Umberto **Berardi**

Moving to Sustainable Buildings: **Paths to Adopt Green Innovations in Developed Countries**

VERSITA

Versita Discipline:
Arts, Music, Architecture

Managing Editor:
Monika Michałowicz

Language Editor:
Andrew Kerber

Published by Versita, Versita Ltd, 78 York Street, London W1H 1DP, Great Britain.

ISBN (paperback): 978-83-7656-009-0

ISBN (hardcover): 978-83-7656-010-6

ISBN (for electronic copy): 978-83-7656-011-3

Managing Editor: Monika Michałowicz

Language Editor: Andrew Kerber

www.versita.com

Cover illustration: ©Umberto Berardi

This book is dedicated to all the construction stakeholders that daily help our future by creating sustainable buildings.

Contents

List of Figures

List of Tables

Acknowledgements

Completing this book has been rewarding work but was not absent of challenges. Many people have helped me to overcome those challenges. Therefore, I would like to thank all of them, including those not mentioned here by name.

I am deeply indebted to René Kemp and Jensen Zhang, who have hosted me in their departments as visiting researcher, and have given me the possibilities of new inspirations in an international context.

Another gentleman to whom I am greatly indebted is Jiufa Chen. He has been a friendly teacher and a supporter of my studies.

My small understanding of sustainable innovation management would not be possible without the explanations I received by Vito Albino.

I am also in debt to my first research community at the Politecnico di Bari (and prof. De Tommasi in particular), to Roberto Pietroforte and to the Civil and Environmental Engineering department of the Worcester Polytechnic Institute.

I thank the patience and love of Paola meanwhile I was writing this book. Finally, I must thank the silent presence of my father. His inspiration was the main guide while I was writing these pages.

Foreword

This book is an important contribution to the growing field of sustainable building. The First Conference on Sustainable Construction, organised in 1993 by the International Council for Research and Innovation in Building and Construction (CIB), set the broad issue of sustainability in building on the international research agenda. Scholars from various disciplines joined the conference in Tampa, Florida, which was hosted by the Center of Construction and Environment of the University of Florida, and chaired by Professor Charles Kibert. Sustainable architecture and urban planning, handling of construction and demolition waste, management of building projects, and systems of sustainable innovation were all addressed. The conference concluded with the announcement of an intention to further investigate these topics. Since then, many scholars have focussed on sustainability in building, and today, twenty years later, a number of noteworthy research projects and publications are produced in the expanding field of sustainable building innovation. Scholars have not stopped investigating the theme, and even in times when public attention decreased, researchers continued to develop projects in order to improve knowledge regarding and provide insights into this important issue.

In this field of sustainability and building, Umberto Berardi continues to make significant contributions. This book is one of his major works, and I expect many new contributions of his will follow in the future years. Umberto Berardi is a knowledgeable and front-running researcher in the area of sustainable building innovation. He is aware of the multidisciplinary nature of this field and shares his knowledge on the assessment, rating and improvement of buildings' sustainable qualities, the innovation processes that drive changes in the building industry toward more sustainability, the complex struggle of stakeholders in the project-driven and fragmented building industry, and the organisational methods and theories that can be used to understand and improve eco-innovative building. Umberto Berardi is very knowledgeable; he knows things others do not know and shares it with his readers in this open access book. In more than one way, this is a gift to his readers.

Bart Bossink
Professor of Technology and Innovation
VU University Amsterdam, the Netherlands

Preface

Among international actions for sustainability, makers of programmes and policies are assigning more and more attention to buildings. Many national and local activities encourage sustainable buildings worldwide. At the same time, R&D continually offers new green products, facilitating a transition to sustainability within the building sector. Although sustainable buildings show higher value premium and their number has increased even during the recent international crisis, a transition to a sustainable building sector is far from being reached worldwide.

In spite of many efforts, building practices do not seem to have undergone any significant change. This raises the question of how green innovations are dealt with in construction. The aim of this book is to create an understanding of how sustainable building can be incentivised and of how green innovations may be better managed in the building sector.

This book is based on recent field research of the author. It explores various aspects of transitions of the construction sector to sustainable building through the adoption of green innovations. The research methods range from theoretical discussions about the concept of sustainable building to interviews about preferences of building stakeholders and field studies about the organisation of processes for the adoption of green innovations in sustainable buildings.

The book does not pretend to be exhaustive in the theme of sustainable buildings. However, it aims to contribute to showing how green innovations may be successfully managed in order to help the diffusion of sustainable buildings. This perspective considers both the product-centred focus on green innovations and green buildings, and the process-centred focus on building in a sustainable way. Thereby, the book emphasises the importance of a clear definition of the terms *sustainable building* and *green innovation*, and at the same time, it gives attention to the building process.

The main contribution of this book to the promotion of sustainable buildings consists of a discussion about available definitions and interpretations of the concept of sustainability in the building sector (Chapter 2). This allows an exploring of the differences between *efficient*, *green* and other names used to identify sustainable buildings. Then, the book reviews sustainability assessment methods in the building sector (Chapter 3).

This review is followed by the analysis of the green innovations that have been adopted in a large sample of sustainable buildings in the US (Chapter 4). This first part of the book (Chapters 1 to 4) aims to explore the concepts of *green innovations* and *sustainable buildings* to clarify the sustainability transition that the second part of the book examines.

The contribution of the second part of this book to the topic of building in a sustainable way consists of few analyses about difficulties encountered by the actors of the building sector. This investigation aims to look at drivers and barriers for the diffusion of green innovations in sustainable buildings. In particular, after a general introduction to the adoption of (green) innovations in the building sector (Chapter 5), the book describes the power, motivation and influence of construction stakeholders over the adoption of green innovation in buildings (Chapter 6). Then, the book describes which changes to the interactions between firms can favour a shift of the construction sector to sustainable buildings (Chapter 7). Policies for sustainable building are reviewed and discussed in order to understand which influence every level of government can have in the transition to sustainable buildings (Chapter 8). The concluding chapter reviews the main topics discussed in the book.

The starting point of this book is the importance of the building sector to sustainable development. This requires sustainable buildings and, in general, a transition to sustainability of the construction sector. However, a literature review of definitions of *sustainable building* shows that this terminology needs clarification, as it is often used in a confusing manner. By examining the evolution of the concept of sustainable development in the last years, this book investigates what *sustainability* means in the construction sector. Many constraints hinder a simple definition of what an (environmentally) sustainable building is. In particular, the dependence of the concept on time, scale, domain and social constraints is investigated and discuSustainable assessment systems are then considered, because they represent considerable drivers for sustainable building. Different systems are described and compared in this book to understand which factors are (or have to be) considered for a sustainable building. Later, this book analyses the sustainability assessments of a large sample of American buildings (490 buildings). This presents data about green innovations in buildings that, currently, aim to be defined as sustainable.

The book shows that energy performance is considered the most important criterion in sustainability rating systems and is the least achieved criterion in sustainability assessment results. This means that great barriers are still encountered in the adoption of energy-efficient innovations. In contrast, other performance ratings, such as the water efficiency or indoor-air-quality systems, are successfully managed in sustainable buildings. This shows some differences in managing different green innovations in buildings that aim to be considered sustainable.

The first part of the book concludes with a clarification of the concepts of *green innovations* and *sustainable buildings*. It is hence preliminary to the following chapters, which analyse the green building process by looking at the interactions between stakeholders while they manage the adoption of green innovations. Among other aspects, this book shows the importance of the people behind a transition of the building sector toward sustainability. It also recognises the importance of the social and organisational characteristics of the building processes for the management of green innovations. Sustainability represents a dynamic path for the building sector, and the transition to sustainable building may not be possible without new interactions and relationships between building stakeholders.

This book brings to light the complexities and difficulties in managing green innovations by using a "case study" methodology. In order to deal with the continual flux in green innovations, this book classifies them according to the mechanisms and properties behind their adoption. The challenges that different green technologies pose also receive attention in this book. In particular, green innovations are classified according to the mechanism and properties behind their adoption. Moreover, the integration of innovations with other non-innovative components of the building is investigated in order to define incremental vs. radical, and modular vs. architectural innovations.

This book investigates the influence of construction stakeholders on the adoption of green innovations. The case studies often focus on European, medium-size residential buildings. The influence of project stakeholders on the adoption of different technologies is assessed through interviews, and the stakeholders' influence is measured. The investigation shows the minimal influence over the decision for the adoption of green innovations held by highly motivated stakeholders. Moreover, the study shows that the delay between the buildings' design and their construction discourages the adoption of green innovation.

This book also looks at changes in organisation among firms involved in sustainable construction; it investigates how inter-firm relationships are changing as the sector moves toward sustainability. An organisational model among firms is developed by considering a few features, such as the interaction level of the general contractor with suppliers, the interaction between the general contractor and the design team, and the degree of specialisation of firms and their sustainability qualification. Organisational aspects of traditional and sustainable buildings are compared. The book shows that sustainable buildings are associated with inter-firm relationships as well as co-makership with suppliers and with the design team. The presence of firms with a focussed portfolio on sustainable projects is also important.

Later, this book provides an empirical insight into policies that should motivate a transition to sustainable buildings and suggests improvements to overcome the limits of these policies. Findings show that the actual practices of firms often conflict with the management of green innovations. Moreover, organisational structures and project practices of construction prove to be mismatched with the management of green innovations.

This book shows that the way sustainability issues are handled in construction processes depends on how socio-cultural networks organise themselves. It concludes that there is a need to go beyond the prevalent normative and rationalistic technological view of sustainability and green innovations. This can occur by shifting to a perspective that integrates technical with social aspects of building. Finally, this book suggests that in order to diffuse green innovations in sustainable building, it is necessary to take into account that individuals, when acting, take part in on-going processes of organisation and social practice, which influence the way they act towards and manage green innovations.

Umberto Berardi

Chapter 1

Introduction

The building sector is receiving increasing attention in worldwide policies for sustainable development. This attention to buildings arises from their energy consumption and Greenhouse Gas (GHG) emissions, which in developed countries represent 30 and 40% of the total energy consumption and GHG emissions, respectively (IPCC, 2007, UNEP-SBCI, 2009).

The Eurostat (2012) has recently published the energy consumption data for different sectors in European countries. This shows that the consumptions in the service and household sectors are higher than the consumptions in the transport or industrial sectors in every country. Moreover, the forecasts of the Energy Information Administration show that the energy consumption and GHG emissions in buildings are increasing at a higher rate than in the industrial and transportation sectors (EIA, 2011). Figure 1.1 shows the gigatonnes of CO_2-equivalent ($GtCO_2$) emissions of buildings from the 1970s to 2030s in different parts of the world. As it is evident, the overall emissions are expected to more than double in the next 20 years (IPCC, 2007). Africa, Latin America and Asia are mainly responsible for the increase in consumption and emission trends, due to their rapid urbanisation processes. Similarly, Western Europe will also see an increase of emissions in the coming years.

According to the 4th report of the Intergovernmental Panel on Climate Change, GHG emissions from buildings will amount to 15.6 $GtCO_2$-eq/y in 2030 (IPCC, 2007). In this scenario, the building sector alone could save around 6 $GtCO_2$-eq/y, at a much lower cost than in other sectors (Figure 1.2). Based on 80 studies spanning 36 countries, the IPCC report suggests that a 29% reduction in projected baseline emissions by 2020 is achievable at zero cost (costs below zero US dollars per tCO_2-eq), while further improvements could be made with relatively low levels of investment (IPCC, 2007). Figure 1.2 further shows sectoral estimates of the emission-mitigation potential by using technologies and practices expected to be available by 2030, at various costs, in US dollars per tCO_2-eq. In Figure 1.2, the mitigation potential is expressed in $GtCO_2$-eq/yr and the marginal cost is in US dollars per tCO_2-eq. For each sector, the mitigation potential is represented as three ascending bars, according to the amount that can be achieved at less than 20 USD, less than 50 USD and less than 100 USD per tCO_2-eq. In the building sector, assuming a cost per tCO_2-eq of no more than 100 USD, the global economic-mitigation potential ranges between 5.3 and 6.7 $GtCO_2$- eq/y by 2030, depending on who is forecasting. Most importantly, around 90% of this potential could be achieved at less than 20 USD per tCO_2-eq, far more than what could be achieved in any of the other sectors depicted.

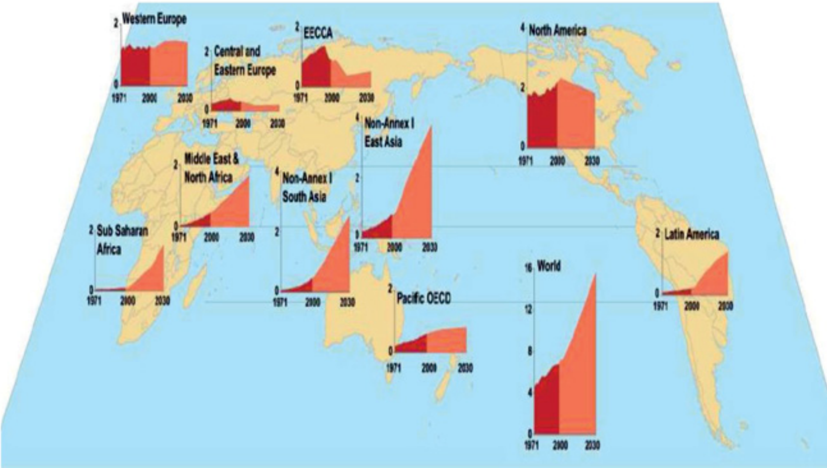


Figure 1.1. GtCO2-eq emissions from buildings worldwide: measured data in red, 1970-2000, and forecast data in orange, 2000-2030 (IPCC, 2007).

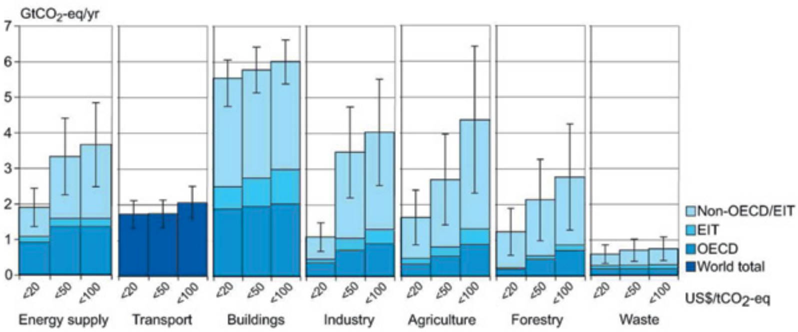


Figure 1.2. Estimated yearly GtCO2-eq potential savings in emissions in 2030 for seven sectors as a function of the cost (<20, <50, <100 $), expressed in USD per tCO2-eq (IPCC, 2007).

Previous data show the urgency of moving towards sustainability in the building sector. The importance of moving towards sustainability in buildings is also given by the contribution of the building sector to the general economy. The overall economic value of construction accounts for 10% of world GDP, being equal to 3 trillion USD worldwide (UNEP, 2003). In most countries, the building sector contributes over 50% of the national capital investment, and on average, it provides 7% of world employment (UNEP, 2003).

The increasing relevance of the building sector in undeveloped and developing countries justifies greater attention towards sustainable buildings, too. In these countries, the building sector is showing unbelievably high rates of increase. The World Bank estimates that by 2015, more than half of the building stock of China will have been constructed during the previous 15 years (Figure 1.3). In China, the construction workforce tripled between 1980 and 1993, moving from a mere 2.3% to a more than 5% share of total employment (UNEP, 2003). In 2007 alone, 0.8 billion square meters of new buildings were constructed in China, and an additional one billion square meters of new buildings will be constructed each year between now and 2020 (Cheng, 2010).

Figure 1.3. Views of the Bund of Shanghai in 1990 and 2010 (http://www.skyscrapercity.com).

As much of the discussion in the present book refers to the Italian building sector, it is useful to understand the current Italian situation. In Italy, the energy consumption in the construction sector is increasing at higher rates than in other sectors, similarly to other European countries. In 2009, the energy consumption of Italy was recorded at 133.2 Million-tonne equivalent of petroleum (Mtep) (CRESME, 2010), of which 46.9 Mtep was used by buildings, 35.2% of the total, as shown in Figure 1.4. This consumption was subdivided into 28.6 Mtep (61.0% of total) in residential buildings and 18.3 Mtep (38.6%) in commercial ones. A ratio of 60 to 40% is common in OECD countries (EIA, 2011).

Even if the building sector has suffered a reduction of investments in most developed countries, it has recorded an increase of investment in the renovation of existing buildings. Figure 1.5 shows that in the last few years, an increase

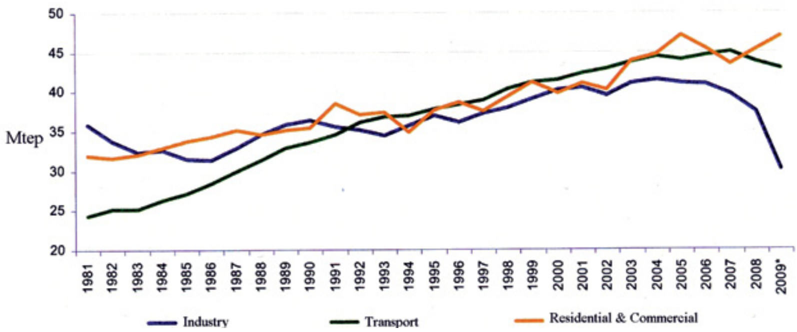


Figure 1.4 Energy consumption series from 1981 to 2009 in Italy expressed in Million-tonne equivalent of petroleum, Mtep, for different sectors (CRESME, 2010).

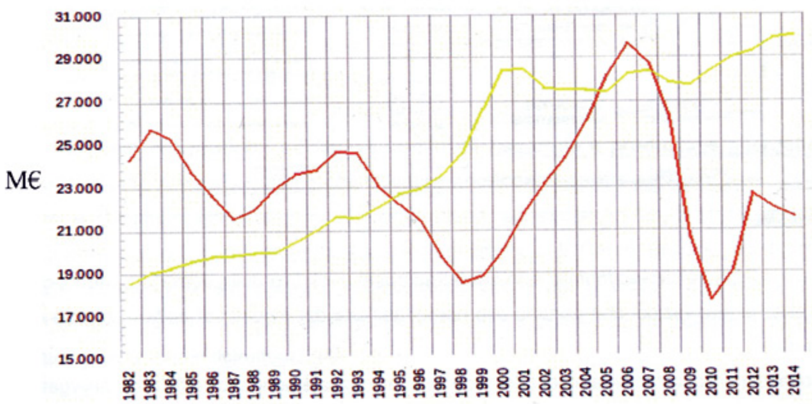


Figure 1.5 Investments in M€ in residential buildings in Italy divided in new construction (red line) and renovations (yellow line), referring values to 1995 price (CRESME, 2010).

of investment in new buildings has been recorded in Italy, too. For example, in 2009, among the 184.0 M€ invested in construction, 72.7 M€ were for new buildings and 78.2 M€ for renovation (CRESME, 2010). These values show the urgency of sustainable building in developed and developing countries.

1.1. Introduction to Moving to Sustainable Building

Previous data show the importance that sustainable buildings have for sustainable development. They justify the necessity of identifying ways to move the building sector toward sustainability. This book tries to contribute to this transition by understanding how to manage green innovations in the building sector, how the building sector can move to sustainability and what this means. This book hopes to overcome a superficial approach to the questions raised by the transition to sustainability of the building sector by looking at real cases in which green innovations are managed.

The development of sustainable building poses a number of technological challenges that have far-reaching implications for the management of innovative processes (Peine, 2009). The interoperability of new green innovations within buildings is particularly important, and the coordination between stakeholders becomes fundamental. In fact, although it is often believed that sustainable buildings should reveal their innovativeness, more and more examples of sustainable buildings have shown a resemblance to traditional ones. However, the level of integration in sustainable buildings often requires new skills, new capabilities and new knowledge. In synthesis, an increasing attention to the management of green innovations is considered necessary for sustainable building.

Relevant questions related to sustainable building concern the inter-organisational process of innovation management among actors of the building process. Figure 1.6 provides a schematic picture of the construction industry and its context. The building industry is composed of many construction-project organisations. These are divided into several stages, which are fragmented among many individuals. Each individual that takes part in the construction project influences the structure at higher levels. This means that phenomena related to the construction process, including the project organisation of individuals involved in construction projects, have to be taken into account. On the other side, the construction industry is influenced by society and, in general, by the natural environment.

