Zongwei Luo *Editor*

Mechanism Design for Sustainability

Techniques and Cases

Springer

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ISBN 978-94-007-5994-7 ISBN 978-94-007-5995-4 (eBook)
DOI 10.1007/978-94-007-5995-4
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2013934349

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Sustainable economy is an economy with “capacity to endure,” where bearable environment, equitable society, and viable economy are well integrated with social, culture, legal, business, financial, and environmental perspectives. To reach for this integration for sustainable development, it is essential to understand and study the mechanisms for interactions and impact from and among these perspectives. This book of mechanism design for sustainability will provide advanced analytics and decision management techniques and tools towards developing sustainable competitive advantages in the studied target context.

This edited book has 14 chapters, contributed by worldwide researchers and practitioners, of innovative concepts, theories, and models; design methods; and case studies and experience sharing in mechanism design to drive better decision makings with practical relevance to sustainable development.

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Zongwei Luo

Acknowledgment

Meanwhile, I would like to think the Springer editor and other anonymous book reviewers to provide valuable suggestions to make this quality book project happen and appear to service the public.

And lastly, enjoy your reading!

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Part I
Introduction

Introduction to Mechanism Design for Sustainability

Zongwei Luo

Abstract In this chapter, an introduction to mechanism design is provided. After a brief overview of the introductory concept of mechanism design, a motivation example is presented illustrating the challenges in manufacturing transformation in China's economic structural change. The role of mechanism design to help the transformation is emphasized, followed by an introduction of mechanism design techniques and cases presented in the remaining chapters of this book.

Keywords Advanced manufacturing • Industry transformation • Mechanism design • Mechanism analysis • Structural change • Sustainability

1 Background

In philosophy, mechanism means "a theory that all natural phenomena can be explained by physical causes," while mechanism design would include such theory design leading to explain natural phenomena or solve natural problems. In practice, mechanism design is also often related to game theory, studying game solutions. Mechanism design for sustainability invites theory as well as practice study toward solutions for sustainable development.

Sustainable development's ultimate goal is to provide "capacity to endure." Toward that, bearable environment, equitable society, and viable economy will have to be well integrated with social, culture, legal, business, financial, and environmental perspectives. To reach for this integration for sustainable development,

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_1,

it is essential to understand and study the mechanisms for interactions among and impact from these perspectives. Sustainability mechanism solutions will then be followed. The mechanism design for sustainability would provide advanced analytics and decision management techniques and tools toward theory and solutions development with sustainable competitive advantages.

The world now is at the point to pursue a sustainable development roadmap that would eventually decouple economic growth from greenhouse gas and other polluting emissions, through social, technological, and business innovations. China, with the largest world manufacturing capacity, is the country with the largest carbon emission in the world. China's manufacturers import resources worldwide and then export major parts of its produced products. China's portion of value add is in fact very small but with a large portion of pollution left. Apparently, China's economy does not hold the capacity to endure if China continues this pattern of economy development. Its current economy structure has to change to facilitate development of technology-rich, high value-add, and service-oriented manufacturing industries. Thus, China's manufacturing industry presents an excellent case of sustainability study needs, which will be discussed in the next few sections.

The rest of this chapter will be divided into two parts. The first part will be devoted to a study of the role of manufacturing industry to sustain China's economy growth as an illustration of the need for mechanism design for sustainability. The change expectation is analyzed. Manufacturing's role in promoting sustainability is discussed. Future trend of manufacturing development is given. And development considerations for smart manufacturing toward sustainability are also analyzed. Beyond manufacturing, as an illustration for mechanism design for sustainability, the second part of this chapter includes a brief overview of the selected book chapters introducing a rather comprehensive view on mechanism design for sustainability techniques, analysis, and case studies.

2 Change Expected

Today the world is at a point facing worldwide economic structural adjustment, change, and reorganization, presenting historical opportunities to China and of course other countries as well. China's national export-oriented economy urgently needs transformation, with urgent need to adjust industrial structures and to enhance domestic demand to sustain China's economic development. Advanced manufacturing, strategic emerging industries, and modern services represent the direction of the scientific, technological, and industrial change, which China has started vigorously to pursue and develop in order to expand and create market demand. Deep integration and synergy among these industries will support China's technological and industrial change, helping China to occupy a favorable position in this competitive world with ongoing global restructuring and international industrial transfer and the international industry adjustment.

3 Manufacturing's Role

Advanced manufacturing's role as the backbone of the country has been re-recognized and has aroused wide attention of major developed countries. These countries have already started a series of advanced manufacturing technology research programs. And without exception, digital manufacturing technology is one of the important components in the study. Europe and the United States proposed "reindustrialization" in recent years and wish to return to the real economy to seize the commanding control of global industrial technology and to further capitalize on the high-end manufacturing. In the USA, President Barack Obama has announced infrastructure and technology policy and steps to restore the center of manufacturing in the US economy. The American Association of Manufacturers has also released several goals for the revitalization of US manufacturing, including (1) the United States to become the world's most superior manufacturing center and a place to attract foreign direct investment, (2) US manufacturers have to meet the economic needs of labor in the twenty-first century, and (3) the US manufacturers become the world's leading innovators. They believe that a world-class manufacturing requires world-class talents for the US's manufacturing sector; if you want to maintain its dominant position in the world, you must have the best domestic and foreign high-skilled personnel in order to maintain a dominant position. To become the world's leading innovators, the United States must maintain research and development activities, with efforts of promotion and protection of intellectual property rights.

In the face of fierce international competition in the twenty-first century, the Chinese government has planned accordingly and launched a series of major and key scientific research and development projects, carrying out special studies in the frontier of advanced manufacturing technology and equipment. In late April of this year, the Ministry of Science and Technology, in combination with other ministries, has issued a "12/5" Manufacturing Information Technology Project Planning, outlining manufacturing information technology projects over the next 5 years for the development of manufacturing services and intelligent manufacturing. In recent years, the National Hi-Tech Research and Development Program (863 Program) in 2008 and 2006 has called for "advanced manufacturing technology major projects in the field of radio frequency identification (RFID) technology and applications" by the development and application of RFID technology to promote transformation and upgrading of China's advanced manufacturing industry.

4 Manufacturing Development Trends

Development of the manufacturing industry so far has involved with multidisciplinary applications, and manufacturing technologies have more and more adopted the latest achievement in materials, mechanics, physics, chemistry, and computer simulation technology, network technology, control technology, nanotechnology, biotechnology, and sensor technology. Currently, with booming economy, China has respected more science- and technology-led economic development. It is generally believed that the Internet/Internet of Things and next generation of information technology will lead to industrial change toward the advent of an era of wisdom and knowledge, promoting the manufacturing industry to shift from the traditional manufacturing toward industrial chain-based manufacturing. The trend and requirements of digital manufacturing, service manufacturing, and intelligent manufacturing will become more apparent and prominent.

4.1 Digital Manufacturing

Digital manufacturing is a strategic choice for manufacturing innovation, including digital design, digital management, digital production, digital manufacturing equipment, and digital enterprise. Further integration of information technology into digital manufacturing will promote and extend digital manufacturing from traditional manufacturing to both ends of the industry chain, evolving toward industrial chain-based digital manufacturing. This industrial chain-based manufacturing would help effective coordination of worldwide design and manufacturing resources, improve the capacity of complex product development and product lifecycle optimization, shorten the development cycle, and reduce development cost, which can greatly enhance the capability of independent innovation and market competitiveness of China's manufacturing industry.

4.2 Service Manufacturing

Development of service manufacturing would be in the direction toward industry chain-based manufacturing providing capacity of customer-oriented, on-demand products and services, improving the consistency between the enterprise and customer goals, and achieving win-win situations. Service manufacturing would stay close to the market and demand, enhance the understanding of the needs and ability to create harmonious win-win development capabilities on the basis of collaborative innovation with customers, and form capability to grasp control of the industrial chain and achieve competitive advantages.

4.3 Intelligent Manufacturing

Intelligent manufacturing evolved from the traditional artificial intelligence, usually demonstrated as intelligent machines to show the performance of flexible and intelligent manufacturing systems in the manufacturing unit and flexible and intelligent network-based integration. Volatility of consumer demand and uncertainty of economic activity continue to grow. Diversified varieties and small batch manufacturing demand will become a normal pattern. Flexible and intelligent manufacturing to realize personalized service manufacturing is a reasonable choice, the development trend of future manufacturing.

5 Smart Manufacturing for Sustainability

All of these trends will lead to smart manufacturing. In recent years, China maintains a booming out looking of rapid economic development. In 2010, its national manufacturing sector has surpassed the USA as the top 1 manufacturing country in the world. At the same time, China is eager to move toward high-end manufacturing power, having set the research theme of smart manufacturing at high priority.

At present, the world is moving toward an era of wisdom, on the bases of digital, intelligent, and service development. Smart manufacturing, established on the basis of digital, service, and intelligent manufacturing, is an effective way to transform traditional manufacturing to achieve high-precision, high-efficiency, and high-reliability manufacturing and enhance the capacity for the transformation and upgrading. In recent years, the USA continues to introduce intelligence into their economic activities. It liberated more and more Americans into more intelligent and higher value-added industries. This intellectual revolution has begun to threaten Chinese manufacturing industry, forcing China to transform from industrial age competition toward seizing the controlling methods and tools to gain global competitive advantages in the era of wisdom and knowledge.

In China, manufacturing is the cornerstone of national economy. However, it seats in the low end of the industrial chain. Its potential pulling power for improving domestic demand on the national economy is not adequately reflected. Big but not strong characterizes China's current manufacturing, with urgent need to improve its competitiveness in the world. Current market situation still demands the implementation for upgrading, transformation, and relocation policies. In the process of this industrial restructuring, smart manufacturing development presents a viable way to leverage this scientific and technological progress to interface and meet the high-end development needs of manufacturing industry.

6 Further Considerations

China's President Hu Jintao has already voiced China's determination to develop its economy in a sustainable way with smart manufacturing development set as one of the strategic emerging industries. However, smart manufacturing development will have to face and address numerous challenges in order to lead to manufacturing sustainability for China to facilitate development of technology-rich, high value-add, and service-oriented manufacturing industries.

Smart manufacturing is by its nature multidisciplinary across the knowledge domains of business, management, and technology, covering a wide spectrum of activities in the economic value chain. To exert a major impact, breakthroughs are necessary in the relevant theories, engineering, and technological aspects in facilitating mechanism design with relevant policy, business, and technology innovation and practice adoption for manufacturing excellence for sustaining China's economy growth. Specifically, the following breakthroughs are needed in respect of the challenges for a major impact: (1) breakthroughs in policy support via forming sustainable ecosystem for world situation adaptation and mitigation; (2) breakthroughs in efficient collaborative methods and operational support in and across the industries and innovative capabilities and financing models to develop technology-rich, high value-add, and service-oriented manufacturing industry; and (3) breakthroughs in enabling high-end product development and manufacturing capacity. All of these demand a careful mechanism design for sustainability.

7 Mechanism Design for Sustainability

China's manufacturing industry exerts an excellent case for illustrating the need of mechanism design for sustainability. In view of this need, state-of-the-art progress in mechanism design for sustainability techniques and case studies is solicited to provide a good reference in the area.

And the rest of the book is organized into three parts, Part II, III, and IV, all contributed by researchers and practitioners worldwide. Part II includes chapters related to mechanism design techniques for sustainability. Part III includes chapters related to sustainability mechanism analysis. Part IV includes sustainability cases. Each of these chapters will introduce mechanism design for sustainability techniques, analysis, or cases. All of those chapters make up an excellent set of reference materials covering a comprehensive range of sustainability issues with academic merits as well as practical relevance. The abstract of each chapter is briefly introduced as follows:

Part	Chapter	Title, authors, and abstract
II	2	Multi-criteria Decision Making: A Mechanism Design Technique for Sustainability
–	–	Fabio De Felice and Antonella Petrillo
–	–	This chapter aims to present an approach based on the analytic hierarchy process (AHP) to manage collaborative relationships under an integrated approach in order to investigate and promote mechanism design for sustainability. With this approach, enterprises will obtain significant information for the decision-making process regarding sustainable performance elements that have the greatest impact on their competitiveness and therefore should be prioritized
–	3	Mechanism Design for Allocation of Carbon Emission Reduction Units: A Study of Global Companies with Strategic Divisions and Partners

(continued)

(continued)

Part	Chapter	Title, authors, and abstract
–	–	Deepak Bagchi, L. Udaya Lakshmi, Y. Narahari, Shantanu Biswas, P. Suresh, S. V. Subrahmanya, and N. Viswanadham
–	–	The problem addressed in this work is concerned with an important challenge faced by any green aware global company to keep its emissions within a prescribed cap. The specific problem is to allocate carbon reductions to its different divisions and supply chain partners in achieving a required target of reductions in its carbon reduction program. Mechanism design theory has shown that it is not possible to achieve the three identified properties simultaneously. Two protocols are proposed and their performance is evaluated using a stylized, representative case study
–	4	Six Sigma Methodology for the Environment Sustainable Development
–	–	Seifedine Kadry
–	–	The Six Sigma methodology, as it has evolved over the last two decades, provides a proven framework for problem-solving and organizational leadership and enables leaders and practitioners to employ new ways of understanding and solving their sustainability problems. While business leaders now understand the importance of environmental sustainability to both profitability and customer satisfaction, few are able to translate good intentions into concrete, measurable improvement programs. Increasingly, these leaders are looking to their corps (Six Sigma experts) of Six Sigma “Master Black Belts,” “Black Belts,” and “Green Belts” to lead and implement innovative programs that simultaneously reduce carbon emissions and provide large cost savings. In my experience, and that of many others, Six Sigma processes show a proven approach for businesses and organizations to improve their performance, and that sustainability programs are in need of this operational approach and discipline. Six Sigma rigors will help a business leader to design a sustainable program for both short- and long-term value creations. The aim of this chapter is to show the importance of applying Six Sigma methodologies to multidisciplinary sustainability-related projects and how to implement it
III	5	Soft TQM for Sustainability: An Empirical Study on Indian Cement Industry and Its Impact on Organizational Performance
–	–	Tripti Singh and Rameshwar Dubey
–	–	As we embark into a new era which has witnessed global slowdown and intense competition to survive, it is quite appropriate to revisit the role of total quality management (TQM) in enabling and supporting firm to sustain superior performance. This chapter is concerned with soft dimensions of TQM which not only help it in successful implementation but also provide sustainable competitive advantage. Sustainability can perhaps be correlated with the principle of excellence which is now gaining wider acceptance in the business community (Zairi 2005). The present research proposes a soft TQM framework and empirically tested the impact of soft dimensions of TQM on its performance in context to Indian cement industry to understand how soft TQM can help Indian cement industry to sustain competitive advantage in long term. The chapter concludes with a statement that soft dimensions of TQM are critical for sustainability which enables cement firms to achieve superior performance
–	6	An Energy Optimization Framework for Sustainability Analysis: Inclusion of Behavioral Parameters as a Virtual Technology in Energy Optimization Models

(continued)

(continued)

Part	Chapter	Title, authors, and abstract
–	–	Roman Kanala, Nathalie Turin, and Emmanuel Fragnière
–	–	This chapter introduces an innovative approach that combines the deductive method used to construct normative energy-economy models and the inductive method of social sciences. Consumer behavior is described via technological attributes and used in virtual process technologies in an energy optimization framework. The main finding is that it is possible to evaluate consumer information and behavior together with technological progress and integrate them on the same modeling platform. The approach eliminates the systematic error on the demand side where the efficiency of demand-side management measures is over optimistic, which may lead to inaccurate decisions and poor policies. Thus, this method paves the way to a new stream in energy modeling
–	7	Supply Chain Evolution for Sustainability Focused Firms: Content Analysis Toward Socially and Environmentally Friendliness
–	–	Ozan Özcan and Kingsley Anthony Reeves Jr.
–	–	The objective of this research was to understand how the organizational structure of sustainability-focused companies changes over time as the companies become more environmentally, economically, and socially sustainable. We applied trend analysis to the sustainability scores and vertical integration level of the companies. The study results demonstrated an increasing trend in both vertical integration and sustainability development of industrials industry companies over a 15-year period. Furthermore, the companies became more vertically integrated as their environmental, economical, and social sustainability increased
–	8	Community Participation Mechanism: A Study of Youth Voices in Conservations' GreenLeaf Marketplace
–	–	Leonard Sonnenschein
–	–	The Youth Voices in Conservation Program has researched youth action toward conservation and sustainability from the classroom, the field site, and within nongovernmental and governmental organizational situations for the past few years. This research found that by developing a residual funding based upon carbon credit offsets created by these localized actions, there is a possibility of conditional cash transfer based upon these "good actions." The results of this research indicate that the Youth Voices in Conservation's GreenLeaf Program may be able to address localized sustainability issues as well as methodology for decreasing carbon footprints and increasing financial sustainability within each community, and consequently the environmental effects from the wide-scale adoption of these plans may be expected
–	9	The "Ecological" Stock: "A Financial Market Instrument for Global Scale Climate Change Mitigation"
–	–	Vicente Rappaccioli Navas
–	–	This financial market instrument first addresses the issue of "global risk": the combined world economic, political, and social risk that is rapidly resulting from the unparalleled planetary environmental degradation and climate change. It provides evidence that "global risk" can be reduced with investments in forest preservation, reforestation, and renewable energy. Furthermore, it shows that in order to achieve the urgently needed global scale climate change mitigation and neutralization, new massive capital investments can be stimulated and, thereby, shifted, through the profit motive utilizing financial product innovations in the free market system with the active participation of the private sector. The "ecological" stock is a certifiable and tradable innovative instrument that incorporates features of a corporate stock, a commodity, a derivative, and perpetuity

(continued)

(continued)

Part	Chapter	Title, authors, and abstract
IV	10	The Sustainable Development of Trasimeno Lake
–	–	Adriano Ciani, Luigi Porcellati Pazzaglia, Lucia Rocchi, Francesco Velatta, and Mauro Natali
–	–	The defense and the development of Lake Trasimeno are a complex and articulated task. Nevertheless, the preservation of a dynamic equilibrium and a management increasingly inspired to the principles of sustainability make up study case of relevant interest and of concern for experts and ordinary citizens who care about the future of the entire world and its essential diversity
–	11	Sustainable Farm: A Case Study of a Small Farm from Pali, India
–	–	Dheeraj Singh, M. K. Choudhary, M. L. Meena, S. Kachhawaha, and P. K. Tomar
–	–	Along with agriculture, the farmer is having livestock which yields milk, and the dung is converted into valuable vermicompost. Thus, this model of multifunctional small farm which integrates crops, horticulture, livestock, and natural vegetation is key to sustainable development in countries dominated by small farms
–	12	Sustainable City: A Case Study of Stormwater Management in Economically Developed Urban Catchments
–	–	Deepshikha Sharma and Arun Kansal
–	–	The present study comprises of qualitatively evaluating the role of sustainable urban drainage systems in stormwater management of dense urban cities. The following chapter talks about an approach to manage rainfall runoff arising due to urbanization which is a direct impact of economic growth of a city
–	13	Sustainable Software: A Study of Software Product Sustainable Development
–	–	Malgorzata Pankowska
–	–	The intention of this chapter is to propose a distinct approach to software development sustainability as well as a different understanding of sustainability in the context of software development. The chapter covers survey of good practices and software development methods as important for sustainable development of software products. Particularly, the author focuses on agile methods and product line engineering as approaches supporting the sustainable development of software product. The analyzed practices and methods are suggested to be implemented for the software company sustainability. The implementation results in saving human efforts as well as energy and computer power
–	14	Sustainability Policy: A Case Study of the Limits to Biofuel Sustainability
–	–	Henrique Pacini, Andrei Cechin, and Semida Silveira
–	–	This chapter explores biofuel sustainability policies, their economic rationale, and specially their limits, as seen from the basic strategies of dematerialization, detoxification, and transmaterialization. The chapter then frames where biofuels' sustainability policies have margin for action, exemplified by the case of the European scheme proposed in 2009. By understanding the economic rationale and guiding principles behind efforts to improve biofuels sustainability, the chapter can contribute to better understand the actual scope and limitations of policy efforts currently aiming to promote responsible biofuel usage. The study concludes by proposing that transparency and dialogue are including parties directly and indirectly affected by biofuel strategies as the only way to legitimize the sharing of risks in this emerging international market

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Part II
Mechanism Design Techniques for Sustainability

Multi-criteria Decision-Making: A Mechanism Design Technique for Sustainability

Fabio De Felice and Antonella Petrillo

Abstract Sustainable development has become a key concept in environmental and economic policy analysis. From this point of view, it is desirable to integrate culture, legal, business, and financial prospective and increase collaboration among enterprises in order to improve sustainable competitiveness. Enterprises that are collaborating need to define and use performance measurement/management frameworks composed of performance elements (objectives, performance indicators, etc.) that facilitate the management of their activity, as well as monitor their strategy and processes. There are several factors that need to be managed properly in order to support collaborative success. So this chapter aims to present an approach based on the analytic hierarchy process (AHP) to manage collaborative relationships under an integrated approach in order to investigate and promote mechanism design for sustainability. With this approach, enterprises will obtain significant information for the decision-making process regarding sustainable performance elements that have the greatest impact on their competitiveness and therefore should be prioritized.

Keywords Decision support • AHP technique • Mechanism design • Sustainability • MCDM

1 Introduction

Sustainable development was most popularly developed by the World Commission on Environment and Development (WCED) in Our Common Future in 1987 (WCED 1987). A direct quotation from WCE Dreads: "*Sustainable development is development that meets the needs of the present without compromising the ability of future*

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_2,

generations to meet their own needs." Since "sustainable development" was adopted as an overarching goal of economic and social development by Agenda 21, many countries, governments, and even private enterprises, it has generated a huge body of research (Hopwood et al. 2005; Pati et al. 2008).

A large body of literature has evolved around the concept of sustainable development; many contributions are in a general and descriptive manner and lack of theoretical and operational analysis (Gnoni et al. 2011). One possible reason may be that elaborating on the concept requires complicated and interdisciplinary approach (Van den Bergh 1996; Paucar-Caceres 2010). Sachs and Reid (2006) highlighted the importance of interdisciplinary strategy in sustainable development.

To reach sustainable development, it is essential to understand and study the mechanisms for interactions and impact among different perspectives. From this point of view, mechanism design for sustainability is a useful approach that intends to provide advanced analytics and decision management techniques and tools toward developing sustainable competitive.

Mechanism design considers how to implement good system wide solutions to problems that involve multiple self-interested agents, each with private information about their preferences. In recent years, mechanism design has found many important applications, for example, in electronic market design, in distributed scheduling problems, and in combinatorial resource allocation problems.

Of course, it is necessary to apply a proper techniques to develop mechanism design for sustainable competitive. What we need is a *systematic and comprehensive approach* to decision-making.

In fact, such as our lives are the sum of our decisions, so in similar way it is also in business or in research spheres. Often, *when* we decide is as important as what we decide. Deciding too quickly can be hazardous; delaying too long can mean missed opportunities. In the end, it is crucial that we make up our mind.

This need calls for a new logic, a new way to cope with the myriad factors that affect the achievement of goals and the consistency of the judgments we use to draw valid conclusions.

From this point of view, decision-making and in particular MCDM – multi-criteria decision-making – is a field that seems very fit to choose the best of a discrete set of alternatives and to apply mechanism design for sustainability. Unlike the usual methods of optimization that assume the availability of measurements, measurements in MCDM are assumed to be derived or interpreted subjectively as indicators of preference and of the strength of preference.

Decision-making is fundamental to furthering our goal of survival and ensuring the quality of our life. *To be a person is to be a decision-maker*. Life is worth little if we are not free to make our own choices.

The analytic hierarchy process (AHP) (developed by Prof. Thomas L. Saaty in the 1970s), the MCDM technique, described in this chapter and now widely used in decision-making – is a theory that depends on the values and judgments of individuals and groups.

Our primary purpose in writing this chapter is to introduce the reader to a new way of making decisions in a complex environment and in particular in *mechanism design* *for sustainability*. The method is based on the user's experience and judgments supported by explanations that ensure a sense of realism and a broad perspective.

The unique features of the chapter are the simplicity of the approach (it involves only simple arithmetic). This approach should not be regarded simply as a technique; it is a general method for coping with unstructured problems.

The process contributes to solving complex problems by structuring a hierarchy of criteria, stakeholders, and outcomes and by eliciting judgments to develop priorities. It also leads to prediction of likely outcomes according to these judgments. The outcome can be used to rank alternatives, allocate resources, conduct benefit/cost comparisons, exercise control in the system by evaluating the sensitivity of the outcome to changes in judgment, and carry out planning of projected and desired futures. A useful by-product is the measurement of how well the leader understands the relations among factors. Although people generally are not consistent, the main concern here is the strength of their inconsistency.

Our ability to choose by reflecting on the complexities of a decision and how that decision may affect the future is largely what separates us from other forms of life. The choices we make depend mostly on what purpose we want to achieve. Our purpose arises out of our vision of what we think is ultimately of greatest importance to us. We then take actions that we believe will allow us to carry out our purpose and fulfill our vision. There are cases, however, when one's freedom of choice is constrained. Many decisions involve groups of people who must reconcile their different criteria and goals. In the end, decision-making is closely related to conflict resolution. Thus, the benefits we derive from the decisions we make are largely determined by how well we can deal with differences in opinion and how well we can foresee risks and opportunities and plan for the future.

The AHP can help bring together a diverse group of people with different perspectives to make the complex decisions required in our time. They offer a structured framework for discussion and debate, a way to include the important intangibles of every major decision together with the tangibles, and a way to resolve conflicts over turf and achieve buy-in to implement the decision at the end of the day (Saaty et al. 2003).

The AHP has been applied to a large variety of decisions: marketing, medical, political, social, and forecasting and prediction and many others. Its accuracy is impressive in predicting economic trends, winners in sports, and other events for which the outcome later became known.

2 The Decision-Making Process and Multi-criteria Decision-Making Methods (MCDM)

Decision-making is the study of identifying and choosing alternatives based on the values and preferences of the decision-maker. Making a decision implies that there are alternative choices to be considered, and in such a case, we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on.

MCDM techniques have become increasingly popular in recent years and are widely used in energy planning (e.g. Cavallaro and Ciraolo 2005; Gamboa and Munda 2007; Stagl 2006). Major advantages of the MCDM methodology over other decision-support methods are that the methodology acknowledges that decision-making is a complex process and helps to provide a rational basis for the structuring of decision-making. MCDM helps to overcome some of these issues to a greater extent than other decision-support tools, such as cost–benefit analysis. The methodology is capable of considering a number of different objectives, which can be weighted to reflect the hierarchy of objectives. The methodology often involves widespread stakeholder participation; this can act to improve the accountability and transparency of decisions reached and to provide greater levels of ownership over the decision-making process and its outcomes. For these reasons, diverse applications of MCDM are often used in government and public sector planning where the accountability of decisions to the public is vital.

MCDM are often used in government and public sector planning where the accountability of decisions to the public is vital. This involvement of stakeholders is one of the main drivers behind the development and use of MCDM. This method facilitates the process of decision-making by making clear the assumptions of the various stakeholders by providing a structured process with an audit trail supporting learning and evaluation. This allows for transparency to stakeholders and can be easily followed by local residents. However, the transparency surrounding the methodology does not necessarily lead to social acceptance of the decision outcome. Social acceptance is based on complex processes involving a variety of cognitive and emotive elements, and different social actors will have different and possibly contrasting viewpoints; in cases where such conflicts arise, full social acceptance may be impossible to achieve. Although social acceptance may be difficult to achieve, the transparency surrounding the method does allow stakeholders to see the processes that were undertaken in the decision-making exercise, even if they do not fully agree with the final decision outcome.

These strengths of the MCDM have led to its rapid development over recent years, and a number of different methods have been developed including ELECTRE III (Roy 1978), analytical hierarchy process (Saaty 1980), PROMETHEE II (Brans et al. 1985), NAIADE (Munda 1995), and MACBETH (Bana e Costa and Vansnick 1997, 1999). MCDM can generally be split into two classes: multiple objective decision-making, where the alternatives are not predetermined but a set of objective functions is optimized until the most efficient solution is found, and multiple attribute decision-making, where alternatives are determined and the decision-maker indicates his preference for each objective, until an efficient solution is found (Haung et al. 1995).

Pohekar and Ramachandran investigated several methods based on weighted averages, priority setting, outranking, fuzzy principles, and their combinations which employed for energy planning decisions. They presented a review of more than 90 published papers to analyze the applicability of the methods. It was observed that AHP is the most popular technique followed by outranking techniques PROMETHEE and the elimination and choice translating reality (ELECTRE) (Pohekar and Ramachandran 2004).

2.1 Scientific Approach for Resolution of Problems

It is very important to make distinction between the cases whether we have a single or multiple criteria.

The decision can be made implicitly by determining the alternative with the best value of the single criterion or aggregate measure.

Consider a multi-attribute decision-making problem with *m* criteria and *n* alternatives. Let $\mathbf{C}_1, \ldots, \mathbf{C}_m$ and $\mathbf{A}_1, \ldots, \mathbf{A}_n$ denote the criteria and alternatives, respectively. A standard feature of multi-attribute decision-making methodology is the *decision table* as shown below. In the table, each row belongs to a criterion, and each column describes the performance of an alternative. The score a_{ij} describes the performance of alternative $\mathbf{A}_j$ against criterion $\mathbf{C}_i$. For the sake of simplicity, we assume that a higher score value means a better performance since any goal of minimization can be easily transformed into a goal of maximization. As shown in decision table, weights $w_1, \ldots, w_m$ are assigned to the criteria. Weight w_i reflects the relative importance of criteria $\mathbf{C}_i$ to the decision and is assumed to be positive. The weights of the criteria are usually determined on subjective basis. They represent the opinion of a single decision-maker or synthesize the opinions of a group of experts using a group decision technique, as well.

The values $x_1, \ldots, x_n$ associated with the alternatives in the decision table are the final ranking values of the alternatives. Usually, higher ranking value means a better performance of the alternative, so the alternative with the highest ranking value is the best of the alternatives (Table 1).

Multi-attribute decision-making techniques can partially or completely rank the alternatives: a single most preferred alternative can be identified, or a short list of a limited number of alternatives can be selected for subsequent detailed appraisal.

Besides some monetary-based and elementary methods, the two main families in the multi-attribute decision-making methods are those based on the multi-attribute utility theory (MAUT) and outranking methods.

The family of MAUT methods consists of aggregating the different criteria into a function, which has to be maximized. Thereby the mathematical conditions of aggregations are examined. This theory allows complete compensation between criteria, that is, the gain on one criterion can compensate the lost on another (Keeney and Raiffa 1976). The concept of outranking was proposed by Roy (1968). The basic idea is as follows. Alternative $\mathbf{A}_i$ outranks $\mathbf{A}_j$ if on a great part of the criteria $\mathbf{A}_i$ performs at least as good as $\mathbf{A}_j$ (concordance condition), while its worse performance is still acceptable on the other criteria (non-discordance condition). After having determined for each pair of alternatives whether one alternative outranks another, these pairwise outranking assessments can be combined into a partial or complete ranking. Contrary to the MAUT methods, where the alternative with the best value of the aggregated function can be obtained and considered as the best one, a partial ranking of an outranking method may not render the best alternative directly. A subset of alternatives can be determined such that any alternative not in

Table 1 The decision table

		X_1	…	…	X_n
		A_1	…	…	A_n
w_1	C_1	a_{11}	…	…	A_{m1}
		…	…	…	…
		…	…	…	…
w_n	C_m	a_{m1}	…	…	a_{mn}

the subset be outranked by at least one member of the subset. The aim is to make this subset as small as possible. This subset of alternatives can be considered as a shortlist, within which a good compromise alternative should be found by further considerations or methods.

2.2 Features of Decision-Making Process

According to Baker et al. (2002), decision-making should start with the identification of the decision-maker(s) and stakeholder(s) in the decision, reducing the possible disagreement about problem definition, requirements, goals and criteria. Then, a general decision-making process can be divided into the following steps:

1. Define the problem.
2. Determine requirements.
3. Establish goals.
4. Identify alternatives.
5. Define criteria.
6. Select a decision-making tool.
7. Evaluate alternatives against criteria.
8. Validate solutions against problem statement.

In decision-making, the consequences of an action are often unknown because they depend on future events. As we said many models exist for multi-criteria decision-making under such conditions of uncertainty.

A decision-making approach should have the following characteristics:

- Be simple in construct
- Be adaptable to both groups and individuals
- Be natural to our intuition and general thinking
- Encourage compromise and consensus building, and
- Does not require inordinate specialization to master and communicate.

In addition, the details of the processes leading up to the decision-making process should be easy to review.

At the core of the problems that our method addresses is the need to assess the benefits, the costs, and the risks of the proposed solutions. We must answer such questions as the following: Which consequences weigh more heavily than others? Which aims are more important than others? What is likely to take place? What should we plan for and how do we bring it about? These and other questions demand a multi-criteria logic. It has been demonstrated over and over by practitioners who use the theory discussed in this chapter that multi-criteria logic gives different and often better answers to these questions than ordinary logic and does it efficiently.

To make a decision, one needs various kinds of knowledge, information, and technical data. These concerns are as follows:

- Details about the problem for which a decision is needed.
- The people or actors involved.
- Their objectives and policies.
- The influences affecting the outcomes.
- The time horizons, scenarios, and constraints.

The decision-making process described in details this chapter meets these criteria. We call it the AHP. The AHP is about breaking a problem down and then aggregating the solutions of all the subproblems into a conclusion. It facilitates decision-making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision. In the simple and most common case, the forces are arranged from the more general and less controllable to the more specific and controllable. The AHP is based on the innate human ability to make sound judgments about small problems. Here *rationality* is as follows:

- Focusing on the goal of solving the problem.
- Knowing enough about a problem to develop a complete structure of relations and influences.
- Having enough knowledge and experience and access to the knowledge and experience of others to assess the priority of influence and dominance (importance, preference, or likelihood to the goal as appropriate) among the relations in the structure.
- Allowing for differences in opinion with an ability to develop a best compromise.

3 Multi-criteria Decision-Making: Analytical Hierarchy Process

As we said sustainable development has become a key concept in environmental and economic policy analysis. From this point of view, it is desirable to integrate culture, legal, business, financial, and environmental perspectives. The importance of establishing collaboration between enterprises has been widely studied in the literature

(Gruat La Forme et al. 2007). Many of the studies highlight the benefits of inter-enterprise collaboration, which mainly deals with the performance improvement/management in key inter-enterprise performance indicators such as faster cycle times, flexible customer response, and increased cash-to-cash velocity (Chae 2009).

From a methodological point of view, it is necessary to select a method to solve this issue. MCDM are widely used for solving problems involving various criteria and multiple agents (Belton and Stewart 2002). One of the most commonly used MCDM methods is the AHP. There are three main reasons that suggest using AHP to model and solve the problem of sustainable development. Firstly, AHP allows modeling complex problems with a hierarchy structure, integrating dependences among elements. Secondly, AHP is adequate for solving problems with both qualitative and quantitative factors (Peniwati 2010). This is an important characteristic as many of the collaboration factors are qualitative such as cultural factors, and many of the methods are mainly developed for quantitative measurement. Thirdly, AHP has been used in group decision problems (Chen et al. 2008) which is the case of a collaborative relationship.

3.1 Origins of Analytical Hierarchical Process

AHP is a decision-making method proposed by Saaty (1980), probably the best known and most widely used model in decision-making. AHP is a powerful decision-making methodology in order to determine the priorities among different criteria. The applications of AHP have produced extensive results in many problems involving planning, resource allocation, priority setting, and selection among alternatives (Vaidya and Kumar 2006). The AHP is an intuitively easy method for formulating and analyzing decisions (Saaty and Kearns 1985). It was developed to solve a specific class of problems that involves prioritization of potential alternate solutions. This is achieved by evaluation of a set of criteria elements and subcriteria elements through a series of pairwise comparisons (Bhyun 2001).

3.2 Features of AHP: Framework and Functioning

The AHP encompasses six basic steps as summarized as follows:
Step 1. AHP uses several small subproblems to present a complex decision problem. Thus, the first act is to decompose the decision problem into a hierarchy with a goal at the top, criteria and subcriteria at levels and sublevels, and decision alternatives at the bottom of the hierarchy (Fig. 1).

Here are some suggestions for an elaborate design of a hierarchy:

1. Identify the overall goal. What are you trying to accomplish? What is the main question?
2. Identify the subgoals of the overall goal. If relevant, identify time horizons that affect the decision.

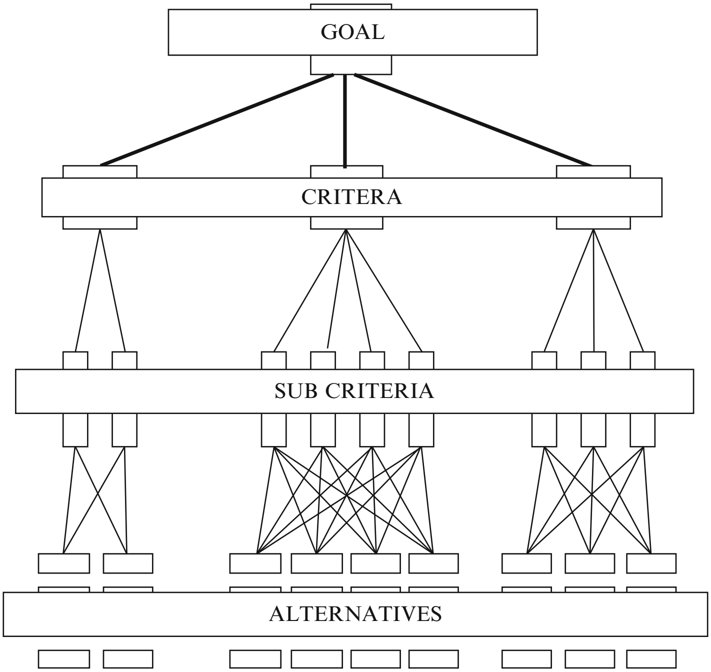

Fig. 1 The hierarchical structure of the decision-making problem

3. Identify criteria that must be satisfied to fulfill the subgoals of the overall goal.
4. Identify subcriteria under each criterion. Note that criteria or subcriteria may be specified in terms of ranges of values of parameters or in terms of verbal intensities such as high, medium, and low.
5. Identify the actors involved.
6. Identify the actors' goals.
7. Identify the actors' policies.
8. Identify options or outcomes.
9. For yes–no decisions, take the most preferred outcome and compare the benefits and costs of making the decision with those of not making it.
10. Do a benefit/cost analysis using marginal values. Because we are dealing with dominance hierarchies, ask which alternative yields the greatest benefit; for costs, which alternative costs the most; and for risks, which alternative is more risky.

Step 2. The decision matrix, which is based on Saaty's nine-point scale (Table 2), is constructed. The decision-maker uses the fundamental 1–9 scale defined by Saaty to assess the priority score. In this context, the assessment of 1 indicates equal importance, 3 moderately more, 5 strongly more, 7 very strongly and 9 indicates extremely more importance. The values of 2, 4, 6, and 8 are allotted to indicate compromise values of importance.

Table 2 Semantic scale of Saaty

Intensity of importance a_{ij}	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

Step 3. The third step involves the comparison in pairs of the elements of the constructed hierarchy. The aim is to set their relative priorities with respect to each of the elements at the next higher level. The pairwise comparison matrix, which is based on the Saaty's 1–9 scale, has the form

$$A = \begin{bmatrix} w_1 / w_1 & \cdots & w_1 / wn \\ \vdots & \ddots & \vdots \\ wn / w_1 & \cdots & wn / wn \end{bmatrix} = \begin{bmatrix} 1 & \cdots & a1n \\ \vdots & \ddots & \vdots \\ 1/a1n & \cdots & 1 \end{bmatrix}$$

Pairwise comparison matrixes (whose column and row are the alternatives) must be formed based on the number of criteria. After determining the alternatives importance in each matrix, the overall importance of each alternative is calculated.

In this matrix, the a_{ij} entry indicates the relative importance of *i*th criterion to *j*th criterion.

Pairwise comparison begins with comparing the relative importance of two selected items. There are $n \times (n-1)/2$ judgments required to develop the set of matrices. If $n \times (n \times 1)/2$ comparisons are consistent with n as the number of criteria, then the elements $\{a_{ij}\}$ will satisfy the following conditions: $a_{ij} = w_i/w_j = 1/a_{ji}$ and $a_{ii} = 1$ with $i, j, k = 1, 2, \ldots, n$. In the comparison matrix, a_{ij} can be interpreted as the degree of preference of *i*th criteria over *j*th criteria. It appears that the weight determination of criteria is more reliable when using pairwise comparisons than obtaining them directly, because it is easier to make a comparison between two attributes than make an overall weight assignment.

Step 4. AHP also calculates an inconsistency index (or consistency ratio) to reflect the consistency of decision-maker's judgments during the evaluation phase. The inconsistency index in both the decision matrix and in pairwise comparison matrices could be calculated with Eq. (1):

$$\mathrm{CI} = \frac{\lambda \max - N}{N - 1} \tag{1}$$

The closer the inconsistency index is to zero, the greater the consistency. The consistency of the assessments is ensured if the equality $a_{ij} \times a_{jk} = a_{ik}$ holds for all criteria. The relevant index should be lower than 0.10 to accept the AHP results as consistent. If this is not the case, the decision-maker should go back to steps 2 and 3 and redo the assessments and comparisons.

The decision-makers have to compare or judge each element by using the relative scale pairwise comparison. The judgments are decided based on the decision-makers' or users' experiences and knowledge.

The decision-maker has to redo the ratios when the comparison matrix fails to pass the consistency test. The value of $\lambda_{\max}$ is computed as the modal value of the result, through employing the original Saaty's procedure, but using the operations if the $\mathrm{CR} > 0.1$, then the judgment matrix must be revised until reaching (or being below) 0.1 consistency value (Anderson et al. 1994; Saaty 1980).

Step 5. Before all the calculations of vector of priorities, the comparison matrix has to be normalized. Therefore, each column has to be divided by the sum of entries of the corresponding column. In that way, a normalized matrix is obtained in which the sum of the elements of each column vector is 1.

Step 6. For the following part, the eigenvalues of this matrix are needed to be calculated which would give the relative weights of criteria (Eq. 2). The relative weights obtained in the third step should verify

$$\mathrm{AW} = \lambda_{\max} W \tag{2}$$

where *A* represents the pairwise comparison matrix, *W* the eigenvector, and $\lambda_{\max}$ the highest eigenvalue. If there are elements at the higher levels of the hierarchy, the obtained weight vector is multiplied with the weight coefficients of the elements at the higher levels, until the top of the hierarchy is reached. The alternative with the highest weight coefficient value should be taken as the best alternative (Işıklar and Buyukozkan 2007).

3.3 Benefits, Costs, Opportunities, and Risks Analysis

In our decision model, we can consider several control criteria or subcriteria, such as economic, social, and political that enable us to study all the influences in a complete analysis of a decision problem and some may have different merits: benefits (B), opportunities (O), costs (C), and risks (R). For each control criterion of these B, O, C, and R, one derives priorities for the alternatives of a decision with respect to all the significant influences that cause some alternatives to have higher priority than others. One then combines the weights of the alternatives according to the weights of the control criteria of each of the B, O, C, and R assessed in terms of strategic criteria (strategic criteria are very basic criteria used by individuals and groups to assess whether they should make any of the many decision they face in their daily operations). Strategic criteria do not depend on any particular decision for their priorities but are assessed in terms of the goals and values of the individual or organization. Finally, one rates (not compares) the top ranked alternative for each B, O, C, and R and uses the resulting weights to combine the values of each alternatives for the four merits and obtain the final answer in the form of priorities (Saaty 2005).

We obtain normalized respective weights, b, o, c and r, and compute the *total outcome* $b\mathrm{B}+o\mathrm{O}-c\mathrm{C}-r\mathrm{R}$ for each alternative. Note that in evaluating the benefits or opportunities, one responds to the question of dominance: which alternative contributes the most benefits or opportunities, whereas for costs or risks, one responds to the question which alternative costs (is subject to greater risks) more, which is opposite in sense to the benefits and opportunities and must be subtracted from them.

Here below in Fig. 2 shows the prioritization of decisions.

3.4 Analysis of Sensitivity

It is often desirable to test the responsiveness or sensitivity of the outcome of a decision to changes in the priorities of the major criteria of that problem. What one does is to change the priority of that criterion keeping the proportions of the priorities for the other criteria the same, so again they all, including the changed criterion, add to one. It is best to illustrate with an example. We have seven criteria and five alternatives for buying a car shown in the hierarchy of Table 3.

The five ways for sensitivity display are shown in Fig. 3 followed by an explanation of each.

3.4.1 Performance Sensitivity

All information about how alternatives behave on each of the criteria is put in a single graph. Each criterion is represented by a vertical line and the points at which the lines representing the alternatives cross that line indicate the values the alternatives have for that criterion, as measured on the right-hand scale. The vertical line next to the right-hand scale, labeled overall, shows the composite weight for each alternative as do the intersections with the scale itself. The priority of a criterion is shown by the height of its rectangle as read from the left scale.

3.4.2 Dynamic Sensitivity

Both criteria and alternatives are represented by horizontal bars on the left and on the right, respectively. Varying the length of the criteria bars gives rise to appropriate variations in the lengths of the bars representing the priorities of the alternatives.

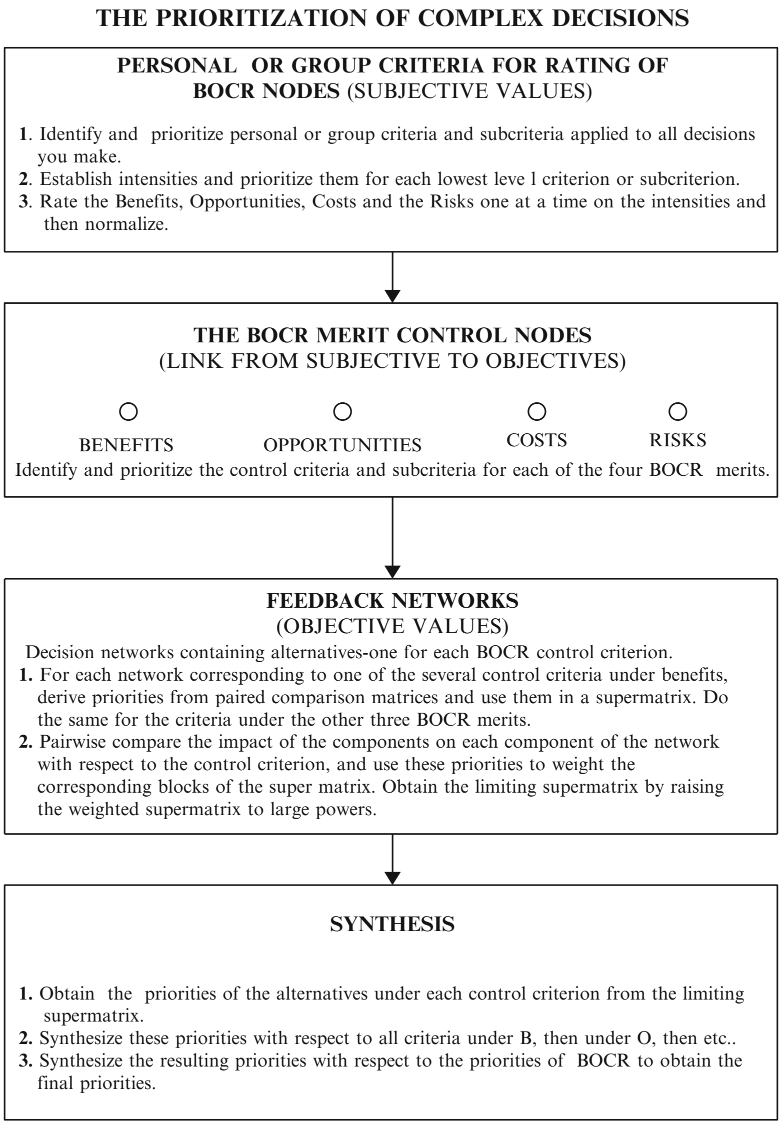

Fig. 2 The prioritization of decisions

When one criterion bar is moved outward, for example, the others automatically and proportionately move inward.

3.4.3 Gradient Sensitivity

Shows the variation of the priorities of the alternatives corresponding to variations in the priority of a single criterion. The intersection of the vertical line with the horizontal scale shows the actual value of the criterion as it arises in the problem.

Table 3 Example of sensitive analysis: hierarchy for buying a car

			GOAL (1.000)			
Initial (0.082)	Maint. (0.080)	Fuel (0.036)	Resale (0.080)	Status (0.254)	Comfort (0.254)	Rel'blty (0.216)
V.W.	V.W.	V.W.	V.W.	V.W.	V.W.	V.W.
Honda	Honda	Honda	Honda	Honda	Honda	Honda
Chevy	Chevy	Chevy	Chevy	Chevy	Chevy	Chevy
Cadillac	Cadillac	Cadillac	Cadillac	Cadillac	Cadillac	Cadillac
Mercedes	Mercedes	Mercedes	Mercedes	Mercedes	Mercedes	Mercedes

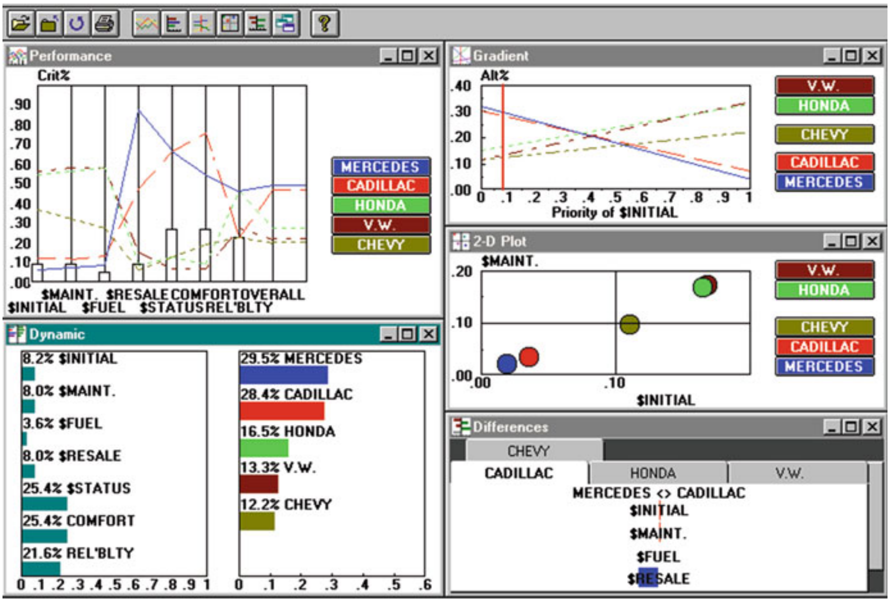

Fig. 3 Five ways to evaluate sensitivity

The intersection of the alternatives' lines with the left-hand vertical scale represents the alternatives' priorities. Moving this line to the left or to the right shows how the alternatives' priorities change as the priority of the criterion changes.

3.4.4 Two-Dimensional Plot

Shows how well the alternatives (represented by circles) perform with respect to pairs of criteria one on the *x*-axis and the other on the *y*-axis. The figure here shows their projection on the diagonal of the rectangle. The farther out on this composite line the projection of a point falls, the better that alternative rates on the two criteria.

3.4.5 Weighted Differences Sensitivity

The lengths of the horizontal bars show the difference for each pair of cars, here given for the Cadillac global priority and the Mercedes global priority, on each of the criteria. If it is positive, it is in favor of the Cadillac (represented on the right); if it is negative, it is in favor of the Mercedes (represented on the left). The overall difference scale is the bottom line in the figure. All pairs of alternatives may be examined in this way. The words in the left side of the figure are not very clear. They are Initial, Maintenance, Fuel, Resale, Status, Comfort, and Reliability.

4 Mechanism Design and AHP: An Example

The theory of mechanism design can be thought of as the "engineering" side of economic theory. Much theoretical work, of course, focuses on *existing* economic institutions. The theorist wants to explain or forecast the economic or social outcomes that these institutions generate. But in mechanism design theory the direction of inquiry is reversed. We begin by identifying our desired outcome or *social goal*. We then ask whether or not an appropriate institution (mechanism) could be designed to attain that goal. If the answer is yes, then we want to know what form that mechanism might take. There are many excellent surveys and text book treatments of implementation theory that go into considerably more detail both technical and conceptual (Baliga and Maskin 2003; Corchon 2008). As in any science, a decision theory needs ways to validate it so in this paragraph we will analyze an example (De Felice and Petrillo 2010).

4.1 Definition of the Problem

The main objective is to analyze a multi-criteria methodological approach based on the AHP methodology in order to examine the scope and feasibility of AHP integrated with public participation approach and sustainable development.

4.1.1 Define of Stakeholders

Identifying or rather selecting stakeholder groups (policy-makers, planners, and administrators in government and other organizations) is a difficult task. The process of selection has to be open and transparent. We chose a group composed of industrials, citizens, environmentalists, agriculturists, and tourism operators.

4.1.2 Define of Alternatives

As alternatives, we chose the three types of energy: electricity production from wind farms, thermal power plants, and nuclear power plants. Here below are depicted alternatives.

- *Nuclear Plants*
- *Features*: Public acceptance does not exist due to some uncertainties related to nuclear energy such as economic performance, proliferation of dangerous material, the threat of terrorism, operation safety, and radioactive waste disposal.
- *Capacity factor*: 60–100%
- *Investment costs (average value)*: €3,000/kW
- *Operating and maintenance costs/capital %*: 50
- *Thermal Plants*
- *Features*: Coal is an essential energy source to generate electricity for thermal power plants. The poor quality of this lignite is responsible for a considerable amount of air pollution.
- *Capacity factor*: 70–90%
- *Investment costs (average value)*: €1,300/kW
- *Operating and maintenance costs/capital %*: 97
- *Nuclear Plants*
- *Features*: Wind power as a practical electric power generation is now becoming more prominent among renewable and the other energy options and all researches focused on improving wind energy generation. Wind energy is accepted by public, industries and politics as a clean, practical, economical, and eco-friendly option.
- *Capacity factor*: 20–40%
- *Investment costs (average value)*: €1,100/kW
- *Operating and maintenance costs/capital %*: 25

4.2 Building of AHP Model

Developing effective energy policy requires that policy-makers take into account the multiple objectives of multiple stakeholders and their conflicting interests. The structure of the proposed AHP Participatory Model is show in Fig. 4.

The use of *multi-criteria approach* involves developing a decision model comprising decision attributes (criteria), subcriteria, and alternatives. Criteria and subcriteria are described in Table 4.

In Table 5 is a given scenario with key relationships of AHP factors.

4.2.1 Comparison of Factors

Since the problem has been structured as a hierarchy, the relations between elements in succeeding levels are obtained by making pairwise comparisons.

4.2.2 Determination of the Weights of Importance for Each Factors

The weights of the decision objectives from the stakeholder group point of view are presented in Table 6.

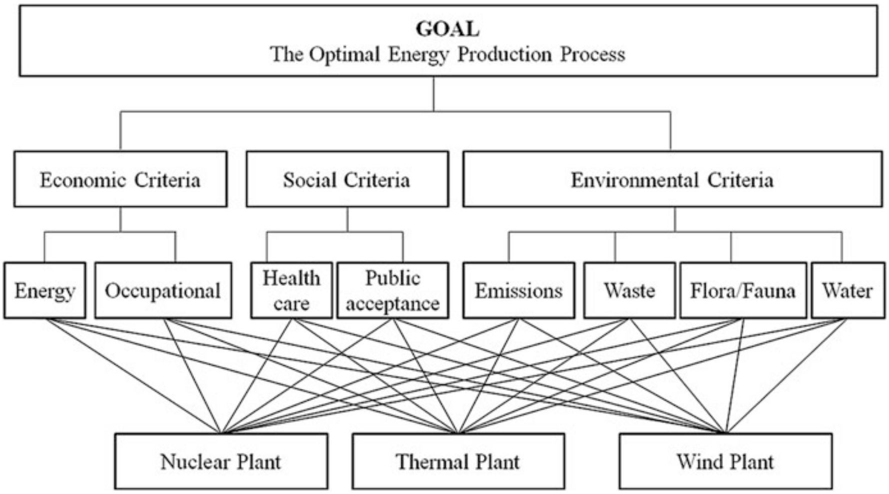

Fig. 4 Proposed AHP participatory model

Table 4 Criteria and subcriteria

Criteria	Subcriteria	
Social goals:	Health care	Activities that not ensure safeguard of population
Social benefits achieved from the development of sustainability level	Public acceptance	Acceptance of qualitative and quantitative consequences on the environment
Economic goals:	Energy	Evaluation of total energy production
Processes associated with planning, scheduling, and coordinating activities. The effectiveness in managing assets to support environmental demand satisfaction	Occupational	Activities can build value through new jobs
Environmental goals:	Emissions	The evaluation and implementation of actions to reduce environmental impacts
Activities can build value through sustainable methods		
	Waste	The needs to reduce waste due energy production
	Flora/fauna	Evaluation of actions to helps maintain biodiversity and reduce environmental damage
	Water	The need to satisfy the requirements for water preservation

4.3 Step 3: Evaluation of Priorities

The global priorities (Table 7) can be calculated on the basis of weighting schema for the stakeholder groups, the importance of objectives from the point of view of the stakeholder groups and the relative priorities of decision alternatives with respect to the objectives.

Table 5 Relation between subcriteria and alternatives

Subcriteria	Nuclear	Wind	Thermal
Health care	High risks	No risks	Low risks
Public acceptance	High resistance	Low resistance	Medium resistance
Energy	High production	Low production	Medium production
Occupational	High value	Medium value	Medium value
Emissions	Radiation	Noise	CO_2, NO_x, SO_2, HM, HW, and fly ash
Waste	High Radioactive waste. Difficult and expensive disposal and storage	No waste	Medium
Flora/fauna	Bad preservation	High preservation	Bad preservation
Water	Bad	Good	Bad

Table 6 Weights of decision objectives

Subcriteria	Nuclear	Wind	Thermal
Health care	0.208	0.489	0.303
Public acceptance	0.155	0.519	0.326
Energy	0.616	0.116	0.268
Occupational	0.600	0.200	0.200
Emissions	0.459	0.156	0.385
Waste	0.755	0.045	0.200
Flora/fauna	0.678	0.122	0.222
Water	0.450	0.150	0.400

Table 7 Global priorities

Alternatives	Social goals	Economic goals	Environmental goals
Nuclear	0.10	0.45	0.15
Wind	0.76	0.21	0.63
Thermal	0.18	0.34	0.22

4.3.1 Analysis of Results

As we can note nuclear power has higher priority of economic goal because of its high capacity factor, efficiency and ever ready of generating electricity. Although social goal and environmental goals have lower priority number than the thermal plant and wind plant. Thermal plant takes the lowest priority from social because of huge amount of waste and high air pollution profiles related with climate change and global warming. Environmental and social factors make wind power the leader in the public eye as it has negligible negative impacts on the environment and human health.

Public acceptance in social factors, which is the reason of the lowest priority number for nuclear, is the main indicator on decision-making.

Although the priority numbers of both nuclear and thermal plant are overall equal, they have no priority against wind plant. Therefore existing thermal plant stations should gradually be substituted by renewable energies.

The results of this study could

- Provide valuable information regarding decision-making tools for strategic sustainable development.
- Facilitate discussions on the sustainable development matter.
- Increase public awareness of environmental/social/economic effects of alternatives.
- Spread environmental information.
- Increase the e-participation (e-democracy) of people in the decision-making process to achieve public awareness consensus.
- Point out decision-makers and procedures of decision processes.

The end result of the model is a measure of the decision-maker's relative preference of one attribute over another attribute.

It is concluded that the model is an effective way to improve participatory decision-making in complex decision situations.

5 Conclusion

Uncertainty is present in many decisions where an action's consequences are unknown because they depend on future events. Multi-criteria decision-making theory offers an axiomatic basis for choice. Many models exist for multi-criteria decision analysis (MCDA) under such conditions of uncertainty.

In this chapter, the multi-criteria decision-making approach was analyzed in the mechanisms design prospective in order to emphasize the potential of this technique to support the mechanisms design.

MCDA is a broad term that comprises many methods and techniques that are intended to assist in making complex decisions involving many aspects or attributes. The main aim is to optimize the decision as a compromise between a set of attributes, usually in conflict. In this work, the technique used is based on the method of AHP. This technique is suitable when the number of alternatives is discrete and is based on the establishment of a hierarchical structure of the problem that supports the integration of conflicting criteria.

The integration of this approach together allows developing a structured plan for the design of mechanisms. When it requires an analysis of the adequacy of mechanisms design, these studies are complemented by technical and economic considerations, which assess the overall adequacy process.

The great strength of AHP is its axiomatic foundation, "justifying the prescriptive approach provided the problem owners accept the related rationality assumptions," but even in its simplest form, the practical implementation of AHP is formidable, requiring the assessment of probability distributions over each attribute. In this work, we developed a deeper and simple analysis of AHP in order to highlight its applicability and feasibility in the field of mechanism design. In doing so, we hope to provide some guidance to practitioners about the types of simplified models that are being used for uncertain decision-making.

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Mechanism Design for Allocation of Carbon Emission Reduction Units: A Study of Global Companies with Strategic Divisions and Partners

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Abstract The problem addressed in this work is concerned with an important challenge faced by any green aware global company to keep its emissions within a prescribed cap. The specific problem is to allocate carbon reductions to its different divisions and supply chain partners in achieving a required target of reductions in its carbon reduction program. The problem becomes a challenging one since the divisions and supply chain partners, being autonomous, could exhibit strategic behavior. We model strategic behavior of the divisions and partners using a game theoretic approach leading to a mechanism design approach to solve this problem. While designing a mechanism for the emission reduction allocation problem, the key properties that need to be satisfied are dominant strategy incentive compatibility (DSIC), strict budget balance (SBB), and allocative efficiency (AE). Mechanism design theory has shown that it is not possible to achieve the above three properties simultaneously. We propose two solutions to the problem satisfying DSIC and AE: (1) a reverse auction protocol and (2) a forward auction protocol, while striving to keep the budget imbalance as low as possible. We compare the performance of the two protocols using a stylized, representative case study.

Keywords Carbon emission reduction • Emission cap • Emission reduction allocation • Mechanism design • Incentive compatibility • Allocative efficiency • Budget imbalance • Vickrey-Clarke-Groves mechanism • Redistribution mechanisms

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_3,

1 Introduction

The impact of global warming and climate change is one of the most seriously talked about issues in recent times. The global warming and climate change phenomenon have been associated with the accumulation of greenhouse gases (GHG) in the atmosphere. Some atmospheric gases, mainly carbon dioxide (CO_2), methane (CH_4), halo carbons (HFCs and PFCs), nitrous oxide (N_2O), and sulfur hexafluoride (SF_6), are called greenhouse gases (GHG). These gases act as a natural blanket retaining the Earth's heat. Among these gases, CO_2 is found to have the maximum effect; hence, GHG emissions are often referred to as carbon emissions. Global economic growth and the surge in industrial activities have increased the accumulation of these gases over a period of time. The emissions are measured in terms of carbon credits where one carbon credit is equivalent to one metric tonne of CO_2 emitted. All other GHGs are converted into carbon equivalent by using standard conversion metrics (UNFCCC 2009).

As the effect of global warming and climate change is significant, countries around the world have started putting in efforts towards finding a solution to mitigate the GHG emissions. One such effort is the *cap and trade* scheme. A cap and trade system allows corporations or national governments to trade emission allowances under an overall cap, or limit, on their emissions. This mechanism involves two parties, the governing body and the regulated entities that emit pollution. The governing body allocates a limit on the total amount of emissions that could be emitted in a given period, called as *cap,* and would issue rights, or allowances, corresponding to that level of emissions. Regulated entities would be required to hold equal or more allowances than their cap for their emissions. Normally the cap on a regulated body is less than the current emissions emitted by it. A cap on emissions limits the total amount of allowable emissions, and it can be lowered to achieve stricter environmental standards.

Let us consider a global company (refer to Fig. 1) that gets a cap on its overall emissions. This cap could be prescribed by a regulatory authority or by any other regulatory process. To honor the cap, the company will be required to reduce its

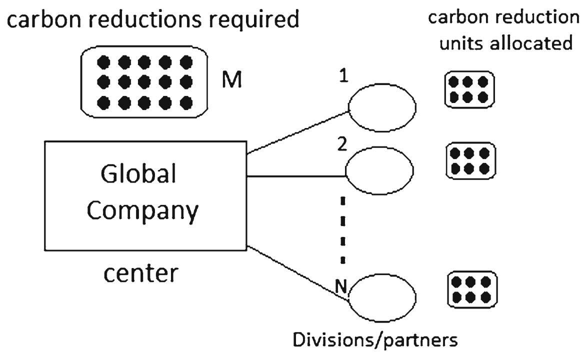

Fig. 1 Allocation of carbon emission reductions among divisions

GHG emissions. As an example, suppose the company currently emits x units of GHG and the company has been stipulated a cap of y emission units. The company is then required to reduce $m = x - y$ emission units (called emission reduction units).

In order to accomplish this, the company would look at its divisions and supply chain partners to help reduce emissions by the required amount. The effort of emission reduction involves cost which could vary among the divisions and partners. We will use the phrase *emitting agents* to describe the divisions and partners involved. Some emitting agents will incur higher costs than others in the task of achieving a certain amount of emission reduction. The challenge for the global company will be to allocate the required number of reductions in a fair manner among the emitting agents, such that the total cost of reduction is minimized. Since the emitting agents are often autonomous entities and could exhibit strategic behavior, the company may not be able to elicit the emission reduction cost curves from the individual emitting agents truthfully. So we invoke techniques from game theory and mechanism design to elicit the cost curves truthfully and then allocate the emission reduction units.

1.1 Examples of Cap and Trade Scheme

We provide two motivating examples in global settings where the research reported in this work are relevant.

1.1.1 Allocation Under the European Union Emission Trading Scheme (EU ETS)

The European Union has shown leadership in this initiative and was one of the early signatories to the Kyoto protocol. A large number of companies in the region have claimed to have adhered to the caps or have offset their extra emissions through credits generated by Clean Development Mechanism (Kyoto protocol). The big worrying factor is that several major polluting industries have not only met their caps but have saved huge amounts of certified emission reduction units. Several campaigners have argued that the system followed by the European Union is flawed and has failed in its fundamental aim to reduce emissions (Ellerman and Joskow 2008). So instead of providing a mechanism for industries to reduce emissions, it has in fact created intangible wealth for many industries. This has totally invented a $126 billion market and has the potential to flare into a $2 trillion green giant over the decade.

1.1.2 Oil and Gas Industry

Industries in this business generally are very large having global presence and financially very strong. They are also among the biggest sources of emissions. Some of the major companies in the segment like British Petroleum (BP), Amoco, and Shell have adopted best practices in achieving sustainability. Sustainable development here refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations General Assembly Report 1987). They have consciously made efforts to reduce their emission levels without losing on the natural growth curve. These three companies have practiced cap and trade mechanism among its units and have reported some interesting positive effects, including the claim of meeting their emission reduction targets within 2 years, on their emission reduction program. We give the case of BP (Akhurst et al. 2003) as a motivating example for the proposed mechanism design approach.

BP is one of the largest corporate in oil and gas. It has operations spread across every aspect of fossil fuels, right from exploration and refining to retail and trading. It also has business in renewable energy like biofuels, solar, and wind. It has operations in more than 80 countries and also has significant carbon footprint across the globe. In the year 2000, BP strategically re-branded itself as "Beyond Petroleum" and set about reducing carbon footprint to 10% less than its emission level in 1990. In the year 2001, BP declared itself a carbon neutral company. Carbon neutral means to have a net zero carbon emission, that is, the total amount of carbon released has been offset either by improving the process or by buying enough carbon credits. BP deployed a cap and trade mechanism among its business units to achieve this (Akhurst et al. 2003). BP has about 150 business units (BUs); a central Integrated Supply and Trading (IST) group was set up to enforce and monitor the cap and trade mechanism among all its business units. To set the ball rolling, each of the 150 BUs was handed out a fixed number of annual allowances (CAP) to emit GHG. Each BU was expected to check and keep its emission levels under the permitted cap. However, they were allowed to trade their allowances among other units throughout the year. At the end of the year, any BU exceeding its cap was allowed to buy offset credits from the external market. BP at an organizational level also decided the cap as 10% less than their total GHG emission level in 1990, and this cap was used as a central link between the cap allocation among the units and the target set out by BP. The aggregate allowances available to individual units were determined using the group cap set by BP.

