2004). The rates used in the present study are 3 % for passive rate and 1 % for active rate. As an example, Table 3 details the DCFA that has been implemented for the evaluation of the strategy 2. The results of the calculation of the IRR over a period of 30 years for all the considered strategies are represented in Table 4. The results of the IRR are perfectly aligned with the main findings available from the scientific literature in this domain, where the IRR of a

Table 3 DCFA model for the evaluation of strategy 2

				Istantaneous Costs-Incomes		*years* 1	2	3	…
				€	%				
COSTS									
technical expenses		6.0%		8,33,896	5.6%				
Total				**8,33,896**	**5.6%**	**8,33,896**			
CONSTRUCTION COSTS		quantity	cost € /m^2						
Residential areas	m^2	8,890	1,335	1,18,68,150	79.9%	1,18,68,150			
Common spaces	m^2	120	800	96,000	0.6%	96,000			
Green areas	m^2	7,000	32	2,24,000	1.5%	2,24,000			
Energy retrofit				17,10,123	11.5%	17,10,123			
Total				**1,38,98,273**	**93.5%**	**1,38,98,273**			
TOTAL PRODUCTION COSTS				**1,47,32,169**	99.2%				
MANAGEMENT COSTS									
Insurance		2.0%	on rents	17,712	0.1%		17,712	17,712	…
Administration		0.45%	on rents	3,985	0.0%		3,985	3,985	…
Maintenance		0.50%	on const. costs	73,190	0.5%		73,190	73,190	…
Vacancy losses		3.30%	on rents	29,225	0.2%		29,225	29,225	…
Total				**1,24,112**	0.8%		**1,24,112**	**1,24,112**	…
TOTAL COSTS				**1,48,56,752**	**100.0%**	**1,47,32,169**	**1,24,112**	**1,24,112**	…
INCOMES (rents)		quantity	rent €/month						
LSHA controlled rent									
one room apartments		0	350	0	0.0%				
two rooms apartments		10	400	48,000	5.4%	48,000	48,000	48,000	…
three rooms apartments		42	500	2,52,000	28.5%	2,52,000	2,52,000	2,52,000	…
four rooms apartments		12	600	86,400	9.8%	87,091	87,091	87,091	…
Free rent									
one room apartments		24	400	1,15,200	13.0%	1,15,200	1,15,200	1,15,200	…
two rooms apartments		64	504	3,87,072	43.4%	3,87,072	3,87,072	3,87,072	…
three rooms apartments		0	600	0	0.0%				
four rooms apartments		0	800	0	0.0%	0			
Residual value									
TOTAL INCOMES				**8,85,600**	**100.0%**	**3**	**8,89,363**	**8,89,363**	**…**
CASH FLOW				-1,39,71,152		-1,38,42,806	7,65,251	7,65,251	
FINANCIAL CHARGES									
Exposition			*yearly*			-1,38,42,806	-1,34,92,839	-1,31,32,373	…
negative interest			3.0%				-4,15,284	-4,04,785	…
positive interest			1.0%			0	0	0	…
ANTE TAXES CASH FLOW						**-1,38,42,806**	**3,49,967**	**3,60,466**	**…**
		yearly							
discount rate		2.00%							
INTERNAL RATE OF RETURN			3.11%						

Table 4 Results of the economic evaluation of the four strategies of intervention

Strategies of intervention	Internal Rate of Return (IRR) (%)
Strategy 1	2.84
Strategy 2	3.11
Strategy 3	4.47
Strategy 4	3.07

social-housing operation ranges between 3 and 4 % (Copiello 2015; Copiello and Bonifaci 2015). It has to be mentioned that, even if the project is related to a social-housing operation, there is a minimum threshold that has to be reached in terms of financial performance of the investment, otherwise the project would not be able to obtain the funding for the construction. In this sense, the IRR is recognized in the literature in the field of investment decisions as a powerful indicator for measuring the financial feasibility of real-estate developments.

4.3 Evaluation of the Social Benefits

4.3.1 Definition of the Set of Criteria

The first step of the MCA model consists in the definition of the family of criteria for the evaluation. Starting from the overall objective of the analysis, which is the identification of the best performing project from the point of view of the generation of social benefits, a comprehensive set of evaluation criteria that reflect all the concerns relevant to the decision problem has been identified. Mention has to be made of the fact that the family of criteria has been defined through the organization of a focus group where representatives of the stakeholders groups (i.e., inhabitants, Local Social Housing Authority, and Municipal Authority) and experts in the fields of urban planning, design, and technology of architecture were involved. The criteria have been organized according to the main criteria that represent the general aspects of the problem (namely, social *mixité*, accessibility, meeting and exchanges, buildings typology, requalification, and disturbance), that have been further divided according to specific sub-criteria (Capolongo et al. 2015). Figure 3 represents the structuring of the decision problem under investigation, while Table 5 details the evaluation criteria and sub-criteria. It is important to assure that both quantitative and qualitative indicators have been included in the evaluation model.

4.3.2 Evaluation of the Alternatives

Once the alternatives and criteria have been defined, a quantitative or qualitative estimation of the impacts of each project in terms of these criteria has to be made. The performance of the alternatives has been measured according to the evaluation criteria of the model (Table 5). The quantitative information for the evaluation has

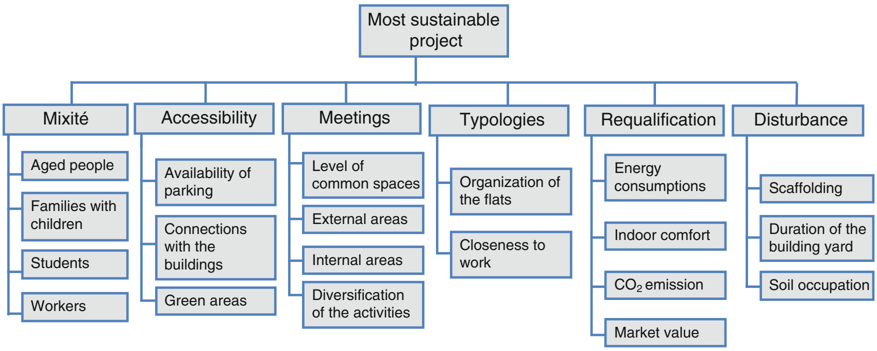

Fig. 3 Structuring of the decision problem for the evaluation of the social benefits of the project

Table 5 Description of the evaluation criteria for the multicriteria model

Criteria	Sub-criteria	Description	Unit of measure
Mixitè		Variety of the inhabitants of the district, according to the typologies of aged people, families with children, students, and workers. The *mixitè* is measured with the diversity index as presented in Eq. (3): $H = \sum_{j=1}^{s} p_j log p_j$ (3) where s is the total number of typologies and p_j is the proportion made up of the jth typology. The index varies between 0 and 1, where the value 0 indicates a very low *mixitè* while the value 1 indicates a very high *mixitè*	No.
Accessibility	Availability of parking	Area of new parking made available by the project	m^2
	Connections with the buildings	Area of spaces for the connection within each block and between the block and the external areas	m^2
	Green areas	Area of spaces left by the project as green areas	m^2
Meetings	Common spaces	Area of spaces for meeting and common activities	m^2
	External areas	Area of open spaces for outdoor collective activities, such as gardening, sport, etc.	m^2
	Internal areas	Area of internal spaces for indoor collective activities, such as laboratories, educational activities, etc.	m^2

(continued)

Table 5 (continued)

Criteria	Sub-criteria	Description	Unit of measure
	Diversification of the activities	Area of multifunctional spaces available for different common activities	m^2
Typlogogies	Organization of the flats	Variety of the apartments provided by the project. The sub-criterion considers the number of one/two/three/four rooms apartments	no.
	Closeness to work	Number of inhabitants living close to their place of study or work	no.
Requalification	Energy consumptions	Reduction of energy cost due to the energy-retrofit measures considered in the project. The variable is measured on a 0–3 points scale where the value 0 indicates a very bad performance and the value 3 indicates a very good performance	Qualitative scale
	Indoors comfort	Increase in the indoor comfort reached inside the buildings as perceived by the occupants	Qualitative scale
	CO_2 emissions	Reduction of greenhouse-gases (GHG) emissions and contribution to avoided impacts on climate change	Qualitative scale
	Market value	Increase in the asset value of the buildings in terms of real-estate valorization granted by the requalification operations	Qualitative scale
Disturbance	Scaffolding	Necessity of using scaffolding and external structures for the construction of the project	Qualitative scale
	Duration of the building yard	Temporal duration of the works for the construction of the project	Qualitative scale
	Soil occupancy	Disturbance of the building works in terms of soil occupation	Qualitative scale

been collected from the technical drawings of the project, while for the qualitative criteria an experts' panel led by the project team worked on the formulation of the judgments. Table 6 presents the performance matrix of the alternative strategies against the evaluation criteria.

The subsequent step involves the normalization procedure that allows one to aggregate non-commensurable items. As highlighted in the OECD Handbook (2008) on constructing composite indicators, normalization is required prior to any data aggregation since the indicators in a data set often have different measurement units. Several normalization techniques exist in the literature and the choice among them should be made depending on the theoretical framework chosen.

Table 6 Perfomance matrix for the multicriteria model

Subcriteria	Alternative strategies			
	1	2	3	4
Mixitè	0.75	0.79	0.46	0.49
Parking [m^2]	3,612	3,612	0	0
Connections [m^2]	1,085	1,085	0	1,085
Green areas [m^2]	2,303	2,303	570	2,303
Common spaces [m^2]	60	120	0	30
External areas [m^2]	336	336	0	168
Internal areas [m^2]	120	120	0	60
Diversification [m^2]	60	120	0	30
One room [no.]	0	24	0	24
Two rooms [no.]	78	74	74	74
Three rooms [no.]	18	42	15	18
Four rooms [no.]	18	12	15	18
Closeness [no.]	70	94	0	148
Energy consumption [qualitative scale]	2	2	0	2
Comfort [qualitative scale]	2	2	0	3
CO_2 emissions [qualitative scale]	3	3	0	3
Market value [qualitative scale]	3	3	1	3
Scaffolding [qualitative scale]	1	1	0	0
Duration [qualitative scale]	1	1	3	2
Soil occupancy [qualitative scale]	2	2	0	1

The method that appeared better-suited for the present study consists of re-scaling the original values in a 0–1 range. The usefulness of the re-scaling procedure translates into a widening effect of the normalized indicators whose original values were extremely close, thereby enhancing even small differences (FEEM 2011).

At a technical level, the raw values of each indicator for the four alternative projects have thus been converted into the 0–1 scale, awarding 0 to the minimum value and 1 to the maximum value. Mention should be made of the fact that the problem under analysis involves both criteria that positively affect the decision (whose corresponding attributes have thus to be maximized) and criteria that negatively affect the decision (whose corresponding attributes have thus to be minimized). As a consequence, intermediate values between the minimum and the maximum have been converted through the following formulas (OECD 2008), depending on the need to maximize or minimize the attribute, respectively:

$$I_i = (x - x_{min})/(x_{max} - x_{min}) \tag{4}$$

$$I_i = (x_{max} - x)/(x_{max} - x_{min}) \tag{5}$$

in which I_i is the normalized index for each indicator and x indicates the raw value of the indicator.

The maximum and minimum values used for this type of normalization are the lowest and the highest values of a specific indicator. These values do not necessarily correspond to the best and worst possible values of that indicator in absolute terms, and they do not represent value judgments. This is quite an arbitrary choice and the selection of the bounds is not without consequences. The reason why this technique has been chosen refers to the general objective of the present application that consists of the selection of the best performing alternative. The focus of the analysis is thus on the relative differences between the alternatives.

4.3.3 Weighting and Aggregation

Once the alternatives have been evaluated, it is necessary to define the importance of the different aspects of the decision problem. As far as the sub-criteria are considered, a specific questionnaire has been developed and submitted to various real stakeholders, including the inhabitants of the housing district, the housing agency that is in charge of the management of the district, and the local association that is active in the territory. With reference to the criteria level, a number of experts with expertise in the field of architecture and planning has been interviewed. As an example, Fig. 4 represents the set of weights for the three categories of stakeholders

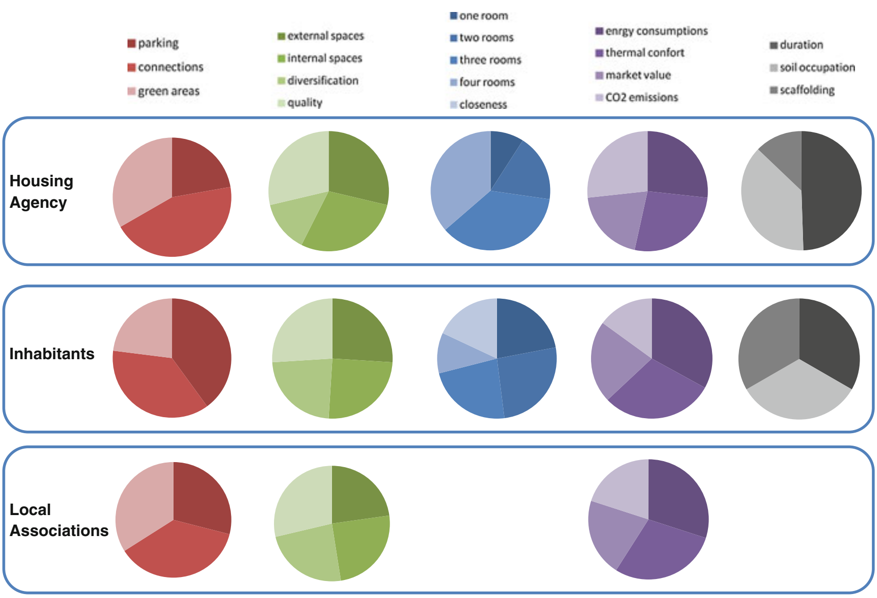

Fig. 4 Sets of weights of the sub-criteria resulting from the local stakeholders (elaboration from Saraniti Pettinato et al. 2014)

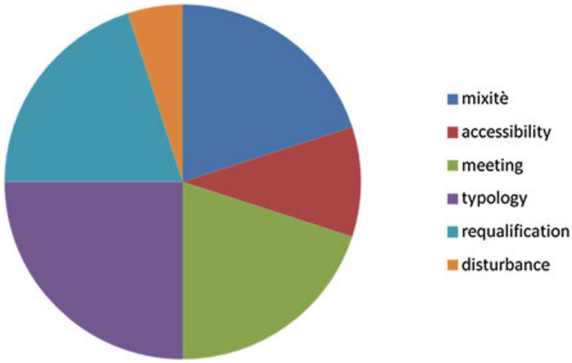

Fig. 5 Set of weights of the evaluation criteria resulting from the experts' panel (elaboration from Saraniti Pettinato et al. 2014)

considered in the application, while Fig. 5 illustrates the weights defined by the experts' panel.

The normalized values of the alternative projects have then been aggregated using the obtained set of weights and additive assumptions to calculate the total value of the specific alternatives. In particular, the final priority of the alternative is obtained by the following Eq. (6):

$$\text{final priority} = \text{normalized performance of the alternative w.r.t. the sub-criteria} \\ * \text{ weight of the sub} - \text{criterion} * \text{ weight of criterion} \tag{6}$$

The calculation developed in the case under investigation provides the final priorities (Table 7).

4.4 *Definition of the Socio-Economic Rating*

According to the proposed methodology illustrated in Sect. 3.3, the results of the economic and social evaluation have been represented in the socio-economic diagram that enables a combined exam of the performances of the alternatives under consideration (Fig. 6).

Table 7 Overall value of the alternative projects obtained from the MCA model

Strategies of intervention	Social evaluation
Strategy 1	0.82
Strategy 2	0.90
Strategy 3	0.31
Strategy 4	0.68

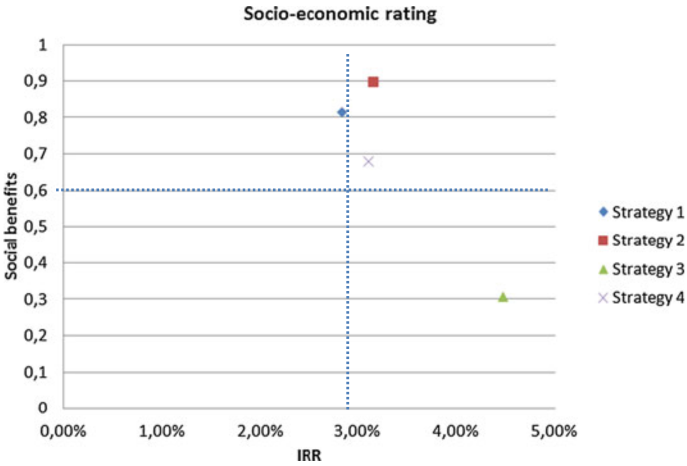

Fig. 6 Socio-economic rating of the alternative strategies under investigation

From the analysis of Fig. 6, it is possible to point out some interesting findings. First, we assume to define a threshold for the classification of the projects. This threshold can be equal to 3 % for the IRR, which represents the economic performance, and 0.6 for the score of the AMC model for the evaluation of the social benefits, which corresponds to the social performance.

Under the aforementioned assumptions, only two interventions seem to be acceptable, namely strategy 2 and strategy 4. From this subset, strategy 2 results in the best-performing solution as it has higher values for both the IRR and for the MCA score.

Moreover, we can summarize the following observations:

- Strategy 1 is determined to be good from a social point of view and, in fact, it allocates lots of spaces for aggregation; on the contrary, strategy 1 does not perform very well from an economic point of view as it proposes many social housing apartments that are rented at a controlled price.
- Strategy 2 is good both from a social and an economic point of view; in fact, this project considers a higher percentage of ordinary apartment in the operation compared with respect strategy 1. These ordinary apartments will be rented at market price, thus increasing the income and the financial convenience of the project.
- Strategy 3 performs very well from an economic point of view; in fact, it has very low intervention costs because the project does not consider the requalification of the external areas and of the common spaces and the energy-retrofitting operations. Conversely, for the same reasons, the strategy is very bad from the point of view of the generation of beneficial effects for the population.

- Strategy 4 is good both from the point of view of the creation of positive social impacts and from the point of view of the economic convenience of the operation; from the social point of view, strategy 4 performs worse than strategy 2 as strategy 4 only considers ordinary apartments, thus decreasing the level of *mixité* of the operation.

5 Conclusions

The paper proposed an original evaluation methodology for the integration of the MCA and the DCFA in the domain of urban and territorial transformations.

In particular, the integrated framework has been applied for supporting the decision problem concerning the selection among four different alternative strategies for the requalification of a social housing district.

The proposed model proved to be effective in informing, in a transparent way, the decision makers about the economic performance of the operation and the achievement of the initial social goals. This is particularly useful in the context of urban regeneration and energy-retrofit operations, where a clear evaluation has to be done in order to examine the impacts on social welfare of this kind of intervention (Mzavanadze et al. 2015)

From the point of view of the future perspectives of the study, it could be useful to test the model by means of specific robustness analysis in order to validate the results of the evaluation. In particular, it would be interesting to study in depth the definition of the acceptability thresholds which have a strong influence of the final outputs. Mention should be made of the fact that, in the present application, the acceptability limit for the financial performance has been set at 3 %; in fact, in the absence of public funds it is of particular importance to verify that the operation is able to provide a minimum economic benefit in order to grant the feasibility of the overall intervention.

Moreover, further investigation can be related to the analysis of more sophisticated MCA models for the evaluation of the social profile of the framework and to the expansion of the model by means of an integration of the MCA tool with cost-benefit analysis (CBA) in order to enlarge the space of the evaluation.

Extra work could be done related to an investigation of the repeatability of the method with the aim of providing a specific evaluation procedure for the definition of the socio-economic rating of urban regeneration programs.

Finally, it would be interesting to explore the question of whether urban regeneration involves processes of gentrification; in particular, the evaluation could investigate if requalification policies have impacts on the high cost of housing, thus reducing housing opportunities for the inhabitants and if these policies determine also other non–housing consequences such as employment effects (Cameron 1992).

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Sustainability Benefits Assessment in Urban Transport Project Appraisal: A New Method of Transport Project Appraisal

Somesh Sharma and Harry Geerlings

Abstract Transport project appraisal is an important tool in complex decision making. It helps in comparing options and prioritizing between competing choices. It can also influence the distribution of financial resources across various projects that are often executed from common sources of funding. Many important decisions taken during the development of a transport project critically rely upon estimates resulting from the project appraisal process. Most widely used appraisal methods are project based such as cost-benefit analysis (CBA), multi-criteria analysis (MCA) and environmental-impact assessment (EIA). For the appraisal of certain types of macro-level transport projects strategic appraisal methods like strategic environmental assessment (SEA) are also applied. Each of these methods has its own limitations and shortcomings which have not improved over time. In this position paper, we present a new methodological approach to transport project appraisal. This approach is based on a systematic assessment of sustainability benefits of a project, hence this approach is named Sustainability Benefits Assessment in Urban Transport Project Appraisal (SBA-UT). The approach has evolved from an in-depth review of the scientific literature about technical constructs and applications of various project appraisal methodologies used for transport project appraisal.

Keywords Urban transport · Project appraisal · Sustainability benefits · Assessment methodologies and techniques

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1 Introduction

Transport is one of the key factors that influence urban growth. The decrease of cost and travel time for transport has made cities more accessible. But this has a trade-off with sustainable development and congestion (Piet and Bruinsma 2015). Transport infrastructure is strongly correlated with urban areas; society is dependent on accessibility. Thus, any kind of intervention or changes in the transport system directly affects social, economic, and environmental aspects of the society.

Urban transport plans are the reflection of a city's spatial development strategy (ADB 2009). From this perspective, it is important that the decision making process in urban transport sector should be based on comprehensive assessment of the social, economic, and environmental impacts of transport-sector interventions. Project appraisal provides useful information for gated decision making for project implementation phases, allocation of resources, and project timelines. It also indicates risks, critical barriers, and opportunities for optimization and improving the effectiveness of efforts. Institutionally, the significance of project appraisal can also be understood as a part of communication strategy, as well as a means of introducing transparency to, and justification for, public investment projects.

This chapter is based on a systematic review of selected literature on transport project appraisal. In Sect. 2 of this chapter, we analyze various challenges with widely applied methodologies in transport project appraisal. Section 3 shows to what extent existing project appraisal methodologies can help in justifying a decision. In Sect. 4 of this chapter, we present the new methodological approach Sustainability Benefits Assessment in Urban Transport Project Appraisal (SBA-UT), which we have derived from lessons learned from the literature. This paper concludes with a theoretical discussion on positioning SBA-UT in the project appraisal process.

2 A Systematic Review of Urban-Transport Project Appraisal and Sustainability

Project appraisal is a process tool that guide governments and investors in making choices for achieving their goals (DIRD 2014). Most often transport projects are appraised primarily for examining the financial viability and economic profitability of various options (Sartori et al. 2014). However, in order to operationalize sustainability, it is imperative to identify comprehensive as well as collective effects of a project on three interrelated systems: the economic system, the ecological system, and the social-cultural system (Sharma and Geerlings 2015). The text below provides a comprehensive review of (successfully) applied methods in transport project appraisal and the challenges of these methods when it comes to a comprehensive assessment for sustainable development.

2.1 Cost-Benefit Analysis

Cost–benefit analysis (CBA) is primarily used at the stage of the assessment of options and project prioritization. A cost-benefit analysis process is primarily based on the concepts of opportunity cost from a long-term perspective. The CBA process is carried out with a set of pre-determined indicators where each indicator is associated with a positive or negative monetary value and is broadly applied to the transport sector (EIB 2013). It is a typical macro-economic approach that is meant to help assessing the welfare benefits to the society represented by economic indicators (Sartori et al. 2014).

A cost-benefit assessment is essentially limited to only those costs and benefits that could be converted into monetary values. In CBA uncertainties mainly arise from the fact that—(1) it is not possible to measure all benefits of a project accumulating over the entire life of the project; and (2) all benefits are not measurable in monetary terms. Estimating benefits of a project over its useful life are difficult to predict because factors on which benefits depend are highly dynamic (Iacono and Levinson 2015). The cost-benefit cost method is sensitive to assumptions. Quantities used, such as the discount rate, are very sensitive to local conditions, and local conditions can change frequently. These induced changes bring several benefits which are not captured in cost-benefit method. Cantarelli and Flyvbjerg (2015) in their study concluded that the main sources of error in CBA are—(1) technical limitations; (2) psychological reasons; and (3) political-economic reasons. Of these three factors, errors in cost estimates pertain to technical limitations, and this has not improved over time (Cantarelli and Flyvbjerg 2015).

2.2 Multi-criteria Analysis

Multi-criterion analysis (MCA) is a decision-making tool that involves several qualitative and quantitative criteria (Hüging et al. 2013) under a common framework of analysis, which considers the relative importance of each criterion (Mendoza et al. 1999). This approach involves the development of a composite score for each project alternative (Schutte and Brits 2012), based on the relative weight and score given to each criterion. The weights and scoring of criteria are based on analytical calculations complemented by the judgment of stakeholders and experts involved in the analysis. The use of multi-criteria analysis in transport project evaluation is considered since there is always a conflict in regard to the impacts of the project (Schutte and Brits 2012) from the perspective of various stakeholders concerned. The primary advantage of MCA over CBA is that it enables inclusion of impacts that cannot be monetarized or cannot be quantified easily in an appraisal (Gühnemann et al. 2012).

A general criticism of MCA is that it is less objective and that there is an inevitable element of subjectivity involved in assigning weights and rankings to different criteria (Gühnemann et al. 2012). The weights are assigned by decision makers' preferences, thus it often appears arbitrary (OECD 2011). That also makes it difficult to replicate a MCA framework from one case to another. In many EU countries, the national appraisal framework for transport infrastructure projects mandates a CBA and (or) MCA (Hüging et al. 2014) with majority applying only MCA (Odgaard 2006; Hüging et al. 2014). Both CBA and MCA are popular applied tools in transport project appraisal, but it can be concluded that neither CBA nor MCA is holistic.

2.3 Environmental Impact Assessment

Environmental Impact Assessment (EIA) can be explained as a systematic assessment of the effects of a proposed project, plan, or program on the environment (Ogola 2009). EIA's key proximate aim of 'providing environmental information' is to enable rational decision making by taking into consideration the likely environmental impacts of different alternatives to a project (Stephen et al. 2007). The EIA was established in 1970 in the USA under the National Environmental Policy Act (NEPA), and is currently practiced in more than 100 countries (Stephen et al. 2007). All major investment banks and bilateral financial institutions recommend a mandatory EIA for all infrastructure projects requiring more than a certain amount of investment. In many countries, EIA is adopted as a national-policy instrument, and it is mandatory to conduct an EIA for major infrastructure projects to obtain project acceptance (Ogola 2009).

The effectiveness of EIA in decision making has increasingly been challenged (Owens et al. 2004; Stephen et al. 2007). The objectivity of EIA is considered to be limited because, in an EIA, impacts are not calculated in monetary terms and this leaves room for bias in decision making as the decision-makers are usually operating within a political arena (Stephen et al. 2007). The transport sector is considered to be one of the biggest emission sources of substances that cause environmental damage like acidification and eutrophication of soil, contamination of water, and direct harm to vegetation (Rolf and Linda 2000). In the transport sector, environment impact assessment (EIA) is typically only applied at the individual project level and less frequently to wider policies, plans, or programs. As a consequence, the consideration of environmental effects is conducted at a local level (Niel and Steer 1996). Niel and Steer (1996) highlighted sever limitations of EIA applied to the transport sector, concluding that EIA can only be applied to short time-scale projects and that it excludes many important aspects in appraisal, such as cumulative effects of various phases of a project.

2.4 Strategic Environmental Assessment

Therivel et al. (1992) defined SEA as "the formalized, systematic and comprehensive process of evaluating environmental impacts of a policy, plan or program and its alternatives, including the preparation of a written report on the findings of that evaluation, and using the findings in publicly-accountable decision making" (Niel and Steer 1996). SEA is a more comprehensive assessment as compared to EIA, and most researchers have recommended making SEA a more flexible process (Jong and Geerlings 2004). The National Environment Policy Act (NEPA) in the USA laid the foundation for SEA in 1969, and the term SEA was coined in the UK in 1989. Since 2004, SEA is a mandatory requirement in EU member countries. SEA is more specifically applied in transport and land-use planning sectors (Ehrhardt and Nilsson 2012). Application of SEA varies from sector to sector and from case to case. While executing an SEA, specific methodologies have to be adopted to capture different stages of the process. An SEA can contain applications of several analytical tools in the process of execution. SEA can be considered as a systematic process tool rather than a precise analytical methodology.

Based on a review of 'Sustainability A-test', Ehrhardt and Nilsson (2012) concluded that SEA barely assesses cross-cutting sustainability aspects. On the contrary, an SEA is expected to be an integrated appraisal of a wider range of sustainability aspects. Furthermore, assessment of cumulative impacts is almost non-existent in SEA. There is a lack of explicit guidance on tool use within the framework of overall SEA guidance. There is a need for improved guidance for SEA and for strengthening the use of tools.

2.5 Multiple-Benefits Assessment

In the recent study 'Climate Smart Development', supported by the World Bank in 2014, there was an emphasis on the integrated assessment of the benefits of green-growth projects. The analytical framework termed as 'multiple-benefits assessment (MBA)' presented in the study provides a four-step set for the assessment of socio-economic benefits that may accrue from low-carbon development policies and projects. The framework attempts to integrate multiple benefits into a macroeconomic model. It demonstrates the additional benefits that can accrue in terms of GDP and employment as the benefits flow through the economy (Akbar et al. 2014). The methodology was applied to seven cases out of which three cases demonstrated multiple benefits from low-carbon policies and four cases demonstrated multiple benefits from developmental projects.

The MBA approach is an attempt to link the benefits of carbon-emission reduction with the local socio-economic benefits of a low-carbon development project. There is a great emphasis on monetization of the benefits. Conceptually, this approach is based on the theories of macroeconomics rather than the theories of sustainable development. Assessment of sustainability benefits requires a new approach that can help in explaining the process of sustainable development from a socio-economic perspective at all levels of interaction between societal systems and natural systems (Sharma and Geerlings 2015).

3 Findings from the Literature

There are several challenges involved in quantification and assessment of all benefits of an urban transport intervention. Benefits of a project can accrue at individual level, local community level or at global level. Different levels and different types of benefits cannot be estimated using a single calculus or econometric method. Currently, there is no standardized method available for assessing all relevant costs, benefits and overall impacts of urban transport projects, which affects the reliability of existing assessments, the comparability of results, and the transferability of measures (Hüging et al. 2014).

Based on the review of various project/appraisal methodologies applied to the transport sector in Sect. 2 of this chapter, it can be concluded that among all the appraisal methodologies, CBA is the most widely applied and is most successful as far as the transport sector is concerned. As seen in the literature, several methods and tools for transport project appraisal were discussed by different authors, however every author has tried to compare other appraisal method with the CBA. It indicates the success, popularity, and prominence of CBA among numerous project-appraisal methodologies. It is also proven that the amount of uncertainty involved in cost-benefit analysis is huge and estimates are often incorrect. In spite of that, CBA is adopted as a mandatory procedure in many advanced countries. It shows the lack of robust and flawless assessment methods and also that only a very limited level of accuracy can be achieved in estimating the impacts of a project. Yet project appraisal is unavoidable in investment projects. Moreover, in review of all the appraisal methodologies, it was evident that decision making using project appraisal is highly sensitive to political considerations.

EIA can be considered as yet another successful method of project appraisal which has a long history of application. However, the main role of EIA is to assess the environmental impacts of transport-sector policies, plans, and projects. As a tool for sustainability assessment, EIA is inadequate because, over and above its intrinsic technical limitations, it provides information about only one pillar of sustainability (environment).

4 Sustainability Benefits Assessment for Transport Project Appraisal

This section presents a new approach for urban-transport project appraisal. The approach is based on benefits assessment (SBA) of transport projects, and in this chapter it is referred to with an acronym SBA-UT. Underlying the concept in the SBA-UT approach is the triple bottom line (TBL) concept of sustainable development,[1] which is also the most widely accepted concept of sustainable development. Operational framework of the methodology can be visualized as an instrument that can help in a systematic appraisal of social, economic, and environmental benefits of transport sector at various scales (individual, local, and global). Sustainability is a sate, but sustainable development is a process of change (Sharma and Geerlings 2015). The model SBA-UT framework (Fig. 1) integrates the three pillars of sustainability (social, economic, and environmental) with the process of transition to sustainable development. The SBA-UT approach assumes that improvements in social, economic, and/or environmental conditions at any level of the societal hierarchy (individual, local, and/or global) is a sustainability benefit which aggregates to overall sustainable development. One of the key postulates of SBA-UT framework is that the sustainability benefits of the transport sector (or a transport project) shall be accounted differentially at individual, local, and global levels.

The conceptual framework of SBA-UT (Fig. 1) portrays the path of how an intervention can lead to social, economic, and environmental improvements in a system. Point X_1 (Fig. 1) indicates the point of intervention, and the three levels (individuals, local community, global community) signify the distributary nature of the benefits. The underlying assumption is that a change in the transport sector of an area can bring a different nature of benefits at different levels of the societal hierarchy. However, all the benefits can be categorized in terms of social, economic, or environmental benefits. The SBA-UT framework implies that analytically benefits should be measured at the level where they accrue (individual, local, or global) and then can be aggregated (represented by point X_2 in Fig. 1).

4.1 Operationalizing the SBA-UT Framework

The SBA-UT methodology follows a scenario-based approach in which two scenarios are created—(1) Pre-project scenario representing the situation before intervention; and (2) Post-project scenario, representing the situation after intervention. The first scenario (pre-project) shall essentially be a fact-based scenario,

[1]In 1987, the World Commission for Environment and Development (WCED) introduced the triple bottom line concept of sustainable development in their report 'Our Common Future' (the Brundtland Report (WCED 1987)).

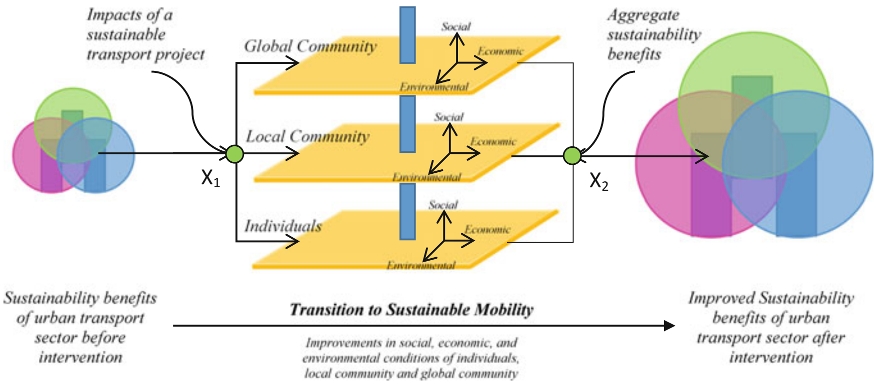

Fig. 1 The model SBA-UT framework for Urban Transport project appraisal (SBA-UT)

whereas the second scenario (post-project) can be predictive if the methodology is used for ex-ante appraisal. It is recommended that pre-project and post-project scenarios shall be created as a Geographical Information System (GIS) database. The advantage of using GIS-based scenario analysis is that mapping helps in measurement of physical as well as thematic quantities (Sharma and Geerlings 2015). Secondly, a GIS enables multi-layer analysis of several datasets which helps in bringing out insights that might remain unnoticed otherwise. A GIS is also the most suitable tool for analyzing temporal effects. After the first scenario (pre-project scenario) is created, a team of experts and stakeholders shall identify a set of (qualitative and quantitative) sustainability indicators that they find as most representative in the given context. The selection of indicators shall be done with the help of existing literature, the goals of the project, and situation analysis using pre-project scenario. It is important to define indicators in such a manner that they can be applied to the second scenario (post-project scenario). Thereafter, the short-listed indicators shall be classified into a 3 × 3 matrix with beneficiary categories (individual, local community, global community) in the column and types of impact (social, economic, environmental) in the rows. The matrix is termed as 'Sustainability Indicators Matrix' (Fig. 2). The sustainability benefits referred to in this framework may be defined as "the relative change in the value of sustainability indicators obtained by comparing pre-project and post-project scenarios". The difference in the value of each indicator is computed respectively in terms of percentage points, which are dimensionless numbers. After computing relative change in each indicator respectively, the values are presented in the form of 'Sustainability Benefits Matrix' (Fig. 2). The aggregation of indicator values in SBA-UT is similar to the process of MCA, however there is less subjectivity in SBA-UT as it does not involve assumption-based weighting of the criteria. A typical equation for calculating sustainability benefits is shown in the Fig. 2:

$$\begin{bmatrix} SISo_{ki} & SIEc_{ki} & SIEn_{ki} \\ SISo_{kl} & SIEc_{kl} & SIEn_{kl} \\ SISo_{kg} & SIEc_{kg} & SIEn_{kg} \end{bmatrix}_{[SI]_k} - \begin{bmatrix} SISo_{ji} & SIEc_{ji} & SIEn_{ji} \\ SISo_{jl} & SIEc_{jl} & SIEn_{jl} \\ SISo_{jg} & SIEc_{jg} & SIEn_{jg} \end{bmatrix}_{[SI]_j} = \begin{bmatrix} \Delta SISo_{i} & \Delta SIEc_{i} & \Delta SIEn_{i} \\ \Delta SISo_{l} & \Delta SIEc_{l} & \Delta SIEn_{l} \\ \Delta SISo_{g} & \Delta SIEc_{g} & \Delta SIEn_{g} \end{bmatrix}_{[\Delta SI]_{k-j}}$$

Where,
$[SI]_k$ = Sustainability indicators matrix for the post-project scenario
$[SI]_j$ = Sustainability indicators matrix for the pre-project scenario
$[\Delta SI]_{k-j}$ = Sustainability benefits matrix
SI = Sustainability Indicator; ΔSI = Relative change in the value of indicator (in percentage points)
So = Social; Ec = Economic; En = Environmental
j = Pre-project scenario; *k* = Post-project scenario
i = individual level; l = local level; g = global level

Fig. 2 Sustainability indicators matrix: a model equation for Sustainability Benefits Assessment using SBA-UT

In order to understand that the overall impact of an intervention will be relatively more on social, economic or environmental aspects the resulting matrix $[\Delta SI]_{k\text{-}j}$ can be further aggregated by applying a unit matrix multiplication function:

$$\begin{bmatrix} 1 & 1 & 1 \end{bmatrix} \times \underbrace{\begin{bmatrix} SISo_{ji} & SIEc_{ji} & SIEn_{ji} \\ SISo_{jl} & SIEc_{jl} & SIEn_{jl} \\ SISo_{jg} & SIEc_{jg} & SIEn_{jg} \end{bmatrix}}_{[\Delta SI]_{k-j}} = \begin{bmatrix} \sum \Delta SISo & \sum \Delta SIEc & \sum \Delta SIEn_i \end{bmatrix}$$

Similarly, in order to visualize that an intervention will produce more benefits for individuals, the local community, or the global community, the transpose resulting matrix $[\Delta SI]_{k-j}^{T}$ can be aggregated as shown below:

$$\begin{bmatrix} 1 & 1 & 1 \end{bmatrix} \times \underbrace{\begin{bmatrix} SISo_{ji} & SISo_{jl} & SISo_{jg} \\ SIEc_{ji} & SIEc_{jl} & SIEc_{jg} \\ SIEn_{ji} & SIEn_{jl} & SIEn_{jg} \end{bmatrix}}_{[\Delta SI]_{k-j}^{T}} = \begin{bmatrix} \sum \Delta SI_i & \sum \Delta SI_l & \sum \Delta SI_g \end{bmatrix}$$

4.2 Defining Sustainability Benefits and Methods for the Assessment of Benefits

Although there is no general agreement about the definition of sustainable transportation, there is consensus among many researchers that the concept of sustainable transportation is not about a 'technological fix' or merely physical conditions, but that it requires organizational challenges, socio-political change, and political willingness (Geerlings 1998; Banister 2008; Sharma and Geerlings 2015). Sustainability is an essentially contested notion; it is intrinsically complex, normative, subjective, and ambiguous (Kasemir et al. 2003; Rotmans 2006), and inherently context-specific (Grin 2004). However, in a transport-project appraisal framework based on benefits assessment, it is imperative to define the term 'sustainability benefits of transport projects'. Based on a review of several studies and scientific articles on costs and benefits of transport projects, we have adopted a definition of sustainability benefits. The discussion on defining sustainability benefits follows.

While analyzing literature on benefit assessment studies, we observed that benefits are measured as impacts. A transport project may have numerous effects on individuals as well as on society in general (Rabl and de Nazelle 2011). Improvements in transport systems and infrastructure may change our transportation behavior. For example, policies that discourage the use of private cars may result in increased commuting by bicycle and walking. Increased physical activity can bring significant benefits to our health and environment (Rabl and de Nazelle 2011). Reduction in use of motor vehicles may help in reducing local air pollution, specifically particulate matter as in reducing greenhouse-gas emission (Woodcock et al. 2009; Xia et al. 2015). A decrease in use of motor vehicles may also significantly reduce congestion and the risk of accidents (Woodcock et al. 2009). There are several indicators of benefits that have been operationalized in cost-benefit assessment of transport projects. However, in operationalization of SBA-UT, we emphasize more understanding the selection of benefit indicators rather than creating a fixed top-down list of indicators. When observed carefully in the literature, it can be seen that benefit is the quantity that was measured in terms of a defined indicator, e.g., reduced used of cars may lead to a reduction in congestion on roads (outcome), but the benefit is the cost saving on road accidents (impact). As an illustration, sustainability benefit indicators are summarized and presented in Tables 1, 2, 3 and 4. The benefit indicators (Tables 1, 2, 3 and 4) are compiled from a systematic review of nine selected recent articles. In each of the study authors have attempted benefits assessment of reduction in the use of private cars. The tables also provide the methods used for the benefits assessment[2] in their respective study.

From this literature review, we can learn that identification of benefit indicators can be based upon a cause-and-effect relationship that exists between outcomes of a project and associated impacts of each outcome, respectively. It can be clearly seen that all the authors have commonly associated all the benefits to the three outcomes of reduction in car use—(1) increase in physical activity (Table 1); (2) reduction in air pollution (Table 2); and (3) reduction in road congestion (Table 3). Most of the benefits related to each of these outcomes are also common among all nine articles,

[2]Within the method of benefits assessment as shown in Tables 1, 2, 3 and 4, respectively, authors have used very specific models and equations for the quantification of each benefit. We recommend that readers refer to the original studies for more detailed information on the methods used for benefits assessment.

Table 1 Benefits from increase in physical activity

Benefits indicators used	Method used for benefits assessment	Source
• All-causes mortality	System Dynamics Modelling (SDM); comparing baseline scenario with policy option scenarios	Macmillan et al. (2014)
• Burden of disease (males) • Burden of disease (females)	Integrated Transport and Health Impact Model (ITHIM); comparing business-as-usual (BAU) scenario for various countries	Thomas et al. (2015)
• All-cause mortality • Life expectancy	Health Impact Assessment (HIA); comparing BAU scenario with eight different scenarios of modal shift	Rojas-Rueda et al. (2012)
• Pre-mature deaths • Years of life lost • Years of living with disabilities • Disability adjusted life years	Comparative Risk Assessment (CRR); comparing baseline scenario and BAU scenario with different policy option scenarios	Woodcock et al. (2009)
• Deaths • Days-adjusted life years	Combination of Comparative Risk Assessment (CRA), Health Impact Assessment (HIA), air pollution models; comparing baseline scenario and BAU scenario with different policy option scenarios	Xia et al. (2015)
• Lifetime health gain benefits • Health gain benefits per year • Risk reduction • Life-expectancy gain	Health Impact Assessment (HIA); comparison of baseline scenario with different scenarios of modal shift	Rabl and de Nazelle (2011)
• Cardiovascular diseases • Dementia • Type 2 diabetes incidences • Breast cancer (women) • Colon cancer (women)	Health Impact Assessment (HIA); comparing BAU scenario with eight different scenarios of modal shift	Rojas-Rueda et al. (2013)

although different authors have used different methods for assessment. It shows that there may be more than one method relevant for the quantification of an indicator. All the methods were based on comparison of scenarios, which indicates that the measurement of benefits is preferably calculated as a relative quantity rather than as a gap or surplus when compared to a benchmark.

Table 2 Benefits from reduction in air pollution

Benefits indicators used	Method used for benefits assessment	Source
• Cardiovascular and respiratory hospitalization	System Dynamics Modelling (SDM); comparing baseline scenario with policy option scenarios	Macmillan et al. (2014)
• Travelers air pollution exposure • Public exposure to air pollution • Reduction in CO_2 emission	Health Impact Assessment (HIA); comparing BAU scenario with eight different scenarios of modal shift	Rojas-Rueda et al. (2012)
• Pre-mature deaths • Years of life lost • Years of living with disabilities • Disability adjusted life years	Comparative Risk Assessment (CRR); comparing baseline scenario and BAU scenario with different policy option scenarios	Woodcock et al. (2009)
• Deaths • Days adjusted life years	Combination of Comparative Risk Assessment (CRA), Health Impact Assessment (HIA), air pollution models; comparing baseline scenario and BAU scenario with different policy option scenarios	Xia et al. (2015)
• Damage cost due to particulate matter ($PM_{2.5}$)	Health Impact Assessment (HIA); comparing baseline scenario with different scenarios of modal shift	Rabl and de Nazelle (2011)
• Cerebrovascular diseases • Lower respiratory tract infections • Pre-term birth • Low birth weight • Cardiovascular diseases	Health Impact Assessment (HIA); BAU scenario with eight different scenarios of modal shift	Rojas-Rueda et al. (2013)

4.3 Consideration of Negative Impacts in SBA-UT

Theoretically, the impacts of a project may improve or deteriorate living conditions in an area. The positive and negative impacts of a project are treated separately in the SBA-UT framework. Where positive impacts are computed in terms of a sustainability benefits matrix (as explained above), the negative effects are given critical consideration and subjective attention. While applying SBA-UT in a transport-project appraisal, the negative impacts shall be identified in a similar manner as benefits, i.e., from the analysis of a baseline scenario, experts' intervention, and stakeholders' involvement. The list of identified potential negative impacts shall be categorized within a similar 3 × 3 matrix. It may not be necessary to create indicators and compute values for the potential negative impacts of the project, although it can be done if needed, depending upon the availability of resources. However, the systematic information about potential negative impacts

Table 3 Benefits from reduction in road congestion

Benefits indicators used	Method used for benefits assessment	Source
• Injury per 1000 cyclists • Number of car-occupant fatalities	System Dynamics Modelling (SDM); comparing baseline scenario with policy option scenarios	Macmillan et al. (2014)
• Pre-mature deaths • Years of life lost • Years of living with disabilities • Disability-adjusted life years	Comparative Risk Assessment (CRR); comparing baseline scenario and BAU scenario with different policy option scenarios	Woodcock et al. (2009)
• Deaths • Days-adjusted life years	Combination of Comparative Risk Assessment (CRA), Health Impact Assessment (HIA), air pollution models; comparing baseline scenario and BAU scenario with different policy option scenarios	Xia et al. (2015)
• Cost saved on fatal accidents	Health Impact Assessment (HIA); comparison of baseline scenario with different scenarios of modal shift	Rabl and de Nazelle (2011)
• Minor injuries • Major injuries	Health Impact Assessment (HIA); BAU scenario with eight different scenarios of modal shift	Rojas-Rueda et al. (2013)

Table 4 Benefits from the combined effect of all three outcomes of a project reducing use of cars for commuting (increase in physical activity, reduction in road congestion, and reduction in air pollution

Benefit indicators used	Method used for benefits assessment	Source
• Accidental deaths • Years of life lost • Years living with disabilities • Disability adjusted life years	Integrated Transport and Health Impact Model (ITHIM); comparing BAU scenario with policy option scenarios	Maizlish et al. (2013)
• Disease burden • Disability adjusted life years • Reduction in CO_2 emissions	Integrated Transport and Health Impact Model (ITHIM); comparing baseline scenario with policy option scenarios	Woodcock et al. (2013)

shall be collected through a series of consultations with stakeholders and users. Unlike other appraisal methods, the SBA-UT framework does not calculate a mathematical measure for the difference between positive impacts and negative impacts of a project. In the SBA-UT framework, the negative-impacts matrix serves as the approval mechanism rather than as a cumulative factor.

4.4 Application of SBA-UT Methodology

The SBA-UT methodology is a framework tool. The scope of potential applications of SBA-UT is much more similar to strategic tools like SEA, rather than for project-based appraisal tools such as CBA or EIA. Institutionally, SBA-UT can be adopted at national, regional, or local levels for evaluating policy, plans, or projects. Some of the potential applications of SBA-UT are briefly described next.

Project Appraisal: The SBA-UT can play a role in measuring the level of sustainability achieved at different points in time during the process of transition. The very specific advantage of SBA-UT methodology over other appraisal methods is that it provides a single framework for a comprehensive accounting of social, economic, and environmental benefits. In principle, SBA-UTS can be applied as an *ex-ante* methodology for the appraisal of proposed transport policies, projects, and plans. It can also be applied as an *ex-post* methodology for auditing. When SBA-UT is applied for a project appraisal, it will not require a supplementary framework for monitoring, reporting, and valuation (MRV) of the project outcomes.

Decision Making: The assessment of benefits or impacts of transport projects using SBA-UT can provide much more elaborate and systematic information to the decision makers at all levels of governance. The multi-level and multi-dimensional analysis of benefits can play an important role in decision making at different stages of project planning and implementation. It provides an evidence-based approach in decision making for project prioritization and phasing for project implementation.

Awareness Creation: The results of SBA-UT support easy visualization of the impacts of a project at various levels, which can help in explaining sustainability benefits of a project to the stakeholders and users. There is a high potential for the SBA-UT to serve as an effective tool for awareness creation. Since the paradigm of project appraisal is already shifting towards considering multiple benefits and co-benefits of a project, the mainstream introduction of SBA-UT will create new opportunities for research and innovations in related fields.

Financing Sustainable Transport Projects: There is an urgent need for integrated national, regional, and local urban planning that can ensure sustainable financing and support sustainable infrastructure development (World Bank 2015). The SBA-UT methodology provides an integrated assessment of local, regional, and global level outcomes of a project and much more elaborate and objective information to the investors that they can use for making their investment decisions.

4.5 Discussion

Some challenges in operationalization of SBA-UT may arise due to the complex nature of concepts involved in the framework. Benefits of a project can be observed at primary, secondary, and tertiary levels, or in the form of direct benefits and indirect benefits. Thus, the challenge is in finding a way to illustrate sustainability benefits with an orientation towards the process of governance. The application and institutionalization of SBA-UT can be greatly facilitated with an inventory of well-defined sustainability indicators. However, it would require extensive research and effort to create such an inventory of indicators. MCA has the similar challenge that there is no standard list of criteria that can be applied in every MCA, although, in the case of CBA, there are standard defined indicators (but that make CBA limited and exclusive). Functional advancement of SBA-UT can be discussed from the point of view of whether SBA-UT should be developed as a strict and exclusive methodology like CBA or if the effort shall be invested to evolve it into a more inclusive methodology like MCA.

The unique strength of the SBA-UT approach is that it highlights issues for the local governance without excluding issues in the larger context (Sharma and Geerlings 2015). However, operationalization of the methodology, along with strong technical skills, will require detailed sets of information and knowledge about the local area in context. Greater application of appraisal methodologies parallels the case of public investments. The application of CBA, EIA, MCA, and MRV frameworks require involvement of external experts because public agencies have limited in-house capacity and technical knowledge about conducting a project appraisal. It might be questionable whether the target users of SBA-UT will have enough technical capacity to adopt a new appraisal methodology or if the capacity-building requirements will pose a serious barrier for institutionalization of SBA-UT.

Present project appraisal methodologies are often presented as golden standards, but they all have their own limitations. Most of the popular appraisal methodologies exhibit an isolated focus on various aspects of sustainability, e.g., CBA has a greater focus on profitability and EIA and SEA have a greater focus on environmental impacts. The major difference between SBA-UT and other traditional project-appraisal methodologies is that SBA-UT is a more holistic, inclusive, and balanced approach. It provides a scope for equal consideration of social, economic and environmental benefits under a common appraisal framework. The use of GIS is highly recommended in the application of SBA-UT, but every change (or benefit) included in the sustainability benefits assessment cannot be assessed only with spatial methods. There will be a requirement for using multiple tools in SBA-UT applications. For example, while the reduction in greenhouse-gas emissions cannot be estimated from maps, it can still be presented in the form of maps as a thematic layer. The SBA-UT methodology in totality is a combination of various assessment methods and not merely a Geographical Information System (Sharma and Geerlings 2015), which is also a similarity with MCA. Uncertainty in estimation is a typical challenge found common in all predictive approaches, and it is also associated with the SBA-UT. The point of discussion is if the challenges to experts in the estimation of sustainability benefits will be too acute or they have faced similar challenges while applying other assessment methods.

5 Conclusions

Based on the literature review, appraisal methodologies can be classified into two types—(1) project-based appraisal methodologies, and (2) strategic appraisal methodologies. Where project-based appraisal methodologies largely include impacts on the direct users, the strategic methodologies include also the impacts on non-users (Iacono and Levinson 2015). The main conclusion of this position paper is that SBA-UT can be most appropriately placed in the category of strategic appraisal methodologies. In terms of applications, SBA-UT can be seen as closely resembling SEA. However, in terms of coverage of impacts, SBA-UT includes all three components of sustainable development (social, economic, and environmental) whereas, SEA largely focuses on environmental impacts.

At the millennium summit (September 2000), the UN-Habitat proposed Millennium Development Goals (UN-Habitat 2002) to be achieved by the year 2015. Under Post-2015 agenda, the UN-Habitat endorsed Sustainable Development Goals (SDGs) in September 2015. The first post-SDG implementation conference Habitat-III will be held in Quito, Ecuador, in October 2016 where tracking and monitoring of SDGs will be discussed. UN-Habitat's issue papers for Habitat-III specifically advocate equitable and balanced planning approaches for the cities of the future. The Habitat-III's agenda puts a clear emphasis on social aspects and quality of life rather than only on climate change and environment. It is certain that, as an effect of Habitat-III, many national, state, and local governments will adopt new goals for their infrastructure projects. The paradigm of urban development is shifting towards holistic sustainable development goals, which will require a collective consideration of all three pillars of sustainability (social, economic, environmental) in decision making.

The SBA-UT methodology presented in this position paper is conceptualized as a tool for the strategic appraisal of urban-transport projects. It is a model framework and can be easily adopted for project appraisal in other infrastructure sectors. The SBA-UT is the first attempt of an appraisal method that establishes a clear integration between sustainable development and the process of transition. The immediate future of decision making for sustainable urban development will demand new appraisal methodologies that are more inclusive, explanatory, and holistic, and this is where SBA-UT can play a role. The SBA-UT methodology is not merely a quantitative technique but is a systematic content approach that focuses on governance challenges for sustainable development.

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A Research Proposal on the Parametric City Governance

Magdalena Wagner

Abstract The issue of spatial management and governance is currently one of major challenges of modern urban planning. Discourse on new ways of urban management gains new meaning and is in fact a discussion about the contemporary urban planners' skills and tools. The paper presents a concept and an initial phase of the research whose main objective is to develop methods that could aid local-level spatial planning and support rational choices. The research presented in the paper examines whether, and to what extent, methods derived from econometrics, operational research, and mathematics could be incorporated into spatial decision-making process. The potential of parametric governance is investigated in order to improve the effectiveness of decision-making in the area of city governance. The reflections presented in this study are, among others, focused on building a system that reflects the internal relations between decisions and projects in urban governance, which are a specific expression of the process of city management. Methods and techniques that would be used to assist the decision-making process in spatial planning should make the process more transparent, objective, and rational as the need to build a new and comprehensive system of urban management is (and will be) a particularly significant challenge in the coming years. The paper discusses the initial outcomes of the presented research and indicates challenges that will be addressed in the further work.

Keywords PROMETHEE · Multi-criteria decision analysis · Urban policy making · City governance

1 Introduction

The paper presents a research concept whose aim is to support spatial planning with innovative and comprehensive tools for the decision-making process. Therefore, the main objective is to develop methods that could aid the local-level spatial planning

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and support rational choices. The issue of spatial decision-making has been raised in a number of scientific works, however, it seems fair to say that this matter has not been thoroughly investigated and resolved yet. Researchers usually pay attention to the conditions and environment of the decision-making process, but no comprehensive solutions have been proposed so far. The research would be checking whether, and to what extent, methods derived from econometrics, operational research, and mathematics could be incorporated into the spatial decision-making process. Problems and obstacles in the policy-making process should be identified and several solutions should constitute a new approach to the urban policy-making procedure. The paper presents the conceptual frame, discusses initial outcomes, and indicates future challenges for the research.

2 Research Questions

The issue of spatial management and governance is currently one of major challenges of modern urban planning. Discourse on new ways of urban management gains new meaning and is, in fact, a discussion about the contemporary urban planners' skills and tools. It also touches the issue of contemporary urban doctrine and its model. The term doctrine can be understood as values or objectives that we want to achieve while shaping space, as well as ways to achieve these goals (Lorens 2010). One of the key challenges is to define the modern urban doctrine so that it covers both the form and the manner of its formulation and decision-making. Lack of such a coherent approach weakens the position of urban planners and has a noticeable negative impact on spatial planning itself. During the 2nd Congress of Polish Town Planning in 2006, the participants stressed that the new doctrine "should consist of determining demands for the city form, ways of building that city (or, more broadly—manufacturing space), and ways of discussion and decision making on the guidelines and forms of urban development" (Lorens 2010). Understanding, improving, and modernizing the last component—ways of discussion and decision making—is the essence of the research. The need to build a new and comprehensive system of urban management is (and will be) a particularly significant challenge in the coming years.

A literature review and my own observations of planning practices indicate a lack of comprehensive and advanced tools that could support spatial decision making at the local level. The procedure of prioritizing spatial projects in a big city was described by Ossowicz (2003) who also paid attention to the use of mathematical analysis in urban policy making. He suggested that numerical models and analyses can and should be used when choosing urban activities pursuing strategy goals. However, to compare other approaches see Markowski (1999), Brol (2004), and Pęski (1999). Urban planners usually conduct complex spatial analyses, however, as Zeleny noticed (2011): "Decision making takes place only when multiple criteria *and* trade-offs are present. All the rest (single criteria, aggregates or utilities) are simply analysis, measurement and search, not decision making".

Therefore, it is crucial to adjust and apply comprehensive decision-support methods in the process of city policy formulation, as such an approach is currently missing.

There are several questions that have arisen during the research. The starting point is an evaluation of the policy-making procedure at the local level. What are the weaknesses of planning procedure and how the process could be improved? City authorities make efforts to choose the best options and goals, however, they may face difficulties when dealing with big data, limited resources, and conflicting actions. The role and importance of city governance in the light of growing uncertainty and fast changes are essential prerequisites to taking up this issue. Methods, which may help answering the question “what, where, and when should be built?”, could significantly improve the quality of the decision-making process at the local level, and thereby positively affect the functioning of the entire city and its community.

Therefore, the second issue that should be addressed is an examination of potential solutions. An assumption was made that spatial governance could be supported by sophisticated mathematical formulas. The question is how it should be done? Which methods shall be used (and which shall be avoided)? Is multi-criteria decision analysis (MCDA) a good solution for urban planners? Answering these questions would enable the selection of the most suitable and accurate techniques for improving spatial decision making.