The building process is divided into multiple sub-tasks, and practices are distributed throughout the process among a high number of actors. Several companies, as well as local authorities, enter and leave the project at different times. During the realisation of a building, multiple activities involving both

Figure 1.6 Context of construction industry from individuals up to the general natural environment (re-adapted from Gluch, 2005).

material and people have to be coordinated in a restricted time and on the same site (Gluch, 2005). Since the construction project evolves over time, the project organisation evolves into a dynamic series of relationships (Stinchcombe, 1985). In this context, the adoption of green innovations is hampered by the time-frame of construction processes, which is often tight and favours short-term, simple, repetitive choices over innovative ones (Bresnen et al., 2004). The management of sustainable innovations is hence limited by organisational boundaries related to time, location, culture, and practice.

Two unsolved topics for the management of innovations in sustainable buildings are (1) how stakeholders organise and structure their activities and (2) which inter- and intra-firm relationships encourage the adoption of innovations (Binder, 2008). Table 1.1 reports the phases of organisational processes for innovations in sustainable buildings, as indicated in a recent study on sustainable Dutch houses (Bossink, 2007). The table shows that the adoption occurs as a succession of eight stages, from the autonomous innovation stage to the co-innovation between firms and the following dismantling of the joint organisation.

The decision-making process on the adoption of innovations is influenced by the relationships between stakeholders in the construction processes. Unfortunately, each stakeholder is involved for different and limited time intervals. Moreover, stakeholders' interests often differ (Winch, 2010). These aspects make the communication between stakeholders difficult and represent barriers for the management of green innovation.

Table 1.1 Organisational stages for the introduction of sustainable innovations in buildings and interaction patterns between firms, re-adapted from Bossink (2007).

Stage		Interaction patterns of sustainable innovations in buildings
Autonomous Innovation ↓	↓	innovate autonomously manage innovation portfolio protect innovations
Networking ↓	↓	choose or are forced to innovate prefer to work with well-known partners realise an influential position in the innovative network
Exploration ↓	↓	explore the costs and revenues of cooperation determine which expertise is needed to develop a cooperative portfolio
Formation ↓	↓	negotiate over the costs and incomes enter into contracts to develop innovation plans
Organisation ↓	↓	establish a joint organisation establish control of bodies to develop an architectural blueprint
Planning ↓	↓	allocate expertise facilitate cooperation and communication start innovation development
Co-innovation ↓	↓	coordinate innovation realisation renegotiate over the costs and incomes sell to the market and meet profitability targets
Dismantling		dismantle the joint organisation

King and Toffel (2007) reviewed literature related to the adoption of sustainable technologies in buildings and examined how such technologies necessitate new organisations among firms. New methods of inter-firm relationships are necessary in order to organise to adoption of green innovations.

In innovation diffusion literature, the process of adoption has often been shown to have been facilitated by institutional forces, which accelerate diffusion itself (Nelson & Winter, 1982). Moreover, the diffusion increases the perception of the legitimacy of any innovation (Loch & Huberman, 1999). This is slowly occurring for several innovations in sustainable buildings (Berardi, 2011). Good experiences stemming from the adoption of green innovations have given a new vigour to innovation management in the building sector. This gives rise to questions regarding how to transform the experiments of sustainable buildings into a paradigm transformation and which factors facilitate innovations.

Researchers have often focussed on the benefits of sustainable building performance and on the bandwagon effect created by the visibility of sustainable building and by their signalling value (Cassidy, 2003). The distinction between intrinsic and signalling benefits for sustainable innovations has recently been considered by King and Toffel, who look at the will of stakeholders to adopt sustainable innovations in buildings (2007). Using the theory of innovation diffusion (Rogers, 2003), King and Lenox (2001) found that firms adopting sustainable innovations obtain superior performance in both the economic and quality aspects of their buildings. Corbett and Klassen (2006) argued that this occurs because sustainability management and sustainable innovations often lead to improvements during the process of construction. *Innovation* has been defined as something new in the environment and social system into which it is introduced (Rogers, 2003). The diffusion of an innovation is influenced by its relative advantage, compatibility, complexity, trialability and observability. The importance of the relativity of the previous adjectives recalls the importance of the context into which the innovation enters. The context specificities are particularly important in studies about green innovations in sustainable buildings, as the organisation of building processes is largely site specific. This book focusses on the interactions among the stakeholders of building processes in which green innovations have been adopted and it investigates both the social and the organisational impacts of the management of green innovations in these building processes.

1.2. Diffusion of Sustainable Building

Sustainable buildings have recently been built worldwide. Many studies suggest that the diffusion of sustainbale buildings will continue in the coming decades, both in developed (Cole, 2011) and developing countries (du Plessis, 2005; Ding, 2008).

In order to understand how and when sustainable buildings diffuse, it is important to be able to recognise a sustainable building. Unfortunately, it is particularly problematic to measure sustainability in the building sector, because this has shown to be difficult to determine through performance measurements (Larsson, 2010). Many methods have been suggested to define and recognise sustainable building, and these methods will be described in Chapters 2 and 3. Different methods have often generated confusion about what is, or even how to identify, a sustainable building (Stenberg & Räisänen, 2006). *Sustainable building* and *green building* are often used interchangeably, and they are often incorrectly shown to be uncorrelated with specific properties or performances of the building.

In previous years, sustainable buildings have been evaluated mainly by considering the number and quality of the green technologies they adopt (Maciel, 2007). Unfortunately, this approach has often caused misunderstanding, as summing green technologies has been shown to be insufficient for judging sustainability (Berardi, 2011).

In this book, the topic of how sustainability should be recognised and measured in the building sector is extensively considered. Moreover, sustainability assessments of building are described, as they have demonstrated necessary to incentivise the diffusion of sustainable building.

Many sustainability assessment systems for buildings have been proposed in the last 20 years worldwide (Figure 1.7). In America, Europe and Asia, sustainability systems have already diffused, and at the present time, only in African countries has the sustainability assessment of building scarcely diffused. Moreover, it should be considered that in Africa, the sustainability of buildings is often intrinsic with building processes, although there is an absence of sustainability assessment systems. Figure 1.8 shows the most well-known systems worldwide, which have diffused in developed countries: BREEAM, CASBEE, LEED and Green Globes.

The diffusion of the sustainability assessment of buildings is largely increasing. Figure 1.9 reports the number of building surfaces that have obtained a sustainability certification in 2010, together with the expected trends until 2020. Obviously, the number of assessed and certified buildings underestimates the number of buildings that have effectively been constructed in a sustainable way. However, the graph helps to measure the diffusion of sustainable buildings. Figure 1.9 also gives important information about the ratio between residential and commercial sustainable buildings. In commercial buildings, the sustainability transition seems easier than in the residential sector. Moreover, Figure 1.9 shows that in commercial buildings,

Figure 1.7 Countries with sustainability assessment codes around the world (Berardi, 2011).

Figure 1.8 Rating sheets of most common sustainability assessment systems for buildings: BREEAM, CASBEE, LEED, Green Globes.

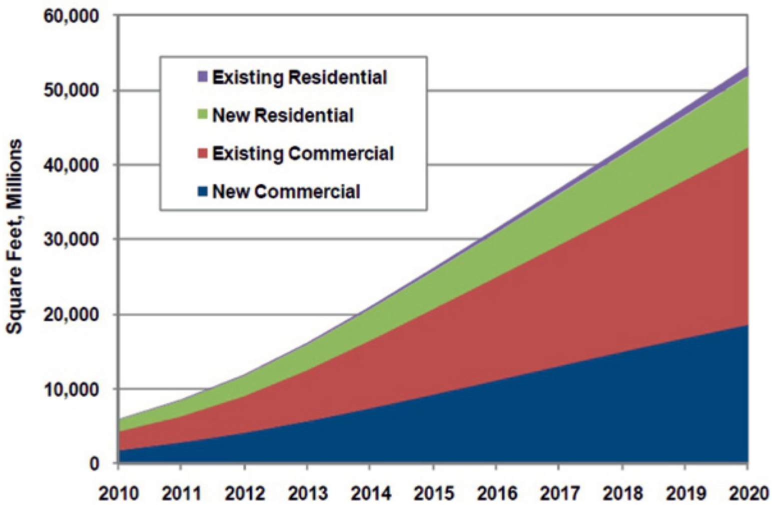


Figure 1.9 Building surface with sustainability certification and trends until 2020 (Bloom & Wheelock, 2010).

sustainability assessments are diffused both in new and existing buildings, whereas only new residential buildings seem to take part in sustainability assessments.

1.3. Moving to Sustainable Building

The numerous benefits of sustainable buildings would suggest that a transition to sustainability within the building sector is both feasible and practical. In fact, sustainable buildings have all the factors necessary to incentivise their diffusion (Pisano, 1996), because institutional, fashionable, cultural and rational forces promote and justify sustainable building.

Many authors have investigated how to realise this transition to sustainable building by looking at the relationships between stakeholders of building processes. These studies have shown that stakeholders' collaboration is crucial (Foster & Green, 200; Seuring, 2011), because although there are advantages to and interest in sustainable buildings, there is a considerable difficulty in creating a transition to building-sector sustainability.

Considering the resistance to change in complex sectors (as in building), Brown and Vergraget have determined that a sense of urgency is important in facilitating such a transition, because urgency promotes attempts to teach and manage new innovations (2008). This sense of urgency is nowadays recorded in several countries and is pushed by policies that have set the ambitious goal of producing zero-energy buildings in the next few years.

However, the diffusion of green innovations is still hampered by many barriers (Manseau & Shields, 2005). The reasons for this are numerous, and the resistance of firms and actors to take the risks associated with new technologies is significant. A significant barrier is also created by the sizable investment required by buildings and by their speculative reason, which justifies focussing on the lowest possible costs (Intrachooto & Horayangkura, 2007).

Table 1.2 reports the main barriers to "greening" the building sector. These barriers have been grouped by lack of economic and financial resources to undertake new technologies, hidden costs, market failures, behavioural and organisational barriers, information limits, and political and structural barriers.

The most common recorded barriers to sustainable innovations are economic ones. The higher initial cost is surely a deterrent to the adoption of green innovations, although the extra cost of green innovations is compensated for in a life-cycle perspective. Intrachooto and Horayangkura (2007) found an average increase in construction cost for green buildings of 2%, whereas the Turner Construction barometer has evaluated the cost premium to meet a US sustainability standard (LEED) as between 0.8% to 11.5%, according to the sustainability level of the building (Tatari & Kucukvar, 2010). These values are generally negligible if compared with the cost of energy consumption or the possible revenues for improvements of the indoor quality of a building.

A few years ago, the Turner Construction barometer (Table 1.3) and McGraw Hill Construction survey (Table 1.4) found that higher construction costs represent the main barrier to green building, because they are perceived as the main discouraging factor by over 66% of building professionals. This data must be considered together with the lack of awareness about the benefits of sustainable building, which 60% of respondents also listed as a barrier.

Studies about small and medium enterprises (SMEs) have shown that most of them view green innovations as expensive to undertake, and consequently, they

Table 1.2 Main barriers to "greening" the building sector.

Barrier for Sustainable Buildings	Definition	Examples	References
Economic financial barriers	Ratio of investment cost to value of energy savings	Higher up-front costs for more efficient equipment and sustainable innovation; Lack of access to financing sustainable innovation; Lack of internalisation of environmental, health and other external costs	Deringer et al., 2004; Carbon Trust, 2005; Levine et al., 2007
Hidden costs	Cost or risks (real or perceived) that are not captured directly in financial flows	Costs and risks due to potential incompatibilities, performance risks and transaction costs; Poor power quality, particularly in some developing countries	Carbon Trust, 2005; Levine et al., 2007
Market failures	Market structures and constraints that prevent a consistent trade-off between specific sustainable investment and benefits	Limitations of the typical building design process; Fragmented market structure; Landlord/tenant split and misplaced incentives; Administrative and regulatory barriers; Imperfect information; Unavailability of equipment locally	Carbon Trust, 2005; Levine et al., 2007
Behavioural and organisational barriers	Behavioural characteristics of individuals and companies that hinder energy-efficient technologies and practices	Tendency to ignore small opportunities for sustainable improvements; Organisational failures; Non-payment and electricity theft; Tradition, behaviour and lifestyle; Transition in energy expertise; Loss of traditional knowledge and non-suitability of Western techniques;	Carbon Trust, 2005; Deringer et al., 2004; Levine et al., 2007
Information barriers	Lack of information provided on sustainable potentials	Lacking awareness of consumers, building managers, construction companies and politicians	Yao et al., 2005; Evander et al., 2004
Political and structural barriers	Structural characteristics of political, economic and energy systems that make sustainable investment difficult	Inefficiency of drafting legislation; Gaps between regions at different levels; Insufficient enforcement of standards; Lack of detailed guidelines, tools and experts; Lack of incentives for investments; Lack of governance/leadership/ interest Lack of equipment testing/ certification	Yao et al., 2005; Deringer et al., 2004

Table 1.3 Factors discouraging green buildings in Turner Construction survey barometer (2005).

Obstacles for Green Buildings	**% of respondents**
Higher construction costs	68%
Lack of awareness of benefits	64%
Sustainability-assessment documentation	54%
Short-term budget horizons	51%
Payback too long	50%
Difficulty quantifying benefits	47%
More complex construction	30%

Table 1.4 Factors discouraging green buildings in McGraw Hill construction survey (2005).

Obstacles for Green Buildings	**% of respondents**
Higher construction costs	64%
Lack of education	52%
Lack of awareness	48%
Different budget availability	45%
Politics	43%
Green building is perceived as a novelty	34%

tend to be highly resistant to using them (Revell & Blackburn, 2007). SMEs have also demonstrated problems in implementing environmental assessment tools (Petts et al., 1999; Tilley, 1999). SMEs barriers tend to include a lack of human and economic resources, aspects related to culture and attitudes of managers, insufficient drivers and a lack of knowledge and experience. If we realise that SMEs are the vast majority of the firms of the building sector in many developed countries, it is possible to justify the perceived difficulties in managing green innovations and moving to sustainable building. This reveals a few of the foci of this book.

1.4. Drivers for Sustainable Building

Numerous studies have investigated drivers for sustainable building, as recently reviewed in Häkkinen and Belloni (2011). Although these studies have found that higher construction costs represent a barrier to sustainable building, buyers have often been shown to be willing to pay more, in rent or in purchasing costs, for sustainable buildings (Häkkinen & Belloni, 2011).

The Turner Construction market barometer (2005) reported the perceived benefits of sustainable buildings against traditional ones. The analysis was performed by interviewing people with and without sustainable building experience to comparatively analyse different perceptions. People with sustainable building experience recognise more benefits than people without that experience, showing that an involvement in sustainable building increases the perception of its benefits. Health and well-being represented the main benefit of sustainable building for both groups of people, receiving 88% and 78% of answers respectively. As construction firms and design teams are not as directly involved in these aspects of sustainable buildings as purchasers and renters, they often do not eschew sustainable building. Moreover, the reasons for constructing green buildings also reveal why they are avoided. In fact, many of the perceived benefits, such as the occupants' productivity, Return of investment (ROI), rents and retail sales, are scarcely among the interests of the most involved actors (architects, general contractor and suppliers) of construction processes.

Table 1.5 shows the results of a survey about the reasons for constructing green buildings, which was taken by a large sample of stakeholders of the building sector.

Many studies have discussed the advantages and preferences of sustainable buildings. Recently, an increasing demand for a quantitative economic assessment of sustainable buildings has emerged. Eichholtz et al. (2009) have looked at rental rates and selling prices in 10,000 buildings and have shown that buildings with a sustainable rating have rental rates 6% higher than otherwise identical buildings, whereas the net sale prices of sustainable buildings are 16% higher. A more recent analysis by Eichholtz et al. (2010) has found that the sustainability label is supported by the market and is therefore more likely to remain in demand at crisis periods. In fact, the increase in the number of sustainable buildings between 2007 and 2009 and the recent downturns in property markets have not significantly affected the returns of sustainable buildings (Eichholtz et al., 2010).

The principal drivers for the adoption of green innovations in buildings have shown to be the requests of users and owners (Tse, 2001; Selih, 2007). In fact, clients are key stakeholders for pushing sustainability requirements. Consequently, the knowledge of clients' preferences has a crucial role in the diffusion of sustainable buildings. Chau et al. (2010) measured preferences for various aspects of sustainable buildings; the final results stated that clients prefer innovations for energy conservation, indoor-air-quality improvement and noise-

Table 1.5 Reasons for Green Buildings (McGraw Hill Construction, 2005).

Reasons for Green Buildings	% of respondents
Lowering life-cycle costs, such as energy efficiencies	73%
Being part of an industry that values the environment	72%
Expanding my business with green building clients	53%
Means for staying informed about LEED	52%
Green product information	51%
Benefit from publicity	44%
Higher ROI on resale	33%
Awards for Green Building	31%

level reduction (Chau et al., 2010). Although previous studies focussed on clients' preferences, many other studies have revealed that the level of awareness about green issues among clients is low. A lack of support from clients has constituted a major barrier for the adoption of green innovations in buildings (Son et al., 2011).

Empire State Building, New York City, US

Since its completion in 1931, the Empire State Building has been the world's most famous office building. Rising 102 stories from the middle of New York City, this Art Deco skyscraper has always been known for its leadership and innovation. The Empire State Building is the single largest New York City landmark.

A few years ago, a team composed by many institutions joined with the Empire State Building Company to transform this building into an icon of energy efficiency and sustainability from which the entire world can learn and benefit.

Consequently, the Empire State Building was subject to a building-wide sustainability retrofit, which allowed the owners to reduce the energy consumption by 39%, cutting the carbon footprint by 105,000 metric tonnes over the next 15 years (equivalent to taking over 20,000 cars off the road).

This refurbishing included the following elements:

- replacing each of the 6,514 windows in a custom, on-site processing centre; re-using more than 96% of existing window glass; and making the windows up to four times less heat conductive;
- incorporating insulated radiative barriers behind each of 6,514 radiators to reflect 24% more heat back into the building;
- installing new variable-speed drives and improved controls of the Chiller Plant Retrofitting, allowing air conditioners to continuously adjust their output to meet demand without wasting energy;
- installing new units of Variable Air Volume (VAV) technology to constantly fine-tune output to match the cooling and ventilation demands of different building spaces, as sensed by the building's central-control network;
- installing the largest wireless-control network ever installed in a building. Every air handler, chiller, radiator, valve and louvre has been equipped with sensors that allow the monitoring and controlling of every piece of equipment in the building in real-time. The new web-based, digital control system allows a transparent monitoring of energy consumption.

1.5. Scope of the Book

From the assumption that the issue of sustainability is unavoidable in the building sector, this book tries to understand how green innovations should be adopted, integrated and managed in buildings. Green innovations have proved to be too complex and interconnected to be solved by individual firms, and to that end, several researchers have developed network and systems approaches to solve sustainability issues. Researchers have proposed to focus more on interdependencies between business and society and use collaborative approaches to engender transitional and systemic changes (Grin at al., 2010). In fact, the level of interdependence helps to develop knowledge about causes, linkages and patterns.

The research journey described in this book has been explorative in the sense that the studies carried out during the research have continuously been influenced by empirical findings in an iterative and dynamic way. This book is hence a journey through a variety of scientific disciplines, spanning from innovation management to sustainable development, green building and construction innovations. Concepts and theories from different scientific fields are applied to explain different phenomena related to the management of green innovations in sustainable buildings. The aim of this book has accordingly not been focussed on testing empirical theory but rather on a building of empirically-based theory. As such, this book serves to increase knowledge within the emerging theory of sustainability in the building sector.

This book acknowledges the need for transition to sustainability within the building sector by looking at ways to manage green innovations. For this, the book focusses on how to manage green innovations. Consequently, the title of the book could be re-defined as *Managing Green Innovations for Promoting Sustainable Buildings*. I state this in order to underline the choice of using both a static and a dynamic point of view when examining the innovations and their management in sustainable building processes. A theory of sustainable building requires a clarification of the concepts of *sustainability*, *green*, *innovation* and *sustainable building*, and we must examine these terms before considering their implication in building processes. Consequently, the goal of the first part of the book is to define various aspects of sustainability in the building sector. To achieve this goal, definitions of *sustainable building* and *sustainability-assessment systems for buildings* are reviewed.