2 The Problem and Relevant Work

2.1 Emission Reduction Allocation Problem

We consider a global company or a large-scale industry that has several independent emitting agents supporting the business of the industry. These emitting agents could be the different divisions of the company and also its supply chain partners. Let us assume that the company has a total of n such agents. The emission reduction process incurs cost, and the cost of per unit of reduction varies among the agents. The motivation for undertaking the mandate to reduce the emissions can be interpreted in the following ways:

- The industry has been mandated a carbon cap by a regulatory authority and the company has to honor this cap by achieving the required quantum of reductions.
- The industry undertakes the emission reduction initiative under corporate social responsibility initiative. Hence, rather than buying the emission reduction units from third party carbon markets, the industry wants to make best use of its internal divisions and partners for this initiative.
- The industry considers the emission reduction initiative as a part of their branding activities. This could be a factor in attracting prospective clients who focus on emission neutral solutions.
- The industry wishes to reduce its emission footprints, but the solution of buying emission reduction units from an outside carbon market may be higher than the cost that the industry incurs through an internal drive.
- The industry by undertaking its own emission reduction initiatives will be better off achieving sustainability.

Based on above observations, we can say that all the emitting agents will be motivated to be a part of this initiative, and further, no players will be worse off by participating in this initiative. We assume that all players are intelligent and have the capability to compute their own emission levels and have an accurate knowledge of cost curves for reducing emissions. The cost curves are private information of emitting agents.

For the purposes of this work, we assume that the cost curve of each agent is a marginally increasing piecewise constant cost curve as shown in Fig. 2. This is a reasonable assumption to make since the marginal cost typically increases with the quantum of emission reduction required. A realistic assumption to make is that each agent has an upper bound on the number of emission reductions possible.

A typical cost curve as described above can be generally given by a sequence of tuples $<p, u, c>$, where p denotes the agent, u is the number of emission units that can be reduced by p at a cost c. The tuples for agent i are given as $<i, u_{i1}, c_{i1}>$, $<i, u_{i2}, c_{i2}>$, …, $<i, u_{it}, \infty>$, where t is the number of tuples in the type of agent i (Arava et al. 2010b). Tεe here shows that the unit cannot reduce more than $u_{i(t-1)}$ number of reductions. Here, c_{ik} is the cost of per unit of reduction for the range $[u_{i(k-1)}+1, u_{ik}]$. For the first tuple for player i, the cost is for $[1, u_{i1}]$. Also, we have $u_{i1}<u_{i2}<\ldots<u_{it}$ and $c_{i1}<c_{i2}<\ldots<c_{it}$ (refer to Fig. 2).

The cost for x units of emission reductions by player i denoted by $\text{cost}_i(x)$ is given by Eq. 1.

$$\text{cost}_i(x) = \begin{cases} I\text{Cost} + S\text{Cost} & \text{if } x > 0 \quad (1) \\ 0 \text{ otherwise} & \quad\quad\quad (2) \end{cases}$$

where

$$I\text{Cost} = \begin{cases} u_{i1} \times c_{i1} & \text{if } x \geq u_{i1} \\ x \times c_{i1} & \text{otherwise} \end{cases}$$

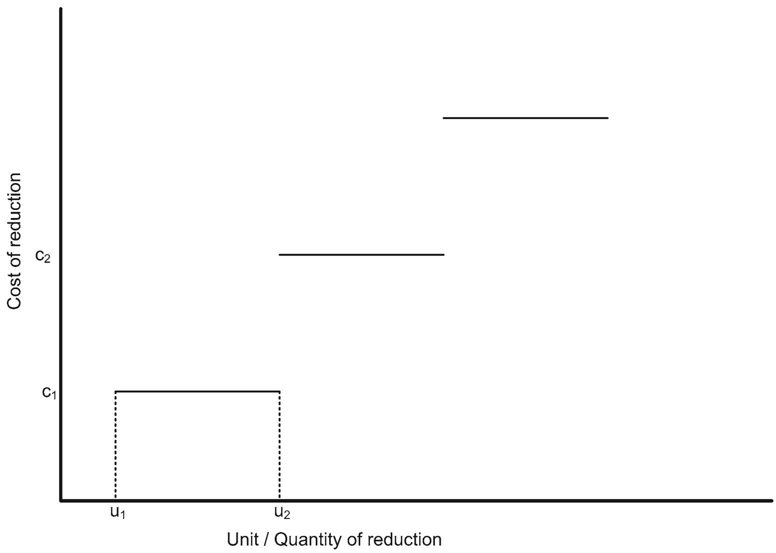

Fig. 2 Cost curves for different agents representing carbon reduction costs

and

$$S\text{Cost} = \begin{cases} \left[x - \left[\sum_{k=1}^{n}(u_{i(k+1)} - u_{ik})\right]\right] \times c_{i(n+1)} + \sum_{k=1}^{n-1}\left[(u_{i(k+1)} - u_{ik}) * c_{i(k+1)}\right] & \text{if } x > u_{i1} \\ 0 \text{ otherwise} \end{cases}$$

To obtain n, we have to proceed as long as $\left[\sum_{k=1}^{n}(u_{i(k+1)} - u_{ik})\right]$, that is, the summation of the number of reductions is less than or equal to x. When $x > u_{i1}$, ICost denotes the cost of first u_{i1} reductions and SCost denotes the cost of the rest $x - u_{i1}$ reductions.

Example: Suppose the bid by player A is <A, 25, 50>, <A, 50, 100>, <A, 75, 125>, <A, 100, ∞>. The cost of 75 units of reduction by player A is 6,875.

The global company or industry in question could be regarded as a social planner having the objective of achieving maximum possible reduction through emitting agents at minimum cost. Let m denote the number of emission units the industry wishes to reduce. The problem is to allocate these m units to n players. In order to allocate the emission reduction units efficiently among its divisions, the company uses the cost curves reported by the agents. Mathematically, this can be described by Eq. 3.

$$\text{Minimize} \sum_{i}\sum_{j}(u_{ij} - u_{i(j-1)})p_{ij} \quad (3)$$

$$\text{subject to} \sum_i \sum_j (u_{ij} - u_{i(j-1)}) \geq m$$

i=1,…,n and j=1,…,t

Another scenario could be where the global company initially fixes a budget b to be used for the emission reduction initiative and seeks to find the maximum value of m that can be achieved from the players. This formulation is given in Eq. 4.

$$\begin{aligned} &\text{maximize } m \\ &\text{s.t. } t\text{cost} \leq b \end{aligned} \tag{4}$$

$t$cost is the total cost for achieving a reduction of m units.

2.2 Related Work

In our work, we focus on using game theory and mechanism design to address the problem of effectively allocating emission reduction units to different emitting agents. For the extensive treatment of game theory and mechanism design with applications, refer to Mas-Collel et al. (1995) and Narahari et al. (2009). The carbon reduction unit allocation has been done in the past using auction or grandfathering or load-based allocations (LBA) method (United Nations Industrial Development Organization Report 2007). Among these methods, the grandfathering approach is quite popular. However, an issue with the grandfathering method is that the cap allotted to a polluter is higher in case the polluter has a history of emitting higher levels of carbon.

Baliga and Maskin (2003) survey the concepts of the theory of mechanism design in the context of environment pollution. They consider the pollution to be an example of economic activities that goes uncharged. Further they have shown that any Pareto-efficient agreement involving two or more communities is vulnerable to free riding. So, it is required that the government has to impose a Pareto-efficient vector of quotas (q_1, …, q_N), where for each j, community j is required to reduce pollution by at least the amount q_j. Further they say that the government has to set a vector of subsidies (s_1, …, s_N), where for each j, community j is paid s_j for each unit of reduction it does. These solutions are studied in two information environments (preference profile is verifiable by the government (complete information) and not verifiable (incomplete information)). However, they have assumed that the cost of per unit of emission reduction is unity.

Dutta and Radner (2000, 2006) model the problem of climate change as a dynamic game between the countries around the globe. The model of the game proposed is strategic, justifying the rational decision processes around the globe. They use noncooperative game theoretic approach in analysis, which may be seen as more realistic than the cooperative counterpart. Three aspects of the problem have been analyzed in these papers: First they explore a Global Pareto Optimum (GPO) paradigm in which each player looks towards identifying the emission profile over the game which maximizes the global welfare; secondly they explore Business as Usual (BAU) model in which each player chooses emission vector leading to maximization of the respective individual welfare, and finally BAU reversion threat model that considers situation where players play according to an agreed-upon norm is explored. The equilibrium vector of this model is sandwiched between GPO and BAU vectors. The model is fairly simple, but the main result only shows that BAU scenario will definitely lead to poor results compared to the global welfare scenario.

The paper by Arava et al. (2010a) introduces carbon economic issues in the world today and carbon economic problems facing global industries. The paper identifies four problems faced by global industries: carbon credit allocation (CCA), carbon credit buying (CCB), carbon credit selling (CCS), and carbon credit exchange (CCE). Further, the paper argues that these problems are best addressed as mechanism design problems and describes in detail the carbon credit allocation problem. Another paper by Arava et al. (2010b) further explores the carbon credit allocation problem for a global industry that wants to reduce their own carbon footprints. The paper assumes that the industry has multiple divisions which have their own cost curves for emission reduction and develops a mechanism to allocate the total emission reduction units to the divisions such that the total cost of reducing the emission is minimum. Both of these papers have an appropriate model for the carbon reduction allocation within an organization, but the approach assumes the players are not strategic.

2.3 Contributions

The specific problem we address in this work is that of a global company (or in general a social planner) allocating carbon emission reductions to its different divisions and supply chain partners towards achieving a required target of carbon reduction units at minimum cost. There is very little extant literature on this problem, and to the best of our knowledge, this problem has been addressed in the literature under a simplified assumption that the divisions and partners are honest and do not indulge in strategic interactions. This assumption is not credible in a real-world setting since the divisions and partners are autonomous entities and may not be willing to reveal private information such as emission reduction cost curves. We explicitly address the issue of strategic nature of players using mechanism design.

- We first justify the use of mechanism design for this problem and identify important properties to be satisfied by any solution to the problem. We focus on three important properties: dominant strategy incentive compatibility (DSIC) (truthfulness), allocative efficiency (AE), and budget balance (BB). The classical Vickrey-Clarke-Groves (VCG) mechanisms satisfy DSIC and AE but do not satisfy BB, so we propose the use of redistribution mechanisms which reduce the budget imbalance while preserving DSIC and AE (due to an impossibility result in mechanism design, DSIC, AE, and BB can never be simultaneously achieved).
- We then set up a reverse auction protocol where the global company (or social planner) procures emission reductions from divisions and partners using an

extension of the redistribution mechanisms proposed by Cavallo (2006). To reduce the budget imbalance further, we propose an innovative forward auction protocol which achieves fewer imbalances when compared to the reverse auction protocol under realistic conditions. Moreover, the forward auction protocol has the appealing characteristic of amply rewarding divisions which reduce the emissions and appropriately penalizing divisions which do not participate in emission reductions.

- We present a detailed case study of a global company with five strategically acting divisions and experiment with the reverse auction protocol and forward auction protocol under three representative scenarios to illustrate the efficacy of the proposed mechanisms.

We believe the mechanisms developed in this work will be a key ingredient of the carbon footprint reduction program of any global company. The results can be applied to any central agency which needs to allocate emission reductions to a set of strategic emitting agents.

3 A Mechanism Design Approach to Emission Reduction Allocation

3.1 Relevance of Mechanism Design to the Problem

The emission reduction allocation problem described above is essentially a decision or optimization problem with incomplete information. More specifically, we have the following characteristics:

- There is a set of players who interact in a strategic way. The players have well-defined payoff functions. They are rational in the sense of striving to maximize their individual payoffs. The objectives of the individual players could be conflicting.
- Each player holds certain information which is private (e.g., cost curves) and only this player would know it deterministically; other players do not know this information deterministically. Thus, the situation is one of incomplete and decentralized information. There is also certain other information which all players know and all players know that all players know and so on. Such information is common knowledge.
- Each player has a choice of certain strategies that are available to them. The players have enough intelligence to determine their best response strategies.

A natural way of modeling problems with the above characteristics is through game theory. In all the cases, it is required to implement a system-wide solution that will satisfy certain desirable properties. In order to do this, an elegant way is to induce a game among the players in such a way that, in equilibrium of the induced game, the desired system-wide solution is implemented. Mechanism design provides the process for such reverse engineering of games. In general, *mechanism* *design* is concerned with settings where a social planner (global company in this case) faces the problem of aggregating the *announced preferences* of multiple agents into a collective (or social) decision when the *actual preferences* are not publicly known. The collective decisions are described by the so-called social choice function. The mechanism design problem is to come up with a mechanism that implements a *desirable* social choice function. Some desirable properties which are sought from a social choice function and hence from the implementing mechanism (and, in the present case, from carbon reduction allocations) are described below (Mas-Collel et al. 1995; Narahari et al. 2009).

3.1.1 Solution Equilibrium

The solution of a mechanism is in equilibrium, if no agent wishes to change its bid, given the information it has about other agents. Many types of equilibria can be computed given the assumptions about the preferences of agents (buyers and sellers), rationality, and information availability. They include *Nash equilibrium*, *Bayesian Nash Equilibrium*, and *weakly dominant strategy equilibrium*. It has been shown that weakly dominant strategy equilibrium is a special case of Nash equilibrium, and Nash equilibrium is a special case of Bayesian Nash Equilibrium.

3.1.2 Efficiency

A general criterion for evaluating a mechanism is *Pareto efficiency*, meaning that no agent could improve its allocation without making at least one other agent worse off. Another metric of efficiency is *allocative efficiency* which is achieved when the total utility of all the winners is maximized. When allocative efficiency is achieved, the resources or items are allocated to the agents who value them most. These two notions are closely related to each other; in fact, when the utility functions take a special form (such as quasi-linear form (Mas-Collel et al. 1995; Narahari et al. 2009)), Pareto efficiency implies allocative efficiency.

3.1.3 Incentive Compatibility

A mechanism is said to be incentive compatible if it is the best response for all the agents to report their true valuations. There are two kinds of incentive compatibility: dominant strategy incentive compatibility (DSIC) and Bayesian incentive compatibility (BIC). DSIC means that each agent finds it optimal to report its true valuation irrespective of what the other agents report. BIC on the other hand means that each agent finds it optimal to report its true valuation whenever all other agents also report their true valuations. Needless to say, DSIC implies BIC; in fact, BIC is a much weaker notion than DSIC. DSIC is also referred to as strategy-proof property. If a mechanism is strategy proof, each agent's decision depends only on its local information, and there is no need whatsoever for the agent to model or compute the strategies of other agents.

3.1.4 Budget Balance

A mechanism is said to be *weakly* budget balanced if the sum of monetary transfers between the buyer and the sellers is nonnegative, that is, in all feasible outcomes the payments by buyers exceed the receipts of sellers. A mechanism is said to be *strongly* budget balanced if net monetary transfer is zero. In other words, budget balance ensures that the mechanism or the auctioneer does not make losses.

3.1.5 Revenue Maximization or Cost Minimization

In an auction where a seller is auctioning a set of items, the seller would like to maximize total revenue earned. On the other hand, in a procurement auction, the buyer would like to procure at minimum cost. Given the difficulty of finding equilibrium strategies, designing cost-minimizing or revenue-maximizing auctions is not easy. In forward auction, we implicitly assume the cost to the seller, for the goods he is auctioning for, is fixed. In wider settings, this may not be the case and then rather than revenue maximization, the goal of the seller will be profit maximization, where Profit = Revenue − Cost.

3.1.6 Individual Rationality

A mechanism is said to be individually rational (or is said to have voluntary participation property) if its allocations do not make any agent worse off than if the agent had not participated in the mechanism. That is, every agent gains a nonnegative utility by participating in the mechanism.

3.2 Mechanisms Relevant for Emission Reduction Allocation

For the problem that we are interested, namely, allocating emission reductions among divisions and partners, the most important properties are incentive compatibility (preferably DSIC), allocative efficiency, minimum budget imbalance, cost minimization, and individual rationality. However, not all of these can be achieved simultaneously (see Mas-Collel et al. 1995; Narahari et al. 2009 for discussion on impossibility results). In this work, our focus is on achieving DSIC, allocative efficiency, and minimizing budget imbalance. DSIC and allocative efficiency are both achieved by the classical Vickrey-Clarke-Groves mechanisms (Vickrey 1961; Clarke 1971; Groves 1973). Among VCG mechanisms, the Groves mechanism (Groves 1973; Mas-Collel et al. 1995; Narahari et al. 2009) is the most general; however, for the current setting, the Clarke mechanism (Clarke 1971; Mas-Collel et al. 1995;

Narahari et al. 2009) suffices. We will therefore use the Clarke mechanism as the first approach for solving the emission reduction allocation problem.

Besides DSIC and AE, another property that would be desirable is (strong) budget balance, meaning that the payments are equal to receipts. It is well known that VCG mechanisms are not strongly budget balanced (Mas-Collel et al. 1995; Narahari et al. 2009) and leave a nonzero budget imbalance in the system. In fact, it is impossible to design any mechanism that satisfies strongly budget balance in addition to the other DSIC and AE (Hurwicz 1975; Green and Laffont 1977, 1979; Myerson and Satterthwaite 1983).

In the light of this impossibility result, several authors have obtained budget balance by sacrificing DSIC or AE (Faltings 2005; Parkes et al. 2001; Feigenbaum et al. 2001). Since DSIC and AE are two fundamental properties that we do not want to compromise, the best we can do is to seek mechanisms that satisfy DSIC and AE but minimize the budget imbalance as much as possible. Redistribution mechanisms achieve this by redistributing the VCG payments in a way that DSIC and AE are preserved and budget imbalance is reduced.

To reduce budget imbalance, various rebate functions have been designed by Bailey (1997), Cavallo (2006), Moulin (2009), and Guo and Conitzer (2007). Moulin (2009) and Guo and Conitzer (2007) designed Groves redistribution mechanism for assignment of m homogeneous objects among $n>m$ agents with unit demand. Guo and Conitzer (2007) also considers multiunit auction with nonincreasing marginal values, but the mechanism is applicable only when $m<n$. But in our work, m can be greater than n as each agent has multiple tuples. In another paper by Guo and Conitzer (2008), m need not be less than n but they assumed that a prior distribution over the agents' valuations is available where as in our work the agents valuation can be anything.

A paper by Bhashyam et al. (2011) proposes a worst-case optimal mechanism for allocation of a single divisible item to a number of agents when the agents report only scalar values. It also proposes optimal-in-expectation mechanism where the prior distribution of the agent's types is assumed to be known for the allocation of single divisible item and compares the two mechanisms. The mechanism is applicable to allocation of indivisible goods also, and it simplifies to the mechanism proposed by Guo and Conitzer (2007), where the single good is divided into m equal parts with $m<n$.

In 2006, Cavallo (2006) designed a mechanism that redistributes a large amount of the total VCG payment while maintaining all of the other desirable properties of the VCG mechanism. Cavallo' s mechanism considers how small an agent could make the total VCG payment by changing his/her bid (the resulting minimal total VCG payment is never greater than the actual total VCG payment) and redistributes $1/n$ of that to the agent.

In this work, we extend Cavallo' s mechanism to our allocation setting where there are multiple indistinguishable units of a single good, and each agent's valuation function is concave, that is, agents have nondecreasing marginal values. Also each agent has multiunit demand. For this setting, Cavallo' s mechanism (2006) coincides with a mechanism proposed by Bailey (1997). Cavallo' s mechanism and Bailey's mechanism are in fact the same in any setting, under which VCG mechanisms satisfy revenue monotonicity, for the following reason: Bailey's mechanism redistributes to each agent $1/n$ of the total VCG payment that would result if this agent were removed from the auction. If the total VCG payment is nondecreasing in agents, then, when computing payments under Cavallo's mechanism, the bid that would minimize the total VCG payment is the one that has a valuation of *zero* for everything, which is equivalent to not participating in the auction. Hence, Cavallo's mechanism results in the same redistribution payment as Bailey's. In this work, we refer to this redistribution mechanism as the Cavallo-Bailey redistribution mechanism.

4 A Reverse Auction Protocol for Allocation of Emission Reductions

Consider that there are n players (divisions and partners) and a social planner (company). Let us say that the mandate on the company is to reduce m carbon units. The players submit their carbon reduction cost curves to the company which then allocates reduction units to the divisions. Since the players are strategic, they may not reveal their cost curves truthfully. This necessitates the use of an appropriate mechanism to solve the allocation problem. An elegant solution is to conduct a reverse auction where the social planner tries to procure m units from the n divisions. An immediate way of doing this is by using VCG mechanisms (Vickrey 1961; Clarke 1971; Groves 1973) which satisfy DSIC and AE properties. For this setting, the Clarke mechanism is quite appropriate.

4.1 Clarke Mechanism Applied to the Problem

The Clarke mechanism (Clarke 1971) works by first choosing an optimal outcome based on bidders' reported preferences and then determining the monetary transfers through the Clarke's payment rule. Essentially, to determine the monetary transfer to bidder i, the Clarke payment rule drops player i from the preference aggregation problem and solves a new problem to obtain an optimal outcome without i. The monetary transfer to bidder i is given by the total value of all bidders other than i under an efficient allocation when bidder i is present in the system minus the total value of all bidders other than i under an efficient allocation when bidder i is absent in the system.

4.1.1 An Algorithm for Allocation of Reduction Units

We now present a simple algorithm that is a modified version of the algorithm used in (Parkes et al. 2005) to our setting to obtain an optimal allocation of emission reduction units. The steps in the algorithm are as follows:

- Set initial cost to zero.
- Sort the tuples in an ascending order of their per unit reduction costs. In the case of duplicates, arrange in the ascending order of the size of the tuple $(u_{ij} - u_{i(j-1)})$.

- It can be seen that the problem is similar to a knapsack problem. Pick the tuples in the above order and fill the knapsack. Cost is incremented by the cost of the tuple added to the knapsack.
- If the final tuple cannot completely fit into the knapsack, then consider only the amount that can fit into the knapsack and calculate the cost accordingly.
- Return the total cost.

The final cost returned by the algorithm is the total cost incurred by the company (social planner) in allocating the emission reductions. Cost incurred by each division depends upon the allocation. We provide an example to illustrate the above algorithm.

Example 1

Let a company be interested in procuring 200 emission reduction units from its four divisions. Let the cost curves of the divisions be the following:

Division 1: ((50, 4), (100, 7), (150, 21), (200, 27), (250, 38))
Division 2: ((50, 7), (100, 23), (150, 40), (200, 60), (250, 62))
Division 3: ((50, 16), (100, 32), (150, 59), (200, 77), (250, 104))
Division 4: ((50, 16), (100, 16), (150, 33), (200, 33), (250, 35))

We sort these tuples and apply the given algorithm. We get $k = \langle 100, 50, 50, 0 \rangle$ as the allocation vector for the above problem. This means 100 reduction units are allocated to division 1, 50 to division 2, 50 to division 3, and 0 to division 4. The cost incurred by division 1 for the allotment of 100 units is 50*(4+7). Similar is the case for divisions 2 and 3. Total cost incurred in performing the reduction is 550+350+800=1,700.

The above allocation turns out to be optimal in this case. In fact, the above algorithm gives a minimum cost solution as proved in (Arava et al. 2010b). If k is the maximum number of tuples among all the preferences, then the total running time of the above algorithm is $O(kn)$.

Example 2

We now illustrate the use of Clarke's mechanism for another illustrative setting. Suppose a company is interested in procuring 120 carbon reduction units from its five divisions. Let the cost curves of the divisions be the following:

Division 1: ((1–10, 4), (11–20, 6), (21–30, 8), (31–40, 10))
Division 2: ((1–10, 3), (11–20, 6), (21–30, 9), (31–40, 12))
Division 3: ((1–10, 6), (11–20, 6), (21–30, 6), (31–40, 6))
Division 4: ((1–10, 8), (11–20, 8), (21–30, 8), (31–40, 8))
Division 5: ((1–10, 6), (11–20, 7), (21–30, 8), (31–40, 9))

An efficient allocation can be achieved by the greedy algorithm. We get $k = \langle 30, 20, 40, 10, 20 \rangle$ as the allocation vector for the above problem. This means 30 reduction units are allocated to division 1, 20 to division 2, 40 to division 3, 10 to division 4, and 20 to division 5. By using Clarke's payment rule, the payments made by the company to divisions 1–5, respectively, are $\langle 240, 160, 320, 80, 160 \rangle$. So the total cost to the company is 960.

The Clarke mechanism is allocatively efficient, which minimizes the total cost of achieving the reductions, and it is DSIC. But from the above example, we can see that the company ends up paying a significant amount of money to the divisions. Also, the divisions which are not allocated any reduction units do not make any payments, which results in *free riding*, which is undesirable.

4.2 Cavallo-Bailey Redistribution Mechanism Applied to the Problem

To eliminate the problems in the previous section, we use the Cavallo-Bailey redistribution mechanism. This mechanism results in no deficit to the company. Also, the divisions which are not allocated any reduction units make a nonnegative payment to the company. Using this mechanism, the redistribution payment made by a division to the center is $1/n$ of the total VCG payment that would result if this division were removed from the auction.

Example 3

For the example above (Example 2), by using this redistribution mechanism, the redistribution payments made by the divisions to the center are as follows: <228, 210, 240, 240, 234>. So the net payments made by the company to the divisions are <12, −50, 80, −160, −74>, and the cost to the company is −192. That is, the budget imbalance in the system is 192. We can observe that the cost to the company using this mechanism is very low when compared to that of the Clarke mechanism.

However, using this mechanism, the divisions, even though they do the reductions, might have to pay a certain amount to the company rather than receiving the payment from the company which may not be in the best interest of the divisions unless it is forced to do so. Hence, the mechanism is not individually rational.

5 A Forward Auction Protocol for Allocation of Emission Reductions

In the context of the reverse auction protocol, we have seen that the divisions often have to pay a certain amount to the company rather than receiving the payment from the company. In this section, we propose an innovative forward auction mechanism to circumvent this problem at least under realistic settings. The forward auction is developed through a suitable reinterpretation of the reverse auction problem described above.

In this interpretation, each of the n divisions bid for escape permits to get permits not to reduce. Let us say that each division can perform a maximum of k reductions. Then the maximum number of reductions possible is nk. Let m be the number of reductions required by the company. Then there are a total of $nk-m$ escape permits for sale. This now becomes a forward auction problem. Using this reinterpretation, we can simply run a (forward) VCG auction for the $nk-m$ permits. The VCG payments made by the divisions depend on the number of permits they bought to avoid reductions. We can call this VCG payment as green tax. The higher the number of escape permits they buy, the higher is the tax they pay. Then this VCG payment collected from the divisions can be redistributed to all the divisions using the Cavallo-Bailey redistribution mechanism. The algorithm to do this is as follows:

- Sort the tuples in nonincreasing order of their per unit reduction costs.
- If x is the maximum number of reductions possible by all the divisions and m is the number of reductions required by the company, then there are $x-m$ escape permits that can be given to the divisions. Allocate these permits to the divisions in decreasing order of their per unit reduction costs using VCG mechanism.
- The resulting budget imbalance is redistributed to the divisions using Cavallo-Bailey redistribution mechanism.

Example 4
In the example above (Example 2), the number of reduction units required by the company is $m=120$. In this example, the total number of reductions possible is $x=200$. Hence, there are 80 escape permits for sale. Allocate these 80 permits to the divisions using the Clarke mechanism. Then the allocation vector is <10, 20, 0, 30, 20>. That is, 10 permits to division 1, 20 permits to division 2, 0 permits to division 3, 30 permits to division 4, and 20 permits to division 5. The VCG payments made by the divisions to the center for buying the permits are <80, 160, 0, 210, 160>. Now, applying Cavallo-Bailey mechanism, these payments can be redistributed to the divisions. The redistribution payments made by the center to the divisions are <100, 100, 122, 96, 96>. The budget imbalance (payments minus the receipts) is 96 which is very low compared to the budget imbalance of 192 in the reverse auction problem setting.

As we can see in the above example, division 3 does not buy any escape permits; hence, the payment (tax) made by division 3 is 0. This will apply to any division not buying permits, and the tax paid by such divisions is 0. Also, they get a nonnegative redistribution amount. So, unlike the reverse auction problem, here, only the divisions buying the escape permits to avoid reductions pay the tax (VCG payment). This ensures that no divisions would free ride the reduction emission process. The total amount collected is redistributed to all the divisions.

6 Comparison of Reverse and Forward Auction Protocols: A Case Study

In this section, we describe a stylized case study involving a global company consisting of five divisions which contribute to carbon emissions by the company. We experiment with three representative cases of cost curves for the divisions. In the first case, the cost curves are similar and have minor variations across the divisions. In the second case, the cost curves exhibit major variations across the divisions.

Table 1 Solution 1: Reverse auction protocol

Division	Number of reductions allocated	Payment made by center to division	Redistribution payment by division to center	Net payment by division to center
1	30	240	228	−12
2	20	160	210	50
3	40	320	240	−80
4	10	80	240	160
5	20	160	234	74

The third case examines a situation where the cost curves exhibit some extreme characteristics. It turns out that all the three cases are realistic in their own way since they represent different types of global company organizations. The purpose of the experimentation is to examine how the two protocols based on reverse auction and forward auction handle the allocations and payments. In particular, we are also interested in the budget imbalance exhibited by the two protocols.

6.1 Case 1: Cost Curves with Minor Variations

Here, we consider the case of divisions which have comparable costs for reductions. The cost curves are provided below. Assume that the number of reduction units required by the company (center) is 120.

Division 1: ((1–10, 4), (11–20, 6), (21–30, 8), (31–40, 10))
Division 2: ((1–10, 3), (11–20, 6), (21–30, 9), (31–40, 12))
Division 3: ((1–10, 6), (11–20, 6), (21–30, 6), (31–40, 6))
Division 4: ((1–10, 8), (11–20, 8), (21–30, 8), (31–40, 8))
Division 5: ((1–10, 6), (11–20, 7), (21–30, 8), (31–40, 9))

Solution 1: Reverse Auction Setting
Table 1 shows the results for this setting. The table lists, for each of the divisions, the number of reductions allocated, VCG payment by center to division, redistribution payment by division to center, and net payment made by the division to the center.

- Using the VCG mechanism, the allocation vector is k = <30, 20, 40, 10, 20>. This means 30 reduction units are allocated to division 1, 20 to division 2, 40 to division 3, 10 to division 4, and 20 to division 5.
- The VCG payments made by the company to divisions 1–5, respectively, are <240, 160, 320, 80, 160>.
- The redistribution payments made by the divisions to the center are as follows: <228, 210, 240, 240, 234>.
- The budget imbalance in the system is 192. The divisions are required to pay an amount of 192 monetary units to the center. Note that division 1 and 3 are receiving appropriate amounts from the center since they are performing substantial

Table 2 Solution 2: Forward auction protocol

Divisions	Number of escape permits	Number of reductions done	Tax levied on divisions	Redistribution payment by center to division	Net payment by division to center
1	10	30	80	100	−20
2	20	20	160	100	60
3	0	40	0	122	−122
4	30	10	210	96	114
5	20	20	160	96	64

carbon reductions. The other divisions are paying appropriate amounts to the center due to relatively lesser number of reductions they are allocated.

Solution 2: Forward Auction Setting
In the current problem, the total number of reductions that are possible by all the divisions is 200. As the number of reduction units required by the company is 120, there are 80 escape permits that can be given to the divisions. Table 2 shows the results for this setting. The table lists, for each of the divisions, the number of escape permits allocated, number of reductions done, VCG payment by division to center (which we call tax levied), redistribution payment by center to division, and net payment made by the division to the center.

- Using the VCG mechanism, the allocation vector of escape permits is k=<10, 20, 0, 30, 20>. This means 10 permits are given to division 1, 20 to division 2, 0 to division 3, 30 to division 4, and 20 to division 5.
- The VCG payments (or green tax paid) by the divisions 1–5 to the center are <80, 160, 0, 210, 160>.
- The redistribution payments made by the center to the divisions are <100, 100, 122, 96, 96>.
- The budget imbalance in the system is 96. Note that the budget imbalance is much less compared to the amount of 192 in the reverse auction setting. Now divisions are required to pay an amount of 96 monetary units to the center. Note that division 1 and division 3 are receiving appropriate amounts from the center since they are performing substantial carbon reductions (the amounts received are higher than those in the case of reverse auction setting). The other divisions are paying appropriate amounts to the center as they buy more number of escape permits and perform less number of reductions.

6.2 Case 2: Cost Curves with Wide Variations

Here, we consider a more realistic scenario where the cost curves are not as similar as in case 1. Division 1 incurs different per unit cost in the four intervals (1–10), (11–20), (21–30), and (31–40). Division 2 incurs the same per unit cost in the entire interval (1–40). Division 3 cannot reduce more than 30 units and division 4 cannot

Table 3 Solution 1: Reverse auction protocol

Division	Number of reductions allocated	Payment made by center to division	Redistribution payment by division to center	Net payment by division to center
1	30	240	184	−56
2	0	0	204	204
3	20	160	162	2
4	20	160	162	2
5	20	160	168	8

reduce more than 20 units. Finally, division 5 has a per unit cost of 5 in the interval (1–20) and a per unit cost of 11 in the interval (21–40). Assume that the number of reduction units required by the company is 90.

Division 1: ((1–10, 4), (11–20, 6), (21–30, 8), (31–40, 12))
Division 2: ((1–40, 8))
Division 3: ((1–20, 5), (21–30, 12), (31–40, ∞))
Division 4: ((1–20, 3), (21–40, ∞))
Division 5: ((1–20, 5), (21–40, 11))

Solution 1: Reverse Auction Setting
Table 3 shows the results for this setting. The table lists, for each of the divisions, the number of reductions allocated, VCG payment by center to division, redistribution payment by division to center, and net payment made by the division to the center.

- Using the VCG mechanism, the allocation vector is k=<30, 0, 20, 20, 20>. This means 30 reduction units are allocated to division 1, 0 to division 2, 20 to division 3, 20 to division 4, and 20 to division 5.
- The VCG payments made by the company to divisions 1–5, respectively, are <240, 0, 160, 160, 160>.
- The redistribution payments made by the divisions to the center are as follows: <184, 204, 162, 162, 168>.
- The budget imbalance in the system is 160. Note that division 1's net payment is −56 which means it is receiving a net payment of 56 monetary units from the center. This is because of the large number of reductions allocated to this division.

Solution 2: Forward Auction Setting
Here, the cost curves are such that the total number of reductions that are possible by all the divisions is 170. As the number of reduction units required by the company is 90, there are 80 escape permits that can be assigned to the divisions. Table 4 shows the results for this setting. The table lists, for each of the divisions, the number of escape permits allocated, number of reductions done, VCG payment by division to center (which we call tax levied), redistribution payment by center to division, and net payment made by the division to the center.

- Using the VCG mechanism, the allocation vector of escape permits is k=<10, 40, 10, 0, 20>. This means 10 permits are given to division 1, 40 to division 2, 10 to division 3, 0 to division 4, and 20 to division 5.

Table 4 Solution 2: Forward auction protocol

Divisions	Number of escape permits	Number of reductions done	Tax levied on divisions	Redistribution payment by center to division	Net payment by division to center
1	10	30	50	72	−22
2	40	0	240	68	172
3	10	20	80	80	0
4	0	20	0	102	−102
5	20	20	140	68	72

- The VCG payments (or green tax) made by divisions 1–5 to the center are <50, 240, 80, 0, 140>.
- The redistribution payments made by the center to the divisions are as follows: <72, 68, 80, 102, 68>.
- The budget imbalance in the system is 120, which is less than 160 incurred in the reverse auction setting. Now divisions are required to pay an amount of 120 monetary units to the center. Note that division 1 and division 4 are receiving appropriate amounts from the center since they are performing substantial carbon reductions. Divisions 2 and 5 are paying appropriate amounts to the center as they buy more number of escape permits and perform less number of reductions. It is interesting to note that division 3 is not paying (receiving) any amount to (from) the center.

6.3 Case 3: Cost Curves with Extreme Variations

Now we consider cost curves which have wide variations. Such cost curves may not be unrealistic. Let the number of reduction units required by the company be 90. The cost curves are as follows.

Division 1: ((1–40, 50))
Division 2: ((1–20, 4), (21–40, 60))
Division 3: ((1–20, 5), (21–30, 8), (31–40, ∞))
Division 4: ((1–20, 3), (21–40, ∞))
Division 5: ((1–20, 5), (21–40, 10))

Solution 1: Reverse Auction Setting
Table 5 shows the results for this setting. The table lists, for each of the divisions, the number of reductions allocated, VCG payment by center to division, redistribution payment by division to center, and net payment made by the division to the center.

- Using the VCG mechanism, the allocation vector is k = <0, 20, 30, 20, 20>. This means 0 reduction units are allocated to division 1, 20 to division 2, 30 to division 3, 20 to division 4, and 20 to division 5.
- The VCG payments made by the company to the divisions 1–5, respectively, are <0, 200, 700, 200, 1,000>.
- The redistribution payments made by the divisions to the center are as follows: <480, 900, 940, 900, 960>.

Table 5 Solution 1: Reverse auction protocol

Division	Number of reductions allocated	Payment made by center to division	Redistribution payment by division to center	Net payment by division to center
1	0	0	480	480
2	20	200	900	700
3	30	700	940	240
4	20	200	900	700
5	20	1,000	960	–40

Table 6 Solution 2: Forward auction protocol

Divisions	Number of escape permits	Number of reductions done	Tax levied on divisions	Redistribution payment by center to division	Net payment by division to center
1	40	0	230	64	166
2	20	20	130	72	58
3	0	30	0	72	–72
4	0	20	0	98	–98
5	20	20	130	64	66

- The budget imbalance in the system is 2080. Note that only division 5 is receiving a net payment from the center while all other divisions are paying up heavily to the center.

Solution 2: Forward Auction Setting

Note that the total number of reductions that are possible by all the divisions is 170. As the number of reduction units required by the company is 90, there are 80 escape permits that can be given to the divisions. Table 6 shows the results for this setting. The table lists, for each of the divisions, the number of escape permits allocated, number of reductions done, VCG payment by division to center (which we call tax levied), redistribution payment by center to division, and net payment made by the division to the center.

- Using the VCG mechanism, the allocation vector of the permits is k=<40, 20, 0, 0, 20>. This means 40 permits are given to division 1, 20 to division 2, 0 to division 3, 0 to division 4, and 20 to division 5.
- The VCG payments (green tax) made by the divisions 1–5, respectively, are <230, 130, 0, 0, 130>.
- The redistribution payments made by the center back to the divisions are as follows: <64, 72, 72, 98, 64>.
- The budget imbalance in the system is 120 which is far less compared to the 2080 obtained in the case of the reverse auction protocol. This clearly shows that the forward auction is able to handle extreme cases such as these very well. Another desirable feature here is the fact that divisions 3 and 4 are now receiving a net payment from the center in recognition of the substantial reductions they are able to carry out.

6.4 Summary of Experiments

We summarize the results of our experiments below.

- From the above representative examples, we can see that the forward auction protocol reduces the budget imbalance compared to the reverse auction protocol under the settings considered. However, this does not prove that the forward auction will always lead to less budget imbalance compared to the reverse auction protocol. This needs a more detailed study.
- In the forward auction protocol, a penalty (green tax) is paid by only those divisions who buy escape permits not to carry out emission reduction. The divisions that do not buy any escape permits do not pay any tax since they are allocated zero escape permits, and hence the VCG payment they incur is zero. The higher the number of escape permits they buy, the higher would be the tax they will have to pay. The tax thus collected by the center is redistributed by the center to the divisions that perform emission reductions. Thus, our goal of rewarding divisions that reduce emissions and levying a penalty on those who do not participate in emission reductions is achieved.
- In all the cases, there is a nonzero overall net payment from the divisions to the center. In the forward auction setting, this has a natural interpretation as these payments are made by the divisions that buy escape permits in order not to participate in carbon emission reductions.
- Results shown in Table 1 bring out a drawback of the reverse auction protocol: we see that even though divisions 3 and 4 carry out maximum number of reductions possible (30 and 20 units, respectively), they end up paying significant amounts of money to the center. In the same breath, results shown in Table 2 bring out a virtue of the forward auction protocol: we see that divisions 3 and 4, instead of paying to the center, actually receive incentive payments from the center.
- Another specific conclusion that can be drawn from case 3 and solution 2 (where the cost curves of the divisions are highly asymmetric) is that budget imbalance is reduced by the use of the forward auction protocol. However, we wish to add immediately that there could be certain scenarios where the reverse auction protocol may perform better.

We emphasize again that both the protocols above satisfy two extremely desirable properties, namely, AE and DSIC.

7 Conclusion

In this work, we addressed the specific problem faced by a global industry or global company in allocating emission reductions to its different divisions and supply chain partners towards achieving a required target in its carbon reduction program. Since the divisions and supply chain partners are autonomous and could exhibit strategic behavior, the problem was modeled as a mechanism design problem.

We first proposed the use of a reverse auction protocol where the company procures reduction units from the divisions and partners based on cost curves reported by them. The use of a straightforward Vickrey-Clarke-Groves (VCG) mechanism for this reverse auction leads to an allocatively efficient and truthful reverse auction protocol for allocating carbon reductions among emitting agents. However, the resulting budget imbalance was found to be high. To reduce budget imbalance, we proposed the use of the Cavallo-Bailey redistribution mechanism. We also proposed an innovative forward auction protocol which seems to yield fewer imbalances when combined with the Cavallo-Bailey redistribution mechanism.

The experimentation in this work is limited to a stylized case study with three representative scenarios. The numerical results show that the forward auction protocol performs better in reducing budget balance. However, this observation is at best empirical. We propose to carry out a detailed simulation study to investigate the relative performance of the two protocols. In fact, it would be of great interest to compare these two protocols in the context of a real-world case study; however, obtaining data (cost curves for emission reductions) for real-world scenario is extremely difficult.

The mechanisms proposed in the work have focused on three properties, namely, DSIC, AE, and reduced budget imbalance. There is abundant scope for investigating other properties such as individual rationality and cost minimization. Another direction for future work would be to come up with a mechanism that is DSIC and strictly budget balanced. Such a mechanism will invariably not satisfy allocative efficiency, so one can try to minimize the loss of efficiency.

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Six Sigma Methodology for the Environment Sustainable Development

Seifedine Kadry

Abstract The Six Sigma (6-σ) methodology, as it has evolved over the last two decades, provides a proven framework for problem solving and organizational leadership and enables leaders and practitioners to employ new ways of understanding and solving their sustainability problems. While business leaders now understand the importance of environmental sustainability to both profitability and customer satisfaction, few are able to translate good intentions into concrete, measurable improvement programs. Increasingly, these leaders are looking to their corps (Six Sigma experts) of Six Sigma "Master Black belts," "Black belts," and "Green belts" to lead and implement innovative programs that simultaneously reduce carbon emissions and provide large cost savings. In my experience, and that of many others, Six Sigma processes show a proven approach for businesses and organizations to improve their performance and that sustainability programs are in need of this operational approach and discipline. Six Sigma rigors will help a business leader to design a sustainable program for both short- and long-term value creations. The aim of this chapter is to show the importance of applying Six Sigma methodologies to multidisciplinary sustainability-related projects and how to implement it.

Keywords Sustainable development • Six Sigma • Carbon emissions • Multi-disciplinary sustainability-related projects • Carbon emissions

1 Introduction

In 2000, the carbon disclosure project (Carbon disclosure project) was launched as a centrally organized effort to get companies to be transparent about carbon emissions, and by the end of 2009, almost 2,500 companies were participating. In 2010,

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_4,

the U.S. Securities and Exchange Commission issued guidance (2010) to public companies saying that they should explain the impacts of climate change and climate regulation on their financial disclosure forms. Whether the initial triggers are intrinsic or extrinsic, there are a multitude of triggers that compel a company dialog to consider launching a formal environmental sustainability program.

The aim of this chapter is to show the power of Six Sigma to solve the current global challenge of environmental sustainability. One of the most complex problems that organizations face today is achieving success through strategies that are compatible with and supportive of environmental sustainability. The goal is to show how typical Six Sigma define, measure, analyze, improve, and control (DMAIC) structures, such as program governance, transfer functions, measurement systems, risk assessment, and process design, lending themselves to environmental sustainability. In this chapter, a case study of sustainability problems, such as excess oxygen reduction, is analyzed using Six Sigma tools.

2 What Is Six Sigma?

The use of Total Quality Management (TQM) as an overall quality program is still prevalent in modern industry, but many companies are extending this kind of initiative to incorporate strategic and financial issues (Puksic and Goricanec 2005). After the TQM hype of the early 1980s, Six Sigma, building on well-proven elements of TQM, can be seen as the current stage of the evolution (Harry 2000): although some conceptual differences exist between TQM activities and Six Sigma systems, the shift from the firsts to a Six Sigma program is a key to successfully implement a quality management system (Wessel and Burcher 2004).

Six Sigma methodology was originally developed by Motorola in 1987 and it targeted a difficult goal of 3.4 parts per million (ppm) defects (Barney 2002). At that time, Motorola was facing the threat of Japanese competition in the electronics industry and needed to carry out drastic improvements in their quality levels (Harry and Schroeder 2002). In 1994, Six Sigma was introduced as a business initiative to "produce high-level results, improve work processes, and expand all employees' skills and change the culture" (ASQ 2002). This introduction was followed by the well-revealed implementation of Six Sigma at General Electric beginning in 1995 (Slater 1999). Sigma is the Greek letter that is a statistical unit of measurement used to define the standard deviation of a population. Therefore, Six Sigma refers to six standard deviations. Likewise, Three Sigma refers to three standard deviations. In probability and statistics, the standard deviation is the most commonly used measure of statistical dispersion; i.e., it measures the degree to which values in a data set are spread. The standard deviation is defined as the square root of the variance, i.e., the root mean square (rms) deviation from the average. It is defined in this way to give us a measure of dispersion. Assuming that defects occur according to a standard normal distribution, this corresponds to approximately 2 quality failures per million parts manufactured. In practical application of the Six Sigma methodology, however, the rate is taken to be 3.4 per million.

Table 1 The relationship between σ, process performance, and process capability

Sigma value	Process performance	Process capability	Process distribution
σ=1.67	3σ	1.00	Normal ($\overline{x}$ =10, σ=1.67)
σ=1.25	4σ	1.33	Normal ($\overline{x}$ =10, σ=1.25)
σ=1.00	5σ	1.67	Normal ($\overline{x}$ =10, σ=1.00)
σ=0.83	6σ	2.00	Normal ($\overline{x}$ =10, σ=0.83)

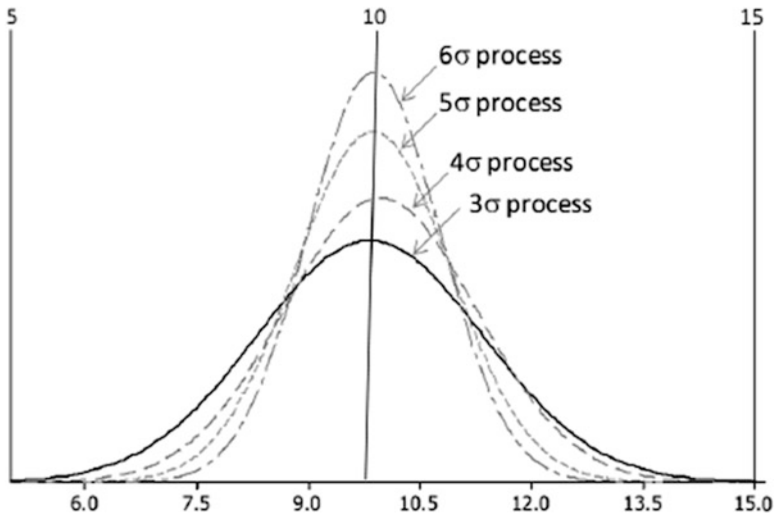

Fig. 1 Three, Four, Five, and Six Sigma processes for our laboratory example

Initially, many believed that such high process reliability was impossible, and Three Sigma (67,000 defects per million opportunities, or DPMO) was considered acceptable. However, market leaders have measurably reached Six Sigma in numerous processes.

According to the Six Sigma methodology a 6-σ process yields fewer defects than a 3-, 4-, or 5-σ process. It is a name given to indicate how much of the data falls within the customers' requirements. The higher the process sigma, the more of the process outputs, products, and services meet customers' requirements – or the fewer the defects. Table 1 and Fig. 1 provide further resolution of the riddle involving the relationship between σ value and process performance. The associated assumed process distributions in Table 1 are used to construct Fig. 1.

The challenge of the Six Sigma methodology is to utilize a set of quality and management tools, through a systematic process, to improve key operational and business processes so they achieve 6-σ performances for key process indicators/metrics. Table 2 provides examples of 6-σ performances for selected processes.

Table 2 Examples of 6-σ performances

Sector	Key process indicator	6-σ performance
Manufacturing	Outer diameter of a shaft produced on a lathe	3.4 defects out of 1 million shafts are produced
Healthcare	Waiting time of patients receiving primary healthcare service at a clinic	3.4 out of 1 million patients wait excessively
Higher education	Publications from funded research projects by the research administration	3.4 out of 1 million funded projects fail to produce publications
Telecommunication	Interruptions in mobile calls made by customers of a local service provider	3.4 interruptions out of 1 million calls

According to Mikel Harry and Richard Schroeder, each sigma improvement in a business process (e.g., moving from a 5-σ to 6-σ) translates into about "10% net income improvement, a 20% margin improvement, and a 10–30% capital reduction" (Harry and Schroeder 2000). This is supported with several success stories such as:

- By 1998, AlliedSignal saved $1.5 Billion from implementing its 6-σ program in 1994.
- By 1998, GE realized from initiating 6-σ programs in 1996 the following gains:
  – Revenues rose 11%.
  – Earnings rose 13%.
  – Working capital turns rose to 9.2% from 7.2% in 1997.

2.1 DMAIC Cycle

Six Sigma methodology is basically including five steps. They are definition, measure, analysis, improve, and control (DMAIC). The systematic improvement methodology has been successfully approved in solution of forging defects, achieved lower costs, and met customer requirements.

The DMAIC problem-solving methodology and the associated tools and training to support the methodology have evolved over the past 20 years to become a set of powerful, robust, and widely adopted practices. The methodology was specifically developed to help teams get root-cause problem solving more efficiently. The DMAIC (McCarty et al. 2011) problem-solving methodology (Fig. 2) was developed to help teams answer five key questions with regard to any problem:

2.1.1 Define

The purpose of the define phase is to identify and/or validate the project opportunity, develop the process that will drive the green initiative, define critical stakeholder

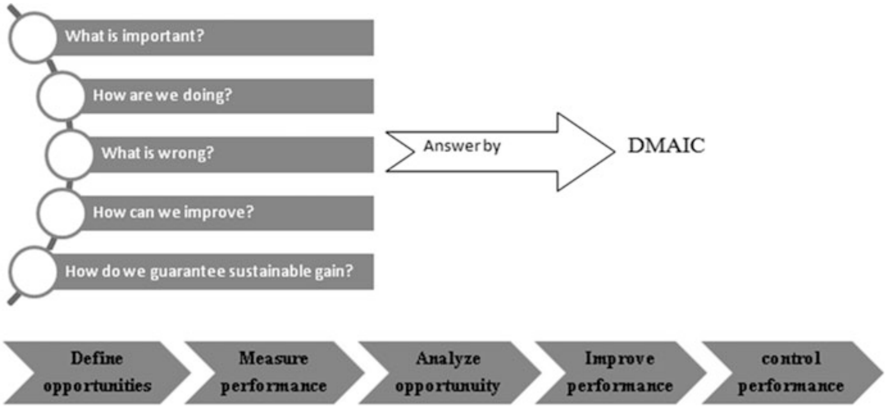

Fig. 2 DMAIC processes

Table 3 Define phase

Objectives	Activities	Tools
• Identify the improvement opportunity • Develop the current state process • Define critical shareholder requirement • Prepare to be an effective project team	• Create team • Develop team charter • Perform stakeholder analysis • Document process map • Identify barriers within process • Perform value stream analysis	• Team charter • Stakeholder analysis • Flowchart • Value analysis *Deliverables* • Prioritized shareholder requirements • Current state process map • Clear team charter • Quick wins

requirements, and prepare team members to act as an effective project team. This focused session has the effect of pulling the team together around a common understanding of the green problem that they are trying to solve and the goals and objectives that they share. Key activities of the define phase (Table 3) include the following:

- Validate/identify the green improvement opportunity.
- Validate/develop the team charter.
- Identify and map processes.
- Identify quick wins, and refine the work process.
- Gather expectations of various stakeholders and convert those expectations into critical project requirements.
- Develop team guidelines and ground rules.

Table 4 The measure phase

Objectives	Activities	Tools
• Identify key measure to evaluate the success • Establish baseline performance for the processes the team is about to analyze	• Identify input process and output indicators • Develop operational definition and measurement plan • Plot and evaluate data • Determine if special cause exist • Determine performance level • Collect benchmark data	• Flowchart • Data check sheet • Benchmark data collection • Surveillance • Graph and charting *Deliverables* • Data collection plan • Baseline data set

This activity helps to get the team excited about the potential for the project and motivated team members to set an aggressive work plan and agree on team norms. With its define workshop completed, the team was ready to move into the measure phase.

2.1.2 Measure

In the measure phase, teams determine what they should measure and what techniques and tools they can use to conduct the measurement and data collection, and then they review methods for ensuring that their measurement process is valid and accurate. Once the measurement plan is in place, the measure phase continues as the measurement and data collection take place. Data collection continues until the team finds that it has a statistically valid sample size from which to conduct valid data analysis. Typical activities during the measure phase (Table 4) include the following:

- Determine process performance.
- Identify input, process, and output indicators.
- Develop operational definitions and a measurement plan.
- Plot and analyze data.
- Determine if special causes exist.
- Collect other baseline performance data.

2.1.3 Analyze

The purpose of the analyze phase is to provide teams with the techniques and tools they need to stratify and analyze the data collected during the measure phase in order to identify a specific problem (root cause) and create an easily understood problem statement. When teams reach a point in which they want to analyze available data, they are confronted with two potential failure modes.

Table 5 The analyze phase

Objectives	Activities	Tools
• Analyze the opportunity to identify a specific problem defined by an easily understood problem statement • Determine true sources of variation and potential failure modes that lead to shareholder dissatisfaction	• Analyze current state • Develop problem statement • Identify cost causes • Validate root causes • Perform statistical analysis • Identify performance gaps	• Run charts • Control charts • Cause and effect diagrams • Statistical tools
		Deliverables
		• Source of variation study • Validated root causes • Problem statement • Potential solutions

These failure modes are either a lack of relevant data or too much data and an inability to determine how to analyze those data in ways that will lead to relevant conclusions aligned with the problem the team is trying to solve. Teams typically follow a process of first creating a problem statement or hypothesis of what the problem is (e.g., "Lighting is the number one source of energy loss in this data center"). Then teams use data-stratification techniques, comparative analysis, and regression analysis to either prove or disprove the hypothesis. Teams will run through a number of hypothesis statements and the associated analysis until they can statistically prove that they have identified the sources of variation that are the most valid root causes of the problem. The list of activities and techniques employed by teams in the analyze phase (Table 5) typically could include the following:

- Development of the problem statement.
- Stratification of the data.
- Comparative analysis of multiple data sets.
- Performing sources-of-variation studies.
- Analysis of failure modes and effects.
- Regression analysis to determine the strongest correlations with the problem statement.
- Identification of root causes.
- Design of root-cause verification analysis.
- Validation of root causes.
- Design of experimental studies to statistically prove the root cause.

2.1.4 Improve

The purpose of the improve phase is to enable teams to identify, evaluate, and select the right improvement solutions and then to develop a change-management approach to assist the organization in adapting to the changes introduced through

Table 6 The improve phase

Objectives	Activities	Tools
• Identify, evaluate, and select the right improvement solutions • Assist the organization in adapting to the changes introduced through solution implementation	• Brainstorm possible solutions • Perform cost/benefit analysis • Design and execute implementation plan	• Brainstorming • Process simulation • Staff feedback • Implementation planning *Deliverables* • Ideal process design • Business case approved • Implementation plan

solution implementation. The typical sequence of activities during the improve phase (Table 6) is as follows:

- Generate solution ideas.
- Determine solution impacts and benefits.
- Evaluate and select solutions.
- Develop the process map and high-level plan.
- Develop financial analysis and the business case.
- Develop and present the solution storyboard.
- Develop the change-management plan.
- Communicate the solution to all stakeholders.

2.1.5 Control

The purpose of the control phase is to help teams understand the importance of planning and executing against the plan and to determine the approach to be taken to ensure achievement of the targeted results. The control phase also helps teams to understand how to disseminate lessons learned, to identify replication and standardization opportunities processes, and to develop related plans. Most important, the control phase forces teams to think through strategies so that identified benefits and financial impacts actually will be realized when the solution is fully implemented and institutionalized. It also will ensure that the solution will deliver results over a long period of time.

Typical activities that occur during the control phase (Table 7) are as follows:

- Develop the pilot plan.
- Conduct and monitor the pilot.
- Verify reduction in root causes resulting from the solution.
- Identify whether additional solutions are necessary to achieve goal.
- Identify and develop replication and standardization opportunities.
- Integrate and manage solutions into the daily work processes.
- Integrate lessons learned.
- Identify the team's next steps and plans for remaining opportunities.

Table 7 The control phase

Objectives	Activities	Tools
• Understand the importance of execution against the plan • Assure targeted results • Disseminate lessons learned • Prevent reversion to current state	• Determine approach to assure targeted results • Track metrics that will show if ideal process is in control • Review progress reports regularly and adjust as needed to support adoption of new process	• Control charts • Statistical process control • Leadership and change management *Deliverables* • Process control plan • Ongoing monitor and reporting plan • Replication opportunities

In summary, the DMAIC problem-solving methodology, as well as the associated tools and training to support the methodology, is a powerful, robust, and widely adopted set of practices designed to improve the success rate of problem-solving teams. The methodology was developed specifically to help teams get to root-cause problem solving more efficiently and with greater consistency and repeatability across teams. This overview was developed to help the reader gain an appreciation for how the methodology can be applied in the green project team arena and encourage team members to learn the methodology and supporting tools.

While the DMAIC methodology provides teams with the process and tools required, that methodology is not sufficient to ensure that the solutions developed will achieve any level of organizational acceptance and adoption. Throughout a sustainability initiative, the leadership team must implement solid change-management strategies to ensure that the team remains committed, the overall organization understands and supports the sustainability objectives, and the organization therefore is ready to support adoption of the green project team's solutions.

3 Case Study I: Reduce Excess Oxygen in Plant X

In this section the application of the DMAIC cycle to reduce the excess oxygen in plant X (Fig. 3) is explained.

3.1 Define Phase

In this phase the problems of excess oxygen of six boilers in plant X is examined. It is observed that there are some essential problems of the current system: the percentage of excess oxygen which leads to high cost and indirect pollution. The system

Fig. 3 Plant X, six boilers

structure is believed to be convenient for Six Sigma approach and DMAIC cycle. Additionally in this phase, we must define the defect, opportunity, expected annual savings, the objective, and the project plan:

- *Defect*: Any day for any boiler (B1, B2, B3, and B4) average excess $O_2 > 4\%$ and B5 and B6 $O_2 > 4.5\%$
- *Opportunity*: Average reading of 66% of excess O_2 reading>4.0% for the 4 boilers and 4.5% for the remaining 2
- *Objective*: Reducing 70% of existing defect, i.e., reduce excess O_2 % for (B1, B2, B3, and B4) $\leq 4.0\%$ and B5 and B6 $O_2 \leq 4.5\%$
- *Annual savings*: 148.300 $/year

Project plan (Fig. 4):

3.2 Measure Phase

For measure phase, one has to measure the right process and in the right time. It is so important for latter phases of the project. So the oxygen excess percentage in the boilers has been analyzed and relevant times are measured.

The current measure of the oxygen average excess for last 3 years (2008–2011) is given in the following chart (Fig. 5), and the current 6-Sigma calculation is given in Fig. 6:

DPMO: In process improvement efforts, a defect per million opportunities or DPMO is a measure of process performance.

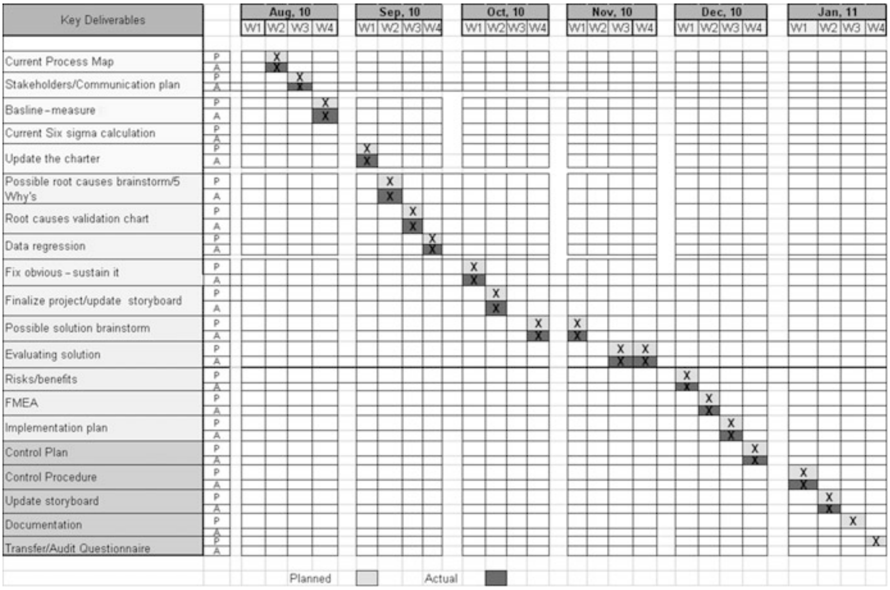

Fig. 4 Project plan

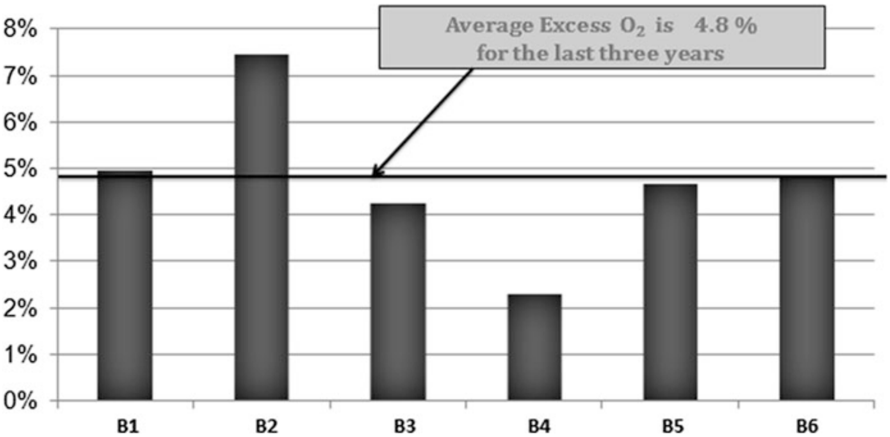

Fig. 5 Oxygen average excess

3.3 Analyze Phase

After it is decided that correct and enough data is collected, the analyze phase has begun. During the analysis of the data, it is determined that there are five main root causes (RC) that affect directly the oxygen excess problem:

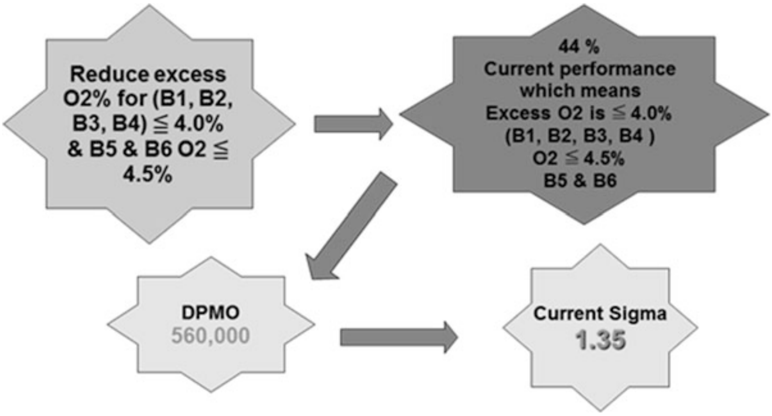

Fig. 6 Current 6-Sigma calculation

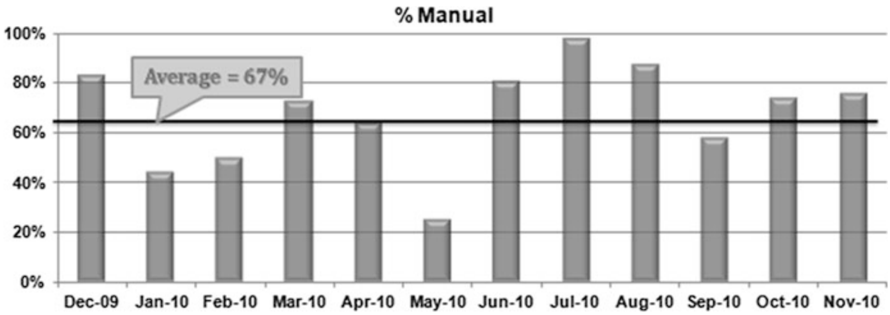

Fig. 7 APC manual most time

1. Control parameter not connected to APC (Air Pollution Control) system and manual most of the time (67%) (Fig. 7).
2. No close follow-up and supervision: Based on the survey results: 50% of surveyed operators confirmed lack of adequate follow-up.
3. O_2 analyzer reading not matching with lab analysis:
   - Operator leaves O_2 in excess.
   - Operator does not take action to reduce O_2.
   - Operator does not refer to analyzer.
   - Operator does not trust analyzer reading.
   - Lab analysis does not match analyzer reading.
4. Operators not aware of excess O_2 operating limits: Based on survey results: 40% of surveyed operators answered correctly.
5. B2 working below the low air pressure alarm: Low combustion air pressure alarm was set at 100 mm-W.G. Most of the time, operations were done while the alarm was on.

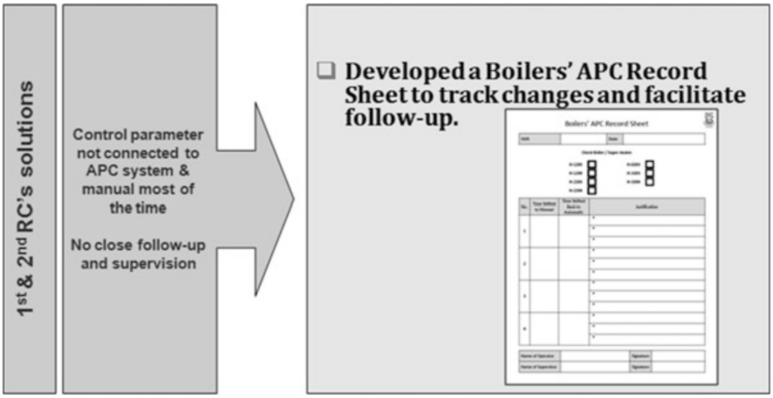

Fig. 8 1st and 2nd root-cause solutions

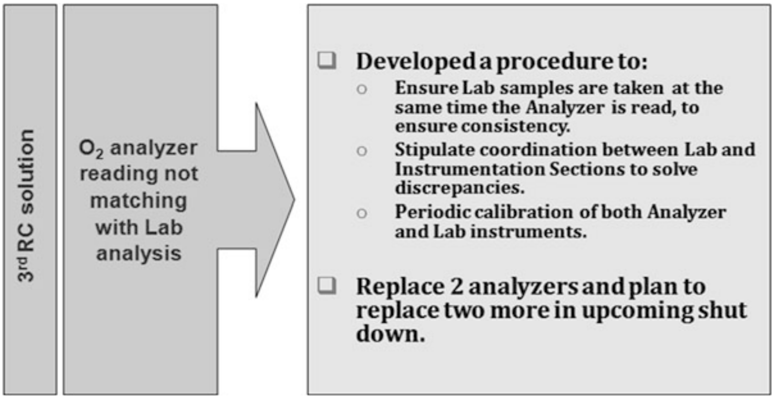

Fig. 9 3rd root-cause solution

3.4 *Improve Phase*

In improve phase, relevant solutions are investigated. While searching for solutions, their applicability is also taken into account. Additionally, its cost should be low (Figs. 8, 9, 10, and 11).

Improvement result (Fig. 12) and Six Sigma before and after (Fig. 13):

3.5 *Control Phase*

The control phase is applied where the changes are indeed valid in the reduction of oxygen excess. Therefore, the O_2 excess percentage is being examined continually. In this phase, we should propose a control plan (Fig. 14).