Another task of the research is to produce solutions that are applicable and repeatable. Could the selected methods be applied in real-world situations? Is it feasible to incorporate these tools into policy making? Would city authorities benefit from the research outcomes? It seems fair to say that addressing these issues is crucial for the work. The research shall make the decision-making process easier (for the decision makers) and more rational, and, therefore, approachable and convenient tools should be developed. Several methods should be studied in detail, then selection of the most adequate ones should be done, and finally these methods should be adjusted to the needs of spatial planning at the local level. A comprehensive set of tools and an advanced approach to solving decision problems in spatial planning could be a useful and original guidance for actors involved in urban policy making. The methods developed during the research would be transformed and presented as computer tools (a sort of matrices and decision trees, where mathematical formulas are hidden and the interface is user-friendly). It is a technical challenge to build a comprehensive set of spatial decision- support tools that would be user-friendly and complex at the same time.

The reflections presented in this study are, among others, focused on building a system that reflects the internal relations between decisions and projects in urban governance, which are a specific expression of the process of city management. Methods and techniques that would be used to assist the decision-making process in spatial planning should make the process more transparent, objective, and rational. Urban policy makers should make decisions responsibly with respect to:

- long-term local policy at the municipal level,
- resources available for development,

- forecasting market conditions in a given period of time,
- policies at national and regional levels and policies of neighbouring municipalities,
- attitude of the society to planned projects (Ossowicz 2003).

Finally, it seems fair to say that developing a comprehensive approach to deal with the complex spatial decision-making process could be a useful contribution in the, still not well-investigated, area of decision-making models in spatial planning.

3 Research Design and Methods

The decision-making process in spatial planning at the local level covers a broad spectrum of issues that are objectives of urban development policy. This challenge involves the need to consider such diverse and complex issues as, among others, housing, transportation, cultural heritage, environmental protection, quality of public spaces, economic activity, or safety. Moreover, it seems fair to say that there is a need to develop new solutions that will provide support for coordinated, rational, and transparent decision making under conditions of risk and uncertainty. Given these requirements, the structure of the research consists of three main parts.

The first part is the structure of spatial decision making at the local level (in Poland). Examination of existing decision-making procedures at the local level would be followed by a general evaluation of the process. References to theoretical and practical aspects would be made. Each step of city policy making would be described and investigated. Weaknesses and "gaps" would be identified as spaces for new solutions which shall be developed in the research. In the process of urban policy making, several steps can be distinguished: complex analyses are followed by formulation of a vision, mission, and main objectives; then operational tasks are identified; and finally projects/activities pursuing these goals are recognized. This procedure is connected with constructing the balance of resources and time schedule of urban projects (Ossowicz 2003). Between these elements several complex interrelationships, feedbacks, and correlations could be identified. Attention should be paid to a relatively large number of bodies, institutions, and groups involved in the decision-making process and the fact that the interests of these parties may sometimes be in conflict. This part of the research would focus, in particular, on:

- the essence of city governance: definitions (city management, city governance, spatial policy, urban policy, etc.), features of governing, city governance in the light of organization and management theory, uncertainty and risk in spatial planning;
- local government: its role and tasks, structure, features, and management instruments;

- urban planning: actors, features and attributes of the local-level spatial planning, models of integrated planning in cities, and models of strategic planning (including models taking into account the specificities of public organizations management);
- city finances;
- controlling and monitoring.

The second part of the research would be a catalogue of possible solutions. Examination of decision-making tools would be followed by an evaluation of their potential for use in the area of spatial planning, regarding the "gaps" identified in the previous chapter. References to other disciplines would be made (i.e., economics, econometrics, mathematics, future studies, and decision theory). Within this subchapter, as a starting point, the decision theory and decision-making models are addressed and presented:

- the rational/classical model: assumes that an individual is always capable of saying which alternative he or she prefers. These preferences are assumed to be complete (a person can always say which of two alternatives he or she considers preferable or that neither is preferred to the other) and transitive (if option A is preferred over option B and option B is preferred over option C, then A is preferred over C). The rational decision maker takes into account available information, probabilities of events, and potential costs and benefits in determining preferences; he or she acts consistently (Tyszka 2004);
- the bounded rationality model: this model does not assume individual rationality in the decision process. Instead, it assumes that people, while they look for the best solution, normally settle for much less, because the decisions they confront typically demand greater information, time, processing capabilities than they possess. They settle for bounded rationality or limited rationality in decisions (Simon 1972);
- other methods and models: Pugh Matrix (also known as decision grid), multiple-step decision models, Vroom-Jago model, recognition-primed decision-making model (model of how people make quick, effective decisions when faced with complex situations), retrospective decision-making model (this model focuses on how decision makers attempt to rationalise their choices after they have been made and try to justify their decisions).

This subchapter would provide information about various approaches to the decision-making process. Given the data, it would be possible to develop framework for making the most rational, logical, and sensible choices in spatial governance with use of new tools (described in the next subchapters).

The second part of the "catalogue" would be devoted to multi-criteria decision analysis (MCDA). This issue is the main interest of the research. MCDA (multi-criteria decision analysis) or MCDM (multi-criteria decision making) is a sub-discipline of operational research and was developed in 1960s in the business sector. MCDA is used in the situation of having multiple, usually conflicting, criteria. Such situations we approach in everyday life, e.g. when choosing a car we take into account price, size, fuel consumption, safety, comfort, etc. Instead of following intuition, the decision-making process could be made more rational with use of the MCDA methods. The development of MCDA is related to computer development, which enabled decision makers to conduct complex analyses of multi-criteria problems. MCDA addresses mainly discrete ill-defined problems (no optimal solution) with not very large sets of alternatives. It can be used to conduct the following operations: choice, ranking, or sorting (Xu and Yang 2001). Therefore, it can be used to choose (e.g. the new location for an investment, a team of workers, an investment plan), rank (e.g. cities, regions, universities, students), or sort (e.g. research projects, cities). MCDA problems could be described with the use of a decision matrix with a set of alternatives a_i, i = {1,…m} and criteria g_j, j = {1,…n}. Three types of tasks/systems can be distinguished: deterministic, stochastic, and fuzzy. In the deterministic system, there is a finite set of possible discrete controls, and $v_j(a_i)$ is a performance value of alternative a_i on criterion g_j. In the case of the stochastic system, the transition function relies on conditional probabilities of accessing some state and is a matrix of probabilities (Stańczak 2005). In the fuzzy system, the performance value of an alternative is expressed by a triangular fuzzy number (Trzaskalik 2014). This subchapter compares several MCDA methods: their potential, scope, fields of application, data needed as input, number of decision makers, and the nature of criteria and alternatives. The research discusses methods based on estimating a value function and methods based on outranking relations. The first group consists of methods such as SAW (Simple Additive Weighting), Fuzzy SAW, AHP, ANP, MAUT, Goal Programming, etc. A value function can be used to derive preferences for the alternatives. To give an insight into these methods, just a few of them are described next:

- The Analytic Hierarchy Process (AHP) is based on mathematics and psychology. It is widely used to help decision-makers in the fields of business, transportation, and education. The most important feature is the group decision making, where each decision maker can have different priorities and values. The problem is decomposed into sub-problems. The pairwise comparison of various aspects of the problem and pairwise comparison of criteria are conducted independently. The decision makers can either provide concrete data or just use their individual and subjective judgement. Those evaluations are computed in order to obtain a comprehensive evaluation of the decision problem. The capability to compare incommensurable elements distinguishes the AHP from other MCDA methods (Saaty and Peniwati 2008). On the other hand, Ronen and Coman (2009) describe how the "valuable discipline of MCDM was abused by the Analytical-Hierarchy-Process (AHP)", and use MCDM as an example of analytical overdose—a "cumbersome and time-consuming process" (Zeleny 2011).
- The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP). The basic structure is an influence network of clusters and elements. Not all decision problems can be structured hierarchically because they involve the interaction and interdependence of elements. The ANP method

takes into account not only that the importance of the criteria determines the importance of the alternatives as in a hierarchy, but also the importance of the alternatives themselves determines the importance of the criteria (Saaty 2008).

- Multi-Attribute Utility Theory (MAUT) is an evaluation scheme which can be used to reconcile many interest groups.
- Goal Programming is a branch of multi-objective optimization. It is similar to linear programming but, instead of having one objective, goal programs can have several objectives; therefore it can be used if there is more than one objective to be achieved (e.g. minimizing cost, maximizing real-estate surface).

The second group (methods based on outranking relations) is widely known mostly for two approaches, i.e. ELECTRE and PROMETHEE. Outranking methods were first developed in France in the late sixties following difficulties experienced with the value function approach in dealing with practical problems. As in the value function approach, outranking methods build a preference relation among alternatives evaluated on several criteria. It is a binary relation S on the set X of alternatives such that xSy (x is at least as good as y), if there are enough arguments to declare that x is at least as good as y, while there is no essential reason to refute that statement. In most outranking methods, the outranking relation is built through a series of pairwise comparisons of the alternatives (Bouyssou 2001). ELECTRE I is the first outranking method, and it gives a good notion of the ideas behind outranking. Other outranking methods are more advanced as they accept differences in the strength of the decision maker's preferences as well as the possibility of the decision maker being indifferent with respect to two alternatives (de Boer et al. 1998). Another outranking method is PROMETHEE (and its descriptive complement geometrical analysis for interactive aid which is better known as GAIA). The fields of application are similar as in the aforementioned AHP technique. The main advantage of the PROMETHEE method is the clear reasoning which helps decision makers build well-structured framework for the decision problem. It is useful for solving complex problems with several criteria that need to be evaluated. The method could be applied to: choosing the best location for an investment, ranking action projects or investment plans, or allocating resources. The information requested by PROMETHEE and GAIA is particularly clear and easy to define for both decision makers and analysts. It is based on a preference function associated to each criterion as well as weights describing their relative importance. Usually there is no alternative optimising all the criteria at the same time, therefore a compromise solution should be selected (Brans and De Smet 2015). To give a better understanding of outranking methods, an example of using PROMETHEE II method is presented below.

If we consider buying a building plot, we take into account several attributes. For instance, we may consider the following criteria:

- f1—utilities/services (water, electricity, etc.)—if yes, then value 1; if not, then value 0;
- f2—price of a plot (thousands, PLN—Polish Zloty)
- f3—ground surface (square metres)

- f4—number of shops within d = 300 m
- f5—distance from city centre (kilometres)

PROMETHEE (as all outranking methods) can deal simultaneously with qualitative and quantitative criteria. Criteria scores can be expressed in their own units. We assume that the price of a plot and distance from city centre should be minimized and that the ground surface and number of shops should be maximized. In this example, we consider four alternatives ai, i = {1, 2, 3, 4}. The starting point is an evaluation matrix, which presents the performance of each alternative in relation to each criterion. Weights giving the relative importance of the criteria are given in the last row of the table (Table 1). Decision makers are required to weigh criteria and to choose a preference function. PROMETHEE does not provide specific guidelines for determining weights for criteria, but assumes that the decision maker is able to weigh the criteria appropriately, at least when the number of criteria is not too large (Macharis et al. 2004). For the purpose of this example, we use method PROMETHEE II for obtaining a complete ranking of alternatives.

Using the data contained in the evaluation matrix, the alternatives are compared pairwise with respect to every single criterion. The results are then calculated and expressed by the preference functions, which are calculated for each pair of options and can range from 0 to 1, where 0 means that there is no difference between the pair of options (indifference), 1 indicates a strong preference, and value between 0 and 1 indicates weak preference:

$$P_j(a, b) = F_j[d_j(a, b)] \, \forall a, b \in A$$

where:

$$d_j(a, b) = g_j(a) - g_j(b)$$

For criteria to be minimised, the preference function should be reversed or alternatively given by:

$$P_j(a, b) = F_j[-d_j(a, b)]$$

In order to facilitate the identification of preferences, six types of particular preference functions have been proposed (see Fig. 1). In each case, 0, 1 or 2 parameters have to be defined, their significance is as follows:

Table 1 Evaluation table

Alternatives	Criteria				
	f_1	f_2	f_3	f_4	f_5
a^1	0	249	830	1	21.5
a^2	1	386	966	8	7
a^3	1	366	873	11	12
a^4	0	340	640	4	8
W_k	0.2	0.3	0.25	0.1	0.15

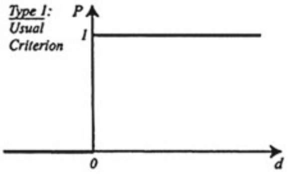
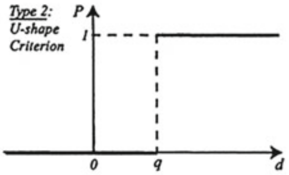
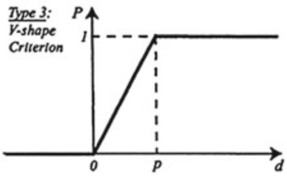
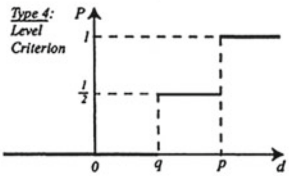
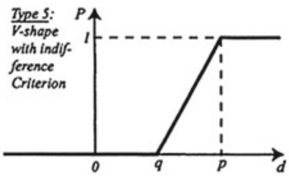
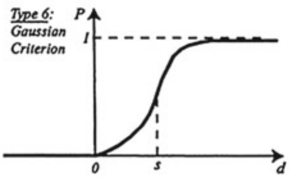
Generalised criterion	Definition	Parameters to fix
 Type 1: Usual Criterion	$P(d) = \begin{cases} 0 & d \leq 0 \\ 1 & d > 0 \end{cases}$	–
 Type 2: U-shape Criterion	$P(d) = \begin{cases} 0 & d \leq q \\ 1 & d > q \end{cases}$	q
 Type 3: V-shape Criterion	$P(d) = \begin{cases} 0 & d \leq 0 \\ \frac{d}{p} & 0 \leq d \leq p \\ 1 & d > p \end{cases}$	p
 Type 4: Level Criterion	$P(d) = \begin{cases} 0 & d \leq q \\ \frac{1}{2} & q < d \leq p \\ 1 & d > p \end{cases}$	p, q
 Type 5: V-shape with indifference Criterion	$P(d) = \begin{cases} 0 & d \leq q \\ \frac{d-q}{p-q} & q < d \leq p \\ 1 & d > p \end{cases}$	p, q
 Type 6: Gaussian Criterion	$P(d) = \begin{cases} 0 & d \leq 0 \\ 1 - e^{-\frac{d^2}{2s^2}} & d > 0 \end{cases}$	s

Fig. 1 Six types of preference function. *Source* http://brasil.cel.agh.edu.pl/~13sustrojny/promethee/#

- q is a threshold of indifference;
- p is a threshold of strict preference (Pj(a, b) = 1);
- s is an intermediate value between q and p.

In the example with the building plot, we use type 1 for the first criterion, namely $f_{1,}$ and type 5 (with indifference threshold and preference threshold) for the rest. The preference degrees for each pair of alternatives on each criteria are presented below (Tables 2, 3, 4, 5 and 6).

Tables 2, 3, 4, 5 and 6 Preference degrees for every pair of alternatives

$$\pi(a_{x1}, a_{x2}) = \sum_{j=1}^{k} w_j P_j(a_{x1}, a_{x2})$$

Table 2 Preference degree for every pair of alternatives with respect to criterion 1

$G_1(d_1)$	a^1	a^2	a^3	a^4
a^1	0	0	0	0
a^2	1	0	0	1
a^3	1	0	0	1
a^4	0	0	0	0

Table 3 Preference degree for every pair of alternatives with respect to criterion 2; indifference threshold and preference threshold

$G_2(d_2)$	a^1	a^2	a^3	a^4	q_k	p_k
a^1	0	1	1	1	5	50
a^2	0	0	0	0		
a^3	0	0.333333	0	0		
a^4	0	1	0.822222	0		

Table 4 Preference degree for every pair of alternatives with respect to criterion 3; indifference threshold and preference threshold

$G_3(d_3)$	a^1	a^2	a^3	a^4	q_k	p_k
a^1	0	0	0	1	10	100
a^2	0.7	0	0.444444	1		
a^3	0.144444	0	0	1		
a^4	0	0	0	0		

Table 5 Preference degree for every pair of alternatives with respect to criterion 4; indifference threshold and preference threshold

$G_4(d_4)$	a^1	a^2	a^3	a^4	q_k	p_k
$a^{\mathbf{1}}$	0	0	0	0	2	6
$a^{\mathbf{2}}$	1	0	0	0.5		
$a^{\mathbf{3}}$	1	0.25	0	1		
$a^{\mathbf{4}}$	0.25	0	0	0		

Table 6 Preference degree for every pair of alternatives with respect to criterion 5; indifference threshold and preference threshold

$G_5(d_5)$	a^1	a^2	a^3	a^4	q_k	p_k
a^1	0	0	0	0	0.5	2
a^2	1	0	1	0.166667		
a^3	1	0	0	0		
a^4	1	0	1	0		

Next, global preference degrees are calculated for each pair of alternatives:

Finally, positive, negative, and net flow scores are calculated in order to obtain a complete ranking of alternatives. In the matrix of global preferences, the sum of the row expresses the strength of an alternative (dominance). The sum of the column expresses how much an alternative is dominated by the other ones (subdominance). A linear ranking is obtained by subtracting the subdominance-value from the dominance-value (Tables 7 and 8).

To sum up the procedure, we may distinguish three main steps:

- Step 1: compute unicriterion preference degree for every pair of alternatives;
- Step 2: compute global preference degree for every pair of alternatives;
- Step 3: compute positive, negative, and net flow scores.

In the example presented above, the best solution, according to the given criteria and their weights, is alternative a^2, followed by a^3, then a^1, and last one is a^4. The PROMETHEE methods (or outranking methods in general) could be used in various multi-criteria problems, such as ranking of investment plots (for various activities) or ranking of city development objectives/goals in the process of strategy making. The scope of the paper is to indicate possible applications of the selected methodologies. These techniques will be thoroughly investigated during further research; PROMETHEE is chosen and presented as an example, just to show its possible application and capabilities in the field of urban planning. It may not be the most suitable solution—it is too early to decide at this stage of the research, however, if the example presented above indicates that it may be a promising and helpful technique.

Other methods that may prove to be useful are those related to problem structuring, for instance the DEMATEL method. Decision Making Trial and Evaluation Laboratory (DEMATEL) is a robust analysis tool used for identification of cause-effect relationships (Fontela and Gabus 1974). It can be used for both tangible and intangible factors. The method is used to illustrate the interrelations among criteria and to find the central criteria to represent the effectiveness of

Table 7 Global preference degree

$\pi(a^i, a^j)$	a^1	a^2	a^3	a^4
a^1	0	0.300	0.300	0.55
a^2	0.625	0	0.261111	0.525
a^3	0.486111	0.125	0	0.55
a^4	0.175	0.300	0.397	0

Table 8 Final ranking (net outranking flows)

	φ^+	φ^-	φ
a^1	0.383	0.429	−0.045
a^2	0.470	0.242	0.229
a^3	0.387	0.319	0.068
a^4	0.291	0.542	−0.251

factors/aspects. In the field of spatial planning, it could be used to show relations between various urban activities/developments (compare with Ogrodnik 2015).

The third subchapter of the “catalogue” would be devoted to methods derived from econophysics, econometrics, mathematics, and other disciplines. Several methods and approaches would be examined to check whether (and to what extent) they could be useful in spatial planning:

- game theory is used to study economic behaviours, including behaviours of firms, markets, and consumers; it could be also used when looking for consensus between stakeholders or city policy goals;
- the Monte Carlo method, as in finances, could be used to value and analyse investments by simulating the various sources of uncertainty affecting their value, and then determining their average value over the range of outcomes (Jaeckel 2002);
- graph theory (mathematical structures used to model pairwise relations between objects; used to model many types of relations and processes);
- critical path analysis (CPM and PERT; for scheduling a set of project activities);
- Markov chains (for representing the decision-making process);
- decision trees (used to structure a strategy towards a goal);
- backcasting (derived from future studies, used to produce scenarios);
- correlation (Pearson, Kendall, Spearman);
- input-output model (for representing interdependencies between different branches of a city economy);
- numerical taxonomy (classification system that deals with the grouping by numerical methods);
- SWOT analysis (used to evaluate the strengths, weaknesses, opportunities and threats);
- several techniques used in business sector (e.g., cost-benefit analysis, Pareto principle and Pareto analysis, ABC classification, Eisenhower’s matrix, NPV, ROI, etc.).

Given an evaluation of a city policy-making procedure and a collection of possible solutions (with respect to this procedure), an attempt could be made to develop comprehensive tool(s) for supporting the spatial decision-making process at the local level. If possible, each step of the planning procedure could be “equipped” with new and innovative tools supporting the decision-making process, therefore, traditional spatial governance would be mixed with computer-based methods and algorithms. The research would stress the most promising solutions that could be incorporated at each stage of spatial development, also with respect to spatial policy making at other levels. A general evaluation of the proposed set of tools could be conducted in order to identify strengths, weaknesses, and limitations that could be addressed in further research.

Analysis of the aforementioned issues would enable drawing conclusions about the possibilities of improving the decision-making process at the local level.

4 Expected Outcomes and Conclusions

The main outcome of the research would be a set of comprehensive and complex tools for supporting city policy making. A "parametric city-governance model", comprising innovative, computer-based methods with already existing spatial procedures, could be produced. The research aims at developing this issue. The vast catalogue of techniques and methods derived from various disciplines would be subjected to critical analysis with respect to their implementation in spatial-planning practice. The methods which would be discussed are subjects of interest of many researchers from such fields and disciplines as mathematics, operational research, economics, and econophysics. The scientific works from these disciplines describe in detail the proposed methods and techniques in terms of their theoretical fundamentals and possible applications. However, it seems that there is no work which combines spatial planning at the municipal level with these methods. In this respect, the research project has the ambition to present the possibility of using these methods in the city policy-making process.

Furthermore, the research would provide identification of strengths and weaknesses of traditional city governance, as the policy-making procedure would be examined in detail and step by step. Deliberations undertaken during the work would include the structure of creating local urban policies: formulating development goals, giving them certain weights, recognizing criteria for selection of priority axes, as well as relations between these objectives and criteria. A large number of decision makers involved in urban policy making and complex nature of the decision-making process make it difficult to avoid shortcomings or omissions in some areas. The research aims to identify and (where possible) to eliminate such "gaps".

Also, an evaluation of the offered solutions in terms of spatial planning may probably enrich the discourse about these techniques. The research would also raise a question (and an answer, to some extent) of how to combine and mix methods from various fields and disciplines. The research would also contribute to answering the question of whether selected techniques derived from other disciplines may be included in spatial-planning procedures. It seems fair to say that, while urban planners rarely decide to look far outside their own academic discipline in search of new tools, however, it may prove to be an effective and efficient solution that would not only improve the planning practice, but also have a rather positive impact on the discipline of architecture and urban planning. A comprehensive overview of methods and techniques supporting the decision-making process and derived from other disciplines should enrich the discussion on their capabilities and potential areas of application.

It seems fair to point out that most of city authorities can influence and determine urban development only to a limited extent, i.e. they establish a framework for other entities, but cannot guarantee that the proposed directions and instructions would be obeyed. Modern cities are built by many independent actors (both public and private) and public authorities face the challenge to appoint them reasonable and attractive conditions for activities and implementation of their projects. There is no doubt that reasonable city governance under uncertainty is particularly significant, which is another important premise justifying undertaking the research.

Finally, a question of what is new in the research and how it can be distinguished from already-existing methods should be addressed. Therefore, it might be essential to briefly stress differences between research objective and already-existing decision models. Decision Support Systems (DSS) are computer-based tools designed to support management decisions (Eom 2001). Spatial Decision Support Systems (SDSS) are interactive, computer-based systems designed to assist in decision making while solving a semi-structured spatial problem (Sprague 1982). In other worlds, SDSS comprises DSS and GIS. However, many of (S)DSS are in fact various models used to better describe data or visualise a system without addressing specific decision problems or helping decision makers in making inevitable trade-offs (Giove et al. 2009). The aim of the research is not to improve already-existing decision support systems. Also simulation models or land-use models such as cellular automata (CA) or Agent Based Models (ABM) are not within the scope of the research. The objective of the research, as it was already mentioned, is to offer a comprehensive set of tools supporting the decision-making process in city policy making under uncertainty, when dealing with several conflicting criteria and taking into account various stakeholders' needs. Therefore, the research focus is not on providing a GIS (or GIS-related) model, DSS, or simulation model. The research also does not decide on goals of a city policy. The author has no right, nor ambition to decide for the city authorities on the best goals for their city. The purpose is to equip planners and city authorities with methods and tools supporting decision making at the local level in order to make more rational and objective choices.

To sum up, the research would offer a set of methods and techniques that would support the urban policy-making process. Likely, an action scheme in which each step of strategic and spatial decision making receives support in the form of advanced tools would be developed. These methods would take the form of convenient and approachable computer tools, and therefore, would have a fairly high probability of being included in the everyday work of urban planners. In 1971, Beaujeu-Garnier and Chabot pointed out that "the city changes, adapts to a particular form of civilization, whose expression they are, and therefore, its definition cannot be the same for all ages and all countries". This statement indicates that cities are hallmarks of civilization—its level and condition. Thus, improving city governance could be perceived as an important issue that may have prominent and positive impact on the development of civilization.

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Part IV
Governance Approaches

Policy and Governance Innovations for Sustainable Urban Development: An Overview of the 2014–2020 Structural Funds Programming in Italy

Ekaterina Domorenok

Abstract This paper deals with policy and governance innovations in EU regional policies, illustrating how the strategy for sustainable urban development has gradually consolidated over time, progressively enlarging the scope of interventions and the related financial resources. As is well known, the current programming (2014–2020) calls for prominent attention to the territorial dimension and, in particular, to the EU urban agenda. In fact, member states have been invited to introduce specific policy instruments in order to promote integrated sustainable development in urban areas at national and regional levels. Evidence from a preliminary analysis of the Italian programming documents shows, however, that the success of these instruments cannot be taken for granted. Quite in line with the experience of other EU countries, the scenario of implementation of the new governance and policy provisions varies significantly across the country, bringing to light a number of obstacles and challenges to their diffusion within domestic policy structures.

Keywords Urban governance · Sustainable development · European union · Regional policies · Place-based

1 Introduction

As is well known, the EU cohesion policy has given rise to numerous policy and governance innovations, in particular as far as urban areas are concerned. After being introduced during the first programming period (1988–94), innovative actions for urban development have evolved first under Urban Pilot Projects (UPP) and later within the Community Initiative Programme (CIP) URBAN. From a substantive point of view, the urban policy innovations can be summarized under the

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umbrella of an integrated cross-sectoral approach, aiming to embrace all different dimensions of urban life—economic, environmental, social, and demographic. In procedural terms, instead, the so-called "URBAN method" has been promoted in order to encourage a participatory approach to programming at a local level, fine-tuned to the perspective of multi-level governance, which implies the involvement of social and economic stakeholders and local civil society in decision making and implementation activities.

Given the rather successful implementation results of the aforementioned initiatives between 1988 and 2006 (European Commission 2008), the EU Commission pushed for the diffusion of both their substantive and procedural elements throughout the mainstream objectives[1] of EU regional policies during the period 2007–2013. Remarkably, in the current programming (2014–2020), two new governance instruments have been introduced—Community-Led Local Development (CLLD) and Integrated Territorial Investments (ITI)—both enabling further strengthening of the participatory and integrated approach to urban development.

After a short overview of policy and governance innovations introduced by EU regional policies to promote sustainable urban development, this paper provides a preliminary analysis of the Italian programming documents for the period 2014–2020, illustrating how the EU-policy guidelines have been implemented and discussing challenges to policy innovations in this field.

2 Policy and Governance Instruments for Sustainable Urban Development in Cohesion Policies 1988–2013

The issue of sustainable urban development has progressively gained importance in EU cohesion policies since the very origins of the Structural Funds (SF) programming. Starting from the late 1980s, specific actions have promoted the view that the various challenges concerning urban areas—economic, environmental, social, and demographic—are interwoven, and success in urban development can only be achieved through an integrated approach. Therefore, the EU Commission (DG Regio) has stressed the need to combine measures concerning physical urban renewal with those fostering education, economic development, social inclusion, and environmental protection (COM(1998)605). In order to enable the design of successfully integrated actions, it has been suggested that the development of strong partnerships involving local citizens, civil society, the local economy, and the various levels of government is an indispensable element. Thus,

[1]During the 2007–2013 programming period, EU regions were admissible for EU SF financing under the following three mainstream objectives: Convergence (those regions having a per capita gross domestic product (GDP) of less than 75 % of the average GDP of the EU-25), Regional Competitiveness and Employment (all other regions), and Territorial Cooperation.

combining capacities and local knowledge has been perceived as essential for identifying shared solutions and achieving well-accepted and sustainable policy results.

Drawing on the abovementioned premises, innovative actions for cities were foreseen within the framework of Urban Pilot Projects (UPP)[2] during the 1989–93 programming period, in accordance with Article 10 of the European Regional Development Fund (ERDF) Reg. (EC) No 2052/88, while in 1994 the URBAN Community Initiative was launched, aiming specifically at promoting an integrated approach by taking account of all dimensions of urban life. The URBAN Initiative applied a package of actions combining the rehabilitation of obsolete infrastructures with economic and labor market actions, complemented by measures to combat the social exclusion inherent in run-down neighborhoods and measures to upgrade the quality of the environment. The so-called 'URBAN method' has been at the core of the Initiative, establishing a bottom–up approach to decision making, based on participation and networking at a local level. In this way, the Managing Authorities (MA) of the CIP URBAN normally coincided with municipal administrations, who were required to act in cooperation with a number of operational bodies, including the steering committee, composed of public authorities at the various territorial levels concerned (national, regional, and local), as well as of social and economic stakeholders and civil society representatives. Quite often, local forums were established, engaging wider local social and economic partnerships and local communities (non-governmental organizations, neighborhood councils, spontaneous groups of individuals, etc.). Collaboration and coordination between all partners concerned were to be guaranteed across all phases of implementation of CIP: from the formulation of actions to be carried out at the local level to the selection of the projects to implement. The commitment of URBAN to involving local citizens in the development and implementation of the programs was highlighted, stressing that the problems of urban deprivation should be solved at the grass-roots level (European Commission 2000).

After two consecutive editions in 1994–1999 and 2000–2006, the CIP URBAN was cancelled in the 2007–2013 programing period, while it was decided that actions for sustainable urban development and the consolidated operational method should be mainstreamed across all thematic objectives of the SF, thereby increasing both the geographical scope of its diffusion and the availability of financial resources (European Commission 2007).

It is worth mentioning that, since the mid-1990s, the overall attention to the urban dimension has substantially increased in many European countries, owing much to the policy process developed around the European Territorial Agenda, which has involved national governments in an intense reflection about the relevance of the territorial dimension for development policies (Domorenok 2009).

[2]During the 1990 to 1993 period, a total of 33 Urban Pilot Projects were initiated under the aegis of Article 10 of the ERDF. These projects were implemented in eleven member states and aimed to support innovation in urban regeneration and planning within the framework of the broader policy for promoting economic and social cohesion.

A number of political declarations approved within such a framework paved the way for the strengthening of actions for integrated urban development in the SF programming for the period 2007–2013. In this way, building on the Lille Action Programme (2000), the Rotterdam Urban Acquis (2004), and the Bristol Accord (2005), the seminal Report "Integrated urban development as a prerequisite for successful urban sustainability" was prepared by the German Presidency in 2006, affirming a strong support for the EU Sustainable Development Strategy and highlighting the objective of protecting, strengthening, and further developing cities. The report has stressed that all dimensions of sustainable development should be taken into account at the same time and with the same weight, including economic prosperity, social balance, and the environment, as well as cultural and health aspects. Moreover, it has been highlighted that particular attention should be paid to the institutional capacity in the member states to be able to implement holistic strategies and coordinated action by all persons and institutions involved in the urban-development process, which reach beyond the boundaries of individual cities. It has been emphasized that, in order to make the multi-level governance system really effective, the coordination of the sectoral policy areas should be improved, and, at the same time, developing a new sense of responsibility for the integrated urban-development policies. The role of integrated urban development and the importance of cities for economic and social cohesion have been reiterated by the "Leipzig Charter on Sustainable European Cities" approved in 2007, stating that cities and metropolitan areas are the engines of Europe's economic development, but at the same time they are the frontline in the battle against obstacles to growth and employment—especially social exclusion and environmental degradation.

Based on the aforementioned political commitments and considerations, the various possibilities to implement urban actions under all mainstream Objectives of the EU Cohesion Policy have been enshrined in the Regulations for the 2007–2013 period, and a common methodological framework for integrated urban development has been defined in the Community Strategic Guidelines. These documents, as well as the Commission's Communication on "Cohesion Policy and Cities" (COM (2006)385), have been an important guidance for the elaboration of national programming documents—National Strategic Reference Frameworks and Operational Programmes (OP) co-financed by the ERDF at the national or regional level. Therefore, the ERDF could, where appropriate, support the development of participative, integrated and sustainable strategies to tackle the high concentration of economic, environmental, and social problems affecting urban areas, whereas member states were invited to develop strategies that would promote sustainable urban development through activities such as: the strengthening of economic growth, the rehabilitation of the physical environment, brownfield redevelopment, the preservation and development of natural and cultural heritage, the promotion of entrepreneurship, local employment, and the provision of services to the population taking account of changing demographic structures. As far as the governance dimension is concerned, it has been stressed that the local authorities have an important role to play in the achievement of sustainable urban development in the cities, whereas the preparation of medium- to long-term development plans for urban regeneration is generally a precondition for success, as it ensures the coherence of investments and of their environmental quality and helps to secure the commitment and participation of the private sector in urban renewal (European Commission 2007). Building on the experience and strengths of the URBAN CIP, member states and regions were offered the possibility to design, program, and implement tailor-made, integrated development operations in all European cities investing up to 10 % of the ERDF, while in the previous periods a limited number of cities (around 200) were selected for sustainable urban-development programs. The ERDF funding of measures under the Regional Competitiveness and Employment objective falling within the scope of Reg. (EC) No 1081/2006 could be raised to 15 % of the program or priority axis concerned. Additionally, a new initiative was launched—Joint European Support for Sustainable Investment in City Areas (JESSICA)—with the purpose of increasing resources and attracting private investments for integrated sustainable urban development. The operational mechanism of this initiative has foreseen the establishment of Urban Development Funds (Urban Authorities), based on a solid public-private partnership, to which MA could delegate the management of a part of SF. It was envisaged that as part of an operational program, SF could finance expenditure of an operation comprising contributions to support financial engineering instruments for enterprises, primarily small- and medium-sized ones, such as venture capital funds, guarantee funds and loan funds, and for urban development funds, that is, funds investing in public-private partnerships and other projects included in an integrated plan for sustainable urban development (Article 44, 78, Reg. (EC) No 1083/2006).

Later on, within the framework of the *place-based* narrative (Mendez 2013), which has guided the last SF reform, the objectives of Integrated Sustainable Urban Development (ISUD) have been included among key horizontal priorities of cohesion policy 2014–2020. Besides including a number of those thematic objectives that specifically target urban development, notably concerning environmental, regeneration, and mobility issues, the new SF regulations require member states to allocate at least 5 % of the total ERDF expenditure for ISUD, whereas cities, sub-regional, or local bodies (Urban Authorities) responsible for implementing sustainable urban strategies shall be responsible for tasks relating, at least, to the selection of operations in accordance with Article 123(6) of Reg. (EU) No 1303/2013. Moreover, in general, the new approach aims to support the development of more holistic integrated urban development strategies and the identification of investment priorities that specifically tackle urban development challenges. Actions for ISUD can be implemented through the so-called mainstream approaches: either a separate OP or a separate Priority axis in an OP. Two new specific tools have been envisaged—Integrated Territorial Investments (ITIs) (Article 36, Reg. (EU) No 1303/2013) and Community-led Local Development (CLLD) (Article 32–35, Reg. (EU) No 1303/2013)—with the purpose of linking the thematic objectives identified in the Partnership Agreements (PA), which is the main programming document at national level and OP, in compliance with Europe 2020 strategy on the one hand, and the territorial dimension on the other. These instruments have been considered to be particularly relevant for the implementation of ISUD, although they could target also other types of territory (i.e., rural-urban, sub-regional, rural, cross border, and territories with specific geographic features). In this way, the ITIs tool has been suggested to be a particularly effective instrument for programming interventions in urban areas, ranging from actions for specific urban neighborhoods with multiple deprivations, metropolitan, and larger urban areas (e.g., a network of small- or medium-sized cities). It is a functional instrument, which can be programmed to cover innovation and competitiveness, low-carbon economy and renewables, and social cohesion themes, and it does not necessarily need geographically contiguous territories. According to EU guidelines, local bodies should be significantly involved in the implementation of ISUD through ITIs, taking on responsibilities concerning the strategy development, animation, and project generation, selection or pre-selection of project activities, etc. The other tool—CLLD—is instead envisaged for territorially delimited sub-regional areas and is based on an ad hoc, bottom–up development strategy, mobilizing, and involving local communities and organizations. The CLLD approach is strongly rooted in the experience of locally driven CIP, which were developed, among others, within the Urban Pilot Projects and the URBAN CIP. Both instruments have been expected to boost the territorial potential of development, especially in urban areas, while states and regions were supposed to possess enough experience and skills to be able to translate them smoothly into practice.

However, although the EU approach to the territorial dimension seems to be better spelled out for the 2014–2020 programming compared to the 2007–13 period, a preliminary analysis of its implementation in a sample of countries has brought to light several challenges (Zwet et al. 2014). Not only have several ambiguities and omissions been pointed out in the EU guidelines, but many concerns have also been expressed in relation to administrative and institutional capacity at the local level, as well as to the way the results orientation and thematic concentration obligations are applied. The following aspects have been mentioned among the difficulties in the implementation of the new instruments: inadequate capacity of local bodies to meet increased financial and operational responsibilities, as they often have limited expertise or resources to implement projects; scarce representativeness and operational capacity of local partnerships; the risk of political interference and urban rivalry (the largest cities vs. others); and possible tensions between local and central level administrations as a consequence of delegation of responsibilities, etc.

Although in some countries the relatively high rate of adoption of what are voluntary tools (ITIs and CLLD) confirms that authorities at member-state level recognize their value, and have a certain level of enthusiasm for integrated territorial approaches, the MA are often 'caught in the middle' between the Commission on the one hand, which is 'pushing' for the use of integrated approaches in order to coordinate ESI Funds, and local actors on the other hand, who are keen to use territorial approaches in order to secure ring-fenced multi-annual funding (Zwet et al. 2014). In fact, the MA face the difficult task of having to establish structures and implement mechanisms that are in line with the expectations of local actors, or which may conform to the letter—but not the spirit—of the regulations. Thus, both thematic concentration and local responsibility for integrated development strategies are considered positive, but there is an inherent tension between the two.

In such a perspective, the Italian programming of ESI funds for the 2014–2020 period will be analyzed in the next section, showing how, along with an intense diffusion of the objective of ISUD at different territorial levels, the application of the new governance tools and their territorialization has been limited.

3 Sustainable Urban Development in the 2014–2020 Italian Programming: Objectives and Governance

The issue of sustainable urban development, signed on October 29, 2014, is mentioned as a crosscutting priority by the Italian Partnership Agreement. Given their enormous potential for economic growth, on the one hand, and the manifold challenges on the other, cities are considered to be a strategic territorial priority for the current programming period in the country, with the aim of achieving the following objectives:

(a) increased role of institutions of urban government as key actors of interdisciplinary and inter-institutional dialogue, as well as of the management of collective services;
(b) adequate adaptation of project-management tools to territorial needs enabling the achievement of common objectives;
(c) tangible implementation of thematic innovations foreseen by the ESF Regulation (e.g., social inclusion);
(d) effective coordination between ordinary and additional financial resources;
(e) concrete steps to encourage the process of establishment of metropolitan cities and local governance reforms;
(f) guarantee of the involvement of citizens, civil society, and different levels of government in the definition and implementation of investments; and
(g) limitation of urban sprawl and soil sealing.

The aforementioned objectives have been translated into the three ‘drivers of development’, which constitute the core of the Italian urban strategy at the national level and from which OP at the national and regional levels were to choose when defining specific actions:

- the redesign and modernization of urban services for residents and users;
- practices and projects for social inclusion for the most disadvantaged social groups and neighborhoods;
- the strengthening of the cities’ capacity to support local segments of global production chains.

A fourth driver could be added at the regional level, combining several thematic objectives.[3] In order to implement the new strategy, two target categories of urban areas have been identified. The first category includes ten metropolitan cities defined by Law 56/2014 (the so-called Delrio Law)—Rome, Bari, Bologna, Genova, Firenze, Milano, Napoli, Torino, Reggio Calabria, and Venice, while the other comprises cities selected by the Special Status Regions[4] and includes Cagliari, Reggio Catania, Messina, and Palermo. These cities are covered by the National Operational Programme (NOP) METRO "Metropolitan Cities", entirely devoted to the objective of sustainable urban development and co-financed by the ERFD and the ESF.

Such an approach shows a considerable improvement compared to the previous programing period (2007–2013), when the competitiveness of urban systems was the only action for city development at the national level financed exclusively by the ERDF. Moreover, the NOP has introduced an important novelty in terms of urban governance architecture: Municipal authorities of the corresponding metropolitan cities are supposed to act as intermediate programming bodies—Urban Authorities—whereas in the past they were only the beneficiaries of project financing. In compliance with Article 7.4 of the ERFD Regulation (No 1301/2013), the NOP identifies mayors of the capital cities as Urban Authorities, who are responsible at least for the selection of projects in accordance with the principle of joint project management and shared strategic planning by the UA and the MA of the program (National Agency for Territorial Cohesion). As far as priority actions are concerned, the scope of the program appears to be rather limited: it focuses on the two first drivers, aiming at promoting sustainable mobility and energy efficiency in public buildings and lighting (TO 2 e 4) and measures against poverty and social exclusion (TO 9). Moreover, it is worth emphasizing that only non-material investments can cover the whole territory of metropolitan cities, while other actions will focus exclusively on the county seats. As Table 1 shows, financial allocations

[3]The following Thematic Objectives (TO) for the EU Structural and Investment Funds interventions have been defined to translate the Europe 2020 priorities into regional policies: (1) Strengthening research, technological development and innovation; (2) Enhancing access to, and use and quality of; information and communication technologies (ICT); (3) Enhancing the competitiveness of small- and medium-sized enterprises (SMEs); (4) Supporting the shift towards a low-carbon economy in all sectors; (5) Promoting climate change adaptation, risk prevention and management; (6) Preserving and protecting the environment and promoting resource efficiency; (7) Promoting sustainable transport and removing bottlenecks in key network infrastructures; (8) Promoting sustainable and quality employment and supporting labor mobility; (9) Promoting social inclusion, combating poverty, and any discrimination, (10) Investing in education, training, and vocational training for skills and life-long learning; and (11) Enhancing the institutional capacity of public authorities and stakeholders and efficient public administration.

[4]In Italy, there are fifteen regions with ordinary status (regioni a statuto ordinario): Piedmont, Lombardy, Veneto, Liguria, Emilia-Romagna, Tuscany, Umbria, Marche, Lazio, Abruzzo, Molise, Campania, Puglia, Basilicata, and Calabria; while five regions—Friuli-Venezia Giulia, Sardinia, Sicily, Trentino-Alto Adige/Südtirol, and the Valle d'Aosta—have a special autonomous status (regioni autonome a statuto speciale), taking into account relevant geographically and/or culturally specific features.

Table 1 Priority axes and EU co-financing of the NOP METRO (based on the data reported by the NOP METRO)

Axis	Title	Funding (million €)	%	EU fund	Thematic objective
1	Digital agenda	98.084.915,00	16.7	ERDF	2
2	Sustainable public services and urban mobility	210.808.800,00	35	ERDF	4
3	Services for social inclusion	142.376.058,00	24.2	ESF	9
4	Infrastructures for social inclusion	113.306.228,00	19.2	ERDF	9
5	Technical assistance	23.523.999,00	4.1	ERDF	11
	Total	588.100.000,00	100	–	–

Table 2 Comprehensive funding of the NOR METRO by category of region (based on the data reported by the NOP METRO)

Regions	Cities	Funding
Less developed	Bari, Naples, Reggio Calabria, Catania, Messina, Palermo	566.533.333,00
Transition	Cagliari	40.800.000,00
More developed	Bologna, Rome, Genova, Milan, Turin, Florence, Venice	285.600.000,00

will mainly be concentrated on the South of the country, depending on the category of regions (Table 2).

Finally, considering that the total amount of financing assigned to the program is around 900 million euros, there seems to be a risk of fragmentation of resources between different axes and cities. Taking into account the above described design of the NOP METRO, urban strategies defined at the regional level were expected to cover other thematic objectives, in particular Competitiveness and enterprises (TO3), Climate and environmental risks (TO5) and Environmental protection (TO6), as well as to guarantee complementary measures for metropolitan cities not covered by the national program. Furthermore, it has been observed that a number of actions planned for ISUD within the framework of the NOP during 2014–2020 overlap, in territorial and thematic terms, with actions implemented between 2007 and 2013, in particular with regards to e-government, e-learning, sustainability in public services, urban mobility, and energy efficiency in metropolitan areas. In this way, not only does the innovative potential of actions for SUD appear to be rather limited in the current programing period, but their positive impact also risks being undermined, given that the outputs of several projects previously financed in the aforementioned sectors were far from successful (Tortorella 2015).

As far as Regional Operational Programmes (ROP) are concerned, actions for integrated sustainable urban development have been foreseen by all of them, although the approach to programming differs widely across the country. A specific axis for ISUD has been designed by 11 ROP with a comprehensive allocation of about 786 million, compared to 9 ROP with 5 billion of euros in the 2007–2013 programming period (Tortorella 2015). Thus, quite surprisingly, the comprehensive amount of resources for sustainable urban development has decreased by 3.5 billion during the current programming, although the number of operational programmes dealing explicitly with this issue has increased (IFEL 2015). At the same time, some interesting policy innovations have been introduced at the regional level out of specific programs or axes. For example, ROP ERDF of Tuscany has foreseen actions for high-speed internet in the Florence region, which cannot be covered by the NOP 'Metropolitan Cities', whereas ROP Lombardy plans to buy railcars to employ in the suburbs of the metropolitan city of Milano to integrate the actions planned by the NOP METRO, etc.

As for the diffusion of innovations in governance architectures, around 53 % of resources do not have any specific territorial target, whereas a larger part of resources (27 %) have been assigned to big cities (more than 50,000 inhabitants) with a substantially lower share (15 %) allocated for small and medium towns (between 5,000 and 50,000 inhabitants). Besides, a considerable difference exists between more and less developed regions: for the former category almost 70 % of resources has a territorial target, while in less developed regions this amount decreases to 46.6 % (IFEL 2015). Some regional strategies have targeted specific types of urban areas (e.g., Functional Urban Areas in Tuscany) in order to plan future interventions but without using new governance instruments.

Overall, the adoption of CLLD and ITIs has proved limited in Italy, although a specific section on "Integrated approach to territorial development to implement through the Development and Investment Funds" has been envisaged in the Partnership Agreement, specifying that the many forms of integrated territorial planning developed in the country during the previous decades could be enhanced through the new governance tools. Only a few regions have introduced ITI-type arrangements to design actions for sustainable urban development (Marche, Molise, Basilicata, Sardinia, and Sicily), while others have avoided the adoption of these tools (and in particular of ITI) because of their high organizational complexity. Remarkably, rarely has the experience of the past URBAN CIP been taken into consideration,[5] while only two regions (Sardinia and Sicily) had relied on a similar kind of tool for integrated programming already in the period 2007–2013. Instead, no specific actions for integrated urban development have been foreseen in the operational programs for ERFD of Bolzano, Trento, Valle d'Aosta, and Lazio.

[5]The following URBAN CIP programs were implemented in Italy during the previous decades: Bari, Cagliari, Catanzaro, Cosenza, Foggia, Lecce, Napoli, Palermo, Roma, Salerno, Siracusa Ortigia, Regio Calabria, and Venezia Porto Marghera (1994–1999); Carrara, Caserta, Crotone, Genoa, Milan, Mister Bianco, Mola di Bari, Pescara, Taranto, and Turin (2000–2006). The PIC URBAN Genoa was supported during both programming periods.

4 Conclusions

Obviously enough, the above overview presents only a preliminary picture of policy outputs, as many other actions will be introduced in the forthcoming years. However, it provides a number of important insights with regards the scenario of the diffusion of policy and governance innovations within the framework of EU-cohesion polices related, in particular, to sustainable urban development. As illustrated, the EU has promoted specific policy objectives and governance tools since the 1990s in order to address the issue of development in urban areas in the perspective of sustainability. A progressive consolidation of these tools at the EU level has not been accompanied, however, by their extensive diffusion across member states. What is particularly striking, as the analysis of the Italian case shows, is that during the current programming period, when the place-based approach (Barca 2009) is strongly advocated by the EU, the task of matching the European guidance with local needs, passing through the national and regional levels of programming, remains quite a challenge. Moreover, besides concerns about the capacity of local authorities and partnerships to guarantee effective and efficient performance of functions that can be delegated to them according to the new regulations, a more general problem of governing development polices in multi-level systems seems to arise, as a limited adoption of the new policy instruments has partly been due to many uncertainties, high complexity, and insufficiently clear operational provisions for their application on the ground.

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A Critical Reflection on Smart Governance in Italy: Definition and Challenges for a Sustainable Urban Regeneration

Chiara Garau, Ginevra Balletto and Luigi Mundula

Coming together is the beginning.
Keeping together is progress.
Working together is success.
Henry Ford (1863–1947).

Abstract The aim of this work is to analyze the projects carried out by public institutions in the field of smartness, in order to reflect on the most effective mechanisms of governance. To this end, the paper is organized into two main sections. The first section provides a literature analysis of theoretical frameworks as they pertain to the role of political bodies, the policies, and their impacts on local communities in relation to the governance of smart cities. The second section explores the ongoing implementation of "smart city" projects in Italy, in order to understand how cities address their development perspectives from a conceptual framework to the construction of an actual urban space, faced with divergent politics, messy social systems, and different scales of urban governance. In this framework, disparities between urban governance scales and ideologies encompassing smart cities seem linked to the relational systems that local administrations can develop between neighboring cities. The final section summarizes the authors' conclusions, giving particular attention to how networked urban systems are programmed, because they have been found to be key to strategic and transformative planning.

Keywords Smart urban governance · Governance · Urban policies · Italian smart projects · Smart cities

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1 Introduction

The complexities that characterize today's urban dynamics make it difficult to describe, apply, or even to approach the concept of "smart cities".[1] For example, there is no agreement on what the administrative, functional, or social boundaries of a city should be. Consequently, identifying the optimum spatial unit for purposes of analysis is not always easy. Moreover, the urban context, when associated with the idea of "smartness"—a synonym for growth, sustainability, efficiency, inclusiveness, and technology—must necessarily refer to a territory that exceeds the strictly administrative boundaries of a city, because the entire location-based system is affected by changes emanating from the urban enter. In other words, urban dynamism produces a complex territorial geography, irreducible to traditional political, administrative, and hierarchical partitions, where local institutions serve as a complex network interlinked with the central city and even the nation. Since it is difficult to generalize—because of the different characteristics of individual urban contexts—the authors hypothesize that national urban policies must be integrated with good local governance in order to create smart, effective, sustainable cities. Without this integration, a long-term vision is not possible. Instead, the outcome will be weak, fragmented leadership, incapable of developing strategies and objectives in line with the European policies on smart cities (Donolo and Federico 2013; Mistretta and Garau 2013).

To this end, the European Union (EU) has for years promoted the use of several governance tools to facilitate the development of European cities into smart cities. These include policy documents and guidance (such as the Europe 2020 Strategy); specific forms of direct and indirect funding (direct-management funding is being provided in the case of Horizon 2020, and indirect EU funding includes the structural funds provided under the European Regional Development Fund [ERDF]); and policies aimed at creating partnerships between member states (such as the European Innovation Partnership on Smart Cities and Communities [EIP SCC]). In Italy, a process aimed at transforming cities into smart cities began in recent years, and national governing bodies have implemented specific governance tools that are in line with the latest European trends. In 2012, the Italian government approved a decree titled "Urgent measures for innovation and growth: The digital agenda and start-up."[2] This decree established the Digital Agenda for Europe (DAE), coordination and networking tools (the EIP SCC European initiative is

[1]The literature seems rather discordant in framing the "smart city" concept. Some authors define it as a paradigm (Kunzmann 2014; Lombardi et al. 2015); others as a fashionable trend of the moment (Lu et al. 2015); others simply as a label (Caragliu et al. 2011).

[2]The Italian Digital Agenda (ADI), i.e., a steering committee, and makes reference to a decree dated October 18, 2012 to further urgent measures for the growth of the country and has established a process for implementing ADE. (The Dynamics of Broadband Markets in Europe: Realizing the 2020 Digital Agenda.)

being implemented in Italy through the establishment of a Smart City National Observatory), and funding mechanisms.

These initiatives provide the scope needed to orient public action towards new local governance models, thereby enabling adaptation to urban changes and transforming the processes of urban development in an innovative way (Puppim de Oliveira et al. 2013). This innovation obviously embraces technological progress that leads to improved local economies and greater productivity (Meijer and Bolívar 2015). It also requires the involvement of authorized leadership and the participation of all stakeholders. From this perspective, Information Communication Technology (ICT) can be a powerful tool for triggering the interactive, participatory, and information-based urban environments, that are supported by the policies and subsequent actions of local authorities and communities (Garau 2013). In a nutshell, this represents the creation of what we call "smart communities."

In the current urban scenario—characterized by the pervasiveness of concepts such as ICT, smartness, flows, and territorial aggregations—good urban planning and the optimal management of a city's resources are possible, when environmental, social, and economic aspects are closely integrated in a medium- and long-term framework for action.

Having framed the role of policies and government institutions in Italy, this paper now analyzes the effects of Italy's current smart governance tools (policies and evolving laws) and highlights how local public bodies have implemented the "smart city" concept in their territories. This analysis has been conducted by studying publicly-funded projects that have been completed by Italy's community, national, regional, or local institutions, and cataloged in the *Italiansmartcity* platform. The data collected during this part of the study was then compared with the data provided on the iCity Rate platform. This platform was created to assess the smart performance of Italian cities.

2 Smart Governance: The Role of Policies and Government Institutions in Italy

The DAE is one of the initiatives under the EU 2020 strategy that defined member states' 2020 growth objectives. A common goal is the enhancement of social and economic benefits, related to environmental sustainability, the computerization of public agencies, and improved productivity and social cohesion, as a consequence of the optimal use of information and communications technologies.

In order to achieve its stated objectives, the EU DAE was translated into national initiatives, to be activated at the local level. The Italian Digital Agenda (*Agenda Digitale Italiana* [ADI]), established in 2012, is Italy's national initiative. Its main objective has been to advance Italy's progress toward a networked society as quickly as possible, and more specifically, to achieve a level comparable to that of other European countries. The objective has been to ensure that Italy would not be excluded from competing in global online networks. Once achieved, this goal will enhance the use and management of ICT technologies, as well as those of sectors emerging in the domains of public administration and other enterprises.

To this end, Italy established the Agency for Digital Italy (*Agenzia per l'Italia digitale* [AgID]), which has accelerated the process of digitization through legislative, regulatory, and programming measures, as well as through the implementation of initiatives, proposals, and projects (AgID 2015). In other words, the AgID formulated a series of strategic priorities related to infrastructure and architectures; public administration; open data; digital competence; smart cities and communities; projects and international programs; and the innovations market). The objective of doing so was to ensure that the ADI's objectives were in line with the DAE's objectives (Neirotti et al. 2013; AGID 2015).

The smart perspective has provided an opportunity for growth, and in some ways entrusts governments with a great responsibility for promoting and facilitating investments in larger individual territories. According to Healey (2007), urban-planning activities—such as identifying framing dimensions, setting realistic timeline, and coordinating the implementation of policies/strategies and the activities of actors—represent only some aspects of the urban planning field. In fact, they must necessarily be integrated with the paradigms of smart cities, increasingly focused on European regulatory and financial parameters.

Although this perspective assumes a reticular approach, the planning restrictions, urban prescriptions, and building interventions necessary to urban regeneration are based on traditional approval and implementation mechanisms. On the one hand, they protect and re-qualify the built urban fabric, reconnecting central and peripheral areas, and thereby creating a broader balance between urban services, public spaces, and housing. On the other hand, everything happens according to rather long timelines, and long timelines are contrary to the philosophy of smart cities.

In this regard, the municipality appears to be the public entity most likely to be at the center of a process that identifies active-resolutive strategies. Because of its size and access to local administrative tools, the municipality can operate on the social fabric, and foster the integration of programming logic and individual public policies with relative ease (Maurasse 2015).

Obviously, considering each city as an isolated "island" bordered by administrative boundaries will not lead to this integration. Instead, it has to be pursued by defining partnerships and conducting negotiations, primarily between the various neighboring municipalities. It must be based on an understanding of a diversity of interests and objectives, and be geared toward the paradigm of a Smart Territory[3] rather than a Smart City. Within this framework, Italy's recent adoption of the law

[3]The authors intend the term Smart Territory to mean a wide area identified by specific characteristics that make it unique. In this regard, the literature is varied. However, in the literature, this definition is translated in different ways, depending on the field (geography, urban planning, or regional economy) and on the nationality of the authors. Besides the Smart Territory terminology (Louman et al. 2015; Carroll et al. 2014), we can find similar terms such as Smart Region (Roth et al. 2013; Morandi et al. 2015) and Smart Land (Bonomi et al. 2014).

56/2014 (also known as Delrio law[4]) is of particular interest. This law 56/2014 has prompted reflections on the new institutional architecture of metropolitan cities: they appear to be complex organisms that exceed the strictly administrative boundaries and define continuous relations with neighboring areas even if these are managed by different administrations.

Therefore, this law has led local governments to define their own administrative boundaries, at different levels of scale, and to establish or strengthen renovated aggregative modalities, especially among neighboring municipalities. Based on this reasoning, if public authorities are asked to reflect on economic and social development, in a way that requires going beyond their administrative mandates, the community has to be more active in assuming new responsibilities with respect to balancing the social system and environmental sustainability over the long run. It is a *cives-civitas* (between the citizen and the city) "agreement" that includes everyone —individuals in local administrative organizations, including municipalities, unions of municipalities, and metropolitan cities.

These public actors, therefore, play a key role in the development and consolidation of a smart city, particularly with regard to integrating various dimensions of urban development, such as their sustainability, resilience, and smartness, and thereby fostering "smart governance."

To avoid repeating failures that occur all too often, it is necessary to build shared perspectives on desirable scenarios. However, they have to be accompanied by assessments of the feasibility and effectiveness of the actions proposed and foster cooperation and coordination between different sectors in the same local administration.

This does not necessarily imply a loss of centrality in politics and a more "progressive" administration, but rather, it implies a re-design of leadership, and the creation of a systemic vision. These objectives are not limited to producing and protecting common goods and services, but include governing the dense urban network of relationships and the place-based system that includes the smart city. In this sense, a close relationship between the city (*strictu sensu*) and the territory constitutes the basis for establishing new leadership and new social responsibilities.

To achieve this goal, the administration should create new structures and/or introduce new functions dedicated to consolidating the network of relationships, in order to become a reference point for citizens. This process is also crucial to the formation of a shared understanding among the different stakeholders: it is not possible to establish common lines of action without a shared awareness of issues and needs, agreement on cultural values, and reliable, constructive approaches to providing public goods.