Among other aspects, the book reveals and underlines the importance of people behind a transition to sustainability in the building sector. This means that a greater attention to the social and organisational characteristics of building processes must be recognised in studies about sustainable building.

The main research foci of this book are

- *how sustainability is identified and measured in the building sector* and
- *how the building sector is (re-)organising for the adoption of sustainable innovations*.
- Aside from these main questions, others are investigated in the book. These include
- *how do stakeholders influence the sustainability of a building?*
- *which stakeholders are more active in implementing sustainability in buildings?*
- *how are green innovations managed in the building sector?*
- *which characteristics of green innovations influence their adoption?*

1.6. Structure of the Book

The theoretical framework of this study stems from three streams of literature: sustainability assessment, innovation management and sustainable building (Figure 1.10). *Sustainable building* is considered as the practical field of application in which to manage green innovations in order to be able to assess the sustainability of the processes and products being introduced.

In the following three chapters, the previous three fields are considered one by one; each chapter concentrates on one of the fields. In this way, the literature review of each chapter is more consistently organised. Chapter 2 introduces the concepts of sustainable and green building. The chapter discusses the meaning

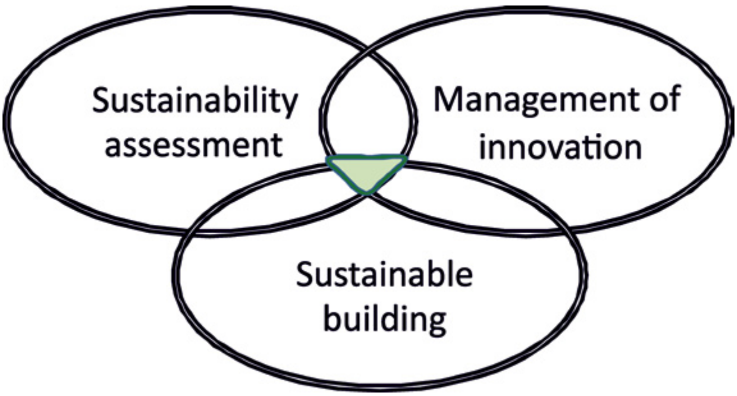


Figure 1.10 Theoretical positioning of the book, which covers topics at the intersection between sustainability assessment, sustainable building and management of construction innovation.

of the concept of sustainable building and tries to understand its peculiarities. The scope of this chapter is to clarify what *sustainable* and *green* buildings are and how it is possible to recognise sustainability in the building sector. Chapter 3 reviews sustainability-assessment methods in the building sector. The discussion focusses on the assessment criteria of rating systems. This highlights the structure of sustainability rating systems and enables discussion of current practices in sustainable building. Chapter 4 describes the results of sustainability assessments in large samples of buildings. The analysis of assessments enables discussion about characteristics of sustainable buildings. Then, we consider the innovations already adopted and attempts to define the main characteristics of sustainable buildings.

Chapter 5 discusses the adoption of green innovations in the building sector. The chapter starts with a brief introduction to innovation literature. It first considers the distinction between modular and radical innovations before examining the concept of architectural innovations. Chapter 6 outlines the influence of construction stakeholders on green innovations in sustainable buildings. An important barrier to the adoption of green innovations is the structure of the construction process, which is based on temporary relationships between many small firms that collaborate within a single-project perspective. The differences in the interests among actors are obstacles to the adoption of green technologies. The chapter attempts to make a contribution to an understanding of why the adoption of green innovations is limited by measuring the influence of some stakeholders towards this adoption.

Chapter 7 considers the organisational relationships between firms involved in construction processes. It investigates how these relationships change with a movement towards sustainable building practices, develops and presents a research model for the analysis of organisational changes within construction processes. The chapter focusses on the ways these relationships evolve in several Italian case studies. Chapter 8 discusses policies for sustainable building and their effectiveness. It concludes with an evaluation of the efficacy of existing policies for "greening" the residential building sector and suggests future policies to encourage further "greening".

Chapter 2

Definition of sustainable building

This chapter attempts to achieve a clear understanding of what a sustainable building is. The use of this terminology is rapidly increasing despite the absence of a clear, widely accepted definition. In some sense, if the building sector has recently been accused of *green washing*, or falsely advertising buildings as sustainable, it is in part because the term *sustainable building* is often used in a confusing way.

In the literature, several different definitions of *sustainable building* have been proposed; meanwhile, journals and books use the term daily. Unfortunately, the available definitions seem incomplete and often prove to be only partially useful due to bias.

A good starting point for this chapter is to define the concept of *sustainable development*. An often-abused term and for which many definitions have been proposed in the last three decades, *sustainable development* needs clarification (Basiago, 1995; Martens, 2006). Several papers have recently discussed what *sustainable* (Martens, 2006) and *sustainable development* mean (Hueting & Reijnders, 2004) and how it can be operationalised and identified (Hopwood et al., 2005). This chapter contextualises the ongoing debate in order to reconceptualise what a sustainable building is.

The building sector is receiving increasing attention in worldwide policies for sustainable development. This attention to the building sector arises from its energy consumption and GHG emissions. Data reported in Chapter 1 have shown the importance of sustainable buildings to sustainable development (Sev, 2009). In this scenario, it is fundamental to clarify ways to identify a sustainable building, a green building and a green innovation. In fact, it is important to overcome a superficial approach to the identification of sustainable buildings (Berardi, 2011).

Through offering a path to the reconceptualisation of *sustainable building*, this chapter enriches the following discussions about assessing the sustainability of buildings (Chapter 3), managing problems related to green innovations (Chapters 6 and 7) and developing policies to encourage sustainable building (Chapter 8).

This chapter is structured in five sections: Section 1 recalls the concepts of *sustainable development* and *sustainability science*; Section 2 describes the role of buildings in sustainable development; Section 3 discusses the concept of *sustainable building* according to the constraints given by time, scale, domain and people; Section 4 proposes identifiable characteristics of a sustainable building; and finally, Section 5 summarises the findings of the review and conceptualisation of *sustainable building*.

2.1. Sustainable Development and Sustainability Science

Sustainable development is not a single, well-defined concept. At least one hundred definitions have been proposed (Hopwood et al., 2005). However, these definitions have been largely incomplete, as some of the nuances of *sustainable development* are excluded from each (Robinson, 2004).

The concept of sustainable development goes back to the 1970s. Its theoretical framework evolved after the publication "The Limits to Growth" by the Club of Rome, in 1972. The UN Conference on the Human Environment, held in Stockholm in the same year, was the first major international gathering to discuss sustainability on a global scale. It created considerable momentum and a series of recommendations that later led to the establishment of the United Nations Environment Programme (UNEP) and to the creation of numerous national environmental protection agencies.

One of the first definitions of *sustainable development* was given in 1981 by Lester Brown, who stressed the importance of considering future generations in *Building a Sustainable Society*. However, the most famous conceptualisation was given in 1987 by the Brundtland Commission, which stated that "sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Such a broad and open approach has been appreciated through the years, making the Brundtland definition the most widely accepted one.

The concept of sustainable development is slightly different from that of sustainability, even if they are sometimes treated interchangeably. It must be emphasised that the concept of sustainable development contains a reference to *development*, which is not required for the sustainability of a system. *Sustainability* can be defined as "the capacity for continuance into a long-term future" whereas *sustainable development* is the process by which we move towards or consider sustainability (Porritt, 2007). The idea of sustainable development as a process recalls the results of the Forum for the Future, "a dynamic process which enables all people to realise their potential and to improve their quality of life in ways which simultaneously protect and enhance the life-support systems of the Earth" (Porritt, 2007).

Sustainability has received different interpretations (Yanarella & Bartilow, 2000) but never an official definition, and a resistance to determining one has emerged (Fowke & Prasad, 1996). Paradoxically, *sustainability* and *sustainable development* have also suffered from definitional ambiguity by the United Nations. However, the diversity between definitions has often represented the strength and breadth of these concepts (IPCC, 2007).

Looking at the common denominator of the definitions and interpretations of *sustainability* and *sustainable development*, Grosskurth and Rotmans (2005) identified four peculiarities and uncertainties in identifying sustainability: it is time-dependent, it includes several levels of space (and scale), it suggests multiple dimensions and it is socially depended.

The time dependence, already presented in the intergenerational approach of the Brundtland definition, requires us to consider a long-term perspective in sustainability discourses. This raises the question: how far into the future should our gaze extend? The further ahead in time we go, the more uncertainty emerges (Kemp & Martens, 2007). Sustainability is a present-day concept that extends into the future. Bagheri and Hjorth (2007) suggest adopting a dynamic approach that considers transformable processes towards sustainability, as it cannot be a fixed goal, but rather continually evolves. In this sense, sustainability requires an adaptive flexibility according to the available knowledge at any given time (Kemp et al., 2005; Walker & Salt, 2006).

The second aspect of the concepts regards spatial dependence. Brand and Karvonen (2007) argue that sustainability is locally specific and more a matter of local interpretation than an objective or universal goal. This creates a discussion about the boundaries of the concept of sustainability: globalisation and the interconnectivity of systems, people and markets counteract a local approach. In this sense, the impact of every action spans from a local scale to a global one, and sustainability therefore requires continuous evaluation at several levels in order to be contextualised globally.

The third aspect of sustainability regards the domains into which it can be divided. The concept of sustainability has been categorised in the environmental, social and economic dimensions (WCED, 1987). However, an increasing pressure towards recognition of the cultural and political dimensions of sustainability has recently evolved (Hopwood et al., 2005; Vallance et al., 2011). This conceptualisation in different dimensions has fragmented the concept of sustainability, leading to several misunderstandings (Yanarella & Bartilow, 2000; Williams & Millington, 2004). This division has also been criticised because sustainability has often been considered and evaluated exclusively according to the environmental dimension (Hueting & Reijnders, 2004). An environmentally-based interpretation of sustainability ignores the broad ambition of the concept (WCED, 1987; Hugé et al., 2012).

This eco-centred approach has been criticised for being elitist and exclusive. Roe (1998) condemned it as a version of managerialism that perpetuates a technocratic control, which tries to consider sustainable development as a scientific blueprint, the contents of which can be determined by scientists alone. We must recognize that *sustainable development* often involves non-environmental aspects (Hajer, 1995; van Zeijl-Rozema et al., 2008). The 2002 World Summit on Sustainable Development in Johannesburg produced a shift in the perception of *sustainable development* to encompass a more comprehensive consideration of social and economic dimensions of development. This change was driven by the emerging needs of developing countries and was strongly influenced by the discussion over how to reach the Millennium Development Goals.

However, current interpretations of *development* as purely a growth factor run the risk of limiting a real and integrated approach to sustainability. In fact, a too-optimistic view recently suggested that economic growth could solve problems in reaching sustainability goals, as innovations and technologies will be able to generate a more sustainable world (Hopwood et al., 2005). The limits of this approach have recently increased the attention towards the social and behavioural aspects for sustainability (Vallance et al., 2011). This logic has recently led Martens (2006) to refuse the division into domains, affirming that *sustainable development* lies precisely in the interrelations between dimensions that are often conflicting in practice (Berardi, 2011, 2012).

The fourth peculiarity of sustainability regards the multiple interpretations of its concept. In fact, the necessity of considering different points of view requires accepting uncertainty and differences. Sustainable development has shown the need for a pluralistic approach, which has to take into account multiple actors at several levels. This is the only way to create a common vision of sustainable development, minimising trade-offs and the different perceptions of the stakeholders, also in the building sector (Häkkinen & Belloni, 2011; Berardi, 2012). According to this, many governments have recently started measuring sustainability mainly through the quality of life and the well-being of citizens (DEFRA, 2011). McCool and Stankey (2004) stress that sustainability is socially related, and any definition needs to be cultural and normative. In this sense, participation and organisation among people is unavoidable.

As evident from previous discussion, many definitions of sustainable development are possible. In the past, it was often considered an objective and clear concept based on scientific evidence and consensus. More recently, it has been reinterpreted as relative, socially rooted and contextually dependent (Yanarella & Bartilow, 2000; Martens, 2006).

Given their ambiguity and uncertainty, the concepts of sustainable development and sustainability are continually revised. For example, a worldwide discussion is currently underway to reconnect the three dimensions of sustainable development in a more balanced perspective.

Together with this an on-going discussion is focussing on the several levels of sustainability. On the basis of the pioneer work of the economist Herman Daly (1996), Williams and Millington (2004) have distinguished strong and weak sustainability. Strong sustainability moves from the belief that it is not possible to accept an exchange between environment and economy, as these are not substitutable aspects. Obviously, a continuum from strong to weak sustainability exists, always allowing the possibility to strengthen or weaken sustainable development and what a sustainable object is. Following this discussion, Kemp (2010) stated that the "sustainable" attribute is not related to technology and cannot be used as a label for an object. In fact, an object cannot be evaluated independently from the ideation and production processes, the way and intensity of its use and the dismantling policies.

Consequently, it is always a risk to label something as sustainable. Finally, the evolution of the concept has shown that sustainability is better used as an evaluation perspective in a long-term path than as a fixed and rigid status. This discussion about the new meanings of sustainability will now be applied to the building sector, in order to understand the role and meaning of sustainable building.

The process of revision of the meaning of sustainability has led to the concept of mode-2 science (Gibbons et al., 1994). This concept emerged from the necessity to overcome the traditional academic and technocratic considerations of science, because they are unable to describe today's subjects completely. Table 2.1 compares the properties of a traditional and a new mode of science. Kates et al. (2001) showed that the characteristics of sustainability configure sustainability science, because the requirements of sustainability sufficiently cover the properties of mode-2 science. The two modes of science differ in their considerations of technology and its power for sustainability. In fact, mode-2 science overcomes the Galilean and technocratic view of the world and considers sustainability as an uncertain and participative process.

Table 2.1 Comparison of properties of mode-1 and mode-2 science (Gibbons et al., 1994).

Mode-1 science	Mode-2 science
Academic Mono-disciplinary Technocratic Certain Predictive	Academic and social Trans- and interdisciplinary Participative Uncertain Exploratory

2.2. Contextualising sustainability in sustainable buildings

In this section, the recent interpretations of sustainability are applied to the building sector to help in identifying sustainable buildings.

Difficulties have always emerged in defining sustainable buildings. A unit of measure for these has recently been offered by sustainability assessment systems. These have appeared worldwide in the last 20 years and, although several differences between them exist, they share a common framework of what a sustainable building is (Berardi, 2012). Through the years, these systems have contributed to increase the awareness among the actors of the building sector about criteria and objectives of sustainability, and they have become a framework of reference to assess and measure the sustainability of buildings. According to these systems a building is sustainable if it is built in an ecologically-oriented way which reduces its impact on the environment. However, many limits have recently been revealed in these systems (Berardi, 2011; Conte & Monno, 2012); the evaluation is limited to the physical boundaries of the building, and it is mainly (or only) interpreted from the environmental perspective. Consequently, sustainability assessment methods have been accused of reducing the sustainability of building to the functioning of individual environmental criteria reflecting an idea of building as a consumer of resources (Conte & Monno, 2012). Chapter 3 is dedicated to reviewing and comparing these systems.

Hill and Bowen (1997) suggested the principles of sustainable construction, which have been largely considered in sustainability assessment systems. However, a shared definition of a sustainable building is still lacking. Lowe (2007) discussed the requirements for a sustainable building in the context of climate change and stressed the importance of GHG emission by limiting the energy requirements of buildings. In principle, a sustainable building has often been considered as a healthy built environment, based on ecological principles and resource efficiency (Kibert, 2012). By breaking down this definition, a sustainable building has been defined as a building with high efficiency in the use of energy, water and materials, and reduced impacts on the health and the environment through better siting, design, construction, operation, maintenance and removal throughout its life cycle (Cassidy, 2003).

The U.S. Environmental Protection Agency (EPA) stated that sustainable building is the practice of creating structures by using processes that are environmentally responsible, resource efficient and impact minimising in their life cycle from siting to deconstruction (EPA, 2008). Table 2.2 reports a list of the impacts that, according to the EPA, sustainable buildings should minimise (obviously, given the role of this agency, mainly environmental impacts are considered).

Table 2.2 Environmental resources and impacts minimised in a sustainable building, re-adapted from EPA (2008).

Resource Consumption	**Environmental Impact**	→	**Ultimate Effects**
• **Energy** • Water • Materials • Site • Biodiversity	• **Waste** • Air pollution • Water pollution & Storm-water run off • Indoor pollution • Heat islands	→	• **Harm to Human Health** • Environment Degradation • Loss of Resources

A sustainable building can be a new construction or the retrofit of an existing building. It has to be fully designed to answer its main functions: to provide space, to guarantee good indoor climate, to provide safety and security, to allow the use of goods and tools, to control the relationship with its surroundings, to take advantage of the site without damaging it, and to bring meaning (CIB, 2010). Consequently, a building contributes to sustainable development when designed and operated to match the appropriate fitness for use with minimum environmental impact, and when it is also able to encourage improvements in economic, social and cultural aspects of every stakeholder who is involved in the building process at every level.

The concept of sustainable building emerged before that of sustainable development, when in the middle of the last century, several communities, driven by the ambition of an ecological world, advocated for green buildings. At the same time, the energy crisis which followed the embargo by OPEC led to the promotion of regulations to limit the energy consumption of buildings. As a result, energy consumption became a unit of measure for the sustainability of a building: green buildings were then required to be disconnected from the service grids and make use of natural materials. Still now, the Green Building Strategy of the EPA states that a "green building is also known as a sustainable or high-performance building" (EPA, 2008). In fact, especially in the U.S., these terms are used interchangeably.

A comparison between common sustainability assessment systems for buildings has shown that the greatest weight among the sustainability assessment criteria is generally assigned to energy performance (Berardi, 2011). This is probably a consequence of the fact that the energy consumption of a building allows an easy perception of its characteristics, also given the economic implications of the consumption.

The large use of environmentally-related criteria for the sustainability of a building generates the necessity of clarifying the differences between the concepts of green and sustainable buildings. Table 2.3 compares the major issues of green buildings and sustainable ones, readapting information in UNEP (2003). In summary, the main differences consist of the economic and social dimensions of the sustainability, which only apply to sustainable buildings. Sustainable buildings enlarge the boundaries and increase the requirements of green ones because they aim at satisfying all dimensions of sustainability. In this book, the implications of economic and social impacts related to the building are considered, and, hence, the focus is on sustainable building.

The evolution of the concept of sustainability, described in Section 2.1, implies a new consideration of the attribute of sustainability in the built environment. In particular, a shift to a "cradle-to-cradle" approach in the evaluation of the sustainability of a building is nowadays unavoidable (McDonough & Braungart, 2002). Until a few years ago, the sustainability evaluation of buildings looked at

Table 2.3. Major issues in green and sustainable buildings, re-adapted from UNEP (2003).

Major Issues of the Building Performance	Green Building	Sustainable Building
Consumption of non-renewable resources	x	x
Water consumption	x	x
Materials consumption	x	x
Land use	x	x
Impacts on site ecology	x	x
Urban and planning issues	(x)	x
Greenhouse gas emissions	x	x
Atmospheric emissions	x	x
Solid waste & liquid effluents	x	x
Indoor well-being: air quality, lighting, acoustics	(x)	x
Longevity, adaptability, flexibility		x
Operations and maintenance		x
Facilities management		x
Social issues (access, education, inclusion)		x
Economic considerations		x
Cultural perception and inspiration		x

a time-limited life of building materials, and partially considered their impacts on a long-term perspective. However, given that 70% of all the materials ever extracted are in the built environment (Kibert, 2007), it is obvious that a sustainable building has to integrally manage the materials and resources it requires in the longest perspective.

Reed (2007) has described the necessity to consider and design building materials as biological nutrients which provide nourishment after use and circulate through the world's systems in closed-loop cycles of production, recovery and re-manufacture. To promote sustainability in the built environment, Reed (2007) proposes shifting from green design towards a state of regeneration. He describes green design as continual improvement in design. He looks at the present concept of sustainable design as the point where the planet could be maintained over time in a neutral stage. The necessity for an in-depth approach to building design in which humans restart being an integral part of nature (reconciliatory design) and co-evolve in a systemic whole with nature (regenerative design) represents the last frontier of sustainable building design.