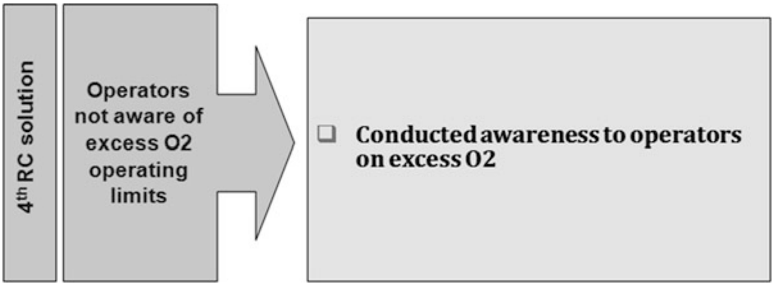

Fig. 10 4th root-cause solution

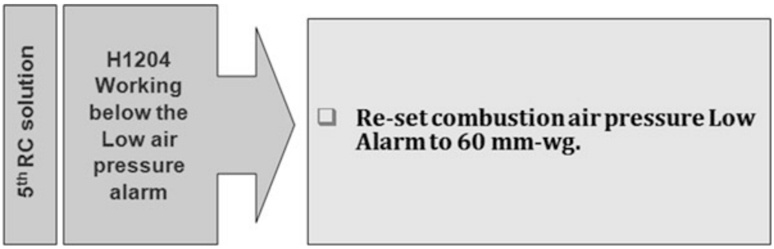

Fig. 11 5th root-cause solution

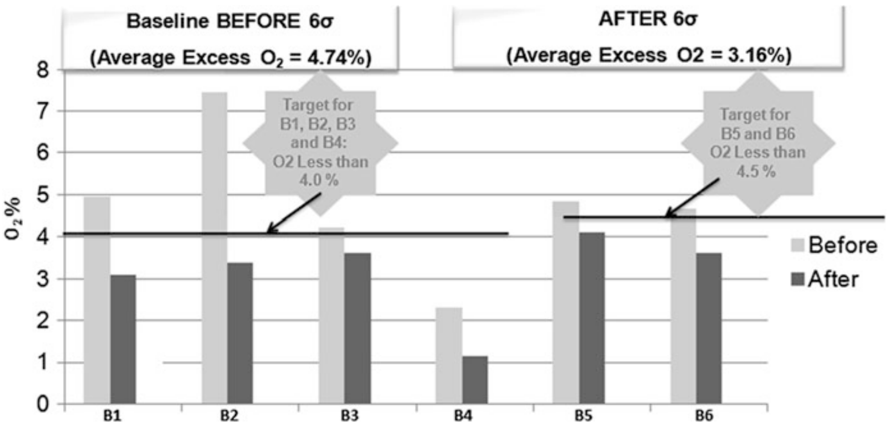

Fig. 12 Result of the improvement

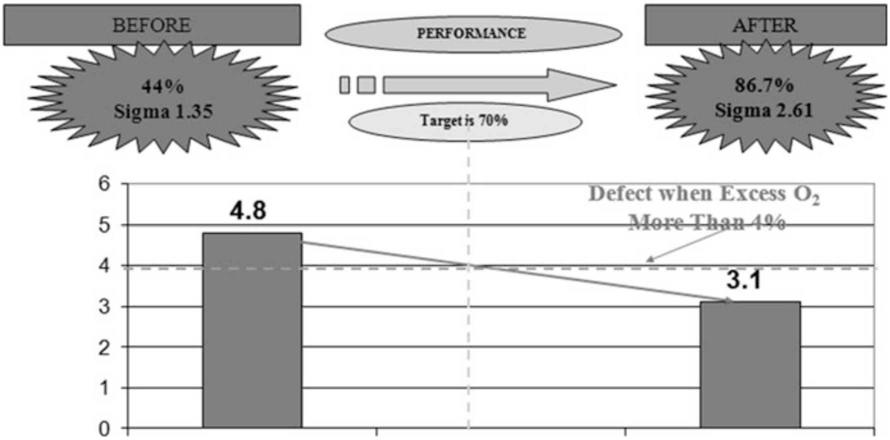

Fig. 13 Six Sigma calculation before and after

Indicators	Performance Standards	Item	Frequency	Contingency Plans	Procedures Standards
	Specs, targets, control limits	**What to check**	**When to check**	**Corrective actions**	
Excess O_2 : B1, B2, B3 B4, B5, B6	Not more than 4.0% and 4.5 %	Item 1 Item 2	Monthly (Include Daily Average)	Reduce air flow to bring O2 reading back to less than 4.0% and 4.5 %	Follow the excess O2 instruction
Combustion Air Pressure	MMWG 80-120 450-500	Item3 Item 4	Monthly (Include Daily Average	Re-conduct awareness to the Control Room operators	Follow the excess O2 instruction
Boilers on APC mode	on Automatic mode all the time	APC	Monthly report	Reconduct awareness to the Control Room operators	Follow the excess O2 instruction
Monthly report	Less than 30% of the defect	Excess O_2	Monthly	Reconduct awareness to the Control Room operators	Follow the excess O_2 instruction

Fig. 14 Control plan

4 Conclusion

Consumers, regulators, and shareholders are all clamoring for sustainability. With the public's growing environmental awareness, consumers are actively seeking "greener" options. Regulators and legislators are changing the landscape for environmental reporting, compliance, and transparency. Shareholders and investors have made environmental and social performance a top consideration. At the same time, many environmentalists claim that cutting greenhouse gases, reducing waste, increasing recycling, and broadly shrinking a company's "impact footprint" will reduce costs.

The sustainability imperative is growing, but along with it comes the recognition that improving sustainability is more difficult than some companies hoped – and many environmentalists would admit. However, by broadening Lean Six Sigma to include sustainability goals, companies can leverage a powerful and well-established performance improvement methodology to jump-start new sustainability programs or substantially boost existing ones. In this way, companies may well be able to marry together the critical goals of being good corporate citizens while improving their bottom line.

In this chapter, we study the applicability of Six Sigma concept to sustainable project. The studied case study shows a remarkable improvement to sustainability.

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Soft TQM for Sustainability: An Empirical Study on Indian Cement Industry and Its Impact on Organizational Performance

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Abstract Firms gained advantage dramatically from the quality revolution, such as Toyota and Motorola, treated quality as an opportunity for process improvements rather than as a cost (Fust and Walker, Corporate sustainability initiatives: the next TQM [white paper]. Executive Insight, pp 1–8. Available at: http://www.kornferryinstitute.com/about_us/by_industry/industrial/publication/620/Corporate_Sustainability_Initiatives_The_Next_TQM, 2007). However, to survive in intense worse era, companies are beginning to embrace sustainability as an opportunity to gain competitive advantage. As we embark into new era which has witnessed global slowdown and intense competition to survive, it is quite appropriate to revisit the role of total quality management (TQM) in enabling and supporting firm to sustain superior performance. This chapter is concerned with soft dimensions of TQM which not only help it in successful implementation but also provide sustainable competitive advantage. Sustainability can perhaps be correlated with the principle of excellence which is now gaining wider acceptance in the business community (Zairi, TQM sustainability: how to maintain it gains through transformational change. Unpublished manuscript, School of Management, University of Bradford, 2005). The present research proposes a soft TQM framework and empirically tested the impact of soft dimensions of TQM on its performance in context to Indian cement industry to understand how soft TQM can help Indian cement industry to sustain competitive advantage in long term. The chapter concludes with a statement that soft dimensions of TQM are critical for sustainability which enable cement firms to achieve superior performance.

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_5,

Keywords TQM • Leadership • HR • Relationship with partners • ROI • Sustainability

1 Introduction

TQM is considered as a strategy, and therefore, much more than terminology and tools, TQM provides a unifying framework that brings a range of "good management practices" to bear simultaneously (Reed et al. 1996). TQM is simply the process of building quality into goods and services from the beginning and making quality everyone's concern and responsibility. The success of TQM depends on the genuine commitment to quality by every member of the organization. According to Ho and Fung (1994), TQM is a way of managing to improve the effectiveness, flexibility, and competitiveness of a business as a whole. It is also a method of removing waste, by involving everyone in improving the way things are done. According to Vuppalapati et al. (1995), TQM is an integrative philosophy of management for continuously improving the quality of products and processes to achieve customer satisfaction. According to Kanji and Asher (1993), TQM is a continuous process of improvement for individuals, groups of people, and whole firms; it encompasses a set of four principles (delight the customer, management by fact, people-based management, and continuous improvement) and eight core concepts (customer satisfaction, internal customers are real, all work is process, measurement, teamwork, people make quality, continuous improvement cycle, and prevention) (Kanji 1998). Currently there is lot of discussions or awareness about the quality of the manufacturing industries in India particularly among automotive sectors and its ancillary manufacturing units, steel manufacturing units, cement manufacturing units, etc. It can be presumed that this is due to double-digit growth of manufacturing sector in India.

India is the second largest producer of cement on the globe after China. In total, India manufactures over 251.2 million tonnes of cement per year (CMIE 2011). The cement industry in India has received a great impetus from a number of infrastructure projects taken up by the Government of India like road networks and housing facilities. While the Indian cement industry enjoys a phenomenal phase of growth, experts reveal that it is poised toward a highly prosperous future. Most of the Indian cement companies have now adopted TQM as their guiding philosophy, and most of the plants of Ultratech (formerly Grasim Cements) have acquired ISO 9001, ISO 14001, and QHSAS. Similarly other players like ACC Limited, Ambuja Cement, Century Cement, Lafarge Cement, Heidelberg, and other big players have also implemented Quality Management System comparable to any plants in other developing and developed nation. Beside this Indian cement companies are also adopting quality tools like 5 S, TPM, BPR, and KAIZEN besides other statistical tools like control charts, run chart, and Ishikawa diagram. However, key quality issues identified by the researcher are:

- *Green Management*: Air and dust emissions and solid waste generated from the kiln in the heating process pose major threat to environment. There is always possibility that source of drinking water can get contaminated with heavy metals present in waste generated during cement production (Salim and Salem 2010). In order to protect the environment, Government has enforced strict regulations related to carbon emissions and environmental protection (Loreti Group 2008; ACC 2008, 2009; Selim and Salem 2010). Future sustainability of cement production and cement firms lies in the efficient *Green Management* practice.
- *Use of Alternative Fuel*: Cement industry is high intensively of raw materials and energy with fuel accounting for 30–40% of the production costs. Owing to such high impact of fuel cost on cost of finished product, the effective use of alternative fuel has become a serious concern among cement companies engaged in cement production (Steinweg 2008; Miller 2009; Selim 2009; Selim and Salem 2010).
- *Warehousing and Packaging*: Warehouse is either public owned or private owned but the conditions of cement warehouse in India are very poor in comparison to other countries like China, Thailand, Vietnam, Malaysia, and Sri Lanka. According to a senior official of Ultratech Cement, it is estimated that 0.5–1 metric tonne of cement gets wasted during loading and unloading of cement bags from a wagon carrying load ranges between 56 and 61 tonne at plant site and at railway siding. The maximum wastages occur at railway siding because in entire country, loading or unloading of cement bags from wagon or truck is mostly manual process using steel hook which causes puncture in HDPE (high-density polyethylene) cement bag.
- *Transportation and Distribution Losses During Transit and Storage*: During transportation wastages result due to bursting of cement bags due to extreme rough handling, poor condition of wagon, untrained labor uses steel hook with sharp edge, wrong delivery of product to the customer site, or most of the times due to lack of proper coordination among sales team, sales unit logistics (outbound logistics), and plant logistics (inbound logistics). This results in huge inventory level in warehouses which further leads to operational problems within warehouses which are:
  - Improper stacking
  - Frequent accidents inside storage house
  - Violation of FIFO (first in, first out) practice
  - Lower layer bags get solidified due to column pressure

  From above we can infer that quality of the finished goods critically depends upon transportation, storage and handling, and distribution (warehousing) activities.

1.1 Research Aim and Objectives

The central problem of the study is how we can make TQM implementation effective in an organization through soft dimensions for sustainability. It further leads toward identification of research objectives of the study as given below:

- To study the role of soft dimensions of TQM for sustainability of firm.
- To propose and validate a research model testing soft dimensions of TQM and firm performance.
- TQM and firm performance.

2 Literature Review

Exhaustive literature review was done through available secondary sources like books, journals, monographs, reports, magazines, newspapers, and online sources. The aim of the literature review is to understand total quality management (TQM), its origin, conceptual development, definition, its present status, and quality practices. The various quality tools and award model are studied in detail to assess the dimensions that lead to effective implementation of TQM and its relationship with firm performance.

In this section Indian cement industry is discussed in detail to provide a clear picture about the industry and the importance of TQM practices in cement industry. The objectives of literature review are:

- To define TQM
- TQM and sustainability
- To review quality tools
- To understand hard and soft dimensions of TQM.

2.1 Definitions of TQM

Numerous definitions have been given on TQM by quality gurus, practitioners, and academicians. Berry (1991) defined TQM process as a total corporate focus on meeting and exceeding customer's expectations and significantly reducing costs resulting from poor quality by adopting a new management system and corporate culture (Yusof 1999). Wolkins (1996) outlined TQM as a tool to integrate fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach focused on continuous improvement. TQM can be defined as a set of techniques and procedures used to reduce or eliminate variation from a production process or service-delivery system in order to improve efficiency, reliability, and quality (Steingard and Fitzgibbons 1993). From various definitions as reported in literature, that TQM can be viewed as a tool for sustaining competitive advantage by improving profitability and reducing cost (Feigenbaum 1983; Pike and Barnes 1996; Oakland 1989; Taddese and Osada 2011; Kristianto et al. 2012).

2.2 TQM and Sustainability

Sustainability here can be termed as "the ability of an organization to adapt to change and respond to global demands and meet customers demand to achieve and maintain superior competitive performance" (Zairi and Liburd 2001). In another literature sustainability is termed as the development that meets present needs without compromising with the ability of future generations to meet their own needs. In intense competitive era when the operating cost is increasing, the cost of input materials and energy is increasing with much higher pace, and uncertainty atmosphere in terms of supply and demands has now forced Indian manufacturers to reformulate strategies to achieve sustainability in performance. TQM can help a firm to achieve sustainability (Curry and Kadasah 2002; Schonoberger 1986). In one of the study in Saudi Arabia, many manufacturers started copying the tools and techniques in hope that they will reap the benefits of TQM, but unfortunately story turned out to be bad investment (Ahmed and Schroeder 2002). The reason was quite simple that most of the TQM implementation project failed because of poor understanding of cultural and social dynamics of the organizations and place. This has prompted researchers to investigate how soft dimensions of TQM can help organizations to achieve sustainability.

2.3 Review of Quality Tools

Quality tools are graphical techniques employed to assess, to appraise, and to provide solutions to quality issues. They are helpful in troubleshooting issues related to quality. They are very simple because they are suitable for people with little formal training in statistics and because they can be used to solve the vast majority of quality-related issues. The tools most commonly used in Indian firms are the cause-and-effect or Ishikawa diagram or fish-bone diagram (FBD), check sheet, control chart, histogram, Pareto chart, scatter diagram, stratification (alternately flow chart or run chart), brainstorming, suggestion scheme, PERT/CPM, PDCA cycle, KAIZEN activities, total productive maintenance (TPM), business process reengineering, and 5 S (Khanna et al. 2003; Khanna 2009; Tripathi 2010; Ando and Kumar 2009; Natarajan and Senthil 2011).

2.4 Understanding Hard and Soft Dimensions of TQM

However, while TQM has been much talked up by gurus/consultants and practitioners promoting their companies, there is growing evidence of its spreading influence if not of its effectiveness. Almost half of corporate respondents and over one-third of individual managers agreed that of the suggested techniques and managerial changes, the biggest impact on the future would be TQM (Wheatley 1991). Yet there is increasing evidence that TQM has not fulfilled its promise (Kearney 1992; Miller 1992; Cruise O'Brien and Voss 1992; The Economist Intelligence Unit 1992; Wilkinson et al. 1993). Furthermore many of the problems arising appear to have been those relating to human resource (HR) issues such as management style, attitudes, and culture. One possible explanation for this is that TQM has developed from a quality assurance ideology and consequently focuses on the "hard" measurable aspects such as costs and production/operation performance to the relative neglect of the so-called soft aspects.

For the most part, however, the principal contributions to the analysis of TQM and its operation have come from people in the Operations Management area (e.g., Oakland 1989; Dale and Plunkett 1990; Dale 1994). Arguably, this has led to a preoccupation with the so-called hard production-orientated aspects of TQM as opposed to its "softer" human resource management (HRM) characteristics. This means that less attention has been focused on people-management issues such as appropriate supervisory styles, compensation/payment systems, teamwork, industrial relations, and the implications for different managerial functions.

Thus, the limitations of TQM can be at least partially attributed to the neglect of human resource policies in the organization and a failure to align the HR policies with TQM to ensure integration. These critical "soft" issues are apparent from most reports, and research yet remains relatively unexplored in comparison with the use of quality management tools and techniques and quality systems (Wilkinson et al. 1992). In recent years, TQM has been taken up by a number of HR writers who have seen it as an opportunity for the function to play a strategic role.

Ho and Fung (1994) identified ten TQM elements: leadership, commitment, total customer satisfaction, continuous improvement, total involvement, training and education, ownership, reward and recognition, error prevention, and cooperation and teamwork. Waldman (1994) identified eight key TQM elements as the following: top management commitment to place quality as a top priority, a broad definition of quality as meeting customers' expectations, TQM values and vision, development of a quality culture, involvement and empowerment of all organizational members in cooperative efforts to achieve quality improvements, an orientation toward managing by fact, the commitment to continuously improve employees' capabilities and work processes through training and benchmarking, and attempts to get external suppliers and customers involved in TQM efforts. Mann and Kehoe (1994) divided TQM into ten elements. They are supplier improvement, process control and improvement, internal customer focus, measurement and reporting, leadership, quality system, participation, recognition, education and training, and external customer focus. In Powell's (1995) study, the following elements were identified as TQM framework: executive commitment, adopting the philosophy, closer to customers, closer to suppliers, benchmarking, training, open organization, employee empowerment, zero-defects mentality, flexible manufacturing, process improvement, and measurement. Black and Porter (1996) identified ten critical factors of TQM: people and customer management, supplier partnership, communication of improvement information, customer satisfaction orientation, external interface management, strategic quality management, teamwork structure for improvement, operational quality planning, quality improvement measurement systems, and corporate quality culture. Choi and Eboch (1998) studied the TQM paradox using management of process quality, human resources management, strategic quality planning, and information and analysis as the constructs of TQM implementation.

The key dimensions of TQM identified are leadership, human resource focus, relationship with partners, culture, customer focus and satisfaction, and tool and techniques (Saylor 1992; Oschman 2002; Anderson et al. 1994; Chinese Quality Awards 2001; Gunasekaran 1999; EFQM 2003).

After thorough analysis of the content and available researches and literature, these soft dimensions were further listed. An overlapping of concepts, systems, and functions is found out. Some of the important observations that can be drawn are as follows:

- Due to origin of TQM from Operations Management stream, there has been an obsession of hard dimensions, i.e., Statistical Quality Control, Quality Function Deployment, and Six Sigma.
- The following dimensions are important for successful implementation, i.e., leadership, human resource focus, relationship with partners, and quality culture.

2.4.1 Soft Dimensions of TQM

Keeping the research objectives in mind, the focus is on soft dimensions of TQM which are critical success factors for implementation of TQM. The conceptual definitions of the Identified Soft Dimensions that support TQM implementation are presented in the tabulated form as below in Table 1.

Thus, some of the important points that can be concluded from this section are:

- There is an increasing role of management and the people behind it for successful implementation of TQM.
- The following soft dimensions are critical for successful implementation of TQM, viz., the role of leadership, quality culture, role of HR functions, and relationship with partners.
- The role of leadership and management is an important aspect for successful implementation of TQM.
- Human resource functions of an organization have an important role in successful implementation of TQM. It includes the planning function, recruitment and selection, training and development, performance appraisal, compensation management, and communications.
- The role of partners and their relationship with the organization is an important aspect for successful implementation of TQM. Partners would consist of internal and external customers, associated companies, suppliers, and the stakeholders including community and society.

Table 1 Soft dimensions for successful implementation of TQM

Constructs	Sources	Definition(s)
Leadership	Juran and Gryna (1997), Karaszewski (2010), and Rui et al. (2010)	Leadership helps to establish quality policies and goals, to provide resources and problem-oriented training, and to stimulate improvement which is vital to TQM implementation and its effect on firm performance
	Anderson et al. (1994) and Choi and Behling (1997)	Leadership is the ability of top management to establish practices and lead a long-term vision for the firm, driven by changing customer requirements as opposed to an internal management control role
	European Quality Award (1994) and Malcom Baldridge National Quality Award (1997)	Leadership is crucial in creating the goals, values, and systems that guide the pursuit of continuous performance improvement
	Minjoon et al. (2006)	Leaders through *leadership* are expected to set quality as a priority while allocating adequate resources to continuous quality improvement and evaluating employees based on their performance
Customer needs	Deming (1986) and Flynn et al. (1995)	*Customer satisfaction* is the result of offering product, keeping the needs of customer
	Feigenbaum (1983)	Customer satisfaction is the output of the customer focus initiative. The customer complaints should therefore be treated with top priority
	Juran and Gryna (1997)	Customer satisfaction is the result of implementation of the customer feedbacks to improve the quality of the product offered to the customer
	EFQM (2003)	Customer satisfaction measures are used to drive improvement and better understand the factors that drive market
People results management	Tenner and Detoro (1992)	People results management is the work based on the skills and participation of every employee and his or her understanding of what is required. Educating and training of employees provides the knowledge required for the mission, vision, direction, and strategy of the organization as well as the skills they need, to secure quality improvement and resolve problems
	Pace (1989) as cited by Bergman and Klefsjo (1994), and Tenner and DeToro (1992)	People result is a process designed to empower members of an organization to make decisions and to solve problems related to their level in the organization
	Irianto (2005)	People results management from quality perspective attempts to achieve two objectives, i.e., to realize the potential of working capability and to engender communication, participation, trust, teamwork, empowerment, personal development, and pride

Partnership and resources	Hong and Satit (2005)	Partnership and resources is how the organization plans and manages its external partnerships and internal resources in order to support its policy and strategy and the effective operation of its processes. Internal and external partnership resources should seek to develop long-term objectives, thereby creating basis for mutual investment. Partners and resources should address the key requirements for success of the partnership, means of regular communication, approaches to evaluating progress, and means for adapting to changing conditions
	EFQM (2003)	External partnerships and finances are managed, and performance requirements are carefully defined and used to select suppliers and partnerships
Human resource focus Empowerment	Lee et al. (2003), Mahour and Lester (2007), and Haffer and Kristensen (2010)	Human resource focus is an initiative which has positive impact on final quality of the product
	Parast et al. (2006)	Human resource focus is the important component of TQM which has positive impact on business performance
	Karia and Asaari (2006)	Human resource focus is an effort in which company need to invest in training to improve the overall performance of the company
	EFQM(2003)	Human resource focus is characterized as work and jobs carefully designed, organized, and managed to provide opportunities for individual initiative and self-directed responsibility
	Bowen and Lawler (1992)	Empowerment is defined as sharing with frontline employee information about organizations' performance, information about rewards based on organization performance, and knowledge that enables employees to understand and contribute to the organizational performance
Training	Cherrington (1995)	Training refers to the acquisition of specific skills or knowledge, to perform particular activities or a specific job
	Brown (1994)	Training addresses issues of awareness, cultural change to develop appropriate attitudes and quality-related values, equipping employees with tools and techniques for quality improvement, and training in job roles
	Hackman and Wagemann (1995)	Training is the second most commonly used TQM implementation practice in the United States. Firms that implement TQM invest heavily in training for employees at different levels
	Karia and Asaari (2006)	Training and education have a significant positive effect on job involvement, job satisfaction, and organizational commitment

(continued)

Table 1 (continued)

Constructs	Sources	Definition(s)
Communication	Karia and Asaari (2006), Thiagarajan and Zairi (1998), and Oschman (2002)	Communication is for the development of awareness and building commitment toward quality in an organizations' environment
	Thiagarajan and Zairi (1998)	Communication helps to foster good employee and employer relationship
Quality culture	Oschman 2002	Quality culture is defined as feeling of togetherness, empowered employees, and no compromise with success
	Reid and Crisp (2007)	Quality culture is about sticking to core value, i.e., excellence, integrity, teamwork, innovation

Table 2 List of benefits of TQM

Benefits	Authors
Better product or service quality	Deming (1986), Oakland (1989), Holloway et al. (1995), James (1996), Reed et al. (1996), and Mohanty and Lakhe (1998)
Promoting continuous improvement	Spencer (1994), Reed et al. (1996), Waldman (1994), James (1996), and Bounds et al. (1994)
Enhances firm's profitability/ productivity	Waldman (1994), Ahire and Kiran (1995), James (1996), Oakland (1989), Mohanty and Lakhe (1998), Sun (2000), Fotopoulos and Psomas (2009a), and Desai (2012)
Improvement in market share	Buzzel and Gale (1987), Reed et al. (1996), and Mohanty and Lakhe (1998)
Increases flexibility	James (1996) and Reed et al. (1996)
Customer satisfaction	Jarrod and Chester (2008) and Kristianto et al. (2012)
Waste reduction	Talib et al. (2011)
Improvement in revenue	Wisner and Eakins (1994), Mehmet et al. (2006), Fotopoulos and Psomas (2009a, b), and Raja et al. (2011)
Reduces cost	Mehmet et al. (2006), Fotopoulus and Posmas (2009a, b), and Raja et al. (2011)
ROI (return on investment)	Cole (1992) and GAO/NSIAD-91-190 (1991)

- The role of HR philosophy/strategy related to quality is an important dimension for successful implementation of TQM. It includes human resource strategy, process, control systems, and statistical techniques for quality management.

2.5 TQM and Firm Performance

It is equally important to understand how TQM implementation affects a firm performance. What tangible and intangible benefits occur that define effective and efficient implementation of TQM of a firm?

In brief researcher can conclude the benefits of TQM in tabulated form in Table 2 as:

2.6 Indian Cement Industry

The demand and supply of cement have undergone a phenomenal growth in India. On the whole, the fact that India is a fast developing nation presents an enormous scope for the development of cement industry. The present section deals with the production status of Indian cement industry, its potential, the level of technology, scope, FDI, and future prospects for the industry.

Production Capacity: Demand in the cement industry has seen enormous growth due to the growth of infrastructure, residential and commercial projects. Cement production in India is anticipated to increase to 315–320 million tonne (MT) by the end of the fiscal year (2011) from the current 300 MT.

Technology Upgradation: At present, the cement industry in the country is undergoing a technological change on account of upgradation and assimilation witnessed in the sector. Presently, not less than 93% of the total capacity is wholly based on manufacturing under the modern dry process, which is deemed more environment-friendly, while the remaining rest 7% employs old wet and semidry process technology. The cement industry in India has developed its technical capabilities to produce a range of cement types including Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC), Portland Blast Furnace Slag Cement (PBFS), Oil Well Cement, Rapid Hardening Portland Cement, Sulphate Resisting Portland Cement, and White Cement.

FDI and Future Prospects: Progressive liberalization and easing of foreign direct investment (FDI) norms in various sectors paved the way for growth in FDI, which led to growing demand for office space from multinational companies (MNCs) and other foreign investors. Total FDI in the cement sector between April 2000 and August 2010 stood at US$ 1.9 billion (source: CMA report 2011). The cement industry in India is known for its linkages with other sectors. The Government of India has taken various steps to provide the required impetus to the industry. At present 100% FDI is allowed in this industry. Both the state and export policies promote cement production. Exporters can claim duty drawbacks on imports of coal and furnace oil up to 20% of the total value of imports. Most state governments offer fiscal incentives in the form of sales tax exemptions/deferrals in order to attract investment. According to a recent research report titled *"Indian Cement Industry Forecast to 2012"* published by research firm RNCOS in the year 2011 highlights that cement industry in India has witnessed massive growth on the back of various industrial developments and pro-economic policies of the Union Government. This has helped attracting the attention of various global cement giants, thereby sparking off a wave of mergers and acquisitions in several states. The report has estimated India's cement consumption to grow at a compound annual growth rate (CAGR) of 11%, between 2011–2012 and 2013–2014. The research which focused on the demand-supply outlook and the cement pricing in various regions of the country revealed that Andhra Pradesh topped the chart in 2008–2009 in terms of large plants and its installed capacity in India. Fast-growing economy and the regulatory support are expected to further encourage the industry players to embark on expansion plans. Furthermore, it is estimated that the Government's assistance to several infrastructure projects, road networks, and housing facilities will boost the growth in cement consumption in the near future (Indian Cement Review 2008).

Highlights of the Indian cement industry as shown in Table 3 are given below.

The number of large cement plants in India is approximately 42 and mini and white cement plants are 365, with installed capacity of 234.30 (MT) and 11.10

Table 3 Cement industry profile in India

Companies nos.	42
Numbers of cement plants	139
Installed capacity (MT)	234.30
Cement production (MT) in the year 2009–2010	168.29
Plants with capacity of one MT and above	97
Manpower employed	120,000
Annual turnover in Mn.$ in the FY 2010	18,000
Statistics: mini and white cement plants	
Cement plants (nos.) approx.	365
Installed capacity (MT)	11.10
Cement production (MT) 2010–2011	6.00

Source: Cement Manufacturers Association of India (2011)

Table 4 Profile of top Indian cement companies

Companies	Production capacity ('000) MT	Installed capacity ('000) MT
ACC Limited	17,902	18,640
Gujarat Ambuja Cements Limited	15,094	16,860
Ultratech	13,707	17,000
Grasim	14,649	14,115
India Cements	8,434	8,810
JK Cements Limited	6,174	6,680
Jaypee Cements	6,316	6,531
Century Cements	6,636	6,300
Heidelberg (Madras Cement)	4,550	5,457
Birla Corp	5,150	5,113

Source: Cement Manufacturers Association of India (2009)

(MT), respectively, as per publication of Cement Manufacturers Association of India, 2011. The annual turnover was over Rs. 18,000 crore in the financial year 2010. This above statistics shows that large cement industry has provided direct employment opportunities to more than 120,000 people and indirect employment to more than 3.6 lakhs people. It also provides clinker to other mini cement plants so that available clinker can be fully utilized. However, there is an immense opportunity to increase the installed production capacity from 1 million tonne to 2 million and above to take advantage of economy of scale provided that nearest market within a radius of 200 km can support the plant.

2.6.1 Major Cement Plants in India

In India over 70% of cement production is primarily contributed by top 10 companies. The list of top 10 companies is presented in Table 4.

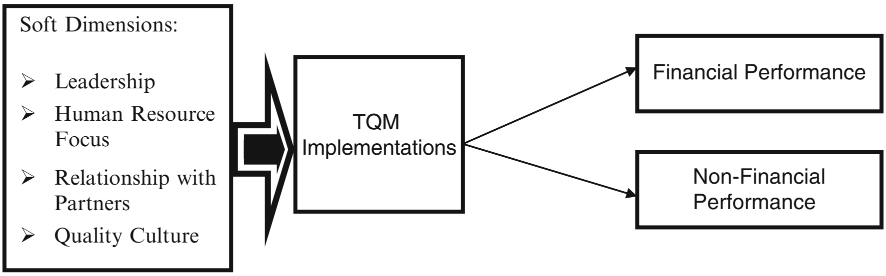

Fig. 1 A conceptual model of the relationship between TQM implementations for sustainability

3 Research Design

This section deals with methodology used to carry out research study as a systematic and scientific investigation. In order to further validate the theoretical concepts, an empirical research is undertaken. This section establishes a research framework or research design which is given below as:

- Specifying the research objective of study.
- Refining and redefining the research framework, hypotheses, sampling plan, questionnaire design, questionnaire administration, and quantitative techniques to be used for the purpose of the study.
- Understanding interrelationship between theoretical concepts and principles in a conceptual framework.
- Hypotheses development.

3.1 Proposed Theoretical Framework

The present study integrates several soft dimensions of TQM and impacts of these soft dimensions on successful implementation of TQM in Indian cement industry. On the basis of the preceding discussion and the synthesis of the existing literature, a proposed conceptual framework for the current research is shown in Fig. 1. The two main components that constitute the conceptual framework include the soft dimensions of TQM and successful implementation of TQM which will be measured in terms of firm performance variables.

3.1.1 Assumptions of the Study

The hypotheses to be tested in this study are developed on the basis of the research objectives and questions; the theoretical framework also serves as a basis for hypotheses development. The overall research hypotheses are that there is a positive association of leadership, HR focus, relationship management with partners, and quality culture with firm performance. These hypotheses are strongly supported by many studies both theoretically and empirically in a variety of fields as it is clearly reflected in literature review.

3.1.2 Hypotheses of the Study

- *Hypothesis 1*: There is a positive relationship between the leadership and successful TQM implementation.
- *Hypothesis 2*: There is a positive relationship between the human resource function and successful TQM implementation.
- *Hypothesis 3*: There is a positive relationship between the relationship management with partners and successful TQM implementation.
- *Hypothesis 4*: There is a positive relationship between the quality culture and successful TQM implementation.

3.2 Sampling Plan

This study focused on the cement manufacturing companies in India. The cement manufacturing companies in India were identified through database of Cement Manufacturers Association. It provides the list of companies operating in India, their contact address, their type of business, and their type of ownership. The study was carried out in 28 cement manufacturing firms where 275 usable questionnaires were used for data analysis.

4 Data Analysis and Findings

This section presents the analysis of the data collected for study and the findings related to it. Data exploration as a step prior to analysis is carried out. After coding the data, all necessary assumptions of parametric test are checked, and then multivariate data analysis is conducted. It is analyzed by using statistical software package SPSS 16.

4.1 Instrument Reliability and Validity

According to Hair (1995), reliability of a variable reflects the extent to which a variable or a set of variables is consistent in what it is intended to measure where validity of the variable reflects the extent that differences in scores among objectives reflect the objects' true differences related to the construct that is sought to be measured (Hair et al. 1999). The reliability of a variable is a necessary but not a sufficient condition for its validity. Validity can never be established unequivocally, but can only be inferred either by direct assessment or indirectly by assessing reliability.

Rules of thumb suggest that the item-to-total correlations exceed 0.5 and that the inter-item correlations exceed 0.3. For the second type of diagnostic measure, the generally agreed upon lower limit for Chronbach's Alpha is 0.7, although may decrease to 0.6 in exploratory research (Hair et al. 1999; Nunnally 1978). In order to assess the reliability of the measures in this study, item-to-total correlations and Chronbach's Alpha were employed. And as suggested by Nunnally (1978), the criteria for retaining a scale item include an item-to-total correlation of at least 0.35 (Nunnally 1978) and a Chronbach's Alpha for the scale of at least 0.7. The Chronbach's Alpha was calculated for each soft dimensions and TQM implementation constructs. It presents item-to-total correlations for four functional constructs (leadership, human resource focus, relationship management with partners, and culture). The Chronbach's Alpha for various constructs are as follows 0.733 (leadership), 0.831 (human resource functions), 0.882 (relationship management with partners), and 0.822 (culture), respectively, which indicates that they meet the requirement by Nunnally (1978).

4.2 Regression Analysis and Hypotheses Testing

In statistics, *linear regression* is an approach to modeling the relationship between a scalar variable *y or dependent variable or endogenous variable* and one or more explanatory variables or independent variables or exogenous variables denoted with *X*. The case of one explanatory variable is called *simple regression*. Given a data set $\{y_i, x_{i1}, \ldots, x_{ip}\}_{i=1}^{n}$ of n statistical units, a linear regression model assumes that the relationship between the dependent variable y_i and the p-vector of regressors x_i is linear. This relationship is modeled through a so-called disturbance term ε_i – an unobserved random variable that adds noise to the linear relationship between the dependent variable and regressors. Thus, the model takes the form

$$Y = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 \ldots + \text{Error}$$

where ′ denotes the transpose, so that $x_i'\beta$ is the inner product between vectors x_i and β.

Often these n equations are stacked together and written in vector form as

$$Y = \beta X + €,$$

The basic assumptions of the use of regression are:

1. All predictor and outcome variables must be quantitative, i.e., to be measured at the interval level.
2. Ratio of cases to independent variables: In order to empirically test a model, the minimum sample size is $(50 + 8K)$, where K is the no. of predictors (Field 2005).

Table 5 Summary of linear multiple regression analysis of five models

Model	*R*	Square *R*	Durbin-Watson value	*F*	Sig	+ Beta	– Beta
Model 1 ROI	0.787	**0.620**	1.630	21.443	0.000	L, HR, QC	**RM**
Model 2 QPS	0.609	0.371	1.775	10.976	0.000	L, QC	HR, RM
Model 3 WROSM	0.643	0.414	1.598	8.716	0.000	L, HR, QC	HR, RM
Model 4 WRDM	0.644	0.414	2.032	4.7332	0.000	L, QC	HR, RM
Model 5 EBIDTA	**0.725**	**0.525**	**1.558**	**1.6332**	**0.166**	**L, HR, RM**	**QC**

In our research there are 25 predictors and sample size is 275 which satisfy the assumption.

Variables should be free from multicollinearity. High multicollinearity increases the complexity due to interrelationships of variables. It is to be checked in regression analysis itself.

Simple multiple regression analysis with four soft dimensions of TQM as independent variables and the five performance factors as dependent variables were conducted. A total five models were run individually to understand how the predictor variables predict the outcome.

Model 1: Return on investment (ROI).
Model 2: Improvement of quality of product of product and services (QPS).
Model 3: Waste reduction due to defects management (WRDM).
Model 4: Waste reduction due to successful management of overstocks (WROSM).
Model 5: EBIDTA.

The tables below show the result of the regression. It includes value of model R^2, the two-tail t-value for the significance of beta (or the regression itself), and the estimate and the intercept. The estimates of the understandardized and standardized slope (beta) are also presented in Table 5 as shown:

From the above comparative Table 5, we conclude that Model 1 explains 62% of the total variance. Thus, the same has been further taken as a basis of further testing of hypotheses.

4.2.1 Research Hypotheses Testing

- *Hypothesis 1*: There is a positive relationship between the leadership and successful TQM implementation.

There is significant association between leadership and performance of a firm ($R=0.312$) as shown in Appendix 1. The beta coefficient of leadership is 0.210

Table 6 Summary of hypothesis testing

Hypothesis	Description	Result of hypothesis
H1	There is a positive relationship between the leadership and successful TQM implementation	Supported
H2	There is a positive relationship between the human resource function and successful TQM implementation	Supported
H3	There is a positive relationship between the relationship management with partners and successful TQM implementation	Not supported
H4	There is a positive relationship between the culture and successful TQM implementation	Supported

which is statistically significant at 0.000 as shown in Appendix 1. Thus, *Hypothesis 1* is supported (Table 6).

- *Hypothesis 2*: There is a positive relationship between the human resource function and successful TQM implementation.

There is significant association between human resource function and performance of a firm ($R = 0.136$) as shown in Appendix 1. The beta coefficient of human resource function is 0.187 which is statistically significant at 0.015, which is within ±0.05 as shown in Appendix 1. Thus, *Hypothesis 2* is supported.

- *Hypothesis 3:* There is a positive relationship between the relationship management with partners and successful TQM implementation.

There is significant association between relationship management and performance of a firm ($R = 0.030$) as shown in Appendix 1 but the value of R is very small. The beta coefficient of relationship management is −0.246 which is statistically significant at 0.001, which is within ±0.05 as shown in Appendix 1. However, the beta coefficient is negative, hence the *Hypothesis 3* is not supported.

- *Hypothesis 4:* There is a positive relationship between the culture and successful TQM implementation.

There is significant association between culture and performance of a firm ($R = 0.401$). The beta coefficient of culture is 0.393 which is statistically significant at 0.000. Thus, *Hypothesis 4* is supported.

5 Conclusions, Recommendations, and Further Scope of the Study

This section presents conclusions and recommendations drawn from quantitative and qualitative analysis. Conclusions are drawn on the basis of literature review and reference available in the area. The framework concluded from hypotheses testing is also presented in this section. Observations and insight of the researcher are also duly incorporated in this section. Subsequently recommendations based on the same are listed below. At the end, unique contributions of the research, managerial implications, limitations of the research, and some future research directions are given.

5.1 Conclusions from Literature Review Section

- TQM is an integrated philosophy as well as many firms consider it as a strategic tool to gain competitive advantage for sustainability.
- A management philosophy and company practices which aim to harness the human and material resources of an organization in the most effective way to achieve the objectives of the organization.
- The quality tools most commonly used in Indian firms are the cause-and-effect or Ishikawa diagram or fish-bone diagram (FBD), check sheet, control chart, histogram, Pareto chart, scatter diagram, stratification (alternately flow chart or run chart), brainstorming, suggestion scheme, PERT/CPM, PDCA cycle, KAIZEN activities, total productive maintenance (TPM), business process reengineering, and 5 S.
- TQM can be analyzed from microperspective which is made up of important components which can be further classified into two broad categories as hard dimensions and soft dimensions.
- Literature available on soft dimensions of TQM in Indian context is not adequate, and none of the model present in literature deals with Indian cement industry.
- Due to origin of TQM from Operations Management stream, there has been an obsession of hard dimensions, i.e., Statistical Quality Control, Quality Function Deployment, and Six Sigma.
- The following dimensions are important for successful implementation, i.e., leadership, human resource focus, relationship with partners, and quality culture.
- The following soft dimensions are critical for successful implementation of TQM, viz., the role of leadership, quality culture, role of HR functions, and relationship with partners.
- TQM implementation leads to financial and nonfinancial benefits.
- TQM creates various strategic advantages to firm and improves competitiveness, revenues, market share, ROI, and firms' profitability and productivity.
- It motivates employees leading to greater commitment and satisfaction.
- It improves product quality, delivering higher value to customer and enhances customer satisfaction.
- Most of the big cement manufacturers in the India have implemented Quality Management System comparable to any plants in other developing and developed nation.
- Indian cement companies are also adopting quality tools like 5 S, TPM, BPR, and KAIZEN besides other statistical tools like control charts, run chart, and Ishikawa diagram.

- Poor packaging quality results in high wastages during transit. Most of the times while loading or unloading, cement bags get damaged. Warehouse is either public owned or private owned but the conditions of warehouse are very poor, and use of conventional material handling results in wastages.
- Resource constraints like depleting limestone mines in India, lack of availability of high-quality coal, high carbon content in slag, or quality fly ash.
- Green manufacturing and compliance to strict environmental norm will define the sustainability of cement industry in future, and TQM implementation can really help company to meet high-quality demand in *green way*.

5.2 Conclusions from Data Analysis Section

- The Chronbach's Alpha for various constructs are as follows: 0.733 (leadership), 0.831 (human resource functions), 0.882 (relationship management with partners), and 0.822 (culture), respectively, which indicates that they meet the requirement by Nunnally (1978). This clearly concludes that constructs chosen for study are reliable.
- The value of KMO is 0.644 which is greater than 0.5 and significant at 0.000 which means that the variables are highly correlated enough to provide reasonable basis of factor analysis.
- The communalities' matrix of all variables used is quite high, which indicates that the extracted components represent the variable well. There is significant association between leadership and ROI of a firm ($R = 0.312$). The beta coefficient of leadership is 0.210 which is statistically significant at 0.000. Thus, *Hypothesis 1* is supported.
- There is significant association between human resource function and ROI of a firm ($R = 0.136$). The beta coefficient of human resource function is 0.187 which is statistically significant at 0.015, which is within ±0.05. *Hypothesis 2* is supported.
- There is significant association between relationship management and ROI of a firm ($R = 0.030$) but the value of R is very small. The beta coefficient of relationship management is −0.246 which is statistically significant at 0.001, which is within ±0.05. *Hypothesis 3* is not supported.
- There is significant association between culture and ROI of a firm ($R = 0.401$). The beta coefficient of culture is 0.393 which is statistically significant at 0.000. *Hypothesis 4* is supported.

Simple multiple regression analysis with four soft dimensions of TQM as independent variables and the five performance factors as dependent variables were conducted using SPSS 16. A total five models were run individually to understand how the predictor variables predict the outcome of the ROI, improvement of quality of product of product and services, waste reduction due to defects management, waste reduction due to successful management of overstocks, and EBIDTA. The result of hypothesis testing shows that out of four hypotheses, three hypotheses are supported

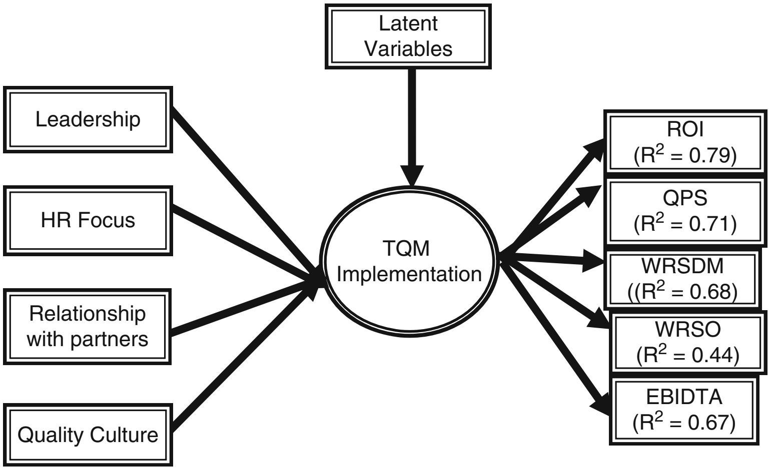

Fig. 2 Conclusive research framework

except one hypothesis (i.e., third hypothesis). Based on the result, researcher proposes a new model as shown in Fig. 2 as:

The colored portion does not support hypotheses.

Here variable relationship with partners does not support the model whereas EBIDTA is not statistically significant.

5.3 Recommendations

- Relationship management is the area which has been ignored. The suppliers, transporters, CFA's, and customers are not yet involved in decision-making process, except few companies like ACC Limited, Ultratech, and Ambuja Cement have recently adopted this practice. But on large scale this area needed to be built up.
- Indian cement companies must make action plan to adopt and implement TQM for effectiveness and efficiency, including processes for continuous improvement and implementation of the quality system and procedures to satisfy the customers' needs, in compliance with the cement industry requirement. This is to ensure and enhance the level of business performance management of firms in the Indian cement industry.
- Update and development of new instrumentation standards of acceptability for all features and requirement (if necessary) and monitoring information about customer satisfaction as a performance metric.
- Establishing measurement and monitoring methods to ensure the compatibility of the design, product, and process requirements are attained.
- An effort must be initiated to reduce shipping cycle time in order to improve transporters' satisfaction level.

- Training for drivers and labors working for industry must be provided due treatment, and particularly Indian cement industry must ensure minimum quality of work life for these indirect labors that play vital role in the growth of the industry.
- There must be proper liasioning between Indian railway and cement industry as most of the time due to poor infrastructure like poor lighting facility at railway sidings or poor conditions of wagons result in huge demurrages or wastages of finished goods.
- Improve reliability of delivery. Most of the time due to poor reliability, dealers/retailers fails to serve their customers.
- Companies need to inculcate green practices.
- Companies are very much driven by Hard TQM dimensions, and soft dimensions are ignored most of the time which is only major reason behind poor EBIDTA or high inventory stock or huge wastage which arises during transportation or handling.

It must be understood that in order to sustain competitive advantage, firms need to ensure that each partners across the supply chain network, right from the suppliers till final delivery, must be covered under TQM umbrella as any failure in any link can derail entire supply chain. In such situations the role of leadership and human touch, involving partners and by sowing the seeds of quality culture which is driven toward achieving excellence is characterized by ten attributes, i.e., a bias for action, close to the customer, autonomy and entrepreneurship, productivity through people, hands on, value driven, stick to knitting, simple form, lean staff, and simultaneous loose-tight properties (Peters and Austin 1985).

5.4 Future Research Directions

While this study was able to provide additional insight into four soft dimensions of TQM and its relationship with firm performance, it also revealed areas that would benefit from further research. First, this study focused only on four soft dimensions of TQM in cement industry. Future research could thus focus on the other dimensions such as hard dimensions, ethics and values, and SCM. By doing so, a better and fuller understanding on the effects of TQM on firm performance may be achieved. Second, there is a strong need for longitudinal research. A longitudinal analysis of companies over time would provide data to address at least two research questions: (1) is there a time lag between investing in TQM and achieving an expected performance, and (2) is there a particular order in which these investments should be made? Third, this study failed to support one of the proposed hypotheses related to the relationship with partners and firm performance. Hence, there is a need for further study on the influence of different external variables on firm performance. It certainly takes time to undertake any change from the past. So there is an important need to investigate the differences in the future when managers had enough time to change their management styles. Finally, to be able to generalize the results of this study, future research might be extended to other industries like service and to other countries both developing and industrialized.

Appendix 1: Regression Coefficients

Model		Unstandardized coefficients		Standardized coefficients			Correlations			Collinearity statistics	
		B	Std. error	Beta	*t*	Sig.	Zero-order	Partial	Part	Tolerance	VIF
Constant		**.781**	.462		1.691	.0092					
	L	.357	.097	**.210**	3.686	.000	.312	.219	.195	.864	1.157
	HR	.182	.074	**.187**	2.455	.015	.136	.148	.130	.484	2.065
	RM	−.213	.066	**−.246**	−3.239	.001	.030	−.193	−.172	.488	2.049
	QC	.501	.072	**.393**	6.950	.000	.401	.390	.368	.878	1.139

Source: SPSS16 output table

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Part III
Sustainability Mechanism and Analysis

An Energy Optimization Framework for Sustainability Analysis: Inclusion of Behavioral Parameters as a Virtual Technology in Energy Optimization Models

Roman Kanala, Nathalie Turin, and Emmanuel Fragnière

Abstract This chapter introduces an innovative approach that combines the deductive method used to construct normative energy-economy models and the inductive method of social sciences. Consumer behavior is described via technological attributes and used in virtual process technologies in an energy optimization framework. The main finding is that it is possible to evaluate consumer information and behavior together with technological progress and integrate them on the same modeling platform. The approach eliminates the systematic error on the demand side where the efficiency of demand-side management measures is over optimistic, which may lead to inaccurate decisions and poor policies. Thus, this method paves the way to a new stream in energy modeling.

Keywords Energy models • Demand-side management • Virtual technology • Consumer behavior • Sociological survey • Social MARKAL

1 Context

The definition of development depends on the scientific discipline that defines the context; for example, development of an organ points to medicine; development of an organism, to biology; and development of knowledge, to pedagogy. Economic development denotes either a growth or structural changes in a

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Research supported by SNF research grant IZERZ0_142217.

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_6, © Springer Science+Business Media Dordrecht 2013

geographic zone or of a population for which it means more wealth or an improvement of living conditions. Economic development is associated with progress. Often, development is a shortcut for economic development. However, economic growth is only one of the components of the economic development and can be measured by simple indicators, such as GDP or by more elaborated indexes, such as the human development index or indexes reflecting economic inequalities. Interchanging the terms of growth and GDP growth is an even more reductionist approach, but its advantage stems from its simplicity and because financial flows are usually one of the best documented statistics.

Development is sustainable if it meets the needs of the present without compromising the ability of future generations to meet their own needs. There is a large consensus that the challenges of climate change are such that our usual way of life and the associated energy consumption patterns are not sustainable as we continue privileging growth over structural changes whose precondition is awareness. Elaborating models is the first step toward identifying and understanding the key issues, drivers, and barriers, to development. Optimization models in particular, because of their technology richness, are useful to describe societies that are undergoing structural changes rather than simple economic growth. However, in neoclassical models, the behavioral, psychological, and social drivers of consumption are poorly depicted.

Optimization models based on economic equilibria share a common flaw that comes from implicit hypothesis of perfect information and the hypothesis of perfect economic rationality. While these hypotheses are satisfied on the supply side with a small number of players, such as ministries, corporations, power stations, and equipment for extraction, conversion, or processing energy carriers, on the demand side, we have a huge number of decentralized decision makers who make pennyworth decisions very often, sometimes even several times a day. Experience shows that consumers do not always behave rationally, among other reasons, because they are not in possession of the information necessary to make the best choice, but also because their personal preference does not correspond to the economic criterion of minimal cost.

For example, people do not buy a car just simply to get from point A to point B; rather, they also use it as a shopping bag, umbrella, status symbol, or toy. One presented study, which was conducted just prior to the administrative ban on the sale of incandescence bulbs in the EU and Switzerland, explores consumers' information, perceptions, attitudes, and behavior toward low-consumption bulbs as a technology mix that includes halogen lamps, fluorescent bulbs, and LED bulbs. Several rational but noneconomic factors that influence the consumption of light were identified, along with irrational factors that make people acquire and use old incandescent bulbs or overconsume light. Many elderly people suffer from macular degenerescence, which alters their vision and color perception. Such persons refuse fluorescent bulbs and seek incandescent, halogen, or LED light bulbs. In one of our recent surveys, we have also observed that people may feel a need to turn on all the lights in the room they are in, or even all the lights in the house, because of a fear of darkness.

These modeling anomalies were addressed by additional equations in the MARKAL model, which is a partial economic equilibrium model used to assess energy choices that was developed in the 1970s under the aegis of the International

Energy Agency. This approach is entirely compatible with MARKAL formalism and the user-friendly interface tool called ANSWER (Nguene et al. 2011). The approach consists of adding virtual technologies corresponding to energy savings and to technology switches that complete the "classical" competition between demand technologies based on economic criteria. In order to prevent unlimited consumption of this free technology, instead of using bounds that depend on the subjective judgment and erudition of the analyst, we have introduced upstream virtual process technologies that represent information and marketing campaigns in favor of rational energy use and in favor of technology switching. Like the real-life information campaigns themselves, these virtual technologies are not free. They have an investment cost, and in that way, they compete with classical technologies, acting as a trigger of energy savings and/or additional incentive for technology switching. These virtual technologies penetrate into an optimal investment solution as soon as their cost is low enough to be economically viable in comparison to "real" technologies.

In order to assess important coefficients, such as the efficiency of these virtual technologies and their yield, special sociological surveys were developed to measure the consumers' information, perceptions, attitudes, and behaviors. In addition to a classical sociological survey, we also proposed to use an ethnomethodology approach to identify the most interesting hypotheses to be measured.

We thus have a case study using a mixed methodological approach: deductive, like in bottom-up engineering models, and inductive, like in social sciences. This eliminates the systematic error that comes from neglecting irrational consumers' behavior and eliminates subjectivity of the modeler if the demand-side management measures are restricted by simple bounds in a MARKAL family of models. However, the approach described can be used in any optimization model based on the concept of economic equilibrium.

This chapter is organized as follows. Section 2 will present a brief literature review introducing both MARKAL models and several academic findings that highlight the importance of consumer behavior. In Sect. 3, we present the methodology employed to integrate behavioral parameters into the MARKAL framework. To illustrate our methodology, we will present a case study in Sect. 4 based on qualitative and quantitative methods to show how those human factors can be integrated into technological models. Conclusions will be presented in Sect 5.

2 Literature Review

In this section, the authors briefly present the MARKAL energy-economy model on which this article relies and then the main limitations of such models by outlining the strong sociological dimension characterizing energy consumption and the behavior of consumers. To conclude this section, the authors will present arguments that justify the relevance of a sociological approach to the existing MARKAL family of models.

Models are used to analyze different scenarios for possible future situations. Energy-economy models can be used as management tools for decision making, and an important number of them have been developed through the years. The use of a long-term optimization model such as MARKAL is interesting in particular when the decision maker faces multiple choices and seeks to define a sound long-term policy to avoid locking into a particular path. A general overview of energy-economy models that include environmental parameters is provided by Nakata (2004) and, more recently, by Bhattacharyya and Timilsina (2010).

The MARKAL (MARKet ALlocation) family of models has been developed under the aegis of the Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency (IEA). A MARKAL model is a bottom-up, technology-based dynamic linear programming (LP) model; however, MARKAL itself is not a model but rather a convention of how to name variables and parameters in a model and how to group them into sets for easy mathematical operations. The first MARKAL models were built at a country level and then extended to groups of countries bound by international trade. Recent modeling efforts are aimed at developing a global MARKAL-World. But MARKAL models also underwent downsizing toward regional, city, and community models. Also, several extensions were added to the original model formulation, such as elastic demands (Loulou and Lavigne 1996), links to the macroeconomy (Manne and Wene 1992), extensions with mixed integer and binary programming to model lumped investments (Fragnière 1995) and stochastic programming (Fragnière 1995; Fragnière and Haurie 1996), as well as linking with GIS (geographic information systems) (Fragnière et al. 1999). This contribution describes a new extension to include social parameters, hence the name social MARKAL. The outline of the residential lighting case study has been published in Fragnière et al. (2010).

In its standard form, MARKAL allows the modeler to find the least costly technology combinations that satisfy a specified level of demand for goods and services under certain constraints. In past decades, attention on global warming has raised a number of challenges and conferences, such as Kyoto or, more recently, Durban, and has led countries to review their environmental policies. Such new constraints can be well integrated into MARKAL models to help countries design new ways to respect their obligations. Specific interests on reducing costs and CO_2 emissions have already been addressed by Fragnière et al. (1999) and Turton and Barreto (2006). Even if MARKAL models take into consideration several external factors, so far, none of them have integrated end-user consumer's behavior as an important factor to determine energy efficiency, savings, and emission reduction. A report of the United Nations Environment Programme (UNEP 2008) has shown that more than 80% of total energy consumption takes place during the use of buildings (heating, cooking, cooling, etc.). This result highlights the importance of taking into consideration people's behavior toward their energy consumption. Rice and Paisley (1981) have defined energy conservation as the behavioral changes of using less energy.

Some authors focused on communication about energy conservation or consumption. Bottrill (2007) has shown that tools used to promote energy conservation lack the ability to give people advice to accurately monitor their energy use and provide them with meaningful feedback and guidance for modifying their energy consumption. Rydin et al. (2007) and Nye and Burgess (2008) outlined the importance of engaging root practice(s) and the context in which those practices take place to generalize changes and make them permanent. Other studies have shown that an increase in communication about environmental behavior in a family likely goes with an increase in environmental behavior (Hondo and Baba 2010).

Previous studies have discussed some specific action that affects energy consumption. Gyberg and Palm (2009) highlighted that people provide two motivations for changing their behavior: lower energy costs and a reduced impact on environment. Ouyang and Hokao (2009) studied the relationship between electricity consumption and household lifestyle. In their study's context, improving consumption behavior can save up to 10% of energy use. Weber et al. (2009) analyzed the influence of the consumer's information of their choice of one of six electricity pricing schemas in canton of Geneva, where tariffs depend upon the origin of the electricity. Finally, Räthzel and Uzzell (2009) found that individual behavior is the most important cause of environmental degradation through open-ended questions. Through these texts, one can see that energy-use behavior depends on our culture and on socioeconomic aspects and that information can play a role in providing wider awareness to citizens. This chapter aims to include such behavioral aspects into the MARKAL framework.

3 Methodology

In this section, we present the methodology we employed to integrate the results of sociological surveys into the MARKAL model. In general, results are only valid for one given technology but also only for the given region within a homogenous socioeconomic context and for the given point of time. These results are not transposable to other technologies or other groups of consumers with different ethnologic and social characteristics and may also evolve over time. It seems to be a good idea to foresee a repeated survey for every concerned technology and each point in time close to MARKAL periods.

A MARKAL model is a multi-period activity model. Typically, there are nine periods in 5-year steps. MARKAL equations are organized in order to represent a RES (reference energy system) that shows energy flows and relationships between energy carriers, technologies, and demands. A technology is equipment used to extract, transform, or consume energy carriers or to satisfy some useful demand. The activity of a technology in MARKAL comprises variables of investment, installed capacities, and operation levels, as well as emissions of a given technology. A technology takes energy as its input and produces energy or satisfies a demand on the output with attributes like efficiency, life, period of first availability, capacity factor, availability factor, and all cost (investment, operation, and maintenance) and emission coefficients. Emissions may be bound to technological activities, like CO_2, or to technical parameters of the technology, like NO_x, which depends on temperature of combustion. The

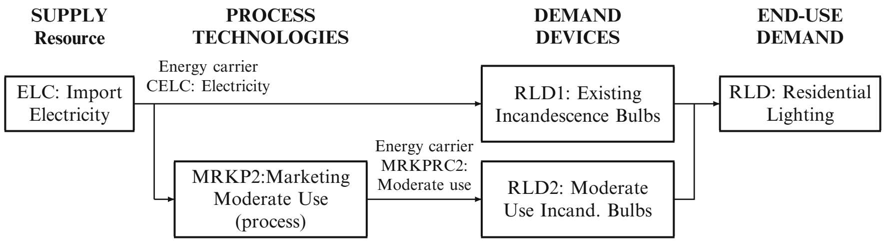

Fig. 1 A simple RES with one single useful demand and a virtual technology: moderate use

constraints are an important part of the model as they represent the energy system organization, energy balances, capacity transfer processes, demand to be satisfied, scarcity of resources, and emission limits. The objective function is the total sum of discounted contributions for each period for all system costs, including the investment, operation, and maintenance cost of technologies and energy carriers. Salvage values of the installed equipment at the end of the programming period must also to be added to the objective function. At the beginning of the optimization period, residual already-installed equipment is also taken into account. The mathematical exercise is to find a configuration of technology activities that give the minimum cost in the objective function. Thus, the result of a MARKAL optimization run is the vector of activities of all of the technologies. Some technologies that cost less will penetrate into optimal solution and have nonzero activities; others will be left out with zero results.

The innovation of our approach stems from considering behavior a virtual technology that formally has the attributes of a "real" MARKAL technology and whose activities can be quantified. It is transforming energy input into energy output (savings), costs money (investment), and may even produce emissions.

The following examples are taken from the light bulbs case, but the schema may be applied in general. We may encounter the following cases displayed on a RES:

1. The case of the information campaign in favor of moderate use. In this case, we have at least one real technology and at least one virtual technology to assess moderate use due to an information campaign. Here, a real technology, incandescence light bulbs, is in competition with energy savings triggered by behavioral changes (Fig. 1).
2. Information campaign supporting the technology switch to improve technical attributes of the installed technology mix. This case is defined as follows: at least two real technologies that are in competition (incandescence bulbs and low-consumption bulbs) and at least one virtual technology that, in addition to "classical" MARKAL competition based on least cost, is forcing the technology switch through an information and marketing campaign (Fig. 2).
3. Information campaigns both in favor of energy savings through moderate use and a technology switch with at least two real technologies in a "classical" MARKAL competition, completed by two virtual technologies based on infor-

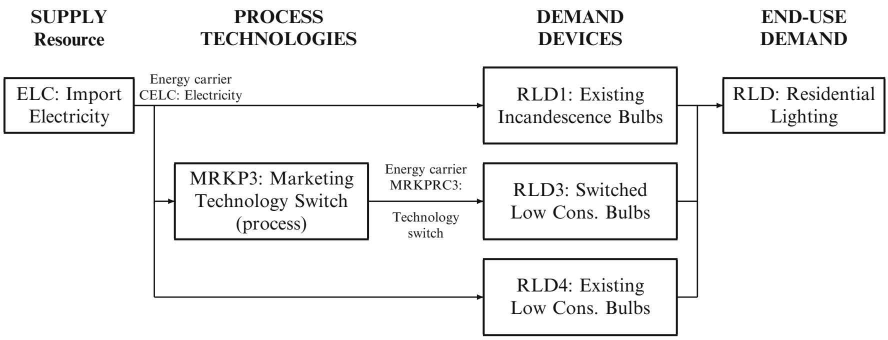

Fig. 2 A RES with two demand technologies and a virtual technology: technology switch triggered by information campaign

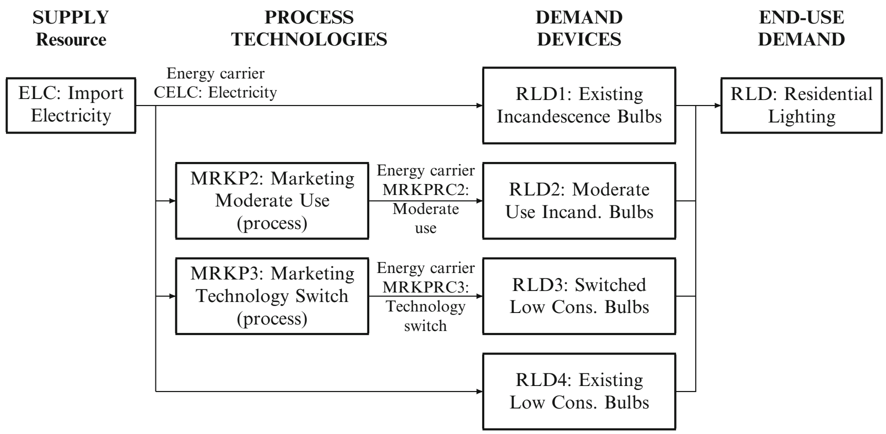

Fig. 3 A RES with two demand technologies and two virtual technologies linked to their respective information campaigns: moderate use and technology switch

mation and marketing campaigns—one in favor of moderate use of the technology and one to promote technology switch (Fig. 3).

This latter example is the original case of lighting bulbs, which is based on the municipal MARKAL model for the city of Nyon near Geneva. This is one of the simplest possible MARKAL models, because in Nyon, there are no extraction, conversion, or process technologies, so all the energy carriers are imported and directly consumed. In that way, it is possible to have a minimal, but still complete and self-contained, MARKAL model for just one end-use demand category, which is residential lighting. All other electricity demands are additive but can be modeled separately. The model is so simple that it can be easily programmed in any tool, including direct modeling in a mathematical programming language such as GAMS, AMPL, or OSEMOSYS. The construction of the model goes in the usual way from defining the useful demand through energy carriers to technologies. If working with an integrated tool like ANSWER, attention has to be given to define virtual energy carriers with correct dimension (TJ or PJ) and members of the energy carrier set ENC or high temperature heat or cooling set EHC before introducing virtual process technologies or to create a proper class of virtual information and marketing technologies. This will allow the modeler to escape the need to define too many parameters and avoid complicated accounting like with electricity.

Virtual process technologies MRKP2 and MRKP3, which transform electricity ELC into virtual energy carriers, have a nonzero investment cost, as determined by the technology mix needed to reach consumers. The approximate cost of different advertisement campaigns is known. This concerns advertisements on TV, radio, newspapers, public transportation, and individualized campaigns that use, for example, flyers, personalized letters, and information stands at selling points. The proportion of people who are most likely hit by one of these modes is measured by the survey. From these parameters, one can determine the investment cost needed to trigger the desired level of modification of people's behavior. It is, of course, possible to consider all these information vectors separately instead of as one aggregated information campaign. In that case, the model will choose the most cost-effective way to inform people. The virtual process technology of information and the marketing campaign itself does not produce energy savings. Instead, it produces a virtual energy carrier that can be called awareness or motivation for moderate use or for technology switch. Information campaigns trigger energy savings through moderate use or technology switch, if a sufficient amount of money has been invested into it. One cannot purchase half of a TV advertisement. This has to be a lumped investment and is modeled as a binary variable that is either chosen or not. The virtual technology (energy savings or technology switch) whose effects are triggered by the information campaign is directly acting on the energy consumption. It has no investment cost but might have a shorter lifespan. That way, it is possible to model the fading-away effect of an information campaign, a phenomenon known as the rebound effect.

In order to compute the technical coefficients for MARKAL virtual technologies—the yields of virtual technologies—we used the results of a survey conducted in the Geneva area between October and December 2009. The fundamental idea is to measure the following:

1. The proportion of people who are well informed and behave according to economic rationality.
2. The proportion of people who do not behave rationally, but if hit by an information/marketing campaign, they may be willing to change their attitude and start behaving rationally. The above two parameters are not defined by one single question but rather as a result of cross-analysis of several questions. The most important parameters are the values of energy output for one unit of input denoted OUT(ENT)p.
3. People who cannot be influenced by information campaigns will optimize their usefulness based on criteria other than economic criteria, and only an administra-

Table 1 Yields of virtual process technologies representing information campaigns

Energy carrier	Energy output OUT(ENT)p	Determined from
MRKPRC2	0.246	Q15, answer 2 (information campaign)
MRKPRC3	0.442	Cross-analysis of Q13/Q14

tive ban on the concerned technology will prevent them from continuing to using it. This parameter can be modeled as a bound whose value can be obtained directly from a question in the survey.

The following Table 1 denotes the values and how they were found:

Q13: Did you know that a household that changes half of its incandescent bulbs with low-consumption bulbs can save approximately 200 Frs per year? (yes, no)

Q14: With this information, would you change at least a half of your bulbs? (yes, no, yes I did it already)

Q15: Your electricity consumption could change the following: (2 possible answers)

- Opinion of a close person (neighbor, relative, colleague)
- An information campaign in the media, advertisements
- A request from your children
- A modification of your revenue
- An important electricity price increase
- Nothing would change my behavior.