When engaged in decision-making processes, authorities rely on having access to data that represent the context in which they are working. That said, it is necessary to emphasize that, where there are strong communities, there are strong

[4]The name of this law comes from the name of the Minister of Infrastructures and Transport, Graziano Delrio.

institutions. Fragile institutional visions are the result of weaknesses in the community, which in turn feed a vicious circle that leads to disaffection and a gradual decrease in the provision of urban common goods.

Having the necessary skills, taking responsibility, and strong community relations are the factors that must "draw" the new citizenship. A strong concept of social capital is important to having real, smart, sustainable, and inclusive growth. It requires having the courage to envision outcomes beyond those defined in the agreement and focusing on citizenship and institutional trust, while supporting and promoting forms of active citizenship.

This reasoning leads to the interpretation of smart governance as a coordinated, integrated, distributed, and hybrid process[5] (Meijer 2015), in which local cooperative knowledge is linked with the most appropriate technologies to the quality of the urban environment, planning tools, and the existing programming. This creates the ability to solve problems in a systematic way.

In other words, smart governance becomes a wider urban strategy, aimed at improving the quality of life in urban areas where technological innovation enhances the development of social capital. As Deaton (2010) has emphasized, technological innovation facilitates all types of trade, and enables one to measure all the micro and macro phenomena and their correlations, thereby creating a "snapshot" of the processes that are to be monitored, measured, and evaluated.

Numerous studies have attempted to use this line of thinking to conduct research in order to monitor, measure, and evaluate urban processes and smart governance, though they have not always been able to analyze the dynamics at the micro- and macro-levels simultaneously. The most recent studies (Toppeta 2010; Caragliu et al. 2011; Huggins and Clifton 2011; Dodgson and Gann 2011; Abdulrahman et al. 2012; Between 2013; Mundula et al. 2015; Marsal-Llacuna 2015) have used as a starting point the measurements conducted by Giffinger et al. (2007) of smart cities. Other studies are based on concepts that address the urban debate (UNCHS 1999; Kaufmann et al. 2005; Rosales 2011; Shen et al. 2013). Some studies are focused on more sectoral and specification analysis (Cox and Mari 1988, 1991; Peck 2005; Doel and Hubbard 2002; Garau et al. 2015), and still others focus on the quality of urban life (Marans 2003; Lazauskaitė et al. 2015; Fulford et al. 2015). The level of confidence that has emerged from these studies' use of measurements, evaluations, comparisons, and classifications, has contributed to transforming the role of city governance. In addition, these studies have revealed that the determining factors for

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[5]In particular, Mejer argues: "the idea of smart city governance as concentrated intelligence stresses that new technologies—big data, data warehousing, monitoring tools—enable central steering actors to strengthen their intelligence, provide more integrated services, develop better policies, and steer other actors in the city more effectively. […] The idea of distributed intelligence highlights that new technologies—social media, Internet, open data—enable the various actors in the city to collaborate more effectively and produce better solutions for the city. […] The two modes of smart city governance are ideal types and should be seen as extremes on a scale of smart in other word, city governance. Intermediate forms are modes of hybrid smart city governance. Hybrids may lean towards one of the extremes or form a balanced combination of concentrated and distributed forms of governance" (Meijer 2015: 77–78).

smart governance assessment are: the network between neighboring cities; the amount of funded projects; and the amount of funding. For this reason, in the next section, the authors analyze them and apply the system to these factors.

3 Italian Projects in Support of Smart Urban Governance

It is apparent that governing urban complexity, which includes understanding all its political, social, and territorial implications, and embracing the evolutionary process that leads to smart cities, is a particularly sensitive topic, because it requires a collective effort by planning and management agencies from the EU to local levels. In Italy, this task is further complicated by the national context, which is characterized by some metropolitan hubs that are in opposition to prevailing small, and often contiguous, centers. The first of these, despite being the most problematic in terms of economic and social conflicts and environmental impacts, are more likely to be internationally competitive. The latter are likely to be the victims of provincialism, at the edge of a renewal process that presupposes a greater effort to remove traditional governance, and is too closely bound to previous administrative boundaries and sectoral policies.

Italian cities have disparate urban governance scales, and their objectives vary by city. These factors have significant impacts on how actors frame their work and priorities. To provide an overview of the Italian situation, the Smart Cities platform —organized and promoted by the National Association of Italian Municipalities (*Associazione Nazionale dei Comuni italiani,* [ANCI])—documents project experiences that have a smart perspective. The platform is currently being implemented by 158 Italian municipalities (http://www.italiansmartcity.it/).

As shown in Table 1, "government" has seen less investment (only 3 % of the total) than any other sector (environment 8 %; economy 10 %; people 5 %; living 8 %; mobility 22 %; planning 27 %; energy 17 %). The municipalities that have implemented the highest number of projects on the theme of government are Milan (13.5 %, 11 of 81 projects in total); Lecce (35.7 %, 10 of 28 projects); Turin (12.8 %, 10 of 78 projects); Pordenone (30 %, 9 of 30 projects); Bergamo (27 %, 6 of 22 projects); Rieti (26 %, 6 of 23 projects); Cagliari (12.5 %, 6 of 48 projects); and Palermo (42.8 %, 6 of 14 projects). The projects listed deal primarily with the following sub-themes: open data; eGovernment; managing public spaces and commons; and transparency and e-democracy. Twenty-three other projects related to planning were added to this list, in a subsector called governance. Of these, twelve have been implemented without any funding (Table 1).

These data summarize the already initiated, ongoing, and completed projects at the local level, while also providing an assessment of the same in relation to the ability to impact the three dimensions of sustainable development: (1) economic, or the ability to generate income and employment for the population, and to influence the territory's levels of economic growth; (2) social, meaning the ability to guarantee that human welfare conditions are equally distributed among all classes; and

Table 1 Funding levels and numbers of municipalities involved in smart initiatives by sector (Adapted from the Italian Smart Cities platform. Accessed March 30, 2016)

Sectors	Euro	Budget %	Projects's number	Municipalities involved	Municipalities involved %
Environment	€ 289.981.711	8 %	191	83	53 %
Economy	€ 376.906.091	10 %	113	53	34 %
People	€ 171.416.226	5 %	181	58	37 %
Living	€ 283.099.247	8 %	168	76	48 %
Mobility	€ 820.513.992	22 %	245	80	51 %
Planning	€ 1.012.075.377	27 %	103	45	28 %
Planning-Governance	€ 8.276.688,90	1 % (of planning)	23	17	38 % (of planning)
Energy	€ 642.492.459	17 %	139	55	35 %
Government	€ 113.673.883	3 %	169	54	34 %
Total	€ 3.710.158.986	100 %	1308	158	100 %

(3) environmental, meaning the ability to maintain the quality and continual availability of natural resources. However, this dataset give us no idea of the cities' performance in absolute terms—a city's performance relative to its own targets or "internal performance"—or in relative terms—a city's performance relative to that of other cities or "external performance." This assessment is provided in the iCity Rate dataset (http://www.icitylab.com/the-relationship-icityrate/edition-2015/data-2015/) using a composite index of smartness.

This index is comprised of the values for seven dimensions (economy, living, environment, mobility, people, governance, and legality), each of which is based on twelve indicators. It includes the values from all provincial capitals from 2012 to 2015. The first problem that arises is comparing these datasets with those in the Italiansmartcities' platform database, which analyzes the projects of 158 cities on eight dimensions (environment, energy, economy, people, living, mobility, government, and planning). A two-step solution has been used to resolve this problem. Firstly, the definitions of the dimensions in each of the two datasets were compared. From this analysis, it was possible to confirm the following: four areas were perfectly matched (economy, living, mobility, and people); environment and energy dimensions of the Italiansmartcities platform matched the environment dimension in the iCity rate; and, the government and planning dimensions matched the governance sector in the iCity rate. The legalities are not comparable, but these data are only available for 2015. Once correspondence had been established between the dimensions, only those cities represented in both datasets were selected for this study, for a total of 53 cities.

Even though it is not possible to assert that the projects documented in the Italiansmartcities platform (ranging from 2012 to 2015, of which most are not concluded) had influenced the values of the indicators of the respective cities (ranging from 2012 and 2015), it is possible to assess those dimensions in which the cities had made investments between 2012 and 2015, and stated each city's performance against each dimension in 2012 (even though we do not know if the administrators knew the indexes' values).

To conduct this assessment, we proceeded in two steps. Firstly, for each city, we ranked the performances of the projects implemented between 2012 and 2015 by (a) their different dimensions in 2012 (r_1), (b) the number of projects undertaken (r_2), and (c) their amounts (r_3). Secondly, we built two indexes that ranged between −1 and 1 (correlation between r_1 and r_2, correlation between r_1 and r_3), and displayed them on a Cartesian graph as coordinates (Fig. 1).

This analysis highlighted four types of cities, which we categorized as smart, follower, start-up, or, as usual:

(1) Smart Cities: these were cities that have funded few projects at low levels, in the dimensions for which their performance was higher, and many projects at high levels, for which their performance was lower
(2) Follower Cities: these were cities that have funded many projects at a low level, in dimensions for which their performance was higher, and few projects at a high amount for which the performance was lower

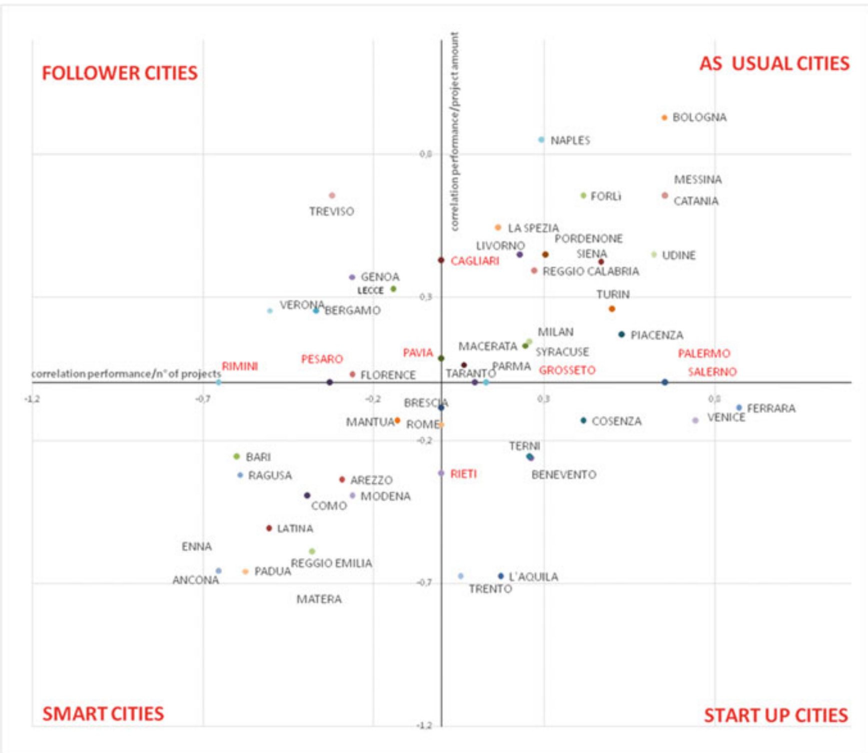

Fig. 1 Investments and the numbers of city projects initiated, relative to their performance (*Source* Adapted from the Italian smart cities and iCity Rate platforms.)

(3) Start-up Cities: these cities funded few projects at a high level, in the dimensions for which their performance was higher, and many projects at a low amount for which their performance was lower;
(4) As usual Cities: these cities funded many projects at a high level, in the dimensions for which their performance was higher, and a few projects at a low level for which the their performance was lower

These results show that most of the cities (18) tended to invest in the dimensions for which their performance was higher, and quite a large number (14) tended to invest in dimensions for which their performance was lower. Thirteen of the cities analyzed were either follower cities (six) or start-up cities (seven). Finally there were five cities (Grosseto, Palermo, Pesaro, Rimini, and Salerno) in which the projects had been developed at no cost, so it is not possible to calculate correlations between the variables, and three cities (Cagliari, Pavia, and Rieti) that showed no correlation between their performance in the different dimensions in 2012 and the number of projects undertaken. Looking in detail at the performance of the same 53 cities in terms of smart governance, it is apparent that cities with good value in terms of smart governance are among the best (except in the case of Trieste) (Table 2 and Fig. 2).

At first, this result might appear to suggest that “smart governance” is very significant in generating urban smartness. It is true, however, that the definition of smart governance used to classify projects in the iCity Rate platform does not correspond with the one we think is most appropriate: smart governance is a process capable of activating relations and synergies between local actors within a broader context than that of the city’s administrative border. The definition used in the iCity Rate platform instead adopts a quantitative approach, in which smartness is defined by the process of implementing urban growth through technological solutions, rather than through triggering forms of relational networks, and providing support to the development of smart communities.

Table 2 I City ranking 2014–2015 (I City Ranking 2015)

Cities	Ranking 2014	Ranking 2015	Ranking smart governance 2014	Ranking smart governance 2015
Milan	1	1	10	12
Bologna	2	2	3	2
Florence	3	3	1	1
Modena	4	4	4	4
Venice	6	5	7	8
Parma	10	6	11	9
Reggio Emilia	8	7	12	10
Trento	13	8	10	9
Padua	5	9	6	11
Trieste	9	10	47	56

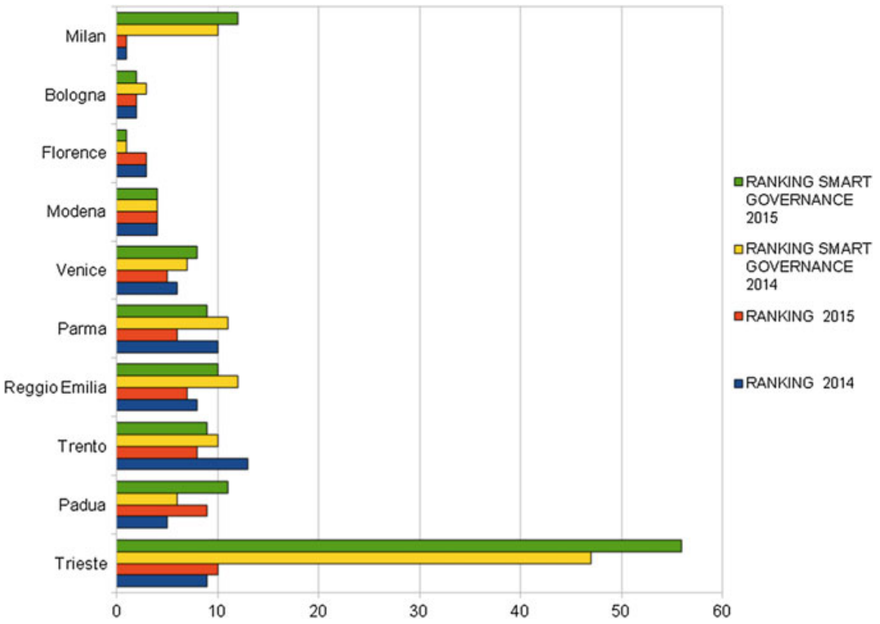

Fig. 2 I City Ranking 2014–2015 (I City Ranking 2015)

Looking at the ranking of the projects' smart governance dimensions (Italiansmart platform), it is apparent that there is an inverse correlation in terms of ranking: the best-performing cities are those with lower investment values. The explanation for this can be addressed through a new generation of smart governance. In fact, the framing of all dimensions (environment, economy, people, living, mobility, planning, energy, and government) contributes to the construction of those relational processes, the virtuous dynamics necessary to the development of a smart city, and to the emergence of smart communities. In other words, to initiate the needed change that will enable and empower strategic and transformative planning, changing the usual way of programming urban-networked systems may be all that is needed.

4 Strategic Vision and Smart Governance for Sustainable Urban Regeneration

Based on this study's findings, building a smart region is a matter of governance, which is understood as a concept that embraces all sub-sectors in which smartness has been structured, based on a shared vision that is consistent with, and feasible in, the domain of declared smart projects.

To this end, as a first step, the authors examined whether the same 53 cities previously analyzed, and in particular the top ten smart cities in the ranking based on iCity Rate data (Table 2), had spatial strategic plans. Of the 53 cities, 26 have a strategic plan, and of the top ten, only five cities (Milan, Bologna, Florence, Venice and Trento) have a spatial strategic plan. Although the number is partial, this result may suggest that having a spatial strategic plan—namely, an urban planning tool stating a declared vision—may be a necessary but not a sufficient condition for stating that a city has the basis for a smart city. This is also apparent among cities that have a strategic spatial plan but are ranked lowest in the 2015 ranking, such as Cagliari, which is in 60th place, and which also has a metropolitan spatial strategic plan, and Messina, in 93rd place, or Reggio Calabria, in 102nd place. Secondly, this result depend on a city's performance, rather than on its endowments (Mundula and Auci 2015).

How did a city without a spatial strategic plan emerge as a smart city? Why are cities with strategic plans not among the top cities in the smart cities ranking? With reference to the second question, a possible answer is that the planning choices were not coherent, or had not matured enough to demonstrate their effects and their impacts.

In addition, the survey indicates that some top-ranked cities have been leaders in some sectors for years—for example, Bologna is recognized as a university city, and Florence and Venice as tourist cities. This suggests that, over the years, they have developed an approach aimed at promoting their brands. They have urban strategies that "embrace" their cities, each recognizing a style that feels like its own, and, because of it, is recognized by all others.

City branding is a marketing-sector concept, and has as its first purpose the development of destinations—primarily tourism destinations. Nonetheless, the capacity of these cities to recognize shared objectives and to systematize their own resources for achieving them actually enables the coincidence of brand and vision. This coincidence is confirmed in the recent literature on this subject (Merrilees et al. 2009) which tends to shift the focus from non-resident stakeholders (tourists) to resident stakeholders, because they not only have a longer time horizon, but also a perspective that extends from the city to the region (Olins 2003). This approach is based on people's perceptions and images and places them at the center of the activities designed to shape smart regions and their futures. Choosing and managing the brand or the vision, and recalling the idea of the place's identity, becomes an attempt to influence and treat the mental maps of city stakeholders in a way that is coherent with present circumstances and the future needs of the city.

For all these reasons, the logical next step to evaluating the smartness of cities involves analyzing their resource allocations, in relation to the measurement of their urban performance, i.e., evaluating how cities transform their branding and developing planning statements that put into play the relational processes between neighboring cities (referred to by descriptors such as strategic plans, or health) that are ultimately expressed as coherent administrative acts (Fig. 3).

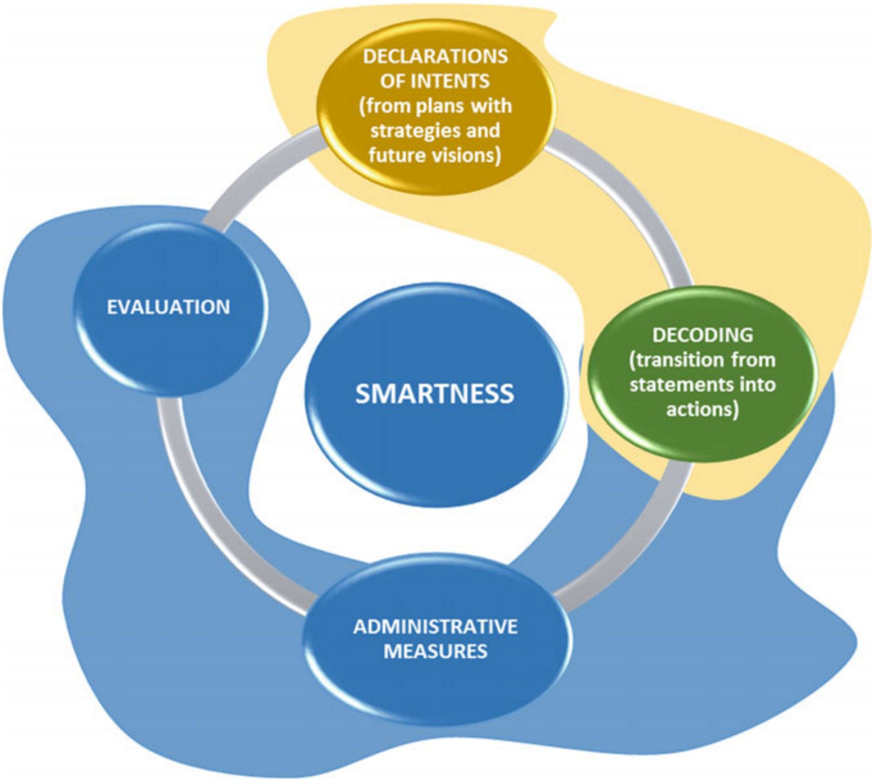

Fig. 3 Evaluation of the cities performance

By adopting this approach, the process of developing strategic plans, in a broad sense, can become a condition that is not only necessary, but also sufficient, for building a smart region.

5 Conclusions

This work has enabled us to identify and reflect on some needed and essential aspects of achieving sustainable urban regeneration in a smart key: managing policies with dedicated responsibilities; focusing on relational components between cities; engaging actors in a "common direction" with regard to the organization of collective action; and mobilizing resources in a cohesive and closer way. The comparison of the 53 cities conducted in this study has shown that the majority of the cities (18) tend to invest in those dimensions in which their performance is higher, and quite a number (14) tend to invest in the dimensions in which their performance is lower.

In relation to these results, we must be aware of what all this means, not so much in terms of technical feasibility, but rather in terms of political and human capital, by taking a multidisciplinary approach, and fostering "visionary leadership," capable of governing, but also capable of sharing values, concerted actions, mobilizing resources, and looking towards the future of community.

Finally, the projects that have been analyzed provide evidence from which can emerge new stimuli, in order to create a reshaped leadership within a specific urban context. In other words, there is not one strategy that is appropriate for all cities, but certainly there is a best strategy for each city. It is to be found by sharing and extrapolating the successes of other cities, as part of a healthy competition between cities, city branding (Lucarelli and Berg 2011) and big-city urban events such as Expo 2016, the Olympics in Turin 2006, international trade fairs such as Colombiadi of Genoa, and the Olympics in Rome 2020 (Balletto 2003).

In relation to these results, we must be aware of what all this means, not so much in terms of technical feasibility, but rather in terms of political and human capital, by taking a multidisciplinary approach, and fostering "visionary leadership," capable of governing, but also capable of sharing values, concerted actions, mobilizing resources, and looking towards the future of community.

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How to Become a Smart City: Learning from Amsterdam

Luca Mora and Roberto Bolici

Abstract This exploratory study has been carried out to better understand the development process of strategies that allow large European cities to become smart. This aim is achieved through the analysis of the Amsterdam's smart city strategy. By using case study research with a descriptive approach, the activities undertaken during the implementation of this successful initiative have been mapped and organized in a step-by-step roadmap. This made it possible to obtain a detailed description of the entire development process, useful knowledge to consider for other similar initiatives, and a conceptual framework for future comparative research. All these results will support the construction of a holistic and empirically valid theory able to explain how to build effective smart city strategies in this type of urban area.

Keywords Smart city · Strategy · Roadmap · Development process · Amsterdam

1 Introduction

The first scientific publication to introduce the term smart city dates back more than 20 years ago (Komninos 2011; Schaffers et al. 2011), but a common definition capable of explaining its meaning is still missing. A multitude of interpretations can be found in scholarly literature (e.g., Allwinkle and Cruickshank 2011; Batty et al. 2012; Caragliu et al. 2011; Dirks and Keeling 2009; Giffinger et al. 2007; Harrison et al. 2010; Manville et al. 2014; Washburn et al. 2010), and this condition has generated an extremely confused scenario (Hollands 2008). However, by considering the comparative analyses proposed in recent studies (Chourabi et al. 2012; Nam and Pardo 2011a, b; Reviglio et al. 2013), despite some differences, these

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definitions seem to share a similar idea of what smart cities are: urban areas in which information and communication technologies (ICTs) are used as a tool for providing a solution to the multi-faceted problems that limit their sustainable development in social, economic, and/or environmental terms.

During recent years, transforming ordinary urban environments in smart cities has become a priority for a growing number of local governments and an ambitious aim that they are trying to achieve by launching specific strategies characterized by many different approaches (Angelidou 2014). In a short time, smart cities have become an expanding phenomenon in the real world. According to the data provided by Lee and Hancock (2012), more than 140 urban areas worldwide have launched a smart city strategy before 2013. Moreover, as reported by Manville et al. (2014), 240 of the 486 cities with a population above 100,000 inhabitants and belonging to the EU Member States were working in this field before 2014. This is a growth trend which is evident not only in the number of cases, but also in the production of scholarly literature dealing with smart cities.

However, even if smart city research is growing together with the interest of an ever broader scientific community, the level of knowledge concerning the possible ways in which smart city strategies can be implemented is very limited. In the literature produced to date, there is an evident lack of explicit and holistic procedures that can be used to guide the actors involved in the development of smart city strategies towards successful results (Abdoullaev 2011; Angelidou 2014; Chourabi et al. 2012; Frei et al. 2012; GSMA et al. 2011; Hollands 2008; Komninos 2011; Nam and Pardo 2011b). This consideration is valid for any type of city, whether small, medium, or large in size, precisely as observed by Kitchin (2014): "presently [research on smart cities] has four shortcomings [including] an absence of in-depth empirical case studies of specific smart city initiatives and comparative research that contrasts smart city developments in different locales". Only a few examples of procedures can be found in scientific publications, but they are characterized by a low level of detail and come mainly from the gray literature produced by the corporate sector (Dirks et al. 2010; Berthon and Guittat 2011; Clarke 2013). As a consequence, two relevant research questions call for a quick response: what are the essential steps to consider for developing successful smart city strategies? And how are they organized?

By focusing the attention on large cities,[1] this study makes a valuable contribution to fill this knowledge gap. Specifically, the activities undertaken during the implementation of the successful smart city strategy proposed by the City of Amsterdam have been mapped and organized in a step-by-step roadmap. This made it possible to obtain: a detailed description of the entire development process; useful knowledge to consider in other similar initiatives; and a possible conceptual framework for supporting future comparative research. This activity represents an

[1]Large cities are urban areas with a population of between 500,000 and 1.5 million inhabitants. This definition aligns with the classification system of urban areas proposed by the Organisation for Economic Co-operation and Development (OECD) (Brezzi et al. 2012).

important step towards the construction of an empirically valid theory able to explain how to develop smart city strategies in large European cities in the best way possible.

2 Methodological Notes

Descriptive case study research as defined by Yin (2009) has been employed for the qualitative analysis of the Amsterdam's smart city strategy. This case has been selected using a theoretical sampling approach (Yin 2009; Eisenhardt 1989). With a population of nearly 800.000 inhabitants, Amsterdam falls within the category of large cities (Gemeente Amsterdam 2014c), and its success in the field of smart cities makes its strategy an ideal sample to analyze. This success is demonstrated by the multiple awards that the city has received during recent years and its international positioning as a smart city (I amsterdam 2011, 2012, 2013; Collins 2013; Cohen 2012, 2014). One of the most important award comes from the European Parliament, which has included the Dutch capital among the six most successful smart cities in Europe (Manville et al. 2014).

Data for the analysis has been collected from multiple sources of evidence identified with a series of searches performed in various online databases during the period between July and August 2014. A total of 198 sources has been collected. Archive records and documents produced by organizations directly involved in the development of the smart city strategy have been considered as primary sources (e.g., agendas, minutes of meetings, press releases, news and newsletters, conference presentations and conference speeches, reports, brochures, videos, governmental acts, articles, and web-pages). Additional data has been acquired from documents produced by organizations not directly involved in the initiative of Amsterdam. These sources have been considered as secondary (e.g., reports, interviews, journal and online articles, books, as well as research project deliverables). This approach has enabled analysis of the case through the consideration of the different perspectives of multiple observers. Moreover, the final description of the process and the conceptual framework have gained greater strength thanks to the triangulation made possible by the use of multiple sources of evidence (Yin 2009; Eisenhardt 1989; George and Bennett 2005; Voss et al. 2002).

Coding analysis has been used to facilitate the management of the vast amount of data collected from the sources. This phase of the study has been developed considering the procedure described by Voss et al. (2002) and Strauss and Corbin (1990). Through the coding process, raw data has been reorganized and the activities which characterize the development process of the Amsterdam's smart city strategy have been listed in chronological order. This made it possible to build a step-by-step roadmap which has been described and illustrated through the production of a "story" (Bourgeois and Eisenhardt 1988): a detailed report in which the data associated with the case has been summarized and presented in a narrative form (within-case analysis) (Miles and Huberman 1994).

3 Results

The analysis has enabled the construction of a step-by-step roadmap that describes the development process of the Amsterdam's smart city strategy (see Fig. 1). The roadmap, which is composed by five main phases and 16 different activities, is presented in the following pages.

3.1 *Phase 1: Starting*

In the case of Amsterdam, the smart city strategy is called "Amsterdam Smart City programme" and the idea to start this initiative was developed in 2007 (Baron 2012c), thanks to the collaboration between the Amsterdam Innovation Motor

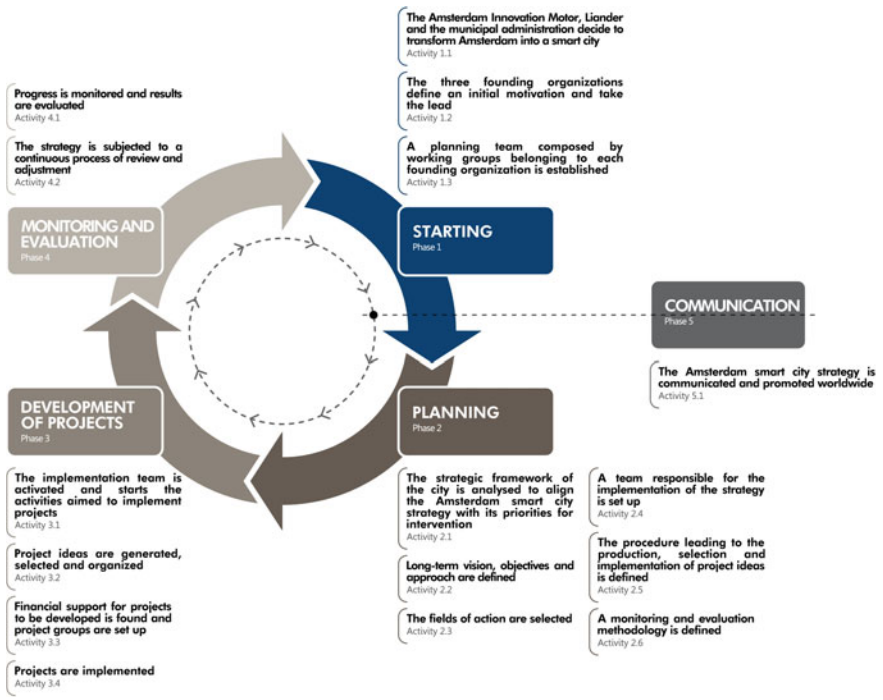

Fig. 1 The development process of the Amsterdam's smart city strategy

(AIM),[2] the energy-network operator Liander,[3] and the municipal administration (Amsterdam Smart City 2010, 2011a, b; Annen 2011; Baron 2010, 2012d; Bigliani and Gallotti 2009; Brinkman and Baron 2012; European Commission 2011; Turner et al. 2009; Velthausz 2011a; Vermast 2011a, b). Supported by the belief that "ICTs improve the way cities function" (Baron 2012b), these three organizations have become the initiators of a strategy which is currently underway, and the main driving force behind all the activities that are carried out to guarantee its progressive implementation.

Their decision to transform Amsterdam into a smart city has been supported by both political commitment and a clear motivation: the desire to use ICTs for helping the city to solve its environmental problems and build an urban environment that is "definitely sustainable" (Gemeente Amsterdam 2011a). Technology has been identified as "a key enabler to address climate issues" (Brinkman and Meuwissen 2010), and the smart city strategy has become an opportunity to achieve the strategic objectives defined by the City of Amsterdam in a faster way (Amsterdam Smart City 2011a). Moreover, despite the change in the municipal administration which occurred in 2010 (van der Laan 2014), the municipality's commitment to the use of information technologies for promoting environmental sustainability has remained stable over time and clearly emerges in many policy documents (Gemeente Amsterdam 2010, 2011b, 2012a, 2014a, b).

After clarifying the motivation for launching the smart city strategy, the three initiators have acquired full responsibility for its development, starting from the planning phase. The planning activities started in 2008 (Bigliani and Gallotti 2009; Turner et al. 2009) and have been implemented by a specific team composed by various working groups belonging to each founding organization (Brinkman and Meuwissen 2010). For example, the Climate Office of the municipality of Amsterdam and the ICT Cluster of the Amsterdam Innovation Motor (Brinkman and Meuwissen 2010; European Commission 2011), both established in 2008. The first is part of the Physical Planning Department (Guri et al. 2012) and has the task of undertaking projects and initiatives aimed at reducing carbon-dioxide emissions in the city of Amsterdam (Gemeente Amsterdam 2008). The second, instead, formed the core of the ICT activities in the AIM and was responsible for generating

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[2]The AIM is a foundation established in 2006 that helps to preserve and strengthen the Amsterdam Metropolitan Area's authoritative position in the knowledge economy. By supporting new ideas and ventures that stimulate entrepreneurship, this foundation constantly develops new initiatives collaborating with universities, industries, local governments, and many other independent organizations. The initiatives developed by the Amsterdam Innovation Motor are connected to four strategic areas: creative industries and new media; information and communication technology (ICT); life sciences; and sustainability (Amsterdam Innovation Motor 2009, 2011; Amsterdam Smart City 2011a). Starting from 2013, the AIM has become part of the Amsterdam Economic Board (Amsterdam Economic Board 2014; The Technopolicy Network 2014).

[3]Liander is a Dutch energy-grid operator which forms part of Alliander, the largest energy company in the Netherlands. Its task is to build, maintain, and manage energy networks in order to distribute gas and electricity to large parts of the Netherlands, including the Amsterdam Metropolitan Area (Amsterdam Innovation Motor 2009).

and managing new projects linked to this sector (Amsterdam Innovation Motor 2009). Since 2013, when the AIM and the KennisKring Amsterdam (Amsterdam Knowledge Network Foundation) were merged to become the Amsterdam Economic Board,[4] this working group has been included in the new ICT/e-Science Cluster (Amsterdam Economic Board 2014; The Technopolicy Network 2014).

3.2 Phase 2: Planning

Different activities have been conducted during the planning phase. First of all, the Amsterdam's smart city strategy has been correctly included within the strategic framework of the city and aligned with its priorities for intervention, with particular reference to the need to contrast climate change through a significant reduction of carbon-dioxide emissions. This framework represents the result of the convergence of several strategies proposed at the local and European levels to address the problems reported in the initial motivation (Annen 2011; Baron 2010, 2012b; Brinkman and Meuwissen 2010; Schuurman 2011; Stahlavsky 2011; Velthausz 2011a, b; Vermast 2011a, b, 2012).

As pointed out by Joke van Antwerpen, Director of the Amsterdam Innovation Motor, "Amsterdam Smart City is closely linked to the New Amsterdam Climate programme, which states clear climate goals for the city of Amsterdam […] and encourage change in the energy consumption of citizens" (Smart Meters 2009). This program focuses attention on a specific goal to achieve and a long-term vision to realize: "in recent years it has become urgently clear that we must find an answer to the climate problem. The city executive of Amsterdam, together with many other parties in our city, wants to face this challenge. We have committed ourselves to reducing our CO_2 emissions by 40 % in 2025 (compared to 1990)" (Gemeente Amsterdam 2008). In this way, Amsterdam can be turned into "one of the most sustainable cities in the world" by 2025 (Gemeente Amsterdam 2009).

The smart city strategy has been aligned with the objectives, priorities, and vision proposed in the New Amsterdam Climate program. The strategy, indeed, looks forward to 2025 and its ultimate goals are: (1) to support the reduction of energy wastage and carbon-dioxide emissions in the metropolitan area of Amsterdam; (2) to promote sustainable economic growth based on technological innovation, taking advantage of the possibilities offered by ICTs and changing citizens' behaviors to induce more sustainable life styles (Annen 2011; Amsterdam Economic Board 2012; Amsterdam Smart City 2010, 2011a, 2014g; Brinkman

[4]The Amsterdam Economic Board is a foundation which performs the same functions of the AIM: "under the umbrella of the Amsterdam Economic Board, representatives from governmental agencies, research institutes and the business world have jointly taken responsibility to work towards strengthening the economy of the Amsterdam Metropolitan Area. The Board strives to stimulate and support sustainable collaboration, innovation and growth in the region, and strengthen international competitiveness" (Amsterdam Economic Board 2014).

2011; Brinkman and Meuwissen 2010; European Commission 2011; Schuurman 2011; Vermast 2011a, b). Moreover, the analysis of carbon-dioxide emissions included in the New Amsterdam Climate program has been used to select the fields of action, which correspond to "the largest CO_2 emitters in the city" (Turner et al. 2009): living spaces; working spaces; mobility; and public spaces. These fields "are estimated to account for a third of the city's emissions each" (Philipson 2009).

In order to achieve these goals, a specific approach has been defined based on the continuous and constant development of ICT-based projects. Each project and the technological solutions which characterize it are tested during an initial pilot phase. At the end of the test period, the results obtained are analyzed and the best initiatives are considered for a subsequent implementation phase on a large scale. Furthermore, four key principles have been selected for guiding the development of both the strategy and individual projects:

(1) Collective effort: a highly collaborative approach is considered fundamental for achieving results. For this reason, cooperation between the public and private sectors is constantly stimulated and supported in every project, together with the involvement of citizens (Public-Private-People Partnership);
(2) Economic viability: only the most advantageous projects can be considered for potential large-scale implementation;
(3) Tech push/pull demand: the action against the climate change has to be supported through technological innovation and the stimulation of behavioral change;
(4) Knowledge dissemination: sharing and spreading the knowledge acquired during the path towards the smart city transformation are considered as actions of crucial importance (Amsterdam Smart City 2011a; Brinkman 2011; Schuurman 2011; Stahlavsky 2011; Vermast 2011a, b, 2012; Velthausz 2011b; Schaffers et al. 2012; Turner et al. 2009).

To ensure high involvement of citizens during the development of projects and stimulate a change in their behavior, a Living Lab methodology has been chosen. In this way, technological solutions can be tested in a real-life environment through the active involvement of the city's inhabitants (Amsterdam Economic Board 2012; Baron 2012c, d; van Veen 2012; Vermast 2012). As suggested by Joost Brinkman, Manager of the Amsterdam Smart City programme between 2009 and 2011, "the essence of the Amsterdam approach is that Living Labs are being used for the projects […]. Involving […] citizens is essential […] since the tested technologies are useless without [their] acceptance and experience" (Brinkman 2011). This choice is consistent with the objectives of the strategy and its key principles.

Another important activity which has been carried out during the planning phase is the definition of a new organization able to ensure the proper implementation of projects, which is described as an "open platform […] that unites [public and private] parties and acts independently" (Annen 2011). This organization has been called Amsterdam Smart City (European Commission 2011) and structured as a foundation (Reviglio et al. 2013; Stahlavsky 2011). Moreover, it has been split into various working groups with specific roles and responsibilities: Focus Group; Sponsor Group; Communication Group; Project Group; and Work Group (Brinkman 2011; Brinkman and Meuwissen 2010; Velthausz 2011a). All the groups have been activated during the third phase and are composed mainly of representatives from the AIM, Liander, and other external consultants. These include Accenture, which is one of the world's largest consulting firms in the fields of ICTs. As reported by Joke van Antwerpen: "we chose Accenture for its innovative thinking in helping city authorities and utilities come together in responding to climate change challenges, as well as its expertise in smart-grid and smart-metering technologies" (Smart Meters 2009). Along with Accenture, the independent research institute TNO has been selected as a strategic partner (Amsterdam Smart City 2014g; Annen 2011), but to play a different role: "to make sure that the research results would be recorded, underpinned, and shared based on a rigid scientific foundation" (Amsterdam Smart City 2011a).

Finally, the procedure leading to the production, selection, and implementation of project ideas has been precisely defined (Brinkman 2011; Brinkman and Meuwissen 2010; Velthausz 2011a), together with a methodology for monitoring and evaluating the results of projects (Amsterdam Smart City 2011a; Schaffers et al. 2012). Both are discussed in the next sections.

3.3 Phase 3: Development of Projects

The Amsterdam's smart city strategy is based on the continuous development of ICT-based projects that enable the introduction of new applications, services, devices, and technological infrastructures within the city in the short and medium term. To ensure their proper coordination and implementation, the Amsterdam Smart City Foundation has been activated. In this way, the strategy has moved "from the holistic view [of the planning phase] to concrete projects" (Baron 2012b).

To select and implement projects, the foundation uses the procedure defined during the planning phase. Each potential project starts with a Concept Development Phase during which the project idea is explored in detail. Ideas can be developed by the Amsterdam Smart City Foundation or submitted by external entities. Mainly considering feasibility, costs, and CO_2 reduction potential, the Focus Group has the task of approving or rejecting the proposal. If approved, the foundation identifies the most appropriate project partners and invites them to participate, collecting their applications. Once the working group is in place, the Execution Phase begins. In this second phase, roles and responsibilities of the various partners are specified in a Project Initiation Document which has to be signed by each of them. The project management activities have to be carried out by one of the partners. The foundation, instead, works transversally by providing support, monitoring, and general planning of all the project activities (Brinkman and Baron 2012; Bigliani and Gallotti 2009; Stahlavsky 2011; Velthausz 2011a).

"Projects are funded by the several companies and governmental organizations that are involved in [their implementation]" (Brinkman and Meuwissen 2010). The Amsterdam Smart City Foundation is assured of obtaining commitment and resources from a partner by signing an agreement in which the details of the collaboration are specified. The signature of the agreements and the Project Initiation Document by the working group's members allow a project to be started according to the priorities established by the foundation with an overall action plan (Brinkman 2011; Brinkman and Meuwissen 2010; Velthausz 2011a).

The development of projects is an activity that has continued to grow over time. Sixteen projects have been concluded between 2009 and 2011 (Amsterdam Smart City 2011a; Annen 2011; Brinkman 2011) but there are now more than 70 (Amsterdam Smart City 2014g). This growth has occurred in parallel with the increasing number of new public and private organizations interested in actively supporting the development of the Amsterdam's smart city strategy. In 2011, there were about 70 active partners (Annen 2011; van der Woude 2011; Velthausz 2011b; Vermast 2011b), and over the years, the number has increased to more than 160 (Amsterdam Smart City 2014g). These include mainly grid operators and utilities, governmental organizations, housing corporations, universities, financial institutions, telecom and ICT companies, transport and waste management companies, and technology start-ups (Schaffers et al. 2012).

3.4 Phase 4: Monitoring and Evaluation

The monitoring of progress and the evaluation of results are performed periodically, thanks to the collaboration between the Amsterdam Smart City Foundation and the project partners. These activities are carried out using the procedure established during the planning phase and allow to: establish if the actions taken have produced a positive result; review the distance to the final target in terms of CO_2 emissions reduction; and select which projects should be developed at the urban or regional level. All the results achieved through the individual projects in the period 2009–2011 have been published in a single report distributed through the website of the initiative. This report includes the value cases of each project and has also been used to present a comprehensive assessment of the work done in relation to the overall objectives of the strategy (Amsterdam Smart City 2011a, 2014g).

The value case is "an expanded business case" that is used to estimate the potential for saving energy and reducing CO_2 emissions offered by the technological solutions used in a project. They are based on four indicators: "(1) energy saving, per unit, in the pilot: depending on the pilot, a unit could be a household, a company, a school, or something else; (2) total reduction of CO_2 emissions: this express the total CO_2 emissions in tons that were prevented by the pilot; (3) realistic scaling up: […] the amount of CO_2 in tons that will be prevented if the pilot were to be done in the whole of Amsterdam [considering] less than optimistic assumptions; (4) maximum scaling up: same as realistic scaling up, but this time with somewhat more naive assumptions, such as that everyone would participate in any given measure”. Suppositions represent the expectations regarding “how effectively the implemented systems will work” and are usually defined by considering the data acquired during the pilot phase (Amsterdam Smart City 2011a).

Moreover, it is important to note that the Amsterdam’s smart city strategy is managed with a dynamic approach. The various stages are never definitively closed but are subjected to a continuous process of review and adjustment aimed at improving the structure and functioning of the strategy. For example, the fields of action have been changed four years after the beginning of the initiative. They have now increased from four to seven: smart mobility, smart living, smart society, big and open data, smart areas, smart economy, and infrastructures (Amsterdam Smart City 2014g).

3.5 Phase 5: Communication

In the case of Amsterdam, “all gained knowledge and learnings are shared broadly” (Brinkman 2011). Knowledge sharing represents a transversal and continuous activity that is carried out by the Amsterdam Smart City Foundation from the beginning of Phase 3. The aim is not only to inform but also “to get free publicity” and encourage the creation of new alliances (Brinkman 2011).

Conference events are one of the main communication tools used to spread the knowledge associated with the strategy and promote the work done. The Amsterdam Smart City Foundation, indeed, has participated in more than 50 national and international conferences (Amsterdam Smart City 2011a). During these conferences, the features of the Amsterdam’s smart city strategy have been described in-depth, namely: objectives; priorities for action; strategic principles; financial strategy; planning of activities; stakeholders; and results achieved with projects (e.g., Annen 2011; Baron 2010, 2012d; Schuurman 2011; van der Woude 2011; Vermast 2011a, b; Velthausz 2011a).

These data and information are also disseminated with the continual production of articles, news, press releases, and reports (e.g., Amsterdam Smart City 2011a, 2012b, 2014d; Baron 2012a, 2013; Brinkman 2011; Gemeente Amsterdam 2012b, 2013). These informative documents are incorporated mainly into a single web platform dedicated to the smart city strategy (Amsterdam Smart City 2014g). This interactive portal has been developed between 2009 and 2010, and continuously improved, expanded, and updated over the years (Amsterdam Smart City 2012a).

What is more, the following means are also used: a newsletter service (Amsterdam Smart City 2011d); presentations and guided tours for organizations that express an interest in becoming partners of the initiative (Amsterdam Smart City 2011a); meetings with all the partners (Amsterdam Smart City 2013e, 2014f); competitions, meetings and workshops organized to stimulate the active participation of citizens (Amsterdam Smart City 2013b, c, d, 2014a, b, c), as well as international conferences such as the Smart City Event, which is now in its fifth edition (Amsterdam Smart City 2014e); social networks such as Facebook, LinkedIn, and Twitter (Amsterdam Smart City 2011a, 2014g); and finally, a dedicated YouTube channel used to release new videos periodically (Amsterdam Smart City 2010, 2011b, c, 2013a; Brinkman and Baron 2012).

4 Discussion and Conclusions

This exploratory study shows that Amsterdam is a pioneer in the smart city movement, and its success results from an approach closely linked to strategic urban planning principles (Santucci et al. 2011). To shape its smart city strategy, the city has chosen a way based on strategic thinking, collaboration, and inclusive criteria. The course to take has been accurately planned before acting, and the activities to perform have been organized within a strategic framework.

By using strategic urban planning, the municipal administration and the other funding partners have managed the complexity of smart city strategies by effectively combining the importance of new ICT infrastructures and digital services (Dirks and Keeling 2009; Gil-Castineira et al. 2011; Schaffers et al. 2011) with many other non-technological critical factors that are widely discussed in smart city research. For example: leadership and political commitment (Alawadhi et al. 2012; Chourabi et al. 2012; Hill et al. 2011); governance and funding capability (Washburn et al. 2010); coordination, sponsorship, and support across departments (Naphade et al. 2011); collaboration between stakeholders and organizations across multiple sectors (Beck 2011; Paskaleva 2009); innovative business and operating models (Belissent et al. 2010; Webb et al. 2011); long-term vision, performance metrics and commitment from the top (Moss Kanter and Litow 2009); the capability to connect short-term ICT-based projects and initiatives to real local needs (Komninos et al. 2014), and the benefits from "the enormous innovative potential of grass-roots efforts" (Ratti and Townsend 2011), avoiding the risks of an excessively top-down approach (Townsend et al. 2011; Deakin and Al Wear 2011).

Building on the lesson learned from Amsterdam, strategic urban planning seems to be an effective tool when used to govern the progressive transformation of cities in smart environments (Komninos 2014). However, this assumption is supported only by a single case analysis, and the relationship between strategic planning and smart cities is still a largely unknown field (Angelidou 2014). Considering this situation, future comparative research is required, not only to support a broader generalization of the results achieved but also to ensure the progressive construction of an empirically valid theory for explaining how to build smart city strategies in large European cities. However, this need to be done without forgetting that the absence of development methodologies is not an issue limited to large cities. On the contrary, it is extended to any type of urban area, and represents a serious shortcoming that needs to be overcome as soon as possible.

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Living Labs: A New Tool for Co-production?

Giorgia Nesti

Abstract Living Labs are places for real-life test and experimentation where users and experts co-create innovative products and services through an ICT-based collaboration. Founded in the context of private firms, LLs evolved into a policy tool implemented to facilitate service innovation also in the public sector. Furthermore, due to their strong focus on user participation, LLs are now increasingly central in the smart-city strategy of various municipalities such as Barcelona, Helsinki, Tallinn and Birmingham. Citizen creativity, in fact, is an integral part of smart cities and the 'laboratory dimension' perfectly fits with this new approach to urban development. Namely, the transformation of the city into a living lab is aimed at supporting the process of policy innovation at the municipal level through local empowerment and the promotion of partnership among enterprises, public administration and citizens. In this respect, LLs can be viewed as a new form of co-production that is a process through which citizens participate in the design and creation of products or services that are less expensive and better tailored to citizens' needs. Drawing on data related to 59 LLs listed in the database of the European Network of LLs, the paper is aimed at describing the main characteristics of LLs and at examining their strengths and weaknesses as co-production tools.

Keywords Living labs · Co-production · Open innovation · Citizen participation · Smart cities

1 Introduction

The economic crisis that is affecting the European Union (EU) has re-launched the debate on co-production, i.e. the participation of citizens in the provision of public services. This policy tool is considered a practical solution both to constraints on

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public financing and to complex problems, such as environmental pollution, ageing, and unemployment. Through user engagement, in fact, services would be less expensive and better tailored to citizens' needs. Within the debate, a relevant place is assigned to the Living Lab, a real-life test–and-experimentation environment where users and producers co-create innovative products (Christiansen and Bunt 2012; Bason et al. 2013; Eskelinen et al. 2015). Living Labs (LLs) are open innovative ecosystems, where end-users and producers interact through an ICT-based collaboration (Pallot et al. 2010).

Even if the LL approach was originally adopted in the industrial context, it now covers different sectors with different applications. For instance, LLs have gradually become part of the smart-city strategy adopted by several municipalities in the EU as a means to promote citizen participation in the creation of a sustainable urban environment. As a consequence, in recent years, LLs have achieved some popularity among scholars and practitioners, especially in the field of local innovation, and the literature on LL methodology has grown impressively. Nevertheless empirical research of LLs' organisation, domains of interests, strengths and weaknesses is still scarce.

The present paper aims to fill this gap by presenting the results of a qualitative survey on 59 Living Labs operating in the EU and listed on the database of the European Network of Living Labs (ENoLL), a Brussels-based non-profit organisation that gathers LLs from all over the world.

Through the qualitative analysis of the database, the paper will attempt to answer to the following research questions: How are LLs organized and which are their domains of interest?; How do LLs operate?; What is their working methodology?; Can LLs be conceptualized as a new tool for co-production?; and if so, what are their main strengths and weaknesses?

The paper proceeds as follows. Part 2 defines the concept of co-production and identifies its core elements, its advantages and its limitations. Part 3 describes LLs, explains their working methodology and focuses on the role they perform in the smart-city approach. Part 4 illustrates the empirical research and presents data collected through the qualitative analysis. It describes how LLs are managed and their activities. Then it points out some key features emerging from the in-depth analysis of some European cases. Part 5 discusses the LL approach as a tool for co-production and analyses its main strengths and weaknesses.

What emerges from our analysis is that the concept of LL covers a wide range of experiences across the European Union. LLs are run by different types of organisations and operate in various policy areas. Nevertheless they share a peculiar methodology and certain distinctive characteristics that make them a potential innovative form of co-production. This trend, we conclude, calls for further research and further reflections on the transformation of public governance at the local level.

2 Co-production: A Brief Outline

The idea of co-production was originally developed in the US during the 1970s and 1980s as a means to cut public expenses and to improve service efficiency (see, for instance, the seminal work of Ostrom and Baugh 1973). The core idea of co-production, in fact, is that citizens—individually or organised in groups or associations—participate with professionals in the definition and in the delivery of services or goods that prove to be better tailored to their needs.

In current years, the debate about co-production has gained momentum after the emergence of the economic crisis and the diffusion of new programs of fiscal austerity, both at the national and at the local levels. In parallel, other factors influenced the debate (Loeffer 2009). First, the diffusion of innovations in the ICT sector and, namely, of the Web 2.0 that enable users with more active participation in policy-making. Second, the rise of the so-called "assertive citizen" (Griffiths et al. 2009), that is, a citizen who is aware of his or her rights and who claims more quality. Third, the emergence of the New Public Governance movement, aimed at promoting innovation in public administration, a stronger commitment to improve policy outcomes and a pluralist approach to service delivery, through the involvement of external actors (Osborne 2006).

The distinctive characteristic of co-production is, in sum, the active participation of users in service provision through collaboration with professionals and experts. Users are actively engaged in the process to contribute their experience and knowledge to define and create services really targeted on their needs and, therefore, more efficient (Loffler 2009). In the word of Boyle and Harris (2009: 11) users are the "vital ingredient which allow public service professionals to be effective".

Operationally, co-production can be conceived as a relationship of collaboration among the public sector, users (individuals or communities) and professionals activated in the pre-production stage (co-planning and co-designing) and in the production stage (co-management and co-delivery) of the service cycle (Bovaird and Downe 2008). Full co-production entails users and professionals totally sharing the task of planning, designing and delivering the service (Bovaird 2007).

Co-production, indeed, holds a strong normative component since it empowers citizens, it enables civic participation and it boosts social capital. Viewed in this terms, the idea of co-production challenges economic and managerial theories of public administration and calls for a new approach to policy-making, where officials, experts and citizens work jointly and where democracy is strengthened through active participation in policy production (Ryan 2012: 321). However co-production also suffers from some limitations. It is, in fact, costly, because it requires professionals and public managers to develop new professional skills, such as networking and co-ordination capacities. It is risky, because often users are not able to engage themselves in co-production practices over a long time. It is complex, because conflicts frequently arise between professionals and users when they do not share the same point of view about how to manage a service. It is democratically weak, because when responsibilities for the delivery of a service are not clearly assigned, accountability is diluted.

All in all, nevertheless, co-production represents an intriguing opportunity for all those who are interested in promoting subsidiarity and in improving civic engagement, in particular when urban innovation is at stake.

3 Defining Living Labs

Professor William J. Mitchell of the MIT Media Lab and School of Architecture was the first to use the expression “Living Lab” to define a user-centric research method aimed at prototyping, validating and refining, in a real-life context, solutions for challenges related to health, energy and creativity.[1] Living Labs (LLs) come into being as a novel research method to test products. Their original purpose was to give firms immediate feedback on users’ response to innovative artefacts, particularly in the ICT market, where innovations are costly and products often unsuccessful.

From Mitchell’s original definition, others were developed over the following decades. For Ballon et al., for instance, a Living Lab is “an experimentation environment in which technology is given shape in real life contexts and in which (end) users are considered ‘co-producers’” (Ballon et al. 2005: 3). For others “a Living Lab is a system enabling people, users/buyers of services and products, to take active roles as contributors and co-creators in the research, development and innovation process” (CoreLabs 2007: 9). What all these and other definitions share is the idea that LLs are both a physical space where, and a methodology through which, stakeholders, particularly users, participate in the development, testing and evaluation of a product or a service assisted by experts, using an open-driven approach to innovation.

As a research methodology, LLs usually adopt a four-stage procedure (Pierson and Lievens 2005). In the first stage, *contextualisation*, experts evaluate the state-of-the-art of the sector where the experimentation is going to take place. They define the research framework and select the sample of users to be involved. Then experts assess user needs and collect all the related information. In the second stage, *concretisation*, experts describe the everyday behaviour of users and their perceptions of the scope of the experimentation. In the third stage, *implementation,* users are involved in co-designing and in prototyping products and services through various techniques (brainstorming, questionnaires, focus groups, interviews, etc.). Once they have been designed, products or services are tested in real-life settings to enable experts to iteratively improve the prototype. Testing may cover mock-ups, single features or more complete live testing. In the final stage, *feedback*, users are asked to give their opinion about their experience. The aim of this activity is to

[1]See http://livinglabs.mit.edu/.

assess variations in perceptions and attitudes related to the product or service that has been created. Then recommendations for the diffusion of the product or service are issued.

LL methodology has known a certain amount of success in the European Union, where LLs became a sort of “fad” after the launch of the European Network of Living Labs (ENoLL) in November 2006 under the Finnish Presidency. The Prime Minister Matti Vanhanen stated, in fact, that the Network was to be seen as a concrete action to put the Lisbon strategy into practice as a large-scale experimentation platform for the creation of new services, business and technologies.[2] The former European Commission strongly encouraged the adoption of LLs as a means to improve EU competitiveness and growth. In 2009, the Directorate-General for the Information Society and Media stated that the LLs concept was to be linked to the second pillar “strengthening innovation and investment in ICT research” of the i2010 policy strategy. This led to the funding of many research projects under the Strategic Objective “Collaborative Working Environments” of the ICT theme in the Six Framework Programme and further funding was planned under the Co-operation Programme of the Seventh Framework Programme, the ICT Policy Support Programme of the Competitiveness and Innovation Programme (CIP), the Interreg IVc and other initiatives managed by the Directorate General Regional Policy. Between 2010 and 2012, the European Commission financed the Coordinating action FIREBALL (Future Internet Research and Experimentation by Adopting Living Labs towards Smart Cities) that acknowledged the importance of LLs as “generators of solutions” to challenges faced by cities and that emphasized the role of LLs in promoting citizens involvement in the development of smart cities.

Interestingly, therefore, the EU approach to LLs goes beyond the traditional idea of an innovative business model. LLs are here conceived as a strategic opportunity to improve the creation of multi-stakeholders partnerships where citizens are at the centre. According to ENoLL, in fact, LLs are public, private and people partnership (PPPP) for user-driven open innovation. For this reason, LLs are tightly coupled with the smart-city strategy adopted by various municipalities (just like Amsterdam, Barcelona, and Helsinki). The concept of smart city designates an innovative paradigm for city governance that aims to integrate the different visions of urban, economic, environmental, institutional, technological and social change into a holistic view of sustainable development. Smart cities are mainly committed to adopt innovative solutions in order to reduce CO_2 emissions, and this goal is achieved through actions in the field of mobility, energy, environment, economy and housing. But sustainability is also pursued through policies aimed at improving citizens’ quality of life (like health, care, eGovernment, etc.). The smart-city approach strongly relies on citizen participation in the policy cycle and this is pursued through an extensive use of information and communication technologies.

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[2]See *The launch of a European Network of Living Labs—Co-creation of innovation in public, private and civic partnership*, Press release 8.2.2006, accessed at: https://ec.europa.eu/digital-single-market/en/news/launch-european-network-living-labs-co-creation-innovation-public-private-and-civic-partnership

The Web 2.0 paradigm, in fact, puts users at the centre of innovation since users can contribute to the development of technological solutions. By the same token, within smart cities, citizens are encouraged to contribute with their creativity to the proposal of innovative solutions and the "laboratory dimension" perfectly fits with this new model of urban development.