A regenerative design approach allows the integration of physical, functional, and spiritual attributes in an integrative perspective (du Plessis & Cole, 2011). Obviously, a regenerative approach in the built environment is a long way from the fragmentation indicated in current practices for sustainable buildings based on the simple and disconnected adoption of green technologies. For this, systemic thinking and a reconciled partnership with nature have to replace the technocratic approach which still characterises the sustainability in the built environment. This concept of a sustainable building exceeds the environmental perspective and looks at the building as live system with dynamic flows with the nature (Reed, 2007). This means that the building cannot be considered as a simple consumer of resources of the planet. Consequently, a sustainable building should be an active entity which is designed to help a metabolism of human being that regenerates the built environment within the natural capital.

2.3. Factors of uncertainty in defining sustainable buildings

The previous section has discussed the evolution of the concept of sustainable buildings in relation to the most recent definitions of sustainability. In this section, a few factors of uncertainty in defining of a sustainable building are discussed. In particular, the section considers the uncertainty of the concept of sustainable building in relation to time, site, domain and people-related factors.

2.3.1. Time uncertainty

The evaluation of sustainability is always carried out at one time and with one time horizon. As described in Section 2.1, sustainability requires consideration of the whole life-cycle. Unfortunately, this is difficult to predict in the built environment because historical buildings have shown that they can exist much longer than expected.

Regarding the time interval within which the evaluation of sustainability is done, it should be recognised that sustainability is a time relative concept which depends on the knowledge available at the time of the evaluation. Consequently, what is considered sustainable at one moment can be assessed as unsustainable in another. An example of the lack of knowledge regarding the materials used in construction is the use of asbestos panels in the 1970s, which were promoted for thermal insulation properties, before understanding the negative impact of asbestos on human health.

Considering the several adaptations which can occur to a building during its life cycle, paradigms such as flexibility and adaptability have recently emerged as fundamental aspects for a sustainable building that needs to easily accommodate new requirements (Parr & Zaretsky, 2010). Sustainability of buildings requires considering requirements and functions dynamically. Buildings are ever-changing and are characterised by continuous adaptations according to unpredictable patterns. This recalls the contribution of sustainable buildings to the resilience of the built environment (Cole, 2012). This resilience was defined as the ability to resist to changes brought by external and internal impacts (Walker & Salt, 2006). This concept is receiving an increasing attention because it considers the long-term capacity of a system to sustain changes (Edwards, 2010).

Building processes and consumptions show ever-changing and unpredictable patterns (du Plessis & Cole, 2011). This implies a continuous adaptability of a sustainable building, which should increase the resilience of the built environment by adapting to its metabolism.

2.3.2. Scale uncertainty

The dependence of sustainability on the built environment from the spatial scale of evaluation has often been considered. In fact, different tools for sustainability assessments have been developed (Berardi, 2012). Regional adaptations of the requirements of sustainable building have been considered to identify the connections of buildings within its neighbourhood and community, although often in an insufficient way (Kibert, 2007). In fact, although a general framework for sustainable buildings can be drawn at a regional level, the interaction of a building with its environment makes the sustainable attribute specifically related to each building. This means that sustainability cannot be defined in absolute terms. In a certain way, this relates to the idea that the sustainable attribute cannot be applied to a technology (Kemp, 2010). In fact, if an ecological product is promoted far from its production site, it becomes unsustainable in the same way as it would be difficult to consider a highly efficient skyscraper built in the desert as sustainable. Unfortunately, this consideration is often missing in current labels of sustainable buildings.

The importance of the interaction between the building and its surroundings has also increasingly been recognised by the recent promotion of sustainability assessment systems at the scale of neighbourhoods and communities (Berardi, 2013). In fact, the interconnections of a building with the surrounding infrastructure (public transportation, workplace, public buildings) have recently been recognised as unavoidable aspects of a sustainable building (Berardi, 2011).

In the last years, the spatial dimension of sustainability has also been applied to consider the products and subcomponents of buildings as well as the building in its entirety. However, the previous discussions have shown the limits of evaluating sustainability at a building level, asking for cross-scales evaluations which have to exceed the boundaries of the building (Berardi, 2011; Conte & Monno, 2012). Finally, the spatial dependence of sustainable development complicates the decision of which is the most appropriate scale in sustainability evaluations; the boundaries of the inter-connections between a building and its surroundings require adaptation case by case.

2.3.3. Domain uncertainty

The evaluation of sustainable buildings has often considered unequally the different domains of sustainability and it has preferred an environmentalist approach (Berardi, 2012). The importance of considering all the dimensions is increasingly emerging with the diffusion of sustainable building policies in underdeveloped and developing countries. The inevitability of considering the different meanings of these economic and social dimensions in different countries increases the uncertainty of the sustainable label. In fact, the goals of sustainable building in underdeveloped and developing countries are still lacking (UNEP-SBCI, 2009).

A way to underline the uncertainty associated with sustainable building is to identify an economically sustainable building. The economic domain implies the affordability to support the direct and indirect costs of the building, without neglecting other essential needs (Son et al., 2011). This requisite depends on the context and people and also recalls the time uncertainty of economic sustainability. In fact, a change in what is an economically sustainable choice in buildings is possible according to economic cycles and markets developments.

Finally, recalling the refuse of the division of sustainability into domains (Martens, 2006), also for the identification of sustainable building it is more and more necessary to consider all the domains, as well as the interrelations between dimensions.

2.3.4. Social uncertainty

The most-ignored dimension of sustainability is likely the social one. People perceive a building, its impact and effects in different ways. This is a constraint for spread of sustainable buildings given the difficulty of establishing common sustainable requirements between people (Chapter 6 of this book).

The differences between stakeholders imply different points of view in sustainability priorities, and consequently, they make the identification and the characteristics of a sustainable building dependent on the point of view (du Plessis & Cole, 2011). For example, a community generally considers a building sustainable when it has low construction waste, whereas an occupant looks at the indoor environmental quality (Parr & Zaretsky, 2010).

Numerous attempts at defining the social aspects of a building have generally considered concepts as quality of life or sustainable livelihood (Vallance et al., 2011; Dempsey et al., 2011). These attempts have increased the uncertainty of social sustainability because they have been unable to support a unique scientific acceptance of the social sustainability requirements. Contribution towards the creation a sense of community is undoubtedly an important requirement to the building, also in the context of this book. However, the practical meaning and ways to prove these aspects remain open research questions.

The relativity of the concept of sustainability gives a social character to the meaning of sustainable. Obviously, the social dependence of sustainability in the building sector could be addressed through a participative process in which different stakeholders express and contribute with their idea of sustainability (Moffat & Kohler, 2008). This requires a social context with knowledge sharing between individuals, where sustainability emerges through participative decisions (Bagheri & Hjorth, 2007).

2.4. The Identification of a Sustainable Building

The discussion in Section 2.2 has shown that "sustainable building" is a wide and difficult-to-achieve target. Section 2.3 examined a few aspects which makes it an open, relative and uncertain concept. This section tries to re-define the concept with some indications to identify a sustainable building.

If Kemp (2010) affirmed that if sustainable technology does not exist, a few doubts about the application of the attribute to a building make sense. The dependence on scale has shown the importance of enlarging the spatial boundaries in the evaluation of sustainability in order to consider the connections between a building and its surrounding. Returning to the distinction between green and sustainable buildings, it is possible to agree that an environmentally friendly building can be realised almost everywhere. In fact, by using local materials and renewable, energy efficient technologies, it is possible to minimise the environmental impact of a building. On the contrary, a sustainable building also implies considering the social and economic dimensions. In this sense, several experiences of communities which have implemented many sustainable innovations, such as the BedZed in London or the Olympic Village in Vancouver, are good examples of sustainable buildings, mainly because they are encouraging sustainable lifestyles.

While the challenges of sustainable development are global, strategies for addressing sustainability in the built environment are essentially local and differ from region to region. These strategies reflect the preconditions and needs of a site, not only in the built environment, but also in the social environment (ISO 15392, 2008). The latter includes strategies for social equity, cultural and heritage issues, traditions, human health, and social infrastructure, as well as safe and healthy environments. A sustainable building has to consider the impact of housing and residential environments on the physical and mental health of the occupants as well. Psychological and social functions of housing shift the meaning of the building from that of a physical living place to that of a "home". This encourages considering the social network that a sustainable building must help to create.

Summarising the previous discussion, a sustainable building has to be a healthy facility designed and built in a cradle-to-cradle resource-efficient manner, using ecological principles, social equity, and life-cycle quality value. According to this, a sustainable building should:

- adhere to ethical standards by ethical trading throughout the supply chain and by providing safe and healthy work environments.
- provide a place that meets needs with a mix of tenure types and ensure flexibility.
- conserve local heritage and culture.
- integrate the building in the local context also guaranteeing access to local infrastructure and services.

After the First International Conference on Sustainable Construction, the "Sustainable Construction" Task Group of CIB articulated seven principles of sustainable construction. This should reduce resource consumption, reuse resources, use recycled resources, protect nature, eliminate toxics materials, apply a life-cycle approach and focus on quality. These principles have to be considered for any resource and in any phase of the building span. However, the discussion in the CIB has recently led to reinterpreting the visions of sustainable buildings (CIB, 2010). According to this, a sustainable building must:

1. Apply the general principles of sustainability, and hence, promote continual improvement, equity, global thinking and local action, a holistic approach, long-term consideration of precaution and risk, responsibility, and transparency.
2. Involve all interested parties through a collaborative approach in design, construction, and maintenance processes, so that it can meet occupants' needs individually and collectively.
3. Be completely integrated into the relevant local plans and infrastructure, and connect into the existing services, networks, urban and suburban grids.
4. Be designed from a life-cycle perspective, covering planning, design, construction, operation and maintenance, renovation and end of life, considering all other phases during the evaluation of performance at each phase.
5. Have its environmental impact minimised over the (estimated or remaining) service life. This takes into consideration regional and global requirements, resource efficiency together with waste and emissions reduction.
6. Deliver economic value over time, taking into account future life-cycle costs of operation, maintenance, refurbishment and disposal.
7. Provide social and cultural value over time and for all the people in a way that provides a sense of place, and is related and integrated into the local culture.

8. Be healthy, comfortable, safe and accessible for all. Health criteria include indoor air quality whereas comfort criteria include acoustic, thermal, visual and olfactory comfort. It must allow safe working conditions during its construction and service life, and full accessibility to everyone in the use of building facilities.
9. Be user-friendly, simple and cost-effective in operation, with measurable performances over time. People should understand the philosophy and the strategies included in the building and should be incentivised to behave sustainably.
10. Be adaptable throughout the service life and with an end-of-life strategy. The building has to allow adaptation by changing performance and functionality requirements, in accordance with new constraints.

The convergence between these new principles set forth in the above decalogue and other recent requirements for sustainable building, such as the principles reported in the Sustainable by Design Declaration of the International Union of Architects (UIA, 2009), suggests that a new common vision of sustainable building is emerging.

Summarising these recent interpretations, a sustainable building can be defined as a healthy facility designed and built in a cradle-to-cradle resource-efficient manner, using ecological principles, social equity, and life-cycle quality value, and which promotes a sense of sustainable community. According to this, a sustainable building should increase:

- demand for safe building, flexibility, market and economic value.
- neutralisation of environmental impacts by including its context and its regeneration.
- human well-being and occupants’ satisfaction.
- social equity, aesthetics improvements, and preservation of cultural values.

All previous requirements are scarcely considered in current sustainability assessment systems and are rarely taken into account referring to sustainable buildings.

2.5. Conclusions

This chapter has reviewed and discussed definitions of sustainable building to help clarify a core concept of this book.

The evolution of the concept of sustainable development suggested that reflection on the term “sustainable building” is necessary. Without a common interpretation of what a sustainable building is, actions are chaotic, policies are misunderstood, and the great opportunity to generate a sustainable shift in the construction sector may be missed.

In this book, the discussion will be mostly focussed on sustainable innovations and buildings in a more restricted meaning term. This means that environmentally sustainable innovations will mainly be considered, and that the economic and social implications of technologies will be taken into account secondarily. This is also the approach of the following chapters, which will describe and compare the systems that are currently used for sustainability assessments in the building sector.

Chapter 3

Sustainability Assessment of Buildings

In the previous chapters, sustainable buildings have been presented as a priority for a sustainable world. This is increasing the request of ways to measure the sustainability of buildings (Hellstrom, 2007; Steurer & Hametner, 2011). In fact, more and more it is clear that the assessment of sustainability of buildings is an essential prerequisite to its promotion.

Sustainability assessment can be defined as the process of identifying, predicting and evaluating the potential impacts of initiatives and alternatives according to the different dimensions and requirements which have been indicated for sustainability (Devuyst, 2000). The possibility to assess sustainability is particularly important for a sector as inertial and conflicting as that of buildings (Winston, 2010).

The main scope of this chapter is to review sustainability assessment practices for buildings both describing existing sustainability rating systems and assessment results in a sample of buildings. The chapter focusses on the evaluation criteria of rating systems. An analysis of building assessments through a sustainable rating system enables the discussion of the green features which are mostly evaluated in sustainable buildings.

The chapter does not aim at presenting a complete theory of sustainability assessment, but it endeavours to discuss the current state of sustainability assessment in the construction sector through a review of current systems. Section 1 contains an introduction to the sustainability assessment. This implies describing the diffusion of sustainability assessment worldwide and possible approaches for assessment. Section 2 contains a description of several assessment systems. Finally, trends of sustainability assessment in the building sector are discussed.

3.1. Sustainability Assessment

3.1.1. Diffusion of sustainability assessment

According to many studies, sustainability assessment is necessary to increase the diffusion of sustainable buildings (Cheng et al., 2008; Ding, 2008). Unfortunately, the construction sector is unfamiliar with performance measurements, and although many assessment systems already exist worldwide, their diffusion is still low in absolute terms. Sustainability measurements, in the building sector, are capturing much attention worldwide, rapidly moving from fashionable certifications to current practices. In 2010, 650 million square meters obtained a sustainability certification throughout the world, with projections for 1100 million square meters in 2012 and for more than 4600 million square meters in 2020, as shown in Figure 1.9 (Bloom & Wheelock, 2010).

Sustainability building certification programs and rating systems are used worldwide with the only exception being Africa. Figure 3.1 shows the main sustainability assessment systems which are implemented around the world.

Figure 3.1 Sustainability assessment systems around the world (Berardi, 2011).

The diffusion of sustainability assessment is increasing, and the subject is becoming common in specialised press and journals (Bloom & Wheelock, 2010). According to the innovation diffusion theory of Moore (1991), communication is the most important element for the introduction of a new paradigm. If the new paradigm is the sustainability assessments of the building sector, sustainability certifications represent the necessary driver. Proof of the importance of communication in promotion of sustainable building has been given by the European Directive EPBD which has required putting energy consumption certificates in contracts, and energy plaques at the entrance of public buildings (EPBD, 2010).

The increasing number of certified buildings shows that the awareness for sustainability is increasing. Moreover, many rating systems allow defining several sustainability grades and a trend towards higher sustainability levels in the last few years has been recorded (Bloom & Wheelock, 2010).

3.1.2. Possible approaches to sustainability assessment

Sustainable buildings have been broadly defined as buildings which encompass environmental, social and economic standards, together with technical aspects (Rwelamila et al., 2000). As seen in Chapter 2, it is often unclear how to categorise and recognise sustainable buildings. In fact, a frequently discussed topic is how sustainability should be measured (Steurer & Hametner, 2011). After the energy crisis in the 1970s, regulations promoted energy consumption limits for buildings around the world. As a result, energy evaluations became the sustainability measure for building assessments.

Meanwhile, sustainability consciousness has evolved, and nowadays, assessments generally consider energy consumption as just one among other parameters. The complexity of a building often suggested a multidisciplinary approach in the sustainability assessment (Langston & Ding, 2001). This is also because buildings cannot be considered as assemblies of raw materials, but they are generally high-order products which incorporate different technologies assembled according to unique processes. The sustainability of a building should, therefore, be evaluated for every subcomponent, for the integration among them in functional units and assembled systems (e.g. the air conditioning system, the envelope), as well as for the building in its entirety.

A possible approach to sustainability evaluation is through the sustainability assessment of building products. This approach is internationally established for many kinds of products. Three types of product environmental labels exist and are defined in ISO 14020 (2000). These are the eco-certification of environmental labels (type I), the self-declared environmental claims (type II), and the environmental declarations (type III). Among these, type III is the most common label for building products. However, environmental evaluations of products are rarely performed by manufacturers, and the diffusion of Environmental Product Declarations (EPD) in the building sector is low (McGraw-Hill Construction, 2008). Assessment systems for sustainable products have been developed in different countries: among others, the American Green Seal, the European Eco-Label, the French NF Environment Mark, the German Blue Angel, and the Japanese Eco Mark should be mentioned. Moreover, specific evaluations for building products exist, especially for timber- and concrete-based products both in North America and in North Europe.

Since 2011, the new European Construction Products Directive (CPD) states that the evaluation of the use of resources is part of the assessment for the CE mark. This should imply a larger diffusion of environmental assessments for the construction sector, at least in Europe.

Energy labels represent another way of assessing the sustainability of building products, although they are only useful for equipment (e.g. heat pumps). However, the adoption of certified sustainable materials is not sufficient to obtain a sustainable building because the complexity of these requires a holistic and integrated approach (Ding, 2008). For example, the sustainability assessment of a building product needs to consider difficulties in predicting factors such as transportation distance or wastes. In this sense, sustainability labels for products only constitute a database for a sustainability analysis.

Construction is a complex input-output sector where the material flux is difficult to standardise and, rarely, a priori programmed (Cole, 1998). Some research states that sustainability can be better evaluated by looking at the building as a process. Weather, orientation and local parameters continually influence the operational needs of the building and the technologies which are adopted in a building can behave in different ways, being more or less sustainable. Moreover, buildings are constructed according to a specific design defined according to clients' requests. Finally, construction stakeholders constitute a variegated network of subjects (de Blois et al., 2011) and differences among them imply several possible points of view in sustainability assessment. In this sense, Cole (1998) stated that sustainability varies according to stakeholders: a community aims at low construction wastes whereas an occupant looks at indoor environmental quality. Given that sustainability assessment should include the evaluation of social and economic parameters, definition of a universally-accepted system to assess sustainability in the building sector is complex.

3.2. Sustainability Rating Systems

According to ISO 15392 (2008), and coherently with sustainability definitions, construction sustainability includes considering sustainable development in its three primary domains (economic, environmental and social), while meeting the requirements for technical and functional performance. More than 600 sustainability assessment rating systems are available worldwide for buildings (BRE, 2008), as reported in Figure 3.1. New systems are continually proposed and the most diffused ones receive a yearly update. This evolving situation has led to the release of two standards: "Sustainability in building construction - Framework for methods of assessment of the environmental performance of construction works - Part 1: Buildings" (ISO 21931-1, 2010) and "Sustainability of construction works - Sustainability assessment of buildings - General framework" (ISO 15643-1, 2010).

Systems for sustainability assessment span from energetic evaluation to multi-dimensional quality assessment. According to Hastings and Wall (2007), they can be grouped into:

- Cumulative Energy Demand (CED) systems which focus on energy consumption;
- Life Cycle Analysis (LCA) systems which focus on environmental aspects;
- Total Quality Assessment (TQA) systems which evaluate the ecological, economic and social aspects of sustainability in a building (and in its components).

The above division should not be regarded as absolute because many assessment systems do not fit perfectly into one category. CED systems are often mono-dimensional and aim at measuring sustainability of the building through energy-related measurements. LCA systems measure the impact of the building on the environment by assessing the emission of one or more chemical substances related to the building construction and operation. LCA can have one or more evaluation parameters whereas, TQA are multi-dimensional as they assess several parameters. The first two categories of systems have a quantitative approach to the assessment, whereas a TQA system generally has a qualitative or quantitative approach for different criteria. In the following sections CED, LCA and TQA systems are described.

3.2.1. Cumulative Energy Demand systems

CED systems measure and evaluate the energy consumption of the building. Energy is furnished to buildings to cover needs such as heating, ventilation, air conditioning, water heating, lighting, entertainment and telecommunications. The specification of the energy request is of primary importance as CED systems can refer to just some of the above consumptions (often, just heating and hot water consumption) or can consider all needs without distinction regarding the final use.

CED systems evaluate the energy consumption over a time unit which generally corresponds to one year. However, monthly or semi-annual evaluations have been proposed (Marszal et al., 2011). Energy consumption for residential buildings in developed countries at middle latitudes assumes values of some hundreds of kilowatt hour per square meter net floor surface per year (kWh/m^2a): for example, heat consumption of traditional European and U.S. buildings is 200 kWh/m^2a on average (Butera, 2010).