The model has to be completed by a set of reasonable constraints and bounds. For example, the capacity of the new technology (in our case, low-consumption bulbs) should be bound at least to its residual level at the beginning of the programming period; otherwise, it might be completely phased out under certain conditions (depending on input values) as a result of optimization. The incompressible ratio of people who will never buy low-consumption bulbs unless the old incandescent bulbs are administratively banned is, in our case, fixed to 9.9% (proportion of "no" answer to Question 12 in survey 2009: If you were better informed about advantages of low-consumption bulbs, would you be ready to completely abandon the incandescence bulbs?, yes, no). The constraints in the model should also include a limit for the number of incandescent bulbs switched off that should not exceed the number of installed incandescent bulbs in each period because one cannot switch off bulbs that do not exist. In a similar way, for the technology switch, the number of switched bulbs has to be lower or at most equal to the number of old incandescent bulbs for each period. Similar or other bounds and constraints have to be considered for each specific case.

Sensitivity analysis shows the behavior of the model. If the cost of the information and marketing campaigns is too high, we fall into a case of "classical" MARKAL competition of technologies. Only the cheaper technology will enter the optimal solution; however, bounds we introduced will prevent the bang-bang effect, where all the nonoptimal bulbs would completely disappear. With the investment cost of virtual process technologies becoming lower, one or the other (or even both) virtual technologies will become part of the optimal solution. Again, bounds and constraints will prevent the model from behaving illogically, like replacing all of the lighting through energy savings without real bulbs or by unlimited switching. If the cost of the information campaign is low enough, virtual technologies will appear at the beginning and remain present until the end of the modeling period. Attention has to be given to reasonable values of all the parameters, especially when adding multiple virtual technologies. Working with real numbers for an existing MARKAL model and real results of a survey, like in the present chapter, helps to create a realistic picture and shows the importance of well-defined constraints and bounds.

4 Case Studies

In this section, we will present a recent survey that we developed at the Geneva School of Business Administration (Haute École de Gestion de Genève HEG-GE) to illustrate how these behavioral data were originally collected. The school was created in 2006 as a laboratory for market research (LEM, Laboratoire d'Études de Marché) whose main objective is to form students to marketing survey techniques. These studies have been specifically conducted on energy consumption behavior using complementary methods: qualitative and quantitative sociological survey and an ethnomethodology survey. For the recent studies, we present a concise resume of first findings, and a more thorough exploration of results will follow.

A qualitative part is conducted to understand consumer behaviors regarding energy consumption. The research started with a literature review, which helped us build a qualitative interview schedule of seven questions that address the perceptions, attitudes, information, and behavior of the consumers. We submitted those questions to people living in the Geneva area through semi-directive interviews during the months of October and November 2011. The semi-directive interview technique consists of open-ended questions that give the interviewee the opportunity to talk and give his/her point of view, submit his/her habits, reflect on his/her behaviors, etc. The objective was to obtain in-depth findings about consumer behavior from their perspective. We collected 24 interviews, of which 13 rented and 11 were home owners. Hypotheses were built from a synthesis after collecting all data. The main findings of this first part are two relations of energy advertisement and media devices such as TV, PCs, and smartphones. The first one tended to show a need for consumers to be taught how they can act on their consumption. For maximum impact, instead of being general and abstract, a successful energy advertising campaign should target everyday life situations and behaviors. The second hypothesis was that people use media devices primarily for information or entertainment.

After constructing these hypotheses, they were then tested in the quantitative part of our survey. It resulted in a 21-question questionnaire, including seven ethnology questions for statistical purposes such as age, sex, occupation, and house tenants or owners. The size of the sample was 495 questionnaires collected during the month of

December 2011. In addition to the questions regarding the two hypotheses mentioned, we questioned people on their consumption habits of water, heating, and lighting, impact of an increase in prices for their consumption, elements that influence their attitude toward energy, and, finally, their knowledge of energy production sources. The first three questions asked people what action they take to save water, heating, and electricity. Results show that for water, around two third of respondents said that they close the tap while brushing their teeth, and approximately the same percentage say they prefer to take a shower rather than a bath. The use of a washing machine (both for dishes and clothes) was mentioned by approximately 35% of respondents. Only 5% of respondents admit they have no particular reflex to save water. An interesting result is that 23% of respondents say they have no particular reflex to save heat. Concerning electricity, 79% of people interviewed said they turn lights off when leaving a room. Forty-three percent of people say they use low-consumption bulbs. Only 5% of respondents say they have no particular reflex to save electricity. Those first results seem to confirm that people pay more attention to their energy consumption when it is visible, which was hypothesized in another ethnomethodologic survey conducted between January and March 2011.

As most incentives focus on price, we were willing to know how people would react to doubling energy prices. Fifteen percent of asked people say it is not very probable that this would affect their behavior, while 5% firmly claim they would not change anything. The other 80% of consumers would probably, or very probably, adjust their behavior to reflect the change in price.

We also wanted to identify the major factors that direct people's behavior toward energy consumption. The most represented group, 40% of respondents, claims to find source in their personal values, and 24% of people mention the parental education. The link of parental education and a lifelong habit to turn off the lights was already examined thanks to an earlier survey conducted in 2009 that also served to determine MARKAL technical coefficients. The questions were as follows:

Q3: Do you turn off lights systematically when you leave a room? (yes, no)
Q5: Did your parents used to ask you to turn off lights when leaving a room? (yes, no, don't know).

To explore this relationship, we constructed the following hypothesis H_0: There is no relationship between turning off lights systematically after leaving a room and parental education to turn off lights. The values of chi-square for the two questions were 71 and 422, respectively, with an asymptotic significance of 0.000, which means that H_0 can be rejected with alpha risk zero. Thus, one can conclude that there is a statistically significant relationship between parental education to turn off lights and the behavior turning lights off when leaving a room.

Following the controversy on security concerns of nuclear energy and the political steps to abandon it, we were interested in to what extent people know about the source of electricity they consume. In Switzerland, 40% of electricity is of nuclear origin. Many of the advertisements made by energy providers (Services Industriels de Genève and Romande Energie) mention the source of the tariff plans they offer, but only 26% of respondents say they know their electricity pro-

Table 2 In your opinion, what is the most efficient advertisement vector to make people aware of their electricity consumption?

	N	%	valid %
Television	335	67.7	67.8
Internet	27	5.5	5.5
Radio	18	3.6	3.6
Advertisement of energy providers	82	16.6	16.6
Advertisement in public transportation	11	2.2	2.2
Other	21	4.2	4.3
Total valid answers	494	99.8	100.0
Missing answer	1	0.2	
Total	495	100.0	

duction source. Among people who say they do not know, 66% say they would like to know how their electricity is produced. This shows an interest, but people have not been able to find, absorb, and assimilate the information despite many possibilities to access it.

We were particularly interested in working on two hypotheses. The first one consisted of saying that a better targeted advertisement would result in a more effective impact on consumer consumption. In the quantitative questionnaire, we introduced the following question: “In your opinion, what is the most efficient advertisement vector to make people sensible to their electricity consumption?” Sixty-eight percent of respondents said that television is the best way to inform people. Far behind, 17% thought that advertisements by energy providers are a good vector of information. Even if there were only few people who consider Internet an efficient channel, we saw a slight evolution through age categories, as younger people tend to pay more attention to it (Table 2).

The very low score of advertisement in public transportation can be surprising in the Geneva area, as the SIG (Services Industriels de Genève, local energy provider) regularly uses advertising campaigns in buses and in tramways. In the category “others,” most people discussed education during their childhood.

The second hypothesis assumed that people turn on media devices only when they need to use them. To test this, we had one question: “For what reasons do you turn on the television?” Seventy-two percent of interviewed people said that it is for distraction and 56%, for information. Only 10% of people turn their TV on just to not feel lonely and a further 9% as an everyday stereotype. Among the 7% of “other” responses, most do not have a television or do not watch it (Table 3).

This result confirms the hypothesis found using the qualitative method: Most people turn on their television when they really want to watch it and pay attention to what is on. As shown in the previous section, this set of behavioral data is then modeled as a virtual technology to be included in the MARKAL model.

Table 3 For what reasons do you turn on the television? (max. 2 answers)

	Answers *N*	Percentage of answers (%)	Percentage of observations (%)
Need for information	275	35.3	55.6
Distraction (movies, series, variety shows, etc.)	356	45.7	71.9
Need of company, simulator of presence	48	6.2	9.7
I turn it on without thinking about, like an everyday stereotype	44	5.6	8.9
To keep children busy	20	2.6	4.0
Other	36	4.6	7.3
Total	779	100.0	157.4

5 Conclusion

Until now, policies made based on energy optimization models were hit by a systematic error on the demand side, as they were overoptimistic when it comes to the use of demand-side management (DSM) measures. The hypotheses of the perfect information and of perfect economic rationality are not well satisfied with a huge number of actors making frequent decisions concerning small amounts. This concerns the purchase of efficient technologies and the way people use the technologies.

In this chapter, we have shown one possible way to quantify these phenomena while improving the model accuracy using virtual process technologies in a MARKAL modeling framework that brings parameters of technology and parameters of behavior to the same platform. The approach is fully compatible with already-developed and existing tools and can be optionally included in any MARKAL/TIMES model that emphasizes the demand side.

Another desired application of this research is to extend the concept from lighting bulbs to passenger cars and the transportation sector. Choice, acquisition, and the use of passenger cars as an alternative to public transportation are a domain of exciting modeling challenges. Ultimately, a complete behavioral database will be employed to develop consistent long-term energy environmental scenarios involving technological progress and social change.

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Supply Chain Evolution for Sustainability-Focused Firms: Content Analysis towards Socially and Environmentally Friendliness

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Abstract The objective of this research was to understand how the organizational structure of sustainability-focused companies changes over time as the companies become more environmentally, economically, and socially sustainable. We applied trend analysis to the sustainability Scores, and vertical integration level of the companies. Our sample consisted of ten sustainability-focused companies from the industrials industry. We used the content analysis of annual reports to calculate sustainability development scores and applied the Fan and Lang's method to determine the vertical integration level of the companies. The study results demonstrated an increasing trend in both vertical integration and sustainability development of industrials industry companies over a 15-year of period. Furthermore, the companies became more vertically integrated as their environmental, economical, and social sustainability increased.

Keywords Sustainable development • Sustainability • Vertical integration • Trend analysis • Content analysis of annual reports • Spearman correlation

1 Introduction

Developing environmental management strategies affects the whole community as well as the earth's ecology. Employees, environmental activists, communities, and non-governmental organizations are increasingly applying pressure to companies to consider sustainability principles as they manage the material and information flows along their supply chains. As discussed in (Ozcan and Reeves 2011b), the natural resource-based view and natural transaction cost economics literature state that

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_7,

sustainability-focused companies (SFCs) tend to be more vertically integrated. Additionally, the results of the previous parts of the study illustrate that, especially in production related industries, SFCs have a more vertically integrated organizational structure than their non-sustainable counterparts (Ozcan and Reeves 2011a).

After the report of the World Commission on Economic Development (WCED 1987), the term sustainability became very popular since the report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 43). The commitment of companies to sustainable management increasingly changes over time. Even consumers are making sustainability-focused decisions when they purchase vehicles and decline plastic bags at supermarkets. According to a recent Deloitte survey of more than 1,000 business travelers in April 2008, 95% of respondents thought that lodging companies should be undertaking green initiatives. Institutional theory states that in modern societies, many programs and policies are enforced by public opinion, knowledge, social prestige, and laws (Meyer and Rowan 1977).

As stated in natural resource-based theory, environmental management is a strategic resource that can produce a competitive advantage and progress towards more sustainable production (Hart 1995; Menguc and Ozanne 2005). The natural resources that contribute to the competitive advantage are assumed to be difficult to replicate because they are rare and/or specific to a given firm (Barney 1991; Reed and Defillippi 1990), tacit (causally ambiguous), or socially complex (Teece 1982; Winter 1987).

Additionally, according to the literature, superior environmental performance leads to better industry performance (Porter and Van der Linde 1995; Rosen 2001; Russo and Fouts 1997). Analyzing *Fortune Magazine*'s ratings of corporate reputations, McGuire et al. (1988) stated that social responsibility positively affects financial performance. According to Klassen and McLaughlin (1996), environmental management is an important dimension of firm management and operations strategies, and strong environmental performance increases the value of companies. The results of Feldman et al. (1996) showed that firms increase their financial market value if they make environmental investments that go beyond strict regulatory compliance.

There are limited numbers of studies that discuss the evolution of sustainability-focused strategies. Different from previous studies in the literature, we examined the evolution of sustainability-focused strategies and compared this evolution with the vertical integration of companies over the same period of time. Content analysis (Weber 1985) was used to evaluate the annual reports of the firms. Institutional theory examines how social choices are shaped, mediated, and channeled by the institutional environment. This study offers contributions to institutional theory and the relationship between organizations and environmental strategies. Moreover, our research seeks to make a contribution by building a framework for understanding how organizational structures and corporate environmental strategies coevolve. Longitudinal analysis empirically measured changes in the organizational structure of a firm in correlation with the evolution of its corporate environmental strategy.

The rest of this study is organized as follows: Sect. 2 provides a comprehensive literature review of vertical integration, environmental management strategy evolution, and sustainable development types. In Sect. 3, after documenting the sample and data sources, we employ our vertical integration measurement and content analysis. Section 4 presents the results of the analysis and discusses possible explanations for the results, and finally, Sect. 5 concludes the study results.

2 Literature on Vertical and Environmental Evolution

There are several studies in the literature that analyze trends in the vertical integration level of companies. Adelman (1955), Laffer (1969), Nelson (1963), and Tucker and Wilder (1977) found that the vertical integration level of companies remained about the same or indicated little variation over the decades. On the other hand, Maddigan (1981) discovered an upward trend in the index that is contrary to results of value added over sales method and its variations. Fan and Lang (2000) examined the relatedness patterns of US firms between 1979 and 1997 and reported an increasing trend in the vertical integration level of firms over time. Hutzschenreuter and Gröne (2009) assessed the influence of foreign competition on vertical integration strategies of US and German companies using a longitudinal study. Our study adds a different dimension to the literature which analyzes trends of vertical integration of companies.

Additionally, the environmental management literature presents studies that focus on the evolution of sustainability-focused strategies of companies using longitudinal analysis. For example, Hoffman (1999) empirically analyzed the changes in the constituency of an organizational field and correlated those changes with the traditions adopted by the US chemical industry from 1960 through 1993. Bansal (2005) explored the impact of resource-based and institutional factors on corporate sustainable development in Canadian firms that operate in the oil and gas, mining, and forestry industries from 1986 to 1995. Bansal (2005) used time-series cross-sectional data techniques to analyze company annual reports and interview industry members. Lee and Rhee (2007) explored the change in sustainability-focused strategies based on the resource-based view and institutional theory utilizing a longitudinal-empirical analysis and conducting mail surveys in South Korea in 2001 and 2004. This study contributes to the literature with investigating relationship of vertical integration and sustainable development using longitudinal analysis.

Ingram and Frazier (1980) investigated whether a high degree of correlation should exist between these indices and the content of their disclosures when firms' environmental disclosures are reflective of their environmental activities. According to the content analysis of Carlson et al. (1993), environmental advertising claims, which present the environmental benefits of products and the environmental image of an organization, may cause confusion and inconsistencies. Jose and Lee (2007) investigated the environmental management policies and practices of the Fortune's Global 200 largest corporations using a content analysis of the environmental reports. Jose and Lee (2007) stated that 52 companies lacked the needed information on their websites. Additionally, seven companies did not have information in English. Moreover, voluntary dissemination of corporate environmental information is more common in Western European countries and Japan than in the United States. In a similar study, Gill et al. (2008) conducted web content analysis to examine the economic, social, and environmental disclosures in Europe, North America, and Asia oil and gas firms. They found that firms should completely disclose their information to effectively manage their relationships with their key stakeholders. In their case study research, Cruz and Boehe (2008) conducted interviews with the members of a global value chain and analyzed these interviews with content analysis. They concluded that managers need to be aware of corporate social responsibility strategies, and awareness building may influence the competitiveness of their sustainable value chain. The contribution of this study to literature is conducting content analysis to the annual reports over a 15-year of period.

The report of the World Commission on Economic Development (WCED 1987) stated that sustainable development required the simultaneous adoption of social, economic, and environmental principles. According to the triple bottom-line approach (Elkington 2002; Foran et al. 2005), if any one of the principles is not supported, development cannot be accepted as sustainable. Although eco-efficiency is a very important part of corporate strategies, it is not sufficient (Welford 1997). Dyllick and Hockerts (2002) have framed the three dimensions and defined sustainability as

> …meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities etc.), without compromising its ability to meet the needs of future stakeholders as well. Towards this goal, firms have to maintain and grow their economic, social and environmental capital base while actively contributing to sustainability in the political domain. From this definition, three key elements of corporate sustainability can be identified: Integrating the economic, ecological and social aspects in a 'triple-bottom line.' (p. 131)

In our study, we accepted economic, social, and environmental sustainability as three dimensions together. Therefore, we will accept a company as a sustainable company when it matches the societal expectations, does not engage in an activity that degrades the ecosystem, and ensures liquidity while producing a persistent above-average return to their shareholders.

3 Research Methodology

3.1 Sample

In our previous study (Ozcan and Reeves 2011b), we showed that in production-oriented industries, especially in medical devices and industrials industries, sustainability-focused companies (SFCs) have more vertically integrated organization structure than their non-sustainable competitors in the same industries. In this part of the research, we will focus on only one industry because industry type is one of the main effects that impact the vertical integration level of the companies (Fan and Goyal 2006; Lindstrom and Rozell 1993). Selecting companies that are specifically focused in one industry also avoids the problems associated with measuring firms that are operating in vastly different industries in accordance with the methodology of Lindstrom and Rozell (1993).

The companies that operate in the industrials industry were drawn from the union of three sets. These companies integrate long-term economic, environmental, and social aspects into their business strategies. The first set is the "Dow Jones Sustainability United States Index" and consists of 14 US industrials industry firms. This index is reviewed with a questionnaire annually to ensure that it represents the leading sustainable companies. This index also utilizes information from the company's documents, such as sustainability, environmental, social, financial, and health-safety reports. Appendix A presents the set of criteria and weightings that used to assess the economic, environmental, and social aspects of the companies. The second set is "The Global 100 Most Sustainable Corporations" list which has been compiled by the *Corporate Knights* magazine since 2005. After eliminating overlaps, we obtained seven industrials industry companies by combining the 2005–2009 lists. The annual list of Global 100 is announced each year during the World Economic Forum in Davos. The performance indicators that are developed by Corporate Knights Research Group are given in Appendix B. The third set, "SB20: The World's Top Sustainable Business Stocks," has been created by Progressive Investor for 6 years. We eliminated the overlapping companies and obtained seven sustainable industrials businesses in the combined list. The newsletter works with a group of judges, who are stock analysts, to select, nominate, and discuss companies. The criteria for the list are not announced in detail; however, they are accumulated under two main categories: environmental and financial criteria. Companies should make announcements and progress in meeting objectives, have advanced green technologies, and lead society to a sustainable future. Financial criteria evaluate the profitability of the companies and expect strong management skills and balance sheet.

We compiled our sample from US companies. There are two main reasons: first, we eliminated the country effect (Acemoglu 2009) on vertical integration; second, we used only the input-output tables for the USA. Since all three lists have similar criteria, we combined these lists and finally got 15 companies (see Appendix C). However, information for some companies is not available in our databases. We assume that the companies that are listed in these sets are successful in pursuing and/or monitoring sustainability activities.

Similar to the studies of Tolbert and Zucker (1983) and Bansal (2005), we used 4 years of data to evaluate the changes in corporate social development. Since we use the I–O Tables of Bureau Economic Analysis to measure the vertical integration level, we examined the corresponding annual reports of sustainable industrials industry companies in the years of 1987, 1992, 1997, and 2002. Benchmark I–O tables are prepared at 5-year intervals which provide an extensive accounting of the production of goods and services by industry and commodity, the income earned in each industry, and the distribution of sales for each good and service to industries and final users such as consumers, businesses, governments, and foreigners. We started from the year 1987 as the sustainability being started popularized after the report of WCED (1987). The latest available I–O table was published in 2002; 2007 tables will be available in 2012.

Since we used the annual reports as the source of content analysis, publicly traded companies were selected for our sample. The final sample includes ten industrials industry SFCs that have annual reports in 1987, 1992, 1997, and 2002. The average firm age in 2011 was 90 years; the oldest company is 112 years old. The average firm size in 2011 was $35.5 billion dollar in assets, and the largest one has $68.5 billion in assets. The average employee size is 97,000, and the largest one has 208,000 employees. The procedures described in the next section provide a systematic method for quantifying the content of firms' annual reports.

3.2 Data Analysis

The vertical integration level of SFCs was measured at intervals over the 15 years to observe any historical changes using the Fan and Lang (2000) method. We selected 10 SFCs and observed their organizational structure change as their environmental, economical, and social performance improved. For examining the evolution of sustainability of companies, we performed a content analysis of company annual reports. The annual reports are available through the company websites and Mergent Online and LexisNexis databases. The sustainability reports will be used for the cross control of sustainability practices which were obtained from the companies' websites and databases.

The use of annual reports was criticized by some scholars. For example, the content analysis study of Ingram and Frazier (1980) revealed that annual reports may be inconsistent. Their study found that annual reports of the poorer environmental performers contained more environmental disclosures than the better performers. Bowman and Haire (1975) noted that the annual report is addressed to stockholders, and this fact may cause inconsistent disclosures. As a further example, although Bowman and Haire (1975) found a positive relation between emphasis on corporate social responsibility in annual reports and the Moskowitz ratings (Moskowitz 1972), Preston (1978) could not find an association.

To avoid this inconsistency, in addition to annual reports, we analyzed the content of 2005 sustainability reports to make sure that the SFCs accomplished what they previously mentioned in their annual reports. We searched for each code in the 2005 sustainability reports of the companies. If they did not have related performance metrics or disclosure, we did not include these codes for these companies. Moreover, according to another critic, annual reports may provide incomplete information (McGuire et al. 1988). Using the annual reports of the public companies, we assume that the SEC regulations discourage companies from disclosing incomplete information.

In spite of these critiques about annual reports, several scholars used them to obtain longitudinal data (Miller and Friesen 1984; Pettus 2001). As stated in Ginsberg (1988) and Huff (1982), annual reports and other corporate documents are useful sources to study strategic change. As stated in Barr et al. (1992, p. 21), "while statements in annual reports may not precisely mirror the time period of a change, over long periods the exact timing of change is less important than overall patterns of change". Miller and Friesen (1980, p. 272) asserted that "the only way to perform longitudinal research on many organizations is through detailed, published reports containing continuous history." Finally, Bansal (2005, p. 207) pointed out, "annual reports are unobtrusive, so that firms cannot engage in research-specific posturing as they can with interviews or surveys." Therefore, we used annual reports as a source of data for measuring the change in variables.

The content analysis method was conducted on annual reports to scrutinize content and characterize the environmental strategies. In our research, we mainly utilized the coding list of the study of Bansal (2005). The items of the analysis are grounded in theory and relevant to the firms in the sample. Bansal used a three-step approach to generate this list. In the first step, she defined sustainable development using the academic- and practitioner-oriented literature. In the second step, Bansal interviewed practitioners and reviewed the annual reports to generate a comprehensive list of items that define sustainability from a social, economics, and environmental perspective. Finally, the reliability of items, representing all three dimensions of sustainable development, was tested by a group of researchers. In addition to Bansal's codes, we utilized the criteria of Dow Jones Sustainability and Global 100 Most Sustainable Corporations indices since we compiled our sample from these indices. We discussed the final set of codes with industry and academic experts, who are specialized in sustainable development. The final set of codes that was used in content analysis was given in Table 1.

As a result of the content analysis of annual reports, the coder calculated a final "sustainable development score" for each company for the years 1987, 1992, 1997, and 2002. Following the method of Bansal (2005), each item was coded as "0" or "1," where "0" represents no observance of the item and "1" represents the observance the item. Two main criteria were taken into consideration. The first criterion was set to avoid the criticism of inconsistency and unreliability in annual reports. For a company to have a score greater than zero for an item, this item must be mentioned in the sustainability report of 2005. Second, since the accomplishment of sustainable development requires the integration of its social, economic, and environmental components, a firm must have at least one item reported in each category.

While determining the final "sustainable development score" for each company, the number of observed items in each component was divided by the total number of possible items in this category. For example, if the coder observed 6 items out of 9 "environmental sustainability" category items, 3 items out of 7 "economical sustainability" category items, and 4 items out of 8 "social sustainability" category items, then the company's sustainable development score (SDS) would be $(6/9+3/7+4/8)$. Therefore, a company's SDS score can be between 0 and 3.

Table 1 Codes Used as the Source of Content Analysis

Environmental Sustainability
1. Manufactured products that have a less environmentally harmful impact than in previous years or than its competitors
2. Manufactured products with less environmentally damaging or replenished inputs than in previous years or than its competitors
3. Reduced environmental impacts of production processes or eliminated environmentally damaging processes
4. In environmentally important places, eliminating and reducing operations
5. Continuous process improvement to improve environmental performance
6. Reduced waste by streamlining processes
7. Usage of waste as inputs for own processes
8. Responsible waste disposal
9. Responsible Handled or stored toxic (hazard) waste responsibly
Economical Sustainability
1. Worked with government officials to protect the company's interests
2. Reduced costs of inputs for same level of outputs
3. Reduced costs for waste management for same level of outputs
4. Differentiated the process or product based on the marketing efforts of the process/product's environmental performance
5. Sold waste product for revenue
6. Created spin-off technologies that could be profitably applied to other areas of the business
7. Have risk and crisis management strategies[a]
Social Sustainability
1. Considered interests of stakeholders in investment decisions by creating a formal dialogue
2. Communicated the firm's environmental impacts and risks to the general public
3. Improved employee or community health and safety
4. Protected claims and rights of local community
5. Showed concern for the visual aspects of the firm's facilities and operations
6. Recognized and acted on the need to fund local community initiatives
7. Existence of women on the Board of Directors[b]
8. Transparency at disclosing a specific data point (total employee compensation, total CO2e, total waste, total water, or total energy)[b]

Note: These codes of content analysis were adopted from Bansal (2005)
[a]Dow Jones Sustainability Index
[b]Global 100 Most Sustainable Corporations Index

Manual content analysis was conducted; however, manual coding to assess the presence of an issue has been criticized. Potter and Levine-Donnerstein (1999) pointed out that coder fatigue and the misapplication of coding rules are the primary threats to reliability. If coders have very different schema, there can be very little consistency in coding (Folger et al. 1984). To prevent low consistency, keeping coders free of fatigue, providing them with excellent training on a detailed and extensive set of coding rules, and using the same schema is suggested (Potter and Levine-Donnerstein 1999). Analyzing the same subset of the sample with a pair of coders is a typical inter-coder reliability test in content analysis methodology (For example, see King (1995) and Bansal (2005)).

The typical inter-coder reliability in content analysis methodology is to have a pair of coders analyze the same subset of the sample (Potter and Levine-Donnerstein 1999). Inter-coder reliability tests whether two raters looking at the same occurrence give consistent ratings. In order to test the degree of consistency in decision making of coders, the second coder made judgments on 18 randomly selected annual reports. The first and second coders used in the study are PhD students who are specialized in sustainable supply chains. Cohen's kappa was used as a statistical measure of inter-coder reliability. The result of Cohen's Kappa test ranges from −1.0 to 1.0, where values close to 1 mean good reliability, values near zero indicate poor agreement, and values less than zero signify that agreement is even less than that which could be attributed to chance.

4 Results

Data were extracted from the annual reports in target years for each company by a single rater. The example phrases, which were observed in the reports, can be found in Table 2. Additionally, the 18 annual reports were coded by a second rater who is also specialized in sustainable supply chains. The codes were compared, and inter-rater reliability was measured with Cohen's Kappa as 0.81, which

Table 2 The Example Phrases Obtained from the Reports that Illustrate the Existence of Category Items

Environmental Sustainability
"The Company is subject to federal and state requirements for protection of the environment, including those for discharge of hazardous materials and remediation of contaminated sites"
"60 percent of our forests in Canada were certified as meeting the Canadian Standards Association's (CSA) Sustainable Forest Management Standard"
"Capital expenditures for environmental purposes have included pollution control devices—such as wastewater treatment plants, ground-water monitoring devices, air strippers or separators, and incinerators—at new and existing facilities constructed or upgraded in the normal course of business"
Economical Sustainability
"The Company has an agreement with the U.S. Government with respect to certain of the Company pension plans"
"We participate in source reduction and waste management through storage and collection of recyclables"
"Our company sells the waste paper and plastics for the revenue"
Social Sustainability
"Our company is working to improve water quality and its efficient use while preventing corrosion and helping customers meet environmental goals"
"We are building local relationships, coordinating local business activities and developing strategies that create greater value and opportunities for the enterprise"
"We are striving to incorporate safety concerns into the design of every manufacturing process and the organization of every workplace"

Table 3 Trend Analysis of Vertical Integration and Sustainable Development

	Pooled	1987	1992	1997	2002	ANOVA *F* value
(*n*)	40	10	10	10	10	–
Vertical Integration						
Mean	0.0137	0.0025	0.0039	0.0134	0.0352	7.13*
Stand. Dev.	0.03	0.00	0.01	0.01	0.05	
Range	0–0.1781	0–0.0148	0–0.0291	0–0.0401	0–0.1781	
Sustainable Development						
Pooled						
Mean	1.81	0.98	1.70	2.15	2.39	47.47*
Stand. Dev.	0.72	0.75	0.38	0.22	0.41	
Range	0–3.00	0–2.01	1.23–2.51	1.89–2.51	1.86–3.00	
Environmental Sustainability						
Mean	0.65	0.38	0.60	0.77	0.84	7.62*
Stand. Dev.	0.23	0.18	0.15	0.12	0.14	
Range	0–1.00	0–0.67	0.44–0.89	0.56–0.89	0.56–1.00	
Economical Sustainability						
Mean	0.59	0.44	0.51	0.70	0.69	15.43*
Stand. Dev.	0.19	0.17	0.17	0.11	0.20	
Range	0.29–1.00	0.29–0.71	0.29–0.86	0.57–0.86	0.43–1.00	
Social Sustainability						
Mean	0.63	0.39	0.59	0.69	0.86	35.07*
Stand. Dev.	0.25	0.26	0.16	0.15	0.14	
Range	0–1.00	0–0.75	0.38–0.86	0.38–0.88	0.63–1.00	

*$p < 0.001$

satisfies the investigators. In order to preserve consistency, only the codes from the primary coder were used.

Additionally, we examined the trend in sustainability development and vertical integration using ANOVA trend analysis. Table 3 shows the descriptive statistics and ANOVA F value for sustainable development scores for each of the sustainable development principles and vertical integration levels from 1987 to 2002. According to trend analysis, we observed that the total sustainability scores of the companies are significantly different in each panel year and increasing trend over the time period ($F = 47.47$; $p < 0.001$).

Table 3 also shows with an increasing trend in each principle of sustainability: environmental ($F = 7.62$; $p < 0.001$), economical ($F = 15.43$; $p < 0.001$), and social ($F = 35.07$; $p < 0.001$) sustainability. Moreover, we determined a significant difference in each panel year and increasing trend in the vertical integration level of the companies ($F = 15.43$; $p < 0.001$).

Spearman's rank correlation coefficient was used to identify the strength of correlation between the data set of vertical integration and sustainability development score of each company whether the correlation is positive or negative. Spearman's correlation test can be used for very small samples, in other words, when the normality

Table 4 The Change in Vertical Integration and Sustainable Development

	1987	1992 VI/SDS	1997 VI/SDS	2002 VI/SDS	R_S	*p* value
Company 1	First year	±	+/+	+/+	0.80	0.015
Company 2		+/+	+/+	+/–	0.80	0.02
Company 3		±	+/+	–/+	0.60	0.40
Company 4		±	+/+	–/+	0.60	0.194
Company 5		+/0	+/0	+/+	0.78	0.02
Company 6		+/+	+/+	+/–	0.40	0.60
Company 7		±	+/0	+/+	0.32	0.68
Company 8		+/+	+/+	+/+	1	<0.0001
Company 9		+/+	–/+	+/+	0.80	0.02
Company 10		±	+/+	–/–	0.60	0.40
Mean		+/+	+/+	+/+	1	<0.0001

assumptions for that measure cannot be assumed. In his seminal paper (Spearman 1904), he examined the hearing and seeing ability of five individuals. The measure of correlation as given by Spearman (1904) is usually designated by R_S. This part of our research examined how the organization structure of SFCs changes over time as the companies become more socially and environmentally aware.

In Ozcan and Reeves (2011b), we observed that the companies in industrials industry tend to be more vertically integrated compared to their non-sustainable competitors. Since we selected our sample from sustainable company lists and the sustainability concept has been popularized starting from 1987, we were expecting an increasing trend in the sustainable development of these companies from 1987 to 1992. Therefore, we would like to know if there is a tendency for high vertical integration level (VIL) to be associated with high sustainability development scores (SDS).

Then the null hypothesis is

H_0 = There is no monotonic relationship between VILs and SDS scores,
and the alternative hypothesis of interest is
H_1 = There is a monotonic relationship between VILs and SDS scores.

Table 4 provides the increases and decreases in vertical integration (VI) and sustainability development score (SDS), Spearman correlation coefficient (R_S), and p values.

The result of spearman correlation test illustrates that the correlation coefficient is equal to or more than 0.6 for eight companies. As for Company 6, it is observed that both the vertical integration and SDS scores are high for every year even though they have different ranking. Only an unexpected decrease in vertical integration score of Company 7 was observed between 1987 and 1997. A two-tailed *p* value <0.05 was considered to be statistically significant for all companies that have correlation coefficient equal or greater than 0.80. Although *p* values are not less than 0.05, the companies that have 0.6 correlation coefficient can still be acceptable because we have only 4 years. The mean values of SDS and VIL scores illustrate perfect correlation and significant *p* value.

As for the second analysis of co-evolution, we applied regression analysis. Since we are examining the change in vertical integration as companies become more environmentally aware, we determined SDS scores as an independent variable and VIL scores as a dependent variable. If we consider time as an effect, we obtained p value as 0.0388. On the other hand, if we do not consider time as an effect, then we obtained *p* value as 0.0221. We will discuss the time effect in detail in the next section. As a result, both of the analyses illustrates that vertical integration level of companies increase as the companies becomes more economically sustainable and environmentally sustainable.

5 Conclusion and Discussion

In Ozcan and Reeves (2011a), we showed that sustainability-focused companies (SFCs) tend to be more vertically integrated than their competitors. In this research, we compared the vertical integration level of companies and any changes in their environmental strategies over the period time to understand how SFCs change their organizational structure as they become more environmentally, economically, and socially sustainable. To avoid the industry effect, we selected companies only from a single industry. We used three indices to determine the SFCs; with the combination of these indices and limitation of the databases, we obtained 10 SFCs from the industrials industry.

We analyzed the annual reports of SFCs for the years 1987, 1992, 1997, and 2002. The result of our content analyses assigned a sustainability development score for each SFC based on the three aspects of sustainable development: environmental, economical, and social sustainability. Moreover, we measured the vertical integration level of companies using the Fan and Lang (2000) method for these 4-years panel. After collecting our data, conducting content analysis and vertical integration calculations, we analyzed the trend in both vertical integration and sustainability development of the companies. Furthermore, using the spearman correlation test, we observed how organizational structure coevolved with sustainable development over the period of time.

The results of our analyses indicated that there is an increasing trend in both sustainable development and vertical integration level for the companies in the industrials industry. In addition to the increasing trend, the vertical integration level increased parallel to the sustainability developments of companies. To produce environmentally friendly products and processes, SFCs would like to increase their control of their suppliers. As stated by natural transaction cost economics, to decrease the contracting costs, and to avoid uncertainty and asset specificity, companies increase their vertical integration level. Parallel to this theory, as stated by natural resource-based view, companies increase their vertical integration level since their resources (i.e., inputs), which affect their sustainability, are valuable, rare, inimitable, and non-substitutable. These results contribute to our previous study and to the natural transaction cost economics and natural resource-based view theories.

Nevertheless, there are certain limitations to this study which must be considered. First, restricting the sample to only industrials industry may limit the generalization of the findings. However, since the industry type impacts the vertical integration level and each industry has its own unique dynamics, we should focus only one industry in vertical integration comparisons. Second, although we had more than ten companies in our indices, we had to restrict our sample to ten because of the limitations in databases. The limitations about databases that we used in vertical integration calculations were discussed in Ozcan and Reeves (2011a). Additionally, there were also limitations in databases that provide annual reports. Company websites provide annual reports to the certain time. The most famous database for annual reports is the Edgar database of The Securities and Exchange Commission; however, the Edgar database started collection from 1996. The annual reports before this year obtained from commercial databases that provide in a limited manner. Finally, although we mentioned the inconsistencies in the annual reports and tried to avoid these with sustainability reports cross control, some scholars still would like to consider as a limitation.

Other future research directions are suggested by the limitations of our study. Our results are based on relatively small sample and on an unusual sampling strategy. Therefore, future studies may consider additional indices or methods for determining sustainability-focused companies. At the time we prepared this study, only 2002 data were available; therefore, the future studies may use 2007 data after December 2011.

In our study, to examine the co-evolution of VIL and SDS scores, we wanted to limit external factor that affect this relationship. For instance, we selected companies from the same country to avoid the country and macro effects, from the same industry to avoid the industry effects, and from the same economical or financial level to avoid some micro effects. Although these are the main factors, there may be other small factors. Even though we consider time effect, future studies may consider additional microlevel factors.

Appendices

Appendix A: Criteria and Weightings for Dow Jones Sustainability Index

Dimension	Criteria	Weighting
Economic	Codes of conduct/compliance/corruption and bribery	6.0%
	Corporate governance	6.0%
	Risk and crisis management	6.0%
	Industry-specific criteria	Depends on industry
Environment	Environmental reporting[a]	3.0%
	Industry-specific criteria	Depends on industry

(continued)

(continued)

Dimension	Criteria	Weighting
Social	Corporate citizenship/philanthropy	3.0%
	Labor practice indicators	5.0%
	Human capital development	5.5%
	Social reporting[a]	3.0%
	Talent attraction and retention	5.5%
	Industry-specific criteria	Depends on industry

Source: http://www.sustainability-index.com/07_htmle/assessment/criteria.html
[a]Criteria assessed based on publicly available information

Appendix B: Criteria and Weightings for Global 100 Sustainable Company List

Dimension	Calculation methodology	Weighting
Energy productivity[a]	US$ sales/gigajoules of total energy consumed	75%
	Increase in resource productivity equal to or exceeding 6% per annum	25%
Water productivity[a]	US$ sales/total cubic meters of water consumed	75%
	Increase in resource productivity equal to or exceeding 6% per annum	25%
Carbon productivity[a]	US$ sales/metric tons of total CO_2e emitted	75%
	Increase in resource productivity equal to or exceeding 6% per annum	25%
Waste productivity[a]	US$ sales/metric tons of total waste produced	75%
	Increase in resource productivity equal to or exceeding 6% per annum	25%
Leadership diversity	The percentage of women on the Board of Directors	100%
CEO-to-average worker pay[a]	Highest company compensation package in US$/average employee compensation in US$	75%
	Average employee compensation calculated as total company compensation/total employees	25%
Taxes paid	(US$ statutory tax obligation—US$ cash taxes paid)/US$ statutory tax obligation	100% of maximum
	1 – the result in #1 up to a maximum of 100%	
Sustainability leadership[b]	Binary system with 1 awarded for presence of a sustainability committee within the company and 0 for absence	25%
	Binary system with 1 awarded for presence of at least one Board member on the committee and 0 for absence	75%
Sustainability pay link	Binary system with 1 awarded for at least one Director's remuneration being linked to extra-financial performance and 0 for absence of a link	100%

(continued)

(continued)

Innovation capacity[a]	US$ R&D/US$ Sales	100%
Transparency[b]	Binary system with 1 awarded for disclosure on a specific data point and 0 for absence for of disclosure. (e.g., total workforce; R&D expenditures)	50%
	Score of 0 to 1 awarded for level of GRI adherence and verification	50%

Source: www.global100.org
[a]Final score (0–1) based on a normalized z-score
[b]Final score (0–1) based on a weighted average

Appendix C: List of Sustainability-Focused Companies in the Sample

3 M Co.
Accenture Ltd.
Agilent Technologies Inc.
Boeing Co.
Caterpillar Inc.
Cummins Inc.
Ecolab Inc.
General Electric Co.
IMS Health Inc.
Interface Inc.
Lindsay Corp.
Manpower Inc.
MeadWestvaco Corp.
Rockwell Collins Inc.
United Parcel Service Inc.
United Technologies Corp.
Weyerhaeuser Co.
Xerox Corp.

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Community Participation Mechanism: A Study of Youth Voices in Conservation's GreenLeaf Marketplace

Leonard Sonnenschein

Abstract This chapter focuses on international mechanisms for addressing climate change, focusing on linkages and multistakeholder communications, adaptations, and adoptions for greater sustainability. Since the Kyoto Protocol was organized, the idea of creating a carbon credit marketplace has been widely discussed. The United Nations has created a carbon credit certification process, and, at this point, there are a number of recognized evaluators for these credits. Unfortunately, the credit marketplace has substantially changed, and the availability of using this type of financial transaction for encouragement of developing countries to utilize their present initiatives to receive funds for their transition towards sustainability for which the developed countries and corporations would purchase these credits has failed. Failure in the sense that when funds are received by these developing countries, these funds are often diverted and actions towards a lower-carbon lifestyle have not been achieved. Conversely, a number of agencies have funded more localized projects that engage in developing sustainable actions in communities through improved mechanisms, such as sustainable forestry and agriculture and sustainable lifestyles including improved cooking stoves, water recycling, and waste recycling through biogas generation. Many of these projects at the point of achievement for their sustainability lack continued funding necessary to allow for sustainable development.

The Youth Voices in Conservation Program has researched youth action towards conservation and sustainability from the classroom, the field site, and within non-governmental and governmental organizational situations for the past few years. This research found that by developing a residual funding based upon carbon credit offsets created by these localized actions, there is a possibility of conditional cash transfer based upon these "good actions." During the latter half of July 2011, intensive fieldwork in conjunction with UNDP-GEF Small Grants Projects and Center for Environment Education (CEE) occurred in India. Ten projects were evaluated for

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*, 139
DOI 10.1007/978-94-007-5995-4_8,

the establishment of an intranet/Internet evaluation mechanism that would allow for the development of the GreenLeaf Marketplace. Projects were also evaluated for their approach to reducing the carbon impact which correlated to the community financially, educationally, and environmentally. Detailed description of how this methodology works for developing financial environmental and financial communities will be discussed. It is hoped through a global mechanism that other localities throughout the world will be able to sign up through this computer-based system. The results of this research indicate that the Youth Voices in Conservation's GreenLeaf Program may be able to address localized sustainability issues as well as methodology for decreasing carbon footprints and increasing financial sustainabilities within each community, and consequently, the environmental effects from the wide-scale adoption of these plans may be expected. It is anticipated that these credit mechanisms may be used with local bank issuance for green purposes with conditional cash transfer as part of the residual credit program.

Key words Carbon market • Sustainability • Sustainable lifestyles • Local actions • Environment • Climate change • Education

1 Introduction

1.1 What Is Climate Change?

Global warming, also known as climate change, is one of the most urgent issues affecting our planet today. Global warming is an increase in global average surface temperature due to natural or anthropogenic climate change. Due to global warming, environmental changes have occurred in the marine habitats, consequently changing the flora and fauna in their growth and development and even decreasing their populations. This in turn causes the loss of biodiversity, adversely affecting the long-term health of the oceans at large.

Three of the well-documented sources of global warming are increasing concentrations of carbon dioxide in the atmosphere, alterations in the biogeochemistry of the global nitrogen cycle, and ongoing land-use/land-cover change (Vitousek 1994). Human activity has increased carbon dioxide concentrations from 280 to 355 microlitres per litre since 1800 (Vitousek 1994). This increase in carbon dioxide is likely to have climatic consequences–and certainly it has direct effects on biota in all Earth's terrestrial ecosystems. The global nitrogen cycle has been altered by human activity to such an extent that more nitrogen is fixed annually by humanity (primarily for nitrogen fertilizer) than by all natural pathways combined (Vitousek 1994). This added nitrogen alters the chemistry of the atmosphere and of aquatic ecosystems, contributes to eutrophication of the biosphere, and has substantial regional effects on biological diversity in the most affected areas. Human land-use/land-cover change has transformed one-half of Earth's non-icy surfaces. This in and of itself probably represents the most important component of global change now and has profound effects on biological diversity on land and on ecosystems downwind and downstream of affected areas (Vitousek 1994). These three, along with other equally certain components of global environmental change, are the primary causes of anticipated changes in climate and of ongoing losses of biological diversity. They are caused in turn by the extraordinary growth in size and resource use of the human population (Vitousek 1994).

1.2 The Urgency of Climate Change

As the rate of climate change continues to outpace predictions, it brings about a crisis upon humankind. Global warming affects sea-level rise, weather patterns, global water movement, topography, rainfall, desertification, and more. The issue of climate change pervades every aspect of the environment–land, air and water. Climate change affects sustainability and the sustainable development within societies through changes in weather frequency, distribution of flora and fauna, food security, economic expenses for natural disasters, higher ambient temperatures, etc.

1.3 What Is Sustainability?

According to the U.S. Environmental Protection Agency, sustainability is based on a simple and long-recognized factual premise: everything that humans require for their survival and well-being depends, directly or indirectly, on the natural environment. The environment provides the air we breathe, the water we drink, and the food we eat. It defines in fundamental ways the communities in which we live and is the source for renewable and nonrenewable resources on which civilization depends. Our health and well-being, our economy, and our security all require a high-quality environment. When we act on that understanding, we tend to prosper; when we do not, we suffer.

Sustainability is a balance between the social, environmental, and economic sectors of life, eliciting consequences which are bearable, equitable, and viable. Education is needed in order to explain the causes, consequences of inaction, and opportunities for action. Informal science learning theory suggests that of the numerous factors identified as being influential to increasing environmental awareness and pro-environmental behavior, values and beliefs are significant. Collaborations between informal science educators and the community should be encouraged. The general populous neither sees sustainability as pertaining to a realm outside of their daily lives nor do they see how small daily actions can impact the sustainability of our planet. The welfare of a community is developed and maintained through literate citizenry and is built upon the understanding and wise use of scientific research, technical knowledge, and cognitive skills. The scientific community recognizes the need for environmental education and action on the topic of biodiversity loss. Informal learning organizations are influential to increasing environmental awareness and pro-environmental behavior.

Due to global warming, environmental changes have occurred in terrestrial and aquatic habitats consequently changing the flora and fauna in their growth and development and even decreasing their populations. This in turn causes the loss of biodiversity, adversely affecting the long-term health of ecosystems at large.

Biodiversity is a natural insurance policy against climate change. Global climate change is already impacting biodiversity in the following ways (Parmesan and Yohe 2003):

- Changes in distribution
- Increased extinction rates
- Changes in reproduction timings
- Changes in length of growing seasons for plants
- Shifting migration ranges of insects and animals
- Modified flowering and fruiting cycles

As ecosystems become affected by climate change, the number of taxa present decreases. This decrease has a causal relationship upon tourism based upon the sites travelers can see within a specific region of the world. Without knowledge of this connection, communities may suffer great consequences.

The United Nations' Millennium Development Goals (MDGs) are the product of international consensus on a framework by which nations can assess tangible progress towards sustainable development (United Nations). The goals are:

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria, and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.

Sustainable development and adaptive capacity for coping with climate change have common determinants. It is easy, therefore, to conclude that climate change has the potential to affect the progress of nations and societies towards sustainability. Climate change impacts on the timing, flow, and amount of available freshwater resources could, for example, affect the ability of developing countries to increase access to potable water. It is conceivable that climate change could have measurable consequences on food security (Combes, 2005). Climate change may impact death rates associated with malaria (Combes, 2005).

Whether synergistic effects or trade-offs will dominate interactions between climate impacts, adaptation decisions and sustainable development decisions depend, at least in part, on the particular decisions that are made. Decisions on how countries will acquire sufficient energy to sustain growing demand will, for example, play crucial roles in determining the sustainability of economic development. If those demands are met by increasing fossil fuel combustion, then amplifying feedbacks to climate change should be expected.

2 Project Fiscal Sustainability

Often left out of the carbon offset value equation is the bankable calculation of sustainability from the business sense. Through the usage of self-help groups and other similarly organized entities and their existing relationship with banking institutions and sound fiscal management, project sustainability can be achieved.

Self-help groups (SHGs) are formed by nongovernmental organizations (NGOs), government agencies, or banks. SHGs are expected to extend financial services to the poor and contribute to the alleviation of rural poverty. Linked not only to banks but also to wider development programs, SHGs are seen to confer many benefits, both economic and social (EDA Rural Systems, 2006). SHGs enable members to grow their savings and to access the credit which banks are increasingly willing to lend. SHGs can also be community platforms from which men and women become active in village affairs, stand for local election, or take action to address social or community issues (EDA Rural Systems, 2006).

SHGs work in a micro-sized financial base including depositing and managing savings, lending, and borrowing, and the base has to have effective and transparent management with sound guidance. Clear guidelines and systematic record-keeping for microfinance transactions are essential for the success of this business model.

SHGs provide a platform for microfinance loans. Microcredit or microfinance is a very small loan to someone who is considered "unbankable" and is too poor to be considered under the normal credit system. They may lack credit history, steady employment, or live in poverty. It was first introduced to provide work for the poor in Third World countries. Since then it has been successful and continues to grow around the world. Some SHGs are very successful through this microfinance incubation process. As each SHG prospers, the scope of funded projects can be expanded. With the existing infrastructure and support that SHGs create in tandem with bank partnerships and supervision, this is a concrete solution for the alleviation of poverty.

Women from different social and economic levels are joining SHGs, including the poor and some very poor. This process continues as the numbers grow. However, the barriers to entry for the poor are high – not only do they have lower incomes, but their incomes are usually more variable. To reduce barriers for the poor means allowing more flexibility to cater to varying and seasonal cash flows, for example, allowing varying deposit amounts and frequency, perhaps with a specified annual minimum. The same principle applies to access to credit and repayment, again within specified minimum norms. SHG members reflect a diverse membership covering different social and economic categories, including those who are poor (below the poverty line) and "borderline" (above the poverty line but vulnerable to risk).

Data on other economic and social indicators reflect the poverty profile: 38% of SHG members work as casual laborers, though 29% work in own agriculture, and 17% are engaged in a nonfarm enterprise (EDA Rural Systems, 2006). Schooling levels of SHG members are very low: 74% had no schooling, 11% had some adult education to become "neo-literate," and 15% had some schooling (mainly at primary level) (EDA Rural Systems, 2006). The microfinance sector has given a great boost to the rural poor in India to reach reasonable economic, social, and cultural empowerment leading to better life in participating households.

Funds can be designed to support innovative, risk-friendly, unconventional experiments in farm, nonfarm, and microfinance sectors that would have the potential to promote livelihood opportunities and employment in rural areas.

Utilizing the profit from carbon offset credits to create residual income and seed money for future project expansion is a recipe for financial sustainability. As more credit earnings are saved, a greater quantity of microfinance credit can be received in the future. Success begets success.

3 The Need for International Mechanisms for Addressing Climate Change

International mechanisms are needed for addressing climate change, focusing on linkages and multistakeholder communications, and adaptations for greater sustainabililty.

In order to combat climate change, it is required to decrease global emissions to roughly 80% below 1990 levels by the year 2050 (Kollmuss et al. 2008). Such dramatic emission reductions require a sharp move away from fossil fuel, significant improvements in energy efficiency, and substantial reorganization of our current economic system. This transition can only be achieved by comprehensive national and international climate policies.

Carbon offsetting is an increasingly popular means of taking action. By paying someone else to reduce greenhouse gas emissions elsewhere, the purchaser of a carbon offset aims to compensate for – or "offset" – their own emissions (Kollmuss et al. 2008). Individuals seek to offset their travel emissions and companies claim "climate neutrality" by buying large quantities of carbon offsets to "neutralize" their carbon footprint or that of their products.

Carbon offset markets exist both under *compliance schemes* and as *voluntary programs*. Compliance markets are created and regulated by mandatory regional, national, and international carbon reduction regimes, such as the Kyoto Protocol and the European Union's Emissions Trading Scheme (Kollmuss et al. 2008). Voluntary offset markets function outside of the compliance markets and enable companies and individuals to purchase carbon offsets on a voluntary basis. Carbon markets have already seen a substantial economic initiation and will likely grow considerably over the coming years as the effects of climate change intensify (Kollmuss et al. 2008). The voluntary market is also growing rapidly.

Examples of carbon markets include:

- Clean Development Mechanism (CDM)
- Gold Standard (GS)
- Voluntary Carbon Standard 2007 (VCS 2007)
- VER+
- The Voluntary Offset Standard (VOS)
- Chicago Climate Exchange (CCX)
- The Climate, Community and Biodiversity Standards (CCBS)
- Plan Vivo System

- ISO 14064-2
- GHG Protocol for Project Accounting

The voluntary market may have particular advantages over compliance schemes (Kollmuss et al. 2008):

- Enabling involvement for countries that have not ratified the Kyoto Protocol.
- Heightened possibilities of broad participation.
- Flexibility in standards creates the promotion of project innovation and experimentation.
- Increase in corporate goodwill as businesses see the local benefits of the program.
- Cost-effectiveness of programs benefits all levels of society and increase participation.
- Higher reductions without harming the poor and other sectors of society.

4 The Kyoto Protocol

"Emissions trading, as set out in Article 17 of the Kyoto Protocol, allows countries that have emission units to spare – emissions permitted them but not "used" – and to sell this excess capacity to countries that are over their targets. Thus, a new commodity was created in the form of emission reductions or removals. Since carbon dioxide is the principal greenhouse gas, people speak simply of trading in carbon. Carbon is now tracked and traded like any other commodity. This is known as the "carbon market." More than actual emissions units can be traded and sold under the Kyoto Protocol's emissions trading scheme.

The other units which may be transferred under the scheme, each equal to 1 ton of CO_2, may be in the form of:

- A removal unit (*RMU*) on the basis of land use, land-use change, and forestry activities such as reforestation
- An emission reduction unit (*ERU*) generated by a joint implementation project
- A certified emission reduction (*CER*) generated from a clean development mechanism project activity

Transfers and acquisitions of these units are tracked and recorded through the registry systems under the Kyoto Protocol. An international transaction log ensures secure transfer of emission reduction units between countries (UNFCCC 1997)".

5 Creating a Carbon Credit Marketplace

Since the Kyoto Protocol was organized, the idea of creating a carbon credit marketplace flourished. There are two types of carbon commodities, allowances and offsets, and the systems that create them are (1) cap-and-trade systems and (2) offsets or carbon credits (Kollmuss et al. 2008).

Table 1 Distinguishing features of cap-and-trade and baseline-and-credit systems

Features	Cap-and-trade	Baseline-and-credit
Exchanged commodity	Allowances	Carbon credits
Quantity available	Determined by overall cap	Generated by each new project
Market dynamic	Buyers and sellers have competing and mutually balanced interests in allowances trades	Buyers and sellers both have an interest in maximizing the offsets generated by a project
Sources covered	Usually high emitters such as the energy sector and energy intensive industries	As defined by each standard. Not limited to just high-emitting sectors
Independent third party	Minor role in verifying emissions inventories	Fundamental role in verifying the credibility of the counterfactual baseline and thus the authenticity ("additionality") of the claimed emission reductions
Emissions impact of trade	Neutral, as is ensured by zero-sum nature of allowance trades	Neutral, providing projects are additional. Otherwise, net increase in emissions
		Possible decrease in emissions in the voluntary market

Source: Kollmuss et al. (2008)

Under a *cap-and-trade system*, an overall cap is set to achieve emissions reductions. Each of the participants within a cap-and-trade system (usually countries, regions, or industries) is allocated a certain number of allowances based on an emissions reduction target. In a cap-and-trade system, the cap constitutes a finite supply of allowances, set by regulation and political negotiation. These allowances are then neither created nor removed but merely traded among participants. This finite supply creates a scarcity and drives the demand and price for allowances (Kollmuss et al. 2008).

A cap-and-trade system aims to internalize (some of) the costs of emissions and thus drives actors to seek cost-effective means to reduce their emissions. The challenge in a cap-and-trade program is to determine the appropriate level at which to set the cap and which should be stringent enough to induce the desired level and rate of change, while minimizing overall economic costs.

A *baseline-and-credit system* in contrast does not entail a finite supply of allowances. It does not involve projects that are implemented under the umbrella of a cap-and-trade system. Rather, more credits are generated with each new project implemented. These credits can then be used by buyers to comply with a regulatory emission target to "offset" an emitting activity (such as an airline flight) or to be a "carbon-neutral" organization with zero "net" emissions (Table 1) (Kollmuss et al. 2008).

Carbon offset projects can be grouped by type of project. Most projects may be broadly categorized into bio-sequestration, industrial gases, methane, energy efficiency, and renewable energy projects. Not all project types are equally effective at delivering the emissions reductions that they initially set out to deliver. Statistics on what percentage of projected emissions are realized should be kept.

5.1 Pitfalls of These Markets

Carbon offset markets are not without their critics. Critics point out the poor quality of carbon offset projects. They raise concerns over equality and fairness based on the argument that carbon offsetting enables developed nations to perpetuate unsustainable lifestyles by funding carbon projects in developing countries. Some argue that these projects rarely lead to benefits for the host community and have even compared the offset market to colonialism (Kollmuss et al. 2008). Accounting methods for offsets are seen as too inaccurate to justify claims of real emission reductions or to support the achievement of "carbon neutrality." The voluntary offset market in particular has been criticized for its lack of transparency, quality assurance, and third-party standards (Kollmuss et al. 2008).

Conflict of interest is an overarching detriment to the veracity of carbon offset claims. Key aspects to keeping the carbon markets on ethical ground include third-party verification of credits earned, keeping the application and approval processes separate, and keeping registries to keep track of credits to prevent cross-posting of the same credits by different parties (Fig. 1).

5.2 Actors Within a Carbon Offset Project

Designing, implementing, and operating a carbon offset project require the involvement of a large number of parties, stakeholders, and authorities. Although each project may vary, here are some of the roles as stated by the Global Carbon Project (Kollmuss et al. 2008):

Project Owner
The operator and owner of the physical installation where the emission reduction project takes place can be any private person, company, or other organization (Kollmuss et al. 2008).

Project Developers
A person or organization with the intention to develop an emission reduction project could be the project owner, a consultant, or specialized services provider (Kollmuss et al. 2008).

Project Funders
Banks, private equity firms, private investors, nonprofit organizations, and other organizations may lend or invest equity to fund a project (Kollmuss et al. 2008).

Stakeholders
Stakeholders are individuals and organizations that are directly or indirectly affected by the emission reduction project (Kollmuss et al. 2008).

Third-Party Auditors, Validators, and Verifiers
Many of the voluntary offset standards require a third-party auditor to validate and verify a project's climate-saving potential and achieved emission reductions (Kollmuss et al. 2008).

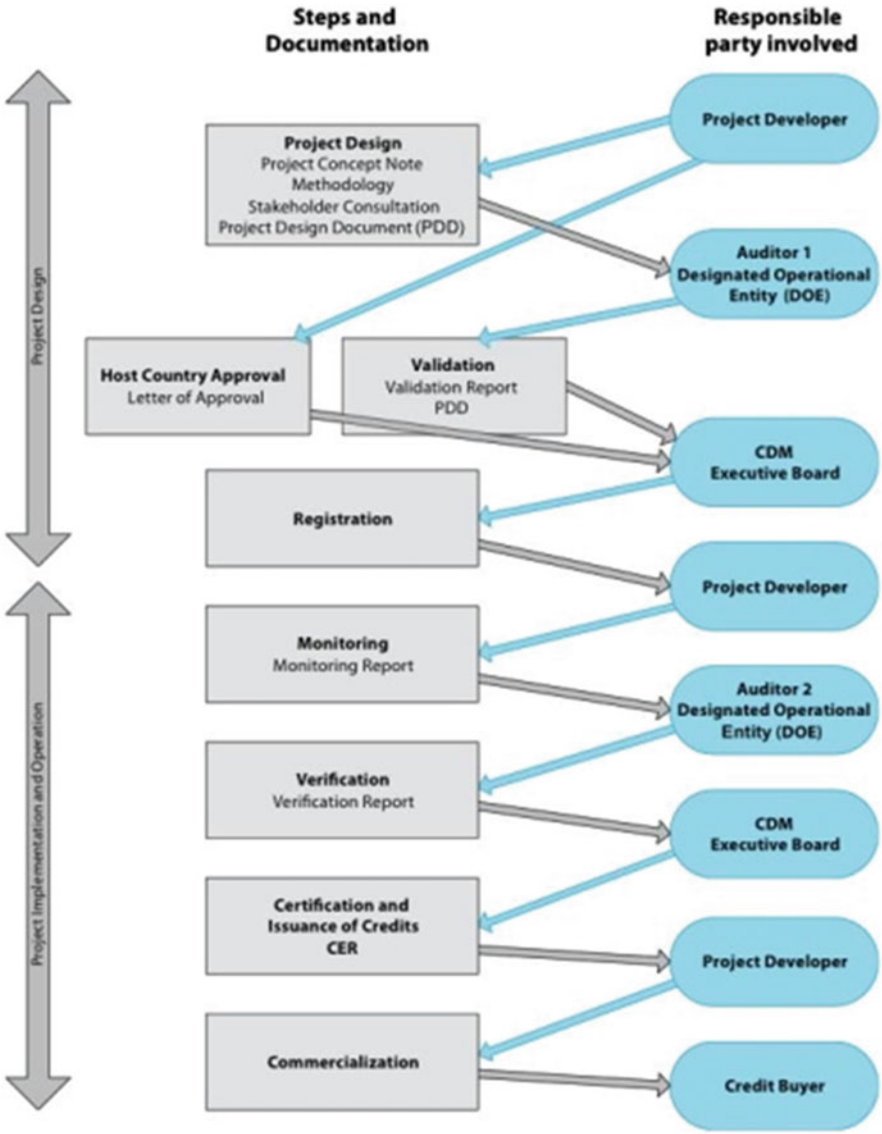


Fig. 1 The life cycle of a carbon offset credit project through the clean development mechanism (Source: Kollmuss et al. 2008).

Standards Organization
In the absence of national and international legislation, standard organizations define a set of rules and criteria for voluntary emission reduction credits (Kollmuss et al. 2008).

Brokers and Exchanges
In the wholesale market, emission offset buyers and sellers can have a transaction facilitated by brokers or exchanges. Exchanges are usually preferred for frequent trades or large volumes of products with standardized contracts or products, while

brokers typically arrange transactions for non-standardized products, occasionally traded and often in small volumes (Kollmuss et al. 2008).

Trader
Professional emission reduction traders purchase and sell emission reductions by taking advantage of market price distortions and arbitrage possibilities (Kollmuss et al. 2008).

Offset Providers
Offset providers act as aggregators and retailers between project developers and buyers. They provide a convenient way for consumers and businesses to access a portfolio of project offsets (Kollmuss et al. 2008).

Final Buyers
Individuals and organizations purchase carbon offsets for counterbalancing GHG emissions (Kollmuss et al. 2008).

6 The Solution

6.1 Youth Voices in Conservation's GreenLeaf Program

Youth Voices is a multifaceted environmental program which utilizes public awareness, youth education, environmental projects, and carbon offset credits to facilitate the long-term reduction in carbon usage within everyday living. The carbon offset credits enable these innovative projects to be self-sustainable. Banks will be the third-party validators and moderators of carbon credit fund dissemination. The need for this innovative, comprehensive program is dire worldwide.

6.2 Youth Education

In order to ameliorate the effects of climate change, education for young people (children and youth) in the formal education system and through governmental and nongovernmental organizations is essential. Based on the premise that what children learn today will shape the world tomorrow, instilling environmental awareness at a young age is the best way to achieve the goal of climate neutrality and to protect the environment.

The youth, together with children representing about one-third of the global population, are concerned with the increasing threat posed by rising global carbon emissions and the changing climate. The youth who are on the threshold of becoming active participants in society as citizens, decision makers, and leaders are already experiencing the impacts of the changing global environment in their communities. Both formal and informal educational strategies need to be created for youth including how to translate knowledge into advocacy and action and make climate change education transformative and how climate-sensitive livelihood options could be created. Additional aspects of youth education that will need to be addressed include teachers training, hands-on/field-based activities, eco-clubs, and camping. Youth Voices in Conservation and its GreenLeaf Program are a prime example. This program incorporates youth and community education while bringing economic value to local communities by incorporating carbon offset values to youth-run environmental projects. The youth are also key in transferring information they have learned to their families and friends, creating a continuum of educational transfer. Education is necessary to increase the probability of sustainable choices made individually within households and businesses to prevent the counteraction of the carbon offset values created.

6.3 Greater Public Awareness

While the public is becoming more aware of environmental issues, still much more can be done. Education about local ecology; protected areas; usage of green technologies; sourcing of food from local, green producers; and creating a small museum featuring the local culture, people, historic information, cultures, flora, fauna, and geology would be examples of awareness strategies.

For the local peoples, public awareness is key. For any sustainable actions to occur, multistakeholder meetings with participants from governmental, nongovernmental, industry, and local peoples must first be held. There is a delicate balance between economic and environmental factors. By engaging the public, addressing the difficult issues and disagreements which may exist, a consensus can be reached, although it may take work to achieve. Inclusion of the native peoples is essential to this process and a true buy-in from the public must be accomplished.

The general public includes:

- A diverse group of residents
- Religious institutions
- Economic enterprises
- Service institutions (health, educational, hotels, travel services)
- Infrastructure (transport, utilities, etc.)

Community organizing is emphatically bottom-up. It is the community members who select the issues, proffer the solutions, and drive strategy and execution.

Below are goals for communicating sustainability to the community:

- To better define what sustainability is to the lay person.
- To show concretely how to be sustainable in every aspect of life.
- Raise much-needed community awareness of what actions can be taken individually to live sustainably and positively impact our environment.
- To use the elicited results as a prototype for national expansion.
- Present the knowledge to enable consumers to make decisions that minimize energy usage and maximize environmental benefits.
- Encourage a more cost-efficient operation of utilities.
- Reduce the carbon footprint by reducing energy usage.
- Provide information on the latest technology available to reduce energy usage to provide for a safe and sustainable ecosystem.

The *Low-Carbon Lifestyles* model for sustainable living will be encouraged for project offices and, ultimately, for individual households. *Low-Carbon Lifestyles* is a set of materials focusing on green living which is written in an easy-to-understand language, based on up-to-date science and policy inputs. It aims to arm a reader with facts and figures on how small changes in everyday actions can help reduce an individual's contribution to greenhouse gas emissions in the atmosphere and also save money. It focuses on climate-friendly choices we all can make in the use of electrical appliances, transport, paper, water, etc. All data is relevant to the Indian context and the choices presented are practical and easy to adopt. The tool kit consists of:

- *A trainer's guide with practical climate-friendly actions that can be adopted in our daily life and a quantitative estimation of reduction of greenhouse gas emissions by individual actions*
- *An excel sheet with necessary calculations*, *which can be used by trainers to quantify energy and cost savings*, *and carbon dioxide emissions reduction*
- *A PowerPoint presentation on climate change basics*, *how we are responsible*, *and the impacts on India*

These tools can be used to track effectiveness of projects within offices, schools, and corporations. With the decrease in energy usage, a better climate will result. The vision of *Low-Carbon Lifestyles* is to create a prosperous but not a wasteful society and an economy that is self-sustaining. Individual efforts may seem like drops in the ocean. However, the impacts from the positive changes from these efforts in lifestyles and consumption patterns by millions of people will make significant contributions towards a more climate-friendly Earth.

6.3.1 Environmental Projects

Local entities will carry out projects which help counteract climate change and engage sustainable development and sustainable lifestyles to significantly decrease the carbon footprint which may otherwise be created. Only projects which have significant short-term and long-term impacts are promoted and presented. Benefits within the following five areas are sought: equity, sustainability, efficiency, participatory decision-making, and accountability. Project examples include biodiversity conservation, climate change mitigation, protection of fisheries, prevention of land degradation (primarily desertification and deforestation), and elimination of persistent organic pollutants through community-based approaches.

6.3.2 Carbon Offset Credits

The intention of utilizing carbon offset credits for environmental projects is to create project and livelihood sustainability. Oftentimes, projects are unable to survive beyond the point when the initial funding received runs out. Carbon credits incentivize the project operators to perform their best to earn the best value for their efforts. To ensure the veracity of value statements, banks will be the independent third-party

Fig. 2 Mysore palace, Mysore, Karnataka, India

validators for the projects and will moderate the redemption and usage of reward cards to ensure that proceeds will not be used towards unsustainable lifestyles.