4 Living Labs in the EU: The ENoLL Database

How are LLs organized and managed? How do they work?

The LLs landscape is quite polyhedric. LLs have experienced a stunning popularity in the last 10 years with varied spontaneous experimentation conducted throughout the world. Consequently, in trying to describe them, two problems emerge. The first concerns the selection of the "best practice" to be analysed. The second is how to classify LLs since their organizations and domains of intervention often differ, even if they share certain core characteristics. To overcome these problems, I decided to rely on data available on the ENoLL website, a reference point for the LL community operating at the international and at the EU level. ENoLL was created in 2006 and legally established as an international, non-profit, independent association of Living Labs in 2010. It is based in Brussels and it is composed by a General Assembly, a Chair, and a Council made up of 18 members. Membership to ENoLL is granted to those LLS that prove to meet the twenty criteria[3] suggested to apply. Seven teams of experts are charged for the selection of candidates and the admission to the network.

In March 2016 there were 378 LLs listed on the website: 299 (79 %) of these were from the EU and 79 (21 %) were from other countries. The prevalence of LLs from the EU is due to the fact that the creation of LLs was strongly encouraged by European institutions. Most of the EU labs, in fact, were created after 2006. One hundred and sixty seven LLs are current ENoLL members, i.e. they have the status

[3]The criteria for selection are: (1) evidence of co-created values from research, development and innovation, (2) values/services offered/provided to LL actors, (3) measures to involve users, (4) reality usage contexts, where the LL runs its operations, (5) user-centricity within the entire service process, (6) full product lifecycle support—capability and maturity, (7) LL covers several entities within value-chain(s), (8) quality of user-driven innovation methods and tools, (9) availability of required technology and/ or test-beds, (10) evidence of expertise gained for LL operations, (11) commitment to open processes, (12) IPR principles supporting capability and openness, (13) openness towards new partners and investors, (14) business-citizens-government partnership: strength and maturity, (15) organisation of LL governance, management and operations, (16) business model for LL sustainability, (17) interest and capacity to be active in EU innovation systems, (18) international networking experience, (19) channels (e.g. web) supporting public visibility and interaction, (20) people/positions dedicated to LL management and operations (see http://www.scribd.com/doc/254557130/ENoLL-9th-Wave-of-Membership-Brochure-2015-pdf).

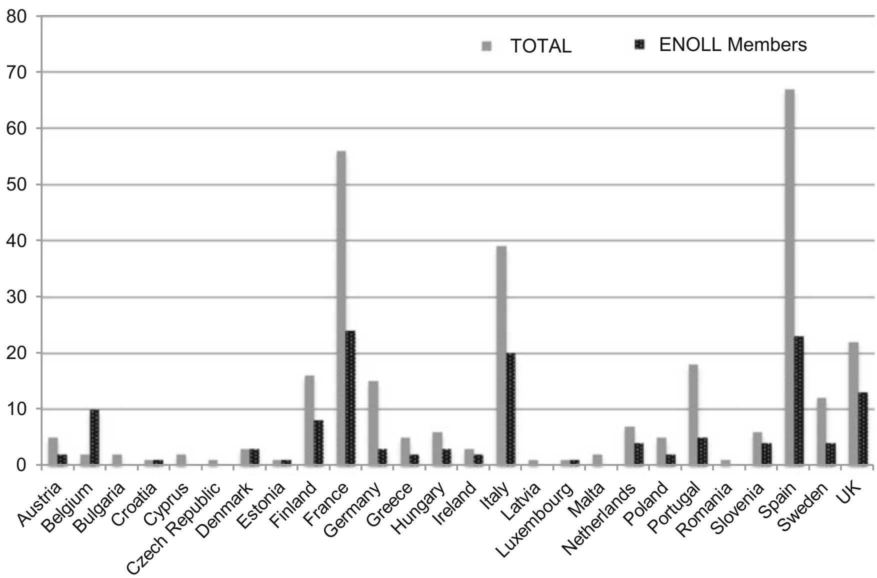


Fig. 1 Living Labs in the European Union

of adherent or effective members,[4] 135 of them are from the EU and 32 are from other countries. Figure 1 shows the number of LLs from the EU listed on the ENoLL website, divided between members and non-members.

Detailed descriptions of each LL are available only for members. A pdf document indicating organisation, scopes, domain of interest, contacts and website is provided for each LL. Nevertheless, since there is no standard format for such documents, the type of information provided can vary significantly.

I decided to restrict my analysis to the 135 members established in the European Union, in order to have more comparable data. I went through their descriptions listed in the ENoLL database and I integrated them with information and documents available on each individual LL's website. This double-step procedure has proved necessary as the ENoLL database is not up to date and some LLs are no longer in operation, even if they are still recognised as members. Moreover, other organizations have been excluded from the analysis because they did not have the basic characteristic of a LL, i.e. the involvement of users in the process of co-design and/or co-production. The final list of LLs has, thus, been reduced to 59 units, distributed among Member States of the European Union as follows (see Fig. 2):

[4]Adherent members are organisations that represent a Living Lab, which was duly selected according to ENoLL criteria but that do not pay any membership fee, except an annual administrative fee and have no voting rights in the General Assembly. Executive members are those who pay the annual fee and therefore have the right to vote in the Assembly.

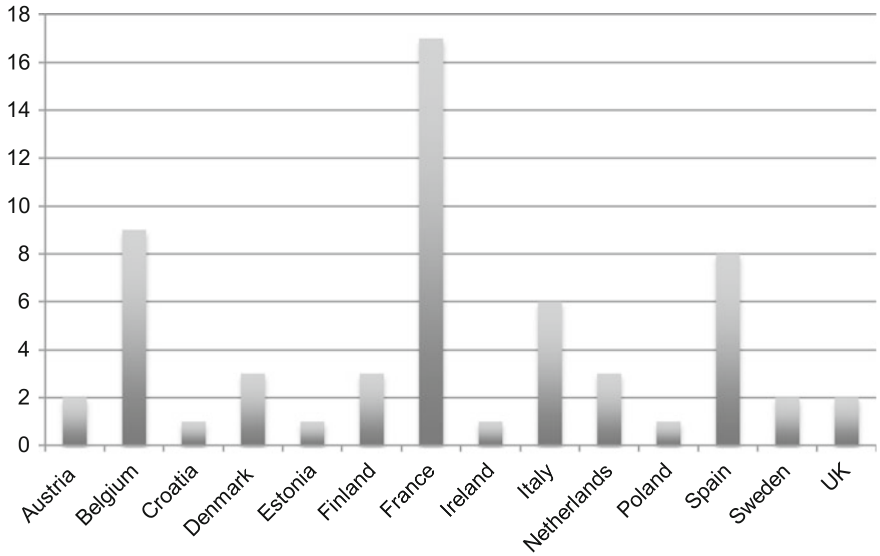


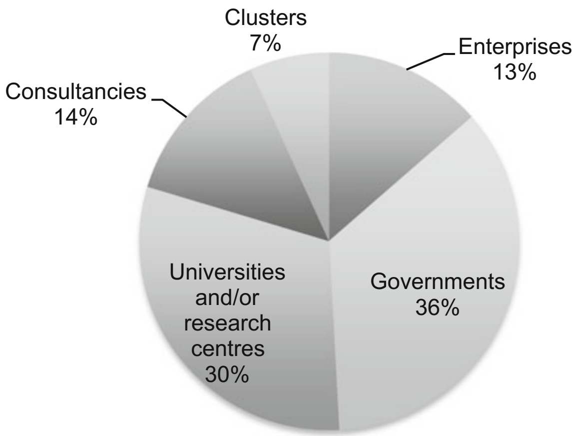
Fig. 2 Distribution of Living Labs among Member States of the European Union

Descriptions have been supplemented by the literature and by some key informant interviews with experts, public officials and LLs' coordinators.

On the basis of the in-depth analysis of the 59 case studies five typologies of organisational structures that manage and fund LLs have been identified (see Fig. 3):

1. enterprises;
2. governments;
3. universities and/or research centres;

Fig. 3 Who manages Living Labs



4. consultancies;
5. clusters.

In the first category, there are eight LLs coordinated by private firms or foundations. The second category is the most numerous with 21 LLs financed by local, regional and/or national governments. 18 LLs are hosted by universities or public research institutions. Eight LLs are managed and financed by a cluster of enterprises, universities, consultancies and local authorities. Four LLs are managed by private consultancies. Thus, most LLs (39 out of 59, 66 %) are of a public nature, but public institutions are also present in the eight clusters. "Pure" private LLs are the minority (12 out of 59).

The prevalently public nature of LLs has already been emphasized in the literature (Feurstein et al. 2008; Bergvall-Kåreborn and Ståhlbröst 2009; Alcotra 2011; Almirall et al. 2012). LLs are often setup by public administrations or research institutions because of the experimental nature of their activities. Particularly in the European Union, where innovation is often costly and risky, enterprises—in particular small and medium—are encouraged to participate in the innovation process transferring the costs for R&D to public institutions and enabling them to test product or services before they have been launched in the market. Moreover, universities are important players simply because they already have structures, technologies and trained staff to implement LLs.

Ten thematic domains of interest have also been identified for these 59 LLs. The areas cover:

1. Information and communications technologies (apps, telecommunications and mobile services, new media and internet services) of which there are 21 LLs;
2. eHealth and eCare (innovative services for the elderly and the disadvantaged, Internet-of-Things for the elderly) of which there are 30 LLs;
3. Energy, smart grid and sustainable buildings (solar panel, etc.) of which there are eight LLs;
4. Transport, logistics and automotive (eMobility) with six LLs;
5. eGovernment (mainly web-portals for public communications) with five LLs;
6. Creative industries and culture (online platforms) with nine LLs;
7. Tourism (touristic guides for mobile phones, online platforms) with five LLs;
8. Food and agriculture (an experimental restaurant, a service laboratory) with two LLs;
9. Planning, housing and urban regeneration with five LLs;
10. Services for business and commerce (assistance systems for production, iBeacons, online catalogues, etc.) with four LLs.

The resulting number of LLs is higher than 59 because some of them operate across multiple domains.

Figure 4 illustrates the distribution of LLs according to their typology and their domain of interest.

LLs run by private companies are concentrated in the health and care sector (four LLs). Consultancies cover mainly the health-and-care sector (two LLs) and ICTs

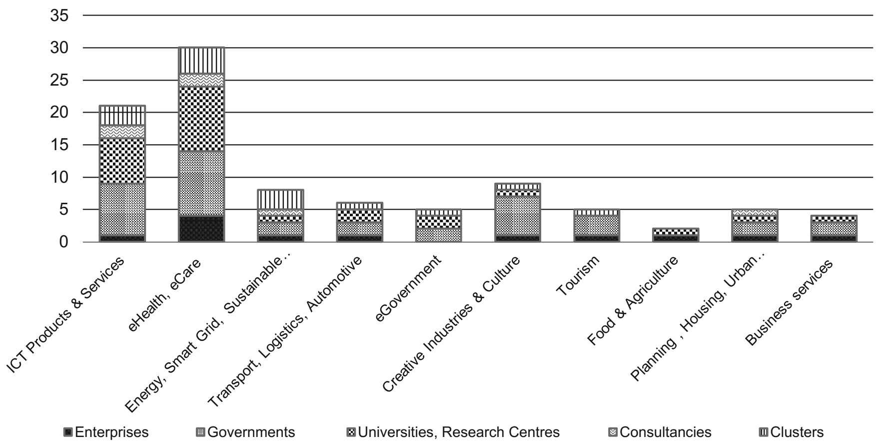


Fig. 4 Domains of interest of Living Labs

(two LLs). LLs financed by governments deal with eHealth and eCare (ten LLs), ICTs (eight LLs), culture and creative industries (six LLs), tourism (three LLs) and with transports, eGovernment, planning, and business services (two LLs each). Universities run LLs operating in the eHealth and eCare sector (ten LLs) and in ICTs (seven LLs). Clusters manage LLs for health and care (four LLs), ICTs (three LLs), and energy (three LLs).

The majority of LLs offers services, i.e., advice and service engineering (33 out of 59). Ten LLs plan and manufacture products while 16 LLs produce both products and services. A particular relevant feature of LLs is that, regardless of the thematic domain, they concern mainly the application of ICTs and the Internet-of-Things (IoT) to service delivery. This obviously explains why there are so many LLs operating in the ICTs (21 LLs): ICTs are the innovative business sector *par excellence* and there is a wide community of users/developers committed to help industries to improve their products. But the adoption of new technologies characterizes also other domains such as health and care (see below), energy, mobility, tourism, business, and commerce, that is to say, all those policy sectors where the application of ICT and IoT has been already successfully tested.

Interestingly, 13 out of 59 LLs explicitly identify smart cities among their targets of action. LLs in Graz, Brussels, Ghent, Aarhus, Albertslund, Tartu, Helsinki, Paris, Trento, Krakow, Barcelona, Manchester, and Birmingham offer a testing environment for services (e.g., urban planning, renewable energies solutions, communication and branding, and e-government) and products (apps, smart grids, and lighting solutions). The smart-city approach, in fact, puts citizens at the center of urban innovation, and LLs are places where municipalities can involve citizens and industries in developing new solutions to improve the quality of city life. Through ICTs and Web 2.0, people can participate with local governments and firms in planning, designing, and developing products and services that are better tailored to their needs, that can contribute to render urban development more sustainable, and that are less expensive.

Another important aspect is that LLs are concentrated in eHealth and eCare area (30 LLs). A possible explanation is that here collaboration between professional and users has a long-standing tradition, and LLs represent a sort of evolution from the original model, which was almost exclusively based on human interaction among people, to a new one. This new type of collaboration entails user participation in the development and application of the IoT to service delivery, in particular in the creation and implementation of digital devices to assist the elderly.

Concerning methodology, LLs are always portrayed on their websites as highly innovative systems to develop, test, and prototype products or services and their user-centered perspective is emphasized as *the* added value of their approach. Yet, the methodology adopted by each LL is seldom explicit. Most of the LLs state that they promote open innovation, but they do not clarify how this takes place. A few cases describe their methodology in terms of co-production. The process entails ideation and co-design, engineering, development and implementation, experimentation, and evaluation. Different qualitative and quantitative techniques are adopted in each stage of the process to create the service: brainstorming, interviews, questionnaires, prototyping, mock-ups, etc. Users are involved in the process offline, through ethnographic techniques, or online through platforms and/or social networks where they register themselves on a voluntary basis.

5 Living Labs and Co-production: Promises and Pitfalls

The data presented above confirms the multi-faceted nature of the LL approach. Created in the context of private firms, as a new way to test products, LLs evolved into a policy tool implemented to facilitate service innovation also in the public sector.

So can we conceive LLs as a new form of co-production? We can answer affirmatively to our question. According to Tonurist et al. (2015), in fact, the creation of LLs runs in parallel to the diffusion of the paradigm of co-production. Namely, LLs can be conceived as small-scale projects of co-production based on an extensive use of ICTs and on models of open innovation. They are lean organizations, often characterized as start-ups, with few workers and an autonomous budget, specifically aimed at rapid planning and prototyping. For these reasons, LLs can also be considered as quick experimental forms of innovation (Tonurist et al. 2015).

Main strengths of the LL approach are all those related to co-production practices, such as: their relative low cost compared to traditional co-production services due to their strong focalized nature; the involvement and empowerment of users; and the strong orientation towards outcome efficiency.

However, LLs show also many weaknesses. As data suggests, the first striking feature of LLs is that they have a high mortality rate. There are 378 LLs in the ENoLL database, but de facto not all the LLs are currently in operation. According to one of the experts I interviewed, this problem is caused by three factors. First, LLs are now probably in the down part of the "Gartner's Hype cycle" that characterizes the development of ICTs. Particularly in the business sector, after their initial popularity (the "Technology Trigger" stage) and the diffusion of successful stories (the "Peak of inflated expectations" stage), interest in LLs has physiologically declined (the "Through of Disillusionment" stage). In the following years, we will probably witness a re-launch and consolidation of the LL experience (the "Slope of Enlightenment" and the "Plateau of Productivity" stages), but so far, LLs have lost part of their initial attractiveness. The second problem is that LLs do not produce "disruptive innovation", i.e., they do not produce outputs that alter significantly the market, so firms do not perceive LLs as a real tool to improve their products and are not encouraged to invest in this type of innovation. Third, there are fewer incentives to create a LL now than 10 years ago, due to lack of public funding and in particular of EU grants, and private actors do not want to bear the costs for staffing, selection of users, selection of real settings, etc. I add other possible explanations for LLs' mortality. First, LLs are focused on the creation and application of ICTs, a sector where innovations rapidly become obsolete, and this also applies to the Labs where they are created. Second, LLs with a public nature suffer from a high mortality rate because they are often "sponsored" by politicians (i.e., ministries, mayors, etc.), or chief-executive officials who create them to carry out specific projects. Thus, when they have fulfilled their tasks, and/or they miss the political or bureaucratic support, they close (Tonurist et al. 2015). Furthermore, long-term survival would require changes in the LLs' structure, staff and budget that would be too expensive for a public organization.

Another critical point in the LL approach is the engagement and long-lasting commitment of users. Even if user empowerment is viewed as the key benefit of co-production, experience reveal that citizens often are not too concerned with participation. Consequently, voluntary participation rarely produces a sufficient number of users to be included in the project or else it produces a community of "geeks" who are not really representative of the whole population (Bergvall-Kåreborn and Ståhlbröst 2009; Juujrvi and Pesso 2013). Second, co-production in LLs can be a relatively long process so people often get tired of it and abandon the project to turn to other activities. Third, if the LL does not produce a service or a product that is quickly implemented, the process leads to distrust and insecurity and eventually to disengagement (Bergvall-Kåreborn and Ståhlbröst 2009). This latest finding is also consistent with recent research on co-production, which concludes that participation in co-production processes is higher when individuals perceive they are "making the difference" (Bovaird et al. 2013).

A final problem, in particular for LLs managed by the public sector, relates to the prevalent culture diffused in the bureaucracy. The co-production approach adopted by LLs requires public administration to rethink and re-design traditional models of service delivery and to change its mind-set towards more openness and transparency, a transformation that is difficult to engender. Moreover, the smart-city approach runs the risk of “technology determinism”. For some mayors or chief officers of smart cities, in fact, the temptation could be to chase the latest infrastructure or ICT without first defining for what purposes it should serve. Thus LLs should be part of smart-city strategies that have to be steered by local administrators and that must integrate both technical and political goals.

6 Conclusions

The paper was aimed at describing the main characteristics of the LL approach and at examining its strengths and weaknesses as a co-production tool.

My analysis reveals that LLs existing on EU territory were established after 2006 with the creation of ENoLL. In general term, these LLs are small-scale organizations, with few employees and an autonomous budget. They are managed by public institutions, namely local governments and universities that run them both singularly or within a wider cluster of public and private actors. They work primarily in the area of eHealth, eCare, and ICTs offering services and, to a lesser extent, products based on the application of the IoT. Their methodology is based on the involvement of users in the creation, development, and production of a “prototype” of a product or a service. For this reason, they can be conceived as form of co-production. Moreover, due to their experimental nature, LLs activities are increasingly utilized in developing urban innovation policies and, namely, in the context of the smart-city approach, to improve the quality of the urban environment and of citizens’ lives.

The principal advantage of using LLs for testing new services or products is that they focus on peoples’ needs and that they have a strong commitment to integrate users’ knowledge within the policy-process. A second advantage is that they represent a relatively low-cost solution for the experimentation on innovative projects.

The main limitations of the LL approach concern the difficulty to engage citizens in experimentations for a relatively long time, and their high mortality due to lack of funding, of political support, and of long-term planning.

A relatively unexplored area of research is the impact LLs could have on public administration. Some preliminary experiences in the implementation of the LLs methodology within smart cities suggest that policy-makers should change their behavior and the organizational culture in order to grasp all the potential benefits of LLs. But the extent to which this should take place and the costs associated with such a transformation call for further empirical and theoretical research.

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Participatory Practices in London Urban Strategies: The Example of Bankside in the Borough of Southwark

Francesca Leccis

Abstract In the United Kingdom people have realized that the traditional centralized government, characterized by a top-down approach, does not improve people lives. On the contrary, it generates bureaucracy and makes people feel constrained and deceived rather than included in the decision-making process and among the makers of their future, as it should be in a healthy democracy. For this reason, great power was devolved from the central government to local authorities, local communities, neighborhoods, and individuals through the approval of the Localism Act of 2011. This paper briefly introduces the act and analyzes Community's engagement in the planning process and in the regeneration program in the district of Bankside, in the London Borough of Southwark. It is articulated via the following parts: the introduction, the description of the Localism Act, the presentation of the process of definition of the Neighbourhood Plan, the illustration of the Neighbourhood Plan of Bankside, the exposition of the experiences with the Bankside program, the regeneration program of Bankside, which includes the description of the various organizations that operate in the area, and the illustration of the various activities carried out in the area to involve the local community, the evaluation of community engagement with a particular focus on the case study, and the conclusion. The paper shows the positive impact of community involvement in planning processes and provides recommendations for policy makers based on the successful practices in the neighborhood of Bankside. In addition, recommendations for further research are provided at the end.

Keywords Participatory practices · Community participation · Engagement · Neighborhood planning · Social model

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1 Introduction

The then recently elected President of the USA, Barak Obama, on his first day in office issued a memorandum in which he called for community engagement, collaboration, and public monitoring (Sifry 2010), thus recognizing the potential of knowledge in the hands of the population. Moreover, he identified in the citizens "the eyes and ears" of the system of surveillance of public expenditure ensuring strong transparency so that public money is not wasted (Hendler 2009). Nevertheless, the United States is not the only country that has revised its governmental approach in order to become more inclusive. Indeed, the shift of responsibilities from the central government to local communities and citizen involvement is manifest in program and policy documents (Elwood 2004) that have been launched worldwide (Irvin and Stansbury 2004) since the 1950s (Day 1997). According to this approach, authorities have the role to enable, rather than to control, and the leadership of urban regeneration programs is entrusted to local communities (Taylor 2000). Thanks to this shift, it is possible to benefit from community knowledge of the area, both in terms of problems and existing community networks (Wilkinson and Applebee 1999). Local realities become the heart of development interventions (Hickey and Mohan 2005) and people's knowledge, the knowledge retained by the local community—nowhere to be found in written documents—is accessed (Chambers 1983). Community engagement is vital to ensure sustainable programs, but communities need government support to effectively operate, especially in deprived areas where volunteering is limited (Duncan and Thomas 2000). Enabling poor communities to make their voices heard is fundamental since this often is the only possibility they have to participate in shaping their area (Taylor 2000). A severe weakness of community participation is community representation. Indeed, Botes and van Rensburg (2000) explained that it frequently occurs that only rich and well-educated people get involved, whereas Gaigher et al. (1995) illustrate how poor groups are sometimes considered to be an obstacle to community participation and face difficulties in getting involved (Campbell 2011). In order to promote the participation of disadvantaged groups, it might be beneficial to involve residents before the delivery of the programs so that the capacity to develop from the bottom is realized in the long run (Batty et al. 2010). On the contrary, areas of intervention are usually identified by the central government on the basis of national priorities determined through indexes like the index of deprivation (ODS 2006) so that residents passively receive the initiative rather than actively promote it (Duncan and Thomas 2000). This is what happened, for example, in Southwark when it was selected as a "neighborhood planning front runner authority" to test the Localism Act. The Localism Act, passed in November 2011, shifts more decision-making powers from central government into the hands of individuals, communities, and councils that, thereby, gain new rights and more power (DCLG 2011). Before the approval of the law, when the Localism bill was first drafted, in November 2010, Southwark had the chance to work with community groups to test and apply some principles of neighborhood planning before the proposal became law. The Council started collaborating with groups in Bankside and Bermondsey to prepare neighborhood plans for their areas (Southwark Council 2014). Both the Localism Act and the Neighborhood Plan of Bankside will be described in the paper.

Nevertheless, residents of Bankside were not new to this kind of involvement. Indeed, they had already experienced forms of participation when the regeneration program of the area (the Bankside program) was launched with the opening of the Tate Modern Gallery in the year 2000. The promoters of the initiative engaged with the local community since the very beginning of the process, continuing the engagement for all the duration of the project, and it continues today. They organize steering groups, consultations, and activities, and they encouraged people to use the Tate. The development of the Bankside Program, the establishment of various community groups, and the organization of various activities will be illustrated in the following sections.

2 The Localism Act

The aim of the Localism Act is to make the planning system more democratic and more effective, and to ensure that decisions about housing are taken locally. It gives new freedoms and flexibilities to local governments and new rights and powers to communities and individuals. It covers a wide range of issues related to local public services, with a specific focus on the general power of competence, community rights, neighborhood planning, and housing (DCLG 2011). The essential guide published by the Department for Communities and Local Government explains how decentralization became real thanks to six measures (see Fig. 1) which each government must take. These lead to the change from a *Big Government* to a *Big Society,* where citizens collaborate in diverse and personal ways to achieve common goals. In particular, the first two measures are essential in the process since decentralization cannot happen without removing the unnecessary bureaucracy and regulation that restrict local action and do so without creating the right conditions to get people involved. The following two actions provide the necessary support to progress toward decentralization, i.e., fund management and service alternatives creation, which ends service monopolies and ensures services of higher quality. The last two measures enable citizens to take complete control of the process thanks to the complete transparency concerning public-money expenditure, the empowerment of citizens' participation, and the creation of more opportunities to hear local voices through the ballot box (DCLG 2010).

Fig. 1 The six actions of decentralization (DCLG 2010)

3 The Neighborhood Plan

Among the innovations brought by the Localism Act is the introduction of neighborhood planning, which establishes how communities can get more involved in planning for their areas. The Neighbourhood Plan focuses on creating plans and policies to guide new development and in some cases granting planning permission for certain types of development. The Neighbourhood Plan needs to comply with the National Planning Policy Framework and the Local Development Plan and needs to demonstrate it properly considered the views of the local community, landowners, and developers (Bevan 2011). Once it has been subjected to an independent examination and any necessary modifications made to ensure they plan meets all legal requirements, it is subject to a public referendum and, if it receives 50 % of the votes cast in a referendum, it is approved (Parliament 2011). When it is in force, it has real legal force, since it becomes part of the statutory development plan for the area, which means that planning decisions have to be made on the basis that the local community gains more influence and control over the development of its area. In addition, since the process is led by authorized local community organizations, like neighborhood forums, it is easier to properly engage with the wider local community from the very beginning of the process so that real needs and expectations of the area guide and shape the development (Chetwyn 2013).

The Neighborhood Plan process can be summarized in six stages illustrated in Table 1. It can be noticed that both the local community organization and the local authority have important tasks to accomplish and that consultation and community involvement have a preeminent role in the process.

Table 1 Stages of the neighborhood plan process (Adapted from London Borough of Richmond upon Thames 2012)

Stages	Local community organization	Local authority
Getting started	Community desire to shape growth and development of their place Definition of team, vision, objectives, and program for developing the plan	Engage with community groups to identify needs and desires Identify whether formal neighborhood plan is the most appropriate tool
Designations	Apply to the council for a neighborhood area to be designated Apply to the council for a neighborhood forum to be designated	Publicize proposed area and designate a neighborhood area Publicize proposed forum and make decision on designation
Developing the plan	Work up details with the community Gather relevant information, strengths, and weaknesses, formalize vision and objectives, develop policies and implementation plan Check for conformity with strategic policies in local development plan Extensively engage with community and consult consultees as appropriate	Provide advice and assistance such as on conformity and strategic policies Set out any evidence requirements Advise when/which consultees to be consulted Advise on need for strategic environmental assessment and/or sustainability appraisal
Submission and examination	Submission to the council Opportunity for consultees to provide written representations Check of conformity with local and national policy, compatibility with European legislation and contribution to sustainable development	Fund examination Publicize the plan Appoint examiner with consent of community Send submission and written representations to examiner Check of the examiner's report, proposal is in compliance with local and national policy, compatible with European legislation and contributes to sustainable development
Referendum	Proceed to community referendum seeking adoption	Fund and undertake referendum (simple majority vote is required)
Making of the plan	Proceed to making of plan of order by the council	If majority vote is obtained, make a plan or order Publicize/notify about decision

4 The Neighbourhood Plan of Bankside

In order to test the process of neighborhood planning before approval, the government encouraged collaboration between local authorities and communities to work on pilot plans. The definition of the Bankside Neighborhood Plan has been chosen as a pilot project because of the mixed-use nature of the neighborhood. Indeed, Bankside is composed of various entities that give it its unique identity. Figure 2 shows the different groups and influences in the area and the connections among them. In this way, various stakeholders from different sectors were involved

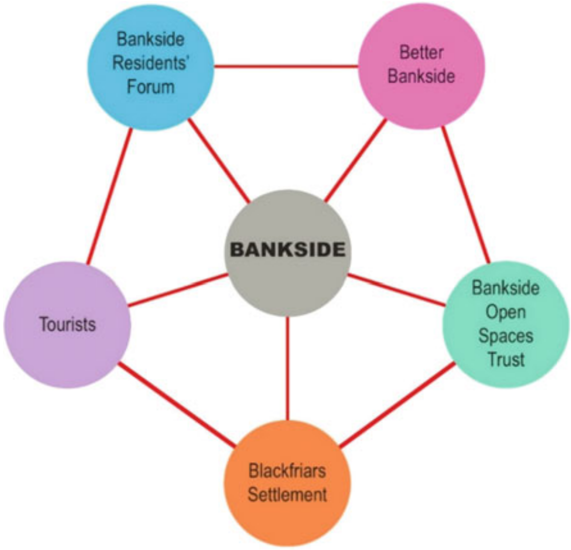

Fig. 2 Groups and influences in Bankside (Compiled by the author, source K1)

in the elaboration of the plan (We Are Bankside 2015). The Bankside Neighborhood Area and Business Area were formally designated on 14 May 2013. Subsequently the Neighborhood Forum was approved on 14 June 2013. It included residents, business and, community-interest groups of the local area (Southwark Council 2014). It has to be underlined that the neighborhood forum relied upon some existing relations that facilitated the launch of the project, such us the collaborative relation between the Residents' Forum and Better Bankside. By using the existing layers and structures of the community, it has been easier to engage a diverse community and numerous businesses including the smaller ones (Planning Aid England 2015). The Neighborhood Forum proposed a plan for future development based on the three principles of sensibility, beneficence, and sustainability, in compliance with local and national policies. Indeed, they wondered if the plan could add value to the location and checked that it would not create a detrimental impact on wider land uses. Moreover, they established it had to be beneficial both for the local economy and for the well-being of people who live and work in the area. In addition, they wanted that it did not compromise future urban growth. In order to identify the emerging priorities for both residents and businesses, a series of open meetings and workshops around themes relevant to the neighborhood plan have been held. At the moment of this writing, the Forum is actively working on the plan on behalf of the wider community (We are Bankside 2015). The Neighborhood Forum is part of a wider organization, called *We Are Bankside*, which also includes the Constituency, composed by the people who live and work in Bankside and will vote in the referendum for the approval of the plan, and the Secretariat, which oversees the progress on actions coming out of the forum, and ensures necessary information is fed back into it (Planning Aid England 2015).

Each group that operates in Bankside plays a different role in the area, and the collaboration and interaction among them ensure that the various community needs are taken into consideration and met, if possible. Thus, the Bankside Residents' Forum represents residents' interests, the organization Better Bankside stands for the businesses of the area, Bankside Open Space Trust looks after green areas, and Blackfriars Settlement takes care of disadvantaged people. In addition, a high number of tourists continuously visit the area. They obviously are not an organized group, but they have a big impact on the area anyway since they contribute to both its economic wealth and liveliness. Hereafter, the four organized groups will be elaborated in detail.

The Bankside Residents' Forum was founded in 1995 by residents who were worried about unrestricted development and various planning issues. Its main task is to inform local residents about the regeneration schemes underway, flanked by the effort to empower their participation in the planning process (BRF 2015). All the members receive a free newsletter, which describes the main ongoing issues, and are invited to quarterly Open Forum meetings where they meet Southwark's MP, councilors, officials, local interest groups, and developers with whom they collaborate to define the best possible place to live (London SE 2015). In the early days, it received no financial support from the Council, but very soon it started getting public funding to employ a part-time coordinator. However, there is no coordinator at that moment since funds became no longer available (K1 2015). According to K1, though, funds could be easily take out of Section 106/CIL[1] of the various developments that are worth billions of pounds. The point is that the Council is trying to discourage the Forum in order to avoid objections.

Better Bankside is a Business Improvement District (BID), inspired by the American model, formally established in 2005 after 4 years of piloting projects (The Means 2015). It is an independent, business-owned- and-led, non-profit company limited by guarantee and run by and for the members. The company has no share capital, and any surpluses generated are reinvested into the company's services. Its aim is to improve the area for commercial activity according to membership needs. For this reason, a satisfaction survey is carried out every year and local businesses are directly involved in the governance of the company through eight theme groups who meet periodically to agree on the elements of the program and through the board, which meets every 6 weeks to review its progress (Better Bankside 2015).

Bankside Open Spaces Trust (BOST) is a charity founded in the year 2000 (BOST 2015a) inspired by the idea of three residents 3 years earlier (BBC 2002). It is run with the help of local people, and it relies on the support of the Council of Southwark, businesses, and various partners (BOST 2015b). Its main task is to encourage collaboration among people to improve local parks and green spaces in

[1]Section 106 and CIL (Community Infrastructure Levy) regulate planning obligations applied to new developments. While the money raised through Section 106 is used to directly mitigate the impact of a proposal, for example to provide affordable housing, money from CIL does not have to be spent on the site from which it is collected.

Bankside being sure they meet local needs (Kimpton et al. 2012). It is with this aim that it manages the community-garden resource center, runs consultations, brings together steering groups, holds events and gardening sessions, looks after gardens, works in partnerships, awards small grants for gardening projects, comments on plans and strategies, enables volunteers, and provides resources to support balcony gardeners (Charity Commission 2015). They currently manage 13 gardens and open spaces (BOST 2015c), and feedback is positive. People are happy about the various initiatives as it is shown by the positive messages they write on the official Facebook page and website.

Blackfriars Settlement is a charity based in Southwark for over 125 years, which creates and provides community services and support. It receives a small amount of co-funding from the Council, and it has a number of contracts for various projects such as youth work and English as a second language. It also benefits from expert advice like the support of the British program *Digital Champion Training* (K3 2015). It works with people helping them to reach their educational, social, and economic potentials, to achieve their aspirations, and to improve their well-being. It coordinates the contributions of local volunteers and community partners to teach individuals new skills, help them to build their confidence, and achieve social inclusion (Blackfriars Settlement 2015).

5 The Bankside Program

The Bankside program was developed between the 20th and the 21st centuries in the ward of Cathedrals in the London Borough of Southwark with the aim to regenerate the whole area by combining the opening of an art museum, the Tate Modern Gallery, with a series of activities addressed to the local community. The museum plays a preeminent role in the project, but it is not the only component, since a series of activities and strategically organized interventions support it by trying to meet the needs of local communities, businesses, and tourists (Hyslop 2012). The Tate Modern project strongly believed in community participation and pioneered the so-called *Social Model* to effectively engage the local community since the very beginning of its delivery. The model, illustrated below, works thanks to various organizations (Bankside Residents' Forum, Better Bankside, Bankside Open Spaces Trust, and Blackfriars Settlement) that collaborate to provide planning advice and support. In order to better understand how the model works, the various organizations working in the area have been studied, the different activities arranged to involve the local community have been analyzed, and three key-informants have been interviewed. The first one (K1) covered the riverside frontage from Tower Bridge to Blackfriars Road over the last 25 years and was the coordinator of the Bankside Resident Forum from 2009 to 2011. The second one (K2) is the Curator of Regeneration and Community Partnerships at the Tate. The third one is the director of the charity Blackfriars Settlement.

5.1 The Social Model

The Social Model is an innovative method of delivering community partnerships by museums, no longer based on educational and outreach programs but through meaningful engagement with audiences and community partnerships (K2 2015). The strategy document is articulated through four objectives: community involvement and partnerships in the business and activities of the museum; social responsibility for the impacts of this international attraction on the local area; relationships with business, cultural, tourism, and residents' partners; and creation of connections among communities and audiences at the local, national and international levels. In order to achieve these, it identifies seven key points:

- community dialogue encouragement
- democratization of museum work
- creation of partnerships with communities
- creation of partnerships with cultural organizations
- creativity and artists centrality in community projects
- personalized and active programs

Examples of initiatives planned to realize these key points are: the *Tate Modern Community Garden*, the *Tate Modern Community Film Club*, *Community Private Views, Tate Modern and You*, *Collaborative Commissions*, *South Bank and Bankside Cultural Quarter*, *Bankside Urban Forest*, *Better Bankside,* and *Merge*. They are described later in this paper.

The Tate Modern Community Garden is composed of a group of local people who live within walking distance of the gallery and can practice their gardening in an area of the site where the Tate Modern Gallery is located and which has been set aside specifically for a community-garden use (BOST 2015d). Its creation involved local residents through a series of steering groups, events, and activities like marking maps with places of significance, linking plants in the garden with artworks in the Tate collection, and identifying the meaning of the garden in people's lives (Tate 2015a). Residents had been consulted in 2001 by the creative organization *Magic Me* and their ideas about the project influenced its design, which was commissioned to the garden designer Lucy Williams (Tate 2015b). The garden organizes a range of different events throughout the year, from planting days, volunteering opportunities, regular parents, and children workshops to after-school events. The program *Friends of the Garden* is free for local residents to join and the steering group composed of local residents meet regularly to discuss the garden's progress (Tate 2015c).

The idea of a community film club was suggested by a resident during a meeting of the Bankside Resident Forum. Originally, only films that displayed South London were screened, whereas nowadays every movie evocative of London is included in the playlist (London SE1 2015). The free membership is only for residents of Southwark and Lambeth and entitles residents to have free access to all the club screenings and watch films in comfortable cinema surroundings, receive regular film club mailings and program notes, enjoy free refreshments served before the film screening, and discuss films over a drink (Tate 2015d).

K2 The community selects the film that we screen and they also write the program and they introduce the film and we usually screen 6 films per year.

The aim is to strengthen community cohesion and engage a wide range of community members, which now include more than 1000 people who are non-traditional gallery goers (Hyslop et al. 2015).

Private viewings of the Tate Modern Gallery are another opportunity for local people to meet each other. They are open only to residents of Bankside and Lambeth, who can enjoy free guided tours of the museum after hours and can see the special temporary exhibitions twice a year (Tate 2015e). The private viewings also include complimentary refreshments and sometimes the outcomes of special projects, developed in relation to the special exhibition, are presented on this occasion (Hyslop et al. 2015). For example, in conjunction with the temporary exhibition *Henri Matisse: The Cut-Outs*, held in 2014, the project *Cutting into Colour* was conducted. For this initiative, people of the parish of St Mary's Newington in Kennington designed and made a chasuble for their church guided by the artist Sarah Sparkes and the result was showcased during the evening private viewings (Tate 2015f).

Tate Modern and You is a community newsletter regularly produced in partnership with a neighborhood or section of the local community and in collaboration with artists and local organizations (Tate 2015g). The project is an alternative way to explore the neighborhood and to strengthen links with different communities across the ward. It often acts as a forum for local discussion among people living near the gallery (Hyslop et al. 2015).

Collaborative Commission invites artists to carry out a period of research and work with a community group or neighborhood within the framework of the Tate Modern projects (Hyslop et al. 2015). An example of these is *Skirt of the Black Mouth*, which encouraged visitors to interact, converse, and reflect to imagine what the construction site of the Tate Modern was and how it could be used in the future (Tate 2012a). Another example is *Walkways*, which aimed at transforming everyday actions into conscious performances, which are personal, poetic, and political and will resonate with most people's experience of urban life (Tate 2012b).

South Bank and Bankside Cultural Quarter was established in 2005. It is a federation of 22 publicly funded cultural organizations in the area, business improvement districts, universities, and the two local authorities. They work together in education and public realm initiatives and had a special role during the Olympics (Hyslop et al. 2015).

Bankside Urban Forest is a long-term partnership project launched in 2007 to improve the quality of the public realm, landscaping and public spaces in the Bankside area (Southwark Council 2015). In addition to the predominant ecological aspect, there are social and economic objectives. The program encourages public-private partnerships and stimulates the participation of local residents, businesses, developers, and landowners through various small- and large-scale projects (Better Bankside 2012).

Merge is an annual arts, music, and performance festival to promote events and happenings that celebrate the rich heritage and contemporary culture of Bankside. It is supported by Better Bankside and Regeneration and Community Partnerships at Tate (Tate 2013). It attracts artists from all over the world called to work in unusual contexts and offers numerous free exhibitions, which reach the wide audience. Artists, performers, art organizations, and collectives have the opportunity to collaborate in experimental partnerships, and emergent talents have the chance to exhibit alongside high-profile international artists without commercial constraints. Local communities, workers, and visitors are both participants and audiences; they take part in discussions and debates about contemporary art and culture and are encouraged to take ownership of projects (Merge 2015).

6 Measuring Community Engagement

The Scottish Community Development Centre examined the experience of more than 500 community and agencies representatives and developed ten standards, and their relative indicators, to ensure a top-quality effective engagement process (SCDC 2005). They are reported in Table 2.

The framework defined by the SCDC can be applied to evaluate the case study of Bankside. Concerning the involvement standard, many activities have been organized either by the Council or by the local population, so that many people have been involved. Large support has been ensured through the supply of needed equipment in a suitable center located in a convenient and well/connected area of the neighborhood. Citizens have been involved since the very beginning of the project, but not in the strategic phase, when the government decided to locate the museum at the site of the abandoned power station. The methods used encompass all the traditional ones of meetings and a number of new ones described in the previous section. The open forum meetings are a good example of dialogue between the community and Southwark's MP, councilors, officials, local interest groups, and developers. On the whole, all the indicators of the standards of "working together," "sharing information," and "working with others" are met, but sometimes developers omit thorny details when they present the projects. It is in these situations that the critical sensibility of the community conducts its hardest task, to identify possible scenarios not depicted and ask for explanations and reassurances. The improvement standard is basically entrusted to volunteer organizations. Feedback was provided during the meetings and taken into account in subsequent proposals, but additional observations were usually made during the following assemblies. Practices and lessons learned are reported in many publications, but evaluation of the engagement process cannot be found in any of them.

Table 2 Indicators to measure effectiveness of community engagement (Author's elaboration from SCDC 2005)

Standard	Indicators
Involvement	• Representation of all the interested groups • Promotion of the involvement of people who experience difficulties to participate • Involvement of all the people affected even though not organized in groups • People involved are prepared, show willingness, and commitment to participate, dialogue continuously with those they represent, and have the legitimacy and authority to take decisions and actions
Support	• Absence of practical barriers (e.g., access, transportation, assistance, communication aids, meeting time) • Absence of financial barriers (e.g., out of pocket expenses, loss of earnings) • Access to needed equipment (e.g., computers, telephones) • Availability of impartial and specialist professional support
Planning	• Involvement of participants since the early stages • Participants agree upon the time schedule, the purpose of involvement, and their respective roles and responsibilities • Identification of resources, definition of measurable and realistic results, assessment of constraints and opportunities • Review of plans following the evaluation of the performance
Methods	• Methods used are acceptable to the participants and appropriate for the purpose, needs, and circumstances of involvement • Methods are explained and understood by all the participants • Methods are adapted according to feedbacks and enable the expression of different views and the solution of conflicts of interest
Working together	• Open, honest, positive, respectful, and non-discriminatory behavior • Recognition of participants' time value and of communities' statutory requirements • Encouragement of everyone's participation • Procedures agreement and knowledge sharing • Identification of opportunities and discussion of strategies • Efficient, effective, and fair use of resources • Focus on agreed purpose, roles assignment, and action delegation • Skill co-ordination and enhancement, reciprocal learning • Risk assessment, conflict address
Sharing information	• Relevant information is accessible, clear, understandable, and available in appropriate format and time for consultation • All participants have equal access to information and justify why access to certain information is restricted by confidentiality
Working with others	• Establishment of collaboration links with relevant structures, activities, and organizations • Learning from others, avoidance of work duplication, complement of others' work • Encouragement of community engagement

(continued)

Table 2 (continued)

Standard	Indicators
Improvement	• Access to resources, support and opportunities for training for all participants • Identification of learning needs and development of individual's potential • Share of skills, experience, and knowledge
Feedback	• Regular feedback on the considered options, on the agreed actions and decisions, and on their outcomes and impacts • Relevant information is provided in understandable language, promotes positive images of all groups, avoids stereotypes and encourages participation
Monitoring and evaluation	• Evaluation of the engagement process against the intended results • Collection, recording and presentation of relevant information • Drawing of lessons from the evidence • Celebration of progress • Recording and sharing of good practices

7 Conclusion

The paper illustrates how it is possible to change approaches to governance moving from traditional centralized governance characterized by a top–down approach to a more inclusive one where communities are actively involved and initiatives comes from the population rather than being imposed upon them by the government. The Localism Act shifted great power from the government to society. Thanks to this, local communities are empowered to define their own Neighborhood Plan that can steer development in the direction that better meets local needs and aspirations. The example of the Bankside Neighborhood Forum demonstrates that collaboration among different entities is possible. What remains to be verified is its effectiveness and its ability to address the various requisites and to find an appropriate balance point among them. It is now too early to evaluate this, but citizens' empowerment already is a big step forward since it enables people to express their ideas and opinions and to propose their vision for the future of their place. The approach adopted in the Bankside Program has been pioneering in this sense. It proved to be an effective one, a model to replicate and imitate. Indeed, it has been shown that residents have truly been listened to when they proposed ideas and initiatives, so that today there are a number of cultural activities that attract people in the neighborhood social life. The Social Model, with its countless activities, proved to be successful in actively involving local communities. Thanks to the wide range and variety of the activities organized, diverse population groups have been involved. Watching a movie, visiting the gallery, or gardening together constitute the basis for successful community engagement. While there is much to applaud, not all has been smooth sailing. The road to proper community engagement is still a long one, since the idea to regenerate did not come from the bottom, but from the partnership of the Tate Gallery and the Southwark Council that decided to locate the new museum at the site of the abandoned power station. Moreover, any involvement objective was set. Hence, citizen involvement cannot be evaluated against an intended result. In addition, the initial government enthusiasm is declining and the initial support is giving out. Consequently, the initiative that originally demonstrated strong power in guiding the development according to the needs of the local community and introduced a revolution in the government system is now in danger of fading away even before the approval of the Neighbourhood Plan.

For this reason, it is recommendable to not only subsidize community groups so that they can continue and strengthen their activity, but also to listen to citizens' ideas, include them in the decision making process since its very beginning, and collaborate with artists and associations to find new ways of community involvement. In addition, it is fundamental to set objectives at the beginning of the process in order to have criteria to evaluate at the end. Moreover, it is suggested to conduct further research on the impact of the policies and activities illustrated in this paper. Since this piece of research has been realized at the very beginning of the introduction of the Neighborhood Plan, it is necessary to observe the outcomes in the long run to verify its effectiveness. Concerning the activities of the Social Model, it would be interesting to investigate how they changed over the years and to collect residents' opinions on them in order to see if they actually feel adequately involved in their neighborhood life and to listen to suggestions to further improve their participation.

Finally, since the literature review undertaken for this paper showed both the great potential as well as criticisms of participatory practices, further theoretical and empirical analysis about the power and outcomes of collaborative planning within urban regeneration would be beneficial to the matter.

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Development Theories and Infrastructural Planning: the Belluno Province

Giovanni Campeol, Sandra Carollo and Nicola Masotto

Abstract Currently, the English word "smart" has become commonly used in the field of urban and land planning as an adjective referring to an evolving "good", or clever, know-how. It is a word that is usually applied to the process of qualitative urban and land planning, as opposed just to quantitative planning. Since the Conference in Rio de Janeiro in 1992, the urban and planning (but also architectural) disciplines have been accompanied by terminologies that could somehow represent a better way of "carrying out" transformations, passing from an "ecological city" to a "sustainable city" and finally to a "smart city". Each adjective represents a vision of the transformations: for example, an ecological city is a town with more public green areas, the sustainable city pays more attention to the preservation of physical and chemical parameters (air and water quality, etc.), and the smart city is more focused on the realization of efficient technologies. Actually, the above interpretations of transformation do not have a real meaning, as it is absolutely evident that the city and the territory, in compliance with the disciplinary statute, must be transformed by taking into consideration the human, biotic, and abiotic elements, i.e., they must have an environmental approach. The adjective environmental has been defined in the long-standing scientific research (Odum, Leopold, McHarg, Stainer, Nebbia, etc.) which, since the 1930s, has been developing the ability to utilize dynamically and synchronically the three levers that define sustainable development: the economic, the social, and the ecological (biotic and abiotic) levers. Following the historical periods and the geographical contexts, the use of the three levers may

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progressed at different speeds, while yet focusing attention on the feedback among the same levers. In the case study (Belluno province), the environmental (ecological, sustainable, smart) development depends on the infrastructural lever for inverting a phenomenon of social and economic decadence of a territory, also due to pervasive and aggressive competitive policies of the neighboring territories. In fact, in the province of Belluno, environmental development is conditioned by the priority use of the social and economic (primarily infrastructural) levers in the medium and long term. It is evident that this priority in the use of levers is accompanied by the ability to take the opportunities given by the high-quality ecological and landscape conditions existing in the Belluno province.

Keywords Environmental evaluation · Infrastructures · Deficit accessibility · Competitiveness · Population

1 Methodological Introduction

The prior adjectivization of urban and land transformation represents a meaningless exercise, although it is often used to define "policies", because only through the application of environmental evaluation processes (considering abiotic, biotic, and human aspects) is it possible to define the quality of these transformations. As a logical sequence, the environmental evaluation represents the fundamental connecting link between the analysis and the planning apparatus.

The challenge of sustainability in reconciling qualitative (protection of ecologic balance, improvement of the quality of life, etc.) and quantitative (economic growth, increase of per capita wealth, development of production, etc.) development has reinforced the need to evaluate from the environmental viewpoint the implications of human activities in the various fields and has also established the importance of promoting a development able to ensure ecologic compatibility, economic durability, and social participation as a basic condition for a good quality of life. Therefore, the sustainable transformation models need to activate the ecologic, economic, and social levers differently from models based only on economic, ecologic, or prevalently participative transformations. So the concept of the sustainability of transformations must be defined in relation to the mix of natural, economic, and social aspects of a given environment. Hence exists the need for several development models specifically created for an environment, in which the characteristics of ecologic compatibility, economic durability, and social participation are combined in a dynamic balance, although with different weights according to the reference context. In the processes of environmental evaluation, characterized by feed-back between the different planning steps and the consequences on the environmental components, this approach is the element able to provide a valid "aid to decision", and this has resulted from the progress of the discipline Strategic Environmental Assessment. The impact of the planning instruments on the environmental system should be assessed through a diachronic interpretation of the transformations by using chemical, physical, cartographic, or landscape environmental indicators selected on the basis of clear criteria that directly correlate with planning.

The theories about urban and land planning should always be characterized by an analytical system able to objectively identify the problems of a given geographic area, without being influenced by ideological postulations. In this sense, the adjectives given to the "city", such as those historically most used, i.e., "ecological", "sustainable" and today "smart", have a prevalently cultural meaning linked to the "fashions of the age". Starting from the refutation of the adjectivization given to the urban and land transformations, this paper aims to develop the topic of the development in a mountainous area by adopting a theoretical and methodological approach characterized by the following steps:

- analysis, through objective indicators, of a mountainous territory, the Belluno province, which enables recognition of the most relevant critical elements in the poor infrastructures, especially transport;
- analysis of the transport system of the alpine area, the role of the Belluno province, and the competitiveness of the various territorial systems;
- identification of an environmental evaluation model for choosing the best performing transport scenario for the development of the Belluno province.

This paper therefore does not apply an evaluation model, but it identifies suitable typology intentionally using only some information on transport that is considered strategic. The reference evaluation discipline which is utilized is multi-criteria decision analysis (MCDA) that, through the evaluation methodology called Analytic Hierarchy Process (AHP), enables one to find out alternatives among the transport territorial scenarios for the geographic area of the Belluno province. In identifying the transport solutions, in the case study, the "0" (zero) option has not been considered as a comparable alternative, as this option has proved unable to produce any change simulation with regard to the criticality of the established facts. As a consequence, if this option had been, simulated a faulty methodological approach would have been carried out.

2 The Case Study of the Strategic Plan in the Province of Belluno

The elaboration of the Strategic Plan (SP) in the Province of Belluno started in 2006 and has been characterized by a wide process of participation and the collaboration of all sectors composing the provincial administration, as well as of many external entities and actors. This process has led to the formulation of a shared "operational framework" to implement the projects considered as strategic for the development of Belluno province. This planning document also includes the application of environmental evaluation, which has been realized on two levels:

- the first, on a macro scale (all the province of Belluno), has assessed aggregately all possible positive and negative impacts on the environment since the realization of the "projects" established by the SP, without a precise territoriality;
- the second, on more narrowly-defined geographical areas inside the province of Belluno, has evaluated the "projects" included in the SP, which can be limited in the territory as they can be sources of pressure with precise environmental targets.

The evaluation of the environmental sustainability produced for the strategic plan highlighted the criticalities of the Belluno area, among which the most serious is the absence of a highway system able to connect the Belluno province with the north and north-east of Europe. The analyses carried out at that time, still valid today, showed the substantial weakness of the Province of Belluno in the national context, and even more so in the international context.

> […] In short, Belluno is presently positioned in the high part of the medium-low competitiveness level, with a value of 432 out of 1,000.[1] This value is undoubtedly unsatisfactory, but it should be evaluated considering that Italy as a whole does not present, even in its strongest realities, any values in line with the international best practice. The most competitive Italian realities (which are never mountain areas) have values ranging from 500 to 540 out of 1,000 (evaluated as medium-high competitive potential), compared with European realities whose development models range from 580 to 670 out of 1,000 (high, although not very high competitive potential)[2] (Barnabò et al. 2007).

In 2006 the SP stated that

> […] the main weakness, which slows down the whole system, is the infrastructure in the territory. The value measured is among the lowest in Italy and in Europe; the indicator shows an infrastructural framework (including material and immaterial infrastructures) that hinders not only external relationships (risk of remoteness), but also internal movements (poor territorial and, consequently, social integration). This analysis underlines a global fragility of the current development model in the Province that, without an intentional intervention strongly based upon some priorities, risks of slipping behind. A merely incremental management, made of answers to isolated questions, would not be enough to help Belluno take the challenges of the new century (Barnabò et al. 2007).

The infrastructural system was designed to become the main strategic lever and the SP identified the fundamental goal by the slogan "from isolation to integration". In fact, the critical points of the infrastructural system were well analyzed and studied (Fig. 1):

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[1]It should be stated that, in the elaboration of the model, the value 1,000 is only a theoretical limit, since, to reach it, for example, high potentials should coexist in terms of economic system (typical of high-potential areas) and of incentive systems, typical of less developed areas. Also, among the areas analyzed by PERegions, no Italian area reaches the measured levels of "very high potential" (whereas, in Europe, these levels are reached in the most advanced areas as regards the markets of the most advanced industrial sectors).

[2]It will be useful and somehow necessary, during the implementation of the strategic plan, to carry out comparative analyses of Italian and international territorial situations that can be compared with Belluno as regards the type of development.

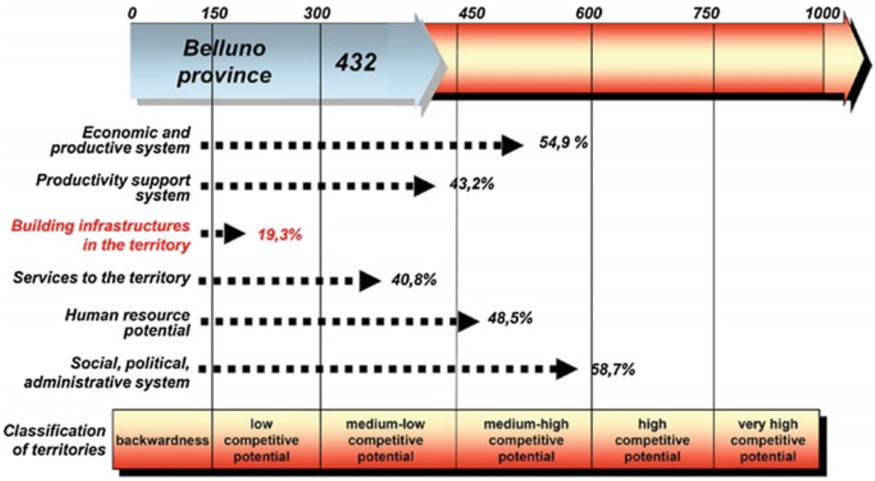

Fig. 1 The present competitive potential of the Province of Belluno (Analysis PERegions 2006)

> […] the general indicator of infrastructure in the province of Belluno rates the province at the 95th position in the list of Italian provinces, penultimate position just before the province of Ragusa.[3] Even analysing the situation more in details, with reference to each infrastructural typology, there are no positive elements as for all typologies the value of the indicator is always lower than the national average (Barnabò et al. 2007).

In addition, the SP explained that:

> […] it is a well-known criticality, worsened by the chronic delay in investment (except for some punctual interventions which have solved some local problems without, however, intervening on the global model) together with a continuously unproductive debate on mobility […] (Barnabò et al. 2007).

The weak infrastructure in the Belluno province is still currently strongly influenced by a road network with a "junction" structure "[…] to which 'major roads', mainly coinciding with other important access roads to the different valleys, are linked […]" (Barnabò et al. 2007). This condition causes:

> […] the relations between municipalities and the traffic on the roads develop essentially on the same routes, because alternative ways can be travelled only coming from outside the province (the two major roads right or left of the Piave valley and the only highway, A27 "Venice-Belluno") […] (Barnabò et al. 2007).

In conclusion, the SP confirmed the weakness of the road network in the province of Belluno so:

> […] the structure of the road network leads the "major roads" to support the traffic of all components transiting through our province, from short-distance mobility for the movements of workers and students to long-distance journeys represented by the tourist flows to

[3] Reference is made to the recent analyses of Istituto Guglielmo Tagliacarne (Rome).

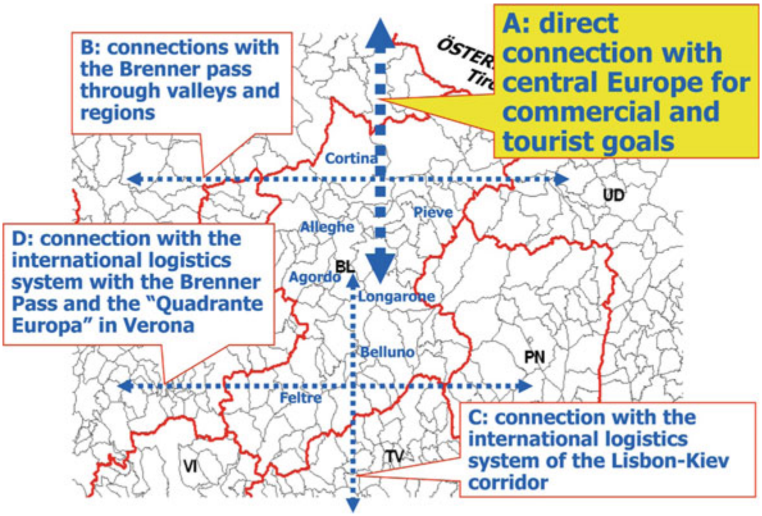

Fig. 2 Guidelines for the definition of mobility objectives (Strategic Plan)

> Cadore, Zoldo or Agordo areas. Apart from the above mentioned tourist components, we cannot forget those tourists simply driving through the province along the A27 Highway, the SS50 State road, and the SR203 Regional road, driving east to west or reaching the Trentino Alto Adige valleys. This element, although less important than global traffic, contributes specifically to the road overloading, in particular on more critical summer, winter or weekend days (Barnabò et al. 2007).