Table 3.1 reports the energy consumptions in residential buildings in some European countries. Referring to traditional buildings, operating energy demand dominates the building CED during the life cycle, being the 80% of the total energy consumption (Suzuki & Oka, 1998). A small energy percentage is consumed for material manufacture and transportation, construction and demolition. Consequently, energy-saving policies have typically only given attention to operation energy performance (EPBD, 2010).

Table 3.1 Average of energy consumptions in residential buildings in some European countries (Butera, 2010).

Country	Energy consumption average (kWh/m²a)
Greece	108
Italy	113
Denmark	144
Switzerland	172
Germany	178
Poland	261
UK	263

Energy consumption requirements of new buildings are largely decreasing under the pressure of more stringent needs (Figure 3.2). In the U.S., zero-energy buildings (or ZEB) have been discussed in the Energy Independence and Security Act (EISA, 2007). The recast of the European Energy Performance of Buildings Directive (EPBD, 2010) has established that only ZEB should be built after 2020. ZEB can be defined as a building with a very high level of energy efficiency, so that the overall annual primary energy consumption is equal to the onsite energy production from renewable energy sources. A universally accepted definition of ZEB is still lacking (Marszal et al., 2011), and several proposed methodologies for assess the sustainability of a ZEB differ for the metric of the analysis (energy, CO_2 emission, costs), the balancing time and the type of energy use considered in the assessment.

As highly efficient buildings are built, the energy needs during construction and demolition processes and the embodied energy in construction materials become relatively more significant for the identification of a sustainable building. This implies that the sustainability of a building must be considered in a life cycle evaluation. Hernandez and Kenny (2010) have defined the life cycle zero-energy building (LC-ZEB) concept for energy consumption equity in a whole life perspective. This requires that sustainability assessments in the building sector should enlarge time and space boundaries in the assessment (Suzuki et al., 1998). Finally, table 3.2 reports few of the proposed definitions of ZEB building.

CED systems are a mono-dimensional analysis which considers the energy flux. Apart from an energy analysis, some researchers have accounted other measurement units, such as exergy (Tronchin & Fabbri, 2008) or emergy (Pulselli et al., 2007). Exergy is the maximum useful work that brings the system into heat reservoir equilibrium, whereas emergy is the available solar energy directly and indirectly used in a transformation. These units of measurement are related to thermodynamic principles of resource use, and may be more appropriate than energy to evaluate building consumption (Marszal et al., 2011), although energy data are more common in literature.

Table 3.2 Net zero-energy building definitions arranged by order of appearance (re-adapted from Kibert, 2012).

Author	Definition
Esbensen and Korsgaard (1977)	A zero-energy house (ZEH) is dimensioned to be self-sufficient in space heating and hot water supply during normal climate conditions in Denmark.
Gilijamse (1995)	A ZEH is defined as a house where no fossil fuels are consumed, and annual electricity consumption equals annual electricity production. Unlike the autarkic situation, the electricity grid acts as a virtual buffer with annually balanced delivers and returns.
Iqbal (2004)	A zero-energy home is one that optimally combines commercially available renewable energy technology with the state-of-the-art energy efficiency construction techniques. A zero-energy home may or may not be grid-connected. In a zero-energy home annual energy consumption is equal to the annual energy production.
Charron (2005)	Homes that utilise solar thermal and solar photovoltaic (PV) technologies to generate as much energy as their yearly load are referred to as net zero-energy solar homes (ZESH).
Torcellini et al. (2006)	A zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable energy technology.
EISA (2007)	A net-zero-energy (NZE) commercial building is a high-performance commercial building designed, constructed and operated: (1) to require a greatly reduced quantity of energy to operate; (2) to meet the balance of energy needs from sources of energy that do not produce greenhouse gases; (3) to act in a manner that will result in no net emissions of greenhouse gases; and (d) to be economically viable.
Mertz et al. (2007)	A net-zero-energy home is a home that, over the course of a year, generates the same amount of energy it consumes. A net-zero-energy home could generate energy through PV panels, a wind turbine or a biogas generator.
Laustsen (2008)	Net-zero-energy buildings are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grid. Seen in these terms, they do not need any fossil fuels for heating, cooling, lighting or other energy uses, although they sometimes draw energy from the grid.
European Commission (2010)	The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
Hernandez and Kenny (2010)	A life-cycle, zero-energy building (LC-ZEB) is one where the primary energy used in the building in operation plus the energy embodied within its constituent materials and systems, including energy-generating ones, over the life of the building is equal to or less than the energy produced by its renewable energy systems over their lifetime.
Lund et al. (2011)	A ZEB combines highly energy-efficient building designs, technical systems and equipment to minimise the heating and electricity demand with on-site renewable energy generation typically including a solar hot water production system and a rooftop PV system. A ZEB can be off- or on-grid.

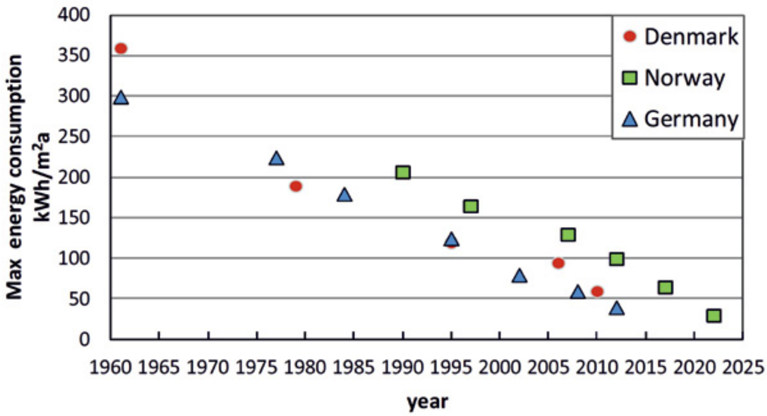


Figure 3.2 Energy requirements for heating in residential building in some European building codes over the years 1960-2025 (data taken from National regulations).

3.2.2. Life Cycle Analysis systems

Several systems have been developed for the environmental assessment of manufactured products, such as Environmental Risk Assessment (ERA), Material Flow Accounting (MFA), Input-Output Analysis (IOA) and Life Cycle Analysis (LCA). These systems generally break down products and processes into elementary parts.

LCA is the most commonly used of the above systems. It divides a building into elementary activities and raw materials to assess the environmental impact over a life cycle from manufacture and transportation to deconstruction and recycling (Seo et al., 2006). LCA is a robust methodology refined on the basis of manufacturing sector experiences. LCA assessments consist of four phases (ISO 14040, 2006): the goal and definition, the life cycle inventory, the life cycle impact assessment, and the improvement assessment. LCA systems allow the comparison of products on the basis of the same functional quality. This describes the quality of a product service as well as its duration. The scientific rigor of LCA is inherent to assessments from cradle to grave phases, although it is limited by uncertainties in collecting data relating to building processes.

LCA diffusion in the building sector is limited by a lack of information (Seo et al., 2006). In fact, the specificities of the construction processes require data for every building material in any region. Databases have been created for LCA evaluations and implemented in specifically designed software in several geographic areas. However, these databases are only valid for assessments in a specific region. The United Nations Environment Program's Sustainable

Buildings & Climate Initiative (UNEP-SBCI) has recently adopted the Common Carbon Metric to consistently assess and compare emissions from buildings around the world.

An obstacle for LCA diffusion is the specialist structure: outputs of LCA systems are represented by environmental impacts expressed through chemical substances, which are not easy to understand (Langston & Ding, 2001). As a matter of fact, LCA systems assess the environmental paradigm of sustainability without considering social and economic impacts. To fit this limit, some studies relate the disaggregation analysis necessary for an LCA with an evaluation of economic costs. Such an approach is interesting for the building sector as life cycle cost (LCC) analysis represents a familiar paradigm to construction stakeholders. Combined LCA-LCC can, hence, be useful to evaluate environmental and economic aspects in life terms by assigning a price to chemical elements.

3.2.3. Total Quality Assessment systems

TQA systems aim at considering the three aspects of sustainability of buildings: environmental issues such as GHG emission and energy consumption, economic aspects such as investment and equity, and social requirements such as accessibility and quality of spaces. The most common TQA systems are the multi-criteria systems. They are largely increasing the attention for sustainable assessment of buildings, as they are highly related to market interests and stakeholders' culture (Newsham et al., 2009).

Multi-criteria systems base the evaluation on criteria measured by several parameters, and compare real performances with reference ones. Each criterion has a certain amount of available points over total assessment and the overall evaluation of sustainability comes out summing the results of assessed criteria. A critical aspect of multi-criteria systems is their additional structure, as they assign scores for positively evaluated elements (Hahn, 2008). Multi-criteria systems are generally easy to understand and can be implemented in steps for each criteria. Moreover, a step implementation is allowed during the analysis: in fact, these systems enable the assessment of the building at several stages, from the concept design to the final construction.

Several multi-criteria systems exist to assess building sustainability worldwide. As many are just the adaptation of more famous ones to regional level or for specific scopes, only the most-adopted systems are considered here. These are BREEAM, LEED, CASBEE, SBTool and Green Globes (also in Figure 1.8). Other famous rating systems are the Australian Building Greenhouse Rating (ABGR), the Green Home Evaluation Manual (GHEM), the Chinese Three Star, the U.S. Assessment & Rating System (STARS), and the South African Sustainable Building Assessment Tool (SBAT).

The United Kingdom was the first country to release a multi-criteria system for sustainability assessment before this concept entered into the agenda of international policies with the Rio Conference. The British Building Research Establishment Environmental Assessment Method (BREEAM) was planned at the beginning of the 1990s by the British Research Establishment, and was released in 1993. The system has a large diffusion in the United Kingdom, where almost 10,000 buildings have been certified. Since 2009, as a consequence of the worldwide attention garnered for this system, an international version has been released, and currently, BREEAM has adapted versions for Canada, Australia and Hong Kong. The system is differentiated for 11 building typologies and its evaluations are expressed in percentage of successful over total available points. The evaluation categories are: management, health and well-being, energy, transport, water, materials, land use, ecology, pollution, and innovation.

A largely spreading rating system is LEED (Leadership in Energy and Environmental Design) which was released in 1998 by the U.S. Green Building Council (GBC). This system is currently available for ten building typologies. There are six evaluation categories to obtain the 69 possible points of the standard in version 2: sustainable site (14 points), water efficiency (5), energy and atmosphere (17), material and resources (13), indoor environment quality (15), innovation, and regional specificities (5). LEED results are then divided in the following categories: at least 26 points for certified buildings, 33 for silver, 39 for gold, 52 for platinum. Although released in the United States, GBC has been diffused worldwide over the years, and recently the World GBC has opened regional chapters in countries in Europe, Africa, America and Asia. Almost 20,000 buildings are registered for certifications, and current requests for new certifications regard buildings in 110 countries.

CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) is a Japanese rating system developed in 2001. CASBEE covers a family of assessment tools based on a life cycle evaluation: pre-design, new construction, existing buildings, and renovation. This system is based on the concept of closed ecosystems and considers two assessment categories, building performance and environmental load. Building performance covers criteria such as indoor environment, quality of services and outdoor environment, whereas environmental loads cover criteria such as energy, resources and materials, reuse and reusability, and off-site environment. By relating the two previous main criteria, CASBEE results are presented as a measure of eco-efficiency on a graph with environmental loads on one axis and quality on the other, so that sustainable buildings for CASBEE have the lowest environmental loads and highest quality. Less than 100 buildings have been certified with this system, although the number is rapidly increasing.

At the end of the '90s, the Sustainable Building Council promoted an internationalisation of rating systems under the leadership of Natural Resources

Canada (NRC). Towards this initiative a common protocol, SBMethod, was developed. Using the general scheme, several countries have then proposed national versions of this system, such as Verde in Spain, SBTool PT in Portugal, and SBTool CZ in the Czech Republic. In Italy, this protocol was implemented in 2000 as SBTool IT, it has been updated in April 2011, and it is known as ITACA. Moreover, ten Italian regions have adopted modified versions of the system to better cover regional specificities. Similar paths have occurred in other countries as well.

In 2005, adapting the Canadian version of BREEAM, the Green Globe Initiative (GBI) launched a new rating system, known as Green Globes. Criteria of this system include project management, site, energy, water, indoor environment, resource, building materials, and solid waste.

A critical aspect of sustainability assessment through multi-criteria systems regards the selection of criteria and weight given to these. In fact, reasons behind choices are not explicit. Figure 3.3 shows weights assigned by the above six systems grouping the criteria of each into seven main categories. Selection of these categories was based on main sustainable building aspects (Langston & Ding, 2001): site selection, energy efficiency, water efficiency, material and resources, indoor environmental quality, waste, pollution, and others, containing criteria that do not fit into the other six. When more than one version of the same system existed, the one applicable to new construction was selected. The attribution of each system criteria into previous categories resulted in some difficulties because both the system structures were not always accessible and criteria among systems did not perfectly overlap.

In Figure 3.3, management and innovation criteria have been included in the category 'others'. For example, LEED assigns 7% of its credits to innovations,

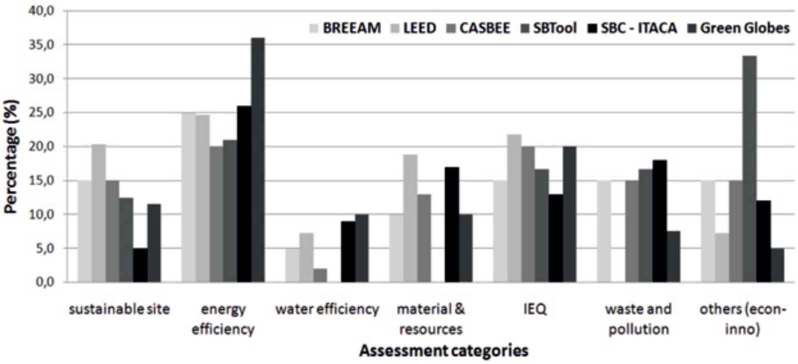


Figure 3.3 Comparison of the weights assigned by six sustainable rating systems, grouping the respective criteria into seven categories.

BREEAM has 15% for construction management, and Green Globe has 12.5% for project management. Moreover, in the category 'others' there are points given by CASBEE for mitigation and off site solar energy and by GBTool for the cultural perception of sustainability. The result of the weight comparison among rating systems agrees with similar studies (Fowler & Rauch, 2006; BRE, 2008).

It is interesting to note in Figure 3.3 that energy efficiency is always considered the most important category among assessment systems for the sustainable building (weight average among the 6 systems 25.5%), followed by IEQ (17.7%), waste and pollution (15.9%), sustainable site (13.2%) and material and resources (11.5%). The Green Globes assigns a higher percentage of its assessment weight to the energy efficient (36%): this is established by the inclusion of criteria which are not presented in other systems, such as the correct size energy-efficient system or energy-efficient transportation.

"Above averages" have not a rigorous meaning because the standard deviations among systems are high. However, studies have shown many similarities among sustainability rating systems (Smith et al., 2006). Finally, it should be remembered that differences among the systems have led to create the Sustainable Building Alliance in order to establish common evaluation categories and to improve comparability of sustainability assessments.

Many studies have discussed the limits of sustainability assessment through rating systems. Unscientific criteria selection has been criticised by both Rumsey and McLellan (2005) and Schendler and Udall (2005). Bowyer et al. (2006) stated the lack of overall life cycle perspective in evaluations. On the same topic, the U.S. National Institute of Standards and Technology (NIST) analysed the LEED system from a LCA perspective leading to the conclusion that it is not a reliable sustainability assessment system (Scheuer & Leoleian, 2002).

From Figure 3.3, it is clear that in the selection of assessment criteria, environmental aspects receive much more attention than economic and social ones when sustainability is considered (Sev, 2009; Berardi, 2012).

Recently, some multi-criteria rating systems more closely related to a TQA have been released. For example, the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), available since 2009, aims to evaluate sustainability through the quality of the building; economic aspects emerge explicitly, and, in the category of technical quality, paradigms such as performance, durability, and ease of cleaning, as well as dismantling and recycling are considered. More attention is paid to social aspects than in other rating systems. Finally, functional aspects such as space efficiency, safety, risk of hazardous incidents, handicap accessibility, suitability for conversion, public access, and art and social integration are considered.

Chapter 4

Green Innovations in Sustainable Buildings

In the present chapter, sustainability rating systems are used as a proxy variable to analyse the characteristics of a large sample of sustainable buildings. In fact, the author believes that the results of sustainability assessments in real buildings can be more useful to understand the state of the art of sustainable building than policies and regulations.

As seen in Section 1.2, sustainability assessments are generally voluntary, and their adoption is often motivated by signalling reasons. This means that the construction firm or the owner of the building decides to perform a sustainability assessment also to communicate something to the outside world (Mlecnik et al., 2010).

According to King and Toffel (2007), signalling and intrinsic benefits are mixed together when sustainable rating systems are used. In their analysis, this clearly emerged from the decreasing number of buildings that obtained a larger number of credits than the minimum for a given certification level. Buildings generally aimed at an established certification level, and rarely showed higher performance than the minimum ones for the given certification level.

In this chapter, a rating system is chosen to discuss aspects of sustainable buildings in developed countries (mainly United States) by looking at statistics of achieved points in certified buildings. Although there is space for improvement in LEED (Bower et al., 2006; Hahn, 2008; Newsham et al., 2009), this is the most diffused system worldwide, and hence, it has been chosen for the analysis. The author thanks the Green Building Council (GBC) in New York for having allowed the use of the data.

4.1. Sustainability Assessments of the Building Sample

A sample of 490 buildings was selected within the GBC database from already completed buildings. Selected buildings belonged to several typologies, with a large majority of commercial (52%) and residential (30%) buildings. The time of construction was very similar among buildings, from 2002 to 2009, hence, a diachronic analysis could not be performed. Figure 4.1 shows earned points over total possible points. The data suggests several considerations:

- Sustainable sites is an important category in the overall evaluation of sustainability (14/69 available points), however, assessed buildings reach less than 50% of the available points on average. The selection of a sustainable site is often influenced by property possibilities, municipal policies, and previous land uses, making a free selection difficult.
- Energy and Atmosphere is the category with the largest number of points (17/69 points). The rate of successful points over possible ones is the lowest among categories (38%), even if this percentage in other studies has been also smaller (30.8% in Bolin, 2003).
- Indoor environmental quality is the second category for available points but the first contributing to the total score, as average earned points are 56% of available ones (59.6% in Bolin, 2003).
- Water efficiency receives only a few points in the standard (5/69), despite its importance for a sustainable building. The most probable reason for this is that few actions can lead to a significant efficiency in the use of this resource and, in fact, buildings obtained 62% of the available points on average.
- Material and Resources category has a considerable number of available points but effectively earned ones are few, with an average of 40%.
- Innovation category has a low number of available points and on average, buildings are successful in this category for 66% of the possible points, which means that sustainable buildings are generally able to fulfil requirements in this category.

With the largest number of achievable points but third in absolute earned points and last in relative earned points to the total achievable ones, the Energy and Atmosphere category shows abnormal percentages. This suggests that energy requirements are still difficult to achieve, and also that projects aimed at sustainability certification under-adopt performances within this category. The low result of Energy and Atmosphere scores can probably be justified by the very low preparedness and the insufficient awareness about requirements of this category among constructors (Son et al., 2011).

Figure 4.1 represents the percentages for buildings of different classes, for certified, silver, gold and platinum buildings. In platinum buildings, the percentage of earned points in the Energy and Atmosphere category increases with respect to other classes of buildings, becoming the most contributing category to the overall score in absolute value (78% of points obtained, with an average of almost 14 points over the 69 available). However, if compared with the total available points in this category, obtained ones have a lower percentage than in other categories. The Material and Resources category also suffers from obtaining a low percentage of points for any class of buildings and, in particular, in platinum ones, this category represents the less successful

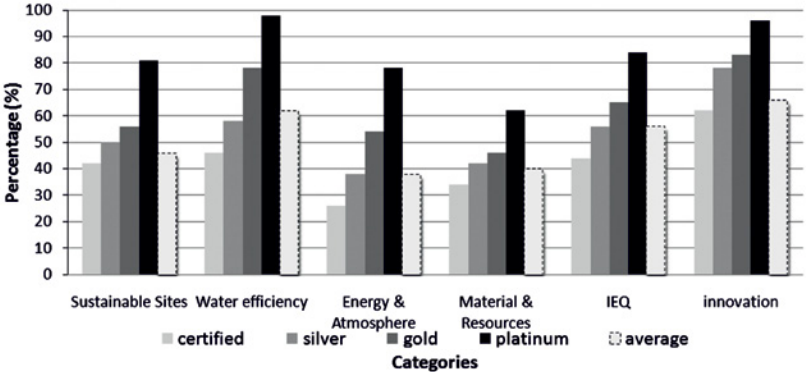


Figure 4.1 Earned points over the total possible in each assessment category for different classes of LEED rated buildings.

one (62%). The high percentage of success in the Innovation category can be justified by the freedom the LEED system allows for points in this category. Moreover, it is interesting to look at the results for the Water Efficiency category: the importance of this resource for sustainable development, together with the ease of designing and building systems of water harvesting, suggest that water efficiency represents an achievable target that can be reached, almost independently from the rate of sustainability certification.