Project Example 1

Vivekananda Trust
771/B, 5th Cross, Roopa Nagar Mysore 570 026, India
http://www.vivekanandatrust.webs.com

Cost: $65,829
In-kind match: $17,080
Cofinancing: $17,077
Carbon offset value in same 2-year period:
7,056 metric tons carbon saved
Wood value saved in same 2-year period: $766,627 (Fig. 2)

What?

Inspired by the vision of Swami Vivekananda, Vivekananda Trust is a service organization with stress on the spiritual evolution of the individual based on the inspiring teachings of Swami Vivekananda.

The focus area of the project falls under the fringe areas of B. R. Hills Wild life Sanctuary. Located on the confluence of Eastern and Western Ghats, B.R. Hills is considered as hot spot of biodiversity and is home to unique flora and fauna belonging to both Eastern and Western Ghats. The forests have been a source of firewood for the once-upon-a-time sparsely populated villages in the surrounding areas. Yet, ever since the surrounding villages started receiving the canal water from 1972, there has been relentless pressure on the forests from the ever-increasing population, resulting in a 30% reduction in the forest cover as revealed by the satellite images. In the fringe area villages of B. R. Hills, like Komaranapura, Yeragamballi, Krishnapura, Vadagare, and Gangvadi, where the use of forest firewood for cooking food is huge, the rainfall has been steadily coming down – 125 mm in 1975 to 109 mm in 2010!

Awareness about the adverse impacts of deforestation, global warming, and climate changes was initially given to the school children in the form of interactions, competitions in drawing and painting, essay writing, etc. For their parents, the awareness was given thru training the self-help groups of women and youths.

Objectives of the Project

1. Create awareness about the deforestation and climate change.
2. Reduce the consumption of forest firewood by installing locally assembled but scientifically designed low-cost ovens in 1,000 households.
3. Improve health and livelihood.

The goal of the project – climate change

The Change

For the village ladies of Yelandur Taluka, the mornings begin in front of the ovens! For them, the oven smoke from the dimly lit kitchens and tears from eyes are the ingredients that go into making of energy-giving food. It has been an endless chorus for them.

But these days Vivekananda Trust has been trying to address these problems. For the whole taluka, the traditional mud oven where forest firewood or sticks as fuel has been used for preparing food, Vivekananda Trust has set an objective of constructing 1,000 smokeless ovens that improve health and hygiene and are environmentally friendly by way of reduced carbon dioxide emissions. The trust is working in the five villages with a program on climate change mitigation and improvement of livelihood with alternative cooking gadgets like smokeless oven that costs around Rs.1,200/-. Seventy percent of the cost is borne by UNDP/GEF/SGP/CEE, Delhi as subsidy for the project. The low-cost three-vessel smokeless oven, around 3 ft in length and 1 ft in height and width, is constructed mostly by making use of locally available materials. A 10-ft length cement pipe, cast iron grate, MS rods, cement, and a specially designed semi-conical aluminum vessel only are brought from outside by the organization. The beneficiary saves over 55–60% of firewood because of this oven. In some of the ovens, broken wall tiles are experimentally used to improve the efficiency of the ovens, which brings down the firewood consumption by another 15%.

"By use of this oven, food preparation is fast and is without smoke of soot" says the beneficiaries Smt. Puspha and Doddamma of Yeragamballi village.

Geographical Location of the Project (Fig. 3)

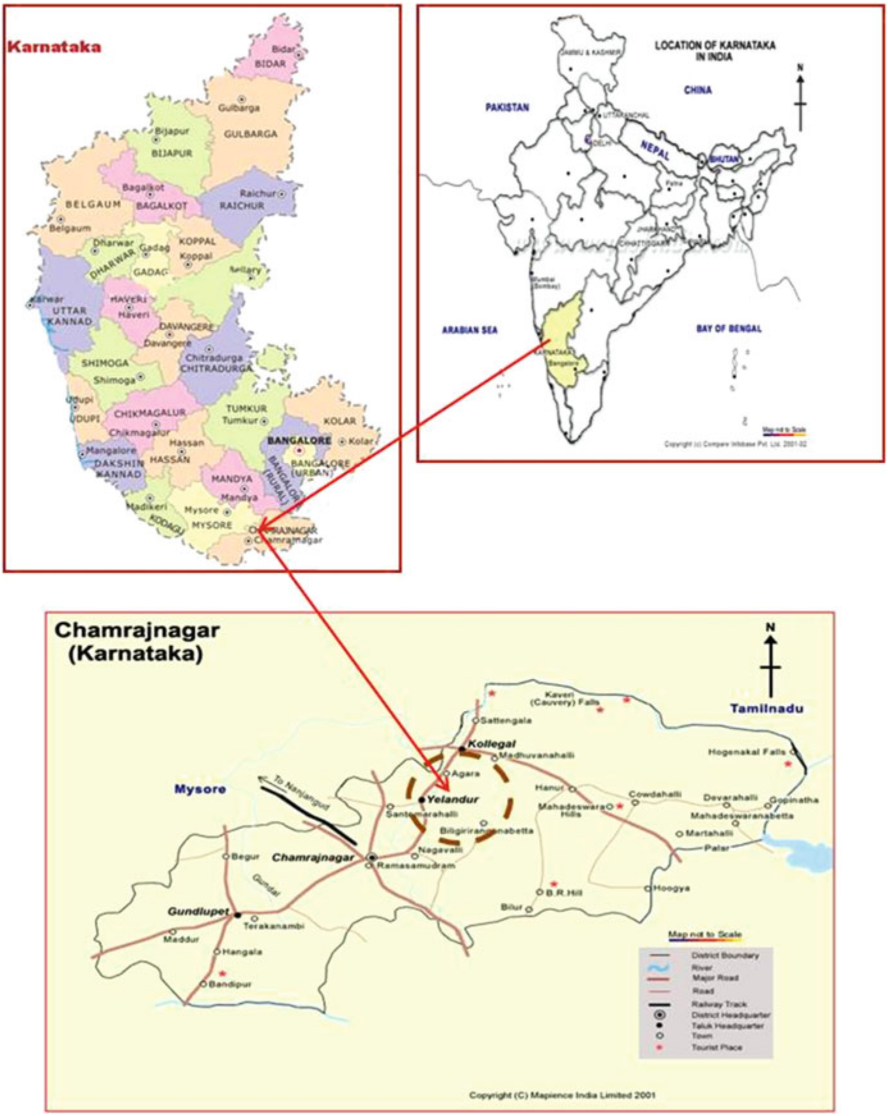


Fig. 3 Maps of Karnataka, India

Partner Project and Partner Organizations

(a) Vivekananda Girijana Kalyana Kendra, B.R. Hills, Karnataka (www.vgkk.org)
(b) Karuna Trust, B.R. Hills, Karnataka (www.karunatrust.org)
(c) IISc, Bangalore, Karnataka
(d) CREST(National Institute of Engineering) Mysore, Karnataka
(e) Shashwat Oorja P Ltd., Pune, Maharashtra (www.shashwatoorja.com)
(f) CCD, Sevayoor, Madurai (www.ccd.org)
(g) Taluk Panchayat, Yelandur
(h) Zilla Panchayat, Chamarajanagar District
(i) Forest officer, Yelandur Taluk, Chamarajanagar
(j) Range Officer, Kollegala, Chamarajanagar District

Cookstove Progress (Figs. 4 and 5)

Fig. 4 Old-style stove

Fig. 5 New-style stove

Financial Support

Amount received from UNDP-GEF	$31,672.00
In-kind donations (i.e., donated hours, volunteer hours, goods, and other services)	$17,080.00 in-kind match Cost of materials provided Donated hours Volunteers hours Goods and services including manual labor
Cofinancing	$17,077.00 – we have been able to access to the cost of materials, volunteer hours, goods, and services including manual labor as part of cofinancing/links and participation from others
Total	**$65,829.00**

How the Project Creates Self-Sustainability

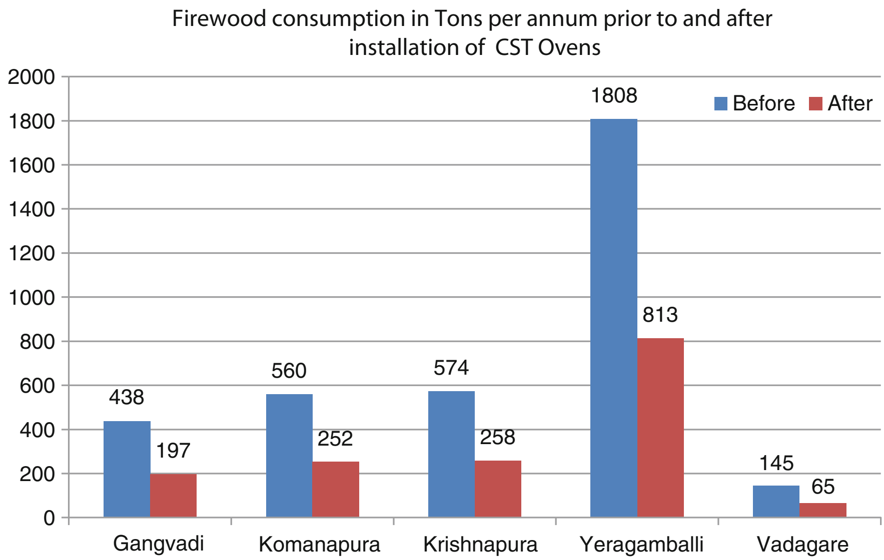
This has immediately reduced carbon emission by around 3,000 M tons per annum. The saving of almost 55% reduction in firewood consumption directly results in a saving of around Rs.15,000/- of firewood used per household per annum. This direct saving will result in improved health and nutritional status of the whole family as the food budget hereafter would get a higher allocation.

The new smokeless ovens ensure a better working atmosphere in the kitchen and reduce most of the lung-infected diseases caused by soot and smoke like cough lung infections and eye-related problems and the related expenditure on its treatment for the entire family. It is estimated that the savings on medical expenditures would be around Rs.2,000/- annum per family.

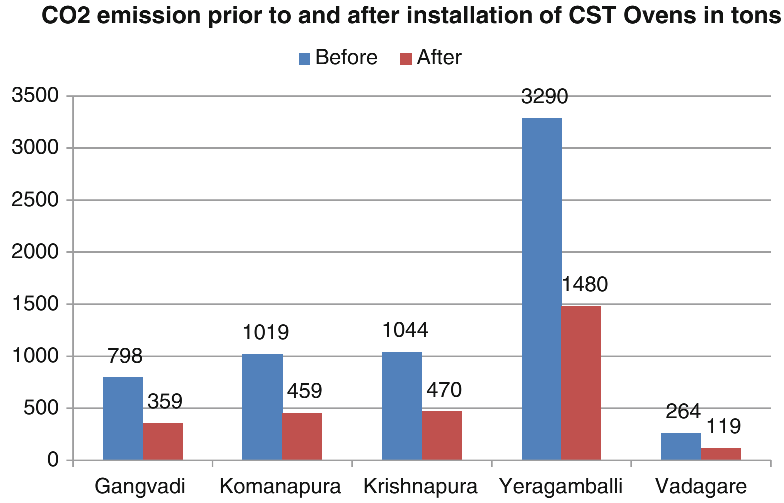
Since the new ovens take lesser time for cooking, it results in saving almost 2 h per day or 730 h per annum which would work out to be 91 man days of employment per family.

This saved time can be constructively employed by the ladies by engaging themselves into vocational skills. Vivekananda Trust has already linked the SHG members belonging to the beneficiaries to bank for getting loan for buying milch cows.

One of long-term impact of having a smokeless oven in the house will be on the children who will not have a problem of underdevelopment of their brain due to certain chemicals being inhaled on a regular basis because of the smoke from the kitchen.



Source: Household sample survey year 2009



Note: 55% reduction in the firewood consumed with CST ovens. Where the wall tiles were lined inside the ovens, the firewood consumption has come down to 65%

1 ton firewood burnt = 1.820 tons CO_2 emission

Values Created

15, 1,742 rupees/family × 1,162 = 17,632,420 rupees × 46 rupees/$ = $383,313 value per year
Wood value saved
$383,313/year
$766,627/2 years
Return on investment
$**11.65** per $1 invested (includes all funds donated including in-kind donations)
$**24.21** per $1 invested (including only GEF contribution)

Socioeconomic Benefits

- Effectiveness of impact for these activities can be seen by the usage by the beneficiaries.
- Seeing the benefits of the CST ovens, people from other villages have started asking for providing it in their villages also.
- Local Panchayat members, seeing the working and benefits of the CST ovens, have informed that they would take up the matter in the Panchayat level.
- Bank linkage for income generation activities like dairy is being followed up. Many of the families were linked with bank thru SHG for the loan for this. Details are being collected and tabulated.

7.10 Photos

Signing up for Youth Voices Program

Small-scale sustainable agricultural area

New cookstove installation

Traditional home where new cookstoves were added

Traditional extended family in village

Happiness with new cookstove

Validation

On July 28, 2011, several of the villages were visited. A majority of the villagers had implemented the smokeless stoves. You can visit our Facebook page (http://www.facebook.com/pages/Youth-Voices-in-Conservation/250801181612583) to see interviews as well as photographs. The individual homeowners interviewed all expressed gratitude for the smokeless ovens insofar as they provided a safer home-cooking situation, burned less fuel, and saved each family a significant amount of money in firewood costs as well as in the efficiency of cooking many foods. The village elders as well as the project activators were equally happy with the success of this community project.

Project Example 2

The Andhyodaya
M C Road Angamaly, Kerala South India 683572
www.theandhyodaya.org

Cost

Financial investments	
Amount received from UNDP-GEF	$438,956
Amount received from local funders	$48,832
Amount received from governmental/nongovernmental organizations in matching funds	$282,667
In-kind donations (i.e., donated hours, volunteer hours, goods, and other services)	12,000 hours
Total amount of funds under the agreement	$770,455

Carbon Offset Value

Annual total carbon offset value from 2003 to 2008 of 86,927 metric tons per year has been validated by an independent validator. In addition to that, Andhyodaya, according to the "Low-Carbon Lifestyle" spreadsheet, has 22,029 metric tons carbon offset. Based upon having 25,446 biogas generators, this would mean approximately 4 metric tons carbon offset value per biogas generator per year.

What?

Environment Preservation Through Construction of Biogas Plants

Project Description

The Andhyodaya, an NGO into renewable energy, water management, environment sanitation, and other social development activities, is in active existence for the past 18 years. For more details, visit www.theandhyodaya.org. Small-scale biogas program was the flagship project of the organization.

Over the years, the NGO has been instrumental in constructing more than 50,000 biogas plants in the state of Kerala. They have a network of coordinators at the taluk level and, in turn, have subsidiary links with teams of technicians and local animators. Most of the local animators are from the milk collection societies. Over the years, they have developed an effective monitoring system to ensure that biogas plants work well.

Biogas plants are of two models: one is a fixed dome model and the other is a floating-drum model. It is true that biogas plants have zero maintenance if the plant is constructed perfectly. Only trained technicians construct the biogas plants.

System of monitoring is as follows (three tiers):

1. In the field, if there is complaint to the plant, the plant owner will contact the concerned coordinator directly and he would do the needful to ensure the functionality of the plant. The coordinator keeps a complaint cum rectification register. The register is checked by the headquarters staff annually.
2. There are beneficiaries calling the NGO headquarters regarding complaints of biogas plants. In this case either the office rectification staff goes to the plant and clears the problem or the headquarters direct a local technician to do the job. The headquarters maintain a register of these cases.
3. Every year, the headquarter staff conducts random inspections of 10 biogas plants under the canopy of each coordinator to ensure the functionality status of biogas plants. We have found this mechanism very effective. The inspection report is finally checked and signed by the Executive Director.

All technical staff at different levels are well versed with all rectification measures as far as a biogas plant is concerned.

In the second phase of the Kerala Carbon Credit Program, our coordinators instructed their teams to select only those plants which are functioning actively. So, defective or defunct plants are not part of the program. In order to be sure of the functionality of the biogas plants during the past years and to ensure the ownership of the land, participants are asked to get the same certification by the Panchayat Raj local body members who are part the Panchayat Raj governance of the country and a powerful local administrative hand. This modality has been approved by the CCX as third-party certification of the protocol. Further, coordinators/their team members are asked to recommend the plant to be included in the Carbon Credit Program. They do the same only after a detailed site visit and discussions with the Panchayat Raj member. These recommendations/certifications are done on the reverse side of each information sheet of the biogas plants, which is called the application form of the Carbon Credit Program. This application form is primarily signed by the applicant himself/herself.

We also have a printed agreement signed by each beneficiary affixing court fee stamp. The agreement mainly states that he/she will maintain the biogas plant effectively and payment terms and that he/she shall not sell the carbon credits to anyone other than The Andhyodaya, the NGO which is the aggregator of the program. It also elaborates some other details of the scheme. Through this document the aggregator enters into agreement with the owner of biogas plant.

The Andhyodaya Green Energy Technology Pvt. Ltd., a CCX-approved offset provider, has been appointed by the NGO to do the registration and trading in the CCX platform.

We have a three line monitoring system of biogas functionality and customer services:

1. *Coordinator – customer line*
   Taluk level biogas coordinators working from 1995 onwards. The beneficiary has close contact with the coordinators. They know them personally because they are from their area. If a plant owner has some problem regarding the biogas plant, he/she will contact the coordinator personally or over phone. After receiving the complaint, the coordinator will visit the plant and do proper service required in order to insure active function of the plant. These coordinators maintain a service register annually. At the end of each year, coordinators submit their service register to the Andhyodaya Headquarters. This document is verified by the project coordinator and the Executive Director.
2. *Headquarters – customer line*
   Each beneficiary is given an operation manual of biogas plants which has the office address and phone numbers on it. The biogas plant owners are encouraged to contact the office directly if they want to communicate something special. The office has a register for this customer care. After receiving a call from a customer, either the field coordinator is directed to attend the case or the project coordinator directly visits the location.

3. *Random verification line*
   In order to ensure that the coordinators do the monitoring of biogas plants perfectly, 10 numbers per coordinator of random verification are conducted by the office staff annually. Selection of these ten sites of each coordinator is strictly done by the Executive Director.

Benefits to Project Partners

- MNRE, GOI – financial support to a historical project in the country
- Funding agency:
  (a) Revenue of 70% CERs of the project for 10 years
  (b) Be a part of a historical project in the country
- Beneficiary – own and use a BGP *almost free*
- Andhyodaya:
  (a) Delivery of a historical project in the country
  (b) Revenue of 30% of CERs towards the cost involved in AMC and a profit for the organization

Other Direct Benefits of the Project

- Carbon emission reduced – 2.5 million metric tons
- Employment generation (1 lakh = 100,000):
  Skilled = 2.5 lakh man days
  Unskilled = 7 lakh man days
- Clean cooking gas for the rural families at 1 lakh cubic meter/annum
- The project replaces (1 crore = 10,000,000):
  1.46 crores kgs of LPG/annum (1 m^3 = 0.40 kg LPG)
  1.28 lakh tons of firewood/annum (1 m^3 = 3.5 kg firewood)
  2.19 crores liters of kerosene/annum (1 m^3 = 0.6 l kerosene)
- Nitrogen-rich organic manure – 7.3 lakhs tons/annum
- Clean and hygienic kitchens in 50,000 families
- Health improvement of women in kitchen 50,000 families

Where Is It? (Fig. 6)

Partner Organizations

SHGs, community organizations, local self-governing bodies

Fig. 6 Map of Angamaly, Kerala, India

Progress (Figs. 7 and 8)

Fig. 7 Home cooking on biogas generator

Fig. 8 Biogas generator

Values

Project Impacts

- The project became an eye-opener to the government bodies and they have made it a policy to promote biogas plants as an effective means for waste management including rubber latex wastewater.
- Being an innovative project, the media took great interest in promoting the program. Ties have been made with the local community organization like family association and self-help group; in fact, awareness generation of the program is still continuing through these organizations.
- The environment preservation committee (EPC) sets up the implementation of the project and they monitor the performance plants constructed and ensure the smooth functioning of them. The beneficiaries contact the members of EPC if they have a problem.
- Almost all the objectives of the agreement are accomplished. It has improved the health and economy of Indian communities and gives a positive impact on global environment.
- The project helps to carbon emission reduction.
- It is an income generation program.
- Domestic fuel is generated and the residual water is suitable for irrigation.

Photos (Figs. 9, 10, 11, and 12)

Fig. 9 Shri. Peter Thettayil, Executive Director, The Andhyodaya

Fig. 10 Peter with a solar heating module.

Fig. 11 Organic feed is consumed by livestock

Fig. 12 Peter pointing to a biogas generator in the ground

Validation

The Andhyodaya has installed over 25,446 biogas generators and has had professional independent certified agents verify the carbon offsets. Unfortunately, when they were ready to go to market with those credits, the carbon exchange credit market bottomed out and the expected residual funds expected from that community were never realized and the funds expected for those adaptations are still going unpaid.

Mr. Peter Thattayil is one of the best examples of how an entrepreneur can aide with local implementation activities that are environmentally sustainable, create a financial base for sustainability, and develop enthusiasm within the local community residents and governmental and nongovernmental leaders as well as his committed group of animators and activators. The Andhyodaya organization aides in the operation of organic farming, biogas generators, carbon sequestration plantings, smokeless cooking stoves, and rainwater harvesting devices. It works from the smallest scale – single-family houses to full-scale endeavors such as schools, hospitals, and convents. My visit of July 27, 2011 to the field projects that Andhyodaya is associated with yielded enthusiasm at all levels indicating that this type of local support can spread across each community.

7 Conclusion

With the onset of climate change, a great push for "green" and sustainable living has occurred. Spurred by the value of saving carbon, financial entities within developed countries have joined the chorus of reducing their carbon input by adopting sustainable practices such as recycling as well as by investing in carbon credits in underdeveloped nations. Various markets and indexes have been created but with limited veracity and self-sustaining methodologies in place. The primary inhibitor to environmental projects which create carbon offset credits is the ability to continue operation beyond expenditure of the initial funding. Creation of a conditional exchange program based on carbon credits enables a higher probability of project self-sufficiency; however, lack of supervision of fund reinvestment may be self-defeating in the long-term goals of sustainable lifestyle development. Additionally, environmental carbon offset projects must be accompanied by youth education and public awareness agendas. Encouraging green lifestyles and business practices in tandem with green education and public awareness brings a holistic approach to each society impacted and tends to have long-term results. The carbon marketplace offers plentiful bounty for those adept, savvy investors while positively affecting the native communities where the projects are located economically, educationally, and environmentally. The Youth Voices in Conservation's GreenLeaf Program is an answer to this dire need. This multifaceted program has all of the essential elements necessary for long-term success in perpetuity. The program is an innovative shortcut towards a green future which is equipped with the veracity necessary for surety in investors looking for sound investments. Youth Voices is currently seeking visionaries who envisage a green future prosperity (Fig. 13).

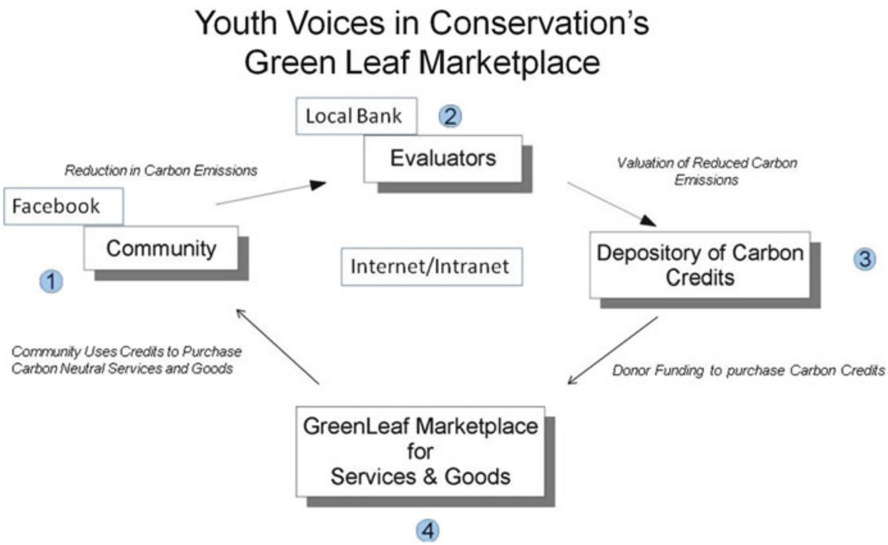


Fig. 13 The GreenLeaf marketplace sequence

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The "Ecological" Stock: "A Financial Market Instrument for Global Scale Climate Change Mitigation"

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Abstract This financial market instrument first addresses the issue of "global risk": the combined world economic, political, and social risks that are rapidly resulting from the unparalleled planetary environmental degradation and climate change. It provides evidence that "global risk" can be reduced with investments in forest preservation, reforestation, and renewable energy. Furthermore, it shows that in order to achieve the urgently needed global scale climate change mitigation and neutralization, new massive capital investments can be stimulated and, thereby, shifted, through the profit motive utilizing financial product innovations in the free market system with the active participation of the private sector. The "Ecological" stock is a certifiable and tradable innovative instrument that incorporates features of a corporate stock, a commodity, a derivative, and a perpetuity.

It aims at developing a world financial market for emissions and environmental services trading by creating financially feasible investments in the following areas: (a) forest conservation and reforestation, (b) renewable energy, (c) CDM projects, and (d) foreign debt swaps for poor and developing countries. The investor acquires certified "Ecological" stocks as a registered security in the national exchange of host (poor, developing, or industrialized) country project and in the international exchanges, with rights to profit and capital gains as well as rights to the certified GHGs emission reductions and the environmental products of the project (carbon sink, water conservation, biogenetics, soil fertility, and global warmth reduction). The shareholder becomes, then, the "ecological" owner of a specific project.

One of its goals is turning the CDM model of the Kyoto Protocol into a new global financial industry under a voluntary scheme as well as under the protocol, using the "Ecological" stock in the exchanges to motivate the participation

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*, 171
DOI 10.1007/978-94-007-5995-4_9, © Springer Science+Business Media Dordrecht 2013

of ALL nations through profitability—economic democratization of climate change mitigation and neutralization—so as to mitigate climate change "beyond a carbon neutral world" and "beyond global emission reductions" in order to start restoring equilibrium in the planetary ecological system, hence, the climate.

Keywords Market • Financial • Instrument • Global risk • Debt swap • Dividend • Profit • Kyoto Protocol • Sustainable development • EcoStock

1 Introduction

The world economy can grow if and only if it is running profitably. Profit is the financial return on investment which allows new capital investments to support continued employment and growth (McConnell). On the opposite, if profit is not present, the added investment required for expansion descends or stops, creating economic recession or stagnancy. Based upon this fact, how can there be probable investments in climate change mitigation from industrialized or developing countries with the absence of financial incentives? A mandatory accord without an economic incentive contradicts the spirit of the free market system and, consequently, of economic stability and growth. The Kyoto Protocol is a mandatory agreement that does not offer any incentive to industrialized nations for emission reductions. Therefore, if the Kyoto Protocol or any national environmental legislation for mandatory emission reductions is to have success, it must provide economic incentives.

Since profitability is the key motivating factor for all capital investments, the global economic system needs revolutionary financial product innovations to motivate economically attractive investments in both sustainable development and climate change mitigation.

Complementarily, if global warming and its consequential polar melting are moving at a speed immeasurable by human science, from the political and economic stand point, what is the most efficient, effective, and quickest option of the world to mitigate climate change? A viable alternative is a massive worldwide shift in new capital investments into renewable energy technology, the conservation of the natural forests, and reforestation in a financially feasible way through financial product innovation and with the active participation of all nations in the capital markets.

The "Ecological"[1] stock, or interchangeably the "EcoStock," has been designed to provide the financial motivating factor for the world economy to achieve "global scale climate change mitigation and neutralization": *profitability*.

[1] Product R&D began in 1996. Basic product design was completed in early 1998. From 1998 to 2006, it has undergone several upgrades and enhancements.

2 Global Risk

"Global risk" (*GR*) is the combined world economic, political, social, and warfare risks that are rapidly resulting from the unparalleled planetary ecological degradation with strategic natural-resource scarcity, over pollution and contamination, drastic climate change, ozone layer depletion, excessive biodiversity loss, and nuclear waste. It involves the appraisal of the following variables by country, region, and the globe in terms of rate, percentage, monetary value, etc.: (1) deforestation; (2) water scarcity and contamination (i.e., rivers, lakes, and underground water sources); (3) soil erosion and contamination; (4) desertification; (5) biodiversity loss; (6) concentration of GHGs in the atmosphere; (7) primary and secondary forest land per capita (forest land/total population), a variable determining the ecosystem capacity to support the economic system and the population; (8) agricultural sustainability; (9) ocean ecosystem degradation; (10) ozone layer depletion; (11) climate change intensity and variability; (12) food security; (13) environmental emigrant, a variable measuring the number of people leaving their native land because of environmental problems, climate change, or agricultural losses; (14) nuclear waste; (15) poverty; (16) unemployment; (17) general price index; (18) environmental law effectiveness; (19) environmental education; (20) R&D on renewable energy technology as a percentage of GDP; (21) disease propagation (i.e., over pollution and contamination with high temperatures and virus and bacteria natural mutation facilitates the propagation of old and new diseases into epidemics); (22) sustainable development as a percentage of GDP; and (23) political and nuclear confrontation probability for the dwindling strategic natural resources.

The measurement of GR links climate change and ecological degradation with the performance of the world economy; that is, GR increments are directly associated with the rising economic losses produced by climate change. Thence, there is a real need to control and reduce GR, which can be accomplished through the global investment areas of the "EcoStock" outlined in the investment section. This is to avoid an economic recession without parallel in recorded history. Moreover, since the current growth economic projection excludes the GR factor from the equation, it needs to be inserted in the balance sheet of national and multinational corporations and in the GDP and GWP calculation. The assessment of GR is, thus, required in order to have a true appraisal of the global economy as well as of the state of the world.

3 The International Financial Market and Climate Change

Structural changes in the world economy, the gradual liberalization of the international monetary system (i.e., from the gold standard to the euro), the development of financial markets, the growth of international trade, and the role of advanced information technology have given the basis and the dynamics of the financial market system of today (Eiteman and Stonehill 1973).

In the commodities market, the rising market prices of gold ($ 35.00/oz. in 1934) and crude oil (approximately $2.00/barrel in 1973) are a direct result of the market pressures that have gradually originated by the above-mentioned trends, mainly the strong dependency on oil (i.e., estimated 40% of energy supply), increasing "global risk" and recent political and military conflicts.

Just to recall a few factors: the gold standard, fluctuating exchange rates and Bretton Woods, the I.M.F., the Smithsonian Agreement of 1971, the oil crisis of 1973 and its consequences (i.e., oil prices quadrupled in 1974), the reform of the international monetary system of 1976, the 2d. oil crisis of 1979, the European Monetary System (1979), the European Currency Unit, and the euro. The outcome has been an increased volatility in currency exchange, interest rates and inflation rates, and, thereby, an increased exposure to such financial risks (Ethier 1983). Gold and other metals have served as an alternative investment to hedge against this type of risks and as well as for speculation, but more recently as a "global risk" hedger thanks to their condition of hard assets and of precious metals.

Today, structurally and functionally, the international financial market has the capability to take in financial product innovations to satisfy new latent demand of the global economy like the urgent necessity to invest in the mitigation of climate change (Labatt and White 2002) and to reduce "global risk" with the active participation of the private sector through the exchanges. Moreover, a gradual integration of the world exchanges and a greater deregulation oriented to foster market efficiency is to the very advantage for the growth of the capital markets, large-scale investment projects and, thus, the world economy.

4 Global Investment Areas of the "Ecological" Stock

The following are perpetual-life projects for sustainable development and climate change mitigation:

(a) Forest conservation. Natural sinks (i.e., the Amazon forest, the Mesoamerican forest, the African tropical forest)
(b) Large-scale reforestation. Restored ecosystem sinks (i.e., Latin America, Africa, India, China, Australia, USA, Russia, EU)
(c) Renewable energy technology. Global emission reductions (i.e., industrialized, developing, and poor nations)
(d) Foreign debt swaps of poor and developing countries for any of the above
(e) CDM projects in the above investment areas.

5 Description

The "Ecological" stock is a hybrid, certifiable, and tradable financial instrument designed for the world exchanges. As a hybrid instrument, it combines augmented and expanded financial features of a corporate stock, a commodity, a derivative, and a perpetuity—a financial product innovation.

6 Objectives

1. Develop a global and profitable financial market for emissions and environmental services trading to generate massive capital investment shifts into climate change mitigation
2. Achieve global emission reductions without limiting targets as well as the neutralization of carbon and other GHGs
3. Financially motivate the participation of all nations in climate change mitigation and neutralization in the capital markets, under the Kyoto Protocol to facilitate its full implementation, as well as under a voluntary scheme
4. “Avoided deforestation”
5. Reduction of “global risk”
6. Major cost reductions in meeting ER commitments
7. Foster market efficiency and portfolio diversification
8. Integration of the major world exchanges and expansion of the capital markets
9. Promote global sustainable development
10. Cutback of large-scale crop losses worldwide
11. Deterrence of a world economic recession
12. Nature conservation
13. Prevention of political conflicts, including nuclear confrontation, for the rapidly dwindling strategic natural resources
14. Conflict avoidance between ER targets and international trade (WTO rules).

7 Hybrid Financial Features

7.1 An Augmented Perpetuity

The “EcoStock” has no maturity date. The investment projects from which it emanates are intrinsically perpetual as the first legally binding condition. In a natural forest or reforestation project, the forest land will be perpetually preserved (i.e., the Amazon forest). A renewable energy project will be open-ended with R&D mandatory requirements for continuous technological upgrades. The legal guarantee for the investors is satisfied by the registration of the project in the national registry of the host country with an irrevocable perpetual condition.

The earnings, the cash inflows and/or dividends, are, therefore, perpetual with payment modes that can be customized to investor’s needs. They can be fixed, periodically adjustable, pegged, floating, or declared.

7.2 A Commodity

It must first be taken into account that climate change mitigation and neutralization occurs not only through GHGs emission reductions but also by the total project’s ecosystem environmental products—specific goods and services produced by a particular project as a result of a positive change in the ecological condition because of the entry in functioning of a renewable technology versus the nonrenewable one or by the restoration of the ecology trough reforestation, "avoided deforestation," or natural forest conservation management improvements. A direct impact, immediate or gradual, in the global ecosystem and the climate system is in the temperature—global warming reduction or offset, which is measurable in degrees centigrade or Fahrenheit with monetary units in favor of the financial value and investment return capacity of a given project.

Three basic conditions must be met in order for an ecosystem environmental product, a renewable energy, or a GHG to be a commodity: transferability, measurability, and marketability. Transferability is satisfied through the "EcoStock" as a certified and registered security in the exchanges (i.e., similarly to the way gold or currencies are traded in the exchanges, which use the traditional financial contracts: derivatives). Measurability is possible for every single commodity. A method of measuring emission reductions of CO_2 and other GHGs is the result of relatively recent scientific achievements, but the aim is to have standardized measurements for every type of environmental and renewable energy commodity. Marketability equates to having latent market demand and financial liquidity. GHGs are marketable commodities not only due to the existence of the Kyoto Protocol and mandatory emission regulations, but also because of the urgent need of the world economy to quickly reduce and neutralize their excessive accumulation in the atmosphere to mitigate climate change. Similarly to gold and other precious metals, environmental products and renewable energy and technology are scarce and precious commodities because of their vital role for the sustainable running of the global economy. Therefore, they have market demand and financial value for climate change mitigation as well as for hedging against market volatility (i.e., oil and gas price sensitivity) and "global risk."

The investment project generates specific commodities and the corresponding Mitigation and Neutralization Certificates (MNCs). The latter one encompasses the certified emission reductions plus the project's overall ecosystem environmental products.

Project	Commodity	MNC
Energy	Renewable energy and technology	ERs of CO_2 and other GHGs global warming reduction/offset
Forest conservation and reforestation	H_2O, O, biogenetics, and soil fertility	ERs of CO_2 (carbon sinks) and other GHGs
		Natural ecosystem production of H_2O, O, biodiversity and soil global warming reduction/offset

Based on the above, the MNC reflects the full contribution of a project to climate change mitigation and neutralization and, thence, its fair market value, integrating the complete financial and climate change factor assessment of any given project. The MNC is also designed to provide customized "Carbon Neutral" or other specific

GHG neutral certification for any member of both the private and the public sector (i.e., corporations, NGOs, municipal governments, and federal governments) of industrialized, developing, and poor countries.

As an integral component, it is intrinsically derived from a share of the "EcoStock." The ratio of a share of a stock to the MNC is flexible or adaptable to the changing needs of the supply and demand side of an evolving market to facilitate the trading in the exchanges by project type. In the voluntary market, besides the basic emission reduction certification, the number of added certifications would depend upon investor's preferences to increase the value of the share or to expand profitability. Similarly to the universal culture in stock investments, the market forces play a relevant role in investor's decision making. Within the regulated market, it would be a function of the environmental laws to meet mandatory compliances or of enhancements of the CDM Modalities and Procedures of the Kyoto Protocol (The Kyoto Protocol).

With the profit motive offered by the "EcoStock," massive capital investment can be shifted into renewable energy technology. Thus, hydrogen-, solar- and wind-powered energy technologies can shortly become the major suppliers of energy and the principal commodities in the global energy market, substituting oil and coal in the world economy, including any type of fuel (i.e., biofuel) that produces heat by combustion. Furthermore, the "EcoStock" offers the option for an early market introduction of strategic ecosystem environmental commodities to accelerate the process of climate change mitigation and neutralization as well as to foster sustainable development. Since the natural ecosystem cycles of carbon, water, oxygen, and soil depend on the declining biodiversity of the planet, which has had, up to now, little price assessment by the economic system, their latent market demand is currently underestimated in spite of the critical role and dependency of these environmental services for the normal running of the world economy and the capital markets. Water, oxygen, soil fertility, and biogenetics are rapidly becoming scarce ecosystem environmental commodities. Water is a strategic commodity whose supply–demand equation in the world economy (i.e., drinking water, H_2O for agriculture and industry and as an energy source) is considerably out of balance because the supply side is dwindling at an unmeasured rate, while the demand side is increasing exponentially. Similarly to water, the fragile situation of oxygen supply and soil fertility availability need to be at the forefront of the world economy (i.e., in 1998 scientist Niles Eldredge (1998) stated that the planetary supply of oxygen is "in imminent danger of collapse" and the "Earth is losing 25 billion tons of topsoil each year through erosion"). Additionally, as the Kyoto Protocol is linked to the Montreal Protocol, the ozone layer-depleting elements can be introduced into the market.

7.3 An Expanded Derivative

The modern technical definition of a derivative is "a financial contract the value of which is derived from the value of another (underlying) asset, such as an equity, bond or commodity" (*The Economist* 1996). However, derivatives are not new;

options and forwards are as old as trade. In recent economic history, money was the most widely used derivative during the period of the gold standard; its price was derived from the value of gold as a universal instrument of exchange. Also, the underlying assets can be financial or nonfinancial in nature.

The market value of the "EcoStock" is derived from the combined value of the following three certifiable and tradable underlying assets:

CCM Asset I (Project)	CCM Asset II (Commodity)	CCM Asset III (MNC)
Energy	Renewable energy/technology	CO_2 and other GHGs global warming reduction/offset
Natural forest and reforested land	H_2O, O, biogenetics and soil fertility	CO_2 (carbon sinks) and other GHGs
		Natural ecosystem cycles global warming reduction/offset

The trading of futures, options, swaps, and "exotics" of "EcoStocks" in the world exchanges will provide significant market flexibility, efficiency, and liquidity with relevant cost reductions for national and multinational corporations under the Kyoto Protocol as well as under a voluntary scheme.

The price calculation of an "Eco Derivative" ranges from relatively simple to rather complex multivariable mathematical equations with I, II, and III underlying assets.

7.3.1 Foreign Debt Swaps

International geopolitical law distributes the global ecosystem in national territories or countries, with jurisdiction over the remaining strategic natural resources and primary forests. A large number of developing and poor countries contain the little standing primary tropical forests and the falling strategic natural resources of the planet. Simultaneously, most developing and poor countries are running with high fiscal deficits and foreign debts and are in the need for long-term solutions.

The "Ecological" stock is a feasible and flexible alternative via swaps: foreign debt for forest conservation, reforestation, and renewable energy projects. The multinational corporation, industrialized government, lending entity or individual investor that swaps the foreign debt will receive in exchange "EcoStocks" from the indebted country in one or more of the following:

1. Forest conservation swaps
2. Reforestation project swaps
3. Renewable energy project swaps

In consequence, developing and poor countries will be competing among themselves for the foreign direct investment for climate change mitigation and neutralization on the three types of investment projects, offering attractive economic incentives to investors.

Since there is a direct linkage between deforestation and natural resource depletion (John 1964) with the level of poverty, crop losses, and food scarcity of a given country (i.e., Haiti, most African and Latin American nations), these types of swaps will contribute not only in mitigating and neutralizing climate change but also in preserving the decreasing strategic natural resources, reducing poverty and increasing food security. Entities like the IMF, the WB, the Paris Club, industrialized governments, and international lending banks have this option available to foster sustainable development in poor and developing countries.

7.4 A Universal Financial Instrument

The primary basis of the "EcoStock" is the profit motive. From the climate change standpoint, the complete mitigation and neutralization without limiting targets are the objectives.

Similarly to the corporate stock, it is a transferable unit of ownership with profit rights through price appreciation and dividends. The added special functionality consists in its hybrid financial features and of encompassing the combined market value of the three certifiable underlying assets described in the above derivative section.

Each share of "EcoStock" is directly binding to a specific project, host country, and geographical location. Investors will select geographical areas or countries of ecological and climate change priorities, which are the ones with the highest market potential (Franklin and Gales 1994). Regarding natural forest preservation and reforestation projects, the share will explicitly state that it does not comprise the right for the exploitation or the depletion of natural resources because it is in opposition to the preservation and the climate change mitigation purpose. Nevertheless, the shareholder is the perpetual ecological owner. This legal quality for forest and reforested lands also has the objective of eliminating the potential political and environmental concerns of the governments and the citizens of host countries regarding national sovereignty.

Depending on investor's preferences, the project's certification for climate change mitigation or neutralization by the corresponding authorized entity can be either under the Kyoto Protocol or under a voluntary scheme. Once a project has obtained the respective certifications, a new kind of corporation needs to be established for the issuance and the registration of "Ecological" stocks and of the MNCs and, thus, for the adequate management of the investment project. Its main mission and business activity is the mitigation and neutralization of climate change as a fixed legally binding and perpetual condition. This binding condition is another sound legal guarantee for investors and the international community under a voluntary scheme and under the Kyoto Protocol and provides the ground stone for the origin of a specialty and novel type of business firm: the Climate Change Mitigation and Neutralization Corporation (CCM Corp.), the only legally authorized organization for the issuance of "EcoStocks" (i.e., in economic history, the entrepreneur's mind has given birth to several legal entities such as the corporation, the cooperative, and the foundation to satisfy different needs for growth and development. The global economy now urges for the creation of specialized business entities or corporations to resolve vital threats like climate change (Tufano 1996)).

The business activity will not be subject to the risk of traditional business cycles because the projects will be operating with an open-ended global demand for climate change mitigation and neutralization as well as for "global risk" hedging. The CCM Corp. may engage in additional complementary activities to augment its core business and expand profit as well as stockholder's value.

Besides the above, as the international financial system becomes gradually more efficient with the integration between the major world exchanges and those of the emerging economies and of host country projects, allowing the trading to take place as a single and free global exchange (Labatt and White 2007), the "EcoStock" is designed to become a financial instrument for universal trading. Once registered in the exchanges, it will be internationally traded as a "universal" security, that is, independently of the geopolitical frontiers and economic differences of nations thanks to its hybrid financial features that provide versatility for practically unlimited modalities to satisfy investor's needs, its attractive expected return on investment, its cost efficiency for emission reductions, its effectiveness to mitigate and neutralize climate change, and its low investment risk.

7.5 The Dividend

The dividend per share of the "EcoStock" is a perpetual one with the flexible payment modalities of the augmented perpetuity: fixed, periodically adjustable, pegged, floating, or declared. Sales and trading will be taking place in the international market and in the host country market (i.e., a renewable energy project will sell energy in the host country as well as trade carbon credits in the international market).

As with any business, profitability is the pillar for a continuous and successful operation. The investment projects, then, will be focusing in achieving economies of scale, operational efficiency, and technological improvements in order to become profitably sustainable. Renewable energy projects will need to be very competitive in order to satisfy permanent R&D requirements for continuous technological upgrades. Forestry and reforestation projects will need to be very innovative in sustainable forestry management.

Investor's preferences will be reflected in a diversity of classes of "EcoStocks" and, in turn, influence the market demand and the price appreciation; that is, the perceived value of "EcoStocks" of, for example, the Amazon forest, the Indonesian forest, an Australian reforestation project, or a China renewable energy project will vary according to investor's assessment of profit potential.

The "Perpetual Growth Model" (Van Horne 1968) of financial theory provides a fair and very basic illustration for projecting the expected return, R:

$$*R = \frac{D1}{\text{Po}} + G$$

$D1$ = Dividend per share at end of first period, Po = Current market price a share, and G = Annual expected dividend growth over the future.

This equation can be modified so that G will change annually according to investor’s estimate of the dividend growth potential in the long run.

8 Market Development

The current players of the financial market plus national and multinational corporations with emission reduction policies, “Carbon Neutral” strategies, or mandatory emission regulations along with local and federal governments, within the Kyoto Protocol or voluntarily, will have the option of investing in “EcoStocks” for two main reasons simultaneously: profit and climate change mitigation and neutralization.

Profitability joined with an attractive investment return and a low investment risk offered by a uniquely versatile financial instrument will be stimulating the supply and demand market forces to grow freely, progressively developing into a new global financial market for emissions and environmental services trading []. This new global market opens the opportunity for large and small investors worldwide to participate in the exchanges in climate change mitigation and carbon and other GHGs emission neutralization: economic democratization of climate change mitigation.

As the new global financial market grows, the free market forces will gradually transform the CDM model of the Kyoto Protocol into a distinctive and profitable financial industry under a voluntary scheme and under the Kyoto Protocol. Profitability and the need to mitigate and neutralize climate change will motivate private and governmental sector participation of all nations in the world exchanges, generating GHGs emission reduction and neutralization projects without limits or predefined targets, allowing the intrinsic investment return attractiveness of the free market system to develop beyond a carbon and other GHGs neutral world and beyond global emission reductions, which are necessary conditions to start restoring the planet’s ecological equilibrium and, thus, the climate system (see Annex I).

Profitability by project type will be the driving investment motivation for the structural development of the market. Additionally, as the secondary market develops, the liquidity of the market will begin to grow providing greater flexibility in the trading.

9 Pricing and Placement

The “EcoStock” generates profitability with certified effectiveness in climate change mitigation and neutralization, making it a novel attraction in the exchanges.

Investor's perception of risk and the expected rate of return on the investment, jointly with the current demand–supply market forces, determine the final price of a security. Complementarily, the estimated market growth potential influences in determining the price appreciation in the short-to-medium run.

In accordance with traditional practices in the exchanges for the introduction of new stocks, the introductory price of the "EcoStock" will be a reference value, under the placement approach of "Making a Market," allowing the demand and supply market forces and investor's risk perception, under the normal efficient market condition, to set the price. The reference price will vary by project type and its final value will reflect all market variables and climate change information regarding the particular investment project.

Market efficiency "means that the market price of a security represents the market's consensus estimate of the value of the security." In order for the market to be efficient, all public information available about the economy, the financial market, and the specific firm is analyzed in the setting of the price. The international financial market, then, needs to fully include into the formal information channels to investors the climate change factor and complementary environmental variables relevant to the decision making process.

Conservatively but not exclusively, the first stock offering strategy could be a "private placement" with preselected multinational corporations and individual and institutional investors. The initial offering can also be realized as a pilot project at a selected major exchange (i.e., LSE, NYSE) with an investment project in a climate change priority developing or poor country.

The success of a "private placement" or of a public pilot trading is relatively easy to estimate, especially if the investor's benefits listed in the following section are taken into account. The profit potential of the "EcoStock," the forecast market growth trend under the voluntary scheme or under the Kyoto Protocol, "global risk," national environmental legislation, and mandatory compliances will be added investment attractiveness for portfolio diversification.

10 Investor's Main Investment Benefits

1. Profit (i.e., dividends plus capital gains)
2. Cost efficiency and cutback in meeting Kyoto Protocol, voluntary, or national mandatory emission reduction targets
3. Avoidance of Kyoto Protocol or national regulatory penalty costs (i.e., in the short run, there will be an increasing number of projects from the supply side of the market readily available as "EcoStocks" to parties with emission reduction commitments.)
4. Financial and nonfinancial benefits from carbon and other GHGs emission neutralization
5. Corporate green-ecological marketing
6. Partial or complementary environmental liability compensation (i.e., when applicable, environmental liabilities and fines could be partially compensated with

investments in "EcoStocks." Corporate environmental costs are gradually being required that they be explicitly accounted for disclosure in the profit and loss statement. Some investors claim that corporations have the customary practice of hiding or downplaying cleanup costs, fines, and other environmental liabilities that shareholders need to know about for their investment decision making.)
7. Lower impact on national budget deficits (i.e., industrialized governments will not need to use their scarce funds and, thus, there will be less pressure on their large national deficits.)
8. Income tax exemptions and environmental tax credits (i.e., these incentives could potentially be offered by governments to stimulate investment.)
9. Global productivity improvement for sustained economic growth.

11 Market Base

The "EcoStock" is designed for a wide target market, including a number of market segments and the global citizen within an economic democratization of climate change mitigation and neutralization.

For the sake of simplicity, the market can be condensed in two large groups of prospect investors.

11.1 The Current Players of the Financial Markets

The portfolio managers, the mutual or equity funds, the speculators and hedgers, the institutional investors, and the investment banks will find the "EcoStock" as a financial innovation with an attractive investment return for expanding portfolio diversification and, thus, reducing portfolio risk.

11.2 The New Prospects

The "EcoStock" will bring new players into the stock and commodity exchanges. Their investment decision will be motivated mainly by new financial returns mixed with the necessity to protect the world economic system, the capital markets, the national industries, and the population from global warming or the climate change threat.

Carbon and other GHGs emission neutrals. This market sector involves national and multinational firms having a corporate strategy of neutralizing their emissions around the globe. The "Ecostock" is designed to offer the most cost-efficient and cost-effective alternative for certified emission neutralization.

Large- and medium-size polluters. A business activity whose production process, product package, and product consumption that creates a hazardous impact to the environment or contributes to climate change is either being required to make modifications in its plant-manufacturing facility, production system, and technology by current environmental regulations or 20 will shortly be by new environmental laws that are under way to reduce emissions. Laws and regulations are generally evenly applied to a particular industry, but not all the firms within an industry have the same financial capacity to make the capital investment to carry out the required changes in the plant or in the technology. To avoid financial distress within a particular corporation or an industry, regulation flexibility can be brought about through the "EcoStock" for the cases of companies whose financial position is not strong enough or justifiably does not permit to satisfy all the requirements of an environmental law or a mandatory regulation. For example, the implementation of the regulation can be turned into gradual steps with the condition that a specified percentage of the delayed change in the production facility or the technology be invested in "EcoStocks." In this manner, an environmental compensation is being created. Also, particular regulations can include tax breaks, income tax exemptions, and environmental tax credits plus nonfinancial incentives for those corporations that invest in "EcoStocks."

Agriculture and the food industry. Many crop losses around the world have been and will continue to be caused by climate change. National and multinational agricultural companies and farmers in general will see investing in "EcoStock" as an opportunity to help mitigate climate change to minimize the probability for crop and financial losses.

The pharmaceutical industry. Leading multinational firms are recognizing that the species of the natural forests contain the medicines for most of the incurable illnesses affecting humanity today and that the future medicine depends on R&D around those native species. These firms are interested in preserving the forests that have the biogenetic asset needed for their core business, which they can cost-efficiently do as shareholders of "EcoStock" from specific tropical and nontropical forests of interest.

The rising new global industries. Several of the fastest growing new industries in different industrialized and developing countries are those that have stemmed from a new business philosophy, one that is characterized by ecologically friendly business practices and by production processes with a vision of making a contribution for the construction of a better, cleaner, and healthier world as well as for expanding their market. Some notorious ones are the industries of renewable energy, organic agriculture, recycling, 100%-natural consumer and health products, and biotechnology, among 21 others. Besides the profit motive of the "EcoStock," as shareholders they will promote a green corporate image, which can help in improving their market penetration or product positioning. Green marketing strategies are already being practiced by a few leader corporations with slogans such as "help preserve the planet" or "save the forest." The "EcoStock" will have its own distinct logo and slogan (i.e., "A world united for climate change mitigation and neutralization").

The global citizens. Citizens and families around the globe have been directly or indirectly affected by environmental problems and climate change. The "EcoStock" will bring about a new investment opportunity in the exchanges for them to participate in resolving a problem that is global.

12 Key Success Variables

1. Beyond traditional thought. Traditional financial thinking must be surpassed to realize that investing in forest conservation, reforestation, and renewable energy projects is good business and that the development of an emission and environmental services trading market through financial product innovation can effectively mitigate and neutralize climate change profitably.
2. “Global risk” awareness. Economic and political leadership—a planetary vision to reduce “global risk” and to achieve true global sustainable development for the well-being and prosperity of all nations.
3. Economic, entrepreneurial, and political will to go beyond the low emission reduction targets of the Kyoto Protocol within the short- term by simply *endorsing* readily functional financial product innovations such as the “EcoStock.”
4. Corporate community will need to foster integration of the world exchanges to stimulate capital market expansion and dynamics.
5. Financial operating transparency and integrity.
6. Ecological transparency and integrity.
7. Foundation of a syndicated bank specialized in the financing of climate change mitigation and neutralization. Industrialized governments can ideally participate in the foundation of this international bank.

13 The CERs and the “EcoStock”

Main Differences

1. The CER is a tradable certificate. The “EcoStock” is a hybrid financial market instrument designed to operate in the world exchanges as a universal security, with the versatility of the combined features of a corporate stock, a commodity, a derivative, and a perpetuity.
2. The CER is limited to only the trading rights for emission reductions, excluding, thus, the environmental products and their climate change mitigation benefits of any given project. The “EcoStock” encompasses perpetual rights of ownership plus rights to dividends, to capital gains, and to the trading of the Mitigation and Neutralization Certificates (MNCs): emission reductions plus the overall project environmental products and, thus, the global warming reduction/offsetting factor plus complementary mitigation benefits.
3. The CER is traded between parties to meet limited emission reduction commitments set by the Kyoto Protocol (Articles 3, 6, 12, and 17). The “EcoStock” is traded for profit, allowing the free market system to mitigate and neutralize climate change without any limit, functionally for both the Kyoto Treaty market as well as for the voluntary market.
4. The CER separates industrialized nations from developing and poor countries. The “EcoStock” unites industrialized nations with developing and poor countries for a common world objective and responsibility.

5. The CER is measured in metric ton. The “EcoStock” is measured in monetary units (i.e., euros; US dollars) as well as in several units of weight besides metric tons because of the different types of certifications it includes in the Mitigation and Neutralization Certificate.

14 Implementation Flow

1. Initial group of investors (i.e., national and multinational corporations, investment banks, individual and institutional investors, venture capital firms)
2. CDM model perpetual projects in monetary units: (A) natural forests conservation, (B) renewable energy, (C) reforestation.
3. Project certification under the Kyoto Protocol or under the voluntary scheme.
4. Establishment of the Climate Change Mitigation Corporation (CCMCorp.).
5. Certified issuance and registration of “EcoStocks” at selected major exchanges (i.e., LSE; NYSE).
6. Certified issuance of the Mitigation and Neutralization Certificate (MNC).
7. Pilot trading.
8. Primary exchange market development.
9. Global trading of “EcoStocks”.
10. Secondary exchange market development.
11. Dividend payout and capital gains.

15 Climate Change and Economic Transformation

Climate change is advancing much faster than the capacity of science to measure or predict it. Thus, “global risk” is increasing at the same rate at the expense of the global economy, the international financial market, and the future of humanity. The consequences for the world, the capital markets, and potential political and military conflicts (including nuclear), between and among nations for the declining strategic natural resources, are quite unpredictable. Climate change and environmental deterioration cannot only have a much greater impact in the world economy, especially in the area of agriculture and human health, but also pose a serious threat to life on the planet. Economic theory, through its production possibilities curve (PPC), states that higher levels of capital investment in the present allow for more and better consumer products in the future; that is, there is always an opportunity cost between capital investment and the production of goods and services. Nevertheless, since all natural resources necessary for the functioning of the world economy come from the ecological system, a prerequisite for climate change mitigation and sustainable development is the investment in the preservation and restoration of Nature and in renewable energy technology. Therefore, the PPC needs to be modified to include the climate change factor, the environmental state of the planet, and the green investments so as to reflect their relationship with world economic performance.

Climate change intensification is directly linked with the excessive and increasing accumulation of CO_2 and other GHGs that continue to be trapped in the atmosphere since the Coal Age of the Industrial Revolution. Considering the unprecedented level of accumulated emissions of GHGs, a 100% emission reduction of GHGs relative to the 1990 level does not guarantee any significant climate change mitigation, especially considering that industrialized and developing-poor countries have substantially increased their emissions since 1997. The latter one account for an estimated 40% of the total emissions, do not have emission reduction commitments, and their emissions will continue to grow, especially in the rapidly growing economies like China and India. The Kyoto Protocol was always conceived as the first small step in climate change mitigation and never as an absolute solution.

Since the 1700s, when industrial capital investment began, the world economy and the human population have grown exponentially without sustainable development principles, which led into the exploitation-production-consumption unsustainable or nonrenewable economic system that continues to operate to the present. Thus, today the global economic system urges for a sustainable development intelligent design (SDID). This design has the objective of establishing the basis of global Sustainable Development with special focus in the mitigation and neutralization of climate change to restore the ecological equilibrium and the climate system of the planet. As a starting point, SDID includes the incorporation of the economic value of the Earth's ecosystem's environmental products, goods, and services, into the economy through the pricing system and, thence, in the accounting of the GDP and GWP to assure constant economic growth.

The international community is at a historical turning point, an unprecedented opportunity for union to transform the economic system based upon a SDID, which will incentive intense capital investment into renewable energy technology, reforestation, and natural forest conservation for the birth of a sustainable global economic system with new ecologically friendly employment-generating industries. If so, what is, then, the actual cost of bypassing this historical opportunity for a revolutionary global economic transformation greater than that of the Industrial Revolution? Is the answer a gradual global economic recession in the short term or partial or total economic collapse in the medium-long term? Environmental Economics blends economics with the physical science—the ecology and the laws of physics. To come to a pragmatic answer, the risk forecast must contemplate universal physical laws, mainly Newton's Third Law of Motion; is the physical reaction to global warming equally and proportionally the opposite: global freeze? It would be necessary to simulate different down-to-earth scenarios (i.e., a planet with half the Amazon and without the remaining central Africa's forests that are being deforested at a striking rate, a climate change two times as intense as the current, the pace of polar melting and the consequent filling of the ocean currents that regulate the climate of the planet) and calculate the total economic impact.

With the current economic system, the most effective, faster, and viable alternative to implement SDID is through the international capital market with financial product innovation. The "EcoStock," as a hybrid, certifiable, and tradable financial instrument, shows, then, that climate change mitigation and neutralization can be done in a financially feasible way with the active and extensive participation of the private sector, investing with certified effectiveness in climate change mitigation and neutralization, while fostering sustainable development. The flexibility and versatility of the "EcoStock" offer nearly unlimited different modalities to satisfy customized business needs of both the supply and the demand side of the market. The "EcoStock" is, therefore, a financial innovation at hand of the international community that will financially feasibly fuel global intensive climate change mitigation and neutralization "beyond a carbon neutral world" and "beyond global emission reductions," facilitating a soft economic transition towards a sustainable development intelligent design. Therefore, the "Ecological" stock in the international exchanges will encourage the participation of ALL nations, through profitability, opening the opportunity for the economic democratization of climate change mitigation and neutralization, gradually resulting in promoting the union of the East and the West, and the North and the South, with true global cooperation independently of investor's country of origin and political ideology, thus strengthening world sustainable economic growth and political stability.

The "EcoStock" is a feasible option available to the international community and is *readily endorsable* by national climate change and environmental legislation as well as by the "Modalities and procedures for a clean development mechanism" as defined in Article 12 of the Kyoto Protocol.

Climate Change Conferences

2004—Emissions Marketing Association (EMA). 8th Annual Fall Meeting and International Conference, Toronto, Canada. 19–22 September 2004. Poster session

2006—EIC Climate Change Conference, Ottawa, Canada. Abstract selection 2007—EUEC 2007, Tucson, the United States of America. Abstract selection and registration

2007—Chemrawn-XVII and ICCDU-IX International Conference on Greenhouse Gases Mitigation and Utilization. Hosted by E.I. DuPont Canada and Queen's University. 8–12 July 2007. Kingston, Ontario, Canada. Speaker-paper presentation

2007—Emissions Trading and Business. 7–9 November 2007. Wittenberg, Germany. Abstract selection and registration

Acknowledgment Special thanks to Dr. Carlos José Pérez, Ph.D., Cornell University, for his review and comments to earlier versions of this document.

Annex I: Empirical Research Findings

The ecology of Earth is a single and close system that functions with its own scientifically describable technology, as a self-sufficient and non- substitutable natural factory, the essence and operation of which is found in its biodiversity through complex biochemical interactions and quantum physical mechanisms. The tropical forests contain the highest concentration of biodiversity and, thus, produce the highest quantities of environmental products to help in the running of the planetary climate system. Statistically, at least 50% of all forests of the planet have been either cut or overexploited. Consequently, the natural factory, Nature, is working at less than 50% of its capacity, with the added adverse condition of being severely constrained and suppressed by the excessive levels of GHGs concentrated in the atmosphere, contamination of continents and oceans, plus overpopulation.

Specific empirical evidence shows that climate balance is considerably restored and climate change reversed within a medium-term (i.e., 6–10 years) (Other references) when forest coverage and natural biodiversity is replenished. There is the same empirical support for the opposite. Computer modeling can simulate and confirm this empirical finding. Further empirical evidence shows that the minimum forest land coverage for all continents required for restoring ecological equilibrium and, consequently, climate balance is 60%. Either a 100% global carbon and other GHGs emission reduction relative to the 1,700 level or a 100% neutralization of GHGs is a prerequisite condition for triggering the natural biochemical interactions and the quantum physical mechanisms of the ecology to start restoring the climate system of Earth. Additionally, considering the proof provided by the Forestry Commission of Great Britain (The Forestry Commission of Great Britain 2006) that "deforestation and land use change currently account for 18% of global emissions of carbon dioxide," reforestation and "avoided deforestation" have a direct scientific and economic linkage to climate change. Therefore, global programs in the areas of forest conservation, reforestation, and renewable energy are elemental to guarantee a significant climate change mitigation and neutralization so as to restore the planetary climate system. These programs can be initiated through profitability with financial product innovation in the free market system.

Methodology of study utilized: Taoism[2]—an ancient eastern empirical method. Countries: Costa Rica, Nicaragua, Mexico, and the USA. Period: 1977–2006, interchangeably among the above-mentioned countries.

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[2] "Taoists concentrated their attention fully on the observation of nature in order to discern the characteristics of the Tao. Thus, they developed an attitude which was essentially scientific and only their deep mistrust in the analytic method prevented them from constructing proper scientific theories. Nevertheless, the careful observation of nature, combined with a strong mystical intuition, led the Taoist sages to profound insights which are confirmed by modern scientific theories" (Fritjof Capra. The Tao of Physics (1977)).

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Part IV
Sustainability Cases

The Sustainable Development of Trasimeno Lake

Adriano Ciani, Luigi Porcellati Pazzaglia, Lucia Rocchi, Francesco Velatta, and Mauro Natali

Abstract Lake Trasimeno, Perugia, is the largest lake in peninsular Italy, with surface characteristics of 128 km^2, the fourth among Italian lakes after Lake Como. This extension is accompanied by a shallow (average 4.3 m, maximum 6 m), so that the lake of Trasimeno is one of the laminar. The Trasimeno Lake is a natural lake with shallow water and flat, bordered by fine beaches. Its basin covers an area of natural feeding of 306 km^2, of which 124 km^2 occupied by the surface of the lake, its overall average volume of about 586 Mm^3. The area was inhabited since prehistoric times, as evidenced by the findings that are now preserved in the National Archaeological Museum. In 217 BC on the shores of the lake took place the battle of Lake Trasimeno, which saw the Carthaginian Hannibal forces defeated the Roman legions of the Consul Gaius Flaminius. Recently, Lake Trasimeno is entered into a new water crisis, perhaps greater than that of the 1950s: the current maximum depth is 4.30 m, but between 2007 and 2008 it fell by 78 cm. Since 2006, the Trasimeno is part of the international Living Lakes, a worldwide network of 52 lakes UN awards for its commitment to sustainable development of the main lakes, wetlands, and other freshwater basins of the world. Within the project called "environmental manifesto" was awarded a quality mark to guarantee and protection of tourists and residents by the companies for compliance with standards and management systems that ensure quality services environment. An interesting example of sustainable development is to build a shed for the "photographic safari drive by ambush." Within the environmental certification projects involving accommodation and government, Local Agenda 21 stands out, a process that promotes sustainable development in its

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*, DOI 10.1007/978-94-007-5995-4_10,

most qualified. From the point of view of the appeal of tourist flows in the lake area for a long time now, it has developed particularly oriented models of respectful accommodation of natural features of the area offering a kind of holiday activities ranging from cross-cultural tourism to the environment. The management of the water level of Lake Trasimeno is very delicate and very risky because in some years it has reached the minimum acceptable level of aquatic flora and fauna. In Polvese Island, the largest extension of a structure of the Provincial Administration Journal dating back to 1,100, school visits, seminars, and conferences to promote the sustainable development strategy can be done. The site throughout the project to equip a small fleet of seagoing service of lake boats that only go with rechargeable batteries from the local systems of solar energy. In order to enable adequate monitoring and efficiently the Provincial Administration since 1985 with a modern system batch of data collection and analysis are the basis of current management and the strategic importance of the lake. It's the complexity of the case and articulated, albeit in a dynamic equilibrium, management increasingly inspired by the principles of sustainability, making it a case study of relevant interest that we hope think may enjoy experts and ordinary citizens who have care about the future of the entire world in its entirety, essential diversity.

1 Preface

Lake Trasimeno, Perugia, is the largest peninsular lake in Italy. Its surface is 124 km^2, which represents the fourth among Italian lakes, after Lake Como. Lake Trasimeno is a natural lake, with shallow water, because of its depth (average 4.3 m, maximum 6 m), bordered by fine beaches. It is considered a laminar lake. Its overall average volume is of about 586 Mm^3 (Figs. 1 and 2).

The basin of Trasimeno covers a natural feeding area of 306 km^2.

Lake Trasimeno is a closed lake with no natural tributaries: for this reason, it has always been strongly sensitive to rainfall. Throughout its history, the lake was subject both to flooding and drought crisis. These phenomena required human intervention.

In the past centuries, the biggest problem was represented by the floods. Because of its flat banks, every rise in the level of Trasimeno caused the flooding of large areas, with severe damage to agricultural activities. For this reason, since the Roman era, a series of artificial channels, which function as emissaries, were made for connecting the lake to the near river Caina. In 1898 a channel was created for working as a spillway of the lake when its height exceeds 257.33 m.