At the start of this situation, the SP of 2006 established the target for the mobility model, characterized by a horizontal networking and especially by the realization of a connection to the North with the tourist market of Central Europe (Fig. 2). In fact:

> […] the strategic goal of the new model is to "network" the province territory inside and, at the same time, outside (regional/inter-regional/state/*interstate*), reaching high performance in terms of effectiveness and efficiency in the supply of transport and related infrastructure, comfort and (low) costs of movements […] (Barnabò et al. 2007).

Even if the SP analysis had highlighted the weakness of infrastructure (especially the road network), considering as a strategic goal the need to "[…] network the province territory inside and, at the same time, outside (regional/inter-regional/state/*interstate*)" (Barnabò et al. 2007), the planning solutions considered at the time were not completely satisfactory since they were based upon the prevailing strategy of horizontal networking, without debating the possible creation of an alpine-motorway pass (Fig. 3).

In fact, Fig. 3 details the layout of the missing territorial relationships of the "international" communication that, consistent with what had been established in the SP, should have been appropriately shown in maps.

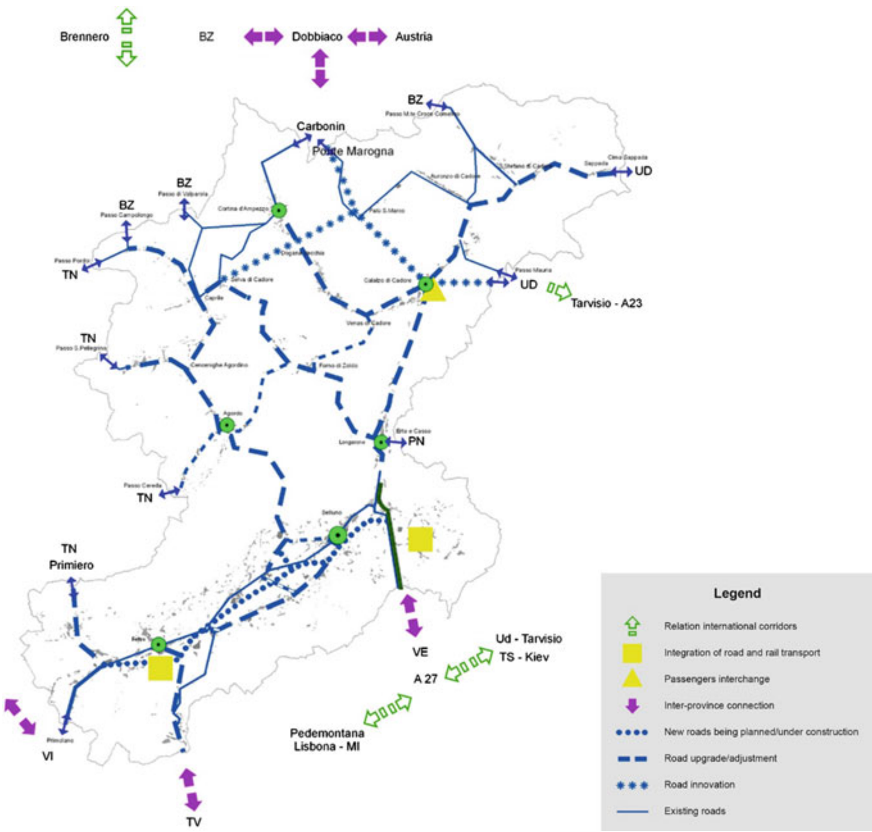

Fig. 3 Projects for the mobility route of the SP: roads (Strategic Plan)

Unluckily, the guidelines of the 2006 Strategic Plan have never been implemented, and this has contributed to accelerate the decline of the Belluno province, also due to a strong competition of the neighboring autonomous provinces of Trento and Bolzano. In these last years in the Province of Belluno, mainly due to the absence of a direct mountain-road pass with the North and North-East of Europe (Fig. 4), the social and economic parameters of the industrial, and especially of the touristic, sectors have worsened, thus becoming the "northern matter" of the Veneto region.

In order to understand this situation, and consistent with the analysis carried out in 2006 by the Strategic Plan of the province of Belluno, it is necessary to briefly analyze the more general trend of alpine movements updated to 2015 and describe the present role of the territory in Belluno province.

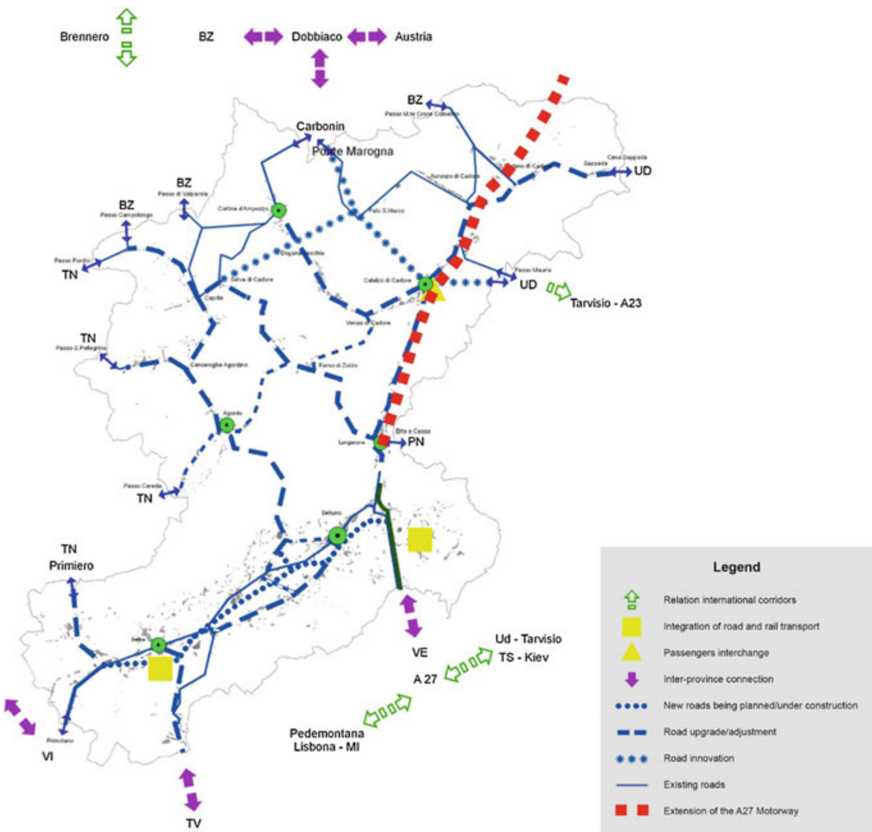

Fig. 4 Projects for the mobility route of the SP: suggested motorway (consistent with the Strategic Plan)

3 Mobility in the Alps

The Italian Alps are characterized by a social and economic structure for which the main source of wealth is supplied by the major roads for cross-border traffic. The only region that does not have an alpine-motorway pass is Veneto, whose border territory to the North is the Province of Belluno. This is actually a *cul-de-sac* between the Trentino Alto Adige and the Friuli Venezia Giulia Regions. In spite of this "communication obstruction" towards northern Europe, the province of Belluno has developed in time strong industry, such as the eyewear district of world-class excellence. However, the globalization processes are seriously undermining the economic model of the province of Belluno because there is no alpine-motorway pass that enables companies in the province to develop fast interchanges with the European market. This geographic isolation should have been solved through the realization of the Venice-Munich highway, which had already been planned at the end of the 60s. However, it has never been completed (except for the Venice-Belluno section) because of the obstacles created especially by the autonomous provinces of Trento and Bolzano, which were worrying that their motorway (A22 of Brenner Pass) could undergo a traffic reduction and consequently might create a potential threat to their economies (Campeol and Masotto 2015).

3.1 European Corridors and the Trans-European Transport Network (TEN-T)

The network of European traffic routes is changing, both to match the evolving economic geography of these last years and for the localization of productive hubs, logistics, and the demand connected with the transport of goods, reinforced by the provisional directions established at higher levels (starting from the EU level). In all this, also regarding communications with other sectors not directly connected with industry (e.g., the sectors related to tourism, services, etc.) help to complete the framework of the new geography of European communications.

Since the second half of the 80s, the panorama concerning the infrastructural development of traffic routes for the functioning of the internal market of the European Union which is able to ensure the social and economic cohesion has been defined by the Trans-European Transport Network (TEN-T). This network project has been characterized by a series of procedural steps, through which the present planning has been established, but not completed yet (Campeol and Masotto 2015).

In January 2014, the European Union defined a new policy for the transport infrastructure, aiming to connect the east and the west and the north and the south of the continent. This new policy aims at completing the missing connections in the transport infrastructure networks of the Member States and removing the technical bottlenecks and obstacles that still currently hinder the functioning of the internal market.

At the end of the long path in the definition, rethink and reconstruction of forecasting hypotheses on the orientations for the TEN-T, this is today characterized by the integration of the various modes of transport considering road and rail systems, airlines, and inland and sea navigation. Thus, the implementation of the TEN-T requires the realization of intermodal infrastructures for all the Member States included in the Trans-European Transport Network (Campeol and Masotto 2015).

3.2 Territorial Competitiveness

Through globalization, some countries, traditionally considered as developing, are rapidly gaining ground on the more developed economic powers, and coming to play an important role in advance of them.

The European Union has been long rethinking its own economic system, aiming to strengthen the competitiveness by opening the markets to Member States (removing the obstacles that hinder or slow down the growth of the market among Member States), enhancing the resources and distinctiveness of the various geographic areas that characterize the European continent (with the evident reference to the EU Member States). As a consequence, the transport system plays a crucial role in Europe in relation to world competitiveness.

If the new geography of European communications is creating new development opportunities, which need to be carefully managed, on the other hand it is also true that the distance from the most important traffic routes, which are being completed, may be an element for further disparities. In other words, the geography of European communications may lead to territorial disproportionality between the areas directly involved in the trans-European transport network and those outside this network. This phenomenon can worsen the marginalization processes of some European territories, thus being contrary to one of the objectives of the European policy, that is, to improve the connections on all the EU territory with the goal to reduce the isolation of some geographical areas (Campeol and Masotto 2015).

The case of the Veneto Region is emblematic, as it is the only region in the Alps without an alpine-road pass, and this situation is progressively weakening the province of Belluno, an enclave between the two European corridors—"Baltic-Adriatic" and "Scandinavia-Mediterranean Sea"—with which it has no direct connections.

It would be strategic for central Veneto, a geographic area that is still among the most dynamic in Europe, to be able to communicate with the European system through a mountain-road pass, which would create direct access to the north and east of Europe. This access would enable a considerable tourist flow to the UNESCO site of the Dolomites (first of all the Belluno province, as most of the UNESCO Dolomites are located in this area), to the world core of the eyewear production, and to the sea port system of the Northern Adriatic, that is Venice and Trieste in Italy and Koper in Slovenia (but also with the Port of Rijeka and Bakar, after the completion of the motorway section from Trieste to Rijeka, crossing Slovenia for 60 km).

4 Evaluation Models

Assimilating the evaluation into the planning processes of transformations means moving in the direction of the "know-how", of the harmonization of transformations with the environmental context in which ecological, historical, landscape, functional, etc. elements coexist in dynamic balance. As a consequence, the transformation strategies coming from political decisions, but also from the interpretation of the environmental potentialities and criticalities, can be redefined through the application of evaluation models and techniques on the impacts, always in accordance with the objectives established by politicians, in order to improve the development "lever" (typology) and make it more appropriate to the reference context. Therefore, the application of the environmental evaluation models enables us to establish the type, the hierarchy, and the importance to attribute to strategic actions in order to manage the transformations, in relation to the characteristics of geographical areas, of environmental strengths (potentialities) and weaknesses (criticalities) of both the state of facts and of the wishes of local communities. These evaluation models permit correction of planning mistakes through monitoring.

For the case study represented by the province of Belluno, an enclave between the very competitive territories of the provinces of Trento and Alto Adige, the application of an environmental evaluation model has enabled the identification of strategic actions for the development of this territory within the strengthening of the international infrastructure system as the main lever to develop the Belluno province.

4.1 The Environmental Performance of Motorway Corridors

The geographic, social, and economic conditions, as well as those concerning alpine mobility and the competitiveness of neighboring territories, make it possible to identify the infrastructural lever for inverting the phenomenon of social and economic decadence of the Belluno province.

Among all the infrastructural projects identified, as shown in the 2006 Strategic Plan, the realization of an alpine-motorway pass seems to be the key strategic action to develop the province of Belluno and make it more competitive (Fig. 5).

For at least 40 years, three main corridors were identified (Fig. 6):

- Route A—designed in the 60s with access to the north in Wiesing, in Austria, after driving through the province of Bolzano;
- Route B—designed between 1986 and 1989, with access to the north in Lienz, Austria;
- Route C—designed between 2005 and 2011, with access in Tolmezzo, Friuli Venezia Giulia region.

Only Routes A and B have been analyzed on a macro-environmental scale, with defined environmental pre-feasibility that enables the establishment of the performance level, whereas Route C has been excluded because it was a weird simulation without a real impact on transport or direct usefulness for the Belluno province and, even more, the Veneto region in general.

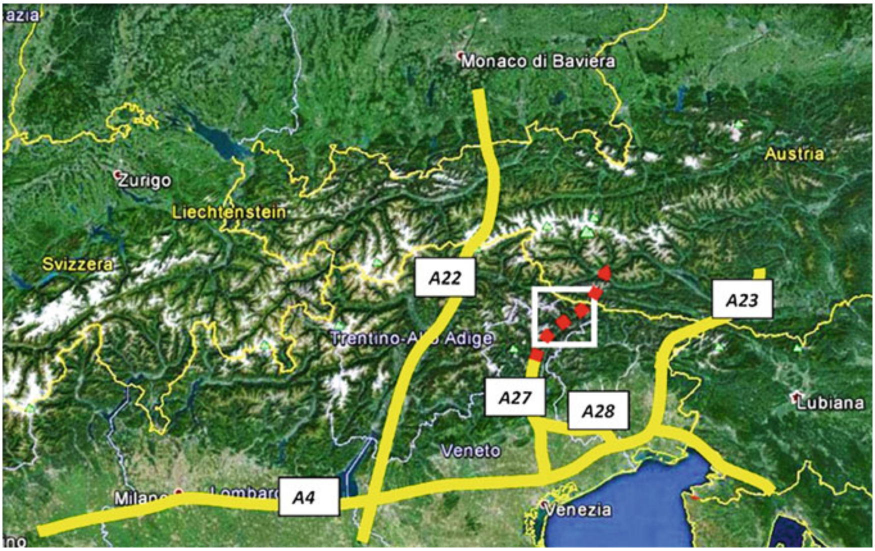

Fig. 5 The geographic context of the extension of the A27 motorway

Fig. 6 The routes analyzed

Table 1 The environmental pre-feasibility

Indicators	Geographic corridor		
	Route A 1960s	Route B 1986–1989	Route C 2005–2011
1. Geographical interferences	Austria and Province of Bolzano	Austria	Friuli Region
2. Geographical length of the corridor from Pian di Vedoia to arrival point in Austria	183 km to Wiesing (A)	119 km to Lienz (A)	–
3. Distance and time from arrival point in Austria to Munich (D)	126 km (1 h, 22′ via A12 e A8)	220 km (2 h, 56′ via A8)	–
4. FUTURE distance and time from Pian di Vedoia (BL) to Munich (local economies)	309 km (3 h e 5′)	339 km (3 h e 23′)	–
5. PRESENT total distance and time from Pian di Vedoia (BL) to Munich (local economies)	639 km (6 h, 26′)	639 km (6 h, 26′)	–
6. % reduction of time and distance	−52 %	−47 %	–
7. FUTURE distance Venice-Munich (regional economy)	411 (4 h, 7′)	441 (4 h, 25′)	–
8. PRESENT distance Venice-Munich (via A22 of the Brenner Pass)	543 (5 h, 21′)	543 (5 h, 21′)	–
9. Construction costs	Very high	Medium	–
Performance	**Low**	**Very high**	

The indicators utilized to define the environmental performance of Routes A and B are the following (and summarized in Table 1):

- Geographical interferences
- Geographical length of the corridor from Pian di Vedoia to the arrival point in Austria
- Distance and time from the arrival point in Austria to Munich (D)
- FUTURE distance and time from Pian di Vedoia (BL) to Munich (local economies)
- PRESENT total distance and time from Pian di Vedoia (BL) to Munich (local economies)
- % reduction of time and distance
- FUTURE distance Venice-Munich (regional economy)
- PRESENT distance Venice-Munich (via A22 of Brenner Pass)
- Construction costs.

4.2 Multi-Criteria Method Decision (MCMD): the AHP Method

The first results of the environmental pre-feasibility (performance table) have highlighted a complex decision problem, which can be characterized by a variety of important aspects, viewpoints, or even decision makers, which do not permit focus on a single objective. In these cases, it is essential to use multi-criteria analysis models (MCMD) that may make it possible to compare and arrange the options existing in the problem on the basis of data about often-contrasting objectives. The multi-criteria analysis aims at providing a support to the decision maker for realizing an acceptable compromise between the different objectives to be reached, which shall be previously transformed into criteria. The criteria obtained will enable the comparison of the various options present in the problem, and these, in turn, will become part of the whole called "alternative".

The identification of the objectives and criteria is a very delicate stage: it is necessary to specify the objectives and criteria with different levels of detail, as the analysis results could be implicitly orientated. Criteria are quantitative or qualitative variables that measure the performances and the impacts of the analyzed alternatives.

Using the various types of methods related to the multi-criteria analysis, the stage of the weight distribution (concerning the objectives of the decision problem) is particularly important; only after this operation is it possible to establish an order of priorities among all the objectives of the problem. Actually, the term "priority" and "weight" are considered as synonyms.

The weighting techniques are numerous, but the simplest commonly used are:

- direct distribution, where a weight or a judgment is given to a criterion, or an objective, following an evaluation scale previously established;
- pairwise comparison, where the various criteria, or objectives, are compared to one another and the values obtained are reported on a square, positive and reciprocal matrix, called a pairwise-comparison matrix.

Finally, in order to verify whether the evaluation of the objectives of the problem is correct, three types of sensitivity analysis can be realized:

- sensitivity of the method; a different method of data standardization and (when possible) of the computation of final scores is applied. This is used to control the dependence of results on the calculation method;
- sensitivity of criteria; it ensures the validity of the adopted scheme by adding or removing some decision criteria;
- sensitivity of weights (the most used); the value judgments of some criteria are modified in order to find out the degree of influence of each factor on the final decision.

A discipline of the MCMD, aiming to support the decision maker in advance of numerous and conflicting evaluations, is multi-criteria decision analysis (MCDA), which makes it possible to obtain a compromise solution in a clear way. The multi-criteria-analysis methods support the decision maker during the organization and the synthesis of complex and often heterogeneous information. This methodology enables the decision-maker to analyze and evaluate various alternatives, by monitoring their impacts on the various actors in the decision process. The MCDA is used in various fields, such as finance, planning, ecology, etc. where it is not possible to directly apply an optimization method, due to the numerous decision criteria (Mocenni 2010).

A fundamental problem in decision theory is how to obtain weights for a set of activities/actions in relation to their importance. Establishing that a given activity/action is more or less important than another requires the adoption of decision criteria, which can be totally or partially shared by the activities/actions being analyzed.

A multi-criteria-decision process will develop and subsequently apply a hierarchical measurement system. The fundamental step is to obtain some weights for each activity/action so as to establish the importance level for each. Consequently, it will be possible to determine which activity/action will be allocated a resource or which activity/action to implement. Moreover, it is necessary to classify the various objectives of the process as regards a set of objectives placed at a higher level, which in turn must be classified on the basis of further objectives, and so on, until reaching a single objective at the top of the hierarchy (Forman and Gass 2001).

The MCDA measurement system, among the most widely used, which may solve these kinds of problems and which we have consequently chosen, is called analytic hierarchy process (AHP). It is a hierarchical analytic process that enables us to make a decision among different options when we have multiple criteria.

The AHP method, as a decision-support system (DSS), is developed in five fundamental steps:

- development of the hierarchy (Fig. 7): in this first step the decision maker analyzes all the aspects of the problem and structures it in a hierarchy composed of several levels. This decomposition of the problem leads to its considerable simplification and enables the decision maker to concentrate her/his analysis on a limited number of decisions. At the top of the hierarchy, there is the goal that the decision maker has established, while at the bottom there are the objectives that enable reaching the goal; at an even lower level, there are the criteria necessary to realize the objectives. The criteria, in turn, can be divided into sub-criteria, as far as the decomposition level makes it necessary to understand the problem;
- elaboration of the pairwise comparison matrix: it consists of identifying the weights to match with each criterion in the hierarchical problem, thanks to the use of an evaluation matrix whose single elements are obtained by pairwise comparisons of the problem criteria;
- determination of the relative local weights: once obtained, the pairwise comparison matrix, in the subsequent step of the model the weights to be matched with each criterion, is evaluated;

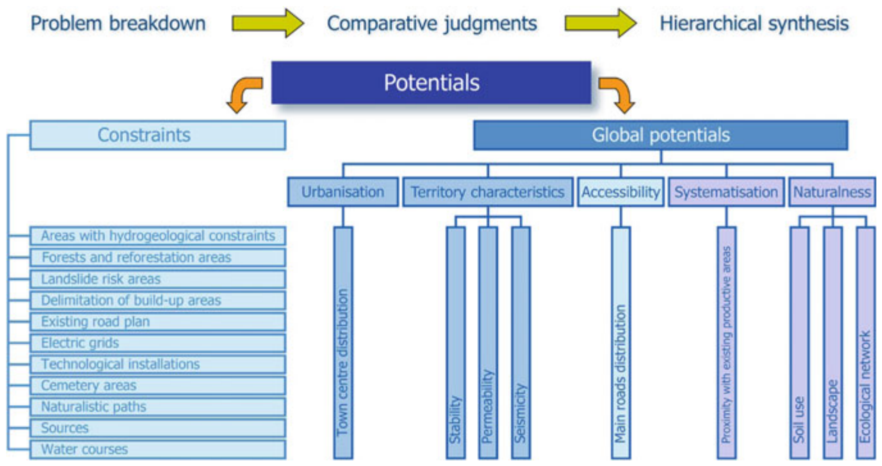

Fig. 7 Diagram of the evaluation method

- analysis of the judgment consistency: in this step of the process, it is necessary to verify whether the weights obtained in the previous step are consistent with the judgments expressed by the decision maker;
- determination of the global weights: the principle of hierarchical composition; this is the final step and it consists of calculating the global weights (or priorities) of the actions. In order to determine the importance of each element in relation to the goal, it is necessary to apply the principle of hierarchical composition (Saaty 1980). The local weights of each element are multiplied by those of the corresponding super-ordered elements and the products obtained are summed up. Proceeding from the top to the bottom, the local weights of all the elements of the hierarchy are thus progressively transformed into global weights. The global weights (or priorities) of the elements placed at the bottom of the hierarchy, in the level after that of the terminal objectives, represent the main result of the evaluation. When the terminal elements are actions, the global weights make it possible to determine an order of preference: the more an action (a project, a strategy, a scenario, etc.) is favored, the more global weight it has.

In the AHP, the weights are determined with the pairwise comparison, and the quantification of the relative importance of the different criteria is derived from the declaration of preference by using the scale of values 1–9. The matrix derived can be analyzed by using a consistency index, which makes it possible to evaluate to what extent the derived weights are consistent with the decision process. In particular, the AHP is a technique that can be easily applied, that is flexible in the choice of inputs, and that enables one to assign priorities to a set of decision alternatives, relating qualitative and quantitative evaluations, otherwise not directly comparable, by combining multidimensional scales of measurements into a single priority scale. Its process structure, well-defined in its consecutive steps, enables attribution of ponderable values to the various environmental components and, through the use of a reliable software (SuperDecisions), it is able to produce clear decisions and to provide immediate answers to the modification of identified inputs. These factors have been essential in the choice of this methodology so that it may be used to identify the performance of the territorial scenarios for the Belluno province.

5 Conclusions

The quality of urban and land development cannot be defined in advance, but only through environmental evaluation models that use correct techniques for the impact assessment and evaluation of performance alternatives. Therefore, there is not a single definition of development but, according to the social, economic, ecological, geomorphological, etc. conditions, evaluation models make it possible to identify the necessary development typologies and actions. The province of Belluno is a typical case in which the strategic action for development is implemented by realizing infrastructures, among which the realization of the motorway typology through an alpine pass turns out to be predominately important.

What comes out from this survey underlines the importance of further exploration of the vector typology that represents, in this case, the preferences of the decision makers, as it is clear that, on the basis of public priorities, the alternatives could also change. This is the reason why it has become necessary to identify an evaluation methodology, such as the AHP, that may lead to identifying the best alternative among the various territorial scenarios assumed for the Belluno province.

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Part V
Demonstration Projects

Transformation of a Small-Livestock, Rural Community into a Green, Nearly-Zero CO_2-Emissions Settlement

Argiro Dimoudi, Vasilis Stathis and Christos Pallas

Abstract The community of Eleonas, North Greece, is characterized by intensive livestock and relatively moderate rural economic activity. Residents of the community produce organic crops and livestock by recycling waste primarily from agricultural and livestock residues. These processes are carried out in a not particularly environmentally-friendly way. The community has a new target: upgrading their economic activities in the region by adopting more environmentally-friendly activities. The strategic vision is developed in hierarchical steps that aim to satisfy the requirements of rational economics and environmental protection:

- the primary goal is to reduce energy waste, air pollution, and pollution of the ample water resources by the current irrational waste management;
- then to meet their reduced energy needs by generating all possible renewable energy from every potential local source, especially biomass, energy crops, and the sun;
- and finally to create conditions that will favor the enhancement of entrepreneurship in the primary (alternative crops) and secondary (milking and slaughterhouses in a livestock park) sectors in the community.

The aim of the project is to convert the Eleonas community into a green community of nearly/zero CO_2 emissions, and thus, demonstrate the capability of development through a different model that will support the decentralized infrastructures.

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1 Description of Settlement

The Eleonas settlement is a small mountainous community of 375 inhabitants (according to 2012 census) built at an elevation of 450 m. It is located about 10 km north-northeast of the city of Serres, in North Greece (see Fig. 1) and is part of Serres municipality. The settlement was probably established before 1200, as one evidence is the existing Byzantine church of Saint Nikolaos, that was built at this period. Also, a vaulted tomb was found near the borders of the village which is also dated at that period.

Its indigenous inhabitants are mainly engaged in livestock production (67 recorded breeders in 2012), but also in olive cultivation. The livestock farming consists of mainly sheep and goats (23,850 animals in 2012) and, secondarily, cattle and pigs (cumulatively, 548 in 2012). Thirdly, the poultry capacity numbered some 700 hens.

The cultivation of olive trees is the traditional agricultural activity in the area and gave its name to the settlement (Elaionas in Greek means 'olive grove'). Olive cultivation spans 1,500 acres and includes 18,000 trees of which about 4,000 are aged 200–300 years old. Olive production amounts to 500 tons/year. While few residents cultivate grains ($\sim$200 ha.), vegetables and fruit trees are also cultivated, but on a residential basis.

Fig. 1 Panoramic view of the Eleonas settlement

The main processing activity is the production of oil and cheese with two olive processing units and one cheese production unit. There is also a poultry processing-and-packaging plant.

There are limited tourist activities, restricted to day visitors to one of the settlement's four restaurants In the settlement there are 112 residential buildings, 4 municipal buildings, and 3 small units in the secondary sector i.e., an olive mill, cheese producer from sheep and goat milk, and the poultry processing unit.

2 Strategy for Becoming a Neutral-Carbon Settlement

The community of Eleonas is characterized by intensive livestock and relatively moderate rural economic activity. Residents of the community produce organic crops and livestock by recycling waste primarily from agricultural and livestock residues. These processes are carried out in a not particularly-environmentally friendly way as the digestion of the residue occurs in an open space.

The community has a new target to upgrade economic activities in the region through environmentally friendly means. The first goal is the utilization of by-products resulting from the economic activities of residents which otherwise pollute the environment. Animal manure can be used for the production of biogas energy. This will significantly reduce the pollution of the atmosphere with methane. The organized operation of the 'livestock park'—which currently is partially operating—can achieve a critical mass of the required animal waste for biogas production, and this will be enhanced by agricultural residues and cultivation of energy crops. The full operation of the 'livestock park' requires specific infrastructure. Adequate water supply for the park is essential to relocate breeders there.

In addition, the community is planning a series of interventions that aim to improve the quality of life of the inhabitants and to upgrade the aesthetics of the settlement with the aim of upgrading its tourism—attracting more day-visitors for walking, for visits to local restaurants, and to develop the market for local products produced by community's women association. The planned infrastructure will increase the energy requirements of the community. The electrical energy produced from biogas will fully cover the needs of the community for electricity following prior extensive energy-saving actions that lead to energy self-sufficiency in the community.

The estimated energy consumption and associated CO_2 emissions of the settlement for buildings and transportation, categorized by energy source, are summarized in Tables 1 and 2.

The energy data were based on a detailed questionnaire-based survey carried out in the settlement, where heating, cooling systems, and respective fuel source was recorded in each building. Electricity data, covering lighting, and equipment were based on data from the Public Electricity Corporation and corresponding

Table 1 Estimated energy consumption (TOE) before interventions

Sector	Electricity	Heating-cooling	Diesel-transport	Biomass	Total
I. Buildings, lighting and secondary sector					
Public buildings	0.35	32.80	–	–	33.15
Public lighting	6.70		–	–	6.70
Residential buildings	30.80	303.00	–	223.8	557.60
Secondary sector	7.90		–	–	7.90
Total I	45.75	335.80	–	223.80	605.35
II. Transport					
Private cars	–	–	0.55	–	–
Commercial vehicles	–	–	0.90	–	–
Garbage and effluent trucks	–	–	1.30	–	–
Public transport	–	–	6.80	–	–
Total II	–	–	9.55	–	9.55

Table 2 Estimated CO_2 eq emissions (tn CO_2 eq) before Interventions

Sector	Electricity	Heating-cooling	Diesel-transport	Biomass	Total
I. Buildings, lighting and secondary sector					
Public buildings	4.06	90.49	–	–	94.55
Public lighting	76.82	–	–	–	76.82
Residential buildings	354.24	222.38	–	–	576.62
Secondary sector	91.29	–	–	–	91.29
Total I	526.41	357.31	–	–	839.28
II. Transport					
Private cars	–	–	15.47	–	–
Commercial vehicles	–	–	2.50	–	–
Garbage and effluent trucks	–	–	4.04	–	–
Public transport	–	–	19.02	–	–
Total II	–	–	41.03	–	41.03
Unused animal manure	–	–	–	5393.66	5393.66
Total	526.41	357.31	41.03	5393.66	6273.97

information from the survey. Estimations of CO_2 emissions were based on conversion coefficients given at the Technical Guide of the Technical Chamber of Greece (TG.TCG 20701-1), the Public Electricity Corporation official site (www.dei.gr).

3 Proposed Interventions

The strategic vision is developed in hierarchical steps that aim to satisfy the requirements of rationality and environmental protection:

- 1st goal: to reduce energy waste, air pollution, and pollution of the abundant water resources caused by current irrational waste management,
- 2nd goal: to cover the reduced energy needs by generating all possible renewable energy from local sources, especially biomass, energy crops, and sun, and
- 3rd goal: to create conditions that will favor the enhancement of entrepreneurship in the primary (alternative crops) and secondary sector e.g., milking and slaughterhouses in the livestock park, tourist activities in the community.

The main actions to achieve these goals are summarized as:

- improve energy efficiency in the residential sector,
- improve energy efficiency in the public building sector,
- improve energy efficiency in the public lighting sector,
- rehabilitate bioclimatically the main open space (main road) of the village,
- introduce electric vehicles for public transport and endogenous commercial transport,
- production of biogas from animal manure and agricultural residues,
- improve water supply to the livestock park to enable breeders to move there,
- manage effluent waste,
- supply compost bins to each house.

4 Energy Efficiency in the Residential Sector

4.1 Survey of Existing Condition

The settlement has no particular architectural character, i.e., it is without special architectural and functional configurations and consists of few story-buildings of up to three floors (ground floor and two floors) (Fig. 2). The average size of the houses, as resulted from the questionnaire survey carried in the settlement, is 122 m^2. The old buildings are constructed from stone with plaster coating on both sides. In the village there are about 31 % stone made buildings, restricted at a ground floor or a ground with additional first floor. In many existing ground floor old stone constructions a floor was added, with bearing structure of reinforced concrete and brick walls those homes are included in the category "houses of reinforced concrete and brick". The houses that were built new or an addition was made to an existing stone construction before 1980 constitute 31 % of the building

Fig. 2 View of the main street in the settlement

stock of the community. Therefore, the building stock that was built before the implementation of Thermal Insulation Regulation—that made obligatory thermal insulation of new buildings—constitute approximately 62 % of the building stock. Other dwellings (38 %) were built after 1980. The survey carried out in the settlement shows that the old constructions are not characterized by good thermal condition, although several of these have been partial renovation mainly with replacement of windows with double pane ones.

The detailed survey of the settlement based on an in situ visit of all buildings, data from a preliminary questionnaire, and an energy audit at a later stage outlined the characteristics of the settlement and revealed the main characteristics of the building stock as summarized in Table 3.

4.2 *Proposed Energy Efficiency Interventions in the Residential Sector*

The ongoing interventions to meet modern needs of older houses, but without architectural constraints, as well as the poor condition of municipal buildings due to poor maintenance and non-continuous use—only the kindergarten works on a daily basis—have led to the aesthetic degradation of the settlement. The main square characterizes the settlement with its tall, old plantain trees and the traditional restaurants which surround them and which simultaneously enable the passage of vehicles.

A coordinated effort to effect energy upgrades of a large number of buildings in the village, with interventions on the buildings' envelopes by adding external insulation to the walls and roof, replacement of windows, the necessary painting of external surfaces, following some aesthetic criteria, which will improve the aesthetic image of the settlement. These interventions will be combined with the

Table 3 Outline of the main characteristics of building stock of the settlement

	A. Stone houses		B. Reinforced concrete and brick houses (built before 1980)			C. Reinforced concrete and brick houses (built after 1980)		
	Ground floor houses	2- or 3-level houses	Ground floor houses	2- or 3-level houses	4-level houses or more	Ground floor houses	2- or 3-level houses	4-level houses or more
Total houses	16	18	10	17	8	2	30	11
Roof								
Flat	–	–	2	2	2	–	7	1
Roof tiles	16	18	8	15	3	2	23	10
Window frames								
Wooden	8	11	3	6	2	–	2	–
Aluminum without thermal break	8	7	7	11	3	2	28	11
Glass								
Single	11	11	5	12	2	1	5	1
Double	5	7	5	5	3	1	25	10
Heating system/fuel								
Boiler-petroleum	1	1	3	6	2	2	14	7
Wood burner	10	16	10	12	4		14	2
Fireplaces	1	2	–	6	3	2	18	6
Cooling system								
Split units/electricity	2	4	4	4	2	–	9	2
None	11	13	6	13	3	2	21	9
Hot water system								
Boiler petroleum	2	2	–	7	2	2	3	4
Electric water heater	16	18	10	17	5	2	30	11
Solar thermal	5	9	2	6	4	1	15	7

bioclimatic upgrade of the main road running through the village, which is delimited by the square of the village at one end and the playground at the other. Along this road, all buildings of cultural significance (e.g., the olive museum, the Byzantine church Saint Nicholas) and public buildings (community office, kindergarten, and the former primary school which will host the activities of Women's Association) of the settlement are aligned. The interventions are summarized so:

- Energy upgrade and aesthetic renovation of houses.
- Bioclimatic redevelopment of the central road of the village with a traffic-calming street, with integration of bioclimatic elements such as placing

cool materials, enriching vegetation, creation of shaded sitting places, and the addition of high-quality street furniture.
- Upgrade of outdoor public spaces, which contribute to use by people and the prevalence of natural elements and environmentally friendly materials.

The proposed redevelopment shall simultaneously: protect the environment, both in the sense of reversing the effects of climate change through bioclimatic solutions; preserve cultural heritage and the historical and social character of the settlement, with upgraded use of municipal buildings and the aesthetic improvement of the facades of settlements' houses; and provide a route for visitors to tour the village. The goal is to combine the regenerated route with other walking routes projects that will emphasize the watercourse that crosses the village.

The main proposed interventions are summarized so:

- Wall insulation in 64 buildings
- Windows and window frames replacement in 36 buildings
- Replacement of 52 outdated boilers with pellet-burning boilers
- Improvements in the public lighting sector
- Addition/replacement of solar collector systems for hot water in 54 buildings
- Supply of two ceiling fans to each residence.

The proposed interventions are estimated to result in:

- reduction in energy consumption by 103 TOE or 18.6 %:
- reduction in CO_2 emissions by 373.64 tn CO_2 eq or 64.76 %; and
- production of 'green energy' (with use of solar panels) by 4 TOE.

5 Energy Efficiency in the Public Building Sector

5.1 Existing Condition

The municipal office and the old school buildings are the oldest buildings, constructed in 1938, while the kindergarten was built in 1968. The old buildings have stone masonry, while the kindergarten was built with reinforced-bearing structure filled with bricks. All buildings have wooden-framed, single-pane windows.

5.2 Interventions—Results

The energy renovation interventions at the public buildings are:

- Insulation of walls
- Replacement of window frames and glass with double-glazed windows

- Shading of windows
- Replacement of existing heating systems with:
    - Pellet-burning boilers (kindergarten)
    - Air-to-air heat pump (old school)
    - Inverter (municipality building)
- Installation of solar collectors for domestic hot water (in kindergarten)

The expected results from the energy renovation of the three public buildings, based on energy simulation of building with the official national energy certification tool, KENAK-TEE (http://portal.tee.gr), are summarized as:

- reduction in energy consumption by 27.07 TOE or 77 % and
- reduction in CO_2 emissions by 106.25 tn CO_2 eq or 85.7 %.

6 Energy Efficiency in Public-Lighting Infrastructure

6.1 Interventions—Results

The interventions in the public-lighting infrastructure consist of:

- Replacement of 125-W high-pressure mercury lamps with LED 60 W (Measure 1),
- Replacement of 250-W high-pressure sodium lamps with LED 120 W (Measure 2)
- Installation of economy lamps 20 W (Measure 3)

The obtained energy savings and the associated CO_2 emissions reduction are summarized in Table 4.

7 Bioclimatic Rehabilitation of the Main Settlement's Road

7.1 Existing Condition

The route that is proposed for bioclimatic redevelopment is the main axis passing through the square and reaches the edge of the village, where a playground is located (Fig. 3) which offers a panoramic view of the surrounding area. It is the main road for the passage of vehicles and for people to get to their homes, and it is connected to the vertical streets of the village. It is also a promenade for pedestrians. The width of the street is narrow and not constant, ranging in some places from about 5.00 m and to upwards of 8.00–8.50 m (Fig. 4).

Table 4 Summary of energy-efficiency measures in the public lighting system-

Interventions	Before interventions			After interventions			Energy (kWh/y)	Savings (%)	Reduction in CO_2 eq emission	
	Installed power (KW)	Energy consumpt (kWh/year)	Emissions CO_2 eq (tonnes)**	Installed power (KW)	Energy consumption (kWh/year)	Emissions CO_2 eq (tonnes)**			(ton/year)	%
Measure1[1]	15.0	62196.0	61.51	7.2	29854.08	29.53	32341.92	52	31.99	52
Measure 2[2]	3.0	12439.2	12.30	1.4	5970.82	5.91	6468.38	52	6.40	52
Measure 3[3]	0.7	2985.4	2.95	0.7	2985.41	2.95	0	0	0.00	0
Total	18.7	77620.6	76.77	9.3	38810.30	38.38	38810.30	50	38.38	50

** emissions coeff ((tn CO_2-eq/kWh) derived from TG.TCG 20701-1/2010
[1]Measure 1: Replacement of 125-W high-pressure mercury lamps with LED 60 W
[2]Measure 2: Replacement of 250-W high-pressure sodium lamps with LED 120 W
[3]Measure 3: Installation of economy lamps 20 W

Fig. 3 View of the kindergarten, old school, and municipal buildings

Fig. 4 Outline of the route to be redeveloped with bioclimatic criteria (Dimoudi S, Tamiolaki A. M. (4–19 Architects Office))

The road is covered with conventional asphalt and there is no vegetation (Fig. 4) along the road to offer shade during summers. The open spaces in the nearby municipal buildings have conventional floor tiles.

In the open spaces of the municipal building, there are some trees such as olive and cherry. The square, which is characterized by its tall plantain trees and natural flowing water, offers shaded areas. The site of the playground has trees and offers shade.

7.2 Proposed Interventions

The main route of the settlement and the yards of the municipal buildings are proposed to be redeveloped with bioclimatic criteria, with the main actions focusing on the change of ground-floor materials and an increase of vegetation. Thus, the main road is proposed to be covered with cool materials—light cool pavers of an area of 3,550 m^2—and the open spaces of nearby public buildings to have tiles replaced with new, cooler ones. Regarding vegetation, local species are the choice for planting in an organized plan, including planting in the yards of nearby public buildings and plantation of plum and linden trees along the length of the main road. The vegetation along the road will be accompanied by sitting benches, at selected locations to provide shaded sitting areas.

7.3 Expected Results

The main goal of the interventions is to improve microclimatic conditions and the thermal comfort conditions in outdoor open spaces both in the main road of the village, and the open spaces of the municipal buildings. The plan also aims at simultaneously protecting the environment, both in the sense of reversing the effects of climate change through bioclimatic solutions, and also for the preservation of cultural heritage and the historical and social character of the settlement. This will be accomplished with the promotion and use of the open spaces in the municipal buildings and the aesthetic improvement of the facades of the town houses, which will be carried out within the framework of this redevelopment.

The bioclimatic redevelopment of the main open space of the settlement is estimated to result in a CO_2 reduction of 142 tn.

8 Biogas Production

The community of Eleonas will generate electricity from biogas, and, as an auto-producer, will cover its own electricity needs. The possible excess energy will cover municipal loads in buildings and installations of the Municipality of Serres, which the inhabitants of Eleonas also use (schools, library, municipal buildings in the city of Serres, landfill facilities, etc.). The produced thermal energy will be used in the future in the new premises of the livestock farm (milking, slaughterhouses, etc.) and be integrated into new stables of the farms that may require thermal loads.

Based on statistics in the region, but also on data collected from farmers about the number of animals, it was estimated that each animal will produce an average amount of manure as shown in Table 5. An anaerobic-fermentation technology was chosen for biogas production, and the produced energy and the energy characteristics of the plant are summarized at Table 6. The average daily consumption of raw materials was estimated at 41.3 tn, with an annual consumption of about 15,084 tn. For the case of manure, an availability of around 200 days/year was assumed, when the animals are stabled at the community pens. On the other days, the animals will be moved to pastures at higher altitudes, outside community limits.

The residue from the overall process (the compost) will be available to farmers as an organic fertilizer because of its high content in nitrogen phosphorus and potassium (NPK), and this will contribute in this way to the growth and development of the rural society but also completing the sustainable cycle of anaerobic digestion.

Table 5 Characteristics of biogas production

Type	Biomass				Standard	Biogas
	tn/year	% Total solids (%)	Total volatile (%)	Volatile solids/year	GVS	m3 CH_4/y
Silage maize	2,300	30.0	95	656	340	222,870
Cow manure	2,380	9.0	80	171	210	35,986
Whey	183	5.0	98	9	350	3,138
Pig manure	172	6.0	80	8	290	2,394
Fatty acids	18	95.0	98	17	900	15,082
Poultry manure	14	40.0	75	4	290	1,218
Sheep and goat manure	3,500	34.5	89	1,075	210	225,682
Total	8,567	25.1	–	1,940	–	506,370
Methane production in the secondary digester	–	–	–	–	–	50,637
Total production of methane (CH4)	–	–	–	–	–	557,007
Total production of biogas	–	23 t/day (1 t/h)	–	63 % CH_4	–	879,062

Table 6 Production of electrical and thermal energy from biogas

Energy characteristics	Amount	Unit
CH_4 production	557.007	m3 CH_4
Fuel energy	5.537	MWh/year
Fuel capacity kW	632	kW
Installed capacity (Electrical)	248	kW e
Fuel energy	5.537	MWh/year
Production of electricity	2.062	MWh/year
Production of thermal energy	2.979	MWh/year
Capacity (Thermal)	340	kW
Thermal energy of processes	439	MWh/year
Consumption of thermal energy	2.539	MWh/year

9 Discussion—Conclusions

All interventions that are proposed were quantified in terms of contribution in CO_2-emission reduction and the results are summarized in Table 7.

The estimated cost for each intervention, together with its associated energy savings, are summarized in Table 8. The overall cost of the proposed interventions in order to convert the settlement to carbon neutrality is about 5.1 million Euros. The project was considered as a demonstration case study for CO_2 neutral community, funded by 100 %, from the sources of the Structural Funds.

Open public information days were organized by Serres Municipality at Eleonas settlement, where all its residents were invited to participate in order to inform them

Table 7 Estimated overall CO_2 balance of the settlement after the interventions

Interventions	Existing emissions CO_2e	Reduced emissions CO_2e	Compensation emissions CO_2e	Balance CO_2e
Energy efficiency in public and residential buildings	–	438.35	–	–
6 Electric trucks	–	33.91	–	–
1 Electric bus with charging station	–	114.76	–	–
Street lighting	–	38.38	–	–
Energy production from biogas	–	5332.50	–	–
Bioclimatic rehabilitation of open spaces	–	136.00	–	–
Vegetation	–	0.40	–	–
Water supply to Livestock park	–	23.45	–	–
Recycle	–	77.51	–	–
Total 1	–	6177.37	–	–
Green energy				
Production by biogas	–	–	2163.71	–
Solar panels	–	–	41.54	–
Total 2	–	–	2205.25	–
Total	6273.97	–	–	−2108.65

about the project's actions and to motivate them to participate. The information days were organized at different stages of the project preparation, and the whole project was presented in detail. This was accompanied by an expression of interest to join the project when residents were invited to sign up.

The operation of the livestock farm will create a better economy of scale, and it will stimulate livestock production. The process of collecting biomass and the cutting-edge technology of the biogas unit is expected to give a new dimension to local entrepreneurship and the wider region which has a similar growth pattern.

Moreover, the extent of pasture (5,010 ha) and the structured collection and disposal of biomass processes will provide new and improved opportunities for creating new self-feeding livestock farms large and small organic way animals.

Finally, another important goal is to create conditions that will favor the enhancement of entrepreneurship in the primary (alternative crops) and secondary (milking and slaughterhouses in livestock park) sector in the community. It will give the opportunity to the community women's' association to have a space—the premises of the old primary school—to host their activities e.g., preparation, exhibitions, market stand for local products and thus encourage local women to be involved and promote their products. The renovated settlement will attract more visitors and boost the local economy.

Table 8 Estimated cost of each intervention and associated energy savings

AXIS of interventions	Sectoral interventions	Type of interventions	Cost (€)	Energy savings (KTOE)	Production of green energy (KTOE)
AXIS 1: Protection of atmospheric environment, sustainable transport climate change (Energy Efficiency, RES)	1.1 Building sector	Insulation	621,596	0.044	–
		Window replacement	314,693		
		Replacement of boilers and burners with biomass boilers	104,000		
		Fans	26,000	0.003	–
		Solar collectors with SolarKeymark	54,000	–	0.004
		Replacement of building light bulbs	863	0.003	–
		Refurbishment of 3 public buildings (town building, school and kindergarten)	73,250	0.00001	–
	1.2 Transport	4 electric trucks + electric clark	82,976	0.012	–
		1 Electric bus and the charging station	388,149	0.040	–
	1.3 Public lighting	Replacement of existing bulbs with LED	48,180	0.003	–
	1.4 CHP from biogas	Electricity production with biogas from local animal manure and agricultural residues	2,059,266	–	0.188
		Cultivation of energy crops	86,100	–	–
	1.6 Bioclimatic rehabilitation of open spaces	Section of central road of approximately 600 m	350,000	–	–
		Green planting	2,500	–	–

(continued)

Table 8 (continued)

AXIS of interventions	Sectoral interventions	Type of interventions	Cost (€)	Energy savings (KTOE)	Production of green energy (KTOE)
AXIS 2: Protection and management of water and wastewater	2.1 Management of water resources	Transport of water to the livestock park	325,000	0.101	–
	2.2 Management of wastewater	Installation of wastewater treatment plant	399,750	−0.007	–
AXIS 4: Solid waste	4.1 Management of residential solid wastes	Recycling buckets	2,400	–	–
		Residential compost buckets	3,900	–	–
Total	–		5082623.00	0.211	0.192

A series of well-structured actions aim at achieving energy efficiency and using renewable-energy sources and the resultant energy in a small-livestock and agricultural settlement to become a neutral carbon community. This settlement will serve as an example for the duplication of these actions in other small communities.

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Interregional Cooperation as a Key Tool for the Achievement of Strategic-Energy and Climate Targets: The Experience of the INTERREG IVC RENERGY and SEE RE-SEEties Projects

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Abstract Interregional cooperation is fundamental to improve the effectiveness of local sustainable energy policies, as a response to overarching EU strategies and commitments. The RENERGY and RE-SEEties projects constitute valuable international cooperative experiences which proved that the transfer of knowledge among scientific institutions and local authorities can support a real synergy among politicians, businesses, and citizens and the achievement of the main targets of the Covenant of Mayors. Both projects produced a methodological toolkit aimed at supporting local authorities in creating a sustainable and resource-efficient future giving rise to local implementation plans ready to be endorsed. The RENERGY project, aimed at developing efficient-energy policies at regional level in an inclusive, integrative approach, focused on the transformation of urban communities from energy consumers to producers. The RENERGY toolkit had the purpose to provide local authorities with a roadmap to develop their Local Implementation Plan (LIP). The methodology was tested by the partners in their communities giving an innovative and positive approach to local energy policy whereas good practice exchanges, Energy Labs and Case Studies, contributed to the transfer of knowledge and to increase local community awareness. The RE-SEEties project was aimed at

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contributing to the resource-efficiency challenge by investigating energy consumption and waste production and disposal, examining the role of potential changes in consumption patterns and policy-making alternatives to support the achievement of resource-efficiency targets. A comprehensive approach to energy and waste flows at the urban level was thus adopted in order to reduce the overall carbon footprint of cities. A step-by-step methodology was devised to approach jointly energy and waste issues, whereas structured initiatives were promoted to support a change of behavior and tight cooperation between municipal officers working on different themes. The interest aroused within and beyond the involved communities, as well as the important results achieved in these two projects, testify to the importance of a proactive engagement of local governments and stakeholders on energy and climate themes, as well as the necessity of adopting a long-term comprehensive approach to ensure socially inclusive growth and a steady transition towards a low-carbon society.

Keywords Interregional cooperation · Sustainable energy policies · Resource efficiency · Local energy planning · Stakeholder engagement

1 Introduction

The European Union policy is aimed at boosting a rational use of resources to increase energy independence, security, competitiveness, and sustainability (COM 105 final 2006). Energy, climate, waste, and resource efficiency are in focus, representing the key aspects to be tackled at the local level to contribute to the achievement of the 2020 energy and climate targets and the more ambitious policy goals beyond 2030 (COM 15 final 2014). In this context it is fundamental to promote "resource efficient communities" that utilize the available resources in the best way, integrating their energy needs in a comprehensive territorial planning strategy (Rae and Bradley 2012). In fact, in the reorganization of urban functions towards resource efficiency, policy makers often have to make challenging decisions aimed at supporting a sustainable use of resources and technological innovation. This implies considering all the dimensions of sustainable development (policy, technology, economy, environment, and society) to devise and implement realistic solutions built on public consensus (Berardi 2013; Djuran et al. 2013; Wǖstenhagen et al. 2007; Dong et al. 2014). Two projects, RENERGY and RE-SEEties, were funded respectively within INTERREG IVC and the South East Europe (SEE) Transnational Cooperation Programmes in order to contribute to energy, resource efficiency, and climate challenges.

The INTERREG IVC RENERGY project (2012–2014) involved twelve partners from Italy, Austria, Portugal, Germany, United Kingdom, Poland, Lithuania, Romania, Denmark, and Hungary, among which three knowledge institutions (CNR-IMAA—Italy, INTELI—Portugal, and KTU—Lithuania) and nine local authorities (Province of Potenza—Italy; Municipality of Tulln—Austria;

Municipality of Worms—Germany; Durham County Council—United Kingdom; The Association of Municipalities Polish Network “Energie Cités”—Poland; Municipality of Avrig—Romania; Municipality of Slagelse—Denmark; Municipality of Szentes—Hungary; and Building for the Future—United Kingdom).

The SEE RE-SEEties project (2012–2014) involved five knowledge institutions (CNR-IMAA—Italy; CRES—Greece; Energiaklub—Hungary; MACEF—Former Republic of Macedonia; and REGEA—Croatia) and eight partner cities (The Local Government of Budapest 18th District—Hungary; Municipality of Aigaleo—Greece; Municipality of Potenza—Italy; City of Nitra—Slovakia; City of Skopje—Former Republic of Macedonia; Harghita County Council—Romania; Municipality of Ptuj—Slovenia; and City of Ivanic-Grad—Croatia).

Both the projects are directly relevant to the context of the EU 2020 Energy Strategy (COM. 639 final 2010; COM 2, 2011) being aimed at providing local authorities with guidance to promote suitable framework conditions for the development of policy strategies based on the enhancement of knowledge, skills and awareness, as well as a proactive stakeholders engagement. In particular, they were addressed at promoting a low-carbon economy at the local level through targeted, concerted actions focused on sustainable-energy uses. A fundamental common objective was to improve the effectiveness of local energy policies by empowering and engaging policy makers and stakeholders, providing them with methods and criteria for the design and assessment of policies and measures, as well as a synopsis of the existing successful good practices and the conditions for their transferability. Moreover, the projects focused on topical challenges such as energy and waste, being aimed at promoting a more efficient use of resources either in supply and end-use sectors or reducing the carbon footprint. The main methodological findings have been made operative in local action plans outlining sustainable development paths and successful good practices to be implemented in the partners regions.

2 Methodological Aspects

The RENERGY and RE-SEEties projects were aimed at providing the local authorities with specific instruments to tackle energy sustainability, addressing the main barriers that can hinder the uptake of renewable and resource-efficiency measures at the local level. A main activity concerned the development and application of customizable tools rooted in renowned and widespread methodologies to develop and monitor local action plans. A step-by-step approach to policy making was followed to incorporate the feedback from the practical application of the methodology in various EU contexts and to valorize the lessons learned. Both the projects encouraged the active engagement of stakeholders to facilitate the implementation of sustainable-energy strategies through increased citizen

Table 1 Main features of the INTERREG IVC RENERGY and SEE RE-SEEties projects

Project	Objectives	Key issues	Target groups	Reference methodologies	Main methodological outputs
INTERREG IVC RENERGY	To promote EE and RES in local communities and to reduce the market barriers for the penetration of new and more efficient technologies	Sustainable energy	Local authorities	IEA—ALEP	Good practices Guidebook
		Climate change	Policy makers	SWOT analysis	Model implementation plan
			SMEs	PEST analysis	RENERGY methodological toolkit
			Citizens		
SEE RE-SEEties	To help municipalities developing integrated waste-and-energy solutions, in order to create resource efficient urban communities	Resource efficiency	Municipalities	Energy forecasting	Guide for successful planning and decision making
		Energy and waste	Public companies	LCA-IWM (waste forecasting)	SEE Methodological Toolkit
			Private companies	ICLEI tool	Local strategies and action plans
			Citizens	CO_2ZW (waste management)	Feasibility studies

awareness. The main features of the RENERGY and RE-SEEties projects are summarized in Table 1.

The RENERGY project was aimed at improving the effectiveness of local and regional policy strategies addressing three main dimensions of sustainability: policy making, energy business, and community. Interregional cooperation and a structured stakeholder engagement enabled a fruitful exchange of knowledge contributing valuably to the exchange and the implementation of good practices.

The RENERGY methodology focused on two complementary issues: how to build and implement a Local Action Plan (LAP) and how to engage actively stakeholders in order to guarantee the success of the strategies and to establish long-lasting cooperation among citizens and local authorities (Cosmi et al. 2014). The RENERGY toolkit (2014) provides local authorities and energy planners with step-by-step guidance to develop a Local Action Plan through a structured cycle that includes the monitoring phase (see Fig. 1). The implementation plan should address the measures to be put into practice in a region according to its weakness and strengths, the local policies in force, the local “enablers”, and the impact they may have in the region.

The first step of the RENERGY methodology deals with the self-assessment analysis that enables performing an in-depth analysis of the territory, identifying the challenges to be addressed and characterizing the policy context (i.e., legislation in force, territorial plans, and other initiatives), the territorial limits, energy consumption and infrastructures, and the economic and social frameworks. This preliminary evaluation is fundamental to set feasible medium-long term targets for

Fig. 1 Main phases of a local implementation plan

sustainable development of the territory. Three well-known methodologies have been utilized to perform a comprehensive assessment integrating the main dimensions of energy sustainability: the Advanced Local Energy Planning—ALEP, developed in the framework of the IEA- ECBCS Annex 33 (Steidle et al. 2000); the SWOT analysis (Shi 2016; Terrados et al. 2007; Chen et al. 2014; Xingang et al. 2013) and the PEST analysis (Zhu et al. 2015; Simanaviciene et al. 2015) widely used as support tools in a strategic decision-making process (Santoyo-Castelazo and Azapagic 2014). Top-down and bottom-up tools integrating quantitative methods for data collection with surveys and interviews were used to gather the data and make explicit stakeholders' expectations (Cosmi et al. 2015). From an operating point of view, an exhaustive analysis of the local community position in respect of Energy Efficiency and Renewable Energy as well as political, social, and economic restraints is needed to describe clearly the community's aspirations. Once the self-assessment has been carried out, the regional strategy should be outlined. Overarching objectives and the future vision should be defined both at the community level and in a wider context according to the cultural, political, and economic background and the envisaged development of the region. From an operating point, strategic objectives and targets, together with key interventions and specific action lines, should be identified to ensure the conversion of the overall strategy, aims, and objectives into results. The action lines should therefore be structured into a set of clear aims and operating actions/objectives with specific, measureable results in order to monitor the success of the plan and to provide feedback for a re-definition of aims and objectives, as well as an improvement of actions. In addition, a financial analysis should be performed to ensure the feasibility of the proposed interventions. At last, in order to make the implementation plan a 'living thing', responsibilities and roles should be well identified foreseeing also a programmed review based on political scrutiny and community reporting.

While the analysis of the regional framework is indispensable to contextualize the vision, objectives, and key actions of any local implementation plan, on the other hand the acceptance and the effectiveness of policy strategies should be ensured by promoting citizen awareness and participation. A structured approach was thus developed to ensure a close and lasting cooperation between energy experts, producers/suppliers, local authorities, and the community based on the Energy Labs concept (Dvarioniene et al. 2015). The Energy Labs represent an innovative way to support innovation valorizing the stakeholder contribution in crucial decisional phases according to their role, encouraging their engagement by advisory and experiential actions. The stakeholders engagement starts with the identification of the main stakeholders' categories (e.g., who has interest in the project or can benefit from its outcomes, who has the knowledge and the power, who is working in the same fields, who may have disadvantages or can be an opponent, etc.). Subsequently brainstorming and a stakeholder analysis is performed to find out their importance and the role they may have in the planning process. The stakeholder overview is documented by tables and mapping that report the fundamental information about their role and the rules for their involvement (e.g., the expected contribution, methods, and timing). It is important to contact stakeholders from the very beginning in order to inform them and get their feedback from the early phases as well as to manage in time possible conflicts (Ruggiero et al. 2014). Various methods for their involvement can be used (e.g., direct interviews, restricted expert meetings, workshops, fairs, open laboratories, testing activities, etc.) according to the purpose of the consultation and the expected outcomes of the Energy Labs.