The comparison between achieved points in silver and gold buildings shows that the improvement in the assessment is lightly influenced by the Material and Resources category. In fact, average earned points in this category are similar among buildings. Conversely, a larger improvement occurs between silver and gold buildings in the Energy and Atmosphere and Water Efficiency categories.

Figure 4.1 disaggregates the statistics in figure 4.2 by representing the earned points for any criteria. This shows which points in each category are more often reached. In the Indoor Environmental Quality category, criteria from IEQ 1.0 to 5.0 are earned by a high percentage of buildings in any class; these criteria correspond to the air monitoring system, system with increased ventilation, management of air quality during construction, use of low emitting materials and control of pollutant sources. This suggests that sustainable buildings have recently learnt how to adopt the innovations related to previous indoor air-quality criteria.

Energy-related criteria are among the less-achieved ones. In particular, the percentage of buildings with renewable energy production is low for any class of buildings, with only 1% of certified buildings able to produce 20% of energy from renewable sources (E&A 2.3). A high energy performance (E&A 1)

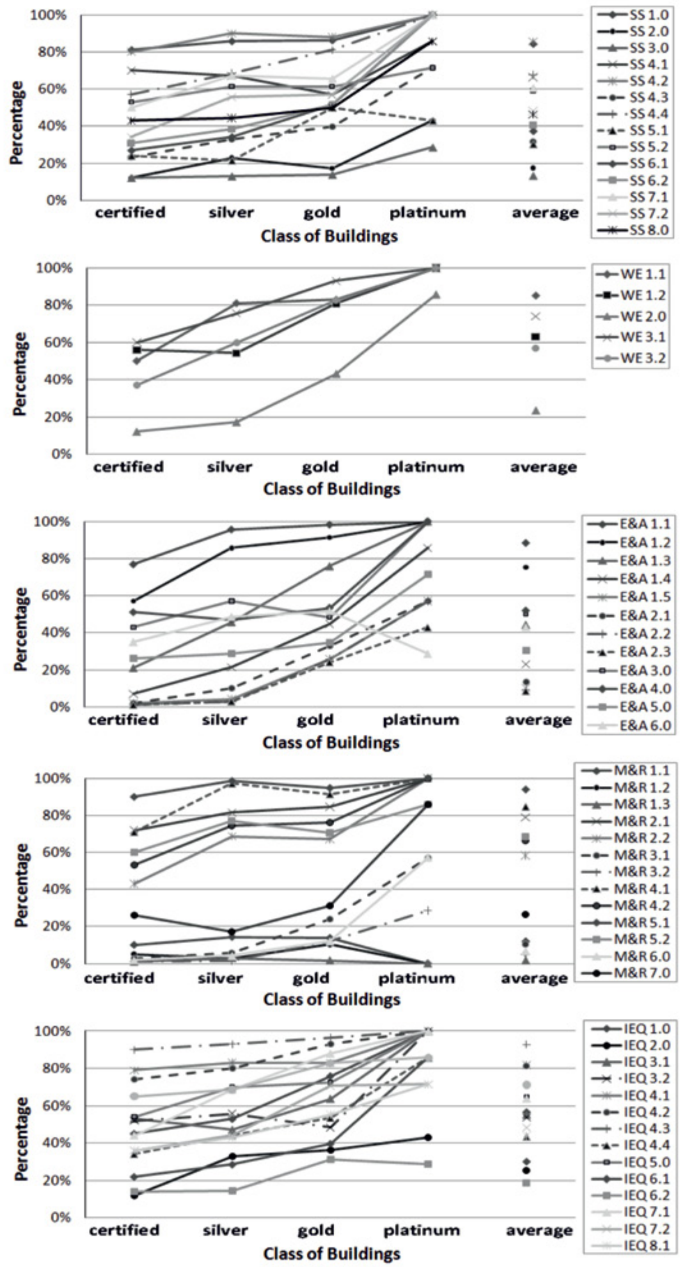


Figure 4.2 Percentages of earned points over total ones in several categories of the LEED system in 490 buildings of different classes (certified, silver, gold, and platinum).

is partially achieved, and many buildings make only limited choices towards adoption of energy saving innovations: high success rates for E&A 1.1, 1.2 (optimise energy performance through lighting power and lighting controls), while low ones for E&A 1.3, 1.4, 1.5 criteria, which are related to the HVAC, equipment and appliances energy savings, respectively.

Urban and brownfield redevelopment criteria (SS 2.0, 3.0) have low success rates: this suggests that the possibility of selecting land is of secondary importance in respect to the construction. On the contrary, criteria about alternative transportation (Public Transportation Access SS 4.1 and Bicycle Storage and Changing Rooms SS 4.2) have a high success rate. This means that sustainable buildings have learnt to adopt innovations related to sustainable mobility.

In the Water Efficiency category, water use reduction has a high percentage of success among all certification levels with values which, in certified buildings, go from 60% for 20% reduction in water use (WE 3.1) to 37% for 30% reduction (WE 3.2). The implementation of Innovative Wastewater Technologies (WE 2.0) represents a complicated target also for best-rated buildings. According to Morris and Matthiessen (2007), this could probably be justified as on-site wastewater treatment adds significant costs.

Finally, criteria in the Material and Resources category have different statistics regarding the successful points. In fact, high successful percentages are reached for construction waste management (M&R 2.1, 2.2) and use of local and regional materials (M&R 5.1, 5.2) in any class of buildings. In contrast, other criteria in this category show a low success rate even in platinum buildings: among these are criteria for adoption of building reuse materials (M&R 1.1, 1.2, 1.3) and rapidly renewable materials (M&R 6.0). This suggests that sustainable buildings are generally able to reduce the impact of their material and resource uses, although this ability is shown by selecting unused materials more than looking at using recycled or low-energy embodied ones.

Obviously, the choice to use the LEED protocol, limiting the evaluation to one rating system, means the analysis is influenced by its structure as well as by its criteria.

House for Young people - Don Leandro Rossi Foundation, Lodi, Italy

This small and unique building is based on three design guidelines: functional suitability, energy saving and technological innovation. These are easily legible in this architectural organism. It aims to host young people with family problems and it was designed under the supervision of the Architectural Technology department of the Polytechnic of Milan.
Energy-saving and technological innovation are visible in morphology of the building, which faces south with a wall. Solar photovoltaic panels and solar panels help reduce the energy consumption to less than 6kWh/m^3, allowing this building to be labeled with the most sustainable category of the local sustainability assessment system. Moreover, the double height living room promotes natural ventilation through the skylight.
Many innovative technologies have been used in this building, especially the mixed structure of steel and laminated wood; external envelope composed by sandwich panels with interposed polystyrene, complemented by various types of ventilated walls hung with horizontal panels and high heat insulating windows. The metal roof raised the shape of the building to intercept solar radiation in summer, and it is inclined towards the internal to help the collection of rainwater for irrigation of gardens.
The willingness to experiment with new technology also suggests adopting different materials in the coating ventilated façade, structure, and plasters.

The Solaire, New York City, US

The Solaire was the first green residential-use building in the US which has been rated the level of Gold with LEED. It was completed in 2003, and is seen as an inspiring project due to its location at Battery Park City, one of the most affluent neighbourhoods in Lower Manhattan New York City. Surrounded by high-energy-consuming office buildings, the Solaire showed a new path for energy efficiency in 2002-2003.

It is often described as an environmentally progressive residential tower. The energy -conserving building design is 35% more energy-efficient than code requires, resulting in a 67% lower electricity demand during peak hour. Among the benefits it offers, residents appreciated:

- photovoltaic panels that convert sunlight to electricity and offer lower electric bills.
- computerised building-management system and environmentally responsible operating and maintenance practices.

The PV panels are integrated in the façade of the building and represented a model to include Renewable Technology as main material of the envelope. The building is also provided with a water recycling system which divides black and grey water to reuse it into the toilets and the green roof.

4.2. Trends in Sustainability Assessment of Buildings

Trends of sustainability assessment of building have been of interest since Crawley and Aho's study (1999). As seen above, single and multi-dimension systems exist. Sustainability assessment was originally based on a single, often energy related, parameter. However, assessments through a single dimension have received much criticism (Nijkamp et al., 1990; Janikowski et al., 2000), as a single criterion is generally unable to measure the sustainability complexity.

An increasing awareness of externalities, risk and long-term effects of a building suggests a large diffusion in the future of multi-criteria systems to assess sustainability of buildings. Available multi-criteria systems have been accused of a lack of completeness as they neglect some criteria: for example, they rarely take into account the economic dimension of the development. This absence prevents the evaluation of the economic consequences of sustainable choices and, therefore, constitutes a great limit for sustainability rating systems (Ding, 2008).

The importance of economic and social evaluations has recently emerged in assessing sustainability of buildings in developing countries where it is more evident that the environment cannot be the only assessment category (Gibberd, 2005).

However, even if it is particularly important to cover all aspects of sustainability in assessment systems, a comprehensive approach to the evaluation has shown to require much detailed information. For example, the last version of GBTool comprises more than 120 criteria. The complexity of sustainability has been pointed out as a limit for the diffusion of sustainable rating systems (Mlecnik et al., 2010). In fact, if sustainability rating systems and sustainability are perceived as too complex, then the diffusion of sustainability practices will be slower. A balance between completeness in coverage and simplicity of use is hence necessary to help diffusing sustainability assessment in the building sector.

An open aspect of sustainability assessment regards possible regional adaptations in assessment criteria. The Italian experience of SBC-ITACA shows that sustainability assessment systems require adaptation to local characteristics and regional priorities. It is evident that sustainability evaluation needs site adaptations in order to fit sustainable requirements with contextual aspects. This means that sustainable innovations and buildings should be evaluated in each context, as they are not general properties. However, local aspects, priorities, and benchmarks are complex to establish, especially when it is necessary to manage many criteria and performance values as in the building sector.

Sustainability rating systems have shown a trend for whole life perspective analysis as the assessment is moving to cover the construction, operation and dismantling phases too. However, limits of sustainability assessments suggest that more complete systems are necessary to assess the multi-dimensional aspects of sustainability.

An important trend in sustainability assessment is the increasing attention to the impact of the building over the neighbourhood. Early assessment systems considered the building as a manufactured product, and evaluated it almost in isolation. However, the importance given to the surrounding site is largely increasing. Also energy requirements have become stronger in the latest versions of this and others assessment systems. This can certainly be motivated by the stricter requests of energy regulations and the greater attention to energy saving in buildings.

4.3. Conclusions

The chapter has shown the importance and the ways to assess sustainability in the building sector. By reviewing current systems for sustainability assessment, the chapter has shown that energy performance is generally considered the most important criteria for sustainability of buildings.

The chapter has reviewed the current status of sustainability assessment in the construction sector describing, and often, criticising, most diffused systems. Although there has been a large and rapid diffusion of these systems, room for their improvement exists. The paper has brought the necessity of improving the communicability of the assessment systems and encouraging a more inclusive approach which could take into account externalities, long-term (or life cycle) effects, economic and social aspects. These are fundamental to rate a building as sustainable.

Results of sustainability assessments in a large sample of U.S. certified buildings have shown that their energy performances are well below the optimal ones, also in sustainable buildings. Reasons for the low adoption of energy-saving innovations are often the high cost of these technologies and the low preparedness of construction actors.

The same situation occurs for other technologies as water-saving ones. The only innovations that show a different behaviour and are more often adopted are those that guarantee good indoor environmental quality. In these cases, it may be sufficient to substitute traditional materials, such as paint, with more sustainable ones (for examples, paint without compound emissions in the air). This substitution is already common in sustainable buildings in U.S.

Chapter 5

Managing Green Innovations in the Building sector

In the previous chapters of this book, the attention was focussed on sustainable buildings in order to clarify the concept of sustainable building and the goal of the management of green innovations in the building sector. The latter is central in the second part of the book.

This chapter starts with a brief introduction to innovation management. Ways to classify innovations are reported by considering the impact of innovations over firms. The distinction between modular and radical innovations is reported before focussing on architectural innovations (Henderson & Clark, 1990). A review of studies about architectural innovations is done, as these innovations can play a prime role for a sustainability transition but, at the same time, they are particularly complicated to manage. In particular, the interest in focussing on architectural innovations is given by their complexity for the production processes.

In the second part of the chapter, the discussion concentrates on innovations in the building sector, often considered low on the scale of innovation. However, several researchers have recently given a new attention to peculiarities of construction innovations. Studies have demonstrated that innovations in buildings are often user-generated, on-site developed, numerous and undeclared. The chapter describes the introduction and diffusion of incremental and radical innovations in the building sector, and it ends discussing the effects of architectural and green innovations when they are adopted in buildings.

5.1. Classifications of Innovation

Innovation is a widely used, but elusive concept. Definitions of this term rarely went beyond the common understanding of innovation as "something new" (Schumpeter, 1976). Innovation literature has often discussed three themes: classification of innovation (1), innovation drivers (2), and response to innovation (3).

Firstly, a main theme of research has been the classification of the forms of innovation (Henderson & Clark, 1990). In particular, within the innovation management literature, an innovation can be either a continuous process or a discontinuous and radical phenomenon. How the innovation is generated is still an open question.

A secondary theme of research has often concerned with the place where innovation occurs. In particular, it has often been of interest if an innovation occurs within closed systems or is boundless. Researchers have found innovation almost everywhere: in creative or entrepreneurial individuals (Schumpeter, 1976), complex multilevel groups (Watson, 2007), knowledge clusters (Pohoryles, 2007), networks and governance structures (Johns et al., 2006). These contrasting results show the importance of the topic.

A third interesting theme for innovation management literature regards the behaviours and the responses to innovation at the individual, group, and contextual levels. Personal factors include the openness to new ideas (Ross, 1974) and tacit knowledge (Howells, 2002). It also considers how peoples' roles, positions, and self-definitions affect their responses (Considine & Lewis, 2007), their freedom to take risks (Lassen et al., 2006), and how the presence of a leadership role fosters innovation (Benn et al., 2006).

For a long time, innovation was seen as a synonym of invention. However, while invention refers to a new aspect of production, innovation is mostly related to the application of research results (Schumpeter, 1976). Innovation is the process of creative destruction which essentially revolutionises the economic structure from within, and constitutes the essential of transformative capitalism (Schumpeter, 1976). Innovation is hence the creative implementation of the new that takes place against a resistant background of everyday activity.

Literature has often tried to classify innovations according to their impact over firm capabilities. Innovations have been divided into two categories: competence-enhancing and competence-destroying. Moreover, innovations have been classified for their connections between product and process innovations. Especially in recent years, innovations have enlarged their boundaries passing from mainly product-related aspects to concepts of practices, processes and structures (Birkinshaw et al., 2008). Furthermore, in recent years, process and service innovations have received a larger attention than traditional product innovations (Pisano, 1996).

Pisano (1996) defined four perspectives in innovation studies: an institutional perspective that focusses on the socioeconomic conditions, a fashion perspective that focusses on the dynamic interplay between users, a cultural perspective that focusses on how an organisation reacts to the introduction of an innovation, and a rational perspective that focusses on how innovation management and individuals deliver improvements in organisational effectiveness.

Patents and R&D expenditures are the most-used parameters in innovation studies. These best apply to product innovations. However, processes and organisational innovations are more difficult to understand and measure (Nelson & Winter, 1982). Recent studies about innovations are considering more social than economic aspects of innovations. In fact, innovation impacts, degrees of effort, development path timings and technological momentum are increasingly studied (Dosi, 2000).

Innovations have been divided into incremental and radical if minor or major changes are imposed by their adoption, respectively (Mansfield, 1968). Later, Freeman (1982) differentiated incremental from radical innovations as improvements in existing concepts from introducing new designs. An incremental innovation introduces relatively minor changes to the existing products, exploits the potential of the established design, and generally reinforces the dominance of established firms (Nelson & Winter, 1982). On the contrary, a radical innovation bases on a different set of scientific principles and, generally, opens up completely new applications (Dutton & Jackson, 1987; Ettlie, 1997).

Limits of the simple incremental vs. radical classification were shown during the 1980s when innovations involving modest changes provoked dramatic competitive consequences (Clark, 1987). Henderson and Clark (1990) proposed a new classification of innovation analysing the linkages between core concepts of a product and its components. They defined four types of innovations, which can be distinguished if the core concepts are reinforced and if the linkages between concepts and components are changed by the innovation. They indicated four categories of innovation, as reported in Table 5.1.

Henderson and Clark's categories can be described in the following way:

- Incremental innovation introduces relatively minor changes to the existing products and processes;
- Modular innovation substitutes a modular element with a new one which generally guarantees a better performance, but which does not need new linkages with other components and maintains the same connections of the overturned element;
- Architectural innovation is a change of a product architecture which leaves unchanged the components and the core design concepts, but elements are reconfigured with new iterations;
- Radical innovation is based on a different set of principles, and often opens up whole new markets and potential applications.

Table 5.1 Classifications of innovation according to Henderson and Clark (1990).

		Core Concepts	
		Reinforced	Overturned
Linkage Between Core Concept and Components	Unchanged	Incremental Innovation	Modular Innovation
	Changed	Architectural Innovation	Radical Innovation

Slaughter (1998) added the category of system innovation. She defined the system innovation as being composed of a large number of innovations. Although the previous categories exist, many innovations are difficult to classify for the difficulties of defining the core concepts and linkages between core concept and components. Moreover, innovation diffusion often leads to an evolutionary pattern which locally modifies the innovation at any introduction (Cainarca et al., 1989). The possibility of evolution trends for innovations suggests considering innovation as a dynamic paradigm (Birkinshaw et al., 2008). The dynamics of impacts and site adaptations of innovation will be considered in the following sections.

5.2. Specificities of Architectural Innovations

The present section is dedicated to architectural innovations. The reason behind the interest in architectural innovations will become clearer in Chapter 7, investigating the impact over the building process of green innovations which are architectural innovations. However, it is possible to say that innovations which need to be integrated in an existing object and which have a strong impact for the architecture of that object (so that they are architectural innovations) represent a significant body of the innovations that the building sector should learn to implement for more sustainable buildings.

Architectural innovations have significant effects over complex products, such as buildings. These usually consist of a large number of components. The architecture concept of a product encompasses the information on how many components the product consists of, how these components are configured together, and how they are built and assembled. The architecture defines the building blocks in terms of what they do and what their interfaces are (Ulrich & Eppinger, 2000). Table 5.2 reports some definitions of architecture in the context of innovation management.

The concept of architecture is related to that of function both represent what a product does (Ulrich, 1995). In studies about architectures, the interfaces among components play a principal role. Many studies have explored modular architectures because these are the simplest configuration for a product, and they have a one-to-one mapping between functional elements and components. Modular architectures were studied by Baldwin and Clark (2000) who indicated three kinds of modularity: in design, in production, and in use. The concept of architecture has extensively been investigated by the Architecture Committee in the Engineering System Department of the Massachusetts Institute of Technology. These studies have focussed on the abstraction of the systems and on the role and influence of architecture in complex systems (Crawley et al., 2004). Ulrich (1995) stated that architecture is relevant for innovation management, as architectural decisions are made in the early phases of the innovation process. The

Table 5.2 Definitions of architecture, according to different sources.