The Trasimeno Lake is a natural resource of great interest, and its management strongly influences the local area both by an environmental and socioeconomic point of view. The stakeholders involved in the area management have very different interests: scientific (the lake is base for the Fish Center Research and the Center of Ornithology), touristic (it is the fourth regional destination), agricultural (the area of Lake Trasimeno is one of the subzone of the olive oil brand "Umbria" POD – Protected Origin Denomination), infrastructural, urban planning and construction,

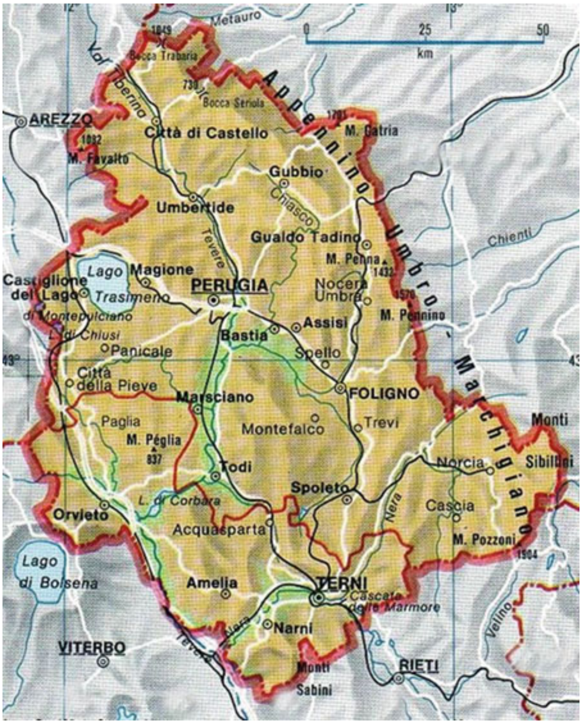

Fig. 1 A simple RES with one single useful demand and a virtual technology: moderate use

landscape, water, and fishing. The complexity of management in the area is due to the presence of such a huge number of stakeholders involved. The main institutional management actor is probably the Province Administration (Province of Perugia). The Province of Perugia controls and coordinates the water management systems, some of the research, and didactic activities and has an important role in the monitoring of hunt and protected areas. Nut the Province Administration is not the unique management institution: in the Umbria Region, the associations of the local municipality are some of the most important institutions operating in the area. In addition, there are also several economic stakeholders, involved in traditional and productive activities, as fishery or tourism. To reach a stable equilibrium between the different interests is quite hard, for the presence of too many actors.

Among the economic activities present in the area of Lake Trasimeno, there is also an ancient tradition of fishery. In its water there are several species of great value freshwater fish, as the eel, carp, tench, pike, and real perish. In particular, the pike (*Esox lucius* Linnaeus 1758) is an indigenous species. According to the newest scientific studies, for its features it is probably a separate species from the Italic pike, which is present usually in Italy (Figs. 3 and 4).

Trasimeno Lake is also a tourist destination for many holiday makers, especially from the central and northern Europe. The main attractions for the tourists are the climate, the bathing water, the food culture, the hospitality, the local history and culture, and the landscape.

Fig. 2 The Trasimeno Lake maps

This is an area of great value today, in which many interests are intertwined. Fisherman, farmers, institution, and tourism sectors are involved in an ongoing debate on the most appropriate management strategies, which identify an example of managing conflicts of interest.

Without a shrewd political research on the composition of the conflict between the various interests described above, the risk of the prevalence of one over the other is possible. The consequence is an irreversible break of the historical sustainable equilibrium. In the last years, Trasimeno has been gradually degraded, for the complexity of the case. A dynamic equilibrium, management increasingly inspired by the principles of sustainability is nowadays applied, making it a case study of relevant.

The present contributor is arranged as follows. After a brief history of the area, four sections are about different sides of sustainable development of the area. In particular, Sections 3 and 4 are dedicated to the programs and activities for the economic and environmental sustainable development. Section 5 deepens the themes of quality of life, while the Sect. 6 is dedicated to the sustainable management of the development. The contributor is closed by main conclusions.

Fig. 3 A panoramic view of the lake

Fig. 4 Trasimeno and Maggiore Island

2 History

The area was inhabited since prehistoric times, as evidenced by the findings which are kept alive in the National Archaeological Museum. In 217 BC, on the shores of the lake took place the battle of Lake Trasimeno. The battle was one of the most important of Second Punic Wars, and the Carthaginian Hannibal forces defeated the Roman legions of the Consul Gaius Flaminius. Subsequently, at the time of Emperor Claudius, to obviate the problem of frequent flooding of Lake Trasimeno, the Romans built the first artificial outlet connected to the Tiber.

In 1422 Braccio da Montone, lord of Perugia, set up a new outlet, for a total length of about 1 km, almost entirely covered. However, this work was not conclusive. Even the famous Leonardo da Vinci studied an ingenious hydraulic system, never put in place, to regulate the flows in excess of the Lake Trasimeno and Chiusi, which also included the involvement of the Tiber and Arno. In the second half of the sixteenth century, Pope Sixtus V decided to divert the only two natural tributaries of Lake Trasimeno, the Rigo Maggiore and the Tresa, toward the lake of Chiusi. Between the eighteenth and nineteenth centuries, further reductions in the catchment area were attempted, but they have never taken place. After years of fierce battles with the demesne and speculators, between 1896 and 1898, the Drainage Consortium, chaired by Guido Pompili, managed to create a new effluent, parallel to the fifteenth century, for a length of 7 km and a capacity of 12 m^3/s. The creation of the outflowing prevented the artificial drying and solved the problem of floods and consequently of malaria. During the 1940s and 1950s of the twentieth century, an intense lowering of the threshold of the new emissary, on behalf of powerful landowners, caused a water crisis. Trasimeno faced a serious risk of drying out, with the maximum depth which felt to 2.93 m at the end of the 1950s. In 1952 the natural tributaries, Rio Maggiore and Tresa, were reintroduced and Trasimeno recovery took place in 1958. Recently, Lake Trasimeno has been entered into a new water crisis, perhaps the greatest it has been faced. The current maximum depth is 4.30 m, but between 2007 and 2008 it fell by 78 cm.

3 Programs and Activities Dedicated to Economic Sustainable Development

The two main businesses in the Trasimeno area are tourism and fishery. Several activities are accomplished to improve them. Often the Province of Perugia Administration is involved, with the roles of coordinator or proposer of projects and activities.

3.1 The Local Institution and Governance of Trasimeno Lake Toward Sustainable Development Strategy

Province Administration is the main local institution that is charged to manage the Trasimeno Lake. This institution has been operating since 1861, the year of the creation of the Italian State. After World War II, year by year, the state of health of the lake takes more attention by the population. The causes of this attention are several: the transformation of the agriculture (with the introduction of the irrigation), the start of the industrialization, and the growth of the water consumes for civil use. The increasing water demand causes a yearly crisis during each summer time powerful by the absence of rains. The presence of this recurrent crisis moves the Province Administration to create a special branch dedicated at the Trasimeno Lake Management. During this last 50 years, several drastic decisions tried to apply the main option of the conservation of the environmental resources. As the example between 1980 and 1985, it was decided to forbid the navigation with boats and motor boats, with the exception just for the small one, managed by the fisherman. Nowadays, it is possible to cross the most part of Trasimeno Lake only by the sailboats with a great positive effect concerning chemical and functional contents of the water basin. Public transportation services between the village on the banks and the islands Polvese and Maggiore were improved. Province Administration has been arranged, time by time, new infrastructural investments, aimed to the economics activities, and also financial support for projects subject concerning sustainability of productions. In the water management sectors, Province Administration arranges the regulation for irrigation and promotes projects to preserve a good level of the water. This policy created the opportunity, today, to regulate the hydrologic level when necessary. Moreover, it supported the use of water, coming from the integrated water system of the Montedoglio dam, at northwest of the Lake for irrigation.

The other local institutions (municipalities, Mountain Community, local action group, touristic promotion offices, basin authorities, public and private cooperatives and consortium) have promoted and followed mainly the strategies of the Province Administration. The role of Province Administration is to manage and integrate the different actions made by the local institutions. Running integrated and intersectoral activities guarantees the sustainability of governance in a dynamic equilibrium.

Since 2006, Trasimeno is part of the international Living Lakes, a worldwide network of 52 lakes UN awards for its commitment to sustainable development of the main lakes, wetlands, and other freshwater basins of the world. Lake Trasimeno achieves the prestigious "Green Schooner," an award assigned by Legambiente, an environmental Italian association. The Legambiente campaign is dedicated to observation and information of the health of Italian's coastal waters, seas, rivers, and lakes. Green Schooner determined that the Lake Trasimeno is the only one not to have "hot spots" and "points that are heavily polluted."

Since 1995 the Province Administration declared the island Polvese, one of the three islands present in the lake, a "Science Park – teaching" dedicated to research and experimentation, training, and environmental education.

The Park of Lake Trasimeno, the largest of the six Regional Parks in Umbria, is one of the unique and important wetlands in Europe for the presence of botanical species and fish fauna of enormous value.

3.2 The Fish Reproduction Center of Trasimeno Lake and Fishing Activities

The Province of Perugia is particularly rich in rivers and lake environments among which Lake Trasimeno is a unique ecosystem, for the aquatic life and fauna. The abundance of fish population is managed by the Province of Perugia, through its Environmental Protection and Wildlife Management Service. In some cases to strengthen some populations, it is needed to make restocking. In these cases, the Province of Perugia can be supported by two Fishing Reproduction Centers, managed by the Province itself. The system of *Borgo Cerreto Fish Reproduction Center of Valnerina* is specialized in production of brown trout (*Salmo trutta*), while the *Fish Reproduction Center of Trasimeno Lake of St. Archangel* aimed at the production of juveniles of various species of warm water fish such as pike (*Esox lucius*), carp (*Cyprinus carpio*), and tench (*Tinca tinca*). The *Fish Reproduction Center of Trasimeno Lake* is born on the initiative of the Consortium's Fisheries and Aquaculture of Trasimeno, situated in the south part of the lake, and a fish farm, known more properly as hatchery, specializing in the production of juveniles of 6–10 cm. The production of fishes is made as a complete cycle, providing from the artificial insemination or natural deposition of eggs and fry, which are increased to the size required. The plant is fed by water of Lake Trasimeno, pumped into a tank load of concrete and distributed by gravity through the conduit open and partly closed, which is the breeding ground tank for the young fishes. The structure consists of two distinct areas: a hatchery and a covered outdoor area with tanks on the ground. In the fish nurseries playing, egg incubation and early rearing, and a short breeding and housing of the finished product before sowing are done. The most high-tech sector is mainly occupied by fiberglass tubs and bottles of Zug for the incubation of eggs. A water filtration plant picked up water from the lake and removes the suspended solids, without altering the characteristic chemical properties. The external sector is instead composed of 14 tanks in the ground, three of which are intended for breeding and housing. The emptying of all the tanks is made by gravity, but before the water used comes back to the lake, it passes through a settling tank and surface impoundment. The production, typically seasonal, begins in February with the reproduction of pike. Until a few years ago, the pike (*Esox lucius* L.) was regarded as a ferocious predator that can kill other fish species in its own environment. Today, thanks to a better understanding of the biology of this species and, in general, of the balance between the existing aquatic species, pike recognized the fundamental role of "regulator" and "breeder" in relation to other fish species, preventing, among the other, an excessive growth of some populations and eliminating the weakest and sick. The pike, in addition to being useful for maintaining a proper

Fig. 5 The pike

Fig. 6 The mirror carp

ecological balance in fresh water, is of great interest to professional sport fishing. The revaluation of this species is, unfortunately, concurrent to a general decline in its presence in the Italian inland waters. The decline of pike is due to the widespread degradation of aquatic environments, with particular reference to areas of care, but also to the phenomena of competition with exotic fish species such as perch trout (*Micropterus salmoides*) (Figs. 5 and 6).

This situation has necessitated the reproduction of juvenile pike, to be used for restocking in support of that species. In the structures of the Fisheries and Aquaculture Consortium, it has been practiced in the past, for over 50 years, the collection of large quantities of eggs from wild brood stock. After the fertilization, the eggs were incubated for a massive final production of larvae yolk sac reabsorbed and returned to the lake at this stage. This practice, however, did not produce the desired effects, so that in Trasimeno, a drastic reduction in the population of pike is recorded. To get over such difficulties, in the southeast of the lake was made the Fishing Reproduction Center of Trasimeno, which began operation in 1985, whose production would be more important. The production cycle, with great regularity, runs every year in mid-February. It begins with the production of eggs obtained from wild brood stock caught in the lake. Females which are not yet fully matured and, therefore, do not yet issue spontaneously eggs are laid over several days in the tanks of the plant. In the past, hormonal stimulation was attempted for increasing of products, but the answer has never been completely satisfactory and the practice was abandoned. Artificial insemination is practiced using the mature females, with a slight compression of the abdomen to release eggs, collected in a plastic container. With the same procedure, the male seed is harvested, usually few drops that come into contact with the fertile eggs. This method is called artificial insemination "dry" because it must occur in the absence of water, which is rapidly absorbed by the eggs and would limit the time for fertilization. Incubation takes place in Zug bottles using filtered lake water thoroughly. The incubation period is 120°-days, and it is based on varying temperature and lasts for 2–4 weeks. At the time of hatching, the eggs are transferred directly into the ponds of growth of the holders, so that the emergence of larvae is made smoothly. The latter, at a density of 35–50/m^2, complete reabsorption of the yolk sac in about 2–3 weeks and then begin to feed on live plankton, which must be present in abundance. The proper management of the planktonic communities of the ponds is of the utmost importance, and it is crucial for achieving good results in the collection. To increase the production of plankton at the time of filling, the ponds are fertilized with cow manure. The water pumped from the lake and in this case is not filtered, brings in the tanks planktonic crustaceans (*Bosmina* sp., *Daphnia* sp.). The presence of rich nutrients stimulates them to reproduce abundantly, although the weather was not favorable. The small sizes of these Cladocera (0.4–0.6 mm) make them suitable to meet the food needs of luccetti in the first 10–15 days of feeding, but are not sufficient to bring the fry to the size required for 6–8 cm. For this reason, in the ponds, along with the larvae of pike, you enter another Cladocera, *Daphnia magna*, reared in tanks at the Center and has the characteristic to achieve extremely large size (4–5 mm). This species of *Daphnia* initially can't be predated by small pike, because it is too great, and, in this way, the population can grow significantly. When even the largest *Daphnia* can be preyed upon, the planktonic population undergoes a drastic reduction in cannibalism and, in any case that has already begun to manifest itself, undergoes a rapid increase. The collection of fry, which at this point is urgent, is normally at the end of April after about 4–5 weeks from sowing of the larvae. The final average densities are obtained "avannotti." For the carp the techniques of artificial reproduction are instead adopted. The players are housed throughout the year in outdoor ponds, keeping separate the males from the females to prevent uncontrolled reproduction. When the water temperature reaches 18 °C, the most suitable for breeding females are chosen, identified by the soft belly and swollen with eggs. We proceed to the preparation of carp pituitary extract which, when injected, will induce ovulation approximately 12 h after treatment. To avoid damage to the fish, which can be reused for many years, these have been anesthetized. The administration of the hormone, after having dissolved in saline, by injecting it happens behind the dorsal fin, at a dose of 3 mg per kg of weight. A similar treatment, but at a lower dose, is administered to males because they produce the most abundant sperm and fluid. When the carp is in ovulation, recognizable by the spontaneous release of some eggs in the tank, we proceed to the squeezing and egg collection. These are immediately fertilized by male sperm, strictly according to the method "dry." Because carp eggs are coated with adhesive in nature that serves to make them adhere to aquatic plants, you must submit to a specific treatment, which eliminates the adhesive. This will put them in bottles incubated in Zug, without sticking to each other. To achieve this, the eggs are washed with a solution of urea and sodium chloride for about an hour, this time you hydrate and harden. Finally, a quick rinse with a solution of tannin eliminates any residual adhesive, and you can put them in incubation. After 3 days at a temperature of 20 °C, the hatching begins. The larvae are then sown in the breeding ponds, in which the first will feed on plankton and subsequently on balanced feed, until the end of harvest season. The reproduction of the tench is adopted instead of the natural method. The players, among which is very easy to distinguish the sexes for large ventral fins of the males, are kept separately in tanks such as carp. When playing, boys and girls are placed in ponds, where the reproduction occurs spontaneously and players are left with the fry until the time of collection. At the end of the season, usually in September, the tubs in which they were reared tench and carp that are slowly emptied and the fry are harvested products, such as pike, in a large network placed at the exhaust. After the necessary counting and weighing, the material produced is used for fish restocking programmed. The Fishing Reproduction Center not limited, however, the production of juveniles for restocking, but is actively engaged in various research and experimentation, in collaboration with the region of Umbria and the University of Perugia. These include monitoring of fish populations prevail natural for better management.

3.3 The Transport System and Infrastructure

The transport system across and in the bank area is an interesting integrated system, mainly arranged by boats and minibus. This system is based on the flexible supply, due to the seasonal modulation of the tourists' presence. This modulation permits to maintain a good level of the pollution impact as in the banks across the lake and at the two islands. The infrastructure has been built without any important intervention for soil, wood, flora, fauna, and water.

3.4 Sustainable Tourism

In the lake area, since a long time, it has been developed a particular model oriented to respectful tourist accommodation of natural features. In particular, there are numerous camping and cottages, which aim to enhance the close contact with nature for tourists, offering a kind of holiday activities ranging from cross-cultural tourism to the environment.

We can define sustainable tourism as all the "tourism activities that can be maintained, or sustained, indefinitely in their social, economic, socioeconomic, cultural, and environmental context" (UNWTO 2011). This definition includes policies, practices, and programs that take into account the needs and quality of life of the environment and communities that support tourist supply (UNWTO 2011). Tourism industry is one of the most important for Italy: it represents 6% of the annual GDP and the 4% of the national labor force (data available at http://www.turismoefinanza.it/). Ecotourism represents the 11% of tourism turnover and the 6% of the tourism firms.

Trasimeno Lake is one of the most important tourist destinations of Umbria Region. According to the official regional data, it represents the fourth destination in Umbria with the 16% of the total presences. Because of the presence of the homonymous park, the area of Trasimeno was interested during the years 2010 and 2011 by the European project SLOW TOURS (action ENT/CIP/09/B/N06S00). Only four projects all around Europe were founded by the EC DG Enterprise and Industry. The project aims at analyzing, collecting, and listing in a coherent framework good practices, certification procedures, and network experiences for tourism in lake areas, to make effective and consistent sustainability and competitiveness. Core of the project is the Sustainability Impact Assessment (SIA), a systematic and iterative process for evaluation of economic, social, and environmental impacts of policies, plans, programs, and strategies, enabling stakeholders involved to participate proactively (Arbter 2003). Moreover, the analysis phase allows for identifying best practices for sustainable tourism, in order to guarantee long-term success of sustainable lake tourism offers. The project aims at realizing a complete tool system for interpreting and applying transferable good practices to sustainable tourism management in lake areas all over Europe. One of the types of sustainable tourism proposed is cycle tourism.

Cycle tourism can be defined as recreational visits, either overnight or day away from home, which involve leisure cycling as a fundamental and significant part of the visit (www.sustrans.org.uk). Around the Trasimeno, there is a cycle path, for 48.96 km, and also Polvese Island is interested by a short and easy route. Improve the cycle tourism is one of the main goals of Park Administration. For this reason, cycle tourism represents one of the leading chapters of the Management Park Plan. Moreover, the Park Administration improved the existing cycle path and has been trying to include it in a wider cycling route. In the Socioeconomic Management Plan of Trasimeno Park, cycle tourism is included in the measure about the greenways (n. 4.1.a). A greenway is a network of land containing routes that are planned, designed, and managed for multiple purposes, including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use (Ahern 1995). Alternatively, according to Turner (1998) is a way which is good also by an environmental point of view. For these reasons, improving greenways and cycle tourism is a way to benefit also the sustainable development of Trasimeno. To reach such a goal is required to improve the length of the cycling routes present at Trasimeno but also their quality. To create new cycling routes is another goal for the Management Plan of the Park. Cycling tourists will have an extreme importance for local economy, because cycling tourism is a slow type of tourism. "Slow tourists" prefer "slow activities," as taste traditional foods, visit little villages, and buy handcraft, all activities which have a great good return for the local economics and society.

Another tourist activity which allows a sustainable development of tourism is the fish tourism. With the term fish tourism, we mean the recreational activities of fishing with professional fishers on the typical traditional boats, while the ichthyic tourism includes also ashore activities. Such activities are typically addressed to tourists, as a way to diversify the tourism offer. Fishing was one of the main historical economic activities of Trasimeno, but nowadays it is a faltering business. Causes of this situation are the getting old of fishers, the low remuneration of activities, and the low social attractiveness of the activities. Fish and ichthyic tourism might be a way to improve the revenue of fishing activity and also to make it more stable thanks to the diversification of activities. Moreover, fishing is an economic activity no longer sustainable in the lake. In the past, the management of fish was not sustainable. In particular, there was a massive and always rational use of restocking. Several not native species were introduced in such a way.

For all this reason in the Socioeconomic Management Plan of Trasimeno Park, restocking is banned and special rules are given to the fishing sector. Moreover, in the plan, some new ideas to promote the sector are present. Fish and ichthyic tourism are two of them. In the measure (4.1.c), fishing tourism is incentivized for its importance as sustainable activity.

3.5 Fotografh Safary

An interesting example of sustainable touristic activities is to build a shed for the "photographic safari drive by ambush" in the territory of the oasis. The hut is located on the island in the artificial lake in this Oasis, used as a "manger" for waterfowl, particularly herons. The structure, with small windows, is completely closed to hide the photographers and to allow the facing in all directions to the pond water and riparian vegetation that delimits. Access to the island and then to the cabin is made by a wooden walkway. This is one of the many important signs of sustainable development that seeks to achieve of the area of Lake Trasimeno.

3.6 Christmas Island of Polvese

For holidays such as Christmas and New Year, the Province has launched an innovative initiative named "Christmas Island." This initiative has based at the Polvese Island which is the bigger part of the Lake. The initiative starts at the day of Christmas, and it has registered a big success among the touristic visitors, which was more than 4,000.

4 Programs and Activities Dedicated to Environmental Sustainable Development

The zone of Trasimeno has a great environmental value. The lake and the area surrounding it are involved in a Regional Park, a Special Protection Area (SPA), and a Site of Community Importance (SCI). The area of Oasis La Valle is important for the research and didactic activities. The Province Administration is involved in the environmental management of such areas, always in cooperation with other stakeholders, as the Park management. The Province has also a crucial role in the water management, which is strictly linked to the environmental one.

4.1 Manifesto of "Environmental and Natural Oasis a Valley"

"Environmental manifesto" is the name of a project, which the Oasis "La Valle" won an award as quality mark. Environmental manifesto guarantees a high level of environmental quality for tourists and residents, in particular, recognition of the efforts undertaken by the companies for compliance with standards and management systems that ensure quality services environment. The Oasis "La Valle" is a center created by the Province Administration and which coordinates all the didactic and scientific activities in the lake. The base of the Oasis "La Valle" is in one of the most beautiful areas of Trasimeno, with its shallow waters and extensive reedbeds. The area, in particular, is an important rest place for thousands of birds nesting along the main migratory routes.

4.2 The Avifauna of Trasimeno Lake

The first scientist who studied the avifauna of Trasimeno was Edgardo Moltoni. In 1962 he published an essay on avifauna of Lake Trasimeno based on observations conducted in the period 1960–1962. Moltoni reported 146 species, plus another 20 he thought likely to be present, but he did not detect. The list was not complete, however, considered even by its own author, who thus commented: "… I certainly miss for lack of comments … a good number, especially those who enter illegally or accidentally Umbria."

4.2.1 The Recent Activities

After the work of Moltoni, the research went through a period of stagnation, mainly due to the almost total lack of regional ornithologists. A sharp recovery occurred only in the late 1980s of the last century, favored both by the emergence of a group of ornithologists from the University of Perugia in Umbria formats and the interest accruing to the Province of Perugia to start a serious monitoring of “bird lake,” whose relevance to local administrators was becoming more aware. The salient steps of these “awakening birds” are summarized as follows:

- 1987: systematic collection of data on species and their phenology
- 1988: beginning of a regular activity of wintering waterfowl count, the first quantitative survey riparian avifauna (Velatta 1990), organized with the transect method
- 1993: monitoring of nesting colonies of herons
- 1996: monitoring of the riparian community of Passeriformes by catching and ringing networks, according to rigidly standardized protocols
- 1997: the first experience of the system of classification into classes of river banks “ornithological” (Velatta et al. 1999), then resumed and deepened between 2004 and 2010 (Velatta et al. 2011)
- 2002: publication of the atlas of breeding birds in the Trasimeno (Velatta 2002)
- 2004: publication of the checklist (the second after that of Moltoni) of the birds of Lake Trasimeno (Velatta et al. 2004)

The Province Administration gives a strong impetus to research. In particular, it was created by the initiative of the Province of Perugia, an ornithological station at the Oasis “La Valle,” where ornithologists from various walks of life began to embark on a fruitful collaboration which resulted in a score of contributions that appeared in scientific journals, in conference proceedings, or in the form of monographs, whose complete list is shown in the bibliography.

4.2.2 The Checklist

The species of birds found on the lake between 1987 and 2011 are well 211 (Table 1), 87 of which are nesting, more or less regularly. Two of them, red partridge and the bearded reedling, however, are missing from the study since 1993 and 2002, respectively.

Among the species reported, over half (121) can be described as “of particular conservation value,” as appearing in at least one of the following lists:

A. Species of Community interest listed in Annex 1 of EEC Directive “Birds” (79/409/EEC 2009/147/EC replacement)
B. Species whose conservation status in Europe is considered negative (BirdLife International 2004)
C. New species included in Red List of breeding birds in Italy (Calvari et al. 1999)

4.2.3 The Wintering Waterfowl

The wintering waterfowl on Lake Trasimeno is monitored since 1988. The census will take place in mid-January of each year, under the Western and West Asian Waterbird Census Palearti, coordinated by ISPRA Italy (National Institute for

Environmental Protection and Research) and wider levels by Wetlands International, organization that works closely with the Secretariat of the Ramsar Convention.

Initially, only Anatidae and coot were subject to the census, but over the years, the number of species involved has been gradually increasing since 2005, and all taxa of aquatic birds were included in the monitoring program. The surveys are carried out with different methods: with telescopes from the shore (making observations in the same places every year), with boats along predetermined routes, and even doing aerial photography. The census workers are both employees and volunteers of the province and region that have passed an appropriate exam of eligibility at Ispra, the government agency that deals with (among other things) research and conservation of wildlife.

In the last 7 years (the period of study in which the monitoring was extended to all species), the average number of waterfowl wintering on the Trasimeno was about 45,000 (Fig. 1). This figure greatly exceeds the threshold value of 20,000 given by Criterion 5 of the Ramsar Convention for identifying wetlands of international importance. The most abundant species was the coot, which has grouped itself 64% of the total population (Fig. 2); the Anatidae has represented another 23%, while species ichthyophagous have collected about 12% of the population.

Over the past 10 years, the consistency of two species has reached values of international importance: coot and ferruginous. Other eight species (wigeon, gadwall, teal, mallard, pochard, little grebe, great crested grebe, cormorant) were present with the stock of national importance. The trends of these ten species, which are particularly relevant, are all significantly positive, calculated over the entire period of monitoring by the Spearman rank correlation coefficient, except in cases of the cormorant and the great crested grebe. Significant positive trends emerged in the area as for whole ducks, diving ducks, and the herons.

The increases observed are probably related to two phenomena that occur simultaneously over the past two decades: the enlargement of the surface of the lake prohibited hunting and the lowering of water level as a result of a particularly dry climatic phase. The changes in the surface ducks, diving ducks, and coots are significantly positively correlated with the extension of the protected area, and negatively with the level of the lake. To estimate the relative importance of the two variables (level and protection) in influencing the trends of Anatidae and coot, it was also calculated their partial correlation coefficient with respect to the size of the population, which expresses the contribution of each independent variable "net" effects on the other (Field 2000). The results suggest that, in the case of coots and diving ducks, the winter consistency is mainly conditioned by the absence of hunting disturbance, while the water level plays a minor role, at least within the limits of variation observed. For ducks surface it seems to be rather the water level the main controlling factor. It should be emphasized that the analysis suffers from the fact that during the period of study, the level of protection has varied inversely (autocorrelation), which prevents to analyze separately the effect of each of the two variables considered individually.

The effect of the layer can be better highlighted if we look only after the establishment of subregional park (in March 1995), because from that moment, the entire lake surface was subjected to ban hunting, and therefore, the surface protected has become constant. The analysis confirms (Table 6) the existence of a significant inverse correlation between the level and abundance of ducks surface, but shows no significant correlation with regard to the level of diving ducks and coots. Even for these two groups, it is not lawful to exclude completely a possible negative effect of water depth, taking into account that the subperiod under consideration (1996–2011) never verified the conditions of particularly high levels typical of the early study period.

The regression model derived for ducks surface indicates a reset of their hair texture when the share of liquid becomes equal to about 257 m above sea level. This value is less than 33 cm in the so-called hydrometric zero of lake (artificial effluent overflow threshold), considered in the planning acts of Basin Authority (excerpt plan for the Lake Trasimeno). This value is aiming as the optimal level for environmental protection of Trasimeno.

4.2.4 Other Remarks

The ornithological importance of Lake Trasimeno is well marked both by the high number of species of particular conservation interest and from the numerical significance of bird populations, which are in many cases significant fractions of the total national population, or even biogeography. However, this situation is based on a delicate balance, which may be affected by both anthropogenic factors and changing environmental conditions. Among the first may have special importance the excessive noise in sensitive areas (e.g., heronries, areas with significant concentrations of wintering birds), in many cases due to recreational activities (boating, flying, hunting camera, easy hiking, etc.) carried out in unregulated manner. Regarding environmental factors, of particular importance seems to be the water level. It directly affects the consistency of certain types of waterfowl, which can no longer find suitable conditions in the presence of water too deep, and there are also strong indications that the decline of the reed (resulting in severe loss of habitat for species such as the purple heron, little bittern, and riparian Passeriformes, including the extinct bearded reedling) is at least partly due to permanent flooding condition of the substrate on which it is installed (Gigante et al., op.cit.).

It is worth noting that maintaining a low water depth is an optimal condition for the conservation of the lake. It also constitutes a critical element in relation to other environmental components: a low water level and high temperatures, for instance, are mentioned as possibly responsible for the “trivialization” of the phytoplankton community of Lake Trasimeno (Todini et al. 2010); the lack of water exchange (due to levels that more than 20 years do not reach the threshold overflow effluent) has resulted in a progressive accumulation of solutes (Ludovisi et al. 2010), and they do predict a possible evolution “brackish” Trasimeno, of course accompanied by a radical transformation of its biological communities. In favor of higher levels, there are also needs of an anthropogenic, related to the tourist-recreational use of the banks and the navigability of which revolve around economic interests are not negligible.

4.3 Lake Trasimeno Park and Local Agenda 21 for Sustainable Development Strategy

The Lake Trasimeno Park was established in 1995 with the purpose of maintaining the integrity and protecting the value of the natural environment, with particular attention to flora and fauna. The lack of natural outlets and the shallow level of the water make up a favorable environment for many different species of fishes, birds, and marsh vegetation, some of them peculiar to the area. The territory of the Park spans across the boundary of the lake and encompasses three islands: Island Maggiore, Island Minore, and Island Polvese – the largest one – which belongs to the Province of Perugia, and it is used for didactic and research purposes on local environment.

The Park was instituted by the regional law Nr 9, May 3, 1995, later revised by the regional law Nr 24, July 23 2007. The Comunità Montana (Mountain Community) and the Association of Trasimeno and Middle Tiber Municipalities jointly manage the 13,200 ha Park. The parties of the association are the municipalities of Magione, Castiglione del Lago, Panicale, Tuoro sul Trasimeno, and Passignano sul Trasimeno. In 1997 an administrative and functional structure started its activity. A working group of representatives of all the implicated party has outlined the fundamental guidelines for the planning of the environmental protection of the lake ecosystem and the promotion of an eco-sustainable economic development. In 2001 the rules of safeguard have been conformed to the provisions of the River Tiber Basin Authority, and talks with the involved parties and the University of Perugia have taken place in order to work out the definitive Plan for the Park and the Long-Term Economic and Social Plan. In the same time, the Transitional Plan of River Tiber Basin Authority dictating the mandatory regulation for the Plan of the Park was presented.

In the following years, several projects have been proposed, among them the one for the rescue of the function and landscape of the most environmentally relevant areas of the five associated municipalities. With these plans, the Park has begun its institutional activity addressed to the improvement of the sites suitable for the development of sustainable tourism. Other projects have concerned the monitoring of fauna and flora and the conservation of the species at risk, such as the population of herons, and the restoration of alluvial forests in the area of Castiglione del Lago airport and of San Savino valley. The projects of the Park are numerous and varied: the protection of slopes and natural areas of vegetation and use of the soil; the survey of fauna and the census of mammalians, the study of evolutionary dynamics of the territory; the restoration of the banks; the preservation of seeds and biodiversity; the wild boar curbing plan; and the projects of study and research. Great attention is paid to the relationship with the local population. Many events are aimed at this purpose, such as the Park marathon, the presentation and diffusion of the various projects, the Castiglione del Lago international show of hot-air balloons, and the excursions and guided tours. Worth of note, as a teaching tool, is the Polvese Island Center for Environmental Experience: a sort of green classroom offering an example of sustainable environment management based on biologic agriculture, energy saving, and herbal purification systems. The Plestina Cooperative runs educational activities concerning environmental tourism and sustainable development through the study of the landscape, the history, the culture of the territory, and the modern relevant technologies. The Polvese Island Center offers a wide range of services to schools and visitors, organizing environmental and cultural trails, guided tours, teaching campuses, meetings, educational courses, and seminars.

The Transitional Plan quoted above is the institutional normative frame defining the strategic objectives for protection of the ecosystem and development of the territory. The envisaged actions are the following: measures aimed at tackling the problems related to the quantity and quality of the water resources; planning of the long-term use of water and soil; and works for the prevention of the hydrometric lowering and the connection with the hydric system of Montedoglio catching basin. The plan has several objectives: restoration of the annual water deficit; prevention of the lowering of the water level of the lake; protection of the ecosystem; reduction of pollutants; maintenance of the hydric network; and promotion of better use of the water.

The Park Agency and the Umbria Regional administrations are the two partners working together for the fulfillment of the Transitional Plan through the Park Long-term Economic and Social Plan. A central instrument for the evaluation of the effect of Park Plan is the Strategic Environmental Evaluation (SEA) established by the European Community regulation 2001/42/CE, June 27, 2001. SEA is the instrument for the integration of environmental issues in the working out of sustainable plans and programs. SEA has the fundamental task of examining and surveying the congruity of the actions with the objectives of the plan itself, as an instrument aimed at environmental protection. The Park Plan is a process of synthesis of many disciplines and sectors offering an exhaustive and up-to-date picture of the reality of the Park and defining an integrated strategy for the management of its territory. The parties involved in the process of elaboration of SEA and the plan are multiple: Perugia Province Administration, Mountain Community, University of Perugia (Department of Applied Biology and Department of Agricultural Economics, farm Appraisal and Agrofood sciences), and the Environment Protection Agency of Umbria. In addition to these, there is a long list of stakeholders involved by the Park planning. Among them are the five important associated municipalities of the lake: Region of Umbria, Region of Tuscany, River Tiber Basin Authority, ASL 2 (local public health organization), Chamber of Commerce of Perugia, CONI (Italy's Olympic Committee), and others. The regulations for SEA process are the already quoted European Community regulation 2001/42/CE; the national Legislative Decree 153, April 3, 2006, concerning "regulations for environment" integrated by the Legislative Decree 04, January 16, 2008; and the Regional Resolution 1953, December 30, 2010. The Park Plan is a tool for the governance of the territory and for the defense of its biodiversity, environment, landscape, and culture. Its objectives are the conservation, restoration, and potentiating of the autochthonous animal and vegetal species, fito- and zoo-cenosis, lake habitats, and broadly of the ecosystem through the preservation of appropriate environmental conditions. Furthermore, it is intended to pursue a balance between the environment and the anthropic component, elaborating models of sustainable use of the territory compatible with the conservation of the autochthonous animal and vegetational forms of life. Finally, it is meant to be an instrument for coordination of the activities and interventions carried out by the different bodies operating within the Park. In December 2010, ARPA Umbria, Region of Umbria, and River Tiber Basin Authority organized a meeting in Castiglione del Lago on available scientific information, assessment of the current state, and proposals for future actions concerning the territory of Lake Trasimeno with particular attention to the Park. The objectives agreed upon are the following: a phase for discussion and merging of the projects between local Administrations, Province, ARPA, and Region of Umbria; the complete adoption of the Plan; the continuation of VAS procedure; the approval of the Plan by the Province of Perugia; and the organization and coordination of the activities entrusted to the Park. The final critical and decisive point debated is that within the environmental certification projects involving accommodation and government, Local Agenda 21 stands out, a process that promotes sustainable development in its most qualified.

4.4 Water Management

The water management of Lake Trasimeno is a strategic issue of the utmost importance because, during the last decades, it has progressively reached the minimum acceptable level for environmental equilibrium and for survival of aquatic flora and fauna.

In 2004, in Central Italy, it has been completed a major project for a water reservoir and a distribution system with a series of dams, the two most important of which are those of Chiascio and Montedoglio. The water supply to the Lake Trasimeno from the Montedoglio reservoir is of 30 million cubic meters per year as a minimum, thus solving or greatly alleviating the problem of water balance of the basin (Figs. 7 and 8).

Although many authorities are involved at different levels in the matter, the Umbria-Tuscany Irrigation Authority is responsible for water management of Lake Trasimeno. Lake Trasimeno is the fourth broadest catchment basin of Italy. It is a laminar lake characterized by a large surface, a shallow depth, and the absence of a natural system of tributary and draining water streams. This makes the water level dependent on the delicate and hardly predictable balance of rainfalls, natural springs, evaporation, draining, and utilization. The very fertile land around the lake has always been the site of intensive cultivations requiring large amounts of water drawn from the lake itself. For all these hydrographical, geological, morphological, and anthropic peculiarities, not only the water level but also the entire environmental equilibrium in the area of Lake Trasimeno is exposed to substantial risks. During the last two millennia, the level of the lake had fluctuations. During the first centuries of the second millennium, an increase in temperature and a decrease in rains occurred, and the water level shrank down; in the middle centuries, the contrary happened and the level grew up. The threat of floods and droughts induced the local communities and governments to undertake interventions such as the digging of draining channels and the diversion of water streams, sometimes away from the lake, often toward it. The water management is under the regulation of a top-down system of authorities going from the national Ministries such as those for the

Fig. 7 The Montedoglio dam

Fig. 8 The Montedoglio dam

Environment and Agriculture, to the local government and administrative bodies of Umbria Region, Perugia Province Administration, and, finally, to the local municipalities, with different levels of political, regulatory, juridical, and technical powers and functions.

The regulatory framework includes the EC Regulations 79/409/CEE as an area of special protection and 92/43/CEE as a site of community relevance and sensible area and vulnerable zone for nitrates of agricultural origin and for chemical compounds as herbicide and pesticide.

The "Piano stralcio per il Lago Trasimeno" is a Transitional Plan for the management of the lake and the surrounding area. The competent Authority for the plan is the River Tiber Basin Authority. The plan defines the strategic objectives for development and protection of the territory to be pursued with any suitable operative instrument of technical and administrative planning. It also promotes new rules and procedures favoring an environmentally sustainable socioeconomical development and the planning of structural and maintenance interventions. It represents an endeavor aimed at harmonizing water resources, anthropic activities, and environment in the perspective of mending current problems and outlining future developments. The declared objectives are:

- Prevention of the lowering of the water level of the lake
- Protection and exploitation of the lake ecosystem
- Curbing of pollutants to water bodies and soil
- Maintenance of the basin hydrographical network
- Policies of limitation of water use for irrigation

The Regional Environmental Agency has started a monitoring program on the effects of 19 streams in letting into the lake on the quality of its water, with particular reference to the impact deriving from agricultural practices. Lake Trasimeno and the two minor lakes of Chiusi and Montepulciano are what remain of a much larger lake occupying vast areas of upper Umbria and Val di Chiana in prehistoric ages, which has progressively shrunk down throughout the geologic eras. The area has been the site of human settlement for millennia. The fluctuation of the water level, with alternations of floods and droughts, has always been a serious concern to the settlers for the consequences on agriculture and livestock. In the past, the main threats were the floods, rather than the droughts, because of the extensive agricultural activities and the sudden, often unpredictable, nature of the phenomenon and its more devastating effects.

Drainage interventions have been carried out during the centuries, probably since the Etruscan and Roman era. Streams have been diverted from the lake, and ditches and canals were dug. The most important works were the diversion of water streams from Lake Trasimeno to lake of Chiusi and the excavation of the so-called "Emissario di Braccio" (Braccio's Outlet) near San Savino in the first decades of the fifteenth century and of another outlet, parallel to the first one, in 1998.

While these interventions have proven effective in controlling excessive increases of water level and floods, they may have aggravated the problem of low levels. The limitation of high levels to the hydrologic zero prevents the pooling of a water reserve capable of attenuating the effects of prolonged dry periods. So, the real and grave problem is represented by low levels, despite the enlargement of the catching basin carried out 50 years ago.

Scarcity of rainfalls, hot temperatures and enhanced evaporation, and continued and intensive use for irrigation, drinking, and other human needs have led to an unprecedented low level, which is currently about 2 m below the hydrologic zero. This has serious environmental and macro- and microclimatic consequences. Changes occur in water temperature and composition, related to various components in suspension, solution, and sediment, enhancing the effects of pollution. The peculiar and uncommon flora and fauna both migratory and nonmigratory of this wet area are exposed to deadly risks. Fishing, economic activities, navigation, and tourism may suffer in the end of severe damages. So, restoring the level of water and preserving a good quality is of vital importance.

Projects for reducing the drawing of water from the lake for agriculture and other needs of the resident population have been made and recently completed.

The reservoirs of dams on river Chiascio and of Montedoglio basin supply water to the Trasimeno basin for irrigation and human use. The connection to Montedoglio, opened in 2011, provides large volumes of water for these purposes and, in particular periods, it is also possible to let in water of good quality into the lake in order to restore its level and composition.

The Montedoglio system is a very important accomplishment expected to stop and revert the ominous trend toward a progressive shrinking and deterioration of the lake.

In addition to the Trasimeno basin, also the Val di Chiana basin is involved in the use of water from Montedoglio. The Umbria- Tuscany Irrigation Authority (EAUT) is an interregional public authority of Umbria and Tuscany competent for the management of structures and water resources of Montedoglio system in the area. EAUT has been established November 2011.

The quality of water is a very important issue, not less important than its level. Many controls on the part of public organisms are taken to regular place and are supervised by ARPA in order to monitor the characteristics of the lake.

In addition to these, studies are carried out by academic and scientific organizations. Many areas have been investigated ranging from the chemical composition of water and sediments to unicellular and multicellular organisms in the water and in the surrounding environment, including ichthyic fauna. Changes in the environment have been described and analyzed; some of them are due to natural causes and many to anthropogenic factors, including unwary attempts to repopulate the fish species. Water management is, therefore, a complex and integrated system of rules and actions, fundamental not only in regulating the water regime of the lake but also in protecting, maintaining, and developing environmental, climatic, biologic, social, cultural, and economic aspects of the delicate ecosystem of this beautiful area.

5 Programs and Activities Dedicated to Quality of Life Sustainable Development

Improving quality of life in areas as Trasimeno often means to improve the technology access. To achieve such a result, the Umbria Region is the principal actor.

5.1 The Broadband, the ICT, and the Internet

According to a recent strategic plan of the Umbria Region concerning the implementation of the broadband in all the Umbria Region, the Trasimeno Lake area is served by the minimum 12 MB/s of the Internet. The improving of connection, and in particular, the broadband, will better the touristic attractiveness. Moreover, it also guarantees the consolidation of population in the area, with positive effect, particularly on the economic sustainability. The presence of the broadband gives the possibility, gradually, to improve the services at the local and touristic population as information, telemedicine, telemarketing, teleworking, and territorial promotion.

5.2 The Services of Trasimeno Lake Promotion

The Regional Agency for Tourism Promotion, the Province Administration, and the other local government and agencies support the image and the future of the area using the more advanced techniques and technologies dedicated at the promotion of the area. In particular, there is a local branch of the Regional Agency for Tourism Promotion exclusively dedicated to the area.

6 Programs and Activities Dedicate to Sustainable Management of Development

Because of the environmental and historical importance of Trasimeno area, training and teaching activities are fundamental. Also in this case the role of Province Administration is crucial. It coordinates and promotes all the environmental training and teaching activities.

6.1 Activities Training and Teaching

Trasimeno Lake and its wet territory, for the delicate environmental balance, have always posed the problem of dealing with a very dynamic and complex interplay of many naturalistic and human components. During the centuries, the use of the area by human settlements has led to a vast body of specific knowledge. Empirical experiences, studies, and research have been gathered in many fields ranging from geology, hydrologic balance and water management, environment, climate, flora, and fauna to the impact of human activities. The peculiarities of the territory have been, in the same time, a necessity and an opportunity for scientific investigation.

An interesting and exhaustive overview of studies and research is carried out and it is under way on Lake Trasimeno and its territory. It has been presented in a meeting on knowledge, evaluation, and proposals for the future of Lake Trasimeno, held at Castiglione del Lago, December 1–2, 2010. The topics have concerned environmental data, satellite water and vegetation monitoring, geologic structure, composition and geologic age of sediments, phytoplankton, evolution of the ichthyic fauna and its management, a numeric decline of animal and vegetal organisms markers of environmental changes, shallow-water ecosystems, Lake Trasimeno and its ecosystem past and future, management strategies according to habitat regulations, antipollution and purification methods, impact of agriculture and zootechnics on Trasimeno catching basin, regional government planning for the protection of Lake Trasimeno, and instruments and integrated strategies for the management of the lake environment. In addition to the scientific investigation and the continuous monitoring of the various components of the complex ecosystem, other cultural and educational instruments and institutions are available for use by a vast public and a variety of interests, from research to leisure.

The Museum of Fishery, located in San Feliciano, has a multidisciplinary approach and offers a comprehensive overview of the territory, including the geological formation of the lake, the naturalistic environment with its forms of animal and vegetal life, the history of the population that have inhabited the area, and the instruments and techniques of fishing. The exhibition is organized according to a temporal criterion reflecting the daily activities of the fishermen from dawn to sunset.

The Museum is the result of cooperation between different public institutions, the University of Perugia, scholars, students, local fishermen, and hunters. A huge amount of data, investigations, as well as local traditions describe “the culture of water” and “the language, the history, and the life,” according to the definitions of the Museum itself, of the populations that have lived on the shores of the lake during centuries making out their living essentially from fishing.

Fishing, as the most important productive activity and a complex professional skill, is framed in a general perspective taking into account environmental, historical, and sociological factors. Five aquariums exhibit the five autochthonous most important fish species of the lake. Ample information is provided concerning other local animal species such as birds, amphibians, reptiles, mammals, and invertebrates. The geological history of the lake, the archaeological findings, and the evolution of fishing techniques, rigs, and boats are exhibited in the chronological order mentioned above.

For teaching and educational purposes, a multimedia hall, a didactic hall, and a bookshop are available. Meetings, workshops, lectures, and laboratories aimed at a vast public of different cultural level and interests, from academic to ordinary visitors, are organized with the common philosophy of offering an integrated vision of the multiple naturalistic, historical, and sociological aspects of the territory. The naturalistic Oasis La Valle, located on the southeastern shore of the lake near San Savino, is a feeding ground for hundreds of species of migratory birds, pausing or wintering and nesting there, protected by cane ticket and marsh vegetation. The Alzavola Cooperative runs the Oasis and provides a wide range of facilities, such as bird watching and an exhibition hall showing historical and naturalistic topics of its territory. It also boasts a Center for Environmental Education with a scientific laboratory equipped with stereoscopic microscopes for research and demonstration and a library of texts on local environment and culture. Exhaustive printed information is available, even in Braille alphabet. The Oasis includes a station for bird ringing and an observatory equipped with binoculars, telescopes, and headphones for bird watching and photography. On the Island Polvese, the Plestina Cooperative runs the Polvese Island Center for Environmental Experience, an example of sustainable environment management based on biologic agriculture, energy saving, and filtering systems of pollutants. Educational programs on environmentally friendly tourism and sustainable development are carried out, with lectures on landscape, history, and culture of the territory and on use of modern technologies. The Center offers a wide range of services to schools and visitors, organizing environmental and cultural trails, guided tours, teaching campuses, meetings, educational courses, and seminars (3, 4, 5).

It is worth of note that the visit to these three facilities is possible with a single ticket. It is encouraged in order to provide a complete and integrated experience and exhaustive information on the naturalistic and cultural peculiarities of the territory.

The area of Lake Trasimeno has been the stage for many historical events, the most known of which is the battle of Lake Trasimeno that took place in 217 BC between the invading army of Cartage led by Hannibal and the army of Rome led by Consul Gaius Flaminius. Historians and military experts are still debating about the site and the course of the fight that resulted in one of the most ruinous defeats of Rome. Scholars and amateurs carry on research and personal investigation, and commemorations of the historical take place regularly, to the point that this has become an element of local cultural identity. Among the cultural activities involving teaching, there is the archaeological research concerning the hydraulic works for the regulation of the level of the lake performed by the Etruscans and the Romans. While many remnants of Roman works have been identified and studied, research is still going on for the identification of those possibly made by the Etruscans. On the whole, it can be said that the territory of Lake Trasimeno offers enormous opportunities for research, teaching, and training in many fields ranging from the naturalistic characteristics, to the problems connected with the balance of the catching basin, and to the local economic issues and the cultural peculiarities. It is desirable that this be made with a holistic vision that integrates different disciplines and levels of intervention from politics, to academy, and to public opinion.

6.2 The SIGLA: Project Management Information System of the Lake Trasimeno

In order to enable adequate monitoring and efficiently the Provincial Administration since 1985, in collaboration with the Region Umbria promote a modern system batch of data collection and analysis, named SIGLA. The system is the basis of current management, and it has a strategic importance for the lake. SIGLA reports data on chemical substance, meteorological condition (rain, in particular), and other environmental data (Figs. 9 and 10).

Fig. 9 The Polvese Island

Fig. 10 The Christmas Island poster 2011

7 Conclusions

The case of Lake Trasimeno is rich in history, culture, traditions, and natural resources. It is an example of a good, modern governance and strong active democratic participation. The valorization of the resource since 1950 has provided an important socioeconomic development throughout the basin. The Trasimeno Lake is a significant case of a weak area with a dynamic equilibrium. In the absence of a good practice of modern democratic governance, it risks of a rapid decline and impoverishment.

The integrated strategy of sustainable development with attention to inter- and intragenerational problems allowed to firmly establish in the local government and in the people a consciousness innovative. It premises to turn weaknesses into strengths in the area for future generations.

In particular, the role of the Province Administration in the area is crucial. It coordinates several actors in the area, but it is also an active promoter of the territory and of economic activities.

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Sustainable Farm: A Case Study of a Small Farm from Pali, India

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Abstract The small-farm model is the surest route to broad-based economic development as they are multiple functionaries and provide immense benefits for society and for the biosphere. In food production, small farms are more productive and more efficient. With regard to cost and return, a small-farm economy offers a clear solution. Thus, a small farmer can intensify biodiversity and the greater the biodiversity, the higher the productivity and stability and sustainability of agriculture. Small family farms are the backbone of a community, of a nation and of a society as a whole. Small biodiverse farms based on internal inputs are in fact the only promise for increasing agricultural productivity, whether productivity is defined in terms of biological productivity or in terms of financial returns, or in terms of energy. This chapter presents a precise review on the benefits of multi-utility of small farms with the case study of Mr. Madan Lal Deora, a progressive farmer of Pali, district of Rajasthan in India who had established himself as a successful farmer adopting diversified farming system. He had adopted multiple cropping and farming system on his farm which is 1 ha in area by growing cereals, oilseeds, pulses, medicinal plants and forest plants with horticultural crops including fruits and vegetables. Along with agriculture, the farmer is having livestock which yields milk and the dung is converted into valuable vermicompost. Thus, this model of multifunctional small farm which integrate crops, horticulture, livestock and natural vegetation is key to sustainable development in countries dominated by small farms.

Keywords Small farmer • Biodiversity • Multifunctional • Multiple cropping • Sustainable development

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_11,

1 Introduction

India is a land of small farmers, with 650 million of her one billion people living on the land and 80% farmers owning less than 2 ha of land. In other words, the land provides livelihood security for 65% of the people, and the small farmers provide food security for one billion. In the US also, the number of small farms is growing by 2% a year. Policies driven by corporate globalisation are pushing farmers off the land and peasants out of agriculture which is not a natural evolutionary process. It is a violent and imposed process. In fact, it is the small biodiverse farm which has higher productivity than large industrial farms. Large farmers and industrial farming has serious limitations on increasing agricultural productivity. One of the key solutions to these challenges is agricultural innovation, to produce optimum and conserve more and thereby improve farmers' lives and the way to this is small sustainable farm (Narain 2011). In the Third World, the focus of rural development is shifting from mechanisation to programmes that strengthen small farmers and their indigenous traditional methods as the small farmers have tremendous scope for increasing productivity because the natural capital, the soil, the water and the biodiversity can be enhanced through conservation and rejuvenation. Sustainable agricultural practices often rely on traditional know-how and local innovation. Local people have a wealth of knowledge about their environment, crops and livestock. They keep locally adapted breeds and crop varieties. They have social structures that manage and conserve common resources, help people in need and maintain the social fabric. Rather than ignoring or replacing this knowledge, sustainable agricultural development seeks to build on it and enrich it with appropriate information from outside. This should be examined on scientific platform for its application (Saxena and Kalra 2011). On large farms, natural resources are exploited and depleted. The soil looses fertility through chemical fertilisers and undergoes compaction by heavy machinery. Biodiversity is eroded since industrial scale farming can only be practised as a monoculture and energy use is intensified, contributing to global warming.

Sustainability has evolved a lot from its original meaning of 'ability to continue'.Brundtlard commission's concept of sustainability referred to development that meets the needs of the present without compromising the ability of future generation to meet their needs. Dr. M.S. Swaminathan (2005) identified 14 major dimensions of sustainable agriculture; and according to him, sustainable agricultural technology should be technologically appropriate, economically feasible and viable, environmentally sound, stable over the long run, efficient in resource use, locally adaptable, socially acceptable and sustainable, implementable in existing political set-up and bureaucratic structure, culturally desirable, renewable, equitable and productive. In the present day, it is of utmost importance that the sustainable dimensions of the developed and transferred technologies should be looked into, and each new technology should satisfy the concept and dimensions of sustainability.

The small farms of India have the highest potential for increasing productivity. There are scientific reasons for this. A small farmer can intensify biodiversity and the higher the biodiversity, the higher the productivity and stability and sustainability of agriculture. The farmers' knowledge and wisdom of packaging mixed cropping,

Fig. 1 Livestock at farmer's field

intercropping, para-cropping and relay cropping through which they have diversified their crop-growing practices for enhanced productivity and profitability as well as mitigating the risk for meeting the diversified household needs can be seen in many tribal belts of India. Small family farms are the backbone of a community, of a nation and of a society as a whole. A landscape of family farms is settled, balanced and stable and generally sustainable as it's the natural shape of society on the land. Such communities aggregate into strong and secure nations. Small biodiverse farms based on internal inputs are in fact the only promise for increasing agricultural productivity, whether productivity is defined in terms of biological productivity or in terms of financial returns, or in terms of energy. Large industrial farms use ten times more energy than they produce as food; most of the energy goes to pollute the atmosphere and destabilise the climate. An earlier Prime Minister of India, Choudhary Charan Singh had said, 'Agriculture being a life process, in actual practice, under given conditions, yields per acre decline as the size of the farm increases (in other words, as the application of human labour and supervision per acre decreases). The above results are well nigh universal; output per acre of investment is higher on small farms than on large farms. Thus, if a crowded, capital-scarce country like India has a choice between a single 100 acre farm and forty 2.5 acre farms, the capital cost to the national economy will be less if a country chooses the small farms'. According to the World Bank (2007), three quarters of poor people in developing countries lived in rural areas in 2002, and they derived their livelihood directly or indirectly from agriculture via small multifunctional farms.

The issues of quality and quantity of agricultural production are imperative if the farmers are to be benefited. The chapter presents a precise review on the benefits of multi-utility of small farms with the case study of Mr. Madan Lal Deora (Fig. 1), a progressive farmer of Pali, district of Rajasthan in India who had established himself as a successful farmer adopting diversified farming system.

Fig. 2 Vermicomposting in trenches

He had adopted multiple cropping and farming systems on his farm which is 1 ha in area by growing cereals, oilseeds, pulses, medicinal plants and forest plants with horticultural crops including fruits and vegetables. Along with agriculture, the farmer is having livestock (Fig. 2) which yields milk, and the dung is converted into valuable vermicompost. He had also turned himself into an entrepreneur by processing and value addition to his farm produce through a tunnel drier. The solar tunnel dryer is a polyhouse-framed structure with UV-stabilised polythene sheet, where products on large scale could be dried under controlled environment. The enterprise consists of different value-added products of typical Indian fruits and vegetables including juice, squash, candy, powder, pickle, dry aonla, churn tablets, preserve and ladoos. All the products are purely organic and have high demand in the local and regional markets (Chandregowda and Kumar 2007).

2 Functionality of Small Diversified Farm

Small farms are multiple functionaries and the benefits they provide for society and for the biosphere are immense. In food production, small farms are more productive and more efficient. With regard to cost and return, a small-farm economy offers a clear solution. For centuries, traditional farmers have developed diverse and locally adapted agricultural systems, managing them with ingenious practices that often result in both community food security and the conservation of agrobiodiversity. This strategy of minimising risk stabilises yields, promotes dietary diversity and maximises returns using low levels of technology and limited resources. These microcosms of agricultural heritage still cover no less than one million ha worldwide, providing cultural and ecological services not only to rural inhabitants but to mankind generally. These services include the preservation of traditional farming knowledge, local crop and animal varieties and native forms of sociocultural organisation. By studying these systems, ecologists can enhance their knowledge of the dynamics of complex systems, especially the relationship between biodiversity and ecosystem function and practical principles for the design of more sustainable agroecosystems appropriate to small farmers. Novel agroecosystem designs have already been modelled on successful traditional farming systems (Altieri 2004). Thus, the small-farm model is also the surest route to broad-based economic development. That means the minimum number of hectares needed to support a family rises, contributing to abandonment of farmland by smaller, poorer farmers. The land goes in the hands of the larger farmers who can compete in a low-price environment by virtue of having very many hectares. They overcome the low-profit per hectare trap precisely by owning vast areas which add up to good profits in total, even if they represent very little on a per hectare basis. The end result is the further concentration of farmland in the ever fewer hands of the largest farmers (Lappé et al. 1998). A penalty is paid for this land concentration in terms of productivity, as large farmers turn to monocultures and machines to farm such vast tracts, and in terms of the environment, as these large mechanised monocultures come to depend on agrochemicals. Jobs are lost as machines replace human labour and draft animals. Natural resources deteriorate as nobody is left who cares about them. Finally, food security is placed in jeopardy. While large farmers almost always use monocultures, and one or at the most two cropping cycles per year, small farmers intercrop various crops on the same field, plant multiple times during the year, and integrate crops, livestock and even aquaculture, making much more intensive use of space and time (Netting 1993; Lappé et al. 1998). Agriculture not only produces/supplies agricultural products but also contributes to food security, by reducing the risks caused by unexpected events or a possible food shortage in the future, to the preservation of land and environment, to the creation of a good landscape and to the maintenance of the local community, through production activities in harmony with the natural environment. All of these roles are known as the 'multifunctionality' of agriculture. Norway has also endorsed the concept of multifunctionality as the basis for special treatment of farming for reasons of environmental protection, food security and viability of rural areas (Norwegian Ministry of Agriculture 1998), as has the European Union to some extent (European Commission 1999) and as have some other countries. Mechanisms that use economic incentives encourage biodiversity conservation either through enhancing the private returns to desired land management activities or efficient utilisation of small diversified farm. The major functionality of small farm under the case study is described as below.

2.1 Diversity and Environmental Benefits

The small farm is a unique world in itself where a variety of plant and animal biodiversity can be found. The case study farm of Mr. Madan Lal is an excellent example where one can find more than 100 cultivated and natural species of plants growing in close harmony supplementing each other. The crops include wheat (*Triticum aestivum*), maize (*Zea mays*), barley (*Hordeum vulgare*), oats (*Avena* spp.), jowar (*Sorghum bicolor*), bajra (*Pennisetum americanum*), mustard (*Brassica nigra*), til (*Sesamum indicum*), castor (*Ricinus communis*) and cotton (*Gossypium* spp.). In spices one can find cumin, fennel, fenugreek and dill in fruits; the major plants are drumstick (*Moringa oleifera*), ber (*Ziziphus mauritiana*), mulberry (*Ficus alba*), jamun (*Sygigium cumini*), aonla (*Emblica officinalis*), custard apple (*Annona squamosa*), gonada (*Cordia myxa*) and fig (*Ficus carica*). In vegetables the farmer is growing mint (*Mentha arvensis*), spinach (*Basella alba*), okra (*Hibiscus esculenta*), tomato (*Lycopersicon esculentum*), ginger (*Asarum canadense*), red and green chillies (*Capsicum annum* L., *Capsicum frutescens* L.), carrot (*Daucus carota*), coriander leaves (*Coriandrum sativum*), fenugreek (*Trigonella foenum-graecum*), peas (*Pisum sativum*), cabbage (*Brassica oleracea*), onion (*Allium cepa*), sweet potato (*Ipomoea batatas*), bitter gourd (*Momordica charantia*), radish (*Raphanus sativus*), sugar beet (*Beta vulgaris* var. *altissima*), cauliflower (*Brassica oleracea botrytis*) and *bathua (Chenopodium album)*. The farm structure contributes to biodiversity, a diverse and aesthetically pleasing rural landscape and open space. In wild plants we can find phog (*Calligonum polygonoides*), angrezi babool (*Prosopis juliflora*), bordi (*Ziziphus nummularia*), lana (*Haloxylon salicorniourn*), bawli (*Acacia jacquemontii*), guggal (*Commiphora wightii*), henna (*Lawsonia inermis*), anwal (*Cassia auriculata*), kair (*Capparis decidua*), ber (*Ziziphus nummularia*), anar (*Punica granatum*), kheep (*Leptadenia pyrotechnica*), aak (*Calotropis procera*), senna (*Cassia angustifolia*) and kaner (*Nerium* spp.) growing on the farm boundary. In general we can see an entire biosphere of the arid zone vegetation with cultivated plants in a small farm. Thus, if the loss of biodiversity or the sustainability of agriculture is of concerns, small farms offer a crucial part of the solution. The farm embodies a diversity of cropping systems, farming systems, landscapes, biological organisation, culture and traditions. Compared to the ecological wasteland of a modern export plantation, the small-farm landscape contains a myriad of biodiversity. The forested areas from which wild foods and leaf litter are extracted; the wood lot; the farm itself with intercropping, agroforestry and large and small livestock; the fish pond; and the backyard garden allow for the preservation of hundreds if not thousands of wild and cultivated species. Proper management of the natural resources of soil and water produces significant environmental benefits for society. The benefits of small farms extend beyond the economic sphere. To begin with, small farmers utilise a broad array of resources and have a vested interest in their sustainability. At the same time, their farming systems are diverse, incorporating and preserving significant functional biodiversity within the farm. By preserving biodiversity, open space and trees, and by reducing land degradation, small farms provide valuable ecosystem services to the larger society. In the United States, small farmers devote 17% of their area to woodlands, compared to only 5% on large farms. Small farms maintain nearly twice as much of their land in 'soil improving uses', including cover crops and green manures (D'Souza and Ikerd 1996). Similar farm had been developed by Mr. M.S. Grewal in Punjab (India) whose main activity covers crop production, foundation hybrid seed production, floriculture cash crop production, fresh vegetable cultivation, relaying crop production and innovative farming (TAAS 2005). In the Third World, peasant farmers show a tremendous ability to prevent and even reverse

Fig. 3 Family and village members involved in processing

land degradation, including soil erosion (Templeton and Scherr 1999). Small farmers can also make better stewards of natural resources, conserving biodiversity and safeguarding the future sustainability of agricultural production. It is the commitment that family members have to their farm and the complexity and integrated nature of small farms which guarantee their advantage in terms of output. Pretty (1997) has documented the productivity of such systems in a wide variety of environments. Sustainable farms are small. They're mixed—mixed crops, mixed trees and mixed livestock—with all three mixed together in an integrated pattern that mimics natural biodiversity and reaps the benefits of collaborating with nature.

2.2 Social and Community Empowerment

The small farms of Mr. Madan Lal use family and village labour (Fig. 3) which is personally committed to the success of the farm instead of unknown hired labour, and farms apply far more labour per unit area than do larger farms.

The farms often use far more inputs per unit area than larger farms, though the mix on small farms favours non-purchased inputs like manure and compost. The farm owner Mr. Madan Lal had become a successful entrepreneur, and now he is motivating other farmers also to adopt his path. The enterprise is having a selling counter at the farmers home itself where the local people come and take various products. As this is a small enterprise which does not have any branch, the outside parties also come in the village and take the processed product however. For the outside market, the orders are placed in advance and the delivery is taken by the party itself. The farmer is earning INR 70,000–90,000 profits a year extra besides providing employment to many needy persons. He had shown that by connecting agriculture with entrepreneurship, one can easily sustain his living along with good savings. The positive results for social and economic aspects are also in close conformity with the study of Veerbhadrai et al. (2003) who reported that entrepreneurship development programmes bring prosperity and raise the income of farmers in rural areas. Today Madan Lal employs 50 labours from his village in his peak season for his aonla enterprise giving employment and social assistance to poor and weaker sections of the society. He had adopted a unique scheme for employment of workers at his enterprise, that is, he takes not more than one worker from each family so that every family has one earning hand; secondly he employs persons for 1 month only so that all the needy persons from his village may get a chance to feed their families. This system is followed in a cycle so that all villagers have access to employment and everyone feels an involvement in the social system. Mr. Madan Lal is inspiring his own as well as nearby farmers to adopt this sustainable farming model for their subsistence and livelihood. A surprisingly impact of the enterprise is he had won many awards and is a well-known personality in social sector. As Mr. Deora is adopting organic farming and processing, many of his products go to Delhi the capital city of India and far markets also. Thus, a small diversified farm produces more equitable economic opportunity for people in rural areas as well as greater social capital. This can provide a greater sense of personal responsibility and feeling of control over one's life, characteristics that are not as readily available to factory line workers. Land owners who rely on local businesses and services for their needs are more likely to have a stake in the well-being of the community and the well-being of its citizens. In turn, local land owners are more likely to be held accountable for any negative actions that harm the community.

2.3 Productivity

The small farm is highly productive and efficient. In India the farmers have stubbornly clung to the land despite more than a century of harsh policies which have undercut their economic viability. In general a small farm has multiple functions which benefit both society and the biosphere and which contribute far more than just a particular commodity, though there is ample evidence that a small-farm model for agricultural development could produce far more food than a large farm pattern ever could. With regard to the selected case study presented in this chapter, the farmer productivity is described as below.

3 Crop Husbandry

The farmer takes only rainy season and winter season crops due to limitation of water and irrigation. In winter the main crops (Table 1) taken are wheat and barley under irrigated condition and mustard and toria under rainfed condition on conserved soil

Table 1 Comparative productivity of different crops at case study farm

S. no.	Name of crops	District productivity Qt/ha	Farmers' field productivity Qt/ha	Output INR/ha
1	Cumin (*Cuminum cyminum*)	6.42	7.43	98,752
2	Wheat (*Triticum aestivum*)	17.89	18.49	25,046
3	Barley (*Hordeum vulgare*)	17.99	18.66	21,468
4	Gram (*Cicer arietinum*)	6.62	7.22	13,240
5	Mustard (*Brassica juneca*)	13.90	15.12	34,750
6	Fenugreek (*Trigonella foenum-graecum*)	15.70	16.34	62,800
7	Fennel (*Foeniculum vulgare*)	12.40	13.21	99,200
8	Greengram (*Vigna radiata*)	5.12	6.14	7,680
9	Sesame (*Sesamum indicum*)	5.42	6.12	16,260
10	Sorghum (*Sorghum bicolor*)	5.07	5.76	5,577
11	Cluster bean (*Cyamopsis tetragonoloba*)	7.08	7.98	7,770
12	Bajra (*Pennisetum glaucum*)	4.90	5.34	4,900
13	Maize (*Zea mays*)	6.52	7.33	10,432

Fig. 4 Bumper yield of aonla

moisture. In rainy season the main crops taken are seasemum, moong, guar, jowar and bajra along with cucurbitaceous crops. The farmer grows dhaincha (*Sesbania aculeata*) during rainy season as cover crops on his fallow land. Cover crops are sown each year of second year or alternatively, the natural vegetation is left to regrow and cover the interrow space. Any of these options accompanied by chemical weed control appears cost-effective compared to tilling the soil. The farmer also takes spice crops mainly cumin, fennel, fenugreek and dill on his limited area under different planting patterns (Figs. 4, 5, and 6) to optimise the yield along with restoration of soil fertility.