The overall objective of RE-SEEties project was to improve the integrated policy-making and strategic planning competences of South East Europe (SEE) municipalities in the field of energy efficiency, RES, and waste valorization in order to turn SEE cities into resource-efficient urban communities. This aim was pursued through a step-by-step methodology based on five pillars and an iterative process (see Fig. 2). The first version of the methodology was developed by the knowledge institutions involved in the project, tested by city partners, and finally revised in order to take into account the conclusions and lessons learned from its application across SEE cities through an intensive strategy-building and stakeholder-engagement process (Salvia et al. 2015).

The **first pillar** of the RE-SEEties methodology is related to the policy-making process, finalized to provide guidelines to policy makers on the regional and local levels, developing appropriate policies in order to achieve resource-efficient communities in the field of energy and waste valorisation. The policy-making process is developed through a cycle process, which consists of five phases, starting from setting an agenda after the identification of the main problems and finally arriving at policy evaluation. The intermediate phases concern policy formulation usually in a public debate, wherein policy is adopted in order to address the problems arising from with the solutions discussed and policy implementation. The **second pillar** provides local and regional authorities with an overview of successful experiences carried out all around Europe in terms of waste valorisation, energy efficiency, and

Fig. 2 Step-by-step methodology—RE-SEEties project

sustainable exploitation of renewable energy sources. On the basis of the selected best practices, local authorities can identify the most appropriate actions and measures which can have immediately positive effects at the local level. The **third pillar** concerns changing behaviors of various target groups, which assumes an important role to reach the fixed sustainable targets. To this end, public authorities, public companies, private companies, and citizens are identified as the main target groups to assure a successful implementation of energy and waste measures. The measures are divided into four groups: regulatory measures (controls in the form of prohibitions or requirements, issued by political or administrative bodies that are mandatory in nature); financial measures (incentives, taxes or feeds); informational measures (used for knowledge transfer, or to persuade, convince, or encourage people to exhibit the desired behavior); and technical measures (related to changes in communal infrastructure and new technical solutions). The **fourth pillar** is related to the technical aspects of strategic planning with the aim to characterize current energy and waste-management systems and to individuate the best pathways in the medium term. In order to support decision making on energy and waste issues, we carried out a careful examination of data, methods, and the tools currently used by city partners in their planning activities and an extensive research on internationally recognized methods and tools delivered by previous projects of research and cooperation. Based on the outcomes of such activities, the technical component is composed of three user-friendly engineering tools: first, the *ICLEI Europe's Basic Climate Toolkit* (Shearer et al. 2013), which enables access to the Baseline Emission Inventory for each city in a format compatible with the requirements of the Covenant of Mayors Sustainable Energy Action Plans (European Commission 2010), individuating two subsets of sectors (government and community); second, the *CO_2ZW waste-management tool* (2013) which provides the ecological footprint of municipal waste-management in terms of greenhouse gas emissions, calculating both generated and avoided emissions; third, the *LCA-IWM waste prognosis model* which is useful to forecast the generation of municipal solid waste on the basis of significant indicators (Den Boer et al. 2005). In addition, two ad hoc calculation tools (a set of energy-forecasting equations and an "add-in" spreadsheet calculator for the ICLEI tool) were developed during the RE-SEEties project to guarantee a full applicability of the proposed methodology by municipal actors and officers (Salvia et al. 2014). In particular, the set of energy forecasting equations enables the estimation of future energy needs for key sectors (residential, commercial, and transport), and they can be fed into the ICLEI tool in order to calculate emissions also for future years. The "add-in" file for the ICLEI tool can be useful when the local administrations lack data, because it calculates input parameters based on primary information and proxy variables derived either from national or regional databases. The strategy building and criteria for assessment is the **fifth pillar** of the step-by-step methodology in which each project's partners develops a case-study profile indicating its main policy goals. The case-study profile is the starting point to elaborate the Local Strategy and Action Plans (LSAPs), to which the relevant stakeholders contribute also through their involvement in the peer-review processes. A specific set of indicators (social, environmental, and economic) and criteria have been selected in order to assess the potential results of case studies and to examine multidisciplinary features of waste and energy (e.g., CO_2 reduction, pollution prevention, job creation, greening, and urban renewal). In particular, eight categories were defined for the energy sector (transport, buildings, public lighting, local energy production from renewable-energy sources, involvement of the private sector, citizens involvement, green public procurement, and local economic impact) and nine categories for the waste sector (waste management, recycling, reusing, replacing, waste to energy, employment creation and financial effects, effect on environment and society, legal, and citizens involvement). The implementation of the assessment obtained from these criteria produced the recommendations that helped in the finalization of the strategies with the most valuable impact on society.

3 Main Results

The RENERGY and RE-SEEties projects, both ended in 2014, addressed key complementary challenges within the framework of sustainable development. Their valuable methodology advancements concerning local energy planning were successfully applied by the project partners for local assessment, feasibility studies, and the definition of Local Action Plans (see Table 2). In the first phase, customized methodologies were developed aimed at systematizing the knowledge background, fostering community awareness, and eliciting the needs and expectations of communities. The proposed approach was then implemented in the partner communities to perform an in-depth analysis of the partner communities, relevantly focusing the

Table 2 Summary of the results achieved by the RENERGY and RE-SEEties projects

Project	Territorial analysis/Action plans	Transfer of knowledge
RENERGY	Eleven self-assessment reports	*Good Practices Guidebook* including 25 selected examples—Six of them transferred and several others providing inspiration) *Three Case studies (Potenza, Tulln, Slagelse)*
	Eleven local implementation plans	*Three Energy-Labs rounds* per partner
		One project website (http://www.renergyproject.eu/)
		Three Leaflets and six newsletters
		Thematic articles
RE-SEEties	Eight RES feasibility studies	*Stakeholder-engagement process*
	Eight local strategy and action plans	*Peer-review workshops*
		One project website (http://www.re-seeties.eu/)
		Three Brochures and three newsletters
		Thematic articles

projects' themes. The last phase focused on the definition of local action plans to be implemented by local authorities in the near future. Both the projects considered stakeholder engagement as a main issue to support the implementation of policies and measures. To this effect, target-tailored events were organized to involve various stakeholder categories and elicit their consensus. Great attention was also given to the European dimension of the studies by drafting policy recommendations (e.g. RENERGY (2013) and RE-SEEties (2014)).

The analysis of the RENERGY partner communities was aimed at outlining the background for the development of sustainable-energy-strategies plans with reference to the three project pillars: policy and governance, renewable-market uptake, and community involvement. Each partner produced an extensive self-assessment report complemented by a detailed SWOT and PEST analysis to highlight strengths, weaknesses/limitations, opportunities, and threats by means of thematic matrices and to provide policy makers with additional strategic political, economic, social, and technological evaluations. The overall results are extensively described in the Self-Assessment Synthesis Report (2013).

Policy analysis was aimed at emphasizing the reference institutional framework that supports energy sustainability. National and regional provisions incorporating European directives, territorial plans (including mitigation and adaptation), green policies promoting renewables, and energy-efficiency implementation in households, as well as money incentives and financial mechanisms that can boost directly or indirectly renewable exploitation and energy efficiency were considered. Moreover, a census of international and national programs and other local initiatives on energy and climate to evaluate the involvement of the communities was also made.

The assessment of the market potential for the uptake of renewable and energy-efficient technologies was based on the analysis of energy supply and demand, the national and local economies, consumers' needs and attitudes, energy-price trends, the impact of existing policy strategies, and subsidies and other financial incentives, as well as the current market opportunities, comparing the different experiences among countries. Although the community features vary significantly, in all countries industry, trade, and services have turned out to be the major contributors to the local economy while industry, households, and transportation had their huge contribution to energy consumption confirmed. Solar (both thermal and PV), wind, hydro, and biomass are the most popular renewable sources. Electricity and natural gas prices are highly variable: among the countries, large variations of electricity prices for industry and big consumers can be observed whereas household prices are more homogeneous. The deep influence on market uptake of population and GDP growth, energy needs for heating and cooling, housing efficiency levels, subsidies, and incentives and policies in place was confirmed. However, the local economy and citizen awareness can deeply influence the exploitation of renewables. As an example, PV technologies are more diffused in the northern countries despite the lower yields rather than in southern countries with their outstanding solar resources, because of lower community awareness and misinformation as hindrance to their full development. A huge impact on the modernization of the energy systems is also borne by affordable energy costs and high investment in new technologies that often discourage the renovation of inefficient buildings. In this context, a monopolistic market is seen as a main barrier to fully implement renewable-energy technologies and to set fair energy prices. Moreover, the market distortion caused by subsidized installation of RES technology in most countries lead to a market failure. In fact, on one hand, governmental incentives meant to relaunch the local economy foster huge investment by foreign investors, in the countries characterized by a low GDP and affected by a lack of liquidity. On the other hand, citizens are in general reluctant to invest their own resources to purchase renewable and more efficient technologies if not adequately rewarded, despite the huge energy-efficiency potential of households.

The analysis of communities was intended to characterize the demographical features, the diffusion of renewable and more efficient technologies, the good practices, and citizens' aspirations and behaviors. A variety of good practices by region was identified to demonstrate how the energy issues are tackled by the various communities and to identify the transferable examples. The results contributed evidence of the straightforward excellence of the northern countries in renewables and energy-efficient deployment, supported by an active involvement of citizens. At the same time, new EU Member Countries (e.g., Hungary, Poland, Lithuania, and Romania) show a great interest in energy efficiency, renewable energy sources and sustainable behavior, as witnessed by the implementation of significant good practices that provided inspiration to most of the partners. Social, political, and economic factors that influence sustainable- energy development of communities were also highlighted by a PEST analysis. Among the social factors, ageing and decrease of population hinder the spread of renewable-energy sources and more efficient technologies, whereas awareness and information boost their acceptance and trigger behavioral changes. Coordination of the activities among stakeholders was also considered essential to settle conflicts and foster the implementation of strategies. As concerns the political factors, EU and national priorities represent the milestone for local strategies, however the implementation of the policy issues cannot set aside the assessment of local needs with the identification of the concrete objectives and targets to be addressed by the action plans. Among the technical factors, infrastructures and technology availability should be taken into account to make the most of renewable and energy-efficiency potentials, whereas training of technicians and managers is fundamental to achieve a steady improvement and foster job creation.

Other important outcomes of the RENERGY project concerned the Case Study exchanges and the Energy Labs, two innovative instruments specifically designed to boost the transfer of knowledge among the partners and within the local community. Three exemplar case studies were designed to illustrate through concrete examples focused on the project pillars how the different issues of energy sustainability are tackled by local communities: Policy Making (Potenza), RES Market Uptake (Tulln), and Community Involvement (Slagelse). In particular, the case studies highlighted virtuous examples to fill common gaps and needs, supporting operative learning in an integrated, interregional-cooperation framework.

Moreover, the Energy Labs were specifically addressed to mobilize local communities. Each partner organized three thematic events ("Build", "Share", and "Discuss the knowledge") in connection with the three project milestones. The first round of Energy Labs was aimed at presenting the project to the community and to build up a common understanding on energy sustainability. The second round was aimed at eliciting the community feedback to define the key issues to be tackled in the Local Implementation Plans, whereas the third round was focused on the presentation and discussion of draft-implementation plans. The Energy Labs have proven their effectiveness to trigger a virtuous process in the communities that fostered active and long-lasting engagement of stakeholders and brought forth their consensus on the policy strategies.

The eleven Local Implementation Plans (developed according to a model template devised in the project) addressed the local energy challenges, deploying a set of measures based on the RENERGY experience. The common overall strategic vision was thus focused on the definition of an integrated energy-policy framework aimed at promoting innovative services within energy-conscious communities for the achievement of ambitious energy-efficiency and climate-protection targets. In this framework, the most advanced communities (frontrunners) aspired to become reference centers to pave the way for a 100 % renewable-energy supply, whereas forerunner communities made operative the innovative solutions and best practices shared within the partnership to valorize endogenous resources and foster energy independence. The local energy-saving targets spanned from 10 to 70 %. The adoption of Energy Management Systems (EMS) was also envisaged to support energy saving through real-time monitoring of energy consumption.

As concerns the good practices implementation, partners identified the most effective examples to be adopted and an intensive knowledge exchange fed into their real transfer to promote energy and carbon saving while encouraging

Table 3 Good practices transferred within the RENERGY project

Exemplar good practice	Implemented good practice
Network for SMEs working in EE and RES	BEEP network (Business Energy Efficiency Project)
Slagelse Municipality	*Durham City Council*
Energy Village Concept	Energy efficiency of Oakenshaw Community
Slagelse Municipality	*Durham City Council*
Euronet 50-50—Network of Energy Saving Schools	Educational initiatives in high schools
	Province of Potenza
Polish Network Energie Cites (PNEC)	Euronet 50/50 Max (promoted by the Kauno regioninė energetikos agentūra)
	Kaunas Technical University (KTU)
Solar Panels for Citizens	Integration of solar collectors in public and private buildings as an electricity source for the parking machines
Polish Network Energie Cites (PNEC)	*Kaunas Technical University (KTU)*
Energy Consulting Lower Austria	Energy consulting network
Tulln Municipality	*Slagelse Municipality*
Sustainable Public Housing Units	Installation of PV panels on five local municipal buildings to reduce energy consumption
Province of Potenza	*Szentes Municipality*

investments in RES & EE. In particular, six good practices were successfully transferred during the project with concrete and measurable impact on the transferring partner (Table 3), whereas several examples were selected for their implementation beyond the project duration.

The case study of the Slagelse model resulted in the most successful experience fostering the creation of local enterprise partnerships to support SMEs and businesses, as well as boosting the energy independence of small communities. A great importance was also acknowledged for the implementation of energy-oriented educational methods, recognizing the fundamental role of the educational system to foster energy awareness and energy-efficient behaviors through the leverage of young generations. As concerns end-use sectors, buildings were the main target of many action plans and provided inspiration for good-practices transfer. Following the successful examples of Tulln and Worms, free consultancy services (household energy check) were implemented to boost building refurbishments and technology innovation. Moreover, taking inspiration by the Tulln case study, many countries declared their interest to implement renewable plants for power and heat production in the near future to decrease energy imports and valorize their endogenous resources.

Each pillar of the step-by-step methodology, developed during the RE-SEEties project, produced very interesting results. As concern the policy-making process, a set of policy recommendations and guidelines for the three thematic areas

Table 4 Feasibility studies developed by RE-SEEties city partners

City	Key issues	Main aim of the feasibility study
Aigaleo	Energy efficiency	To improve the energy performance of a municipal nursery school
Budapest 18th District	Renewable energy sources	To evaluate sound technological solutions for the exploitation of solar energy
Ivanic-Grad	Renewable energy sources	To assess the energy performance of the oil-based heating system in a primary school
Miercurea-Ciuc	Renewable energy sources	To install a biogas CHP plant at the wastewater-treatment plant
	Energy efficiency	To increase the EE of the public lighting system
Nitra	Waste management	To represent in detail MSW and assess the feasibility of waste-to-energy
Potenza	Renewable energy sources	To assess the feasibility for implementing a smart microgrid in a residential area
Ptuj	Waste management	To calculate the total energy potential of alternative fuels based on real mass flows of local alternative fuels
Skopje	Renewable energy sources	To assess the energy performance of a kindergarten's heating system

under focus (waste valorization, energy efficiency, and sustainable exploitation of renewable resources) were elaborated within a very intense stakeholder-engagement process that took place in the eight participating countries with more than 40 meetings and 700 participating governmental representatives, as well as actors of the business sector, academia, and civil society. The eight city partners developed very interesting feasibility studies based on the introduction of innovative solutions and taking into account several factors that influence the investment, such as legal, economic, technological, and environmental issues, as well as other exogenous factors (Table 4).

As result of the third pillar, city partners individuated a consistent set of measures to change behavior (127), focusing their attention on informational measures (80) and less on the financial (22), regulatory (20), and technical (5) measures. Most of the proposed measures are related to energy efficiency (71), whereas a minor number of measures promoted renewable energy sources (38) and sustainable waste management (18). Besides that, all cities conducted intensive local awareness-raising campaigns under the common title "Change your behaviour towards resource efficiency" between April and September 2014. These campaigns were directed at a wide range of stakeholders, including citizens, local governments and public utility companies, small and medium enterprises, and scholars of all ages. The activities organized by the project partners were manifold: exhibitions, school competitions, kindergarten workshops, and local energy days, as well as conferences. All cities took advantage of the local media, in terms of TV interviews, articles, and advertisements. The campaigns proved to be a complete success, reaching more than 650 thousand people in the South East European region, educating local communities and citizens on resource efficiency and waste management.

The application of the proposed set of technical tools for each city partner enables the quantification and visualization of important aspects of energy consumption and waste production. After a first step dedicated to data collection, characterized by great difficulty to estimate energy consumption in the private sector, the set of energy-forecasting equations provided the trend of energy consumption for each city partner from 2012 to 2020, relevant to the commercial, residential, and transport sectors.

The ICLEI tool provided the summary of the GHG emissions for each city partner, both for the government inventory and for the community inventory. As concern the community inventory, the transportation sector provided the highest contribution in Skopje (39 %), Ptuj (52 %), and Potenza (50 %), whereas the commercial sector was the most significant contributor in Ivanić Grad (52 %) and Budapest 18th District (32 %). As concerns the GHG emissions from the government inventory, the building sector provided the highest contribution in Ptuj (74 %), Potenza (57 %), and Ivanić Grad (47 %), whereas the vehicle fleet was responsible for the highest contribution in Skopje (84 %) and Budapest 18th District (74 %).

The CO_2ZW waste-management tool and the LCA-IWM waste-prognosis model enables estimation of the carbon footprint for waste management and to predict future amounts and composition of generated waste.

Each city partner developed local strategies and an action plan, starting from a different initial point. Three partners signed their adhesion to the Covenant of Mayors (CoM 2015) during the project (City of Miercurea Ciuc—Romania, the Budapest 18th district—Hungary, and the city of Ptuj—Slovenia). On the other hand, the other five partners that, at the beginning of the project, had already approved the CoM Sustainable and Energy Action Plan (SEAP), took this opportunity to revise it critically and to highlight the main weaknesses and possible foreseen improvements. The local strategies and action plans were included in a common template, which contains preliminarily the national and local framework, the city case study, and the application of the RE-SEEties technical component. The core of this document is a description of the overall strategy identified at the city level, the definition of the technological measures for the improvement of local infrastructures, and the definition of measures for changing behavior of consumers on the local level. Most of the proposed measures (23 %) are directed to the transport sector and are aimed at improving public-transportation accessibility and performance, encouraging walking and cycling usage so as to reduce travel by private vehicles. A great number of measures (21 %) are aimed at increasing the use of locally available renewable-energy sources, mainly solar, biomass, and also geothermal. The measures related to waste management (16 %) are finalized for increasing the amount of separately collected and recycled materials and reducing the amounts of waste going into landfills. A considerable number of measures are addressed to improve energy efficiency in municipal and public buildings (15 %) and in domestic buildings (8 %), mainly by upgrading insulation, reducing energy losses, and installing building controls. Lighting is also considered of high importance (7 %) given the introduction of measures aimed at renewing public street-lighting systems (lamps substitution and smart metering of lighting needs) and installing energy-saving lamps also in domestic and commercial buildings. Only 2 % of the specific intervention is proposed for the commercial and service sector which is characterized by high complexity. After the elaboration of the measures introduced in each Local Strategy and Action Plan, in order to monitor their implementation, each city partner identified a customized subset of indicators starting from an initial common set of indicators. It was also suggested to complete the Local Strategy and Action with a SWOT analysis in order to diagnose current problems and sketch future action lines taking into account that a strong local political commitment is a key element to implement the proposed measures. The successful implementation of measures at a municipal level can provide an example for citizens, which can lead to the expansion of this sort of measures to private sectors. As concerns weaknesses, some common problems encountered can be highlighted, with particular reference to city-budget restraints, lack of technical capacity of local administration to carry out larger infrastructural projects, and difficulties in obtaining data on energy consumption for private sectors. Opportunities are provided by EU Operational Programmes for energy and waste projects in the new European programming period. The main threats are related to the lack of interest among the local banks for project financing, and consequently the inability to obtain the necessary financial resources.

4 Conclusions

Energy dependence is one of the main causes of vulnerability of the whole European and Regional energy system. As outlined in the European energy security strategy, energy dependence can be reduced by diversifying energy production, investing in renewable sources, and cutting back on energy consumption. To this effect, many voluntary initiatives (e.g., Covenant of Mayors, Energy Cities, and CONCERTO) have been promoted to enable the achievement of the 20_20_20 targets through a bottom-up approach that involves actively local communities. Local action plans in response to the EU energy and climate challenges should therefore outline the specific actions designed to achieve the targets, taking into account local resources potential and energy markets, as well as the effects of behavioral changes.

The Interregional Cooperation projects act as a multiplier to promote the cooperation between countries as a key tool to enhance skills and competences as well as to foster good-practices transfer and the utilization of common methodologies and tools to design and monitor local action plans.

The INTERREG IVC RENERGY and SEE RE-SEEties projects focused on complementary aspects of energy sustainability pointing out the main barriers and opportunities to be addressed by local communities. Both the projects contributed significantly to the improvement of local policies and instruments, proving the effectiveness of interregional cooperation to foster good-practices exchange and virtuous behaviors. In fact, the methodology toolkits designed in both projects, based on renowned methodologies, besides their straightforward implementation in the partner communities, can be easily transferred and applied to other territorial contexts.

Some general consideration can be drawn from the analysis of the projects results with reference to the three main dimensions: policy, market, and community.

As concerns the policy context, national and local government instability, lack of transparency in policy, legislation, alternating economic situation, and conflicts of interests among stakeholders were identified as major threats to sustainable energy development.

As concerns the market, the uneven distribution of renewables, saturation phenomena among the EU countries, high technology costs, and low purchasing power of citizens constitute the main deterrents. As concerns the size, small-scale technologies and decentralized systems have the highest development potential. However this is hampered by outdated infrastructures that nevertheless offer new investment opportunities to energy companies. This situation highlights the necessity of redesigning the system of incentives and business models in order to promote an effective diffusion of renewable technologies and local healthier economies.

From the community point of view, appropriate information and involvement is essential to promote a steady deployment of renewables and energy efficiency. In fact, disinformation, overload of unselected information, and negative campaigns can be detrimental, causing a lack of interest or the reluctance of the community to accept new technologies. In this context, a broad range of consultancy services with the opportunity for private users to receive free advice can support the implementation of renewable and energy-efficient technologies. The expansion of communication media is a good opportunity to reach a large number of citizens and to increase their interest in energy and environmental issues. However, innovative models focused on the education system should be devised and put into practice to foster a renewable-oriented culture and to promote energy conscious behaviors. In fact, the proactive involvement of citizens, encouraged by customized services, can be seen as a privileged tool to mobilize urban communities to boost the implementation RES and energy savings, as well as to promote healthy and vibrant lifestyles.

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More information are available at: http://www.renergyproject.eu/ and www.re-seeties.eu

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EU-GUGLE: A Sustainable Renovation for Smarter Cities from a Pilot Project

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Abstract The European building stock is mature, and expanding cities need inclusive and innovative renovation solutions for all citizens while intensifying city densification. The European project EU-GUGLE aims to reduce primary energy consumption by 40–80 % and increase renewable energy use by 25 % through nearly zero-energy building renovation models for initiating large-scale, Europe-wide replication in cities and communities. About 200,000 m^2 of residential and public buildings are being refurbished by implementing a balanced mix of technical, socio-economic, and financial solutions adapted to local needs. Six EU partner cities are participating, each revitalizing an urban district: Aachen,

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Bratislava, Milan, Sestao, Tampere, and Vienna. The comprehensive integrated approach used in EU-GUGLE is in line with the European Smart City initiative, and each participating city has created nearly zero-energy Smart City master plans based upon lowest-energy thermal renovations coupled with innovative renewable energy services incorporating every aspect of smart district life. All stages of the planning, construction, and post-occupancy phases of the large-scale district renewals are being documented, monitored, and evaluated to create sustainable district renovation methodologies for "smart renovations for smart cities" to meet the objectives of the European Commission's Smart Cities and Communities Initiative for reducing greenhouse gas emissions by 40 % within the European Union by 2020. The paper outlines the approach each city has taken and highlights case studies of the individual solutions created in three of the six cities.

Keywords Smart city · Social housing · Low-energy renovation · Renewable energies · Pilot project

1 Introduction

With the growing urbanization trend, European cities are increasingly facing challenges to cope with the demand to provide adequate living spaces for the rising number of inhabitants while ensuring a high quality of life. At the same time, climate change and limited resources provide the framework for setting ambitious climate goals for the member states of the European Union. Energy efficiency and the integration of renewable energy systems can be seen as the key elements in reducing energy demand for fossil fuels, however, in the urban context, energy is one of these key elements within a more complex structure. In a *Smart City*, the goal is the optimization of the overall system of a city, by ensuring the interaction of various sectors: energy infrastructure, the built environment, urban design, industry, and mobility must be planned together through an integrated approach. Communication technologies subsequently allow these sectors to interact, thus ideally providing an optimum in terms of the smart use of energy and resources. The involvement of stakeholders in this development process is crucial for a successful implementation, as adaptations are mostly carried out in existing cities or city quarters. Refurbishment actions play a particularly important role in the smart city context, as most of the buildings we will inhabit in the future are already being built.

The EU-GUGLE project aims to provide replicable strategies and concrete solutions for large-scale refurbishment projects across Europe. EU-GUGLE stands for "*E*uropean cities serving as a *G*reen *U*rban *G*ate towards *L*eadership in sustainable *E*nergy" and is a European project taking place from 2013 to 2019 involving six partner cities in six countries: Aachen (Germany), Bratislava (Slovakia), Milan (Italy), Sestao (Spain), Tampere (Finland), and Vienna (Austria). The National Renewable Energy Centre in Spain (CENER) coordinates the project and consortium members are from Spain, Austria, Belgium, Finland, Germany, Italy, and Slovakia. Project partners in each city are from local government, public (social) and private housing estates, tenant associations, research centers and universities, utility companies, and private energy consulting companies. Three further cities are actively participating as associated municipalities so they can integrate any lessons learned into their own plans for smart eco-building projects and districts. Gothenburg's district Hammarkullen (Sweden), Plovdiv (Bulgaria), and Gaziantep (Turkey) are the "associated cities" attending replication workshops and having direct access to experts in the field who have experience adapting large-scale building refurbishments at a district level.

Each demonstration city has chosen to revitalize a specific district, setting a benchmark for both the city itself, and an example for other cities to sustainably revitalize their building stocks while incorporating renewable energy sources and reducing primary energy consumption in the range of 40–80 % through the implementation of nearly zero-energy building renovations (Manteca 2015). The revitalization strategies for each city are in line with the European Smart City Initiative. Roughly 200,000 m^2 of residential and public buildings are being revitalized within the framework of the EU-GUGLE project. This project has received funding from the European Union's Seventh Framework Program for research, technological development, and demonstration under grant agreement No ENER/FP7EN/314632/EU-GUGLE.

The building typologies for renewal within the EU-GUGLE project are 19th-century and early 20th-century buildings, and large post-war housing developments mainly from the 1950s to the 1980s. Often the tenants and homeowners are from marginalized social groups such as low-income families, immigrants, and senior citizens. The integrated design process involves many stakeholders such as housing corporations, tenants, designers, and civil servants who make decisions together. Preliminary results among the participating cities have shown how the site-specific concepts and integration strategies have been deployed. An interdisciplinary approach has satisfied the majority of the building users' needs using an innovative and effective mix of strategies ranging from the involvement of social groups to close cooperation with communal authorities.

1.1 Overview of EU-GUGLE in Each Pilot City

Renewal strategies are being implemented and tested during the realization phase of EU-GUGLE. Comprehensive "smart renovation strategies" from the project results are being developed further to be easily transferable to other municipalities across the European Union. The initial replication is taking part in three partner cities within the "replication campaign" (Manteca 2015). This paper gives background information on the participating districts, illustrates the applied concepts, and presents preliminary results from the implemented measures.

2 Involved Districts

The planned revitalizations within the EU-GUGLE project complement the master plans for each city that are for the year 2020 and beyond. All participating cities aside from Sestao have a Sustainable Energy Action Plan (SEAP) to be implemented as a part of the commitment to local sustainable energy by the Covenant of Mayors (Covenant of Mayors 2009). Where possible, the actions within the EU-GUGLE project align with the vision, roadmap, and action plans contained within each city's SEAP. The purpose of all district revitalizations is to highlight the positive impact of large-scale sustainable energy-efficient renovations integrating the production, distribution, and use of renewable energies with the intention to replicate the results in the pilot city's other districts and also in other replication cities (Heidenreich et al. 2015).

Each of the participating districts has a unique context of socio-economic background, size, climate, ownership scheme, and building typology. However, a common element to all buildings in all districts is the requirement for urban revitalization. Table 1 summarizes the pilot districts' refurbishment measures.

The following sections describe the participating districts in greater detail.

2.1 Aachen, Germany

Aachen has a total area of 160.83 km^2 and is situated on the western German border with Belgium and the Netherlands. The City of Aachen focuses strongly on science and education. The large student body of more than 50,000 students represents a

Table 1 Refurbishment characteristics in the districts (Heidenreich et al. 2015)

City district	Building types	Age of building stock
Aachen Nord	Residential apartment blocks	Historical buildings from the 1920s to 1930s, and buildings from the 1970s
Bratislava West and Center	Low-rise and high-rise residential apartment blocks	1930s, 1950s, and 1980s
Milan Zones 4 and 5	Low-rise residential and a child care center	1980s
Sestao Txabarri/El Sol	Low-rise social housing	1890s–1930s
Tampere Tammela	Privately owned residential apartment buildings	1960s–1980s
Vienna Penzing	Mixed social housing and privately-owned low-rise residential apartment blocks	1950s–1970s

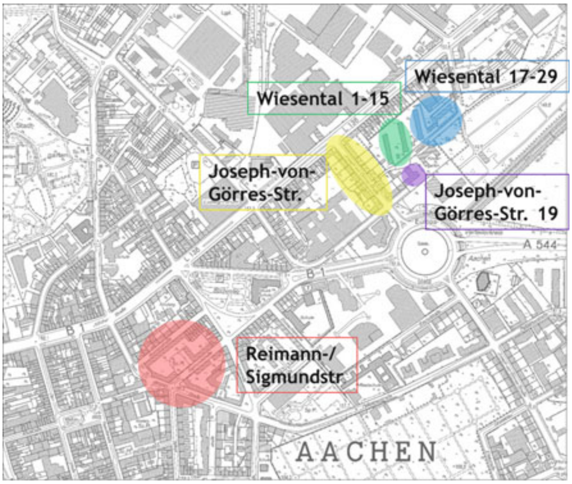

Fig. 1 Aachen's Smart District, Aachen Nord (City of Aachen 2015a)

fifth of the city's total population of 250,000 inhabitants (Vankann 2015). The Aachen North district is a heterogeneous area with a mix of new and historical, industrial, public, and residential buildings (Hemmers 2015). Many residential buildings are listed buildings due to the developments of the last 80 years. Therefore, the district master plan focuses on revitalizing and improving the attractiveness of the 3 km^2 district for its 15,500 inhabitants. It is part of a multi-year urban development program called the Aachen North Social City (Soziale Stadt Aachen-Nord), wherein the efficiency of building envelopes is thermally upgraded, building plant systems are renewed, and the energy infrastructures are being revitalized (Hemmers 2015). Approximately 1,500 of the district residents, or 10 % of the Aachen North population, are directly involved in the EU-GUGLE project. The pilot buildings are owned by the City of Aachen (75 %) and by GEWOGE, a public housing company (25 %). The building locations can be seen in Fig. 1.

2.2 *Bratislava, Slovakia*

Bratislava is the capital and largest city of Slovakia with a total area of 367.58 km^2. Located in the southwest part of the country, it is close to the Austrian, Hungarian and Czech borders. Bratislava straddles both sides of the Danube River and occupies the left bank of the Morava River. The city is divided into five districts and 17 boroughs with a population of circa 420,000 inhabitants. The population density is 1,161 inhabitants/km^2. It is the political, cultural, and economic center of Slovakia. About 20,000 m^2 of residential buildings in two districts represent the typical Bratislava building stock in the project. The pilot districts shown in Fig. 2 are located in the city center and the western part of Bratislava. Most buildings are

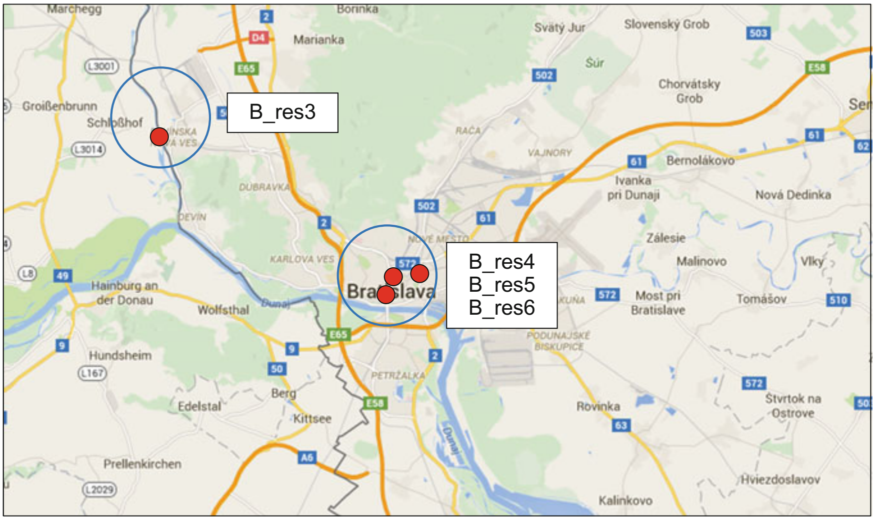

Fig. 2 Bratislava's smart districts in the center and west side of the city (Grünner 2016)

privately owned and are connected to the district heating network (Heidenreich et al. 2015).

2.3 Milan, Italy

Milan is the second largest city in Italy with a total area of circa 182 km^2. It is Italy's main commercial, industrial, and financial center with a population of circa 1.35 million. Milan is the capital of the Lombardy region and is also part of the European Backbone region that curves from the United Kingdom to northern Italy (Faludi 2015; Hospers 2003). Milan has the highest population and industrial densification of the region and is comprised of nine administrative districts (zones). Zones 4 and 5 are involved in the EU-GUGLE project. In the last two years, the city has developed energy, environmental, and sustainable mobility plans that have been subject to public debates. Many stakeholders and have benefitted from the experience gained via EU-GUGLE and other ongoing EU projects. The municipal building regulations have been updated to include incentives for highly efficient buildings. Waste separation of organic material has been introduced in one district after the other and is now implemented in the entire city. As a result, Milan's citizens are now separating more than 50 % of their urban waste, representing one of the highest shares in Europe.

The EU-GUGLE project constitutes an important experience for the municipal building department. A group of municipal architects and engineers are working together to create integrated designs with the scientific assistance of the eERG

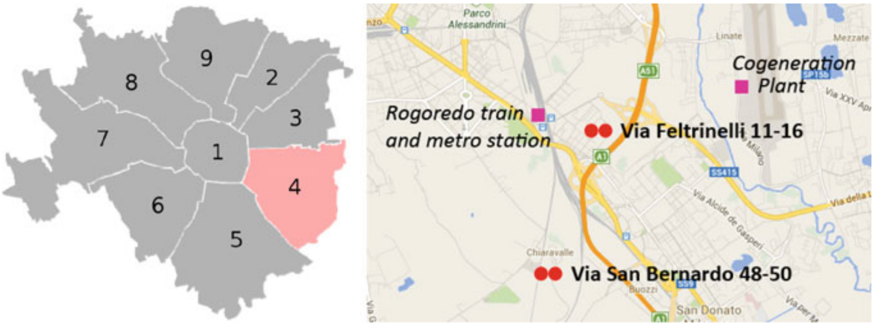

Fig. 3 Milan's smart district, Zone 4, *left*; participating residential buildings in Rogoredo/Santa Giulia, *right* (Sangalli 2016)

group of Politecnico di Milano. The municipal architects and engineers have gained experience in innovative technologies and design methods through this process. As a result, they will be in charge of promoting efficiency and comfort in the upcoming city projects. Zone 4 is located in the southeast and has an area of 21 km^2. Zone 4 has a population of 152,300 inhabitants with a typical urban density of 7,200 people per km^2. Figure 3 shows the pilot buildings in the EU-GUGLE project in relation to the vicinity of public transit and the co-generation plant.

2.4 *Sestao, Spain*

Sestao is a post-industrial municipality located 11 km from Bilbao City, on the left bank of the Estuary of Bilbao. It was on the riverbanks of the Biscay where the 19th-century industrial boom occurred. Sestao has an area of 3.5 km^2 and is primarily industrial. Only 0.9 km^2 is devoted to residential use. Since 1995, Sestao has undergone a deindustrializing process, which is heavily impacting the local economy. The current unemployment rate in Sestao is circa 30 % and the unemployment rate in the city center pilot district is even higher at a rate of 40 %. 1,300 inhabitants live in the city center district. The early 20th-century residential building stock borders an industrial area. 258 timber-framed residences with a total area of 19,008 m^2 range in age from 80 to 100 years. The dwellings have decayed over time. This area is the most strongly affected by the deindustrialization process. Eight groups of housing estates are participating in the pilot project as seen in Fig. 4. Publicly-owned housing corporations own the majority of the housing estates (Heidenreich et al. 2015).

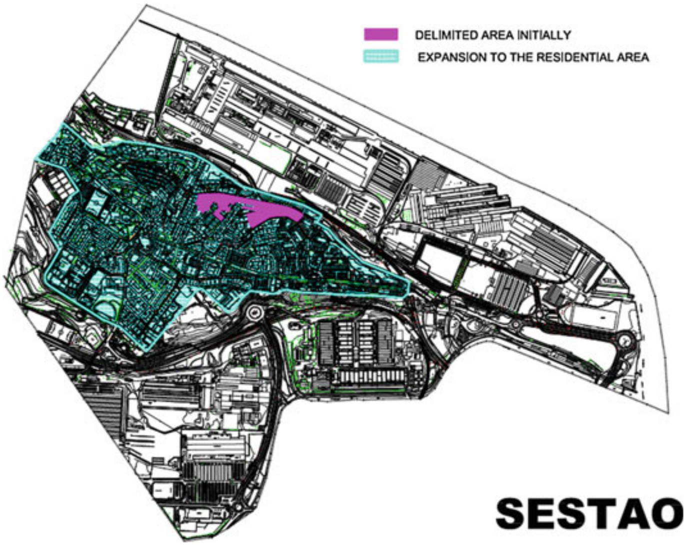

Fig. 4 Sestao's smart district (Garbisu 2016)

2.5 *Tampere, Finland*

Tampere is the third largest city and is the second largest growth center in Finland. Located on the banks of the Tammerkoski Rapids between the Näsijärvi and Pyhäjärvi Lakes, it is also the largest inland city in the Nordic countries with 225,433 inhabitants (Official Statistics of Finland 2016). The EU-GUGLE demonstration project occurs in Tammela, a sparsely built traditional residential area located adjacent to the Tampere city center and the railway. Typical district characteristics include the traditional grid plan, vivid market square, and parks. Tammela requires building refurbishments and therefore has a large potential for infill development.

Tammela has a population of 6,337 inhabitants and is primarily occupied by retirees. The Tammela building stock was mostly constructed from the 1960s to the 1980s. The residences as well as the building sites are privately owned. The majority of occupants are fixed-income retirees, young couples, and students. 560 inhabitants occupy 400 residences (circa 30,000 m^2) in the eight demonstration buildings as seen in Fig. 5.

2.6 *Vienna, Austria*

Vienna, the Austrian capital, is located near the eastern border of Austria close to Slovakia and Hungary. Vienna has 23 administrative districts. The participating

Fig. 5 Tampere city center overview with smart district Tammela marked in *yellow*. *Source* Tampere city center development vision, Tampere City Center Development Program 2015–2030 (Arkkitehdit 2015)

pilot district is Penzing, the 14th District, located in the western part of Vienna as seen in Fig. 6. The total area of the district is 33.96 km^2 with 60 % covered by green space and the *Viennese Woods*. All participating demonstration buildings currently show a high energy demand and urgently need the foreseen renovation. The main foci are the energy efficiency refurbishments of 67,220 m² gross floor area of rental apartments, the use of prefabricated façade elements, the intelligent integration of renewable energy in buildings, and realization of suitable complementary measures to create a high-quality city district.

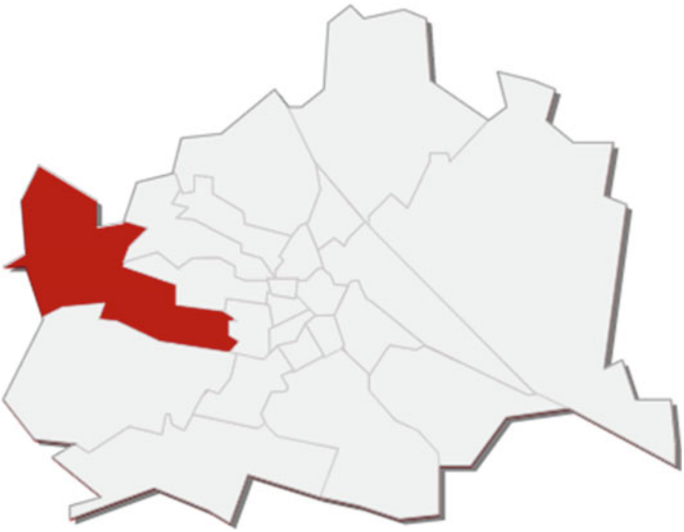

Fig. 6 Vienna's Smart District, Penzing, is shown in *red* (City of Vienna 2016)

3 Concepts in the Smart Districts

The EU's strategy is to reduce greenhouse gas emissions by 20 % from 1990 levels, increase renewable energy use by 20 %, and improve energy efficiency by 20 % (European Commission 2015). Five of the six EU-GUGLE partner cities have signed the Covenant of Mayors (CoM) (Covenant of Mayors 2009) and established their SEAPs as part of their pledge to the CoM and also corresponding to the goals of the EU-GUGLE project.

The concepts described in the following sections outline the responses by local regulatory bodies to meet individual citizen requirements in the three most advanced partner districts of EU-GUGLE: Aachen North, Tampere Tammela, and Vienna Penzing.

3.1 Aachen's Smart City Concepts

Aachen has been developing energy efficiency and climate protection policies for more than 20 years. Aachen participates in the European Climate Alliance, Covenant of Mayors, and the Mayors Adapt Initiatives. The combined initiatives influence the strategies for sustainable mobility, energy efficient building refurbishments, and renewable energy network expansions published in the *Aachen*2030 Master Plan* (Stadt Aachen 2012). The developments in the Aachen North district are underway with future development steps outlined in the "City Center Concept 2022" (Pflüger et al. 2015). Aachen has doubled their commitment to the European Union's 20-20-20 pledge, aiming for 40 % greenhouse gas reductions by 2020 and increasing renewable energy systems integration by 40 %.

The climate protection concept focuses upon building energy conservation and thermal renovations combined with highly efficient building service systems. For Aachen, the renewal of building plant services in thermal building renovations is a central instrument for reaching the goal of reducing local CO2 emissions. Aachen aims to increase the residential refurbishment rate to 2–3 % above the German national average of 1 %. To encourage citizen participation, the city conducts information campaigns to educate homeowners and business owners about the advantages of energy efficiency and renewable energy use through direct mailings, information events, and activities. The altbau plus Information Centre opened in 2004 to encourage citizen participation in the transformation process to a sustainable, energy-efficient city. Energy use advisory centers are successfully developed in Aachen North and will expand to the city center in the near future.

Sustainable transport is the third main issue in Aachen's smart city concept encompassing thermal building renovations and renewable energy expansions. The sustainable transport plan aims to reduce car use by increasing the combined network of public transit, optimizing the cycling infrastructure and e-bike rentals, and developing a combined mobility platform (Stadt Aachen 2012). All considered measures are being implemented in the pilot project in Aachen North.

3.2 Bratislava's Smart City Concepts

The SEAP of Bratislava embodies the smart city concepts for the short and medium terms to reduce carbon dioxide emissions. Bratislava also participates in the Covenant of Mayors. The action plan is an elaboration of the city vision of economic and social sustainability from 2010 to 2020 (City of Bratislava 2013). The SEAP of Bratislava foresees implementation measures in the sectors of transportation, public lighting, and decreasing energy consumption in civic buildings coupled with decreasing energy consumption and related energy costs. The district heating system provides heat for both room heating and DHW for the majority of the urban apartment buildings. Bratislava is not a stockholder of the heat production utilities; therefore, it does not influence the price, production, or supply of heating energy and domestic hot water.

Financing from the state housing development fund (ŠFRB) is focused on funding major thermal building renovations. However, there are no direct financial promotion schemes for deep renovations including substantial renewal of technical systems or the use of renewable energy resources such as photovoltaic and/or solar thermal collectors. The local condominium associations present renewable energy system (RES) solutions to the homeowners for adoption. The building locations in the assigned urban zones present challenges to some technologies using RES.

3.3 Milan's Smart City Concepts

Public consultations reinforced the environmental protection goals in the last years, showing a high citizen demand for conservation of natural resources, sustainable mobility, and a higher quality urban environment. The EU-GUGLE activities are an important test for the application of the municipally approved energy and mobility plans that need to be fully deployed in the next years. A zone at the border of Districts 4 and 5 has been chosen for the implementation of the EU-GUGLE pilot. The building envelopes of three residential, social housing building blocks and a childcare center are undergoing thermal retrofits with high-efficiency building services aimed at large improvements in energy efficiency, comfort, and indoor air quality. Prefabricated elements have been developed and tested on a small-scale with the support of industrial third parties. The prefabricated elements are comprised of decentralized, mechanical ventilation systems, high-efficiency, low noise ventilation fans, extremely compact heat exchangers for heat recovery, air-flow controls based on occupancy, advanced glazing, and movable solar shading (Pagliano et al. 2016).

3.4 Sestao's Smart City Concepts

Sestao revised their municipal master plan beginning from the late 1990s to convert the former industrial sectors into sustainable new districts. Shipbuilding and steelmaking were the primary industries until the 1970s, and many of the industrial buildings have been unused since the 1980s. Key points of the sustainable development plan include environmental regeneration of the urban edge, energy efficiency improvements of municipal services, sustainable mobility promotion, and the measures aligned with the EU-GUGLE project—promotion of energy-efficient building renovations incorporating renewable energy sources, and recyclable and environmentally-friendly building materials to reduce greenhouse gas emissions. The measures within the master plan are scheduled for completion by 2020. Social inclusion is also an essential part of the sustainable development plan, as the reconverted industrial buildings will provide new commercial, social, and cultural facilities improving the quality of life for the inhabitants of the pilot districts (Heidenreich et al. 2015).

The activities in the EU-GUGLE project complement the activities of three other European sustainability projects in Sestao (Sestao Berri 2016a). Sestao Berri 2010 is a joint partnership between the Town Council of Sestao and the Department of Employment and Social Services of the Basque Government and leads all four projects in Sestao (Sestao Berri 2016b).

3.5 Tampere's Smart City Concepts

The first target in Tampere's City Strategy 2025 is for Tampere to take a pioneering role in climate policy (City of Tampere 2012). The 2025 target is to transition to a low-carbon city with greenhouse gas reductions of 40 % below 1990 levels. The key challenge is to focus on ways to make land use, buildings, and traffic systems sustainable. The second priority is to increase heating energy efficiency. District heating is responsible for roughly a third of greenhouse gas emissions. The third key action area is to reduce electricity consumption. Concrete measures include constructing new energy-efficient buildings, improving the energy efficiency of existing buildings, increasing the share of renewable energy sources in local combined power and heat production, replacing cars running on fossil fuel with electric vehicles, and replacing mercury street lighting with intelligent LED lighting. The *ECO2 Project* ran from 2010 to 2015 as a platform to implement both the changes and sustainable approach to all city activities (City of Tampere 2013). The name is an abbreviation for "Eco-Efficient Tampere 2020" and acted as an expert unit providing ecological and energy-efficient solutions working together with cooperation partners. Now the work continues in co-operation with the energy efficiency and/or climate experts in various city departments, and the work is coordinated by the Sustainable Community Department.

In the City of Tampere, every employee is responsible for sustainable energy uses in his or her work. The city uses financial incentives to stimulate the citizens to become involved in sustainable energy uses, e.g., employees qualify for rental discounts if their workspaces are very energy efficient. The city provides free energy information services, mobility management, and organizes several gratis events for citizens throughout the year to stimulate sustainable actions. An information campaign is also a large part of the Tammela EU-GUGLE strategy to reduce energy consumption.

An important aspect of Tampere's environmental strategy is the alignment of various program goals. The eight municipalities within the City of Tampere have adopted a joint regionaIndividual regulatory and non-regulatory incentives for achieving national environmental and economic goals were previously implemented in Vienna that included voluntary measures, coordination mechanisms, and partnershipsl climate strategy in 2010. ECO2 also aligns with the European Union's Covenant of Mayors SEAP, signed in 2009 to ensure consistency in energy efficiency, environmental policies, and visions at district levels (City of Tampere 2012).

3.6 Vienna's Smart City Concepts

Individual regulatory and non-regulatory incentives for achieving national environmental and economic goals were previously implemented in Vienna that included voluntary measures, coordination mechanisms, and partnerships. The EU-GUGLE project builds upon the previous incentives and complements the measures by adopting a holistic cross-sectional approach considering socio-economic issues, direct involvement of stakeholders from different interest groups, and a common performance framework based upon an accurate mix of statistical and empirical data. The activities within the EU-GUGLE project build upon the Viennese Smart City Wien Roadmap for 2020 and beyond. The content of the roadmap is based upon a multidisciplinary stakeholder process, which included participants from the city municipality, research, education, industry, and citizens, and was carried out from 2011 to 2012 (Vienna City Administration 2014). A systems thinking approach was used as a basis to develop important trends and scenarios during the process. The interrelationships between various elements within a system were explored to understand the system as a whole. The bottom-up approach wide acceptance of the outcome and subsequent vision and strategy development. Following the Roadmap, the *Smart City Wien Framework Strategy* was developed to provide a conceptual document that includes detailed measures in three main objectives to ensure a sustainable and holistic approach: resources (objective: highest possible resource preservation); innovation (objective: innovation leadership through cutting-edge research, a strong economy, and education); and quality of living (objective: assurance of a top-level quality of living (Vienna City Administration 2014).

The systems thinking approach has been carried over from Vienna to all other participating cities in the project to define effective interventions, structure procedures, and information dissemination and to prepare project results towards replication measures (Heidenreich et al. 2015).

The master plan for the Vienna Penzing district was redefined in 2012 to align with regional, national, and European environmental goals while simultaneously considering energy-efficient renewable technologies suited to individual user needs within the district. The district master plan is based upon the Smart City Vienna objectives: urban densification, energy-efficient renovation and new building construction, sustainable mobility, increased use of renewable energies, and energy-efficient occupant behavior (Vienna City Administration 2014).

Innovative solutions are being developed within the framework of the EU-GUGLE project and are to be replicated in the second project phase within other Viennese districts.

3.7 Summary for All Participating Districts

The energy efficiency and climate protection programs in each pilot city have been developed over a long period of time and are incorporated into each city's master plan. The timeline for reaching the energy efficiency and climate protection goals ranges between short, medium, and long-term periods depending upon the individual pilot city.

All pilot districts are combining energy efficiencies in residential, municipal, and educational buildings together with the innovative expansions of already existing renewable energy networks, and are promoting more on-site renewable energy generation on a large-scale by using mainly solar thermal and photovoltaic systems. Public and bicycle transport systems, e-mobility, as well as urban energy infrastructures such as district heating networks and public lighting, are being overhauled in order to reduce greenhouse gas emissions, to meet energy efficiency targets from various sectors and to support a better quality of urban living. Tenant and homeowner participation in the decision-making process for the building renovations is a key factor and promoted by different participation schemes in each city.

Programs outside of the EU-GUGLE project at European, federal, provincial, or municipal levels, such as the Covenant of Mayors (2009), Mayors Adapt (2015), or smart city initiatives such as ECO2 and Smart City Wien (City of Tampere 2013; Vienna City Administration 2014), complement the measures in each district making each EU-GUGLE contribution a part of a larger system.

The successful implementation of the energy efficient building renovation measures paired with integrated renewable energy production and distribution are dependent upon the support and participation by very different stakeholders: inhabitants, homeowners, local businesses, researchers, design professionals, construction trades, city councils, and local utilities, as well as regional promotion schemes. The involvement of the general public is encouraged in each participating district through various information campaigns such as direct mail, energy efficiency workshops, direct real-time feedback on energy usage, and consultations.

4 Implemented Methodologies Towards the Sustainability Roadmaps

Each city has created programs to implement the smart city concepts outlined in the previous chapters. The following chapter will detail the individual programs established in selected case studies of Aachen, Tampere, and Vienna to reach their ambitious sustainability goals.

4.1 Aachen's Sustainability Roadmap

The *Aachen City Centre Concept 2022* focuses upon intensifying information and motivation activities to further promote thermal renovations integrating renewable energy production throughout Aachen (Pflüger et al. 2015).

Renewable energy production is to be primarily generated by wind turbines, and also from the solar panels mounted on the roofs of private, educational, civic, and industrial buildings. Increased energy production through the use of highly efficient, combined heat and power plants (CHPs) within industrial buildings form another part of the energy efficiency strategy (Hemmers 2015).

4.1.1 Integrating Renewable Energy

A municipal solar land registry has been established to determine the potential area available for solar thermal and photovoltaic energy production on building roofs. Within the registry are residential building blocks, public, educational, and commercial buildings. The municipal utility, STAWAG, is already cooperating with the City of Aachen to harvest solar energy using photovoltaic arrays on school roofs and other municipal buildings. The Aachen district heating network is being expanded to supply heat from CHPs to public buildings, homeowners, and commercial buildings in the city center. The current district heating power plant is coal-powered and is located on the outskirts of Aachen. The district heating network is also being expanded to supply some EU-GUGLE buildings in the Aachen North pilot district. Some pilot areas are connected to a local CHP system based on heat pumps. The heat within the wastewater canal is absorbed by central heat pumps supplying a separate local, low-exergy heating network. Large heat exchangers collect the heat from the municipal sewer; the heat is transported to five decentralized heat pumps in several interconnected buildings to supply heat at the required temperature levels for room and domestic hot water heating. Feasibility studies are being conducted to determine if the network can be expanded. In one pilot area, the heat supply of the current district heating and the new local heat pump network will be combined. Although there are no photovoltaic arrays on the buildings themselves, the solar-energy production by several photovoltaic plants are being considered on either buildings owned by STAWAG or on municipal buildings in the immediate neighborhood (Hemmers 2015).

4.1.2 Social Sustainability

Social housing and cultural buildings are to be thermally refurbished as part of the social sustainability strategy in Aachen. The higher living comfort provided by the thermal refurbishments is being made available to marginalized and lower-income families who normally cannot afford the renovations. The tenants are involved in the advising process and receive individual consultation about energy-conscious behavior to maximize their indoor comfort while simultaneously conserving energy. The tenants in the participating buildings are informed at regular intervals of the progress of the renovations and celebrate the milestones together with the other project stakeholders. The City of Aachen, together with the *altbau plus* Association, and the Consumer Advisory Board forms the Innovation Vouchers Working Group. The working group has developed a process to launch Innovation Vouchers, a financial subsidy for tenants and homeowners to receive onsite advice about how to reduce their energy consumption through using innovative technologies to meet the sustainability goals (Hemmers 2015).

4.1.3 Energy Conservation Measures

The heating systems in the pilot buildings are being centralized and replaced with highly-efficient heating systems partly based on renewable energies. Some of the existing buildings contain inefficient individual room heaters and others have individual heating boilers for single apartments. Tenants living in these apartments have previously selected individual rooms to heat for short periods, instead of heating the whole apartment as heating costs are prohibitively high in the buildings prior to renovation due to high heat losses through the poorly insulated exterior envelopes. As part of the renovation measures, the building envelopes of the non-designated buildings for building conservation are being insulated. In one case study building, thermal insulation was only possible on the inner courtyard side due to building preservation regulations. In all buildings, the attic floors and cellar ceilings are receiving additional insulation; while windows are being replaced with higher efficiency double-glazed and triple-glazed panes. In two areas, replacing the apartment balconies has eliminated thermal bridges. In some buildings, heat recovery in the mechanical ventilation system has been installed. Lighting in public areas is being converted to LED bulbs (Hemmers 2015).

4.2 *Tampere*

EU-GUGLE is one of several complementary projects within the City of Tampere that focuses on energy efficiency. Together, the projects are realizing the sustainability goals throughout the city. The local utility strives to increase renewable energy production without subsidies. An important aspect of Tampere's sustainability approach is to report actual energy and cost savings through a centralized monitoring system to various stakeholders, including the inhabitants. The following sections outline the sustainability measures included within the Tammela pilot project.

4.2.1 Integrating Renewable Energy

Tampere has a large-scale, centralized, municipal district heating network with CHP that covers the densely-built city area and also partly extends into neighboring districts. The local power utility, which provides and operates the district heating network, has increased the share of renewable energy production in their own facilities from 10 % in 2010 to 30 % in 2015. This has been a major influence on the positive climate turnaround that Tampere has been able to reach in the preceding years. All Tammela pilot buildings are connected to the district heating network. Single-family houses in lower density areas are also producing and using more and more site-specific renewable energy. Heat is primarily produced from ground heat sources and photovoltaic panels produce electricity.

4.2.2 Social Sustainability

As the pilot buildings and building sites are privately owned, the homeowners have formed privately-owned housing co-operatives and/or limited liability housing companies. The individual homeowners are essential in the entire decision-making process for the building renewals. The participants involved in the Tammela pilot project are committed to reaching the goals of sustainability and energy efficiency. The sustainability goals can only be reached when the majority of homeowners in the apartment buildings work collectively to decide upon the extent of the thermal renovations, the types of building services installed in the buildings, and also individual energy use behavior. The process leads to collaborative efforts to meet the goals, where the homeowners support each other. Guidance is provided to both the housing companies and the inhabitants on how to conserve energy (City of Tampere 2013).