Source	**Definition of the Architecture (of a product)**
Ulrich and Seering, 1990	knowledge about the functions of the system and how the components contribute to those functions, which means what they do
Ulrich, 1995	the scheme by which the functions of a product are allocated to physical components
Ulrich and Eppinger, 2000	the arrangement of the functional elements into physical blocks
Baldwin and Clark, 2000	the modules that are part of the system, and what their roles are
Crawley et al., 2004	an abstract description of the entities of a system and the relationship between those entities
Crawley et al., 2004	the embodiment of concept, and the allocation of physical/ informational function to elements of form, and definition of interfaces among the elements and the surrounding context
Fixson, 2005	the fundamental structure of the product, a comprehensive description of a bundle of product characteristics, including number and type of components, number and type of interfaces between those components

importance of the characteristics of innovation in order to implement them in the building sector is particularly high.

Baldwin and Clark (2000) treated the architecture as the abstract description of the entities of a system together with their relationships. In this sense, every system has an architectural structure (Crawley et al., 2004). Obviously, the building represents the best example of product architecture.

Levis (1999) indicated several types of architectures:

- functional architecture, as the ordered list of activities and functions;
- physical architecture, as the representation of resources and interconnections;
- technical architecture, as the elaboration of physical architecture, and the interdependence of the elements;
- operational architecture, as the description of how elements operate and interact.

Architectural knowledge has been defined as the pattern of how components are arranged (Peine, 2009). Obviously, the more complex a product is, the more the architecture is important and the interoperability between components determines far-reaching implications for innovation management.

According to the original concept, an architectural innovation leaves the components and the core concept unchanged. The essence of an architectural innovation is hence the reconfiguration of established systems to link together components in a new way. Since the core concepts of the design remain untouched in architectural innovation, organisations in front of an architectural innovation may mistakenly believe to understand the innovation. On the contrary, recognising that a new technology is architectural in character prompts to switch to a new learning process by investing time and resources. Architectural knowledge is a relevant factor for the capacity to innovate. In fact, when organisations facing innovations continue to rely on their old architectural knowledge, they generally misunderstand the nature of the innovation. Innovation classifications in Section 5.1 can also be considered according to the impact provoked by their adoption: architectural innovations often are silent innovations, although they can be disruptive for consolidated knowledge (Henderson & Clark, 1990; Geroski, 2000). The impact and the barriers to implement and manage an architectural innovation will be the topic of the next section.

5.3. Architectural Innovation Management

The process of innovation management has been defined by Abernathy and Utterback (1978) as the life-cycle from an early moment dominated by intensive competition among different possibilities, through a transitional moment in which a dominant design emerges and it is improved. In its broadest sense, innovation management can be defined as the form and quality of organisational activities (Poole & Van de Ven, 2004). Links between innovation management and inventions have often suggested co-evolution patterns between these. However, a great distance exists between research for invention and innovation management penetrations (Fuggetta, 2009).

The management of architectural innovations is interesting to study because architectural innovation needs a deep management of the new linkages between core concept and components. The concept of architectural innovation was originally defined within a single-firm context; recently it has been applied also to inter-firm contexts (Bozdogan at al., 1998). Studies have shown that supplier integration into the company can help the introduction of architectural innovations. In fact, early supplier participation is a major source of competitive advantage to firms attempting to re-invent their products (Baldwin & Clark, 2000). The importance of innovation networks among firms is increasingly investigated, as product technology is becoming complex. In fact, complex technologies cannot be fully understood in detail by a single firm, and impose a supply chain network among several firms with different capabilities (Kash & Rycroft, 2003).

The management of architectural innovation is particularly critical in the early phases (also known as pre-project activity, concept generation, product planning, idea generation or investigation) because at these stages critical decisions related to the innovations are done (Verganti, 1997). The great importance of innovation management in early phases is due to the high costs and time consumption that adjustments in later stages provoke (Figure 5.1).

An important aspect which can improve the management of architectural innovations is the active integration of suppliers during the exploration stages. This involvement can foster architectural innovations in product definition, resulting in new configurations of how components are linked together in a product. Technical skills of partners can have a key role in the team, also because suppliers are more and more a source of innovation in any sector (von Hippel, 1988). Researchers working in the U.S. defence aircraft industry have shown that suppliers are involved early in the design and development of major components in the 75% of innovation cases (Bozdogan et al., 1998). This underlines the fact that the architectural management innovation is favoured by early suppliers' involvement. Such circumstance moves innovation management from company to network of firms (Ettlie, 1996).

This review of principles of architectural innovation management shows that process and organisational innovations are as necessary as technology ones. In fact, the management of architectural innovations more than other kinds of

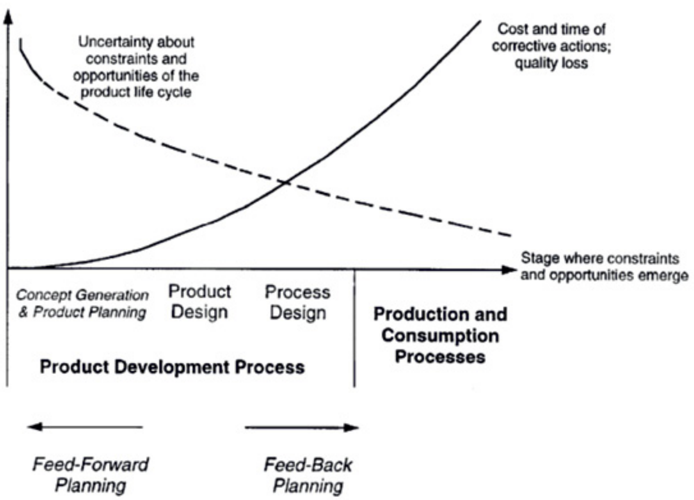


Figure 5.1 Level of uncertainty and cost/time implications during an innovation life cycle (Verganti, 1997).

innovations involves institutions, professional norms, practices, lifestyles, and belief systems. These elements will become clearer when the management of architectural innovation in the building sector is described.

5.4. Innovation in the Building Sector

5.4.1. Construction innovation literature

The general literature about innovation management has proved to be unable to properly fit innovations in the construction sector, because a less formally structured process characterises construction activities. Construction innovation has been an increasing subject in international research (Manseau & Seaden, 2001).

Before reviewing this literature, it is necessary to define what the construction sector is, which is defined by its boundaries and its innovations. Construction is primarily defined as the series of on-site activities of assembly together with the activities for the production of goods that are assembled.

A negative stereotype states that construction innovation rate lags behind other sectors (Manseau & Seaden, 2001). One of the reasons is the use of the formal investment in R&D as a measurement unit for the innovation rate. In the construction sector, R&D is behind the value R&D has in other industries (Manseau & Seaden, 2001). For example, in U.S. research on building practices and technologies constituted about 0.2% of all federal funded research from 2002 to 2004, a low percentage if compared with building-related environmental and economic impacts.

This has favoured the consideration that the construction sector is risk-averse and is conservative with respect to innovations. Almost 30 years ago, the construction sector was defined as the industry that "God forgot and the industrial revolution overlooked" (Lawrence & Dyer, 1983).

A factor which delays innovation diffusion in constructions is the instability of construction processes and markets. Those studies, which affirmed the low innovativeness of the construction sector, generally focussed on construction companies only. Construction companies are strongly dependent on economic cycles, as they work only when construction is in progress. This cyclical situation represents a barrier to innovations for construction firms. Moreover, regulations heavily influence the layout and the scheduling of the activities at the jobsite and represent other barriers to innovations (Nam & Tatum, 1989).

However, a conceptual mistake exists in this approach. Construction innovation studies have avoided understanding that building innovations are often "off the shelf". In fact, the analysis of only those firms that are found on the site presents a misleadingly simplistic view about the complexity of the construction production system, because it neglects the large number of firms that effectively participate in the building process.

Some new methods have been used to assess construction innovations in other firms of the construction sector. These methods include patent mapping, root cause analysis and TRIZ function. However, these methods and unit of measurements are unable to capture the innovation rate of the construction sector. In fact, construction related studies have underestimated the network dimension of the sector, which cannot be considered by just looking at one single firm or process.

Approaches centred on networks of firms, such as the OECD's Oslo model, have recently been proposed. New data for innovation measurements in construction have started to be based on Construction Cluster Approaches (Dahl & Dalum, 2001). From this literature, it emerges that construction is a variegated and complex sector, in which innovation emerges in different ways than in other sectors. Slaughter (1993, 1998) observed that the building sector depends on other industries. She also underlined the importance of ad-hoc micro innovations, which generate from fitting every project to the unique conditions of any particular application (Slaughter, 2000).

5.4.2. Categories of construction innovations

An innovation is a product, process or practice new to the state of the art. Most innovation studies analyse the innovations as discrete and independent events. The independence among innovations may be appropriate for manufacture innovations, where product and processes can be examined separately from other components and systems, but it is difficult to apply to the construction sector. In fact, construction processes are particularly interconnected and their innovations influence the phases with many more implications.

In Section 5.2, different kinds of innovations, spanning from radical to incremental innovations, have been described. That classification is useful for construction innovations too. Incremental innovations have often been considered the only kind of innovations in the building sector (Slaughter, 1996). Reasons for this are connected to the low innovations in design. However, Table 5.3 shows that other kinds of innovations are also possible.

In the building sector, when significant changes are necessary, they often combine many modular innovations. In these cases, innovations are not introduced in isolation but through the coordination of multiple innovations. This led Slaughter (2000) to define the system innovation. These are produced as summations of several interdependent innovations which are favoured by clusters of firms. System interactions are nurtured through coordinated innovation development programmers by firms which interact with networks

Table 5.3 Classification of innovation in categories and their characteristics and example in the building sector.

Innovation	**Definition**	**Characteristics in the building sector**	**Example**
Incremental	Small improvement with minimal impact on other systems (Nelson & Winter, 1977)	Many rules of thumb which effect unique conditions or client requirements often adopted for cost saving, convenience or new regulations	
Modular	Improvement within a specific system with no changes in other components (Winch, 1998)	Innovations which come from manufactures or suppliers of new products. These are product innovations as construction focusses on product enhancement more than process innovations	
Architectural	New way of assembling buildings and reorganising practices (Slaughter, 1993)	Mobile tower cranes accelerated the construction process in the US ('mobile crane culture'). Indoor Air systems are modifying architectural connections of building elements	
System	Sets of large number of interdependent new products and practices (Slaughter, 1993; Cainarca et al. 1989)	Computerisation has involved a process of integration among complementarily activities based on innovations. The interior "drywall" allows the integration of many other small innovations	
Radical	A completely new concept which renders overturned previous approaches (Nelson & Winter, 1977)	The introduction of concrete disrupted the sector knowledge, methods and technologies. Earth brick can have the same impacts over the sector.	

of other firms (Foray & Freeman, 1993). Table 5.3 reports the classification, characteristics and some examples of different categories of innovations in the construction sector.

A few years ago, Gann (1994) indicated four major categories of construction innovations: the use of information technology, mechanisation of construction activities, prefabrication, and diffusion of new materials. Mechanisation and prefabrication are two categories of innovations which have failed to be promising in past decades, whereas new materials are a continuing source of innovations, as subsequent discoveries continually permit new products.

5.5. Actors for Innovation in Construction

The different actors of the construction sector have different influences towards innovation. In principle, construction consists of an aggregation of clients, regulators, contractors, consultants, architects, engineers, and components suppliers, who all together form a complex system industry (Figure 5.2).

The identification of the role of actors as drivers of construction innovation has received a large attention in the last twenty years. A brief review of this literature is reported below. Winch (1998) indicates two integrators among construction stakeholders: one at the design stage (the design team), and one at the construction stage (the contractor).

The role of clients has been largely discussed. Gibb and Isack (2001) argue that public and commercial constructions are client-demanded. However, in the

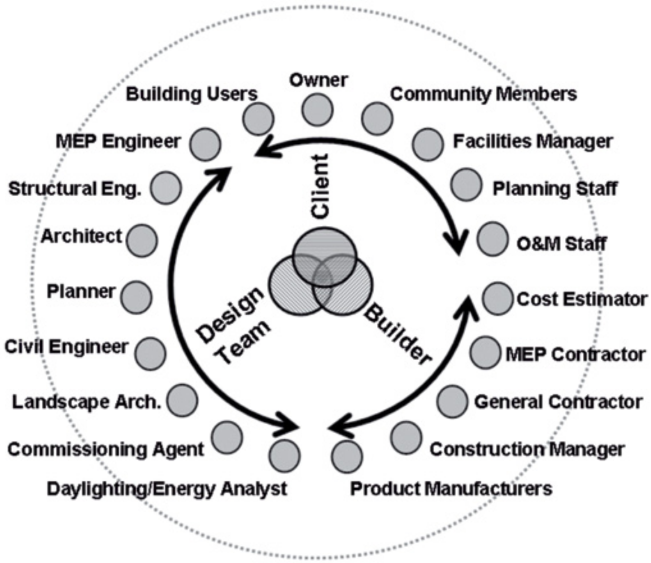


Figure 5.2 Cycles of the stakeholders of a building process grouped in three categories: design team, client and builder (Kubba, 2010).

residential sector, according to Nam and Tatum (1992), client and users demand for innovation are largely a myth. They affirmed that the information imbalance on user opinions led clients to a lack of information to push innovation. Moreover, according to these researchers, there is a self-reinforcing consensus about what a building should look like, and how it performs. This is a reason for clients to silently accept traditional buildings.

Arditi and Kale (1997) argued that innovations are introduced by manufactures of building products. Agapiou and Flagan (1998) affirmed that markets have a prime role, whereas Bernstein and Lemer (1996) stressed the importance of customers. More recently, Sexton and Barrett (2003) have shown that owner's attitudes for innovations are key characteristics for helping the introduction of an innovation in a project. Ling (2003) stated that innovations are based on the behaviour of individuals and thus no classifications of the possible reasons for innovation is possible. Winch (1998) stressed the role of member of professional associations and regulators as drivers of innovations, because they act as integrators and knowledge brokers. Slaughter (1993) concluded that innovation arises from people and firms working on-site explicitly integrating sub-components into the total building system.

If many studies have considered construction actors as drivers of innovations, many others have looked at actors as barriers to innovation in construction. Bernstein and Lemer (1996) pointed out three categories of barriers:

- structural characteristics of the processes as a large number of small firms that interact; multitude of codes and standards, cyclical downturns;
- cultural factors, as emphasis on lowest initial cost, division between labour and craft participants, strong reliance on past experience;
- general impediments, as tort liability, threat of litigation, and high costs.

Bauman and Kracum (1995) focussed on innovation barriers as financing, government regulations, public and political pressures. Tangkar and Arditi (2000) presented the process of innovation in construction as a labyrinth among which many actors collaborate through five phases: invention, creation of innovation, recognition of a need, construction of an environment for the adoption, and diffusion of the innovation.

Governments have sometimes been seen as barriers; however they have often played a prime role as drivers for the introduction of innovations in construction. Unfortunately, regulations generally apply only to new buildings and significant renovations. In developed countries, the construction rate of new buildings compared to the renovation rate of existing buildings is small. For example, in Europe, the estimated annual replacement rate is only 0.07% (CRESME, 2010). Data about the building industry in developing countries, reported in Chapter 1, suggests that regulations can have sizable impacts in these countries.

Several models have been used to understand and drive innovation diffusion in the building sector as technology-push or market-pull models. Simple models have proved to be partially useful in the building sector, given its complexities. Consequently, many non-linear models have been proposed to describe the introduction of innovations:

- firm-centred knowledge networks, theoretically based on the Oslo Manual. In these models, the firm is considered an innovation dynamo, and the distance among actors is the principal influencing factor for innovation.
- production systems that consider the implementation of new ideas after the interaction among workers, so that the relationships which characterise the production system become fundamental.
- complex product systems considers the integration between the innovations in existing systems.
- social processes that give social properties and perspectives to the innovations. These determine a continuous and evolutionary process among actors who interact collectively.

Previous models represent different drivers to understand construction innovations.

Many of the recent innovations in the construction sector are related to sustainable building. In a recent research, Mokhlesian (2010) has focussed on the adoption of innovations for green construction and has found that networks of motivated firms are dominant drivers for the adoption of green innovations. Absorptive capacity obtained though knowledge sharing between partners (Gluch et al., 2009; Bossnik, 2004), or information diffusion (Bartlett & Howard, 2000; Tam et al., 2006) are other main drivers for innovations for sustainable buildings. Finally, it is possible to affirm that higher-order knowledge among stakeholders is required to manage the adoption of innovations in the building sector because this requires that all participants are committed and motivated towards the innovation (Ahmad, 1991).

Slaughter (1993) found that a vast majority of innovations is developed by builders, and contrarily to the common knowledge, construction firms have importance as manufacturers. Using thirty-four innovations as case studies, she underlined the difference in user against manufacture innovations. In her study, builders integrated the products into the total building system and mainly acted over the whole final product, whereas manufacturer innovations were generally confined to single products. Moreover, she found that manufactures commercialised a few of builders' innovations, avoiding those that involved connections of the products with other components because these connections were out from the control of manufactures. According to Slaughter's results, users of building technologies can be important drivers of innovations because the builders can accommodate innovations according to on-site requests (Slaughter, 1993).

A key element that allows for workers to act as champions of innovations is a high competence and experience. At the same time, small firms are extremely sensitive to the cyclic and seasonal nature of the construction market, and hence, they become less inclined to pursue innovations, and long with them, and higher costs.

The approach to the multi-agent relationships in construction has often focussed on the different behaviours during the several stages of construction. In fact, one of the limits to the introduction of innovations is the time in which any stakeholder participates in the construction process. Construction generally starts with the municipal planning, so governments have the first possibility to push innovation. After this, process is ruled by the general contractors, and influenced by the design teams. Lastly, the owner or the future occupants join the process, when the majority of decisions have already been made. In Chapter 6, this timeline approach to innovation management and actors' participations will be extensively described.

5.6. Moving to Green Innovations

Studies dealing with organisational aspects related to the adoption of green innovations are particularly relevant for the present book. Many authors have investigated the development of green products by looking at the networks and collaborations among stakeholders both within the firm and outside it. These studies have showed that collaborations are particularly crucial for green innovations (Dermody & Hanmer-Lloyd, 1998; Foster & Green, 2000; Seuring, 2004).

Dermody and Hanmer-Lloyd (1998) identified three drivers for the integration of green topics in production processes:

- Environmentally skilled people are integrated in the process;
- Existing members start focussing on environmental issues;
- External consultants or designers are used to assist the decision-making unit.

Lenox and Ehrenfeld (1997) studied the organisational process for sustainable design according to resource- based views, capabilities perspectives, organisational learning and exploitation literature. The authors discussed environmental design capabilities, and found that these capabilities develop by the execution of problem-solving activities. Lenox and Ehrenfeld (1997) stated that environmental design capabilities depend on:

- knowledge resources, both internal and external to the firm, in term of experts on environmental impacts and technologies, and knowledge on environmental demand.
- information networks between product development members and resources.
- easily communicable structures between product development team members.

These elements require building a network in which communication linkages connect different knowledge resource nodes (Figure 5.3). The coordination of different resources with the product design team needs a dense information network both within the firm and outside it. This can be facilitated by having a common language and structures in which customers and manufactures can communicate with the design team.

An important study which focussed on green innovations and inter-firm networks has been conducted by Foster and Green (2000). These investigated how green concepts are influencing innovation development, and how information networks can contribute to green issues. The signal flows between stakeholders in an idealised company are modelled in Figure 5.4. In this model,

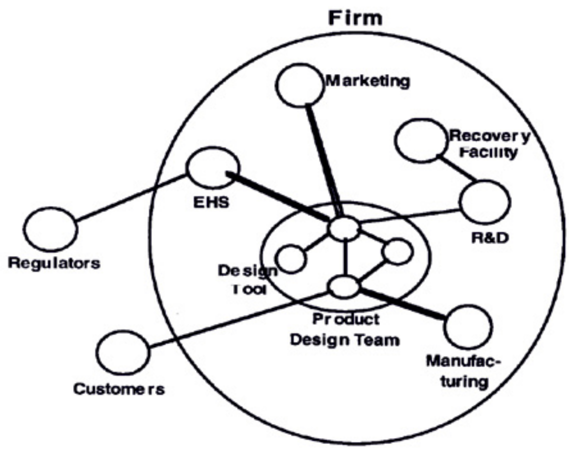


Figure 5.3 Information network of the product design team within and outside the firm (Lenox & Ehrenfeld, 1997).

the sale function is fundamental because it is the principal interface between users and R&D function. This model is complicated by the presence of a unit dedicated to environmental management, which interfaces with both the R&D function and regulators outside the firm. Applying this model to nine case studies, Foster and Green (2000) found that information related to green aspects encounters many obstacles to reach the R&D stage. Moreover, the authors identified three situations which indicated different levels of importance for the green performance issues. In most cases, these can be:

- a key issue for the customer and a driving force for the innovation.
- a key issue for the R&D and sales functions given the opportunity of new markets.
- a simple compliance check which receives little effort.