Fig. 5 Mustard grown in interspaces with aonla

Fig. 6 Henna grown in interspaces of aonla

4 Animal Husbandry

The farmer is having five milch animals, three fine-breed cows and two buffaloes. The animals are used for fulfilling the needs of the family as well as the excess milk is sold in the market at the rate of INR 25–35 per kg, thus contributing to an annual income of INR 7.75 lakh (Table 2). The most important contribution of animals is

Table 2 Economical viability of cattle and buffalo in arid region

S. no.	Type of animal	Total expenditure	Income from milk	Income from manure	Net benefit
1	Buffalo	A. Dry fodder = 15 kg at INR 5/- B. Green fodder = 20 kg at INR 3/- C. Concentrate = 8 kg at INR 15/- D. Total = A + B + C = 75 + 60 + 120 = INR 255/-	20 l at INR 35/- = INR 700/-	15 kg vermicompost at INR 5/- = INR 75/-	700 + 75–255 = INR 520 per day per buffalo
2	Cross-breed cow	A. Dry fodder = 20 kg at INR 5/- B. Green fodder = 20 kg at INR 3/- C. Concentrate = 10 kg at INR 15/- D. Total = A + B + C = 100 + 60 + 150 = INR 310/-	30 l at INR 25/- = INR 725/-	20 kg vermicompost at INR 5/- = INR 100/-	725 + 100–310 = INR 515 per day per cow

Fig. 7 Aloe vera grown on degraded soil

Fig. 8 Agri-horti system

production of vermicompost (Figs. 7 and 8), that is, conversion of animal waste into nutrient-rich compost using earthworms by a scientific procedure.

This vermicompost is used in place of chemical fertilisers for growing of fodder, vegetables, fruits and field crops, thus earning the tag mark of organic produce. Livestock sector not only provides essential protein and nutrition to human diet through milk, eggs, meat, raw material/by-products such as hides and skin, blood, bone and fat but also plays an important role in utilisation of nonedible agricultural by-products (Sharma and Tiwari 2011). Excess vermicompost is also sold in the market, thus contributing to an annual. At the small farm the economics of five animals is as under:

Two buffalo profit in one lactation period of 300 days = INR 520/- per day × 300 days

= INR 156,000/- × 2 = INR 312,000/-

Three cross-breed profit in one lactation period of 300 days = INR 515/- per day × 300 days = INR 154,500/- × 3 = INR 4,635,000/-
Total income from five animals = INR 312,000 + 4,635,000 = INR 775,000/-

5 Horticulture

The farmer is growing different vegetables all year round on his limited land and resources. The main vegetable includes (Fig. 9) tomato, brinjal, okra, cucurbits and greens; among fruits the main crops are aonla (Fig. 10), gonda, drumstick and ber.

Fig. 9 Different vegetables grown on limited land

Fig. 10 Mr. Madan Lal Deora at his farm

Table 3 Economics of aonla by-products

Details	Dried fruit	Ladoo	Candy
Initial investment (INR)	25,000	25,000	25,000
Purchase price of aonla (INR per kg)	5	5	5
Quantity loaded in one batch (kg)	25	20	20
Total purchase price (INR)	125	100	100
Other investment before drying (INR)	45	1,000	550
Labour, water and other (INR per batch)	100	1,400	160
Drying time of one batch (days)	1	2	3
Selling price (INR per kg)	100	450	300
Earning/drying day due to drying of aonla in the farm solar dryer (INR per batch)	200	2,900	1,700

The vegetables are one of major source of earning; they are sold at premium price as they are fully organic and no chemical is used in their package and practice of production. The fruits are also more fresh and of premium quality as they are supplemented on organic manure which is of added advantage to the farmer. The annual income from the fresh and dried vegetables is INR 190,000.00. If a country dominated by small farms like India has to attain nutritional security, it is very essential that the locally produced vegetables and fruits are marketed locally and undergo processing (Nanda 2011). The farmer is growing aonla on large scale which are sold after processing. The details of economics of some of the processed products produced at the farmers own field are presented in Table 3.

Fig. 11 Vermicompost unit

5.1 Efficiency

While small farms are clearly more productive than large farms in terms of output per unit area, claims are often made that large farms are still more efficient. To start with, this depends on the definition of efficiency that one chooses. Small farms make more efficient use of land (Fig. 11). Large farms generally have higher labour productivity due to mechanisation, so they might be considered to be more efficient in labour usage. The definition of efficiency most widely accepted by economists is that of 'total factor productivity', a sort of averaging of the efficiency of use of all the different factors that go into production, including land, labour, inputs and capital. Small farms have greater total factor productivity than large farms in sub-Saharan Africa, Asia, Mexico and Columbia. More recently, the same pattern has been found in Honduras (Gilligan 1998). In a recent, detailed analysis of true total factor productivity, corrected for a number of biases in the data, the advantages to larger farm sizes found by some analysts 'disappear, while there is evidence of diseconomies as farm size increases' (Peterson 1997).

6 Innovation: Local Tunnel Solar Dryer

The new millennium brought into sharp focus the challenges expected of following a model of economic development based on excessive consumption of energy derived from fossil fuels. At the same time there was a threat from global warming, rising sea levels and climate change due to increasing atmospheric pollution caused by the greenhouse gases' emission from economic activities based on fossil fuels. All these have only strengthened the view, which has gained wide currency in recent years that the process of economic development cannot be sustained for long by relying on this model. Thus, there is an increasing realisation that the switchover to renewable sources to meet the growing energy needs of a burgeoning population cannot be delayed any further. Clean and green power for sustainable development has become the motto. Fortunately India is blessed with abundant solar energy potential that can be used for different applications. In most of villages of rural India, electricity supply is hardly 3–4 h per day, and as the cost of petro products is too high, hence, there is need for exploration of renewable energy sources for environmental protection and sustainable development. This part of the chapter presents the innovation of Mr. Madan Lal Deora of Pali district of Rajasthan in India who had made a local tunnel solar drier using his own knowledge using hit and trial method, and he is now a successful entrepreneur having a local solar processing unit at his village Nimaz in Pali district of Rajasthan. In the month of December, solar radiation increases from 2.6 to 4.5 $kWhm^{-2}day^{-1}$ at Pali, whereas during summer season, that is, March to May, this value ranges from 5.0 to 7.4 $kWhm^{-2}day^{-1}$. Pali receives 6.0 $kWhm^{-2}day^{-1}$ global solar radiation and 1.981 $kWhm^{-2}day^{-1}$ diffuse solar radiation on horizontal surface while 6.272 $kWhm^{-2}day^{-1}$ direct solar radiation at normal incidence. The average daily duration of bright sunshine is 8–9 h.

In many rural areas of Rajasthan, the farmers grow fruit and vegetables, which have to be sold in the market immediately after harvesting. When the production is high, the farmers have to sell the material at very low price, thereby incurring great loss. This loss can be minimised by dehydrating fruits and vegetables. The dried products can be stored for longer time in less volume. A successful enterprise can be run based on this principle which can easily utilise the surplus produce facing the seasonal glut. In off seasons the farmer can sell the dried products at higher price. The traditional methods for drying the agricultural produce are to dehydrate the material under direct sunshine. This method of drying is a slow process and usual problems like dust contamination, insect infestation and spoilage due to unexpected rain. These problems can be solved by using either oil-fired or gas-fired or electrically operated dryers. However, in many rural locations in India, the electricity is either not available or too expensive for drying purpose. Thus, in such areas the drying systems based on the electrical heating are inappropriate. Alternatively, fossil-powered dryer can be used, but it poses such financial barriers due to large initial and running cost that these are beyond the reach of small and marginal farmers. In the present energy crisis, it is desirable to apply a little solar technology for dehydration of fruits and vegetables, so that gas, oil and electricity can be saved. Keeping the above facts in mind, this innovation of local drier can prove to be of much help to farmer of most of developing nations where sunshine is abundant. Moreover, the products are easy to sell as the products are having high demand in local market also.

Fig. 12 Product diversification of aonla

The farmer had built a local solar drier for drying different fresh produce of his farm (Fig. 12). A semicircular-shaped solar tunnel dryer having a floor area of 5 m × 3.75 m is designed for drying different processed products.

The solar tunnel dryer is a polyhouse-framed structure with UV-stabilised polythene sheet having a height of 2.25 m, where products on large scale could be dried under controlled environment and which is large enough to permit a person to enter into it and carry out operations such as to load and unload the material to be dried. The orientation of tunnel solar dryer is in east-west direction and ultraviolet-stabilised polycarbonate/polythene sheet of 200-μm size is used as a cover material. The structural components of low tunnel solar drier (LTSD) include hoops, foundation, floor, UV-stabilised polythene film and drying trays. The LTSD consists of three inlets having radius of 15 cm each oriented in southwest direction for entry of fresh air and three outlets at the top of the structure for the easy escape of hot air along with water vapour. The maximum temperature inside the domestic solar dryer reaches 44°C at 14 h, while the minimum temperature inside the solar tunnel dryer was 20°C at 9 h on a typical day in winter season. While maximum and minimum ambient temperatures were 26 and 11°C, respectively, on that day. Cost-wise the unit reaches INR 25,000/- per system, respectively. Aonla pulp from moisture

Fig. 13 Processed products of different vegetables

content of 80.95% to safe moisture content 9.0% can be successfully dried in 2 days at the prevailing conditions in the drier. The farmer is having about 1 ha of land which is entirely covered with the plantation of aonla fruit plants planted at spacing of 6×6 m. The space left in between the plants is utilised for growing crops like wheat, mustard and vegetables like tomato, chillies, onion, garlic, *methi*, egg plant and okra, which supplies the requirement of his family besides giving handsome income from the nearby market. The main enterprise of the farmer is the processing unit of aonla which is well known for its organic and hygienic products. As the farmer is having his own orchard, raw material is no problem. His farm is well maintained having some 20 indigenous-breed plants of aonla (*Emblica officinalis*) which give fruits which are small in size, but they are much in demand due to their medicinal properties. Rest of the plantation is of a very good variety NA-7, which is evolved from Achrya Narendra Dev University of Agriculture and Technology, Faizabad, Utter Pradesh. This variety is excellent in taste, right green in colour with high juice and pulp content and minimum fibres. The different products (Fig. 13) manufactured by the farmer include juice, squash, candy, powder, pickle, dry aonla, churn tablets and preserve.

He manufactures two types of dry aonla: one is direct drying of green aonla which is used in a number of ayurvedic medicines and traditional drugs, and another is the aonla dried after blanching which is used in as eating supplement of betel nut and as a mouth freshener. The farmer produces four types of preserve, namely, chutney preserve produced by making flakes of fruit, preserve from big size fruits from improved cultivars, preserve from small-size fruits from local cultivars and preserve aonla from which seeds had been removed. One product that is known to all and very much in demand is the aonla *ladoo/burfis*. They are made by washing and grating of fresh aonla. This aonla is then roasted in pure butter oil and after cooling mixed with sugar and dry fruits. The product is then kept in solar drier for a day and then converted to either *ladoos* or *burfis*. Drying dehydrating vegetables (Fig. 14), namely, mint, spinach, okra, tomato, ginger, red and green chillies, carrot, coriander leaves, fenugreek, peas, cabbage, onion, sweet potato, bitter gourd, radish, sugar beet, cauliflower, *bathua* and fruits, namely, ber and pomegranate was also very successfully.

Fig. 14 Local tunnel solar drier

The leafy vegetables can be dehydrated within 1 day at the loading rate of 4–5 kg/m^2, whereas other vegetables can be dried within 2 days at loading rate of 8–10 kg/m^2. The green colour of solar-dried products remained as such even after drying. The spinach powder can be used for making 'palak paneer' a special local dish. The coriander and tomato powder can be mixed with ingredients to prepare instant soup/sauce/chutney by adding water. The solar-dried grated carrot can be used for preparing pudding '*gajar ka halwa*'. Thus, the local tunnel solar drier is economically and environmentally profitable and need to be popularised in rural areas of India. This case study is in accordance with the findings of Lin (1997), who concluded that development of cottage- and food-processing enterprise industries is the need of developing nations in rural areas like India and Taiwan.

7 Small Farms in Economic Development

The production of grain and filling of godowns are not the only the goals of farm production; farm resources must also generate wealth for the overall improvement of rural life—including better housing, education, health services and more recreational and cultural opportunities (Rosset 1999). In farming communities dominated by large corporate farms, nearby towns died off. Mechanisation meant that fewer local people were employed, and absentee ownership meant that farm families themselves were no longer to be found. In these corporate-farm towns, the income earned in agriculture was drained off into larger cities to support distant enterprises, while in towns surrounded by family farms, the income circulated among local business establishments, generating jobs and community prosperity.

Where family farms predominated, there were more local businesses, paved streets and sidewalks, schools, parks, churches, clubs, newspapers, better services, higher employment and more civic participation (MacCannell 1967; Durrenberger and Thu 1996). Small-farm livelihood is sustainable, when it 'can cope with and recover from the stress and shocks, maintain its capability and assets, and provide sustainable livelihood opportunities for the next generation…'. The risk of livelihood failure determines the level of vulnerability of a household to income, food, health and nutritional security (Kokate 2011).

This provides a powerful argument that land reform to create a small-farm economy not only is good for local economic development but also is more effective social policy than allowing business as usual to keep driving the poor out of rural areas and into burgeoning cities. Sobhan (1993) argues that *only* land reform holds the potential to address chronic underemployment in most Third World countries. Because small farms use more labour and often less capital to farm a given unit of area, a small-farm model can absorb far more people into gainful activity and reverse the stream of outmigration from rural areas. It turns out that a relatively equitable, small farmer-based rural economy does provide the basis for strong national economic development. This 'farmer road to development' is part of the reason why, early on in its history, the United States developed more rapidly and evenly than Latin America, with its inequitable land distribution characterised by huge haciendas and plantations interspersed with poverty-stricken subsistence farmers (de Janvry 1981). In the United States, independent 'yeoman' farmers formed a vibrant domestic market for manufactured products from urban areas, including farm implements, clothing and other necessities. This domestic demand fuelled economic growth in the urban areas, and the combination gave rise to broad-based growth (Sachs 1987).

8 Conclusion

Agriculture produces not only commodities but also livelihoods, cultures, ecological services, etc., and as such, the products of farming cannot be treated in the same way as other goods. Agricultural policy review, planning and integrated programming must be carried out in the light of the multifunctional aspects of agriculture, particularly with regard to food security and sustainable development. Despite decades of anti-small-farm policies taken by nation states, small and marginal farmers have clung to the soil in amazing numbers. But today we stand at a crossroads. As a whole we are poised to take steps toward global economic integration that poses far greater threats to small farmers than they have ever faced before. Trade liberalisation and globalisation pose a grave threat to the continued existence of small farms throughout the world. The minimum number of hectares needed to support a family rises, contributing to abandonment of farmland by smaller, poorer farmers. Farmers can compete in a low-price environment by virtue of having very many hectares. Rural communities die out as farmers and farm workers migrate to cities.

Natural resources deteriorate as nobody is left who cares about them. Instead of deepening policies that damage small farms, we should implement policies to develop small-farm economies. These might include genuine land reforms and tariff protection for staple foods—so that farmers receive fair prices. By doing so, we will strike at the root causes of poverty, hunger, underdevelopment and degradation of rural ecosystems. Thus, small-farm model is indeed the best and tested route to broadband economic development catering to need of farmers, society and nation.

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Sustainable City: A Case Study of Stormwater Management in Economically Developed Urban Catchments

Deepshikha Sharma and Arun Kansal

Abstract Stormwater run-off is difficult to manage in an economically developed and highly urbanized city. It causes diffuse pollution which impacts despite its local origin are not limited to the local pollution problems. The pollution gets mixed with the waste and impacts public health, aquatic life and ecosystem characteristics. The problem is closely linked to land use (e.g. the application of fertilizer to farmland or forestry plantations; livestock stocking rates on pastureland; handling and transport of oil, chemicals, raw materials and products through catchments). The economic development leads to urbanization which increases the impervious area of the catchment. This results in amplification of stormwater being generated and causes diffuse pollution. Planning of management strategies and application of pollution control measures can be done only after identification of sources which become difficult considering the dense sprawl in the city. The existing drainage systems may have many disadvantages like if run-off being added, it can increase the risk of flooding downstream containing contaminants such as oil, organic matter and toxic metals. Therefore, it is very important to amalgamate the use of sustainable urban drainage systems (SUDs) along with the existing drainage infrastructure in order to minimize the adverse impacts of the stormwater in thriftily established and extensively built-up city. The present study comprises of qualitatively evaluating the role of SUDs in stormwater management of dense urban cities. This chapter talks about an approach to manage rainfall run-off arising due to urbanization which is a direct impact of economic growth of a city. The chapter also highlights the need of SUDs for Delhi (national capital territory of India).

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_12,

Keywords Sustainable urban drainage systems (SUDs) • Filter strips • Filter drains • Infiltration devices and basins and ponds

1 Sustainable Cities

Environment and economy govern the concept of sustainable cities. The concept leads to minimum acceptable quality of life along with natural resource management. A sustainable city includes management of:

- Air quality
- Biodiversity
- Energy, climate change and ozone depletion
- Food and agriculture
- Hazardous materials
- Economy and economic development
- Environmental justice and human health
- Parks, open spaces and streetscapes
- Solid waste
- Transportation
- Water and wastewater
- Municipal expenditures
- Public information and education
- Risk management (activities of high environmental risk)

Consequently, there exists a constant struggle among the above-mentioned areas.

A sustainable city can be achieved by integrating the environmental dimensions into the social and economic sectors accompanied by robust government policy, actions and public participation. A healthy environment, a robust economy and ample employment opportunities form a strong and vigorous city.

Today, there is an urgent requirement to manage the existing cities in a sustainable manner for survival of future generations. Worldwide, there are many small towns and cities which are adopting the ways towards sustainability like Toronto (Canada), San Francisco (USA), Singapore and Cape Town (South Africa) (http://ethisphere.com/2020-global-sustainability-centers/). Most of these countries belong to developed world with stabilized population growth rate. Such examples are rarely found in developing world countries with high population growth rate and rapid urbanization.

Management of water resources is very important to create a sustainable city. Rapid urbanization amplifies the quantum of stormwater generated due to impervious nature of the city. This causes temporary flooding and waterlogging conditions, resulting in unhealthy environment and unaesthetic nuisance. Therefore, it is imperative to formulate and develop a water policy that creates sustainable water use and protect the environment and public health (Sustainable city: sustainable future for San Francisco; http://www.devalt.org/newsletter/jul00/lead.htm).

2 Urbanization

It is estimated that by 2030 more than five billion people will be residing in urban areas specifically Africa and Asia. At present more than half of the world's population is living in towns and cities resulting in economic growth and intense human activities. These activities amplify the local competition for all types of resources, with water among the most vital. In urban areas, water is extensively employed for the waste disposal. In contrast to its positive impacts, various forms associated with water like flooding, drainage, erosion and sedimentation can have detrimental effects on the human activities which augment due to alteration in natural water courses and increased impervious areas as a result of urbanization. A typical urban run-off is loaded with pathogenic and organic substances that are a public health threat. Figure 1 provides the estimated and projected urban and rural population of the world up to 2030.

The economic growth leads to establishment of huge infrastructure and causes rapid urbanization concentrated with human activity. This leads to occurrence of extensive impervious areas and man-made watercourses. As a result, run-off volume and flow increase, causing flooding and habitat destruction. Consequently, pollutants are also transported through the urban watershed, causing diffuse pollution. The volume of run-off and types of pollutants carried vary with the land-use type, rainfall intensity and duration and the time since the last precipitation event. Mallin et al. (2000), Lee et al. (2002), Tong and Chen (2002), Ackerman and Schiff

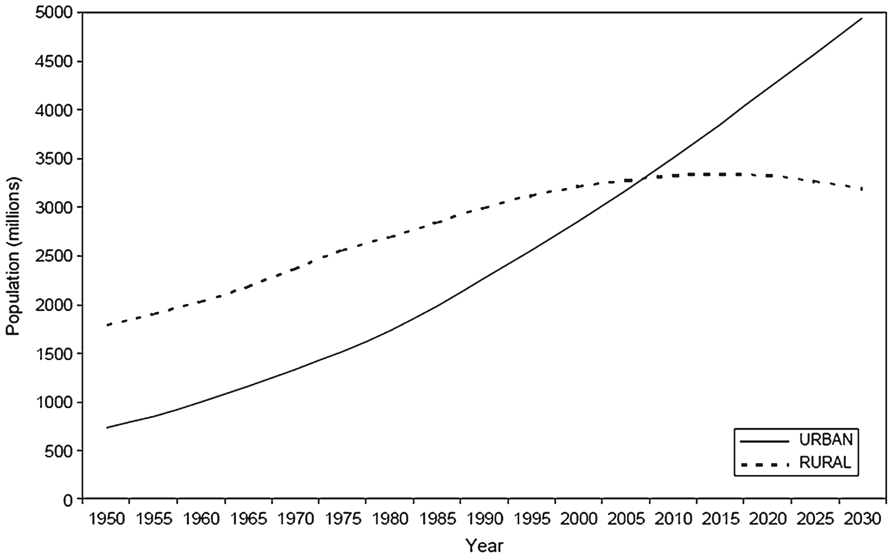

Fig. 1 Estimated and projected size of the world's urban and rural populations, 1950–2030 (Source: UN 2004)

(2003), Graves et al. (2004), Kim et al. (2005, 2007a, b), Yusop et al. (2005), McLeod et al. (2006), Zhao et al. (2007) and Misra (2011) state that land use is the most important factor affecting the extent of diffuse pollution generation and transportation.

Drainage systems are important part of urbanization, and failures in these urban infrastructures like sewer infiltration, leachate from landfills, and direct connection of sanitary sewers to stormwater drains augment the diffuse pollution. Whenever the rainfall occurs, either it will infiltrate the sub-surface or the remainder will be surface run-off. Surface run-off and perhaps infiltration will eventually flow into a watercourse or a receiving water body. This is not the case for an impervious area, where nearly all the rainfall becomes run-off. An urban area is by definition an area of concentrated human activity, which is characterized by extensive impervious areas and man-made watercourses. The result is an increase in run-off volume and flow that can result in flooding, watercourse and habitat destruction. Pollutants are also transported through the urban watershed. Rainfall precipitates atmospheric pollutants. The impact of rainfall will dislodge particles on the surface of the ground. Many pollutants adhere to these particles and are conveyed along with soluble pollutants by the run-off. The momentum associated with the run-off dislodges other contaminant-laden particles. These are transported to a watercourse by the flowing water and progress through the urban watershed. Pollutants generated on and discharged from land surfaces as the result of the action of precipitation on and the subsequent movement of water over the land surface which are commonly referred to as non-point pollutants or dispersed pollutants. Pollutants resulting from the application of water to the land by human activity augment these pollutants. Depending on the type of activity on the land, the volume of run-off and the amount and types of pollutants carried with it will vary. The intensity and duration of precipitation and the time since the last precipitation event also affect the quantity and transport of pollutants generated. Failures in the urban infrastructure (sewer infiltration, leachate from landfills, direct connection of sanitary sewers to stormwater drains) represent another source of pollutant. The diversity in the source and type of pollutants encountered on an urban catchment makes managing stormwater very complicated. On the other hand pollutants discharged into receiving water bodies that exceed the assimilation capacity of these bodies can result in a myriad of problems.

Management of stormwater is difficult due to its diversity in source and pollutant type. Multitude of problems can arise when the levels of pollutants discharged into receiving water bodies exceed their respective assimilative capacities. Diffuse pollution may cause bacterial and viral infections, alteration to natural habitat cycles and breeding, etc. Urban stormwater can cause both quality and quantity problems in receiving waters.

Therefore, it is important to judicially manage water resources which require the conception, planning, design, construction and operation of facilities prior to the various uses of water. Today, water resource managers need to address the problems associated not only with the control and management of run-off quantity but with the maintenance of water quality as well. Pollution threatens the water utility for multipurpose uses and despoils its aesthetic value.

In economically rising, densely populated and highly urbanized cities of the world like Delhi in India, the diffuse pollution occurs due to mixing water from drains carrying urban run-off with the drains carrying domestic sewage before it enters the receiving water bodies. Jamwal et al. (2006) have detailed out the linkages among different land-use types and urban run-off quality and their impacts on human health. They have concluded that temporary flooding and waterlogging causes higher risks of health problems among a large number of population.

3 Diffuse Pollution

The sources of diffuse pollution are widespread across the catchment (D'Arcy et al. 2000). The pollution arises from various non-point sources like return flow from irrigated agriculture, pastures of animals, run-off from range land, agricultural run-off, rainfall run-off from unsewered and impervious area, wet and dry depositions from atmosphere and run-off from roads and landfill sites. The human interventions like deforestation, wetland drainage, construction and outdoor recreation further amplifies the extent of pollution. In addition to the above-mentioned reasons, the climatic conditions, geographic and geologic conditions and land-use type also impact the sources and levels of pollution. In terms of pollutant concentrations, the first flush of the rainfall is considered to be the most harmful. Depending upon the land-use activity, the contaminants from the diffuse sources can be grouped as follows: sediments (TSS, TDS, etc.); oil and toxic chemicals from automobiles (total petroleum hydrocarbons); nutrients from forest, animal and human activities (nitrogenous and phosphorus compounds like pesticides and biocides); and heavy metals (As, Cu, Cd, Ni, Pb and Zn) (International Joint Commission 1974; Zoppou 2001; Campbell et al. 2004; Ukabiala et al. 2010). Goonetilleke et al. (2005) have defined the role of land use in urban stormwater quality management in Gold Coast, Queensland (Australia). Lee and Heaney (2003) studied that 72% of the total run-off volume in Boulder, California, is generated from only 44% of a residential catchment.

The urbanized cities have major problem of waterlogging, especially during rainy season, which causes high rise in diffuse pollution due to stormwater run-off which ultimately results in major health threats to the population. The built-up cities have conventional drainage systems which cause waterlogging and flooding, resulting in pollution. In addition to the above-mentioned problems, the conventional drainage system prevents the groundwater recharge as well. Therefore, it is important to control the diffuse pollution in already built-up cities by using the SUDs.

4 Conventional Drainage System

The major cities in developing countries like Delhi, Mumbai, Kolkata (India) and Dhaka (Bangladesh) suffer from the localized problem of flooding, waterlogging and diffuse pollution. These predicaments occur due to presence of inefficient and weakly managed drainage system. Traditionally, underground man-made pipe systems are designed and constructed to prevent local flooding by flushing the water away immediately which occurs due to rainfall or other land-use activities in a built-up area. However, these drainage systems are designed for specific flow rate and, therefore, cannot capture the fluctuations in the volume of run-off generated. Subsequently, the pollutants arising from urban areas are washed into rivers or into the groundwater. Therefore, it can be said that conventional drainage systems in highly urbanized areas are unable to control both run-off quantity and quality. Often, community facilities and landscaping potential are also ignored while constructing the drainage systems in the developing nations. Consequently, the conventional drainage systems have proven to be unsustainable option which impacts both the terrestrial and aquatic environments. According to NIPC (1997), the conventional drainage systems become unstable when high run-off volume erodes the stream networks, and the pollutant loadings are more concentrated in dried streams due to low flow conditions. Conventional systems, when applied to highly urbanized areas, treat quality, quantity and associated amenities separately resulting in unstable environment.

5 Sustainable Urban Drainage Systems (SUDs)

Worldwide, many initiatives have been taken to manage the stormwater run-off in economically developed countries. Haskins (2012) have developed a methodological framework to manage the urban stormwater run-off in Cape Town. The approach incorporates:

- Population growth and associated adverse development impacts on natural drainage systems
- Heightened community expectations for efficient drainage, flood protection and ecologically healthy rivers
- Increased pressure on open land and the need to protect urban river corridors, wetlands and other drainage routes

Similarly, Logan city council has developed the water-sensitive urban design (WSUD) to protect and enhance the natural waterways in urban catchments by reducing pollution in stormwater run-off (Sustainable Stormwater Management, Logan City Council). Such establishments are rarely found in economically developing regions of the world with high population densities like Asia and Africa.

The diffuse pollution from stormwater can be minimized by establishing SUDs in an existing built-up area. SUDs take account of water quantity, water quality and amenity in a collective manner. SUDs not only contribute to sustainable development but also improve urban design by balancing the different issues that should be influencing the development of communities. SUDs incorporates management practices, control structures and strategies which are specifically designed to efficiently and sustainably drain surface water, while minimizing pollution and managing the impact on water quality of local water bodies. SUDs control the run-off flow rates and volume by minimizing the temporary flooding due to urbanization. They minimize the water pollution and are sensitive towards the environmental setting and the needs of the local community. They also provide a habitat for wildlife in urban watercourses and enhance natural groundwater recharge. They can be easily developed in an urban area where existing sewerage systems are close to full capacity. They are useful for long-term environmental and social factors in decisions about drainage and can also be helpful in the context of wider challenges from climate change and urbanization. Makropoulos et al. (1998) suggested that it is important to identify the sites for establishing SUDs in an existing built area.

The main methods to control diffuse pollution are:

- Prevention
- Technical interventions includes:
  - Filter strips and swales
  - Permeable surfaces and filter drains
  - Infiltration devices
  - Basins and ponds

In a highly urbanized city, run-off attenuation must be achieved by establishing the control measures at all the possible places where the rainwater falls. In addition to quantity control, the above-mentioned methods provide surface water treatment by adopting the natural processes of sedimentation, filtration, adsorption and biological degradation. SUDs are capable of functioning in highly built-up area, ranging from hard-surface to soft-landscape features. Today, there exist a variety of design options for SUDs which enable engineers and planners to consider the existing land use and needs of local people.

5.1 Prevention

It is a strong belief that 'prevention is better than cure', therefore, preventive measures must be taken to minimize the impacts of urban run-off. This can be achieved by site management that incorporates the development and maintenance of structural designs as well as education for the users. Run-off quantity and diffuse pollution can be reduced by minimizing paved areas, institutionalizing rainwater-harvesting units, minimizing directly connected areas like hard pavement and roofed areas which can be drained onto unpaved areas, etc. Similarly, the run-off generated from driveways and footpaths can be drained onto surrounding lawns if present. It is also seen that 'good housekeeping practices' like keeping paved areas clean and planned maintenance regimes and preventing the accumulation of contaminants by placing canopies over areas of potentially high contamination further curtail the risks associated with diffuse pollution.

The public must be informed about the likely impacts of products being used on the diffuse pollution. It is advised that fertilizers, herbicides and pesticides should be used sparingly, and not used where they can be washed directly to a watercourse.

Garbage, litter and animal faeces must be kept out of drainage systems. It is important to keep a check on whether a foul sewer is connected to the surface water system or not. This can be achieved by using SUDs (swales and permeable surfaces). The diffuse pollution arising from roads can be lessened by maintaining the highways and roads (CIRIA 1994).

It has been observed that such measures are undertaken in developed countries like the EU and USA. Similarly, such methods must be adopted by countries of developing world like India and Bangladesh.

5.2 Technical Interventions

The type of SUDs identified and developed in a built-up impervious city can be as follows:

5.2.1 Swales and Filter Strips

Swales are long shallow channels, while filter strips are gently sloping areas of ground; both provide opportunities for slow conveyance and infiltration. They are used to store and drain water evenly off impermeable areas. They are used to trap the transfer of pollutants moving from land to the water bodies. They are capable of removing sediment, organic matter and other pollutants from the run-off (Campbell et al. 2004), while vegetation can take up the nutrients. Both systems allow rainwater to run in sheets through vegetation which slow down and filter the flow. Swales can also be designed for a combination of conveyance, infiltration, detention and treatment of run-off. Initially designed as conveyance systems, swales can also be designed with check dams to increase attenuation and, where applicable, infiltration. However, filter strips can slightly attenuate the flow, but can be used to reduce the drained impermeable area. They can easily be integrated into the surrounding land use, for example, public open space or road verges. In order to provide a visual interest and wildlife habitat, local wild grass and flower species can be introduced (Fig. 2).

5.2.2 Filter Drains and Permeable Surfaces

They are built underground with volume of permeable material which is capable of storing surface water. The pervious pavement systems (Fig. 3) are considered very useful for controlling diffuse pollution due to highly urbanized residential, commercial and industrial areas. Different types of permeable surfaces exist which are as follows:

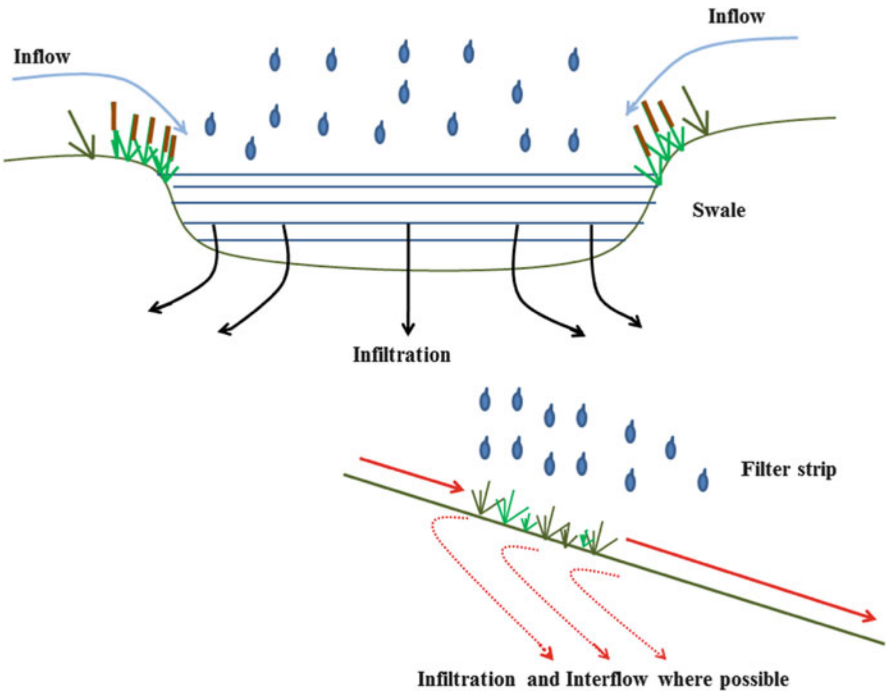

Fig. 2 Swales and filter strips (Source: http://www.ciria.com/suds/filter_strips_and_swales.htm)

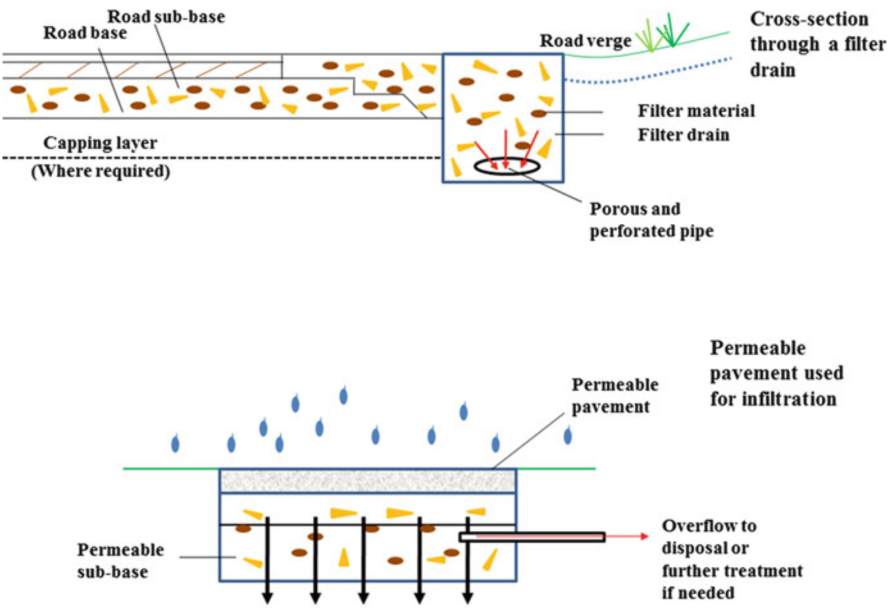

Fig. 3 Cross-section of filter drain and permeable pavement (Source: http://www.ciria.com/suds/permeable_surfaces_and_filter_drains.htm)

- Grass (if the area will not be trafficked)
- Reinforced grass
- Gravelled areas
- Solid paving blocks with large vertical holes filled with gravel
- Solid paving blocks with gaps between the individual units
- Porous paving blocks with a system of voids within the unit
- Porous asphalt
- Continuous surfaces with an inherent system of voids

The pervious surfaces can be either porous or permeable. Water infiltrates across the entire surface in porous surfacing. On the other hand, permeable surfacing is formed of material that is itself impervious to water but allows infiltration through the pattern of voids formed through the surface. The treated stormwater from permeable pavement system is discharged into SUDs. The filter drains and permeable surfaces collect, treat and infiltrate any urban run-off to enhance groundwater recharge, reduction in pollution and recycling of water which otherwise is a waste (Scholz and Grabowiecki 2007).

Depending upon the surface material and surface use, the underlying construction usually consists of a combination of:

- Oil, sharp sand and crushed rock
- One or more layers of different materials, for example, granular and/or geosynthetic layers/geocellar drainage tank
- Permeable geotextile or an impervious geomembrane

If essential, drainage networks to discharge water entering or flowing through the construction may also be included. The outflow from the pervious pavement construction can be achieved in a number of following ways:

- Water contained within the construction is directed to a drainage network either on the subgrade or within the permeable subbase which conveys it to a suitable disposal point.
- Water which enters the pervious surface infiltrates into the groundwater through the base and the excess waters are released via a high-level overflow pipe.

These technologies have high efficiency to reduce the levels of suspended solids, biochemical oxygen demand, chemical oxygen demand and ammonia in the infiltrate water (Pratt et al. 1999), when compared to highway gullies.

They have also been sustainable in effectively and efficiently minimizing the mineral oil deposition and hydrocarbon pollution on urban surfaces. Permeable pavement systems can also be used as an in situ aerobic bioreactor (Pindado et al. 1999).

5.2.3 Infiltration Devices

They can be used directly at source, or the run-off can be conveyed in a pipe or swale to the infiltration area which ultimately traverse water into the ground. They can be integrated into and form part of the landscape. They enhance the natural water storage and drainage capacity of the ground.

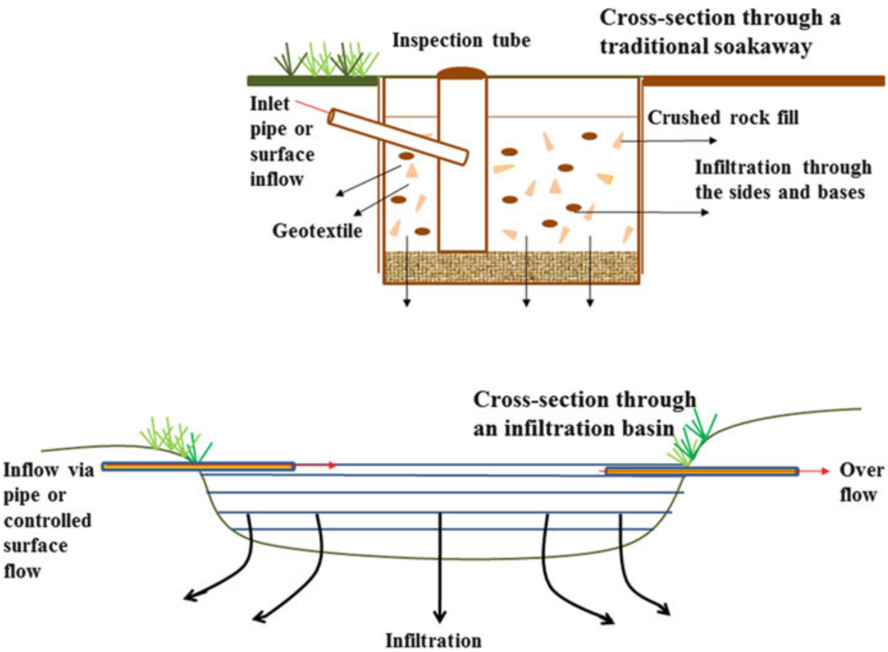

Fig. 4 Cross-section of soakaway and infiltration basin (Source: http://www.ciria.com/suds/infiltration_devices.htm)

Rain falling onto permeable (e.g. sandy) soil soaks into it. Infiltration devices use the natural soaking capacity of soil to dispose of surface water run-off. The use of infiltration devices is limited due to presence of impermeable soil, shallow water table and unstable groundwater with high risks of contamination. The level of run-off treatment done in an infiltration device depends upon the size of the media and the length of the flow path through the system. These factors control the time taken by the run-off to pass into the surrounding soil. It is observed that the polluted run-off may be treated prior to it entering an infiltration device. Infiltration devices can treat run-off via different methods as follows:

- Physical filtration to remove solids
- Adsorption onto the material in the soakaway, trench or surrounding soil
- Biochemical reactions involving microorganisms growing on the fill or in the soil

Different types of infiltration device are as follows:

- Infiltration basins
- Soakaways
- Infiltration trenches

The infiltration basins (Fig. 4) are capable of storing the urban run-off during wet season on the ground surface and are empty during dry season. On the contrary, the soakaways and infiltration trenches are underground structures. Soakaways

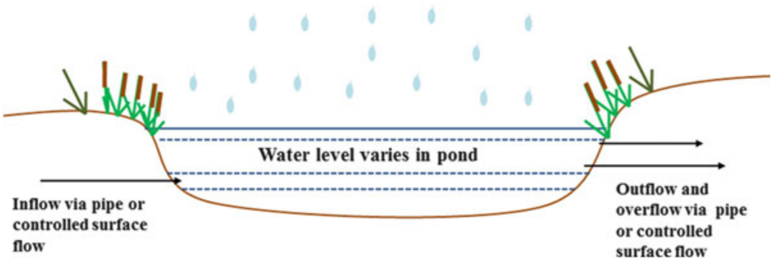

Fig. 5 Basins and ponds (Source: http://www.ciria.com/suds/basins_and_ponds.htm)

and infiltration trenches have underground chambers lined with a porous membrane and filled with coarse crushed rock which are used to store water. Infiltration basins enhances the natural ability of the soil to drain the water by providing large surface area in contact with the surrounding soil, through which the water can pass and store run-off by allowing temporary and shallow ponding on the surface.

Infiltration systems can be easily integrated with the specific site. They can be used as playing grounds, recreational areas or public open space and can be planted with trees and other plants to provide habitat and improve the visual appearance.

5.2.4 Basins and Ponds

Basins are SUDs to store surface run-off that is free from water under dry weather flow conditions. The different types of structure being included under the basins are as follows:

- Floodplains
- Detention basins
- Extended detention basins

The ponds are developed and designed to store water under dry weather conditions as well as during rainy season. Different types of ponds are as follows:

- Balancing and attenuation ponds
- Flood storage reservoirs
- Lagoons
- Retention ponds
- Wetlands

Basins and ponds (Fig. 5) can be combined and designed including both a permanently wet area for run-off treatment and an area for flood attenuation. They can be used for extended treatment or for landscape. Basins can be used for sports and recreation purposes. Wet ponds can be used to store water for reuse.

They store water either as temporary flooding of dry basins and floodplains, or permanent ponds. They control flow rates and subsequent groundwater recharge if there exists no risk of contamination. They treat run-off via following methods:

- Settlement of solids in still water—having plants in the water enhances calm conditions and promotes settlement.
- Adsorption by aquatic vegetation or the soil.
- Biological activity.

Marshy plants are grown to remove pollutants using wetlands specifically designed for stormwater management. The detention ponds hold water for up to 24–28 h, resulting in settlement of urban pollutants. They should be dried between consecutive storm events. Clogging and re-suspension of pollutants is also prevented while designing these ponds (Campbell et al. 2004). Retention ponds degrade pollutant and algae/higher plants uptake nutrients within a retention time of 14–21 days.

6 Planning Framework for SUDs

Urban run-off management demands different number of approaches as the sustainable urban drainage may only be achieved by defining and creating principles with constraints. For example, all three elements of the SUDs, that is, water, quantity, water and ecology, should come under sustainability. As a result, the prime potential sustainability features the official approval of drainage options with technical, environmental, social and economic elements like capital cost, resource use, performance and maintenance (Fig. 6).

A variety of stakeholders who have to work within a given planning and regulatory framework mainly take care of the implementation part of SUDs. To build a decision support system which is commonly known as DSS, planning of SUDs needs a wide approach. However, urban source control drainage systems should be assessed properly by evaluating all multi-criteria and multi-objectives placed

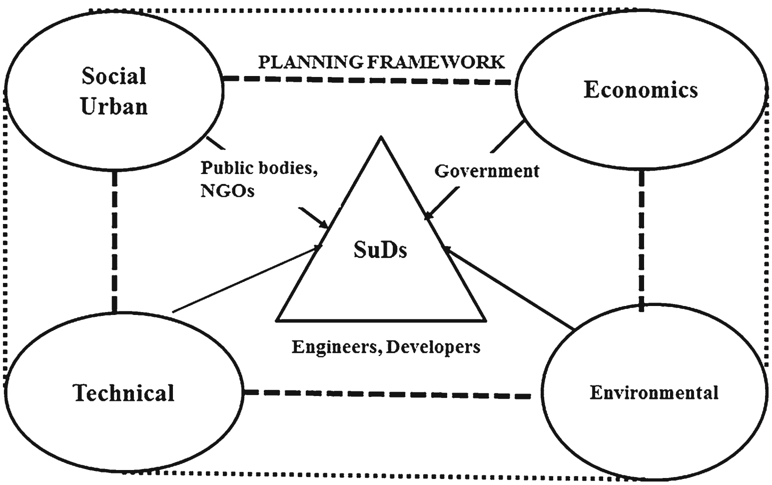

Fig. 6 Sustainability and stakeholders of SUDs (Source: Ellisa et al. 2004)

Table 1 Land requirements for BMPs[a] (Campbell et al. 2004)

BMPs	Total area required out of catchment area
Permeable pavement systems	No extra land required
Swales	3 m more than conventional drainage
Stormwater wetland	
Of catchment, 50% impervious area	8.25%
Of catchment, 25% impervious area	5.75%
Retention pond	
Of catchment, 50% impervious area	3.5%
Of catchment, 25% impervious area	2.5%
Extended detention basins	
Of catchment, 50% impervious area	2.5%
Of catchment, 25% impervious area	1.75%

[a]Based upon 60 min rainfall with depth of 15 mm on area having impermeable clay or loam soils

within an overall decision support framework. The area requirements for these technologies are given in Table 1. Combinations of different types of SUDs are shown in Fig. 7. Table 2 provides a generic listing of criteria for the four polar categories shown in Fig. 7.

Criteria showed in Table 2 basically define SUDs. These are quite dynamic to be adapted and flexible in meeting ever-changing constraints within differing organizations, regulations and customers. However, this approach has a definite requirement of a mix of quantitative and qualitative measures along with the well-defined numerical values. The EIA, which is a must in the study of the environmental impacts, helps the policy and decision makers to evaluate the impacts of establishing SUDs in a particular urban area. On the other hand, before designing and establishing SUDs in any urban city of the world, the assessment of social and community benefits should be taken into consideration. Technically the SUDs must be sound and maintained properly. However, in the end, cost-benefit analysis cannot be ignored. For example, operation and maintenance (O&M) cost should be incorporated by the SUDs economics. Also, before the development of these SUDs, life cycle assessment (LCA) should be completed.

7 Case Study: Stormwater in Delhi

Delhi, capital of India is located at a latitude of 28°34′ N and a longitude of 77°07′ E with an average elevation of 233 m (ranging from 213 to 305 m) above the mean sea level. The total geographic area of Delhi (Fig. 8) is 1,483 km^2 (rural, 689 km^2; urban,

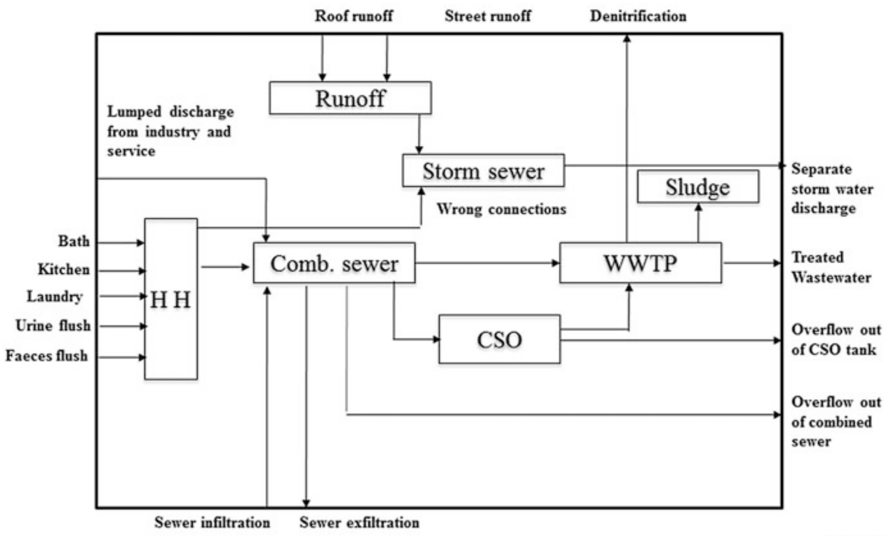

Fig. 7 Proposed SUDs for urban areas, *HH* household, *Comb. sewer* combined sewer, *CSO* combined sewer overflow tank (Source: Huang et al. 2007)

Table 2 Sustainability criteria for SUDs (Ellisa et al. 2004)

Category	Primary criteria
Environmental impacts	Water volume impact
	Water quality impact
	Ecological impact
	Resource use
	Maintenance
Social benefits	Amenity and aesthetics
	Public information and awareness
	Stakeholder acceptability
	Health risks
Technical and scientific performance	System performance
	System reliability
	System durability
	System flexibility and adaptability
Economic factors	Financial risks
	Life cycle costs

624 km^2; and forest, 170 km^2) and the city is divided into three major geographical regions: the Yamuna floodplain, the ridge and the Gangetic Plains. The metropolis has a semiarid climate with variation between summer and winter temperatures. The average annual rainfall is approximately 670 mm (27 in.), most of which falls during the monsoons, in July and September. The River Yamuna, enters Delhi near Palla village and traverses about 50 km long in the city. In the city the river is confined within two barrages, namely, Wazirabad and Okhla barrage. The city can be divided in six drainage basins from stormwater view point, namely, Najafgarh drain,

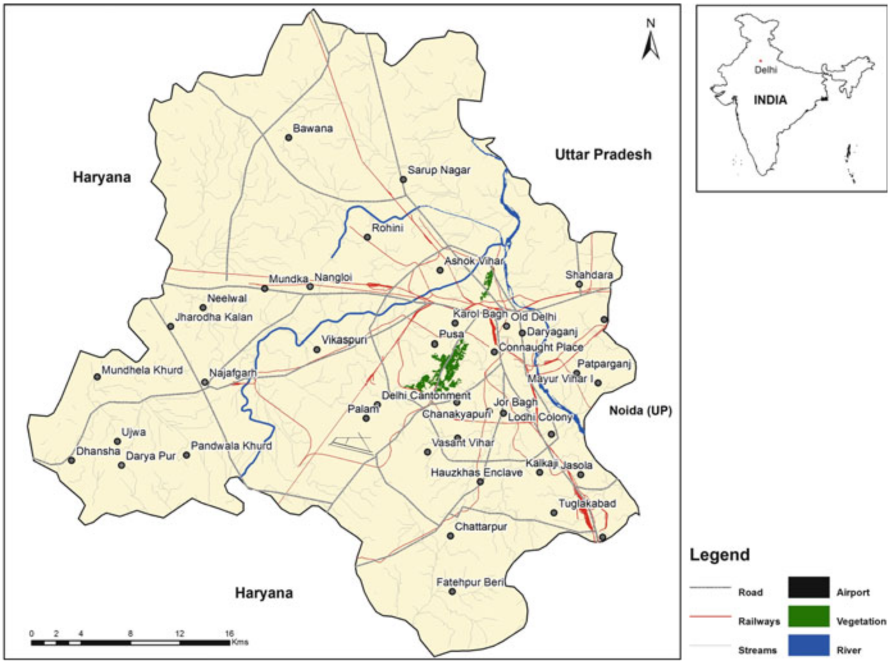

Fig. 8 Profile of Delhi (Source: National Institute of Disaster Management (nidm.gov.in/idmc/Proceedings/Flood/B2%20-%2036.pdf))

Barapullah Nallah, Wildlife sanctuary area discharging through Haryana, drainage of Shahdara area, Bawana drain basin and other drains. These drainage basins, directly or indirectly, discharge the water into River Yamuna. The city as well as the low-lying Yamuna floodplains (Khadar) is prone to recurrent floods, especially during monsoon season.

7.1 *Urbanization in Delhi*

Both, population and economic growth results in high urbanization of the capital city. In 1901, the population of Delhi was 4 lakh and has increased to 16.7 million in 2011. The population density of Delhi has increased from 1,792/km^2 in 1961 to 11,297/km^2 in 2011. The city has observed high economic growth as well. During 2006–2007, the gross state domestic product (GSDP) of Delhi at current prices was estimated as INR 118,240 crores, depicting 16.1% growth over the previous year. The net state domestic product (NSDP) of Delhi at current prices for the year 2006–2007 was estimated as INR 108,706 crores with 17.1% annual growth over the previous year (Economic Survey of India 2007–2008). The growth in per capita income of Delhi has been shown in Fig. 9.

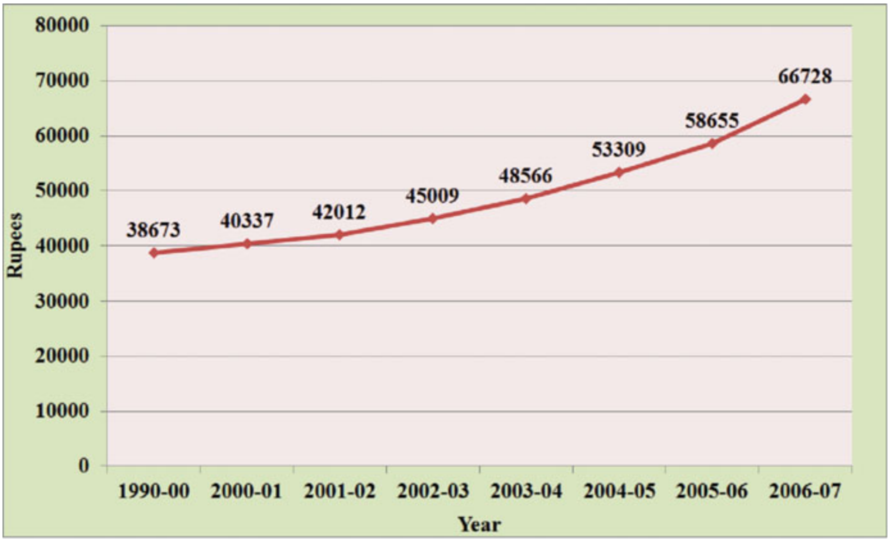

Fig. 9 Per capita income of Delhi (Source: Economic Survey of Delhi 2007–2008)

A study conducted by Sharma et al. (2008, 2012) reveals the tremendous increase in the built-up area in Delhi resulting in high impervious area. It is observed that in 2006, 67% of the city is urbanized (99,361 ha) with only 26% (38,558 ha) of the green area, located either near the riverbanks or at the outskirts of the city. The total river area under water is 1,600 ha and the rest is River Yamuna floodplain which is 9,015 ha (Sharma et al. 2012). This results in augmentation of run-off flow which ultimately impacts the groundwater and surface water quality of Delhi. The intense urbanization during the last four decades has upsurged the paved area and reduced the agricultural land which was used as a percolation zone for rainfall run-off.

It is observed that out of the total 148,300 ha, the net agriculture area sown in 1950–1951 was 97,067 ha which has reduced to 25,000 ha in 2005–2006. Urbanization results in flash flood, waterlogging, etc. The high rise in economic growth and escalating population has put tremendous pressure on the existing drainage system of the capital. It has been observed that during heavy rainfall or flash floods, the existing local drainage system is mostly inadequate to meet the requirement. In addition to rapid and unplanned urbanization, there exist unauthorized residential colonies on the open/agriculture land, which further burdens the existing conventional drainage system. Trespassing by slum dwellers, small shopkeepers, motor garages, garbage dumping, etc. has been noted on the areas which were essentially created for the stormwater management. The conventional drainage system is sometimes choked due to garbage, high siltation, etc. and is not capable to carry full discharge in heavy rain. The existing system is quite old and poorly managed National Institute of Disaster Management (nidm.gov.in/idmc/Proceedings/Flood/B2%20-%2036.pdf). The rainfall run-off generated carries different water quality pollutants (Sharma and Kansal 2010) which further minimize the efficiency of the drainage system and negatively impacts the water quality of the River Yamuna.

7.2 SUDs in Delhi, India

It is very difficult to establish SUDs in an urbanized city of developing nations like India and Bangladesh. Application of geographical information systems (GIS) and remote sensing (RS) shows that due to high economic growth and population density, it is difficult to establish new drainage systems due to dearth of available land. Therefore, it is advisable to formulate an effective and scientifically efficient integrated approach to develop SUDs along with the existing drainage patterns in the city which must include the strengths of engineering and planning departments. The land for the development of filter strips, ponds, basins, swales, etc. can be identified using GIS and RS. These structures can be developed near river bank areas to inhibit the diffuse pollution from entering the directly into the river system.

The diffuse pollution from urbanized cities should be minimized using an integrated approach in order to improve the water availability in the world. It is important to analyse the pollutant concentration in urban run-off. The GIS and RS must be used to map the entire land-use pattern of the city, and total impervious area must be calculated. Diffuse pollution modeling using SWMM, HSPF, SWAT and other models must be done. SUDs should be planned and developed along with existing drainage system of the city.

The Delhi government has designed and constructed various structures to prevent the water flooding and logging in the city which are as follows:

- Establishment of marginal bunds on the banks of River Yamuna.
- Regulators were constructed on Najafgarh drain.
- Channelizing, lining, etc. of drains.
- Desilting; cleaning of road, bell mouth and gullies; removal of debris and solid waste materials from all drains.
- Construction of rainwater-harvesting units, check dam, artificial recharge trenches, village ponds, retention basins.
- Creation/revival of water bodies.
- Floodplain management of River Yamuna.
- Planting trees.

In addition to the above-mentioned plans, there is an urgent need to develop SUDs for the city as well. This can be done in the following ways:

- Developing swales and filter strips for the open spaces and road verges.
- Filter drains and permeable surfaces can be constructed for the pavements.
- Infiltration devices should be constructed and can later be used as playing fields, recreational areas or public open space.

- Basins and ponds can also be constructed, especially near River Yamuna floodplain, to restore the rainfall run-off.
- Installing the pumping stations, considering the futuristic population density zone-wise.

8 Conclusion

The unplanned urbanization, encroaching activities and exploitation of natural drainage channels and urban water bodies along with increase in illegal construction, impervious areas and heavy downpours have led to augmentation of urban rainfall run-off in the capital. In the past, Delhi has suffered from heavy floods which have severely impacted the human lives, animals, trees, plantations and ecosystem of the area. The city would be hugely impacted if the urban flooding is not controlled by adopting the preventive measures like improvement of drainage efficiency and construction of flood-protection structures. It is imperative that the state government must form a local body which should look after the flood control measures with implementation in time-bound manner to provide a healthy living to the residents of the capital city. The conventional drainage system has proved to be insufficient and ineffective in managing the urban run-off in the capital city of India. Therefore, it is important to establish SUDs in the city. There is an urgent need to:

- Incorporate the concept of SUDs in government policy for water management.
- Control flooding and provide safe passage for less frequent and large flood events.
- Optimize the urbanization and land acquisitions.
- Optimize the rainfall flooding by minimizing impervious land and maximizing infiltration.
- Stabilize the landforms and enhance the urban landscapes.
- Minimize the adverse impacts of run-off on ground/surface water quality.

Acknowledgments The authors would like to acknowledge Mr. Amit Srivastava (GIS/RS Specialist, IWMI India) for creating the profile map of Delhi. We would also like to show gratitude towards Ms. Priyanka Banerjee (Sr Journalist, Feature Writer, Efficient Manufacturing; A&D India; Efficient Infrastructure Publish Industry India Pvt. Ltd., Pune, India) for editing and proofreading the chapter. We would also like to thank Dr. Zongwei Luo (the University of Hong Kong) for giving an opportunity to write the book chapter.

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Sustainable Software: A Study of Software Product Sustainable Development

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Abstract The intention of this chapter is to propose a distinct approach to software development sustainability, as well as a different understanding of sustainability in the context of software development. The chapter covers survey of good practices and software development methods as important for sustainable development of software products. Particularly, author focuses on agile methods and product line engineering as approaches supporting the sustainable development of software product. The analyzed practices and methods are suggested to be implemented for the software company sustainability. The implementation results in saving human efforts as well as energy and computer power.

Keywords Agility • Dynamic systems development methodology (DSDM) • Feature-driven development (FDD) • Rapid application development (RAD) • Responsibility management • SCRUM • Software development • Software product line • Corporate sustainability • Software sustainability • Trust management • Value system • XP

1 Introduction

In socioeconomic literature, sustainable development is the practice of meeting the needs of society today without compromising the ability of future generations to meet their own needs (Stavris and Sprangel 2008). The term in its environmental usage refers to the potential longevity of vital human ecological support systems, such as the planet's climatic system, systems of agriculture, industry, forestry and

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*, DOI 10.1007/978-94-007-5995-4_13,

fisheries, and human communities in general and the various systems on which they depend in balance with the impacts of their unsustainable or sustainable design. In each project, project sponsor expects results for prolonged period of time and expects to answer the question of what results will be available in future and how project participants want to ensure project results sustainability, particularly in IT project, where project results arrive a long period of time after the project finishing.

Main hypothesis of this work is that software companies should implement methods which ensure the sustainability of their products. Therefore, agile system development and product line management methods are presented as useful to support the sustainability and maintainability of software products.

In the traditional software organization, the emphasis in software development is on features, bug fixing, and the plan. Development proceeds in a linear fashion, beginning with analysis and design, the development of a plan, coding, testing, fixing of problems, careful tracking against the plan, and then use by customers. In the real world of software development, software must be developed in a complex and changing ecosystem of technology, competitors, and customers. So the programmers must write code and improve it simultaneously, and the software is constantly in a working state. Continual refinement is required for sustainable development. This means adopting a different mindset and being uncompromising in four key areas: a working product every day, continual refinement, defect prevention over detection, and an emphasis on lightweight but continual design. Sustainable development results, where it is possible to be proactive about change.

Software product line represents a paradigm shift in software development. The move towards software product line engineering is usually strongly based on economic considerations, that is, it reduces costs and time to market and improves qualities of the resulting products like their reliability. The approach supports large-scale reuse during software development. Usually, along with the reduction of development costs, a reduction maintenance costs is also achieved. Several aspects contribute to this reduction: the overall amount of code and documentation that must be maintained is dramatically reduced. As the overall size of the application development projects is strongly reduced, the accompanying project risk is reduced as well. Therefore, the first part of the chapter covers discussion on what sustainability is, particularly in the context of software development. The second part comprises analysis of agile methods and explanations of their usefulness for sustainable development. The third part includes presentation of software product line engineering approach as important for corporate sustainability and for sustainability of software products.

2 Sustainability Development

2.1 Idea of Sustainability

Sustainability is a characteristic of a process or state that can be maintained at a certain organizational level. It exemplifies the new problem field for managers and corporate leaders in an emergent network-based organizational world where corporations must maintain consistency of purpose and activity to compete in conditions of constant change. Sustainability is understood as the simultaneous effort of balancing economic, social, and environmental goals for a corporation (Bondy et al. 2007). So, sustainability is a metaphor for describing corporate social responsibility, corporate citizenship, or ethical business conduct.

In 1987, the World Commission on Environment and Development (WCED) related sustainability to corporations and the economy by defining the sustainable development as development that meets the needs of the present without comprising the ability of future generations to meet their own needs (Hilty et al. 2005; Unnerstall 2005). Sustainable development, sustainable growth, and sustainable use have been used interchangeably. Sustainable use is applicable to renewable resources (Clarke 2007). Sustainable development is used as a strategy to improve the quality of human life.

The etymology of "sustainable" carries interesting and important implications for the way the word is used as it includes several contradictions. The word "sustain" is derived from the Latin "sub-tenere," meaning "to uphold." This carries as passive connotation in it and gives the concept an image of stability, persistence, and balance. "Sustainable" is used in a more active sense together with "development." Development means change, progress, and growth. Hence, "sustainable development" can refer to a process which is being uphold or defended at the same time as it implies movement and improvement (Sunden and Wicander 2005). The idea of "sustainable development" includes a normative and active meaning. In this sense, the sustainable development assumes a certain equilibrium among the strategy factors and available resources. Actually, sustainable development has a much broader meaning, including and bringing into balance not only ecology but also sociology and economics. Shrivastava notices the incentives for organizations to support ecologically sustainable development activities that include the following: driving down operating costs, creating a competitive advantage with green consumers, ecologically establishing leadership in their industry, establishing a legitimate sustainability presence with the public and stock markets, reducing long-term risks associated with resource depletion, improving ecosystem and community environment, and positioning their organizations ahead of the regulations (Shrivastava 1995).

2.2 Governance for Sustainability

Governance is a setting of rules, the application of rules, and the enforcement of rules (Mette Kjaer 2004). Proponents of economic liberalism prefer market mechanisms domination, and they do not see the state playing a major role in supporting sustainability. Social democracy is critical to free market system and advocates frequent monitoring by citizens to ensure that market outcomes are justifiable for collective interests and equitable (Benn et al. 2007a, b). Models of governance for sustainability need to concentrate more on change than stability. The existing rules, customs, practices, and rights are seen more as the subject matter of governance to be influenced, than as the main business of governance. Equally, models of governance for sustainability must recognize the limitations of the overburdened state and the consequent need to take advantage of existing social institutions and structures that promote sustainability without heavy-handed intervention (Martin et al. 2007). Governance for sustainability requires a model that is both cognitively and operatively open.

The concept of sustainable development has a futuristic nature, and it implies a change over time. The time dimension of the governance for sustainability is not only about both change and stability, about both history and future, but it is also about now living generations as well as coming people generations (Sunden and Wicander 2005). Sunden and Wicander present two additional dimensions of governance for sustainability (2005). The concept of sustainable development implies a space dimension and also a polarization between different levels of space. This could be expressed as global versus local, industrialized countries versus developing countries, large versus small, center versus peripheral, and in a country or international. A resource dimension and also a competition between different interests are important for governance for sustainability. Governance should ensure sustainability as the continuation of benefits after major assistance from a donor has been completed. The focus is on sustaining the flow of benefits into the future than on sustainable programs or projects. Projects are, by definition, not sustainable as they are a defined investment with a start and finish date. The concept of sustainable benefits does not necessarily mean the continuation of donor-funded activities. Rather, sustainability means that donor-funded initiatives, systems, and processes will continue to generate a flow of benefits after donors have finished their inputs to the project (Undertaking 2001). It should be noticed that sustainability is an attribute of risk assessment in projects. A project that is assessed as having a weak sustainability at selection, design, or implementation will be riskier in achieving its objectives than a project that is assessed as likely to have a high sustainability.

2.3 Corporate Sustainability

Sustainability is seen as being implemented at four levels:

- Board
- Executive
- Corporate
- Operational (Benn et al. 2007a)

The concept of corporate sustainability is one that is gaining increased importance as more research suggests the need for organizations to address sustainability issues in order to resolve environmental and social problems. There is a difference in understanding corporate sustainability between members of public and private organizations, with private organizations as tending towards economic priorities and public organizations taking a more holistic perspective. This suggests that regulations are written by individuals with an understanding which is likely to be different from those to which it is applied (Russell et al. 2007). Corporate sustainability requires internal corporate governance to move to the holistic approach of total responsibility management (Benn et al. 2007a, b). For the corporate sustainability, the following factors seem to be important (Afsarmanesh and Camarinha-Matos 2005):

- Competencies and competencies management, because they represent the capacity for existing resources to perform some tasks or activities
- Value system, because the behavior of an individual, society, or ecosystem is determined by the underlying value system
- System of incentives, associated with costs, accessible assets, tutorials, conferences, courses to enhance productivity and products dissemination, project result dissemination, and core competencies increase
- Trust management, which is a critical antecedent for more efficient and effective communication, collaboration, and knowledge creation

Trust plays an important role to create long time relations and sustainable competitive advantage by reducing governance costs (management costs), costs for internalization (acquisitions), transaction costs between organizations, and impact positively in knowledge creation. Trust facilitates open communication, knowledge sharing, and conflict management.

Sustainability of an ICT activity is strongly influenced by the technology used. Technology issues critical to sustainability are as follows:

- The use of commercially available solutions of IT industry
- A willingness to overcome technical difficulties
- Increase of the opportunities for connectivity (Sunden and Wicander 2005)

Despite the current emphasis on economic sustainability, it is too difficult to determine sustainability criteria for ICT projects. Although many such projects use cost-recovery mechanisms, mostly they declare that project results will be exploited for the established project duration period according to the predetermined plans.