4.2.3 Energy Conservation Measures

The strongly cohesive Finnish culture leads to cooperation towards sharing heating costs, maintenance, and repairs in residential apartment buildings. This cultural background provides the best possible foundation for energy efficiency improvements because it leads to decisions supporting the most effective energy efficiency measures: upgrading the overall building envelope together with technical service systems or installing completely new systems. The heating systems are centralized and all housing companies are connected to the district heating network. The electric supply is conventional. The extensive building renovations are being performed in close collaboration with the residents, housing company boards, and property managers to minimize disruptions to the tenants during the construction process (Heidenreich et al. 2014). The EU-GUGLE pilot buildings have invested in improving heating and ventilation systems. Typical measures have been installations of exhaust-air heat pumps with state of the art real-time energy management systems, the adjustment of heat distribution to individual apartments, and windows with integrated passive ventilation. Exhaust-air heat pumps have been shown to be the most significant measure to conserve energy. 20–45 % of heating energy consumption can be reduced despite higher electricity consumption by the equipment. However, the potential energy savings are highly dependent upon the occupants' interaction with the new heating and ventilation equipment. Thus, the training program for energy-conserving behavior is very important for reaching the energy conservation goals. Feedback to the stakeholders is given in both comparative costs and energy consumption to give an overview of the entire energy system to the utility company and the building managers illustrating the direct impacts of occupant behavior on energy use in real-time.

4.3 Vienna's Sustainability Roadmap

The activities within the EU-GUGLE project align with the Smart City Vienna objectives as outlined in the *Smart City Wien Framework Strategy*, a long-term plan to 2050 for urban development integrating energy, mobility, buildings, and infrastructural developments to move towards the goal of an *intelligent city*, which combines the key aspects of resources, innovation and quality of living (Vienna City Administration 2014). The vision of Vienna as an intelligent city uses innovative solutions based upon information and communications technologies (ICT) that allow higher transparency for sustainable development while minimizing overall consumption of resources. The goals are to reduce per capita greenhouse gas emissions by 35 % by 2030 and by 80 % by 2050, compared to 1990 levels (Vienna City Administration 2014). The purpose of the intelligent city is to support the high quality of life for all inhabitants maintaining Vienna as one of the world's most livable cities (Mercer LLC 2015). EU-GUGLE is one of the several projects working towards achieving the goals of the Smart City Wien Framework Strategy.

4.3.1 Integrating Renewable Energy

Individual households in Vienna are able to select up to 100 % renewable electricity production from various providers. The city offers financial incentives for solar thermal and photovoltaic installations. However, agreements with the majority of building inhabitants and shared costs need to be agreed for each apartment prior to building installation. A Multi-Active Façade has been designed for one of the participating housing estates in Penzing. The Multi-Active Façade is a specially designed pre-fabricated, highly insulated, wall panel system incorporating semi-transparent photovoltaic cells, room-based ventilation with heat recovery, and triple-glazed, passive house-quality windows (Treberspurg 2016). The electricity generated from the photovoltaic modules will be used to power the mechanical ventilation system with heat recovery and will be the power supply for lighting shared areas in the building.

4.3.2 Social Sustainability

More than 400,000 social housing dwellings in Vienna are owned by both the City of Vienna and social housing corporations (Vienna City Administration 2014). The housing complexes are distributed throughout the city and mixed together with privately-owned homes. The tenants within the subsidized housing complexes are people from various demographic backgrounds making the social housing complexes safe and pleasant places to live. Urban mobility is ensured by the extensive public transit network which consists of 1,128 km of underground, bus, and tram lines reaching all corners of the city (Himpele 2015). Public transit is subsidized and is extensively used. Many citizens do not own cars, as reflected in the private car density of 380 cars per 1000 inhabitants (Himpele 2015). Some pilot buildings in the Viennese EU-GUGLE project are privately owned. The living conditions for the inhabitants, especially those in social housing, are improving as a result of the pilot project. The subsidies finance the necessary thermal building refurbishments that are otherwise unaffordable for the social housing tenants. Insulating and enclosing the existing balconies create new winter gardens, thus increasing the total usable floor space in the refurbished apartments. The previously unused attic spaces in some of the buildings are being converted into new apartments, thus increasing both the urban density and the total usable space in the apartment building. The increased income from the new apartments partially finances the renewals for the building. All stakeholders, including the tenants of the social housing complexes, are participating in the renewal process.

4.3.3 Energy Conservation Measures

Vienna is in the process of implementing cost-optimized zero-energy building standards for all construction including new construction, additions, and refurbishments (Vienna City Administration 2014). Innovative, highly energy-efficient building services, especially heating systems, are required in order to meet the goal of reducing heating, ventilation, and air conditioning (HVAC) energy consumption by 1 % per capita and year. Thermal building renewals within the Viennese pilot projects insulate the exterior envelope, install high-performance double and triple-glazed windows, and upgrade current building services to reduce energy for heating and domestic hot water. Other measures include replacing incandescent lighting with LED lighting and installing elevators with energy recovery.

The renovation measures in the demonstration buildings are also sponsored by Vienna's Thewosan program, a promotion scheme for improving the energy-efficiency of existing buildings through thermal refurbishment, upgrading HVAC equipment, and introducing other innovative technologies for reducing greenhouse gas emissions (Wohnfonds Wien 2015).

Initial tests have shown that retrofitting the Multi-Active Façade panels in front of the existing walls can reduce operational energy by up to 90 % (Treberspurg 2016). A high-efficiency ventilation system with heat recovery ensures a constant hygienic air change rate for maintaining very good indoor environmental quality within the refurbished apartments without drafts or heat losses. The extensions of the balcony slab are incorporated into the insulated thermal envelope with the transformation of the balconies into winter gardens, thereby reducing the heat losses through thermal bridges. Prefabrication has several advantages, including reduced construction costs and minimal disruption, as the time on site to execute the thermal refurbishment is reduced from several months to 2 days per apartment. Prefabrication is not only more economical than traditional construction but also enables the tenants to remain in their homes during the shorter installation period.

5 Preliminary Results from the Derived Measures

The following section will show specific building examples of energy-efficient refurbishments integrating on-site renewable energy production in the selected case studies of Aachen, Tampere, and Vienna. The refurbishments are either under construction or have been recently completed.

5.1 Aachen

The majority of the EU-GUGLE residential buildings in Aachen are listed historical buildings. The older pilot buildings do not have centralized heating systems, but rather individual oil or coal-based room heaters. The transition to central heating includes a major installation of hot-water radiators with thermostatic radiator valves. The heating system overhaul increases the number of heated rooms in the

Fig. 7 A_RES_B2 before renovation (*left*) and after renovation (*right*) (City of Aachen 2013, 2015b)

apartments and provides much better heating regulation. The inhabitants can not only regulate, but also view, their own heating energy consumption with the new meters being installed in the apartments. The central heating systems differ in each building. As part of the building renewals, the buildings will either connect to a local heating network based on heat pumps or the municipal district heating network.

The thermal building renewals of A_RES_B2 are currently underway. The protected historical housing complex has five low-rise blocks with 148 apartments and a total conditioned gross floor area of 17,778 m^2. The heating energy demand prior to the renovations ranges from 248 to 277 kWh/m^2/year. After the renovations, the heating energy demand has been calculated to be 73.7 kWh/m^2/year. Measures to reduce building energy use include insulating the basement ceiling, attic floor, and rear façade. Due to the historical significance of the building, the other exterior walls could not be insulated. Triple-glazed windows, LED lighting, and a new centralized heating system connected to the district heating network and the local heating network using heat pumps complete the efficiency measures. The main entrance to the housing complex prior to and after the renovations is visible in Fig. 7.

5.2 Tampere

The first finished pilot in Tampere is a prefabricated panel, residential high-rise building built in the 1980s. It has 54 owner-occupied apartments with a total heated gross floor area of 4,117 m^2. Because the building condition assessment determined that the façade is in good condition, the refurbishment measures mainly focused on upgrading the heating and ventilation systems, replacing doors and windows, and

Fig. 8 Demonstration building T_RES_TAM 7 (City of Tampere 2015)

installing sensor-based LED-lighting systems. Water-saving faucets were installed in the kitchens and bathrooms reducing hot water use. Two exhaust-air heat pumps, 10 m^2 of solar collectors, and new heat exchangers have been installed. The renovations were completed in the summer of 2014. This building and all the Tampere pilots have building energy monitoring systems (BEMs) that are controlled remotely. The advantages of the BEMs are both technical and social. The Chair may convince other residents that the investment has been worthwhile. In addition, measured energy savings have played an important role in communicating the amount of energy and water saved in the participating buildings acting to market the concept in the neighborhood. Figure 8 shows the building after renovation. The effects of the combined measures were simulated prior to commencing the refurbishment. After the refurbishment, the actual weather-corrected purchased heating energy demand was reduced to 38 kWh/m^2/year in 2015 from the pre-refurbishment heating energy consumption of 129 kWh/m^2/year. In total, heating energy consumption was reduced by 70 %.

5.3 Vienna

Thermal building renovations are the primary means to meet the goals of reducing energy consumption and greenhouse gas emissions in Vienna. The residential low-rise building, V_RES_BOKU_2 was built in 1979 and has 24 apartments with a total conditioned gross floor area of 3,100 m^2. Two new stories of apartments were constructed at the attic level during the refurbishment and are being sold privately. The proceeds of the apartment sales partially financed the thermal renovations. The entire building envelope has been insulated including new triple-glazed windows and doors, and an insulated noggin piece installed on the roof. New elevators with energy recovery were installed increasing accessibility

Fig. 9 V_RES_BOKU2 before renovation (*left*), and after renovation (*right*) (Heidenreich 2014, 2015)

within the building while reducing energy consumption. The building prior to and after refurbishment is seen in Fig. 9. A thermal bridge analysis was conducted during the design-development process to help determine the insulation detailing. Daylight simulations and lighting optimization were also conducted during the planning process prior to installing the LED-lighting. The heating energy demand was reduced from 72.8 to 26.2 kWh/m^2/year. The renovations were completed in 2014.

All mentioned buildings undergo building monitoring to better understand whether the calculated performance indicators have been reached.

6 Next Steps

6.1 Aachen

Aachen will continue to refurbish the building stock of the demonstration sites at an accelerated rate to double or triple the amount of thermally refurbished buildings in comparison to the national average. A study has been conducted to assess the feasibility of installing photovoltaic arrays on the flat roofs of educational and industrial buildings. The installation photovoltaic arrays throughout the city on flat roofs will increase the amount of local renewable energy production and will be connected to the municipal electricity grid (Heidenreich et al. 2015). To complement the energy efficiency refurbishments in the buildings, tenant consultations and workshops to train and evaluate energy-conscious behavior are taking place (Hemmers 2015).

6.2 Bratislava

Feasible solutions foreseen in the urban areas of the city districts include photovoltaic, solar collectors for hot water production, and heat recovery. These technologies will be applied in all involved buildings. In addition, heat pumps are considered, but need to be approved by the local authorities (Heidenreich et al. 2014).

The demonstration buildings in Bratislava are in the planning process, and will undergo thermal renovations coupled with installation of innovative HVAC systems. Each site has been assessed according to the building construction type, and the exterior building envelopes are to be insulated with thermal insulation composite systems. All windows are to be replaced with triple-glazed panes with external solar shading. Heat pumps with heat recovery will provide space heating and meet domestic hot water demands in the majority of the pilot sites with a photovoltaic array planned for one housing complex for meeting the space heating and hot water needs. The condominium owners are to receive information on how to most effectively use the new building services equipment and solar shading.

6.3 Milan

The childcare center will be retrofitted using prefabricated integrated elements with a high level of thermal insulation and air tightness. Automated solar shading during the day and summer natural night ventilation via automated windows and two additional stack flow elements will provide summer comfort without active cooling. The building will fulfill the definition of a nearly zero-energy building (NZEB), and will be one of the first examples of a NZEB retrofit in Italy (Causone et al. 2015a, b; Pagliano et al. 2016).

The social housing blocks will also undergo an ambitious deep renovation, though not to the NZEB level. They will be important benchmarks for future activities from technical, organizational, and financial points of view. It was impossible to apply double-flow ventilation on the largest social housing building block because of space limitations. Therefore, an alternative way of recovering energy from the exhaust air has been developed. A heat pump uses the extracted air as a heat source for delivering energy at low temperature for the preparation of domestic hot water. The other two apartment blocks are close to Chiaravalle Abbey and the “agriculture park”. They will be integrated into a redesign of bike access to the abbey and the park for better connection to the district and the city. White roofs and greening are being analyzed as means for reducing the heat island effect. Thermal energy for heating will be generated efficiently in the Linate cogeneration plant owned by the local A2A Energy Utility.

6.4 Sestao

The demonstration buildings for refurbishment were constructed from 1890 to 1930 and aim to reduce energy consumption by more than 50 % from the calculated original energy consumption levels. More than 200 scenarios with five different HVAC systems with and without heat recovery have been considered in whole building simulations to determine the most effective combination to reduce energy demand and consumption for reaching the energy savings targets. None of the demonstration buildings in the base case scenarios have central heating systems and most have rudimentary heaters such as small electric radiators or butane heaters to provide minimal heat in winter. The thermal renovations are improving the efficiency of the building envelopes by increasing insulation levels and replacing windows with higher thermal values. Innovative technologies considered for the demonstration buildings include the use of biomass boilers combined with high energy efficiency ratio (EER) chillers and heat recovery, as well as ground source and high-efficiency heat pumps with heat recovery. The majority of these apartment buildings are either unoccupied or occupied by elderly or immigrant owners. Sestao has established an innovative procedure for carrying out the thermal refurbishments with upgraded building services for apartment buildings. The solution has been developed by Sestao Berri 2010 and is innovative for residential renovations in Spain. The renovation plan is carried out in five stages (Heidenreich et al. 2014):

1. Sestao Berri 2010 purchases both unoccupied and occupied flats from owners who are willing to sell in an apartment building.
2. The first phase of the thermal building renovations with upgraded building systems begin in the unoccupied flats.
3. The tenants who decide to remain in their apartments are temporarily relocated to the newly renovated flats in the apartment building at no cost to the tenants. The tenants are financially compensated with a basic income during the renovations.
4. The second renovation phase begins upon completion of the first phase. Upon completion of the thermal renovations, the formerly unoccupied flats are then put on the market to be sold as social housing, and the tenants move back into their original flats.
5. The sale of the flats as social housing finances the building renovation costs.

The renovation process has been designed to provide the least inconvenience for building inhabitants while simultaneously providing a source of financing for the construction works. All apartment buildings in Sestao participating in the EU-GUGLE project will follow the five-stage renovation process for thermally upgrading the building envelope coupled with an innovative building services installation.

6.5 Tampere

In order to celebrate Finland's centenary, Finland has decided to meet the EU's 20-20-20 goals for 2020 three years early in 2017 (Finnish Ministry of the Environment 2010). The City of Tampere aims to be a resource-efficient and low carbon smart eco-city. It is expected that consumers and businesses through their consumption decisions will lead the free market to become more efficient when using energy in Tampere. All measures form a part of the "energy-smart built environment" vision for Finland that creates "an energy-efficient, low-emission, high quality built environment that employs all necessary means to mitigate climate change" (Finnish Ministry of the Environment 2010). The vision includes five different areas: buildings, energy, waste, transport, and services (utilities) for meeting the goals of the energy-smart built environment (Heidenreich et al. 2015).

6.6 Vienna

Three large-scale social housing projects are in the advanced planning stage and are scheduled for construction tendering later this year. Coupled with one large social housing block is the multi-active façade, an innovative research project using pre-fabricated panels that is part of the *City of the Future* federal research scheme (Treberspurg 2016). Four smaller apartment buildings are at an earlier design phase, and the process used for the completed pilot project is applied to these buildings. The innovative solutions being developed within the framework of the EU-GUGLE project will be replicated in the second project phase within other Viennese districts.

7 Discussion

Even though the 20-20-20 goals by the European Union are quite clear about the desired objective, and the general methodology within EU-GUGLE to meet the objectives is the same in all pilot districts, the resulting solutions are different due to secondary aspects and varying framework conditions that influence each city. Factors such as the existing ownership models for the pilot buildings (i.e., private versus public ownership), the existing condition of the buildings along with the construction typology, the chosen upgrade of the external envelope, the selected HVAC and RES technologies, available financial incentives, municipal regulations, and the condition of the surrounding infrastructure all influence the project outcomes.

The involvement of the varied stakeholders is a key element to the project. Meticulous planning including state of the art whole building simulations still cannot accurately predict the actual energy consumption by the residents and homeowners, as occupants can change their behavior as they adapt to the building technologies and to the higher comfort levels. Cooperation with the homeowners and tenants to tailor the energy efficiency solutions to suit their requirements has been recognized in this project in order to best meet the ambitious sustainability goals. The involvement of the occupants during the planning and post-occupancy stages gives each person involved a greater sense of belonging and motivation to meet the collective goal of energy savings by adapting their own behavior. Studies have shown that energy-related, occupant behavior can cause energy consumption to exceed initial predictions by up to a factor of three (Polinder et al. 2013), but that cohesion in a group with strong leadership can be a strong positive influence on energy-conserving behavior (European Environment Agency 2013).

Quantitative feedback about the effectiveness of the chosen measures through various building monitoring applications is important for all stakeholders. The building monitoring systems provides feedback for stakeholders, such as designers and researchers, who do not usually have access to data regarding the effectiveness of the solutions. Greater involvement by the local governments to create a sustainability framework with financial incentives for innovations in research and creative renovation solutions is enhancing the effectiveness of the project and influences the pace of refurbishment.

8 Future Research Directions

More research is needed about the actual long-term impact of residential energy-related occupant behavior on the total energy consumption of buildings. Many simulations and models of energy-related occupant behavior can be found in the literature, however, long-term access to residential energy use data is difficult to obtain and the predicted energy consumptions in the models are often more optimistic than the actual measured values (Andersen 2009; Branco et al. 2004; Wei et al. 2014). The energy use data from building monitoring in each demonstration district can not only help the building users directly but also improve the general body of knowledge about the interaction of people with new and efficient HVAC systems in residential and institutional buildings on a large scale. The building monitoring systems can also help to verify the extent of the effectiveness of the various measures used to promote energy-efficient behavior. Quantitative data showing the extent to which the goals of energy-efficient behavior change have been met within the energy efficiency directive (European Parliament and Council 2012) can also be measured to determine the effectiveness of the directive.

9 Conclusions

An overview of the activities within the EU-GUGLE demonstration project has been presented illustrating how the integrated approaches involving various stakeholders in the six partner cities are working together to sustainably revitalize approximately 200,000 m^2 of the mature building stock and the urban infrastructure on a district scale. The approach focuses upon improving energy efficiency, decreasing energy consumption, while increasing the portion of innovative HVAC and RES systems. The sustainability goals of the European Union have been aligned with each city's sustainable master plan despite the challenges of very different building traditions, cultures, climates, and political structures in each country. The success of the project is due to the knowledge exchange and integrated efforts of the dedicated stakeholders within each EU-GUGLE pilot. Parallel efforts in related projects within each city help each partner city to move closer to the goals of the European Commission's Smart Cities and Communities Initiative: to reduce primary energy consumption by 40–80 % and increase renewable energy use by 25 % through nearly zero-energy building renovation models by 2020. The pilot projects' results are being extended within the replication cluster as the knowledge, experience, and technical innovations gained within the EU-GUGLE pilot cities are shared within the campaign to the associated cities and abroad via the replication cluster (youris.com European Research Media Center 2016).

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ICT Tools to Foster Small-and-Medium-Enterprise Collaboration in the Energy-Retrofitting Sector

Fabio Disconzi and Arturo Lorenzoni

Abstract Since decades, the European Commission has turned the spotlight on energy efficiency in the building sector. While the technological domain has been investigated achieving interesting results, on the organizational and financial sides there is still a lot of room for new advancements. Especially in certain countries, the construction sector has to face many challenges. The highly fragmented markets, the cumbersome organizational models adopted by big enterprises on the one hand and the lack of knowledge and skills of Small and Medium Enterprises (SMEs) on the other hand, the perpetual variability of supporting schemes, and the plethora of regulation frameworks represent huge barriers in leveraging new ways to collaborate. Focused on SMEs, the NewBEE EU-project sheds light on innovative methodologies to set-up new collaborative business models in the energy-retrofitting sector that may accelerate the transition towards more sustainable buildings and cities. SMEs currently face two main problems: (a) the availability of easy-to-access knowledge and (b) the ineffectiveness of existing organizational and business models. To tackle these issues, NewBEE provides a comprehensive ICT platform to foster innovative methodologies facilitating the collaboration of actors in the energy-retrofitting chain, enabling the adoption of the business models. The paper briefly introduces the NewBEE-project approach followed by the description of the core modules of the tools:

a. Prompt and accessible information about emerging technologies and business model are collected in the information repository.
b. The pre-assessment tool enables buildings' owners to roughly estimate the energy-saving potentials of common renovation processes, receiving in return an order of magnitude of the investment's costs.

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c. The virtual breeding environment is the main module of the tool: it is where SMEs collaborate, putting in place virtual collaborative networks to make a proposal.
d. The financial simulator enables building owners, investors, and SMEs to understand the effects of different financing schemes and the implications of energy-cost variations on the profitability of the investment.
e. The energy assessment module provides a professional tool to simulate the building performance before and after the refurbishment process.

The application of the NewBEE methodology has been tested in four real business cases: Spain, Slovenia, Germany and Finland. Recommendations raised during the demonstration phase are reported. In a mature market like the building one, the NewBEE project shows how innovative ICT technologies may help SMEs to fine-tune their business model, creating opportunities to collaborate both in a virtual and a real way.

Keywords Business models · Energy efficiency · Organizational models · Buildings retrofitting

1 Introduction

More than one third of the total global final-energy use is accounted for by the building sector. The related CO_2 emissions account for approximately one fifth of such emissions, but this figure may double or triple by mid-century, based on several key trends. However, technological solutions to control the increase in final-energy use already exist, even if several barriers hinder the adoption of even of the more cost-effective solutions. Barriers affect many aspects of the finding solutions: imperfect information, split incentives, lack of awareness, transaction costs, inadequate access to financing, and industry fragmentation (IPCC 2014).

The unpredictable cost of energy, the increasing green consciousness of populations, and more severe building regulations are expected to impact the market penetration for low-carbon solutions in the construction sector. While, for large companies and technology providers, it can be relatively easy to adapt their know-how and apply new innovative technologies, materials, and methods, this is not the case for Small and Medium Enterprises (SMEs) which usually have very specific competencies that narrow down to a specific field but don't have prompt access to competitive knowledge and are not used to truly collaborate in networks.

Nevertheless, the role of SMEs in several sectors is not negligible since they are the backbone of the European economy, and the European Commission considers them as "key actors to ensure economic growth, innovation, job creation, and social integration in the EU" (European Commission 2015). Definition of SMEs widely vary around the world: Parker et al. (2009) investigated this in-depth while assessing nearly 50 journal articles and finding that:

> European studies mainly use the European Union's (EU) definition of SMEs "fewer than 250 staff", while Australian studies use "less than 200 staff", USA and South Korean studies use "less than 500 staff", and New Zealand studies use "less than 100 staff".

Although the definition of SMEs widely varies among countries, in this article we adopt the European Union's definition that states "enterprises having less than 250 staff and a turnover lower than 50 million euro" (European Commission 2003).

Along with the need to support SMEs in understanding how to implement emerging energy-technologies, new financial, organizational and social-innovation enablers are required to leverage transformation towards more sustainable buildings and cities.

Enterprises are urged to modify their business model in order to be more responsive to the economic environment, and Information and Communication technologies (ICT) may provide a valuable support. The NewBEE project attempts to explore the capability of ICT tools for fostering collaboration among SMEs and providing guidance to generate project-specific business models.

1.1 Collaboration Fosters Innovation

Fostering collaboration is one of the main targets of the NewBEE-project approach. Since decades, the idea that firm alliances/networks improve the results of business has been researched. Dyer and Singh (1998) stated that "competition between single firms, while perhaps still the rule, is becoming less universal, as pairs and networks of allied firms have begun to compete against each other" and "an increasingly important unit of analysis for understanding competitive advantage is the relationship between firms".

Even before the pervasive advent of ICT, establishing sound and reliable networks brought competitive advantages to companies. Baum et al. (2000) showed the impact of network composition in startups' performance during their early stages. The risks of startups are mitigated when they are able to secure relationships and networks with key actors of the sector/industry; in fact, startups that "at the time of their founding formed upstream and downstream alliances and configure them to provide access to more diverse information and capabilities generally exhibited stronger initial performance".

Also during the early growth of the firm, networks should evolve and adapt in response to resource needs and resource-acquisition challenges (Hite and Hesterly 2001). Firm networks evolve from the kind of networks that have a "high proportion of ties where some type of personal or social identification with the other actor motivates or influences economic actions" (identity-based networks) towards networks where "the potential purposes and functions of the network ties become a more predominant theme than the identity of the ties" (namely, calculative networks).

Collaboration affects SMEs' innovation process. The innovation process requires direct or indirect access to new pools of information, knowledge, and competencies, some of these being produced only in research-intensive and collaborative environments. The former activities are less diffused in SMEs since they usually have less financial and human resources, less access to advanced sources of knowledge, and shorter time horizons compared to large firms. Thus, to compete in fast-changing markets, they should operate in a collaborative environment: SMEs have to be connected to each other in the most effective way, thus promoting exchange of information and competencies. Benefits generated by collaborative networks (CNs) impact the entire lifetime of an enterprise and empirical studies have confirmed that collaborating firms are more innovative than non-collaborating ones (OECD 2001).

The networking process affects also organizational models, managerial practices, and working methods, pushing firms to cope with the increasingly interdisciplinary nature of today's businesses. This is a complex process often hindered by a lack of motivation to do so, but fostering innovation is a key strategy for success, and collaboration is a prerequisite in order to pursue it (OECD 2004).

Entrepreneurs and stakeholders should clearly understand both the potential and the limits of embracing new business opportunities. The formation of new collaboration networks won't benefit all the companies in the same way: understanding how value is created and shared among partners is of paramount importance. Moreover, the definition of an acceptable business model to adopt by a CN depends on the specific business opportunity to exploit. CN's stakeholders need a systematic approach to use in order to clearly describe the business model of the CN, highlighting the elements that shape it and their correlations. Jimenez et al. (2005) proposes a template which helps enterprises to shed light in this field. The proposed methodology, based on an ontology, with a five-step process provides guidance to set the basis for developing and understanding a project-specific business model. It has been partly adopted during development of the NewBEE project.

1.2 ICT Fosters Collaboration

As seen in the previous paragraph, collaborative networks have a high potential as drivers of value creation. The concept of collaboration is very broad. It has been well analyzed in Camarinha-Matos and Afsarmanesh (2008):

> a process in which entities share information, resources and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal. […] a process through which a group of entities enhance the capabilities of each other.

In the NewBEE project, the concept of a collaborative network (CN) is strictly linked to the use on ICT tools and follows the definition given by Camarinha-Matos:

> A collaborative network (CN) is a network consisting of a variety of entities (e.g., organizations and people) that are largely autonomous, geographically distributed, and

heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, and whose interactions are supported by computer network.

The advantages brought by ICTs to SMEs not only impact on their collaborative capabilities but affect several aspects of enterprises. Barba-Sánchez (2007) stated that, especially in fast changing markets, an adequate and intensive use of ICTs is crucial in order to make a business more responsive to market opportunities. "ICT can provide a wide variety of benefits to firms, ICT can reduce business costs, improve productivity and strengthen growth possibilities". Moreover, "the adoption and implementation of ICT by firms can improve business cooperation, business relationships, quality and diffusion of knowledge".

In an economy that is increasingly based on information, a sound and efficient knowledge–management system (KMSs) is increasingly becoming a strategic asset of a company. There is a general consensus that the benefits of a robust, user-friendly and ICT-based KMSs have not been exploited by small firms yet. Not only for internal purposes but also for external ones, there is much room for improvements, and entrepreneurs also perceive the potential. Together with the need of a new kind of Knowledge Management System able to improve operational management and to discover market opportunities, empirical investigation (Evangelista et al. 2010) reveals that "The surveyed firms show the need for wider (external) KMSs enabling inter-firm collaboration in developing collaborative projects." The survey was carried out in 2008, on 18 SMEs operating in a network of 25 companies having working mechanisms similar to the envisioned one of the NewBEE project.

The main barriers in adopting collaborative environments concern the protection of intellectual assets, in fact the survey demonstrates that "the unavailability of partners to share knowledge and the need to protect critical information are the most relevant barriers". But there is some information that SMEs are ready to share: "most important information that firms are willing to share are related to linkages with institutions and funding opportunities." Moreover there are also some areas for developing new KMS practices: "KMSs may support relationships with customers in order to facilitate both the exchange of relevant information and improving communication with them"; the NewBEE project embraces these opportunities by developing a platform with user-friendliness characteristics, dedicated to both practitioners and non-professional people.

1.3 NewBEE Platform as a Project-Specific Business-Model Generator

The interest in the renovation of existing buildings has never been so high. In 2011, the renovation sector was responsible for 7 % of EU GDP, with over 11 million people were directly employed in the building sector. It is clear that the construction sector may play an important role in achieving European targets since “the building stock is the largest single energy consumer in Europe. Its share of total final energy consumption was 40 % in 2012, making buildings responsible for 38 % of the EU’s total CO_2 emissions”.

In this context, the active engagement of SMEs is of crucial importance: the EU building sector is characterized by a high number of small and medium enterprises, most of them operating at the local level. Indeed, “enterprises with less than 50 employees generated 72 % of the sector’s value added, while those with over 250 generated 14 %” (European Commission 2015).

But never before as it has in recent decades, the world is facing deep modifications (e.g., the financial and economic crisis, new needs, demographic variations, etc.), and changes occur at a pace never yet experienced. Also, in the construction-sector advancements in energy technologies for civil buildings (e.g., lighting, ventilation, heating, and air conditioning), the penetration of ICT technologies in control systems (such as remote sensors and remote management), the emerging of new organizational models for enterprises, constantly changing financial incentive mechanisms, social innovations, and new performance-based business models are expected to radically transform the sector.

From the point of view of enterprises, new business models (BM) able to cope with the aforementioned challenges are needed. Especially in the construction sector, the implementation of successful “greener” business models is strictly linked to the involvement of the actors of the entire value chain. There won’t be a real adoption of new business models unless every stakeholder involved in the project commits to their actual adoption. The NewBEE project aimed at developing the framework (i.e., concepts, methodology, and ICT tools) to better address the issue.

Even if large companies have the skills to effectively adopt new technologies since they cover a large span of the value chain, their cumbersome organizational structures generate difficulties in following the pace of changes that new energy technologies, together with ICT advancements, are bringing in all sectors, but also in traditional ones like construction. SMEs, which are characterized by their dimension, small or medium as the acronym says and by a streamlined organization structure, often operate only within a “few rings” of the value chain. This brings into focus two opposite characteristics of SMEs: on the one hand, small dimension causes a lack of capability for widening their knowledge and technical capability, and, on the other hand, a “slim” organization is usually more responsive to external conditions and faster to adapt to project-driven BMs.

But having lighter organizational structures can be a competitive advantage, and the ongoing changes in the construction sector potentially open the door to a larger market that was unattainable until few years ago and only the prerogative of large and structured companies. However, to exploit this opportunity, SMEs need new ways in doing business: they need to collaborate in a new radical way taking advantage of the opportunities offered through collaborative networks.

As stated in the previous paragraphs, both ICT resources (Albesher 2012) and the participation in CNs can be seen as catalyzers of innovations impacting the whole SME business model (Arana and Castellano 2014) affecting also the enterprises' performance (Gronum et al. 2012). Cooperation and active collaboration is no longer a rarely adopted working method, but an increasing trend that is re-shaping the SMEs business models (Mura and Rózsa 2013).

Adopting the Osterwalder framework for business model generation (Osterwalder and Pigneur 2009), the NewBEE project, focusing on the construction sector, aims at supporting SMEs in fostering the development of new BMs through the dynamic creation of project-based CNs by means of web-based tools, and moreover, testing the approach in real in four real business cases.

2 The NewBEE Project

The belief behind the NewBEE project is that advanced ICT tools could foster the SMEs collaboration through the creation of virtual Collaborative Networks enabling the development of tailored energy performance-based business models. The successful implementation of these models, which could unveil synergies amongst SMEs, is closely linked with all the actors of the entire value chain. Therefore, the main innovative aspect of NewBEE is the support of all actors involved in the energy-efficiency value chain of the construction industry, through innovative working methodologies based on a set of ICT tools.

As said in the previous paragraph, innovation is a key factor for enterprises especially in high technological sector like the energy efficiency one. New project-specific and energy performance-based business models can increase the adoption of energy-efficient technologies. NewBEE tools aims at enabling SMEs to set-up collaborative networks before the execution of the intervention, fostering the share of knowledge, best practices, and experiences.

2.1 Introduction to the NewBEE Platform

The multilingual (English, German, Spanish, and Slovenian) web-based NewBEE Platform presented here aims to integrate a set of tools to support SMEs in collaborating and in defining a project-specific business model for energy-efficiency-retrofitting interventions.

The approach behind this mainly consisted of developing tailored tools, with a user-friendly interfaces and in carrying out an "homogeneous platform" to adopt as a basis for the elaboration of new project-specific business models.

The comprehensive approach of NewBEE is based on ICT solutions that will include a 'Marketplace', enabling building owners to identify and place calls for proposals, and SMEs to find retrofitting opportunities. As a result of sharing knowledge, users will be able to choose the optimal technology for energy-efficient retrofitting. And the comprehensive set of tools will enable building owners to publish their requirements by themselves and SMEs to identify business opportunities, ultimately supporting cost and energy-efficient construction. The new concept and innovative methodologies have been validated by testing them in four real business cases (BCs). All the results of the project are available at www.newbee.eu.

2.2 NewBEE Consortium and Working Plan

NewBEE is a research project funded by the European Commission under the Seventh Framework Programme, coordinated by "Tecnalia Research and Innovation" (based in Spain), involving organizations spread throughout Europe. Started in October 2012, it is a 3-year project whose overall aim is to help Small and Medium Enterprises (SMEs) in developing "*New* performance based *B*usiness models in *E*nergy *E*fficient construction work with special incidence in retrofitting sector."

Consortium partnership has involved 17 partners from six different European Countries:

- Five Research and Technical Development centers (RTDs): Tecnalia Research and Innovation (Spain), Fraunhofer IAO (Germany), Institute for Applied Systems Technology Bremen ATB (Germany), Valtion Teknillinen Tutkimuskeskus VTT (Finland), and University of Padua (Italy);
- One large construction company in the role of ESCO: Acciona Infraestructuras (Spain);
- Five SMEs involved in construction sector: FinnEnergia (Finland), Rahm (Germany), Teusa (Spain), Eslamaban (Spain), and Gradbeni Institut ZRMK (Slovenia)
- Two SMEs associations: ifA Bauconsult (Germany) and Slovenski Gradbeni Grozd-Giz SGG (Slovenia)
- Two architects' studios: Eriksson Architects ltd (Finland) and KVA Architects (Finland);
- Two IT developers and vendors: Accrosslimits (Malta) and Conclude (Germany).

The overall work plan has been structured in nine work packages (WPs). WPs followed the logic of research and technological development, starting from the structured collection and analysis of end-users requirements up to the testing and validation of real business cases, through the development of new innovative methodologies supported by ICT tools. RTD and demonstrator WPs were complemented by two important WPs focused on dissemination of results and exploitation of the project (WP8) and on project management (WP9).

At the outset of the project, a structured review of existing methods, tools, and technologies was carried out in reference to envisioned BCs scenarios (WP1 and WP2). Since NewBEE has been a strongly end-user-driven project (SMEs, building owner, ESCOs, architects, and other stakeholders indirectly covered by consortium partners), the key topic of the first phase was to make available a clear analysis of the end-user's requirements to assess both technical and non-technical needs.

Once requirements had been clearly stated, the project elaborated the overall concept specification (WP3) for the new NewBEE methodology, the ICT platform, and services. WP4 dealt with identification of optimal BMs for the energy-efficient-buildings retrofitting, and, together with previous end-user requirements (WP1, WP2), concept terms (WP3) provided specifications for the NewBEE ICT-platform-development phase (WP5). The platform prototype developed during the first phase of the project had followed an iterative approach of testing and improving (WP6), arriving at the integration with the BCs' existing infrastructures.

WP7 had a very important role in the project since it involved several industrial partners from four countries to demonstrate the methodology and ICT tools, and which served as showcases for dissemination and exploitation activities (WP8).

3 The NewBEE Platform: The Set of ICT Tools

The NewBEE set of tools has been developed to foster an early involvement of SMEs and stakeholders of the construction value chain, fostering them to generate the most appropriate BM for each specific project. This is facilitated by the provision of highly accessible knowledge related to several competitive aspects such as best available technologies, organizational models, financial mechanisms, and performance based contracts.

The NewBEE platform is composed of a heterogeneous ICT tool which helps SMEs in dealing with the majority of the challenges described in paragraph 1.2. It consists in six web-based software tools accessible through internet connection and therefore no installation is mandatory for the users.

It includes the following tools:

- *Wiki-based knowledge repository (WIKI)*: the purpose of this tool is to give building owners and professionals access to structured information on retrofitting technologies, organizational, and business models;
- *pre-assessment tool (PTA)*: the purpose of this tool is to support building owners to make a first estimation of needed refurbishment (in terms of technologies and costs) and the magnitude of energy savings;
- *financial calculation tool*: the purpose of this tool is to support building owners and SMEs to compare different financial alternatives for a retrofitting project;
- *marketplace (MP)*: the purpose of this tool is twofold: (i) to support SMEs to find business opportunities (BO) and to search for partners to create a project-driven, virtual, collaborative network to elaborate an offer that satisfies the building owner requirements; (ii) to support building owners to publish a call for proposals, to choose an offer from those received, and to find service providers;

- *energy-performance assessment tool (E-PASS)*: the purpose of this tool is to support SMEs (and advanced building owners) to assess the potential savings of alternative refurbishment projects. It is not intended for standard building owners;
- *business-model assessment tool*: the purpose of this tool is to provide a brief assessment to CEOs and management staff of small companies which are interested in reviewing their business model.

Particular efforts were made to develop the Graphical User Interface (GUI) and the User Experience (UX). It was designed to be used by a wide variety of users, also by people with low knowledge about energy-related topics.

Table 1 summarizes the web url and target groups for each tool of the NewBEE platform.

3.1 Wiki-Based Knowledge Repository

The increasing pace of energy-related technological innovations, the expected global market increment of low- carbon solutions for energy-efficiency retrofitting and the pressing need to handle the knowledge generated by previous projects brought the consortium to design an effective knowledge-management system called the NewBEE wiki-based knowledge repository. The NewBEE wiki gives building owners, practitioners, and experienced professionals access to organized and updated information on the construction sector. The tool is highly usable since it is a media wiki application based on the same software and engine used for the well-known "Wikipedia" portal.

Table 1 Tools and end-users target group

Name of the tool and url	Building owners	SMEs
Wiki-based knowledge repository url: http://www.newbee-wiki.eu/wiki/index.php/Main_Page	X	X
Pre-assessment tool url: http://www.newbee-wiki.eu/step1.php	X	X
Financial calculation tool url: http://www.newbee-wiki.eu/finance/new.php	X	X
Market place url: http://www.atb-bremen.de/marketplace/index?1	X	X
Energy-performance assessment url: http://cic.vtt.fi/epass/vtt/step_1.php		X
Business-model assessment tool url: http://plm.iao.fraunhofer.de/newbee/homePage1.aspx		X

3.2 Pre-assessment Tool (PAT)

Building owners can use the pre-assessment tool to receive a first idea on retrofitting measures and to identify the most appropriate retrofitting technologies based on their requirements. It allows the generation of different technology scenarios that might be appropriate to address the building problem at hand (taking into account, e.g., building characteristics, local climatic conditions, etc.). The tool is useful for getting an estimation of the costs and the magnitude of energy savings. Building owners, after the rough cost and savings analysis are allowed to publish a "call for proposal" in the marketplace or use the data for the evaluation of the project's economics by passing the data to the Financial Calculation Tool.

SMEs might as well use the PAT as a tool for communicate with building owners or to facilitate the transfer of concepts during the initial phases of a renovation project.

3.3 Financial Calculation Tool

The financial calculation tool is a service for users who want to analyze the cash flow generated by a retrofitting project. The main purpose is to improve the building owners' level of awareness in the field of energy economics.

The module enable users to simulate several ways of how to finance a project and provide schematic annual cash flows comprising expenses and savings generated by intervention. Users can simulate effects on cash flow of several finance opportunities (as incentives, loans, taxes reductions, etc.) and generate different scenarios assuming various patterns for annual cost of energy. It also enables users to graphically visualize annual cash flow both in tabular and interactive graphical ways.

3.4 Marketplace

Marketplace can be considered the kernel of the platform and works in connection with PAT. It acts as a catalyzer of business opportunities and translate the NewBEE methodology advancements into features that facilitate SMEs to generate new project-driven CNs and BMs.

The purpose of the marketplace is manifold and depends on the user.

From SMEs point of view it helps them (i) to find BO in refurbishment market and (ii) to search for partners to create a network to elaborate an offer that satisfies the building owner requirements. The marketplace supports SME that provide specific services for energy efficiency refurbishment enabling them to:

- register and participate in a stimulating environment, with high level information and knowledge, with favorable conditions for improving their business model;
- search for business opportunity (proposed by single building owner or by building associations);
- search for partners in order to create a network, able to develop a project-oriented business model;
- provide an offer to the business opportunity proposer as member of an SMEs network

From the building owners' point of view, marketplace is useful to find service providers, in form of single SME (for small projects) or network of them. The market place enables building owners to:

- publish a call for proposal (from scratch or more detailed with the help of the Pre-Assessment tool);
- search for service providers;
- receive refurbishment offers (i.e., building owners can see all offers SMEs' networks made according to their published requirements).

Users' workflows within the marketplace are very complex and interconnected; they cannot be sketched by a step-by-step process. However there are some processes, summarized in Table 2, that represent the functional blocks of the tools.

3.5 Energy Performance Assessment Tool (E-PASS)

With the support of this tool, SMEs and advanced owners can assess the potential energy, cost, and carbon savings resulting from different refurbishment actions broken down into a high level of detail.

Table 2 Main marketplace functionalities

SMEs' functional blocks	Building owners/institutions/business proposers' functional blocks
• Register and log-into the platform; • Filter opportunities • Search for partners • Invite partners • Accept/reject partners • Compose a team • Partners collaboration to create an offer • Team leader send an offer • Get in contact with business proposers	• Register/log-into the platform • Search for service provider • Publish a call for proposal • Select/accept/reject an offer • Get in contact with a network of SMEs

The tool is available for exploitation by SMEs that do not have much resources of their own to develop and learn other professional energy performance assessment tools, but that need energy-performance assessment tools for implementing consultancy, design, product development, marketing, and renovation project management.

The tool makes automatic and “intelligent” assumptions for the analyzed building. Assumptions are based on basic data of the building such as location, building type, construction year, etc. Once the user has inserted a few parameters, the E-PASS tool fetches all necessary details (e.g., the U-values, window-types, water consumptions, electricity consumptions, electric appliances, etc.) from the building-representative databases. Building characteristics and energy systems details can be specified afterwards as needed, enabling more accurate calculations.

3.6 Business Model Assessment Tool

The objective of the business-model assessment is to provide a quick assessment to CEOs and management staff of SMEs that are interested in reviewing their BM. The assessment tool is based on Osterwalder Canvas Model and is deeply connected with the Wiki-based knowledge repository.

The tool itself is a guided questionnaire that gives users the opportunity to do a qualitative rating of their company performance concerning different aspects of their BM. Answers are multiple choice, i.e., the users will tick the box with the answer that reflects the actual performance of their company concerning each aspect that is scrutinized in the questionnaire. Each major building block of a BM (like customer relationship or value proposition) is screened by means of at least two different questions.

4 Demonstrations

Since the NewBEE project outputs, on one hand rely upon new services still not widely adopted and accepted in many working environments, and on the other hand introduce new cooperation paradigms and innovative collaborative models never tested before, real demonstration phase has been extremely important. Activities entered into WP7 served to validate the RTD results in industrial contexts facilitating their dissemination within the retrofitting industry and wider industrial community.

Moreover, the demonstration phase has also enabled the consortium partners to better prepare the conditions for the product development and future commercialization (exploitation of the results), and hence facilitating the envisioned penetration in the market.

The overall target of the demonstrations activities was to operate the NewBEE platform in realistic workspaces, addressing stakeholders' collaboration in the planned scenarios. Industrial partners with the support of RTDs have specifically analyzed business benefits brought by the platform which provide valuable feedback for future developments.

4.1 Business Cases and Sub-business Cases

The comparison between the current retrofitting approaches with NewBEE project functionalities has been tested through their adoption in a set of real situations, called Business Cases (BCs) and feedback have been collected from the stakeholders involved in the value chain.

Each BC has been split into sub-business cases (SBC) with the aim to cover all the most common situations that could emerge in Europe within the energy-retrofitting sector. Geographically, BCs spanned from Spain to Slovenia and from the south of Germany to Finland. Involved stakeholders ranged from the single-building owner who wants to retrofit a little flat to the technical office of a region in charge of retrofitting a dozen multi-flat buildings.

In each business case, stakeholders tried to adopt and to integrate NewBEE project features into the real cases, highlighting obstacles and evaluating innovations and improvements brought by the NewBEE approach to traditional processes.

Four different BCs and twelve SBCs have been studied, in each one of them testing different applications of the NewBEE platform modules.

The following paragraphs summarize the planned targets of sub-business cases and describe how the usage of the platform helped stakeholders in cope with them. Since each BC presented significant differences, a common approach to describing the results is not possible. Each paragraph describes the outcome raised from each BC.

4.2 BC1—Spain

4.2.1 Introduction

The Spanish BC demonstrated the validity of the platform in the retrofitting activities for a block of residential buildings. BC1 planned to adopt the NewBEE methodology and web-tools in four different sub-cases. The targets and the planned activities of each sub-business case can be summarized as follows.

SBC1 target was to investigate the behavior of those *responsible for the building's neighborhood (Neighbors Commission)* that, at the beginning of the retrofitting process, wants to analyze the energy-efficiency potential of the building, to identify the most appropriate technologies, and to obtain support for the refurbishment deployment. In particular, the demonstrator simulates the retrofitting of the facades of a multi-apartment building.

By SBC2, *a group of SMEs* collaborate to participate in a tender for a large project. The target was to evaluate the capability of the platform to enable the setting up of new CNs between SMEs with specific knowledge and competencies, i.e., for complementing their individual expertise in order to facilitate an innovative joint approach to tackle the subject of the tender.

SBC3 dealt with an actual need of a retrofitting project. The demonstrator simulated how a retrofitting intervention can be done by *analyzing the workflow from different users' perspective*. It investigated the usability and the user experience of private building owners and SMEs. An association of homeowners, united in a housing association, was seeking help from various local construction companies, looking to contract directly with companies, without outsourcing or intermediaries. Local companies were looking for other construction companies to create a temporary alliance (CN) with all the needed competencies to solve the problem.

The target of the fourth Spanish sub-case SBC4 was to demonstrate how the NewBEE project can be useful to provide in-depth technical and economic data *to customers* who wanted to know beforehand the energetic behavior they can expect from a specific retrofitting project. The comparison between the results given by the MEEFS technology developed in EU MEEFS Project (http://www.meefs-retrofitting.eu/) and the results delivered by the E-PASS (Expert Energy assessment tool of the NewBEE platform) provided outcomes on the validity of the methodology and platform.

4.2.2 NewBEE Platform Usage

SBC1: Four different modules of the NewBEE Platform have been used and demonstrated: the Wiki-based knowledge repository, the Pre-Assessment Tool, the Financial Calculation Tool, and the Marketplace. The wiki module has been used by the responsible neighborhood community to get general information about different technologies that can be applied in the buildings. PAT provided a rough idea of the energy savings, the magnitude of costs, and the payback period of three different scenarios. The responsible parties investigated the economics of specific scenarios by exploiting features of the financial calculation module. This encouraged those responsible to continue using the platform. Each had have two different possibilities to follow at the same time: to ask for proposals in the Marketplace or to contact an energy consultant.

SBC2: in this scenario, the marketplace features were tested by fostering the creation of virtual collaborative networks in order to make an offer for a big project (the sub-case considered a hospital retrofitting: changing the roofs and improving the energy performance of the walls). Public administration representative registered on the platform and entered the business opportunity. The business opportunity was found by a group of SMEs that could make an offer on the platform. The method for conforming the relations and the formation of the group was managed by the NewBEE platform in a specialized manner that is proper for the retrofitting sector.

Once the NewBEE platform has become a commercial product, the consortium will invite various large organizations to participate, but also groups of smaller organizations that can be constituted as a virtual CN, a temporary union of organizations (also called by end-users as a cluster or joint venture). The NewBee plaftorm facilitated the creation of that kind of network in an innovative fashion, and this sub-case provided valuable hints on the usability of the marketplace, improving the user experience of the processes.

SBC3 tested the usage of marketplace from the point of view of two different actors: building owners and networks of local SMEs. The owners of a building needs were (i) finding a new way to contract companies at minimum costs (especially to avoid outsourcing, the company-searching phase, and intermediary costs), (ii) gaining knowledge about the construction sector, and (iii) making a business proposal. Local SMEs adopted the platform to (i) establish a virtual collaborative network able to be technically complaint with building requirements and (ii) finally make contact with those responsible parties for the business opportunity.

Again, the sub-business case demonstrated that building owners who proposed the business opportunities received several offers from various project-oriented SMEs networks. Once owners have decided to choose one SMEs-network, negotiations began until a common point was achieved; at this point, a new business model was formed, and the retrofitting project would have been started.

SBC4 aims were to test the NewBEE platform comparing the result of a renovation that occurred in Spain (an apartment building located in Merida) with the figures provided by E-PASS tool. The calculated values demonstrated that the E-PASS tool calculated the energy savings related to the insulation work in a convenient way for advising the owner what to expect from this work. The economics of the renovation project had been estimated by using the financial calculator module. Both results were compared with the ones obtained in the real case, and the discrepancies were small, around 10 %, so that the platform demonstrated the accuracy of the fast calculations made by the NewBEE platform.

4.3 German BC

4.3.1 Introduction

The German BC tested the NewBEE methodologies and platform for the most common building type in rural areas, single and multi-family houses. Moreover the methodology and the platform were tested by adopting some modules of the project during a professional working group on energy efficiency.

For this business case, the coverage of the entire value chain has been demonstrated: first contact of the building owner and building users; identification of the most appropriate retrofitting technologies; linkage and collaboration between building owner and construction SMEs; and project management support and testing of the business model assessment.

The German business case investigated three specific sub-cases:

SBC G1: Support of a working group on energy-efficient construction and refurbishment: this business case investigated the adoption of the wiki-knowledge repository within a working group of practitioners in the construction industry practitioners.

SBC G2: Application of NewBEE platform to support the retrofitting of a German single-family building: this scenario validated the NewBEE methodology for the communication and collaboration between building owners and SMEs (specifically Rahm) due to the features provided by NewBEE.

SBC G3: Application of the Business-Model Assessment to support the business development of a SME in the construction industry: this sub-case shows, especially for the company Rahm, how they had conducted the BM assessment and which results/recommendations they achieved.

4.3.2 NewBEE Platform Usage

For each German sub-case, the following tools were tested:

- *SBC G1 sub-case demonstrated the application of the wiki within a working group for the construction industry.* The scenario tested the potential use of the NewBEE platform for companies focused on consultancy (e.g., ifABau Consult) as well as on providing knowledge transfer in the construction industry. Compared to former (traditional) ways of providing the acquired knowledge, like distribution of information by mail or providing a paper-based summary of working group meetings, the NewBEE wiki proved more attractive for working group members. Its perceived advantages were: better information structuring; flexibility concerning continuous adaptations of the content; and the semantic features (like semantic search).
- SBC G2 sub-case demonstrated the adoption of the pre-assessment tool for involving potential customers at early stages of the project. This sub-case highlighted the potential of the pre-assessment tool as a communication helper between the customers and the SMEs, especially during the first phase of the project. After the first meeting, calculation tools were used autonomously by the potential customer to identify various potential raw scenarios for the retrofitting projects. Customer used the wiki to understand the energy technology in detail. The sub-case also tested the marketplace from the point of view of a single SME: Rahm identifies the NewBEE marketplace as an optimal environment for finding business opportunities and partners.
- *SBC G3 sub-case: an SME tested the business model assessment.* The initial idea of the tool was improved with the support of various SMEs in Finland, Germany, and Spain. A working version has been tested with a German SME.

The tool itself is a guided questionnaire that gives users the opportunity to do a qualitative rating of SME performance concerning various aspects of their business model. The NewBEE wiki also provides follow-up information after submitting the assessment. Several business models and business cases are described that are typical for the construction industry and a handbook. It has to be emphasized that the company had no problems to perform the assessment by itself. Feedback provided: "the assessment uses the right language and assesses the critical aspects of an SME business model." After the review of the current business model, in a second step, the business model handbook in the wiki was adopted to improve the business. SMEs, who did the business model assessment, reported some benefits from the structured walk-through of the various aspects that are important for the company performance. They stated they had gained a detailed understanding of the most important aspects of a BM. The BM assessment, due to the organized analysis, also provided clues and suggestions on measures to implement to impact the performance of business model in general. After dealing with the obtained recommendations, a repetition of the assessment helped SMEs to understand the impact of the taken actions.

4.4 *Finland BC*

4.4.1 Introduction

The Finland demonstration phase investigated mainly the usability of the NewBEE tools especially from the viewpoint of the Finnish partner SMEs. It extracted functional requirements based on three cases studies. The Finnish SMEs partners are two architectural offices and one energy consultant. The Finland BC focused on demonstrations of the following tools: the NewBEE Marketplace and E-PASS energy assessment. For the Marketplace, the purpose of the demonstration was to validate the features that help SMEs to find BOs in the refurbishment market and for building owners to find service providers.

The platform was demonstrated in sessions where the Finnish SMEs investigated two different points of view for each tool: the point of views of the building owner and of the SMEs.

4.4.2 NewBEE Platform Usage

The Finnish demonstration sub-cases focused mainly in providing feedback about the usability of the Marketplace and the E-PASS tool. To achieve this aim, several sub-cases have been tested:

MP Case 1: House manager of a housing association creates a business opportunity.

MP Case 2: Energy consultant or architect searches for a business opportunity.

E-PASS Case: Energy consultant or architect uses E-PASS to support a house manager to find sensible opportunities for energy refurbishment.

The BC demonstration was designed so that a house manager in Kuopio supported by the FinnEnergia used the E-PASS tool for an actual building in Kuopio. Together, they followed the steps of a case where a consultant used E-PASS to support a house manager to find sensible opportunities for energy refurbishment. Three house managers participated in the demonstration.

On the basis of the demonstration, the NewBEE tools were useful in principal and might support the work of SMEs in energy-refurbishment markets. The NewBEE platform and Marketplace tool may find their places as a portal that supports building owners to find potential SMEs for energy refurbishment and for SMEs to find partners in order to realize various kinds of refurbishment projects.

4.5 Slovenia BC

4.5.1 Introduction

The Slovenian demo was about the use of the NewBEE platform in the case of large-scale retrofitting project (retrofitting many buildings in the same period).

The proposed case derives from experiences gained during the renewal of the Posočje region after the earthquakes in 1998 and 2004. As more than 3.000 buildings were damaged in the 1998 earthquake, the state organized help to reconstruct the area by securing funds for subsidies to residents in order to reconstruct their damaged homes. The government established the *State Technical Office (STO)* with the role of administrating the governmental financial help and of handling the after-earthquake reconstruction.

According to this context, the Slovenian Business Case demonstrates the adoption of the NewBEE approach by STO for large-scope retrofitting of apartment buildings.

4.5.2 NewBEE Platform Usage

In the case of Slovenian BC, there were three scenarios to demonstrate the NewBEE system in a real environment:

- *SBC1: motivate for retrofit*; use of the NewBEE platform to show to owners of residential multi-apartment old/damaged buildings the potential of energy-efficiency retrofitting; like in the German business case, this sub-case

demonstrate the valuable potential of the platform as a communication tool; its usability coupled with an user-friendly interface enabled experts to explain complex concepts to potential stakeholders;
- *SBC2: finance for retrofit*; use of the NewBEE financial calculator tool for owners "to play" with different scenarios for financing the retrofitting of their building; this sub-case demonstrated the adoption of the financial calculation module by stakeholders;
- *SBC3: connect for retrofit*; test the response of SMEs to published inquiries by using the NewBEE marketplace; SMEs tested the features to create a project-driven network in order to themselves initiate calls-for-proposal related to big-retrofitting works.

5 Conclusions and Considerations

The NewBEE project has been a first attempt introduce into a traditional sector such as the construction sector, an innovative web-based collaborative paradigm such as those already established in the information-and-communication industry. SMEs that embrace the NewBEE methodology are empowered to create "project-driven and tailor made" collaborative networks with other SMEs, developing a project-specific business model in order to compete with large companies.

The portfolio of ICT-tools covers the entire value chain of the construction sector, from information research to financial planning, and proposes a rather new way of doing business for SMEs.

A web-based knowledge management system—The issue of imperfect information flows and the SMEs' lack of ability to learn how to adopt new energy technologies have been the common goal that have guided the development of the wiki-repository. The demonstrator phase showed that this tool has great potential to inculcate the basics for knowledge transfer into SMEs and among them.

Collaboration could start even from customers—The pre-assessment tool has been considered by several interviewed SMEs to be one of the most interesting modules in the platform because it achieves two important goals: it provides a usable "first energy-saving-potential assessment" and provides a "project-cost magnitude" to enable commercial departments to avoid wasted effort. Moreover, the demonstration phase established that the "what happen if…" approach is a powerful marketing tool that encourages the customers to continue investigating the energy-efficiency opportunities, even by themselves, leading them to get in touch with an SME or a network of SMEs (established within the Marketplace).

SMEs networks can compete for big renovation projects by adopting specific business models—the NewBEE project tried to overcome the difficulties of SMEs in participating in big and complex renovation projects due to their lack in knowledge and competencies. The Marketplace, as a network-formation facilitator, can be seen as the tool which could answer to these needs. The guided generation of project-driven networks and "tailored" business models may remove the obstacles that usually hinder SMEs' participation in large construction projects. The demonstration phase has shown that it is possible to create solid, although temporary, collaborative project-driven networks in which SMEs complement their specialties and competences for competing with large companies in the new construction-market sector, like for instance, a city renovation plan.

ICTs help authorities to manage large retrofitting projects—The platform could be easily adopted by technical city offices to promote, organize, and manage renovation plans for cities. Experience gained in the Slovenian demonstrator phase has shown that the NewBEE platform could be adopted as a central virtual hub from which the national/regional/local authorities in charge can conduct the retrofitting process of large areas of cities.

Further developments—Despite the fact that it is clear that the current NewBEE platform is not yet a commercial product, feedback from potential users and SMEs could position it at the readiness level TRL7 that defines it as a "System prototype demonstration in an operational environment (Technology Readiness Level scale)". The two technological levels that remain yet to be made ready can be covered with only a small investment, and the system can already serve as an example of how this goal can be reached.

Acronyms

See Table 3.