On the corporate level, sustainability is a commitment to a new way of commissioning business activities that addresses balanced prosperity of social, economic, and environmental dimensions of businesses. A sustainable business model is a roadmap for achieving sustainability and deals with the issues and dynamic relationships of sustainable dimensions of the businesses (Ahmed and Sundaram 2007). Sustainable business strategies and processes are roadmaps to achieve sustainability, and it is about understanding and considering the positive and negative impacts and minimizing the risk of unintended consequences across sustainability dimensions. Sustainability is a concept and strategy for integrating and balancing three dimensions, that is, economic, environmental, and social (van Osch and Avital 2011). The economic dimension of sustainability concerns the organization's impacts on the economic conditions of its stakeholders and on economic systems at local, national, and global levels. The economic indicators cover flow of capital among different stakeholders and main economic impacts of the organization throughout society. The impact indicators comprise economic performance measures, market presence, and indirect economic impact indicators (GRI 2002). The environmental dimension of sustainability concerns an organization's impact on living and nonliving natural systems. They cover performance related to biodiversity, environmental compliance, and other relevant information such as environmental expenditure and the impacts of products and services. The social dimension of sustainability concerns the impacts an organization has on the social systems within which it operates. The GRI Social Performance Indicators identify key performance aspects surrounding labor practices, human rights, society, and product responsibility (GRI 2002). Social sustainability occurs when the formal and informal processes, systems, structures, and relationships actively support the capacity of current and future generations to create healthy communities (Truex et al. 2011).

In this work, software sustainability is considered as the characteristic of software product development process. For software development companies, sustainability is the selection and the implementation of iterations and incremental methodologies that support long-term technology development and application at low costs, particularly at low usage of energy and reduced human efforts. For IT companies, sustainable software is a certain vision of software development and a strategy to achieve that goal. Although many IT firms declare the acceptance of the Green IT strategy, the verification of the postulate is difficult and demands a separate monitoring effort. In business practice, the software companies apply selected methods to decrease costs as a symptom of the sustainable software strategy realization.

3 Agile Method for Sustainability Development

The research problem is derived from the business information system methodologies and enables business strategy and organizational infrastructure. The research framework is comprised of the following research methodologies:

- Observation—reviewing currently available in publication frameworks of information and business systems, system development processes (observation facilitates the formation and refinement of opinion about corporate sustainability)
- System development methodologies survey—reviewing enables formation of the good practices' proposal for sustainability development.

3.1 Sustainable Software Development Principles

In the real world of software development, software must be developed in a complex and changing ecosystem of technology, competitors, and customers. In sustainable software development, the principles define what you want to accomplish and the practices how you want to go about it. The following principles are applied to achieve sustainable software development (Tate 2005):

- Continual refinement of the product and project practices
- A working product at all times
- A continual investment in and emphasis on design
- Defect prevention and detection

Continual refinement is required, because a software product should always be in a working state to achieve a higher quality. A working product is required for sustainable development because it ensures that time is spent on productive activities (Tate 2005). Less important is documentation of user requirements, software designs. Prototypes are better than a document. In the continual refinement process, an emphasis on the defect prevention is required for sustainable development to ensure the development team is highly efficient and is putting its effort into creating value for the customer.

Software is complex and must evolve continuously over a long period of time. Throughout its life cycle, a software project must contend with changing user requirements in an evolving ecosystem of markets, partners and technology, and competition. In this environment, just about the only thing a software team can rely in is that change is given. While some changes can be anticipated, iterative and incremental development is a good technique for open-ended software projects.

Iterative processes have gained widespread acceptance because they help software providers reduce risk and cost, manage charge, improve productivity, and deliver more effective, timely solutions (Tate 2005). Iterative and incremental development of software involves the iterative application of a set of activities to evaluate a set of assertions, resolve a set of risks, accomplish a set of development objectives, and incrementally produce and refine an effective solution. Iterative and incremental development of software involves the successive refinement of the understanding of the problem, the solution's definition, and solution's implementation by the repetitive application of the core development activities.

For sustainability in software development, there is a need to reemphasize the importance of developing in small incremental iterations. New features and functionalities can be added according to the user financial potential. After each step review is provided, assuming that each step covers design, coding, unit testing, as well as functional verification testing. Stober and Hansmann (2010) propose componentization as a best practice that any new development project needs to consider. The goal is to provide flexible independent components that can be reused to a large extent. Each component exposes a well-defined contract defining how it must be used. Different applications can be assembled from an infrastructure of common components. Stober and Hansmann (2010) argue that componentization is also relevant for mature systems. Therefore, existing monolithic software products can be decomposed into distinct components that can reassembled into new offerings.

3.2 Agile Methods Survey

Agility is the ability to quickly and efficiently respond to change in order to profit in a turbulent business environment. Agility is the ability to balance flexibility and stability (Highsmith 2004). Agility is defined as the ability to detect opportunities for innovation and recognize competitive market opportunities by assembling required assets, knowledge, and relationships with an appropriate speed. Technology agility represents the degree of flexibility of the information technology and the extent of business/IT alignment. In an effort to conceptualize IT agility, the following expressions can be used: scalability, adjustability, connectivity, modularity, and versatility (and also compatibility, interoperability) (Lui and Piccoli 2007). Scalability deals with changes in input conditions. Adjustability is identified with the capability of modifying technologies. Technology with higher adjustability allows to be modified within a shorter time frame, higher frequency, and higher degree of change. Connectivity deals with the degree to which various IT components can exchange data with one another and automatically trigger events to be completed in one of the connected modules. Modularity refers to the capability to treat IT components independently. Technology with higher modularity enables the addition and removal of technology components without significant costs and time delay. IT veracity deals with the ability to incorporate new and different technologies that offer a new set of information-processing capabilities.

There are five key business objectives for a good exploration process of agile project management:

- Continuous innovation to deliver on current customer requirements
- Product adaptability to supply future user demands
- Reduction of delivery schedules to meet market needs and improve performance indicators
- People and process adaptability to respond rapidly to product and business change
- Reliable results to support business growth and profitability (Highsmith 2004)

Agility is not aimed at reacting to change, but as a proactive means to support change (Schelp and Winter 2007). The Agile Manifesto presented an industry-led vision for a profound shift in the information system development paradigm, through the following principles (Stober and Hansmann 2010):

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

Agile software development will imply a substantial amount of communication and collaboration among project participants. Collaboration tools resulting from the ideas of Web 2.0 will be of invaluable help when facilitating interaction between individuals and teams. Web 2.0 allows for the participation of community of users in contributing content to be shared and adding value for the greater success of the project, information gathering, and decentralized distribution. The software companies prefer the openness strategy which supports the reduction of testing efforts, requirements' validation, and even computer power utilization reducing, taking into account the opportunity of end-user involvement in the software production and evaluation process. According to Stober and Hansmann (2010), the good practices defined for the agile project management are the following:

- Keep it simple: a complex system should be split into smaller subsystems that allow creative teams to work concurrently and independently. The goal is to implement componentization for flexible management of software artifacts.
- Keep it flexible: a good architecture needs to be flexible enough to accommodate future extensions, plan changes, and new requirements.
- Keep it small: a system grows by incrementally adding small executable and testable use cases.
- Keep it transparent: the good communication is key to getting the buy-in for an architectural approach.
- Keep it vital: software architecture and design will never be done, but will be continuously refined and improved as the product evolves.

That practices are suggested to be implemented to ensure cost and effort reduction as well as balance between flexibility and pursuing goal achievement.

Agile methods present new nontraditional ways of building complex products and systems. The traditional methods of software development include the experience-based software engineering methods that have been widely practice in the software firms. The traditional methods cover the structured analysis and design methods, the data modeling methods, and the object-oriented analysis and design methods. The following are the commonly used agile methods:

- Extreme programming (XP)
- SCRUM
- Crystal methodology
- Dynamic systems development methodology (DSDM)
- Rapid application development (RAD)
- Feature-driven development

Extreme programming (XP) has few rules and a modest number of best practices, which are all relatively easy to use. It is based on iterations that embody several practices (like RUP), such as small releases, simple design, testing, and continuous integration. XP teams use a simple form of planning and tracking to decide what should be done next and to predict when the project will be finished. XP embraces four core values that its project teams should follow: (1) communication, (2) feedback, (3) simplicity, and (4) courage. The focus is on business value, where the team produces the software in a series of small, fully integrated releases that pass all the tests the client has defined. An XP project defines an integrated set of practices, which requires the full-time, on-site engagement for such a project to work successfully. There is little emphasis on project documentation. The focus of XP is to reduce development costs. Some of the most noteworthy XP practices are:

- Refactoring—restructure the system continually, without changing its behavior, to make it simpler or add flexibility
- Testing
- Pair programming
- Using CRC (class, responsibility, and collaboration) cards, which are applied to teach users of XP the principles of object-orientated design (Charvat 2003)

The purpose of the SCRUM is to restart play quickly, safely, and fairly after a minor infringement. Scrum's two pillars are team empowerment and adaptability (Lavazza et al. 2010). The team maintains equilibrium during each increment, insulated from outside disturbance. Increments are punctuated every 30 days so that the team and management can evaluate what should be done during the next increment; this decision is based on what the team has accomplished and what the environment dictates is the next most important thing to do. The most important benefits of SCRUM are as follows:

- Increase of the end-user involvement in the development process
- Permission for users to change requirements in the project realization period
- Focus only on the most important functionalities
- Achievement of new working functionality every 30 days
- Elimination of the need for projects to be funded more than 30 days in advance

Therefore, SCRUM is based on empirical controls through inspection and adaptation, collaboration in pairs, iterations, and increments' implementation.

The Crystal methodology is a family of methodologies. All Crystal methodologies elements can be reduced to the extent that running software is delivered more frequently and interpersonal communication channels are richer (Charvat 2003). Each member of the Crystal family or methodology addresses different project needs. The focuses of Crystal methodology are to (1) capture those components that make projects successful and (2) provide the project team with sufficient leverage and freedom to perform its work in a fun and creative manner. Crystal methodologies do not encourage vast amounts of project documentation. The lessons learned from previous development projects are captured and reused.

The dynamic systems development methodology (DSDM) is based on rapid application development (RAD) that uses prototyping reiteration to deliver projects. DSDM methodology is speed oriented; however product quality is also taken into account. The simplicity, practicality, and flexibility of the approach are suitable for vendors, SMEs, and consultants, making DSDM relevant across a variety of software companies. For the software development, designers apply model iterations, refinement, and pilot implementations. Throughout the development, feedback is used to evaluate and refine the processes so that they can be rolled out to the wider development population with confidence that they will achieve the benefits expected of them. This approach allows for the cost and human work reduction.

Compared with many traditional methodologies, rapid application development (RAD) compresses the analysis, design, development, and test phases into a dynamic series of short iterative development cycles. RAD uses shorter project phases, which means that benefits are realized much more quickly. With RAD, each iterative development cycle delivers a functional version of the proposed solution. The approach is almost cyclic in nature. Using prototyping allows to reveal results immediately and verify them. The software providers have the advantage of building on their solution and gradually improving it until it reflects what the client requires.

RAD prototyping supports costs reduction (Tate 2005). It allows the project manager and the team to identify risks early during the project life cycle. Making an effort to prototype solutions to risky problems helps to increase the chance of having a working product. Prototypes are an inexpensive way to try out original and innovative ideas, which otherwise would be rejected. Defect prevention is an important principle for sustainable development of software. Prototyping practices can be used to catch defects as early as possible, especially via automated means, so that the burden of testing is not placed on people, whether they are quality assurers, a testing group, or customers.

Feature-driven development (FDD) is the methodology for managing an agile project and for handling the uncertainties that an agile approach introduces. In this approach, a feature is a schedulable requirement associated with the activity used to realize it (Rikkila 2010). These requirements may be user-related requirements, application behavior requirements, or internal requirements. Each feature has a priority and a cost associated with it. The core practices included in this methodology cover iterative and incremental development activities, application of the right artifacts, creation of several simple models in parallel, modeling in small increments and keeping the cohesion of diagrams, working in pairs or in teams, and encouraging other people to help understand the problem. FDD methodology promotes simplicity and testability as well as application of modeling standards and patterns and reusage of the existing resources. Particularly designs are more reusable than code.

Generally, agile methods better suit small projects, where colocated small teams are involved. Project complexity, large team size, and the duration of the project encourage to the choice of a heavyweight methodology. For SMEs, agile methods seem to be comfortable and allow them to avoid bureaucratic methodologies, redundant documentation printing, and overload of control and administrative works. Although for big projects frequent controls are required, it should be noticed that they are not always effective, and for many projects, controls only increase total cost of project. Therefore, many companies favor the agile methodologies. Projects that use agile methodologies are reported to improve time line and cost savings, compared to those developed according to the heavyweight methods established by project donors. Many project sponsors (e.g., governmental agencies) and many managers prefer the heavyweight methodologies, because they want to predict the entire project until the last validation, whereas the agile project teams tend to choose agile methods. Those methods allow them for human effort and paper documentation savings as well as reduction of computer resources usage.

Sustainable software systems development and improvement cannot be achieved with a focus on technology alone. The project success depends on continuously improving people, process, and technology. On the one hand, the software company should operate efficiently, but on the other hand, it is also important to be responsive and adaptive as customer needs change and new opportunities emerge. The software providers should strive for efficiency and flexibility. Efficiency means performing work well without wasted effort (using fewer resources), while flexibility entails responding to change quickly with limited disruption. According to Bell and Orzen (2011), agility is the balance point between the two capabilities: efficiency and flexibility.

The ideas of agile software development have gained acceptance in the mainstream and in the distributed software development community, which wants to achieve the lowering cost of labor (cost reduction), the increasing or decreasing work forces without employing or laying off (workforce scaling), and the obtaining of locally not available expertise (Szoke 2010). The first step towards human effort reduction is the deployment of the team cross-functionality, which determines further agile teams' activities. The other variable is the team distribution which defines whether the team is located on the same or on geographically different sites.

A distributed agile project management approach demands an intensive communication and coordination online; however, the cost of the communication should be small; otherwise, the project will be inefficient. A distributed agile approach can provide better utilization of resources and higher quality feature distribution plans by re-partitioning the features any time or to adapt the plans to the continuously changing situations of agile environments (Szoke 2010).

A better understanding of the various factors that affect successful incorporation of agile methods is believed to provide new valuable theoretical insights and contribute to industrial practices concerning effective usage in organizations (Katayama and Goldman 2010).

The idea of lean development in the software industry was promoted by the agile methodology community, although the agile and lean philosophies have many compatibilities, and key agile principles are based on lean thinking. The lean methodology community could be considered as process oriented, focused on large corporations developing really large systems, while the agile methodology community is usually applied in smaller organizations (Mandic et al. 2010). The lean development proponents argue that in an effective process, the product should flow from one value creating activity to another, avoiding the wasteful activities in between. Flow means minimizing the amount of time that any work item is sitting idle, waiting for someone to work on it. The reduction of flow time is not only in the interest of customer but also for the software company, because the usage of computer power and resources can be reduced. A key aspect of a lean value stream is the simplification of information flows within the stream. Both the external information from the customer and the information generated internally, which is needed to complete the work, have to be considered (Mandic et al. 2010). Lean software development provides a project management philosophy together with a set of principles and tools that help the enterprise to rapidly detect defects and remove them

(Kettunen 2010). Successful software projects achieve the goals by delivering value to end users. Lean development and the agile methods support the idea of cost and work time reduction in software development process.

4 Software Product Line Engineering

Software product line engineering is a strategic approach to developing software. It impacts business, organization, and technology alike and is a proven way to develop a large range of software products and software-intensive systems that are fast and at low costs. The move towards software product line engineering is usually strongly based on economic considerations. Due to its support of large-scale reuse, such approach improves mostly the process side of software development, that is, it reduces costs and time to market and improves qualities of the resulting products like their reliability (van der Linden et al. 2007).

Usually, along with the reduction of development costs, a reduction maintenance costs is also achieved. Several aspects contribute to this reduction: the overall amount of code and documentation that must be maintained is dramatically reduced. As the overall size of the application development projects is strongly reduced, the accompanying project risk is reduced as well.

In 1970s, the concept of product families arrived. While it was initially aimed at variability in nonfunctional characteristics, nowadays it is a valuable approach. The key difference between traditional single system development and software product line engineering is a fundamental shift of focus. Nowadays, instead on the individual system and project, the software company focuses, for a long time, on the software product line.

The software product line engineering and management as a sustainable approach holistically covers the interacting domain and application engineering life cycles from initial product line planning through requirements engineering, reference architecture design, system design, component design and implementation, and testing to delivering products to markets and to some extent, revising the product line and the products based on feedback from the markets (van der Linden et al. 2007; Reuys et al. 2006).

Software product line engineering consists of domain engineering and application engineering. Domain engineering focuses on the development of reusable assets that provide the necessary range of variability. Domain engineering covers the following activities: product management, domain requirement engineering, domain design, domain realization, and domain testing. Application engineering consists of the following activities: application requirement engineering, application design, application realization, and application testing.

In the aspect of sustainable software development, it is important that software product line engineering relies on a distinction of development for reuse and development with reuse (Mansell 2006). In domain engineering (development for reuse), a basis is provided for the actual development of the individual products. The product line infrastructure encompasses all assets that are relevant throughout the software development life cycle. Application engineering (development with reuse) builds the final products on the top of the product line infrastructure. Applied in product line engineering, reuse techniques provide a time and effort reduction in the projects. A repository containing the reusable assets as well as the documentation for its use should be in place. Reuse can be considered as a mechanism to improve the current organizational results and support the quality management. When an organization has already a methodology, procedures, and rules for developing code as well as documentation procedures, the repository eases the introduction of systematic reuse.

Analyses by van der Linden et al. case studies have shown that the business advantages can be obtained from product line engineering (i.e., reduction to less than 50% time to market, reduction of code size by more than 70%, significantly reduced cost of quality, product defect density reduced to 50% of original rate, reduction of calibration and maintenance efforts (up to 20%), reduction of resource consumption (20–30%), and improvement of common look and feel). Software product line engineering enables reuse of test cases by more than 50% (van der Linden et al. 2007).

5 Conclusion

Software quality according to ISO/IEC 25000 (2005) covers many characteristics like, for example, portability, reusability, extensibility, adaptability, modularization, documentation, or readable source code. Another feature is the need of making software products comparable with respect to sustainability, for example, power consumption or resource efficiency during runtime. However, this chapter is to present that the sustainable software is the software whose direct impacts on economics, human beings, and the environment resulting from development, deployment, and usage of the software are minimally negative. A sustainable development process should consider the practices, methods, and techniques that take into account the impact on the environment resulting from the engineering and use of the software product. The sustainability aspects can also be considered as software requirements.

At software company, the impact of sustainable software strategy is included in the development phase by actors, that is, software programmers. Beyond that, in order to reduce the power consumption, the computer systems left by users are automatically switched off. The deactivation phase considers aspects that become important, if software products are taken out of service. The deletion of the old files releases backup resources, which can be used for other backup purposes and thus save energy and natural resources, because there is no need to buy new backup storages.

ICT for sustainable development is not only about Internet connectivity. It is a special intersection of diverse fields of enquiry and applications, linking technology, economics, sociology, and politics (Tongia et al. 2005). Basically, software companies are constantly looking for new ways to improve their performance and to achieve long-term competitive advantage. Not only increasing of the operational efficiency but also removing the possible inefficiencies within the current software development activities are important for sustainable development. Sustainability as a research problem is pervasive and considered at all levels: global, national, municipal, and firm level. Corporate sustainability usually encompasses strategies to meet the needs of stakeholders, while protecting the human and natural resources. However, business organizations have a crucial role to play for the reduction of their environmental impact and risks. So, for example, software companies could apply management practices and software project management methods to efficiently use energy, computer power, and human resources. Presented above in the chapter, agile methods and product line engineering approach are oriented towards the saving of working power at software company. The software companies should be oriented towards achievement of a certain consensus in business environment, instead of the acceptance of action orientation and mechanisms for maximization of IT resource usage.

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Sustainability Policy: A Case Study of the Limits to Biofuel Sustainability

Henrique Pacini, Andrei Cechin, and Semida Silveira

Abstract Biofuels are attractive alternative energy carriers not least due to their interface with existing infrastructure for conventional fuels in the transportation sector. But while representing a renewable alternative to petroleum fuels, an expanded usage of biofuels could conflict with ecological and social systems. In face of this risk, a number of countries are designing sustainability standards and safeguard mechanisms for biofuels, in an attempt to reduce the negative effects of their growing usage. This chapter explores biofuel sustainability policies, their economic rationale, and specially their limits, as seen from the basic strategies of dematerialization, detoxification, and transmaterialization. The chapter then frames where biofuel sustainability policies have margin for action, exemplified by the case of the European scheme proposed in 2009. By understanding the economic rationale and guiding principles behind efforts to improve biofuel sustainability, the chapter can contribute to better understand the actual scope and limitations of policy efforts currently aiming to promote responsible biofuels usage. The study concludes by proposing that transparency and dialogue, including parties directly and indirectly affected by biofuel strategies, as the only way to legitimize the sharing of risks in this emerging international market.

Keywords Biofuels • Sustainability • Policy • Entropy • Substitution • European Union

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4_14,

1 Introduction

Liquid and gaseous biofuels can be used in conventional combustion engines as a complement or substitute to fossil fuels.[1] The merits of biofuels are threefold. Firstly, they have potential to deliver transport services at reduced carbon intensity when compared to conventional fossil-derived fuels. Secondly, potential interface with the existing energy infrastructure in transport makes the adoption of biofuels economical in the short term if compared with other options such as electricity or fuel cells. Finally, biofuels can foster employment and income in rural areas, as well as enhance energy security in a number of nations which have favorable geographical conditions for their production (Pacini and Batidzirai 2011).

By means of interoperability with the infrastructure for gasoline, diesel, and natural gas, policy makers usually attempt to introduce biofuels in manners that ensure a degree of economic attractiveness and adoption by users. In road transport, common strategies are for biofuels to complement (via low blends) or substitute (via high blends) fossil fuels such as gasoline and diesel (Pacini and Silveira 2010, 2011). Although there are production pathways based on organic residues such as biogas, large-scale commercial first-generation biofuels are predominantly based on dedicated energy crops. Examples of mainstream first-generation biofuel crops include sugarcane, sugar beet and sweet sorghum (for ethanol) and rapeseed, and palm and sunflower (for biodiesel). When it comes to second-generation biofuels (those based on lignocellulosic biomass and gasification methods), alternative feedstock such as crop residues and forests are likely to be the main source of inputs (Johnson et al. 2011).

While the utilization of biomass for energy needs is at least as old as mankind, the advent of large-scale, dedicated energy crops for biofuel production is a fairly recent phenomenon. With the internationalization of biofuel markets particularly after 2003, the interplay between biofuels and sustainability became a matter of heated debate (Hira and Oliveira 2009; Sheehan 2009). Because the term *sustainable biofuels* tends to be subject to some degree of arbitrariness, operational policies in this direction have to accommodate a delicate complexity of factors. Biofuels must deliver cost-competitive transport energy services at enough levels to be attractive from a macroeconomic perspective. At the same time, their usage should not lead to the accumulation of negative externalities in the form of net GHG emissions or clash with social and ecological systems.

On the one hand, there are strong biofuel advocates such as Smeets et al. (2008) and Goldemberg et al. (2008), who emphasize the development and environmental merits of biofuel production and use. On the other hand, critics of biofuel such as Pimentel (2004) and Giampietro and Mayumi (2009) challenge the validity of life-cycle GHG emissions as a basis for measuring sustainability in biofuels production.

[1] In the European Renewable Energy Directive (2009/28/EC), biofuels are characterized as liquid or gaseous fuels for transport produced from biomass (EC 2009, p. 27). This is the definition considered for this chapter.

Gnansounou (2011) proposes a model to classify sustainable biofuels. The same author argues that such classification can only work according to predetermined, measurable factors which do not incorporate real-life uncertainties nor dynamic changes in markets and societal preferences. Recent studies surveying sustainability of biofuels in the long run have proven rather inconclusive given the high uncertainty in regard to future land-use change and interplay with social aspects such as food security (Sheehan 2009; Stoeglehner and Narodoslawsky 2009).

Despite uncertainties, volatile energy prices, interest in job creation, and energy security factors contributed towards a strong regulatory push for biofuels in political agendas of different governments since 2005 (Martinot 2006).[2] Major global players have written biofuels into their national energy legislations. The United States adopted its Energy Policy Act in 2005, adopting the National Renewable Fuel Standard which meant a shift from MTBE to ethanol as a gasoline oxygenate.[3] The US drive for biofuels was strengthened by the Energy Independence and Security Act of 2007, which effectively contributed to a 10% ethanol blend in all gasoline sold in the USA after 2010.[4] The European Union started even earlier, with a formal directive fostering biofuels adopted already in 2003 and a new directive with stronger provisions adopted in 2009 (EC 2003, 2009). Globally, demand for biofuels is expected to increase (UNCTAD 2009).

Even with the increase of biofuel consumption in the United States, sustainability considerations were only partly addressed in 2010 by the US Environmental Protection Agency in the form of Greenhouse Gas Thresholds for biofuels, defined according to production pathways.[5] Instead, the European Union has spearheaded the field of biofuel sustainability regulation, when it adopted a set of mandatory sustainability criteria for biofuels in the directive 2009/20/EC (EC 2009). The fulfillment of the criteria is mandatory for biofuels to be counted towards the 10% goal of renewable energy in the European transport sector by 2020.

While many countries set up their strategies for sustainable biofuels, little is said about the entropic limitations of expanding their usage and, most importantly, if current sustainability certification efforts can sufficiently remediate the negative externalities incurred when countries engage in fuel substitution. In other words, can the uptake of biofuels be made in a way that the advantages arising from their

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[2] Private- and NGO-based sustainability schemes for biofuels were also launched by a number of players such as the Swedish ethanol company SEKAB, the Roundtable on Sustainable Biofuels (RSB), and the Brazilian government (*Selo de Combustivel Social*). These are not homogenous and vary in scope, so the authors opted to use the European criteria for its defined scope and potential of creating policy convergence in the area.

[3] US Environmental Protection Agency Renewable Fuel Standard. Available at http://www.epa.gov/otaq/fuels/renewablefuels/index.htm

[4] Renewable Energy World, May 11 2010: Approaching the Blend Wall – What it means for our economic future? Available at http://www.renewableenergyworld.com/rea/blog/post/2010/05/approaching-the-blend-wall-what-it-means-for-our-economic-future

[5] Regulatory Announcement: EPA lifecycle Analysis of Greenhouse Gas Emissions from Renewable fuels. See http://www.epa.gov/otaq/renewablefuels/420f10006.pdf

usage compensate the negative consequences of their expansion? This relates to the way current policy efforts are seeking to promote sustainability in the production and usage of biofuels. A survey of biofuel blending strategies conducted by UNCTAD (2009) illustrated that the adoption of biofuels is being undertaken on a large number of countries. On the other hand, it is often unclear to which extent biofuel can be used without jeopardizing the goal of sustainability. Under current technology, attempts to substitute large amounts of fossil fuels with biofuels imply that economies would likely be forced to sharply downscale the level of services currently derived from low-cost, fossil-powered transport.

In order to promote a better understanding of the limits to substitution in the case of biofuels, this chapter classifies efforts to promote biofuel sustainability under three basic strategies: dematerialization, detoxification, and transmaterialization. The limitations of biofuel sustainability policies are then debated based on an energy quality discussion under the framework of *weak* and *strong sustainability*. The analysis is illustrated by an empirical example on the limits faced by high-performing sugarcane ethanol to substitute for gasoline consumption, as well as an application of the theoretical framework discussed to the European scheme for sustainable biofuels.

This chapter uses the theoretical framework of ecological economics and thermodynamics, analyzing the sustainability strategy of fuel substitution facing conflicting trends of growing demand for energy and the necessity to reduce environmental impact of economic activity (Georgescu-Roegen 1971; Pearce and Atkinson 1993; Daly 1973, 1979; Ayres 2007). The chapter is divided in five sections: (1) introduction; (2) discussion on entropy, energy quality, and limits to sustainability strategies based on fuel substitution; (3) empirical example of the limits to oil substitution with bioethanol, using data from the ten largest sugarcane producers; (4) discussion of how policy efforts are promoting the usage of sustainable biofuels, exemplified by the European Renewable Energy Directive (2009/28/EC); and (5) conclusion and policy recommendations for the numerous countries currently designing their national strategies for sustainable biofuels.

2 Entropy and the Limits to Sustainability Strategies

Sustainability is essentially an inter-temporal concept, and for biofuels it is not different. Sustainable biofuels are those which deliver a desired level of services, are economical, and do not conflict with their supporting environmental and social systems (USDA 2009).

Arguments such as the Environmental Kuznets Curve and the provision of co-services can make the case for situations where an increase in the level of services can in fact strengthen sustainability (Michelini and Razzoli 2004; Pacini 2010). But, it is not so much the amount of services, but the type and composition of services that determine the impact on the environment. Yet, average provision of services has been based on economic growth patterns with high energy and material intensities,

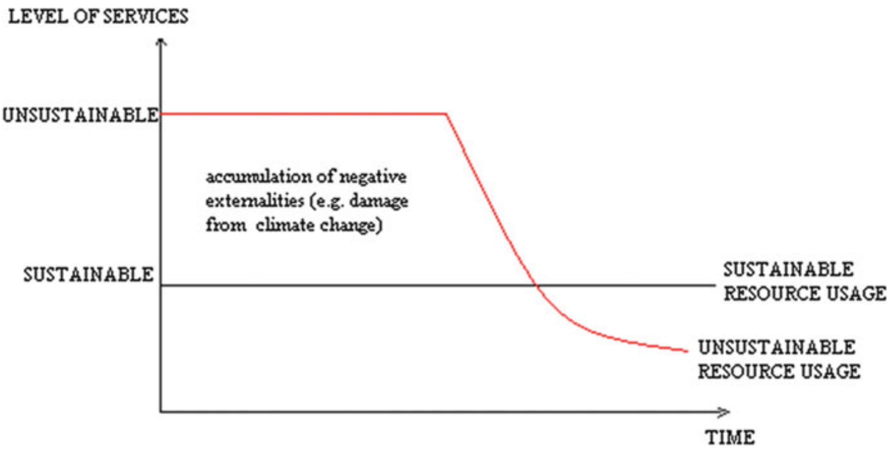

Fig. 1 Usage of nonrenewable resources beyond the carrying capacity of the environment (unsustainable) compared to a level of services compatible with sustainable resource usage (sustainable) (Source: Developed by the authors)

at the same time as co-service provision has lagged behind. Figure 1 seeks to illustrate the capacity of a system to maintain a certain level of services. In other words, it represents the global level of services which can be proportioned at different patterns of resource usage.

Before going into a concrete example of biofuel sustainability, we shall conceptualize the motivations behind it. We then explore the main types of strategies that serve as the base for the policy toolkit to promote sustainable biofuel usage in the European Union.

2.1 Strategies for Sustainability and the Role of Biofuels

The fourth report from the Intergovernmental Panel on Climate Change strengthened the notion that accelerated climate change is mainly due to anthropogenic effects (IPCC 2007). A useful tool to understand the human impacts on the environment was provided by Kaya and Yokobori (1997), who developed a simple equation which illustrates the magnitude of human activity on the climate system. The Kaya identity focuses on CO_2 emissions from anthropogenic sources and is expressed as follows:

$$F = P * \left(\frac{G}{P}\right) * \left(\frac{E}{G}\right) * \left(\frac{F}{E}\right)$$

or

$$F = P * g * e * f$$

where F is global CO_2 emissions from human sources, P is global population, G is world GDP, and E is global primary energy consumption. Then, $g=G/P$ is the global per capita GDP, $e=E/G$ is the energy intensity of world GDP, and $f=F/E$ is the carbon intensity of energy.

The Kaya identity suggests that damages to the climate system are, in a global perspective, directly proportional to the number of individuals (P), the wealth of individuals (g), how much energy is used to run each unit of our economy (e), and the carbon footprint associated to every unit of energy produced (f). With growing population and wealth, emissions increase when material flows in the economy are enabled by carbon-based energy sources which negatively impact the environment.

According to the logic contained in the Kaya identity, mitigating climate change through actions on g would imply constraints on wealth formation up to a point of net impoverishment in case population keeps rising faster than GDP. The natural environment has a limited capacity to replenish resources and absorb pollution, be it CO_2 or other kinds (Röckstrom et al. 2009). Therefore, strategies are needed to reduce the overall impact of human activity on the environment. The basis from the Kaya relation – energy and carbon intensities in the economy – can serve as a basis for sustainability strategies which would still allow continuity in economic and population growth.

In addition to the framework introduced by Kaya (1997), studies by Bringezu et al. (2004) and Shedroff (2009) identified key strategies for sustainable development, classifying these in three main policy categories:

(A) *Dematerialization strategies* seek to reduce the overall energy and mass flows which are required to provide the desired level of services. This strategy can also be understood as increases in process efficiency, which allows achieving the same societal goals at lower energy and material requirements (Ayres and Ayres 2002). Dematerialization has to do with the quantity of materials used to accomplish a task and can be defined as the decoupling of resource use and environmental impact from economic growth. It is usually measured in terms of mass of materials or energy units per unit of economic activity. Since GDP has increased faster than mass or energy consumption, the ratio has been declining for decades in several countries. This has been wrongly interpreted sometimes as dematerialization. However, the evidence of the countries' industrial metabolism shows that the link between economic activity and material consumption is extremely high, that is, resource use per capita continues to increase (Ayres and Warr 2009). Therefore, dematerialization is not happening at the aggregate level, which is the relevant process in environmental terms.

(B) *Detoxification strategies seek to* make waste streams (e.g., CO_2 emissions) and unintended social effects (e.g., land conflicts, exploitation of labor) less toxic and harmful to natural and human systems. Efficient welfare systems and carbon capture and storage technologies fall into this category.

(C) *Transmaterialization strategies* shift usage of materials to those with lower negative externalities. The transmaterialization contempt implies that materials undergo life cycles and substitution as society changes, making industries

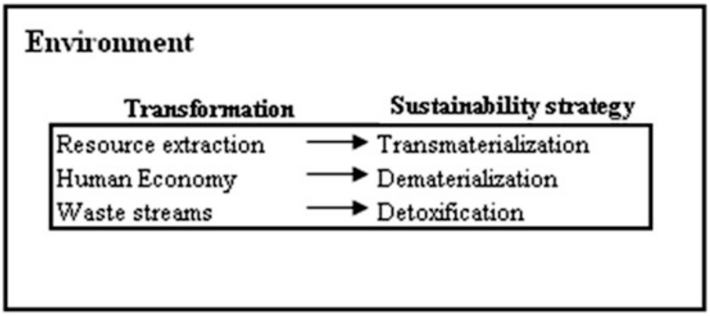

Fig. 2 Fundamental strategies for sustainable development of the human-environmental system (Source: Developed by the authors based on Bringezu et al. (2004) and Shedroff (2009))

replace old materials by newer, technologically more advanced (or less environmentally harmful) materials (Labys 2004). This can be illustrated in concrete terms by the substitution of gasoline by bioethanol, diesel by biodiesel, or coal-fired electricity by hydrogen-fired electricity.

Sustainability strategies can be conceptualized as either isolated actions under each of the categories (A-B-C) or, as it often happens in real-life policy scenarios, taking place in form of a combination of the three. Strategies are not limited to physical and environmental aspects of sustainability – but also take into consideration economic and social issues, such as basic human consumption needs, costs of (alternative) materials, as well as welfare losses from changed industrial dynamics. Figure 2 illustrates a simplified model of the human interaction with the environment and the main areas where sustainability strategies can be applied.[6]

In policy frameworks, the three strategies are often applied at the same time, or as a subcomponent of each other. For example, efficiency improvements (e.g., a form of dematerialization) might require technology shifts for lower resource usage and at the same time apply different energy carriers. The use of coal implies large mass flows connected to the generation of electricity; while the combustion efficiency can be increased for coal burning, it is often the case that increases in process efficiency also invite alternative fuels such as biomass (Annamalai and Wooldridge 2001). Conversely, if the transmaterialization rate is slower than the rate of increase in demand for fuel, the negative externalities of fossil fuels will not cease to accumulate. While biofuels increased their participation in the global energy mix from 53 billion liters in 2007 to 76 billion liters in 2009, that latter number only represented 5% of total gasoline output in the world as of 2009 (REN21 2010). Thus, there is still a long way to go before the negative effects of the fossil dominance can be counteracted by biofuels.

[6] There is no automatic relation between the left column and the right column of Fig. 2. For example, detoxification not only is an end-of-the-pipe strategy but can be also related to resource extraction in environmental management of mines.

In isolation or bundled, the capacity of these strategies to mitigate environmental impacts is limited when the growth rates of economies and populations exceed their application by far. As a matter of fact, this is exactly what has been going on in the last decades. Take the case of dematerialization, for instance. Although there has been a constant decarbonization of the economy in the past decades, emissions have increased by 45% since 1990. Similarly, material intensity decreased 26% from 1980 to 2007, but world GDP growth increased 120%, and world population increased 50% in the period, resulting in an absolute increase of 62% in global resource extraction (IEA 2010).

Since economies usually grow at a faster pace than their environmental efficiency, overall impact continues to grow in absolute terms. This creates one of the limits to dematerialization strategies: while improvements in resource efficiency have taken place, they did not suffice to decouple economic growth from resource use and waste, mainly because technical advances happened at a slower pace than overall economic and population growth.

Another limit to the dematerialization strategy is known as the Jevons Paradox – or rebound effect – when an increase in efficiency in using a resource leads to a medium- to long-term increase in the consumption of that resource rather than a reduction. This direct micro-rebound effect happens because increases in energy efficiency lower the amount of energy necessary to produce a given amount of output, which in turn lowers the cost of production. As the cost of production declines, total demand and consumption increases, resulting in the Jevons Paradox (Polimeni et al. 2008). In addition, there is also an indirect macro-rebound in which improved energy efficiency causes drivers to use the money they save on gasoline to buy other things that produce greenhouse emissions, like new electronic gadgets or vacation trips on fuel-burning planes (Giampietro and Mayumi 2005).

Next sections will compare biofuels to fossil fuels from an entropy-based perspective, aiming to answer the following questions: (1) to what extent can this renewable pathway substitute for oil, meet current energy demand in transport, and replace our dependency on climate-toxic fossil fuels, that is, is full transmaterialization viable, and (2) to what extent can "waste streams" be removed from biofuels production, that is, the negative externalities represented by land conflicts, food insecurity, and land-use environmental effects?

2.2 Entropy and Energy Quality

The first law of thermodynamics implies that energy cannot be created, destroyed, or recycled, but only transformed (Cleveland and Kaufmann 2008). As all energy is either *potential energy* (locked in various states waiting transformation) or *mechanic energy* (on the process of transformation), all what is left is the management of potential energy (stored in various forms) and energy transformation processes to sustain life and promote socioeconomic progress.

The physical concept behind the economics of concentrated energy sources is best embodied by the second law of thermodynamics, which postulates that entropy in isolated systems always tends to increase. The planet is not an isolated system since it is open to energy inflows from outside (the sun). Nevertheless, it is closed to material exchange, which means there is an ominous tendency towards dissipation of these finite materials and the energy concentrated in them. Thus, *high-quality energy*, meaning energy forms with high energy density per weight such as fossil energy sources (coal and oil) and radioactive elements, tends to dissipate into *lower quality energy,* dispersed such as heat during transformation processes.[7]

Even though the first law of thermodynamics guarantees that no energy losses occur in isolated systems, the fact that energy tends to deconcentrate and scatter in the environment implies that the economics-driven preference for concentrated energy sources ultimately leads to depletion of high-quality energy resources. This is the basis for arguments put by Georgescu-Roegen (1971) and Daly (1973, 1992) who claim that the economic system is destined to collapse as low entropy (*high-quality* energy) materials are dissipated and eventually become unavailable as inputs to power further economic growth. According to these authors, although the inflow of energy from the sun would allow theoretically recycling of the dissipated materials, there is no prefect recycling technology available. This leads to a growing "waste basket" which, in the absence of further recovery, will continue growing, ultimately leading the system to collapse.

Such a fatalist description of the human activity is criticized by Ayres (1997, 1999), who pointed out that the conclusion derived from the imperfection of recycling is not necessarily the ultimate collapse. The correct implication is that not all materials on earth are on active service at any given time, since waste can never be eliminated at once.

The external energy flow coming from the sun allows living systems to organize materials and maintain a low state of entropy (Schulze-Makuch and Irwin 2004). Thus, the sun directly supports two processes: substitution (through reconcentration) of *high-quality energy* materials and recycling of the waste basket which would otherwise eventually destroy the economy. Solar inputs used to grow biofuel crops effectively reconcentrate energy, when biomass-derived liquid fuels (e.g., sugarcane ethanol, rapeseed biodiesel) are used to substitute for oil-based fuels.

Apparently, economies strongly favor concentrated sources of energy which took millennia to build up via natural processes and are inherently exhaustible. Can we then quickly reconcentrate energy to serve our needs? Biofuels are produced by growing plants which need time to convert *low-quality* energy (heat, sunlight) into *high-quality* energy (biomass). These plants mature and are transformed through industrial processes into liquid or gaseous fuels. This transformation process concentrates *high-quality energy* into energy carriers that operate well in existing combustion engines and offer economic value in well-established market systems.

[7] *High quality* is here analog to low entropy (i.e., concentrated – like coal, iron ores), and low quality is analog to high entropy (i.e., dispersed – like heat and waste).

Left unmanaged, biomass grows and accumulates naturally in the environment at slow rates. Fortunately, humans manage to interfere with nature, channeling knowledge into agricultural management to grow biomass such as sugarcane and palm in organized crops which can yield much more than what would have been naturally possible. Can we then extend or overcome limitations posed by natural systems by simply increasing the share of human-managed natural assets in the economy?

2.3 Biofuel vs. Oil: Limits to Transmaterialization

As mentioned in previous sections, transmaterialization strategies aim to substitute material use aimed at similar types of service provision, such as mobility, but with lower socio-environmental impacts. Yet, transmaterialization requires that substitution between resources is viable. According to Georgescu-Roegen (1984), substitutability requires the substitute (biofuels) to exist and to reproduce itself without the need for the factor being substituted (oil). As of today, biofuels can hardly reproduce themselves at a systemic level without the fossil inputs embodied in field machinery, fertilizers, and labor (Blottnitz and Curran 2007).

In addition to difficulties in reducing fossil energy inputs, another limitation to substitution arises from the economics of biofuel systems. For example, returns on investment for fossil energy sources are higher than for renewable energy due to the inherent concentrated characteristics of fossil sources (Hall and Cleveland 2005). A single oil well can supply fuel for a large automobile fleet, while the same level of supply pursued via biofuel production would require numerous mills, as well as extensive area, labor, and time inputs. Another way to compare the economics of oil and biofuels is by looking at their labor intensities. Goldemberg et al. (2004) has shown that while one unit of energy output employs one person in the oil industry, the same unit employs 152 in the bioethanol industry. This may have strong social merits, but the labor costs for producing bioethanol are significantly higher than the labor inputs required for extracting a preexisting stock of fossil energy (oil).

As exemplified in the previous sections, governments often manage the introduction of biofuels by setting up both supply- and demand-side incentives. Supply-side instruments include production subsidies, R&D grants, and advantageous financing conditions to producers and distributors of biofuels. Demand-side instruments include government procurement, mandatory blending in gasoline, R&D activities on flex-fuel vehicles, or even pricing schemes aimed at giving biofuels a price advantage when compared to gasoline (Pacini and Silveira 2010, 2011). This approach aims to secure a level of economic sustainability in the biofuel system.

The intense utilization of fossil fuels can be root for enormous problems of climate change, but apparently makes sense in the market economy. Fuel derived from coal and oil generally has high volumetric energy content (high energy density) when compared to renewable (often dispersed) forms of energy such as biomass, wind, and sunlight (Cleveland and Kaufmann 2008, p. 13).[8] The current pattern of quick utilization of fossil fuels accumulated through millions of years illustrates well the case where resources are being exploited beyond their rate of renewal. In the case of biofuels, modern agriculture can reconcentrate *high-quality* energy much faster than nature concentrated oil. However, the speed in which we can produce biofuels is still far below the speed (and scale) necessary to match the amount of oil pumped daily from the globe. Unless many technical breakthroughs congregate to multiply current production yields, first- and second-generation biofuel production methods known today will not be enough to fulfill present needs without sharp downscale in the level of services provided.

2.4 Weak vs. Strong Sustainability Perspectives

In the previous sections, we have seen that there are serious limitations for transmaterialization of fossil fuel for biofuels. Nevertheless, assuming biofuels manage to become independent from oil, could we remove "waste streams" derived from its production, that is, the negative externalities represented by land conflicts, food insecurity, and land-use environmental effects? Or, would a very large expansion of biofuels production conflict with ecosystem services (which are themselves a source of low entropy and necessary for biofuel production)? Any assessment of the environmental sustainability of biofuels has to consider this issue.

The introduction of sustainability criteria into the biofuel market dynamics causes some interesting effects. On the supply side, the impact of sustainability regulations will be primarily on costs and technological routes, as producers have to adapt to new requirements in order to obtain market access. As a consequence, demand will have to cope with the consequences of regulated production: higher fuel prices at the pump and potential limits to the amounts of (certified) sustainable biofuels that can be produced. On the demand side, as different fuels compete for the consumer preference (e.g., gasoline vs. high-ethanol blends), regulators have to come up with ways to introduce sustainability criteria without reducing the price attractiveness of biofuels for consumers.

We shall firstly understand two competing concepts of sustainability, as presented by Pearce and Atkinson (1993). The first is referred to as *weak sustainability* concept and is defended by neoclassical economists such as Sollow (1974) and Nordhaus (1994). Weak sustainability postulates that most constraints can be surmounted via technology and innovation (Goeller and Weinberg 1976; Nordhaus 1994). Still according to the advocates of weak sustainability, the functions of all kinds of natural capital can be mimicked by man-made capital, in what is known as

[8] The energy density of solar radiation can be understood as its average incidence per unit of area (i.e., watts per m^2) on earth.

substitution. It implies that resource scarcities shall be only interpreted as relatives, given the technological ability humans have – given sufficient energy – to convert and reconcentrate resources to compensate for depletion of existing stocks.[9]

The second concept is known as *strong sustainability* and holds that many of the fundamental services provided by nature cannot be replaced by man-made services or systems. It then explicitly indicates a limit to substitution phenomena. Georgescu-Roegen (1971) is among its advocates and states that civilization is dependent on a finite stock of *high-quality* (low entropy) resources stored in the earth's crust. Natural capital cannot be replaced by manufactured capital. They are complementary, and, ultimately, manufactured capital depends on natural capital to reproduce itself.

Truly, natural capital is not only a source of resource flows (solar energy, minerals, fossil fuels, and soil nutrients) ready to be transformed by the production process. Nature is also a provider of services, which include regulatory functions of climate, maintenance of biogeochemical cycles which are essential to life (Gowdy and O'Hara 1997). Despite that, these services have been provided for free as no property rights or prices are assigned to them. Finally, they cannot be replaced if ecosystems are destroyed. Ayres (2007), for instance, defends strong sustainability (thus, limits to substitution) on the basis of the apparent human inability to fully and quickly substitute key components of the global ecosystem, such as the atmosphere, hydrological systems, and life (as a factory of organic compounds).

Avoiding the debate whether full substitution is either possible or impossible, one lesson can be drawn from Ayres's interpretation of the neoclassical economists' and Georgescu-Roegen's positions. This refers to the shadows of gray between the two extremes, meaning that there is some substitution potential between energy inputs, but it would be risky or impossible to attempt full substitution because of the ecological costs of damaging ecosystems to a point that they cease to provide society with its essential services, which are, in turn, not substitutable.

The specific limits to substitution between oil and biofuels are uncertain, but the risks are exacerbated proportionally to the ambition of the substitution strategy. Considering data from the International Energy Agency for 2007, the global production of liquid biofuels (50.92 million tons) corresponded to only 2.71% of the world consumption of liquid fossil fuels (1.87 billion tons). Even with a large increase in biofuel production, biofuels only make 5% of the total gasoline market as of 2009 (REN21 2010). Some studies have proposed ambitious global substitution between gasoline and ethanol (Matthews 2007; McKinsey 2007), but these seem to be counteracted by an increasing body of literature stating that a large

[9] As the substitution phenomenon has a prerequisite which is energy, let us look at the main energy sources available to humans. In a nutshell, there are essentially three energy sources for humans to play with. The first is the radioactive decay of atoms. The second, the gravitational interaction between the earth, the moon, and the sun which partially produce movement in water and air streams in the planet. The third, and perhaps the most important in practical terms, is the incidence of direct radiation from the sun in form of sunlight.

global biofuel expansion poses direct conflicts with food security, biodiversity, water usage, and social equity (Timilsina 2010; Payne 2010; Rosillo-Calle and Johnson 2011).

Since the production of biofuels aims to complement the usage of fossil fuels such as gasoline and diesel, this substitution shall not only occur via increased biofuel production if a strong sustainability strategy is considered, but mainly through a simultaneous reduction in the consumption of fossil fuels. Therefore, mandatory sustainability criteria for biofuels likely reduce the maximum amount of (certified sustainable) biofuels which can be produced, when compared to unregulated production. This means that there is a limit to substitution of fossil fuels by biofuels which is imposed by the sustainability mandatory standards for biofuels. Furthermore, if important players differ greatly in standards, it would result in a fragmentation of the biofuel market. And if standards are too strict, monitoring can be very costly. Fragmentation in market niches and costly monitoring can result in noncompetitive prices. Therefore, in the international arena, the alignment of sustainability standards is important for at least two reasons: it lowers the costs of certification and increases the scale of the market, finally increasing the competitiveness of biofuels.

However, in face of climate change, the strong sustainability view calls for a simultaneous engagement in dematerialization, by means of a parallel reduction in energy usage, particularly fossil fuels. If sustainable biofuels are to be cost competitive when compared to polluting fuels like coal, natural gas, and oil, carbon taxing is a prerequisite. Such a tax will make using dirty fuels more expensive; hence, it will encourage businesses and individuals to reduce consumption and increase energy efficiency. An equilibrium could then be reached on markets: the higher costs of sustainability certification would not drive consumers away from biofuels, since also fossil fuels would increase in price.

A sustainable rate of resource usage in the global transportation sector using exclusively biofuels would likely deliver a lower overall level of services than what is currently attained with oil. This is partly the reason why most policy frameworks for biofuels do not envision complete substitution: for the same cost it would deliver less than we currently have, exacerbating both known and unknown risks.

3 Limits to Sustainable Biofuel Expansion: The Sugarcane Ethanol Example

As exemplified on the previous section, biofuels are an option currently pursued by policy makers in many countries to increase sustainability via transmaterialization, by complementing (and even substituting) liquid fossil fuels and additives such as MTBE. According to UNCTAD (2009), numerous countries have already biofuels blends in place, while others have implemented or are studying stronger substitution strategies via high blends such as E100 and E85 (Hira and Oliveira 2009; Pacini and Silveira 2010, 2011; UNICA 2011).

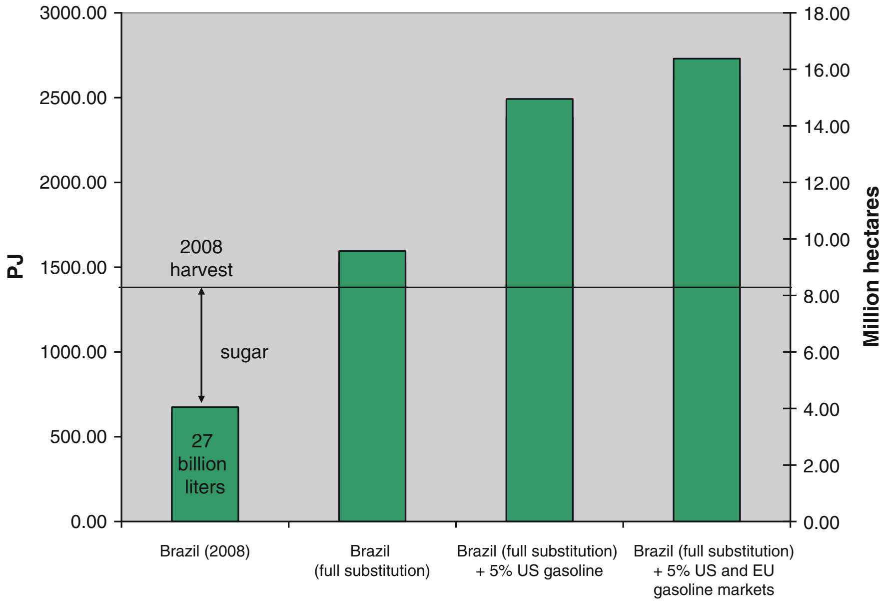

Fig. 3 Hypothetical scenarios for gasoline substitution with sugarcane ethanol, in energy terms [Energy and area requirements for total gasoline substitution and exports in the level of an additional 5% of the US and EU gasoline markets. Conversion factors: 1 tons sugarcane = 85 L ethanol; scenarios do not consider bunker fuels, diesel, nor aviation gasoline.] (Source: Calculated by the authors based on domestic market data from the Brazilian Agency for Oil, Natural Gas and Biofuels (ANP), sugarcane production yields and harvested area from FAOSTAT; US and EU27 aggregate gasoline consumption from the IEA country statistics for the year 2008)

There are, however, practical constraints which indicate how policy making becomes increasingly difficult when higher substitution levels are attempted. In order to illustrate this, scenarios have been created based on internationally recognized data and conservative estimations. Sugarcane ethanol is selected due to its cost-efficient production, as well as ongoing interfaces with energy and agricultural policies of a number of developing countries.

Brazil is the largest sugarcane producer in the world and achieved notoriety by having a highly efficient ethanol industry, producing biofuel which competes with gasoline at roughly USD70/barrel (Hira and Oliveira 2009). Between 2010 and 2011, the country produced 643 petajoules of ethanol equivalent (27 billion liters), while the remainder of the sugarcane harvest was routed to other profitable opportunities such as sugar, animal feed, and beverage production. About half of the domestic light vehicle fleet in Brazil is driven by ethanol, either as a blend in gasoline or as a pure version E100 (Pacini and Silveira 2010). Figure 3 illustrates that even having a fleet capable of adopting biofuels at high levels (thus allowing effective gasoline substitution), ethanol would struggle to completely meet demand for fuel in the country. Interestingly, even if the entire 2008 sugarcane harvest in Brazil had been converted to ethanol production, the country would still fall short of being able to completely replace gasoline (in energy terms) using only ethanol and based on current end-use efficiency levels.

A full conversion of sugarcane harvests towards ethanol is highly unrealistic due to shifting price signals which change the energy price of ethanol, making it sometimes uneconomical to use (Pacini and Silveira 2010, 2011). It would also require a full flex-fuel fleet able to take pure ethanol, while as of 2010 only 46% of the Brazilian vehicles were flex-fuel.[10] Finally, sugarcane producers also observe attractive output options such as domestic and foreign sugar markets. Nevertheless, for a hypothetical upper limit exercise, Fig. 3 illustrates how ethanol production (and correspondent sugarcane plantation area dedicated to ethanol) would need to be increased from the current 4.05 to about 9.58 million hectares, maintaining current yields of 79.27 tons per hectare, only for the complete phaseout of gasoline in the country. Additional scenarios contemplating exports to the US and EU market further increase demand for expansion in sugarcane.

While some studies already estimated very large production potentials for Brazil (McKinsey 2007) and substitution of a large share of fossil fuels globally (Matthews 2007), even with best available technologies for sugarcane-based biofuel production, an aggressive ethanol-gasoline transmaterialization strategy would likely put food security at risk either by foregoing sugar production in favor of ethanol or displacing other food crops. The larger land requirements would in turn jeopardize the biodiversity, land rights, and very cost efficiency of ethanol production, since the best areas tend to be used first – shooting marginal costs up as the sugarcane frontier advances.

Departing from the premise of full substitution, a more realistic approach for biofuels is to act as fuel oxygenates into gasoline pools, such as via replacement of fossil-derived MTBE by bioethanol (UNCTAD 2009; Diaz-Gutierrez et al. 2005). This time, focusing on the more realistic approach of biofuels blends, attention still has to be given to responsible targets for partial substitution. Figure 4 considers the ten largest sugarcane producers in the world and simulates how much gasoline (in energy terms) could be substituted by ethanol, using different shares of their 2008 sugarcane harvest (100% = totality of the harvest for that year).

As becomes clear by the illustration, even for small substitution levels of 5–10% (equivalent to blends of E7 and E13), countries like Mexico, China, and Australia would need to dedicate the majority of their sugarcane production to ethanol. For full substitution of gasoline, Mexico would need 15.5 times the 2008 sugarcane harvest fully dedicated to ethanol, not counting on infrastructure and fleet modification needs. In the Mexican case, the routing of sugarcane feedstock towards ethanol production could also have a negative impact on revenues currently levied on sugar exports, since these enjoy very attractive conditions on the US market under the North American Free Trade Area (NAFTA).

[10] Source: Luciano Losekann and Gustavo Rabello de Castro, Energy Economics Group, Federal University of Rio de Janeiro.

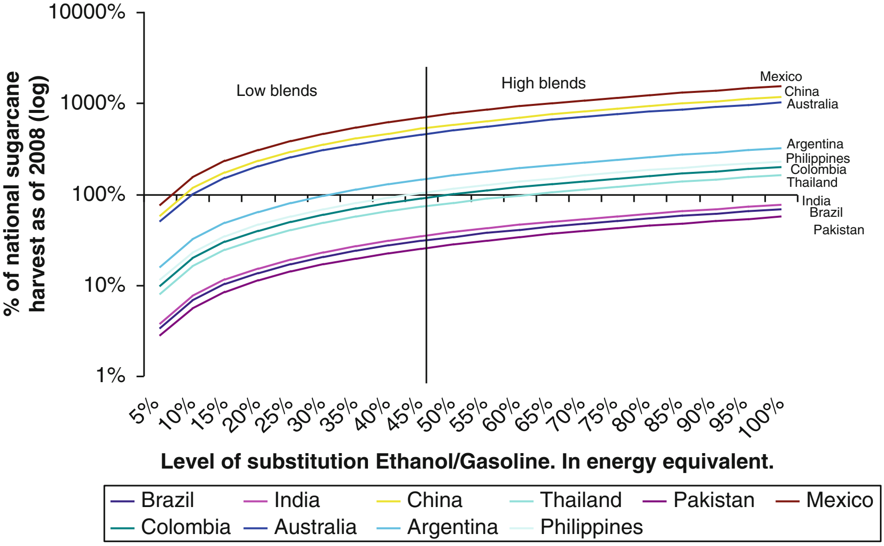

Fig. 4 Percentage of national sugarcane required (in ethanol equivalent) to replace different levels of gasoline from the national fuel pool, considering the ten largest sugarcane producers in the world (Source: Developed based on data from FAOSTAT, the Brazilian Agency for Oil, Natural Gas and Biofuels (ANP), and the International Energy Agency (national energy balances))

For countries which could in principle cover their current gasoline consumption in energy terms via ethanol derived from their current national production (Brazil, India, and Pakistan), two points are worth mentioning. The first is the development level of the economies of India and Pakistan, which will likely make gasoline consumption grow faster than sugarcane harvests. The second is the amount of gasoline in Brazil, which is significantly smaller than in other countries of its economic size due to the already-large participation of ethanol fuel in the transport sector (via low and high blends).

One of the lessons of Figs. 3 and 4 is that levels of substitution are more likely to be within the reach of feedstock production if low blends are used. However, even low blends can quickly require large amounts of major crops, such as the case with the total sugarcane production in Mexico, Cuba, and Australia not sufficing even for gasoline substitution levels under 15% (in energy).

4 Sustainability Policy Efforts: The European Directive 2009/28/EC

The European Union (EU) has adopted in early 2009 a directive which calls for a mandatory target of 10% renewable energy in the transport sector of all European member states by 2020 (EC 2009). Under the expectation that biofuels

Table 1 European sustainability strategy for biofuels

		Characteristic or subcomponent	European Union policy for sustainable biofuels (Art. 17 of 2009/28/EC)
Sustainability strategy for biofuels	*Transmaterialization* (replacing oil for biofuels)	Market introduction	Mandatory share of renewables in transport by 2020. Biofuels only count if certified sustainable
		Monitoring	Policy review every 3 years
	Detoxification (reducing negative externalities of biofuel usage)	GHG emissions reduction threshold	Min 35% reduction from fossil baseline. Threshold increases over time
		Human and labor rights	Adhesion to conventions of the International Labour Organization
		Food security	Report every 2 years
		Environmental conservation	No production in areas of high biodiversity value
		Soil	No production in areas of high carbon stocks
		Air and water issues	Monitoring and reporting
		Land rights in third countries	Monitoring and reporting
	Dematerialization (increasing efficiency in biofuel usage)	Technology development	Second-generation biofuels count double towards national targets

Source: Developed by the authors

are likely to become major contributors to the attainment of this goal, the EU has also established sustainability criteria for the production and usage of biofuels, as to make these eligible towards the proposed 10% target by 2020.

The criteria laid in the European directive call for biofuels to provide a minimum of 35% reduction in lifecycle greenhouse gas (GHG) emissions, when compared to their fossil equivalent (gasoline-ethanol, diesel-biodiesel, natural gas-biogas). The GHG threshold is to be increased to 50% in 2017 and 60% by 2018. In addition, biofuels should not be produced in areas of high biodiversity, in protected areas, or in land containing high carbon stocks.[11,12,13] Moreover, the directive attempts to safeguard social and labor dimensions by calling for biannual reports on food security and labor conditions in biofuel-producing regions both within Europe and abroad (Table 1).

By promoting biofuels, the European directive is in fact trying to encourage *transmaterialization*, or action towards parameter *f* in the Kaya identity, by means

[11] Untouched primary forest and highly biodiverse grasslands.

[12] Areas designated by law as natural reserves.

[13] Wetlands, peat lands, and continuously forested areas.

of a shift towards a fuel that is less carbon intensive than gasoline. Broader transmaterialization strategy contains at the same time subcomponents of detoxification and dematerialization, as the directive launched measures to reduce negative externalities of biofuels deployment in environmental and social systems, as well as pushed for technological development by double-counting advanced biofuels for the national targets of renewable energy in transport by 2020. The directive also gives an incentive for continuous innovation as the minimum GHG thresholds for sustainability certification do increase over time.

The European policy does not take sides on the strong or weak sustainability debate. In face of the uncertainty in the safe levels of substitution between biofuels and fossil fuels, the European directive adopts two flexibility instruments. The first is the inclusion of the term "renewable energy" instead of "biofuels" towards the goal of 10% of final energy consumption in transport by 2020 (EC 2009). By doing so, in addition to avoiding picking a technology winner, the directive allowed other technologies (e.g., electricity, hydrogen, biogas) to supplement the fuel substitution effort, with potentially less collateral effects. The second is the previously mentioned set of verification-based criteria which aim to reduce "waste flows" via internalization of impacts which could happen due to an increased usage of biofuels, such as rebound effects, biodiversity losses, and social conflicts.

While biofuels alone can do little to reduce the energy intensity of the economy, they help reduce the carbon footprint of energy in the transport sector. However, it can be asked if the incorporation of transmaterialization strategy with criteria to mitigate risks in the European directive is enough to achieve sustainable biofuels.

It is important to have in mind that directive 2009/28/EC was proposed in the context of a broader policy effort. The directive was a component of the European climate and energy package launched in January 2008. In addition to renewable energy promotion which aims the *transmaterialization* of fossil energy carriers towards a 20% renewable energy share (biofuels part thereof), the European Commission has pushed forward two other legislative instruments promoting complementary strategies of *dematerialization* and *detoxification*:

- A push for energy efficiency in form of a 20% reduction in primary energy use by 2020
- Measures to stimulate a 20% reduction in GHG emissions by the same date, mainly a fine-tuning of the European Emissions Trading Scheme[14]

The European sustainability scheme for biofuels was itself an attempt to reduce the negative effects of *transmaterializing* transport fuels. There is of course a great deal of uncertainty on what is the optimal threshold for climate mitigation without incurring indirect rebound effects. Rebound effects could occur if, for example, reductions in carbon emissions due to a higher participation of biofuels in the energy matrix could lower sustainability in other sectors, such as jeopardizing affordable food supply and ecosystem service provision in some areas (Polimeni et al. 2008).

[14] See http://ec.europa.eu/environment/climat/climate_action.htm

Biofuels are highly interconnected with social and environmental systems via their dependence on land usage and competitive interaction with other agricultural goods. This is especially relevant at the international level, given that Europe alone does not have enough land resources available to achieve self-sufficiency in biofuels. In this sense, *low-quality* energy has to be reconcentrated elsewhere and then imported to the EU, especially from developing countries with comparative advantages (labor, abundant sunlight, water, and extensive land resources).

This leads to the perception that a higher biofuel usage in Europe carries a limited liability in case of unforeseeable consequences of its sustainability approach for biofuels. The European directive cannot shield against the full range of uncertainties, which exist in unregulated aspects of production such as noncompliance with the directive or an ex post perception that the sustainability criteria were not properly conceived.

Ultimately, biofuels have limitations to promote sustainability in the transport sector in the long run, calling for a diversified energy portfolio and different transport modalities (Timilsina and Shrestha 2010). While advanced biofuels carry great promise, a more cost-effective option to diminish our reliance on fossil fuels in transport fleets has yet to come (Savage 2011). Scientific modeling can provide ranges, but the ambition of goals for renewable energy utilization is ultimately decided by political processes. The European directive adopts a moving target approach aiming at enabling a transport system with less negative externalities. While a sustainability policy for biofuels may contribute to climate change mitigation, it has limits and those should be transparently communicated to national and foreign stakeholders. Biofuel sustainability policies in their current form cannot fully hedge against risks bound to the interplay between environmental and social systems which are intimately linked to land use and international trade. A transparent communication of the benefits – as well as the costs and restrictions bound to different strategies for biofuels usage – must be developed with stakeholders in an open and inclusive manner, mindful of the limits to substitution.

5 Conclusion

A biofuel-only global transport system can only deliver a fraction of services currently provided by fossil fuels. Full substitution of the current energy services from oil towards biofuels is not even desirable due to the human inability to substitute fundamental ecosystem services such as hydrological, phosphorous, and nitrogen cycles in case the expansion of energy crops takes place at the expense of natural biomes. Current sustainability strategies for biofuels have therefore limited effectiveness. In their current form, they can at best reduce, not eliminate, risks associated with the interplay of biofuels with socioeconomic and natural systems. Full transport energy substitution via biofuels cannot deliver strong long-term sustainability. This suggests that emphasis should be given to diversification. Both short-term options – fossil fuels and biofuels – should ideally coexist until humans reduce the cost of alternative energy carriers, as well as engineer other more efficient and climate-friendly energy and mobility systems.

The current European biofuel certification schemes which attempt to guarantee that fuel shift is made in a responsible manner, compatible with other legislative efforts, prove only valuable in the short term, as they are predominantly supply-side instruments attached to explicit goals for 2020 and thus cannot be utilized to make assumptions on sustainability assessments over longer time horizons. Over the longer term, emphasis should be on more fundamental questions of demand: transport and energy systems design, especially the dematerialization of the transport system, should take form of increases in the ratio of efficiency between mobility delivered per energy inputs.

Since there are thermodynamic limits for increases in efficiency of engines, and there is a rebound effect associated to efficiency improvements, it is not possible to avoid the issue of transport infrastructure. A system that delivers mobility services with less energy requirements should unavoidably consider investment in public transportation systems, such as multimodal bus-metro-bikes and car-sharing solutions. Furthermore mobility systems cannot be isolated from the spatial distribution of work in cities. So, in the long run, it will not be possible to avoid the issue of commuting.

Biofuels can help attain sustainability, but only if produced at a scale which delivers a much smaller level of services than what is currently attained with their fossil equivalents. Considering biofuels as a complement rather than a replacement for fossil fuels is a first step. Furthermore, policy efforts should not aim at tackling side effects of biofuels only, but also diversify energy systems, promote rational patterns of resource usage, and encourage transparent legislative processes which include national and foreign players affected by sustainability policies for biofuels through trade in global markets. Regulatory frameworks and energy policies are serious challenges for policy makers. Transparency, efficiency, and diversification are palpable options towards a legitimate burden sharing, while technological options remain restricted.

Acknowledgments The authors express their gratitude for the Swedish Energy Agency, EUBRANEX, and UNCTAD for support provided in the development of this study. The authors would like to thank Dr. Mark Jaccard (Simon Fraser University) for his valuable insights on a previous draft.

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Z. Luo (ed.), *Mechanism Design for Sustainability: Techniques and Cases*,
DOI 10.1007/978-94-007-5995-4,

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