Table 3 List of acronyms

BC	Business Case	KMS	Knowledge Management System
BM	Business Model	PAT	Pre-Assessment Tool
BO	Business Opportunity	RTD	Research and Technical Development
CN	Collaborative Network	SBC	Sub-business case
E-PASS	Energy Performance Assessment tool	SME	Small and Medium Enterprise
ESCO	Energy Service Company	UX	User Experience
ICT	Information and Communications Technology	WP	Work Package
GUI	Graphical User Interface		

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Integrated Urban-Energy Planning for the Redevelopment of the Berlin-Tegel Airport

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Abstract In order to achieve their sustainable targets, cities are today looking for better solutions for integrating infrastructure systems into their urban planning. A large variety of tools exists for decision support both in energy planning and in city planning, but few of them combine detailed multi-energy modelling and a user-centered collaborative development process in the early phases of an urban project. With the opening of the Berlin Brandenburg Airport, the Berlin-Tegel Airport (Berlin TXL) will be redeveloped as an innovative hub for cutting-edge research and industry under the umbrella of *Berlin TXL – The Urban Tech Republic* (UTR). The European Institute for Energy Research (EIFER), the energy provider

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Electricité de France (EDF), the Department of Urban and Regional Planning (ISR) of the University of Technology Berlin (TU Berlin) and the Drees and Sommer Advanced Building Technologies company for energy design started in 2014 a collaboration with Tegel Projekt GmbH, the agency in charge of the development of the site, in order to unify urban and energy planning for the redevelopment of Berlin TXL. Based on an innovative modelling approach coupling both spatial and multi-energy systems, they developed a simulation prototype illustrating the interrelation between different technologies, land uses, and planning decisions. Several collaborative workshops were conducted as *TU Urban_Labs* led by the TU Berlin in order to integrate relevant actors into the planning process. This paper describes the integrative and collaborative approach developed by the participants to answer the needs and questions of Tegel Projekt GmbH regarding the energy planning of the future redevelopment of Berlin TXL according to the spatial setting.

Keywords Integrated urban energy planning · Local energy system · Multi-energy simulation · Spatial modelling · Design thinking

1 Introduction

Cities are today facing crucial urban and environmental challenges as most of the world population lives in urban areas which generate almost 40 % of the total greenhouse-gases (GHG) emissions. In order to achieve their sustainability objectives, cities are looking for better solutions for integrating their infrastructure systems. A key leverage is seen in integrating energy issues into urban planning at various levels. A large variety of tools exists for decision support related to urban energy systems (Keirstead et al. 2012). Yet, few of them combine spatial and multi-energy modelling in the early phases of an urban development project. In addition, such approaches are often driven by an engineering approach and thus lack a collaborative process to integrate the needs of a wider group of stakeholders and future users or inhabitants.

With the opening of the new Berlin Brandenburg Airport, the Berlin-Tegel Airport (Berlin TXL—495 ha) will be transformed into an innovation hub for cutting-edge research and industry under the umbrella of *Berlin TXL—The Urban Tech Republic* (UTR). The concept combines various advanced urban technologies in energy, mobility, recycling, materials, and water management with information and communication technologies for a smarter and greener district. It aims to host more than 800 companies, a university campus, and research institutes. It is planned to create around 15,000 jobs on site. Tegel Projekt GmbH is the development agency commissioned by the state of Berlin for the management of the site.

The European Institute for Energy Research (EIFER), the energy provider Electricité de France (EDF), the Department of Urban and Regional Planning (ISR) of the University of Technology Berlin (TU Berlin), and the Drees & Sommer Advanced Building Technologies company for energy design started in 2014 a collaboration with the local agency in order to integrate urban and energy planning for the redevelopment of Berlin TXL. Based on an innovative modelling approach coupling both spatial and multi-energy systems, the consortium developed a simulation prototype, illustrating the interrelation between different supply and distribution technologies for heating, cooling and electricity, land uses, and planning decisions. Several collaborative workshops were conducted in the *TU Urban_Labs* format developed at the TU Berlin in order to integrate relevant actors, stakeholders, and domain experts into the planning process. This procedural approach enables participants to tackle the main issues related to the energy concept of the UTR and to visualize the effects of specific hypothesis on the energy demand, energy supply, potentials of use of renewable energy, and environmental impacts such as carbon footprints.

This paper aims to describe the integrative and collaborative approach developed by the consortium to answer the needs and questions of Tegel Projekt GmbH regarding the energy planning for the future redevelopment. The aim is to develop an integrated energy concept including the supply, distribution and storage of heating, cooling, and electricity of the future UTR according to its spatial settings.

2 Research Background

2.1 Interrelation Between Urban and Energy Planning

In the field of climate policy, the urban development planning takes conceptual tasks, e.g., through the development of integrated space-related energy and climate change concepts, together with relevant and appropriate professionals. These include numerous strategies and concepts for a climate-friendly and energy-efficient urban redevelopment by inventory remediation but also through new neighborhoods like *Berlin TXL—The Urban Tech Republic*. Climate protection (e.g., energy efficiency, use of renewable energy sources, and climate-friendly mobility) and adaptation to climate change (e.g., storm water management and greening) taking into account economic, social and building cultural objectives, can only be achieved through integrated and spatial approaches (Städtetag 2011). The importance of integrated approaches for urban planning is furthermore underlined by the IPCC (2014) and the Leipzig Charter on Sustainable European Cities (Leipzig Charta 2007).

As urban planning usually affects the transformation of existing spaces, buildings or usages but also the infrastructural conditions, the goal of widely carbon-free cities should be integrated into the development process of the urban infrastructure and into both urban and energy planning. Urban design plays an important role in the planning of energy-efficient cities. It determines not only the structural configuration of the city as the environment in which residents and users live and feel comfortable, but it also has significant impact on the energy balance of districts.

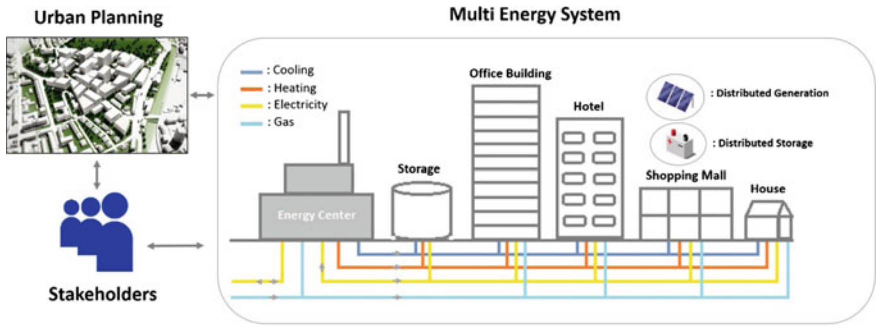

Fig. 1 Illustration of challenges faced by stakeholders regarding urban planning and multi-energy infrastructure (Ge 2015)

Recent studies show indeed that urban form can affect energy demand and production, for instance through exposure to the sun or mixing of uses (Salat 2009; Rode et al. 2014; Daab 2015). Therefore, energy and urban planning in the era of smart and resource-efficient cities are closely interrelated and must be strategically addressed in tandem at the start of any development process (Cajot et al. 2015).

Moreover, urban development processes are accompanied by an increasingly diversified array of stakeholders and demands on urban structures that are ever more complex, as well as interdependencies in almost all areas of planning. This is especially true for overlapping technical infrastructures, which were previously operated independently from one another, and their interactions with the uses of public and private urban spaces. In particular, the development of urban systems under the influence of information and communication technologies, and the resulting ever more compact collection, analysis, and networking of real-time data presents the stakeholders with new challenges (see Fig. 1).

Therefore cooperation between the people who live in the existing space and those who operate the future design as planning is essential. Collaborative planning is understood as a process in which the various actors bring together their knowledge and vision in various different communicative arenas in a process of governance (Lawrence 2000; Healey 2002). It enhances dialogue and communication between stakeholders, leading to consensus building, where planners are not only technical experts but also mediators coordinating the different stakeholders. The early integration of potential investors into the future urban concept then plays a key role. The investment decisions of private players must be involved (Siemens 2009). This cooperation among stakeholders results in a master plan that links up space, the time span of project involvement, and the development of a consistent urban energy infrastructure. The implementation of innovative urban technologies must therefore employ new methods to involve all concerned stakeholders and user groups with regard to urban co-production.

2.2 Existing Tools for Multi-energy System Modelling

In the course of the liberalization and decentralization of urban energy systems, new approaches and tools are required that can map out and visualize these highly interconnected systems (see Fig. 2).

By examining the energy system from a 'bottom-up' perspective, through which the individual as well as the systemic effects of separate objects can be represented, it is possible to analyze the overlapping interactions in the networking and energy sources of subsystems. The multi-energy system approach is an emerging field of research, whose aim is to consider different energy systems (power grids, district heating networks, gas networks, etc.) in a holistic manner, to benefit from the synergies between those systems (Stoyanova et al. 2012).

Several multi-energy system modelling tools have been developed in the last years, which mostly follow two methodologies. The first type of tools are made for specific studies (for example, integration of renewables in the mix or design of stand-alone energy systems), for which the technology mix is optimized for given energy demands (e.g., H2RES (Krajačić et al. 2009)). They are mainly used during the design phase of urban projects, and are often industrialized. However, they often do not consider land use nor using any Geographic Information Systems (GIS) and are very specific. Therefore they are hardly usable at the early phase of urban planning projects to integrate urban and energy planning. On the contrary, the second type of tools are foreseen to be used at early stages of urban planning by urban planners and decision-makers (e.g., EnerGIS (Girardin et al. 2010) or

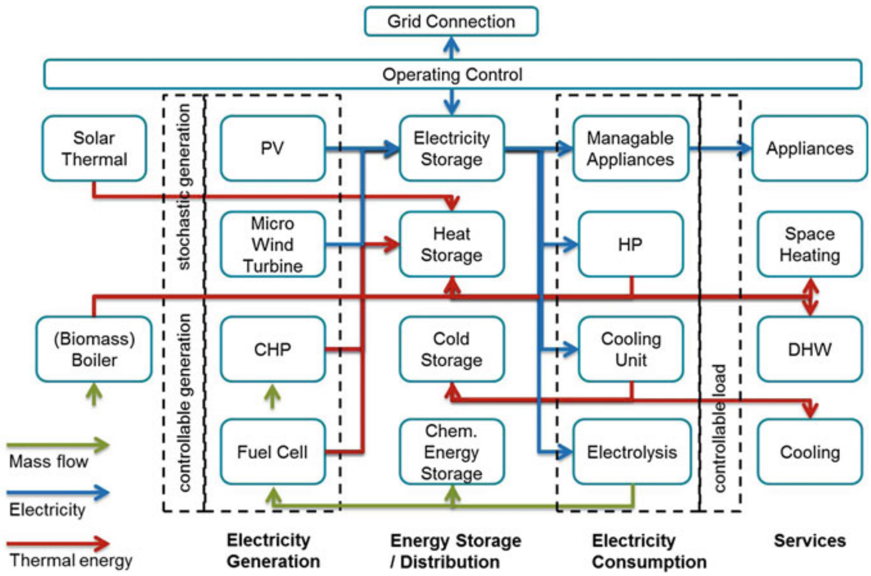

Fig. 2 Connected system components of a multi-energy system (Bahu et al. 2014)

SynCity (Keirstead et al. 2010)). They model the land use, the demand side, and the supply side of urban energy systems, and can support different types of studies.

EIFER has developed simulation approaches and methods in this field that are used to address various issues in the areas of smart grids and/or hybrid systems. Initially, an agent-based approach was proposed to the topic of smart grids, which show a large degree of heterogeneous components interacting with each other, while ensuring stability and efficiency in operation of the system. The agent-based simulation approach enabled individual representation of the various elements of the system (Kremers 2013), while coupling them and replicating them, leading to massive simulations of such complex systems. In Evora et al. (2012), an island power system with a large amount of hybrid PV and battery units at household level was represented and simulated for a period of 1 year, to test operation strategies for massive systems. The approach was then extended to include heat technologies towards the goal of being able to represent multi-energy systems in the same way. This concept is proposed in Gonzalez de Durana et al. (2014), as a technology independent, scalable, and easily extensible approach, through the use of so-called multi-carrier energy hubs. In Oldenburg et al. (2013), it was first applied to a city by implementing the energy concept at an early-phase masterplan for providing an hourly step model based on spatially-adapted load and generation profiles.

Such a shift towards intelligent multi-energy systems reflects current challenges posed by the ambitious targets of integrating high shares of renewable energies in many European countries. These strategies, which are consequently implemented at the local scale, require an increased share of flexible capacity in the electricity grid to accommodate fluctuating loads. Flexible thermal energy needs associated with electricity generation (e.g., cogeneration) or electricity use (e.g., heat pumps) have widely been identified as such additional flexibility measures (IEA 2014). By developing multi-energy system simulation methods, EIFER is looking towards tackling these challenges and considering them within the framework of a wider approach targeting closer integration of urban and energy planning.

3 Methodology

The research project approach follows two major aspects, both triggering a reciprocal update (see Fig. 3). First a digital application was iteratively designed for modelling energy demand, supply, distribution, and storage of the future UTR's urban infrastructure and for evaluating interactions between various technologies and planning decisions. The second crucial component of the project was the Urban Design Thinking Workshop process. As part of the *TU Urban_Lab*, this moderation process ensured the early involvement of stakeholders from industry, academia, and municipal bodies in the updating and refinement of the energy system model, and served to enhance preparations for planning decisions.

In the future, the redevelopment of the Berlin TXL site should use efficient and innovative infrastructure systems in the areas of electricity, heating, and cooling,

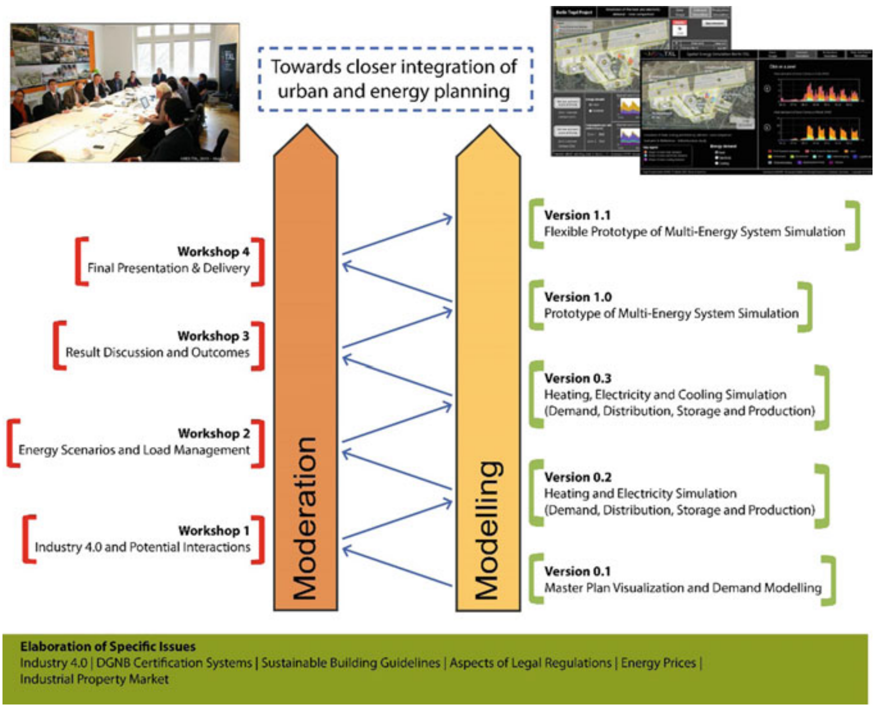

Fig. 3 The research project includes two main aspects: modelling and moderation

among others. The implementation of these new infrastructures requires the foresight to anticipate future needs in order to evaluate the effectiveness and efficiency of different decisions. Therefore EIFER developed an integrated a spatial energy system model within which the interactions of different urban technologies, uses, and planning decisions (e.g., energy efficiency measures) could be visualized and evaluated. Building on the requirements established during the planning (e.g., the masterplan, the infrastructure study conducted by Drees & Sommer, and other investigations), a simulation prototype specifically related to the UTR's future concept was iteratively developed by EIFER (see Fig. 3). Specific load profiles that could visualize future uses were developed by Drees & Sommer. The final simulation prototype is a stand-alone application that can be run on various devices.

By using prototyping and an iterative development process, the risks of missing targets in the implementation are reduced (Eberlinger and Ramge 2014). To this end, the Urban Design Thinking approach currently under development at the *TU Urban_Lab* relies on Design Thinking (Brown 2008, 2009), a method tried and tested in product development, and takes it further to develop a cooperative approach for urban development and transformation processes. The interplay between infrastructure systems and urban spaces can be mapped early on, and throughout the entire process, in order to iteratively adapt the development concepts based on the respective results.

4 Results

The Urban Design Thinking process, together with multi-energy system simulation prototyping, provided several strong value-added results.

Through a series of moderated workshops, a wide range of stakeholders from planning, energy, real estate, and various associations have been involved with the aim to advance development of the energy simulation prototype for the UTR (see Fig. 4).

The *TU Urban_Lab* served as a platform for incorporating the user perspective as well as furthering the development of specifications for the spatial energy model through dialogue between all involved stakeholders. By following the Urban Design Thinking method, the participation and interaction of the stakeholders incorporates three key points:

- *User-centered*: The evolution of urban development and transformation processes is conducted from the outset with the continuous involvement of future users, as is especially the case with Tegel Projekt GmbH. The aim is to produce innovations that are concentrated on the user and so satisfy their needs. To ensure this, the method draws on practices from the design area, which explicitly operates in a user-oriented way;
- *Stakeholder engagement*: The involvement of a large number of stakeholders in the project development enables not only that different views, interests, and approaches be taken into account. This also ensures a stronger focus on the implementation of transformation and infrastructure projects. At the time of implementing the research project, only the Beuth University of Technology had definitely decided to locate its operations in the UTR. Also the operators of technical infrastructure were not yet determined. The stakeholder participation

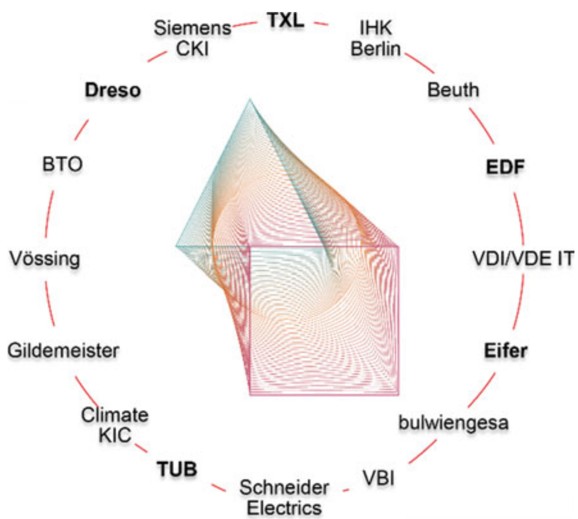

Fig. 4 Urban coproduction by collaboration of stakeholders from community, science, and economy

therefore relied on representative or exemplary organizations and existing partners. This brought experiences, concrete characteristics, and requirements of comparable projects into the research project;
- *Prototyping*: The consistent development of digital and physical prototypes enables the developed concepts to be assessed based on effectiveness and efficiency. The verification of concepts, processes, and products by building prototypes reduces the risks that user-optimized solutions will be missed, with the consequence of high costs and loss of time.

The Urban Design Thinking process is not linear, but runs rather in iterative loops of acceptance, implementation, testing, and adaptation. With specific questions from the modelers (e.g., about the energy scenario or load management) and numerous feedbacks from the relevant stakeholders, it was possible to collect reliable data and assumptions for the successful development of the simulation prototype (see Fig. 3). For example, the model has been extended so that the cooling energy demand and supply components and the simultaneity factors of the load profiles can be adjusted. Based on the spatial energy model, the simulation prototype has been continuously updated and refined to make the project's approaches to problem solving easier to experience and comprehend.

Simulation and mediation are the two pillars of the method that leads to better integration of urban and energy planning, in terms of involvement of stakeholders, goal definition, and shared knowledge on the project (see Fig. 3). Only through the use of the dialogic format were planners and modelers able to collect initial assumptions in the pilot project phase in order to test and adjust them with the aid of the tools under development and then to refine the energy concept (for instance, regarding the on-site potential for renewable energy generation). In direct exchange with the representatives of Tegel Projekt GmbH, the final prototype matched with the requirements of the UTR.

As energy planning is not only dependent on purely technical components, the structural and energy potential, as well as challenges, should be reviewed against the backdrop of prevailing concepts such as industry 4.0 developments. Industry 4.0 is characterized by a strong customization of the products under conditions of highly-flexible production with high volumes (BMBF 2013, 2015). New forms of production with a high degree of automation can possibly enable various different neighborhoods of uses in the future. Housing and production can again be spatially compatible so as to expect diminished emissions. The interactions between urban and typological measures (e.g., spatial settings, distribution of uses, or types of industry) and their influence on energy efficiency, load curves, or energy supply have emerged as key factors. Furthermore, the achievement of a set objectives in the field of energy-efficient measures strongly depends on the opportunities presented by legal regulations and requirements. Therefore the control and steering possibilities that arise from the legal framework (e.g., planning legislation, urban development contracts, etc.) were investigated and passed on as a recommendation for action to Tegel Projekt GmbH.

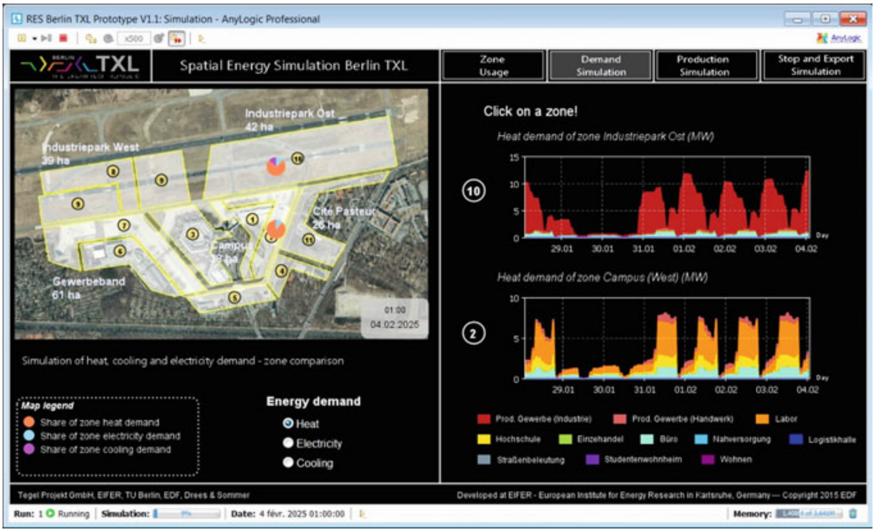

Fig. 5 User interface simulation: calculation of the hourly heat demand in selected construction zones

The spatial simulation of thermal (heating and cooling) and electrical load curves enables the user to select different planning scenarios and to visualize their impacts on the hourly energy demand and supply. In the pilot phase, various scenarios were defined according to the variation in the energy efficiency percentage (i.e., the proportion of decrease in energy demand) or in the share of renewable energy sources installed on-site. The simulation maps indicate zoning and display the system-wide effects of customized planning measures in response to mixed-use and infrastructure planning parameters (see Fig. 5).

Furthermore, these effects were evaluated based on Key Performance Indicators (KPIs) defined during the workshops (e.g., global final and primary energy use, GHG emissions, and share of renewable energy source in the heat or the electricity on-site production—see Fig. 6). The design of the interface was specifically adapted according to the requests of Tegel Projekt GmbH.

The prototype developed serves a dual purpose. As shown by the user-centered development process, the first purpose is to benefit the communication of the innovative energy concept planned for the UTR. According to the needs revealed by the review of existing multi-energy simulation tools for energy planning, the second purpose is the creation of an entirely holistic modelling and simulation approach through the summary of the already completed studies in the field of energy supply and hour-by-hour resolutions, raising then new issues concerning the networking core of the individual systems.

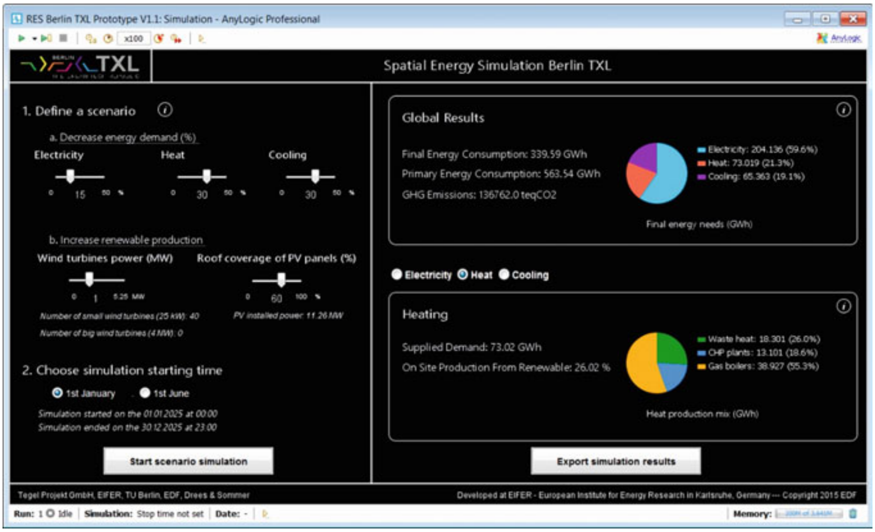

Fig. 6 User interface simulation: analysis of the simulation results based on KPIs

5 Discussion and Outlooks

Based on these different results, the research project contributes to strengthen the integration of urban and energy planning.

Through the Urban Design Thinking process, Tegel Projekt GmbH and relevant stakeholders were early integrated into the planning process. This gave the opportunity for participants to tackle the main issues related to the energy concept of the UTR and to visualize the effects of specific hypothesis on the energy demand and supply. This facilitates an early assessment of the impact of planning decisions made by planners and participating stakeholders. Thus, the iterative process enabled the definition of the specifications for the simulation prototype and the refinement of the energy concept of the UTR.

The simulation prototype provides Tegel Projekt GmbH both with decision support at an early stage and a means of communication for its development strategy. Thus, the continuous monitoring of the planning process via the spatially integrated energy system model enables:

- The visualization of interactions between energy and urban development settings;
- The simulation and visualization of energy flows for different construction sites depending on a variety of assumed uses;

- The scalable adjustment of demand and local generation of electricity, heating, and cooling;
- The observation and evaluation of different scales—ranging from the district level to specific buildings.

The visualization of the simulation results is, in turn, itself a means to communicate adjustments in the development strategy and, as such, serves as a basis for fashioning an integrated energy system model for the UTR site. The presentation of results in various levels of aggregation especially enabled to the examination of KPIs and their relevance with regard to urban planning.

Based on the ongoing development, further issues are discussed with workshop participants in order to create specifications for further development and research. Future applications should decrease the delay of model development with the objective of implementing the discussed strategies immediately in the context of ongoing *TU Urban_Lab* workshops and thus result in a real-time feedback supporting stakeholder discussions. Further issues that can be resolved using the model approach include, for example, operator models for hybrid systems as well as the integration of other technologies. In particular, geothermal energy and the intelligent use of storage technologies are discussed in the workshops. Based on the system components presented in Fig. 2, a variety of applications in an urban setting are possible. Thanks to the modular approach, the model can also be applied to other applications.

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European Union Research and Development Funding on Smart Cities and Their Importance on Climate and Energy Goals

Simon Pezzutto, Farnaz Mosannenzadeh, Gianluca Grilli and Wolfram Sparber

Abstract The scope of this paper is to examine the European Union support in terms of research and development funding on the topic of smart cities. A detailed literature review, based on a project-by-project investigation, and a data analysis process identified these expenditures since the research on this topic was first funded. The portion of the Sixth and Seventh Framework Programs funding dedicated to smart cities is only 3 % of the total funding for energy projects and an all-time low of 1 % is expected within Horizon 2020. The low funding for the investigated field fails to capitalize on the high savings potential represented by the urban primary energy use in Europe. Restructuring the funding distribution for research and development in energy could better fulfill the potential primary energy savings of the European urban sector and contribute to achieving the European Union's climate and energy goals for 2020, 2030, and 2050.

Keywords European Union · Cities · Primary energy · Research and development funding · Smart cities

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1 Introduction

After World War II, the reconstruction of Europe's economy and the establishment of lasting peace was necessary. The major challenge was neutralizing European countries' competition over natural resources. Thus, in 1951, the European Coal and Steel Community (ECSC) was founded. It was an international organization serving the unification of European nations, setting up a common coal and steel market among its member countries. The first member states were France, Federal Republic of Germany, Italy, Netherlands, Belgium, and Luxembourg, leading the way to the creation of the EU (Dinan 2014).

The EU is currently facing unprecedented climate and energy challenges and, to overcome these challenges, has established specific goals for the years 2020, 2030, and 2050. By 2020, the EU aims to decrease greenhouse gas (GHG) emissions by 20 % below 1990 levels. The energy use produced by renewable energy sources (RES) is expected to be 20 %. A 20 % drop in primary energy consumption is to be accomplished by upgrading energy efficiency as well (EC 2015a).

In order to provide a coordinated approach between EU member states and ensure regulatory certainty for investors, an integrated policy framework is necessary to achieve the 2030 goals. By that year, the EU aims to decrease domestic GHG emissions by 40 %, compared to 1990 levels. The energy produced by RES is expected to be 27 % of the total, and permanent improvements in energy efficiency are also foreseen through national policy measures (EC 2015b).

Further efforts are needed by the EU to achieve the 2020 targets, as well as the goals for 2030 and 2050. While the EU is on the right track to reach its RES and carbon emission targets by 2020, it is very likely that the energy efficiency targets will not be met (EC 2011a). The EU member states have affirmed the goal of decreasing Europe's GHG emissions by 80–95 % in comparison to 1990 levels by 2050 (EC 2015c).

In 2010, the primary energy utilization in Europe was almost 1,800 [Mtoe/a] (EUROSTAT 2013). The cities of the EU account for approximately 70 % of the primary energy consumption, and this portion is expected to rise to 75 % by 2030 (EIFER 2015). Three-quarters of Europe's population lives in urban areas and is responsible for roughly the same proportion of CO_2 emissions (Faure and Peeters 2008; EEA 2015). The entire primary energy consumption savings potential at the EU level corresponds to an estimated overall total of 390 [Mtoe/a] each year. Partially because of its large share of whole primary energy usage, the majority of these reductions are attributed to savings in the urban sector (EC 2008; Terluin and Post 2000; BPIE 2015).

Especially the smart city (SC) projects aim to create sustainable and efficient urban areas by addressing energy and climate challenges. The main intervention fields of SC projects concern the application of RES, improvements in energy efficiency, and emissions' offsetting (Pezzutto et al. 2015).

2 Methodology

With regard to the EU research and development (R&D) funding, the framework programs (FPs) have been the most substantial funding source since their inception (1984) (Di Valdalbero 2010; De Jagr 2011; Pezzutto 2014). Concerning the quantification of R&D spending for SC projects, the focus lies on the past two completed framework programs (Sixth and Seventh Framework Programs—FP6 and FP7) as these kinds of activities started in FP6 (Pezzutto et al. 2015). Hence, a period of about one decade (2002–13) is analyzed in detail. The European Commission (EC) provides detailed insights into the historical development of the R&D expenditures at EU level (EC 2012a, b, 2013a, b). These were counter-checked by a number of further scientific sources (WEC 2001; Raque 2005; Milias 2009). Moreover, a closer look at the follow-up program of the FP7, the recently begun Horizon 2020 (2014–20), is provided as well.

With regard to EU R&D funding for the energy sector, non-nuclear and nuclear energy (NNE and NE) funding have been separated (Raque 2005; Milias 2009). The energy funding category includes both.

In order to obtain a clear understanding of the EU NE and NNE R&D in all combined framework programs (FP1–7, 1984–2013), the EU R&D spending on NE was retrieved from EC indications and directly compared with metrics for NNE.

An extensive database was created to quantify the EU funding for NNE related R&D. It contains all FP6 and FP7 energy projects declared by the EC. The mentioned database includes the absolute majority ($\sim$94 %) of the programs' funding declared by the EC dedicated to the energy sector (Di Valdalbero 2010; EC 2013a, b). In order to avoid combining R&D spending provided by the EU and other expenditures, solely the EC contribution per project has been taken into account and not the total budget.

Table 1 summarizes the EC classification method with regard to the NNE section and respective subsections.

There is not a category specifically dedicated to smart cities (SCs). This has been quantified through adding the FP6 and FP7 CONCERTO (demonstrating large-scale reductions in fossil fuel consumption using renewable energy sources and demand management) spending to those of the FP7 smart cities and communities initiative (SCIS 2015; EC 2015c, d, e).

In order to provide a real basis of comparison between NE and NNE spending in the FPs, several sources were combined in Figs. 3 and 4. Thus, the NNE FP7 section also includes funding from the IEE (Intelligent Energy Europe), CIP (Competitiveness and Innovation Framework Program), and EIT (European Institute of Innovation and Technology) programs. In contrast, the NE expenditures include Euratom (European Atomic Energy Community), JRC (Joint Research Centre) activities on NE and Iter (International Thermonuclear Experimental Reactor) spending from FP1 to FP7.

A fundamental and technical analysis has been applied to provide a future scenario of the R&D funding distribution within the energy sector for the Horizon

Table 1 EC classification method of the non-nuclear energy sector and respective subsections (EC 2013a; EUROSTAT 2014a)

Non-nuclear energy section	Non-nuclear energy subsections
Renewable energy sources	Photovoltaics, concentrated solar power, bioenergy, wind energy, ocean energy, geothermal energy, hydro energy, renewable heating and cooling
Coal	Carbon capture storage CO_2 capture, carbon capture storage CO_2 storage, other
Energy networks	
Energy efficiency	Building, CONCERTO, other
Socio economics	
Fuel cells and hydrogen/joint technology initiative fuel cells and hydrogen[a]	Fuel Cells, hydrogen
Energy materials/future emerging technologies	
Energy storage	
Basic research	
All other activities	

[a]In the fuel cells and hydrogen category, the joint technology initiative/fuel cells and hydrogen funding were added to the fuel cells and hydrogen topic, just as the EC calculates

2020 program, and in particular for SCs. The technical analysis consists of a regression calculation for FP6 and FP7 funding values through Horizon 2020. The fundamental investigation is based on anticipated expenditures as retrieved from scientific literature. More weight has been attributed to the indications retrieved by the fundamental analysis, which have been used to adjust the outcome of the technical analysis (Schlichting 2013).

In order to generate an equal basis for comparison among R&D expenditures in time and to calculate reasonable data for future development indications, all monetary amounts are given in real values (2013 prices). The real monetary amounts were calculated using EUROSTAT data on annual inflation rates (EUROSTAT 2015). The year 2013 is selected as the time reference because it is the most recent point in time for EU R&D expenditures within the last completed framework program (FP7).

3 Results

Even if the EU's R&D budget increased by a factor of more than ten from the first to the last completed framework program (FP1–7), in absolute amount of funding (from 6.0 to 63.8 bn.€), R&D spending remained relatively low compared to total EU expenditures, oscillating between approximately 2 and 6 %. Figure 1 indicates the trend of R&D spending within the FPs as a percentage of the respective total EU

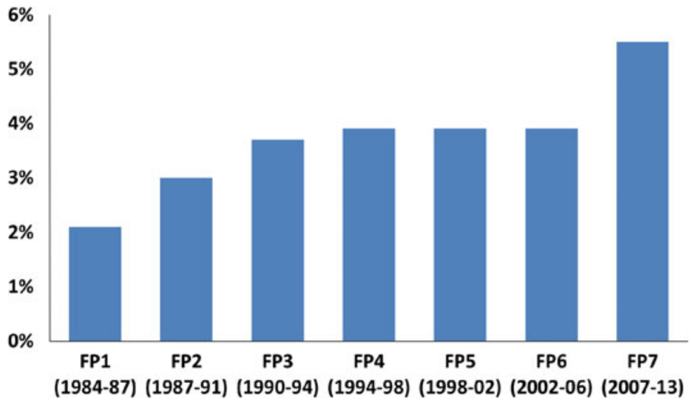

Fig. 1 R&D spending within the framework programs as a percentage of the respective total European Union budgets (%) (WEC 2002; De Jagr 2011; Paris School of Economics 2011; EWEA 2012; EC 2010, 2013c, 2015d) (Almost all indicated FPs have a time overlap. In particular, FP3 began one year before the end of the FP2. The indicated time overlap of the FPs does not correspond with a budget overlap, e.g. FP2 ended in 1991, while FP3 started already in 1990.)

budgets (WEC 2002; De Jagr 2011; Paris School of Economics 2011; EWEA 2012; EC 2010, 2013c, 2015d):

However, taking the population growth caused by the EU enlargement into account, the R&D expenditures per EU inhabitant have declined from around three Euros in the 1980s to two Euros in the 1990s, and one Euro in the mid-2000s (Di Valdalbero 2010).

Moreover, from FP1 to FP7, energy R&D suffered a significant reduction. As Fig. 2 illustrates, the percentage of energy R&D was significantly reduced from FP1 to FP2. From FP3 to FP4 the energy budget increased slightly. Afterwards, a constant reduction until FP7 is evident. As of FP7, the percentage of funding dedicated to energy is roughly one-third of what it was in FP1.

In FP1, energy received the highest single budget of all R&D topics and in FP7 it was in the second to last position. The other fields receiving R&D funding from

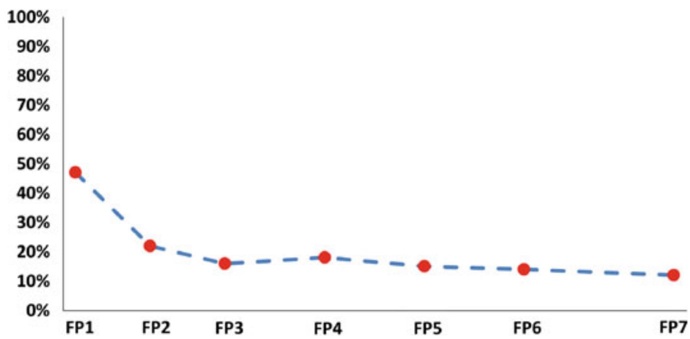

Fig. 2 Energy-theme focus within the seven framework rograms (FP1–7) (%) (Milias 2009)

the EC, such as environment, industrial and material sciences, and information–and-communication technologies gained more and more importance since FP1. The increases in these fields caused the reduction in R&D funding for energy as a percentage of total funding. Only the life sciences received less financing than energy within the last completed FP (FP7) (EKT/NHRF 2013).

In contrast to the decreasing values in terms of percentages, an increase in the total available amount of money occurred for energy from FP1–7. The largest increases occurred between FP3–4 and FP6–7, while there were substantial reductions from FP1 to FP3 and FP4–6. See Fig. 3.

From the first to the last completed FP (FP1–7), the funding for energy research more than tripled, with 3.2 bn.€ allocated in FP1 and 11.5 bn.€ in FP7.

Figure 4 shows a comparison between NE and NNE EU R&D funding during FP1–7. In each of the FPs, NE received more R&D funding than RES and all other

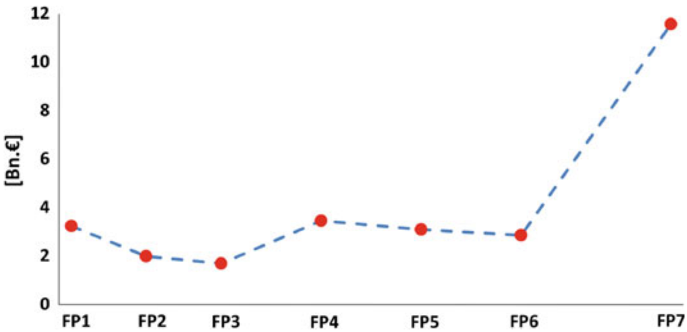

Fig. 3 Energy R&D spending by the European Union (1984–2013) (WEC 2002; Raque 2005; Milias 2009; Di Valdalbero 2010; EUROSTAT 2014b; EC 2013a, 2015d)

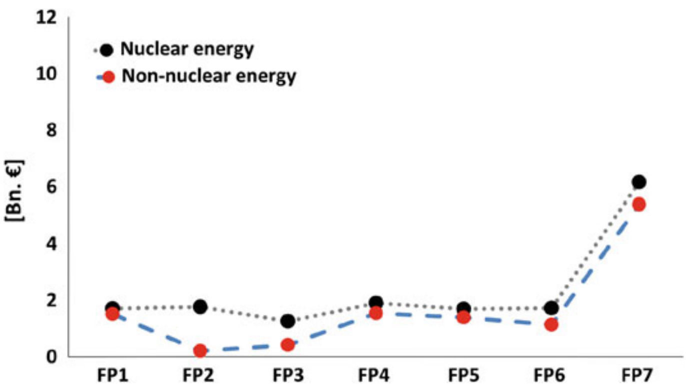

Fig. 4 R&D spending for energy in the framework programs (FP1–7) (%) (EUR-Lex 1983, 1996; Milias 2009; Di Valdalbero 2010, EC 1987, 1993, 1997, 1999, 2013d, e, f, g, h, i) (Without the funding portions of the IEE, CIP and EIT, the NNE R&D spending within FP7 would reach a value of 2.7 bn.€.)

energy sectors combined (EC 2013d, e, 2015d). It has to be stressed that safety, protection from excessive exposure to radiation, maintenance of nuclear security, and radioactive-waste disposal are the key points of the EU NE R&D (EC 2011b).

3.1 The Sixth Framework Program

The Sixth Framework Program had a 24.0 bn.€ budget. From this, approximately 2.8 bn.€ were dedicated to R&D activities in the energy sector. Those 2.8 bn.€ were split into 1.7 bn.€ for NE and 1.1 bn.€ for NNE (Di Valdalbero 2010; EC 2006, 2013a).

Nuclear energy received the absolute majority of energy R&D funding, representing approximately 60 % of the total.

The RES section follows with about 15 % of the energy funding. However, considering the contents of all funded projects, in sum around 20 % of the spending for the energy sector went to RES, as several projects in other categories (within energy efficiency, basic research and all other activities) dealt with renewable energy too. Bioenergy, photovoltaics and wind energy got the largest amount of funding regarding the RES part with around 7, 4 and 2 % respectively. Geothermal and ocean energy follow with about 1 %. Renewable heating and cooling (RHC) and concentrated solar power (CSP) rank in the second to last position with less than 0.5 %, and hydro energy is to found in the last place with around 0.1 %.

The category of fuel-cells and hydrogen/joint technology initiative on fuel cells and hydrogen (FCH/JTI FCH) comes next with approximately 10 % of the total. Within the last mentioned field, fuel cells received approximately 2 % more funding than R&D on the hydrogen theme. Smart cities (CONCERTO) follows with 6 %. In the present case, R&D spending on SCs derive exclusively from CONCERTO projects. Coal shows a value of around 4 %, equally divided between carbon–capture-storage–CO_2-Ccpture (CCS-CO_2 Capture) and carbon–capture-storage–CO_2-storage (CCS-CO_2 Storage). Next, the topic of energy networks is reported as about 2 %. Energy efficiency (other), socio-economics, and all other activities follow with approximately 1 % each. The last positions are held by coal (other), energy storage and basic research (<0.5 %) (EC 2013a). See Fig. 5.

3.2 The Seventh Framework Program

The Seventh Framework Program budget was 63.8 bn.€. From this, about 8.8 bn.€ were dedicated to R&D activities in the energy sector. Those 8.8 bn.€ are split into 6.1 bn.€ for NE and 2.7 bn.€ for NNE (Di Valdalbero 2010; EC 2007, 2013a).

As was the case in the previous FP program (FP6), also within FP7, NE R&D holds the absolute majority of funding, with approximately 68 %.

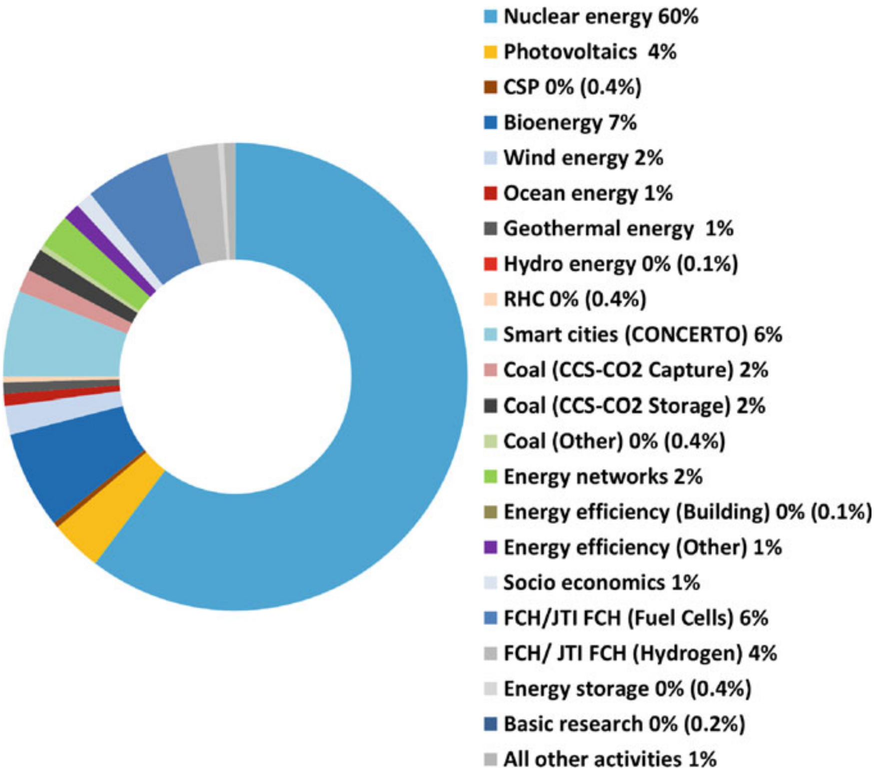

Fig. 5 Sixth Framework Program funding distribution for various energy sectors (2002–06) (EC 2013a) (The section energy efficiency (CONCERTO) is fully taken by smart cities (CONCERTO) and thus do not appear in Fig. 5. The same applies to following Figs. 6 and 7.)

Next, about 12 % of the whole funding for energy in FP7 has been dedicated to RES. Once more bioenergy, photovoltaics, and wind energy received the largest shares of funding within the RES part with around 4, 3 and 2 % respectively. Concentrated solar power, ocean energy, and RHC follow with about 1 % each. Geothermal energy is located in the penultimate position with approximately 0.3 %, and hydro energy is last again, with about 0.2 %.

The FCH/JTI FCH section follows with around 6 %, equally distributed between the fuel cells and hydrogen themes. Energy networks are next with 5 %. Coal shows a value of 3 %, equally divided between CCS-CO_2 Capture, CCS-CO_2 Storage and Other. The topic of smart cities (CONCERTO) and energy efficiency (buildings and other) received about 2 % each. In this case, R&D spending on SCs only partly comes from CONCERTO projects: two-thirds of the 2 % given for smart cities (CONCERTO) R&D funding derive from the FP7 smart cities and communities projects. Energy storage and all other activities follow with approximately 1 % respectively. The last positions are covered by socio economics,

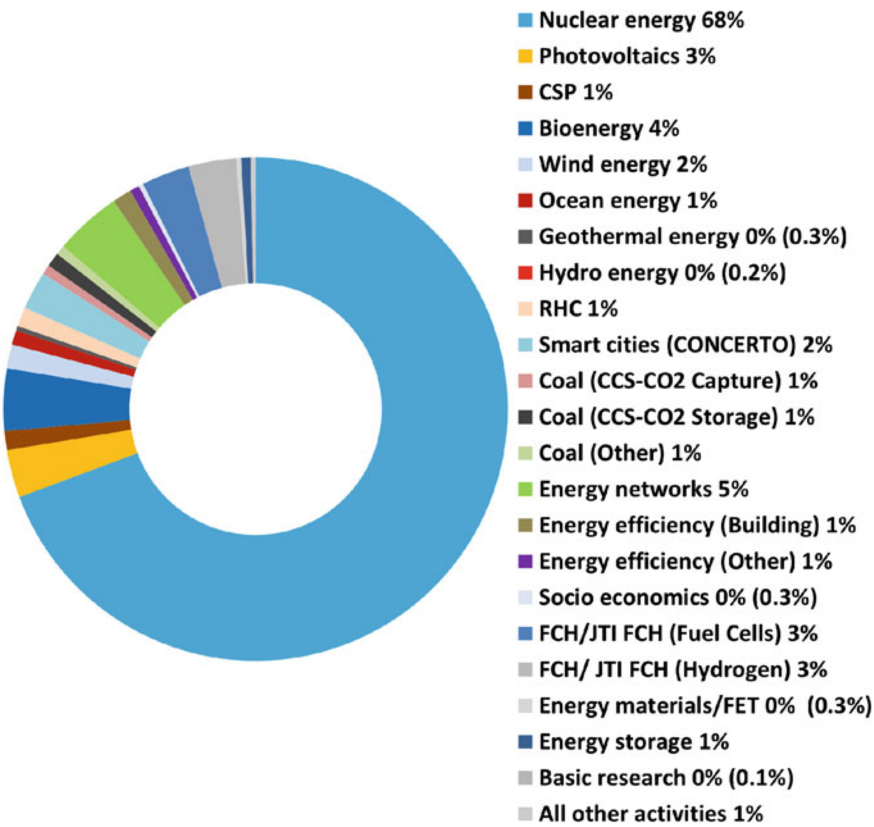

Fig. 6 FP7 R&D funding distribution for various energy sectors (2007–13) (EC 2013a)

Energy materials/FET (future emerging technologies) and basic research (<0.5 %) (EC 2013a). See Fig. 6.

Energy materials/FET is a new topic in FP7. It received less than 0.5 % of R&D energy funds (EC 2013a).

3.3 Comparison of the Sixth and Seventh Framework Programs

Comparing FP6 and FP7, it has to be stressed that there was a significant increase in the total available amount of money for energy research. Hence, the funding for energy R&D in FP6 was around 2.8 bn.€ and at FP7 about 8.8 bn.€ (Milias 2009; Raque 2005). Thus, the total energy budget for the EU FPs has almost tripled from FP6 to FP7. It has to be remembered that the duration of FP7 was almost double that of FP6; FP6 lasted 4 years, while FP7 lasted seven (EC 2006, 2007).

Nuclear energy increased by about nine percentage points in FP7. Contrarily, the smart cities (CONCERTO) field suffered from a significant decrease. In fact, it shows one-third of the value given in the previous FP, which correlates to a loss of 4 % points. Despite this reduction in percentage, a slight increase in total amount of money occurred. The smart cities (CONCERTO) topic was supported by about 169 and 176 mil.€ in FP6 and FP7 respectively. However, the latter cited increase is minor, leading to a measure of approximately the same R&D spending for the smart cities (CONCERTO) theme in FP6 and FP7, with 0.2 bn.€ each.

Also, the FCH/JTI FCH section received significantly less funding, with a reduction of approximately four percentage points. The percentage of funding going to RES decreased for all sources between FP6 and FP7. This is especially apparent for bioenergy, which received approximately only half the share in FP6. Only CSP and RHC show a percentage increase in FP7 compared to the previous program. However, the last two indicated energy categories represent only around 1 % of the total. In contrast to the latter mentioned percentage decrease, a significant increase in the total available amount of money is registered for the entire RES portion in FP7. The latter mentioned topic was supported by around 0.4 and 0.9 bn.€ in FP6 and FP7 respectively. The energy-networks theme increased by about 3 percentage points. Also the energy-efficiency sector (buildings and other) as well as the energy-storage part show an increment of about 1 percentage points. The whole coal theme (CCS-CO_2 capture, CCS-CO_2 storage and other) as well as socio-economics each lost a percentage point. The remaining topics (basic research and all other activities) stayed within the same range (EC 2013a).

3.4 *The Sixth and Seventh Framework Programs*

In order to quantify the total R&D expenditures on the SCs topic since their existence, Fig. 7 merges the funding portions of the various energy sectors of the Sixth and Seventh Framework programs:

Due to the significantly higher amount of R&D funding provided in FP7 compared to FP6, the rankings given in Fig. 7 do not vary considerably from the previous FP7 ranking. Only the SCs topic rose by one rank, exceeding the energy efficiency (buildings and other) theme with 3 and 2 % respectively. The FCH/JTI FCH and energy networks topic gain and lose 1 % respectively, holding the same position as in FP7.

It has to be stated that the majority of the above mentioned ~3 % funding for SCs R&D belongs to CONCERTO projects. The CONCERTO initiative provided almost two-thirds of the funding for SCs (EC 2013a).

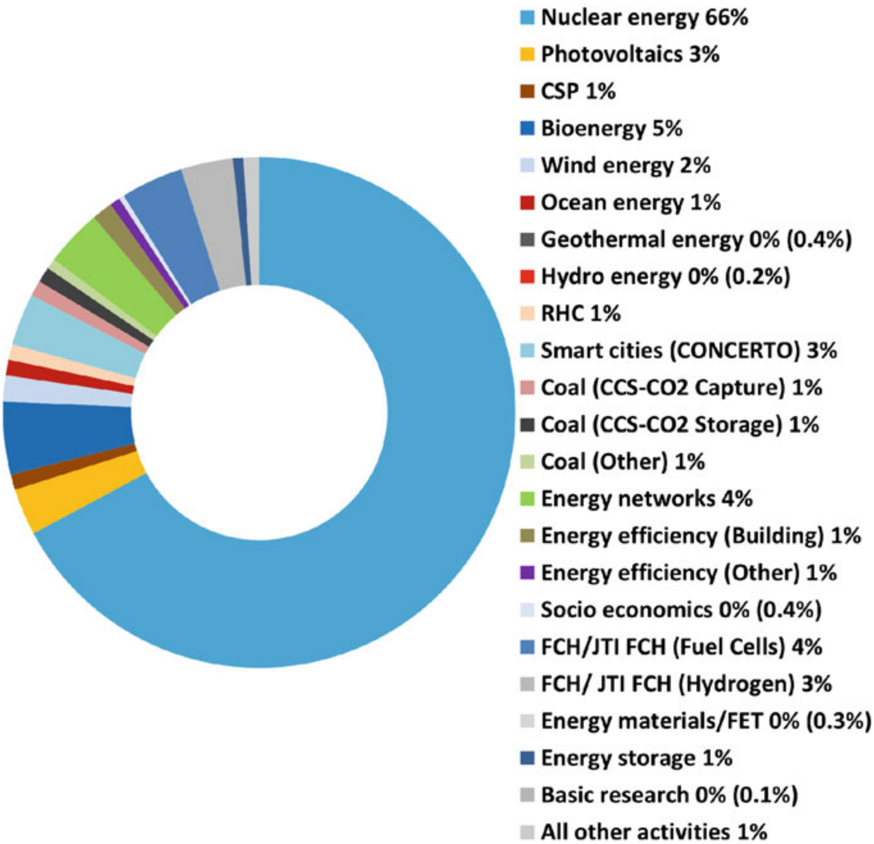

Fig. 7 FP6 and FP7 R&D funding distribution for various energy sectors (2002–13) (EC 2013a)

3.5 Outlook

In order to evaluate a possible future scenario of EU R&D funding assigned to energy related issues and in particular to SCs, the future Horizon 2020 (2014–20) funding program is now considered.

Summing up future expenditures indicated for the NE and NNE sectors separately, both are expected to have an equal amount of funding with approximately 5.9 bn.€ each. Thus, as shown in Fig. 8, NE would remain the sector with the majority of EU R&D expenditures, consuming around half of the total (Milias 2009; EC 2013a, 2015f; ITER 2015).

Next, based on a linear regression until Horizon 2020, a prediction concerning the R&D spending distribution for the various NNE sections has been created. Contrary to the anticipated future expenditures, the linear regression predicted that NE would receive 76 % of the funding. This discrepancy was handled by reducing

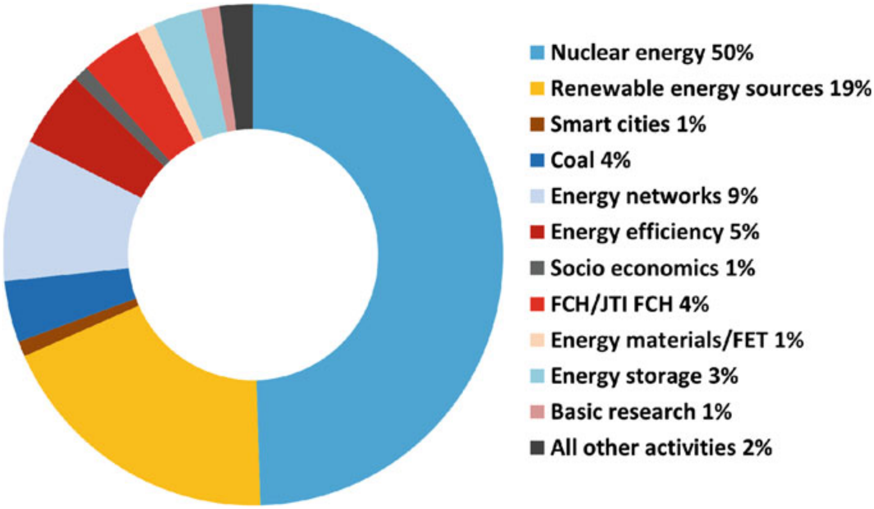

Fig. 8 Expected funding distribution for the Horizon 2020 energy theme (WEC 2002; Milias 2009; Di Valdalbero 2010; EC 2006, 2007, 2013a, 2015f; ITER 2015) (As CONCERTO activities are not planned within Horizon 2020, the smart-cities section stands alone within this chart.)

the NE funding to 50 %, and evenly distributing the difference among the other sectors. Renewable energy sources follow with almost 20 %. Energy networks come next with nearly 10 %. The remaining sectors all represent 5 % or less in the following order: coal, energy efficiency, FCH/JTI FCH, energy storage, all other areas, energy materials/FET, smart cities, socio economics and basic research (Milias 2009; Di Valdalbero 2010; EC 2006, 2007, 2013a, 2015f; ITER 2015).

Figure 8 combines the predictions for the entire energy sector within Horizon 2020.

Regarding the monetary quantification, it has to be stated that the total EU budget increased by around 10 % from FP7 to Horizon 2020, with the total FP7 budget at 63.8 bn.€ and Horizon 2020 at 70.9 bn.€ (EC 2007; EU 2012). Horizon 2020 is expected to last as long as the FP7: 7 years.

4 Discussion and Conclusions

Energy has been central to the European Union ever since its inception, originally as the European Coal and Steel Community in 1951 (El-Agraa 2011: 257). The European Union is taking drastic action to address the current climate and energy challenges. Specific goals for the years 2020, 2030, and 2050 have been established.

However, the European Union funding available for research and development in the energy field has significantly decreased as a percentage since the start of the framework programs. Moreover, because of European Union enlargements and the associated population growth, the expenditures on research and development for each inhabitant has declined from three Euros per person in the 1980s to one Euro per person in the mid-2000s.

The European Union utilized approximately 1,800 [Mtoe/a] of primary energy in 2010. Cities are currently responsible for around 70 % of this consumption and are expected to be responsible for up to 75 % by 2030. Approximately three-quarters of Europeans live in urban areas, and they are responsible for roughly the same percentage of CO_2 emissions.

It is estimated that the European Union can reduce the annual primary-energy consumption by 390 [Mtoe/a]. Because the urban sector uses a large share of the primary energy, it is believed that the majority of these savings could come from improvements in cities.

In particular, smart city projects aim to create sustainable and efficient urban areas by addressing energy challenges. The main intervention fields of smart-city projects concern the application of renewable energy sources, an increase in energy efficiency, and carbon-dioxide-emission reduction.

However, only 3 % of the total energy funding in the Sixth and Seventh Framework Programs was used for smart cities research and development. This value is expected to see an even further reduction within Horizon 2020, reaching a value of 1 %. Moreover, nuclear energy was a major recipient of European Commission research and development financing. From 2002 to 2013, the nuclear sector received significantly more funding than all of the other energy fields combined.

Shifting the focus of European Commission funding to favor smart cities would assist in achieving the 2020, 2030, and 2050 goals. They would then target the sector with the highest energy consumption, and, like the latter mentioned goals, they aim to utilize renewable energy sources and energy efficiency and to reduce greenhouse gas emissions.

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