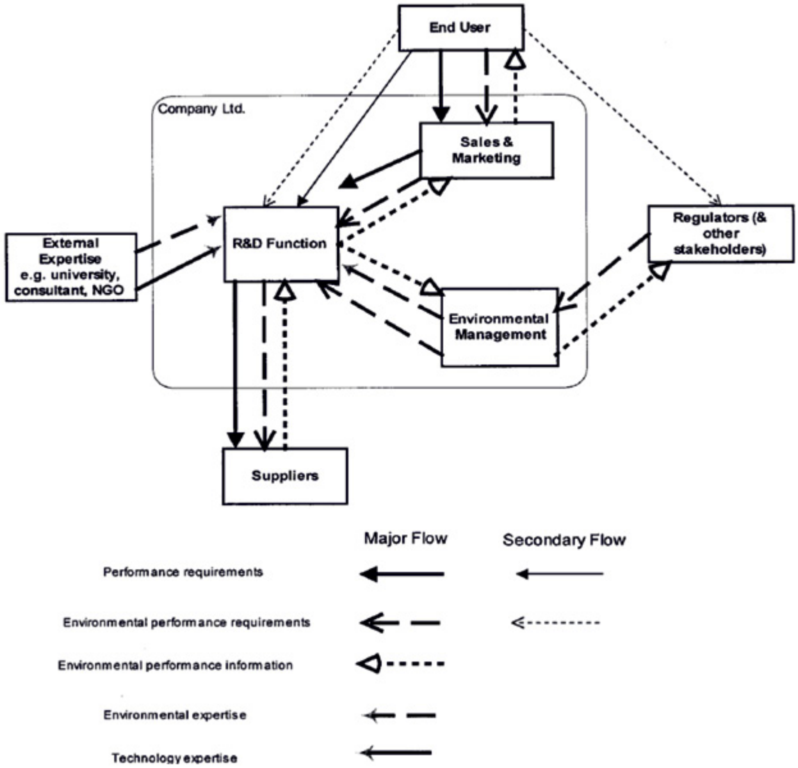


Figure 5.4 Information network in and outside a company with level of flow of each interaction according to the kind of line (Foster & Green, 2000).

5.6.1. Moving the building sector towards green innovations

Sustainable buildings require a higher-order learning which involves new practices of individuals and new institutional paradigms for the adoption of green innovations. As seen previously, a sustainable building is not the simple addition of green technologies and innovations; it requires a holistic approach. A sustainable building needs to be projected and built from an entire life cycle perspective. This means that sustainability principles have to be considered from the project planning phase through the operation and post construction phases (Wu and Pheng Low, 2010).

One way to facilitate the transition to sustainability is through experimentation (Kemp, 1996). A large amount of literature has investigated the first practices of management of sustainable innovations in different sectors (Kemp et al., 1998; Kemp et al., 2005; Bossink, 2007). These studies have shown the importance of experiments in niches to solve the problematic aspects of novelties.

A similar approach has been related to the introduction of an innovation in the construction sector as well. Here, the adoption of sustainable innovations has shown to require a multi-level learning process which involves individuals, institutions and firms (Brown & Vergragt, 2008). An integrative model to explain the adoption of green innovations in new constructions was formulated by Vermeulen and Hovens (2006). They studied the influence on innovation adoption of economic aspects, governmental interventions, company characteristics, markets and society influences (Figure 5.5). They considered the influence of four factors to adoption of sustainable innovations in buildings: the occasion to innovate, the initial perception of the technology, the nature of the decision-making process about innovation, and the result of the assessment of the technology. This study has shown the difference between mature and young green technologies: while young innovations are generally considered as project-specific choices and can be driven by several motivations, mature innovations need all previous steps for success. Vermeulen and Hovens (2006) showed that local policies have an important role in explaining the diffusion of sustainable innovations. Moreover, subsidies and requests by partners have motivating effects.

A general assumption in theories about innovation adoption is that ideas are institutionalised through a process where individuals collectively create a meaning based on their previous knowledge and their social context (Sharma, 2000). In this process, notions are translated into actions. The interpretation and translation of the sustainability requests depends on contextual organisational factors and how corporations legitimized sustainable innovations (Sharma, 2000). As an implication, individuals interpret and act according to their power and interest. In fact, actors commonly determine their preference based on self-interest (Gluch, 2005). They also use their own behaviour as a standard of what

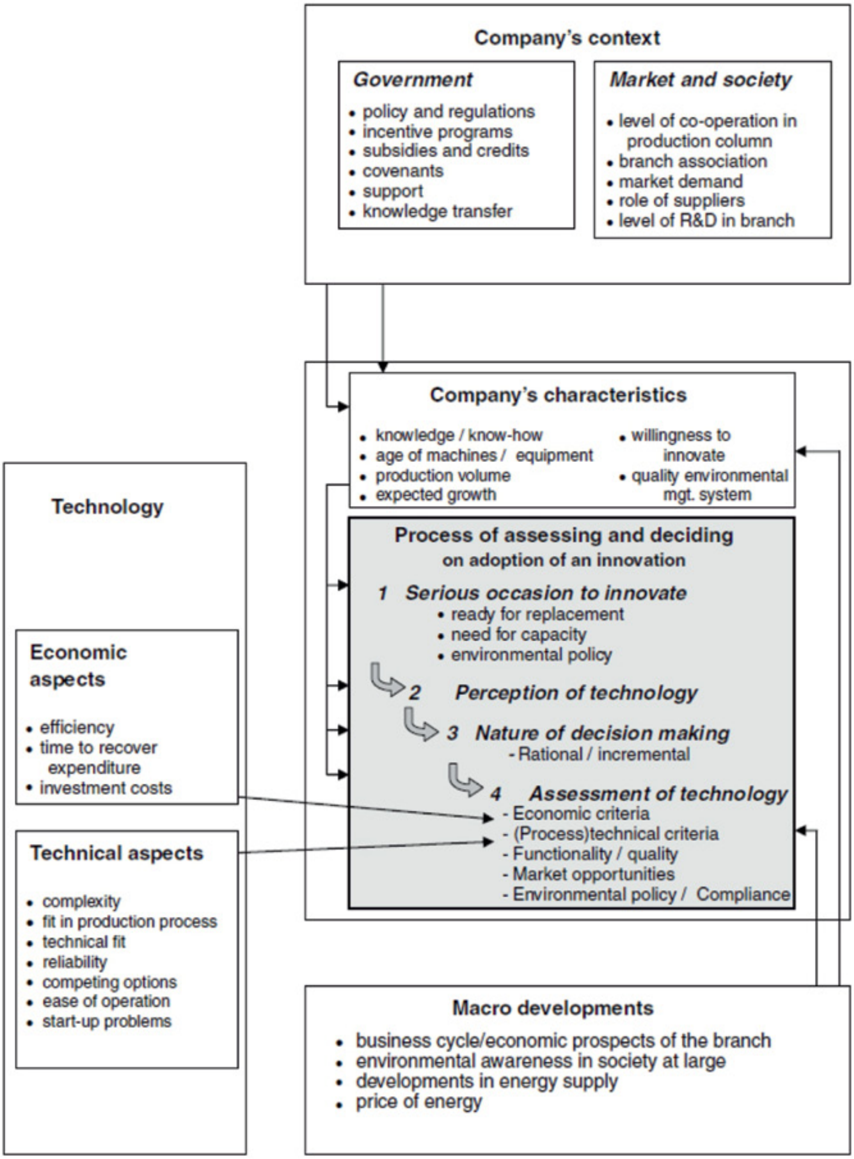


Figure 5.5 Framework for the diffusion of innovations through a process of assessment internal and external to the company in the building sector (Vermeulen & Hovens, 2006).

other people should do, and as a consequence, individuals create a meaning based on their own personal interests and cognitive limits (Eagly & Kulesa, 1997).

Looking at each construction project as a network where individuals join together, actors behave in the project coherently to the common assumption and paradigm within that community (Atkinson et al., 2000). As such, networks can be thought as composed of sub-cultures in which practitioners have their own orientations and influence their understanding. Consequently, the organisation of a network of firms interested and involved in the sustainable building is a social practice engaged of a set of activities that are situated in a specific context and are influenced by a specific history. Within this context, individuals are embedded in patterns of social relationships in which values and social norms play a prime role. The history and context influence these individual's identities, their roles, responsibilities and behaviour (Gann & Salter, 2000; Gluch, 2005).

Lockwood (2006), describing the sustainability transition of the construction sector, indicated ten drivers for the success. Among these, the most important were the coordinate management of the process of adoption of innovation and the holistic vision of the sustainable project.

The management of the adoption of green innovations is particularly difficult because construction processes are not repetitive, every project is site-adapted, and stakeholders are always project-dependent. This unrepeatable combination is typical of building processes, and makes the management of sustainable innovations in buildings difficult.

Another model for the study of sustainable innovations in construction processes has recently been proposed by Bossink (2011). He found that a sustainable innovation can be realised and managed on the level of individuals in a team, on the level of co-innovative teams in and between organisations, and on the level of business environmental forces. According to Bossink (2011), a sustainable innovation originates when these levels are synthesised together. In Figure 5.6, the model of sustainable innovation management is represented. Sustainable innovations need individuals who interact in teams: different figures are necessary for the innovation, as leaders, champions and all the other members of the team. The leadership is needed to direct a team towards an innovation. In particular, the leader has to act according to one of possible different leadership styles: he can be charismatic, instrumental, strategic or innovative. In the model of Bossink (2011), leadership is not sufficient, and the presence of an innovation champion is necessary. Champions are the creative sources of innovation. They can work in different ways, promoting, inventing and gatekeeping innovations. Leaderships and championships need to support each other. Moreover, management of the whole team is necessary to coordinate and control the sustainable innovation process. For this, systems thinking, realistic creativity, innovation foci and process linking can be used. The simultaneous application of some of these approaches successful supports the adoption of green innovation.

At a higher level than teams, there are the organisations. These are composed of several teams. Finally, the building sector is composed of several organisations. Cooperation and co-innovation in and between these organisations contribute to support sustainable innovations. The p-arrows between the team-circles in Figure 5.6 visualise cooperative projects between teams inside an organisation as well as between different organisations. Bossink (2011) showed that management principles that can be used to coordinate multi-teams and stimulate sustainable innovations are design-driven, planning-oriented systematic, targeted, and positioning management.

Business environmental forces can have a stimulating effect on various organisations to contribute adopting sustainable innovations. The main of these forces are sustainable innovations drivers, national policies for sustainable innovations and international issues about sustainability. These forces contribute to sustainable innovations by acting at all levels of multi-team organisations. In

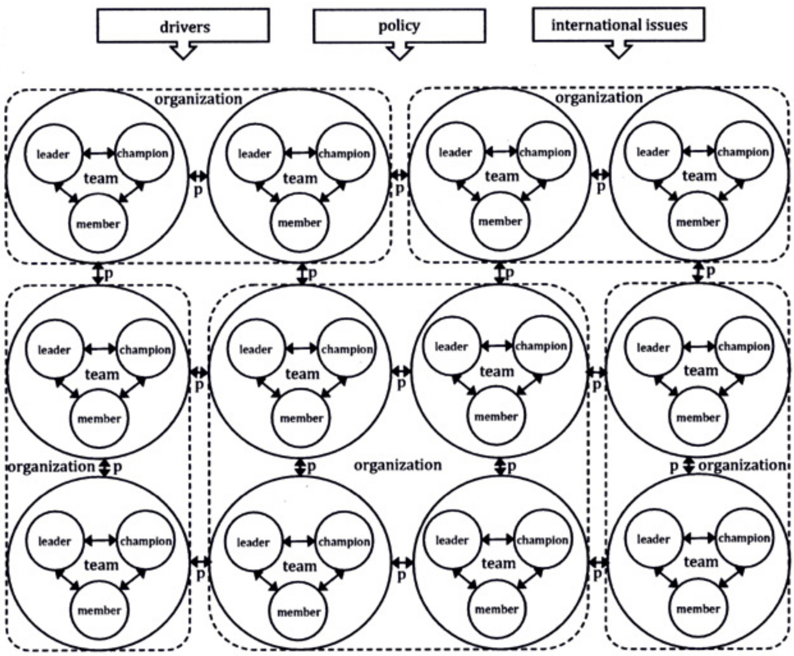


Figure 5.6 Integrated model of management of sustainable innovation considering external drivers and interactions between and within organisations (Bossink, 2011).

fact, they exert on leaders, champions, members of teams, teams and, in and between several public and private organisations. Finally, according to Bossink (2011), sustainable innovation drivers have generally a business nature. The main of these are stakeholder pressure, technological capabilities and knowledge transfer. Obviously, actions simultaneously based on more innovation drivers contribute to the effectiveness of sustainable innovation management.

5.7. Conclusions

The chapter has briefly reviewed some concepts related to the classification of innovations. The concept of architecture has been discussed, with particular focus on architectural innovations. Looking at examples found in literature, some aspects of architectural innovations, as network innovations, early phase design and product modularity have been analysed. Innovation management has been discussed looking at the effects of different kinds of innovations. In particular, this analysis has been done for sustainable innovations in the building sector. This has shown the importance of stakeholders in the process of adoption, and the importance of inter-firm organisation in networks. The following chapters will investigate these influencing aspects for the management of green innovations in residential buildings.

Chapter 6

Construction Stakeholders and Green Innovations

The increasing attention towards sustainability themes has led policies and regulations to promote green technologies in the construction sector. Although many favorable policies have been implemented, several barriers still stymie the adoption of green technologies in buildings (Beerepoot & Beerepoot, 2007; Manseau & Shields, 2005). The high risk in case of failure and the cultural stability about the image of a building are important barriers to changes in organisational practices for the adoption of green innovations (Häkkinen & Belloni, 2011).

It is widely recognised that the construction sector differs from other sectors because its products are unique, expensive, lasting and fixed, whereas its processes are unstable, fragmentary and deprived of a continuous flow (Gluch, 2005). In this chapter, we will focus on a main barrier for the adoption of an innovation, which is represented by the structure of the construction sector. This is based on the temporary network of many actors collaborating side by side in a single project perspective (Anumba et al., 2005; de Blois et al., 2011). The most common barrier to the adoption of sustainable innovations is hence contrasting interests among stakeholders, who consequently behave each against the other. The main example of this is represented by the low interest of the building constructors to invest in energy-saving technologies. One reason for this is that the main benefit for the adoption is for the end-user of the building, whereas the building promoter rarely benefits from innovation implementation (Howarth & Andersson, 1993). Lack of cooperation in the supply chain and inadequate support from governments have often constituted a barrier for energy-efficient choices. Lack of stakeholders with know-how and modest demand represent common barriers to energy efficiency. However, several experiences contradict this simple picture.

Studies have shown that technical and economic potential for the adoption of energy-saving technologies is quantifiable for every stakeholder (Cole, 2000; Svenfelt et al., 2011). Moreover, a strong support from engaged stakeholders has sometimes been a driver for spurring this transformation. For example, institutional customers, such as social housing organisations, generally support the adoption of green technologies in homes. Contrasting examples led to queries which influence stakeholders have on the adoption of energy saving technologies.

This chapter focusses on the preferences of construction stakeholders towards green innovations. Studies about the adoption of green innovations in the construction sector have often focussed on commercial buildings (DeCanio, 1998; de Blois et al., 2011). However, as residential buildings constitute the main typology of building and they have shown particularly resistant to adopt green technologies, residential buildings are analysed in this chapter.

Residential buildings represent the large majority of buildings (Figure 6.1). In Europe, the residential building stock is 75% of the total building stock (ANCE, 2011). In particular, 55% of Italian annual investment in the construction sector is on residential buildings (ANCE, 2011). This helps to explain the importance of the residential sector.

The influence of stakeholders over the adoption of green innovations has shown contrasting results. The lack of cooperation in the supply chain and the inadequate support from governments have constituted barriers for sustainable choices (Lutzenhiser, 1994). Lack of stakeholders with know-how, lack of green production leadership and lack of demand for sustainable innovations represent other barriers for the sustainability transition of any sector, and in particular, of the construction one (Runhaar et al., 2008). On the contrary, the strong support from engaged stakeholders has been a driver for spurring the transformation toward sustainability. For example, Runhaar et al. (2008) found that institutional customers, such as social housing organisations, strongly support the adoption of green technologies in homes.

Contrasting examples led to query about which conditions facilitate the adoption of green innovations. DeCanio (1998) justified the failure in diffusion of energy-saving innovations through the limits of the economic optimisation

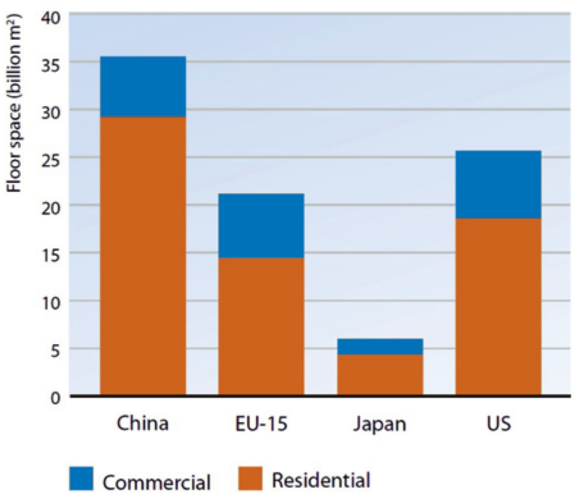


Figure 6.1 Commercial and residential floor space in China, European Union, Japan and US (SBCI, 2007).

and technology innovation rationality. This happens because choices and decisions are always socially embedded and strongly influenced by cultural, personal and institutional constrains (Lutzenhiser, 1994; Gaps, 1998). DeCanio (1998) concluded that human behaviours are difficult to optimise.

Moving from this literature, this chapter aims to understand how stakeholders influence the adoption of sustainable technologies in buildings, and which conditions increase the adoption rates. For this scope, the influence of construction stakeholders over the adoption of green technologies in new buildings is assessed.

The main hypothesis of this research is that the diffusion of energy-saving technologies is slowed by the late participation in the construction process of the stakeholders who have the greatest interest. Consequently, most of the choices related to the construction are done by stakeholders with low motivation for the adoptions of green technologies and high power to impose their will (Cooke et al., 2007). Finally, the chapter aims to identify stakeholders with the potential to push the adoption of energy-saving technologies and conditions which encourage these stakeholders to act.

Two Italian case studies are compared and contrasted: one was promoted by social housing cooperatives, and the other by private construction companies.

The analysis is multidisciplinary and covers several aspects of innovation management as stakeholder engagement, decision-making theory, subjective preference and adoption of an innovation.

The chapter is organised in the following way. Section 1 describes the construction process as a network of stakeholders. This involves the identification of the stakeholders, together with the analysis of their power, and interest. The section analyses the construction process along the time dimension, looking at periods during which each stakeholder participates the construction process. Section 2 describes motivations of stakeholders for the adoption of green technologies. Sections 1 and 2 are based mainly on literature. In contrast, Section 3 reports the empirical application of the previous discussion to the two case studies. Stakeholders are indicated and interviewed to measure their power and interest for adopting energy saving technologies. By comparing the case studies, Section 4 discusses the results of the analysis. Final section contains concluding remarks and suggestions to incentivise the adoption of green innovations.

6.1. Stakeholders of Construction Processes

Section 5.4 has shown that the construction process involves a large number of stakeholders from different backgrounds and with different scopes (Anumba et al., 2005; Chinyio & Olomolaiye, 2009). Consequently, the analysis of stakeholders of constructions is a complex task.

Stakeholders are persons or groups of people who can affect or are affected by the achievement of a project and of organisation's objectives (Freeman et al., 2010). They have been classified as internal or external, if they are members or not of the project (Freeman et al., 2010). Other common divisions are in business against non-business stakeholders, or in primary against secondary stakeholders (Johnson & Scholes, 1999; Newcombe, 2003; Winch, 2010). In the following analysis, only stakeholders who act in a decision-making position for the project organisation and for the adoption of new technologies are considered. The attention is hence restricted to primary stakeholders who have a business or regulative role for the construction project.

6.1.1. Stakeholders' Mapping

Stakeholders' mapping consists of three steps: stakeholders' identification, stakeholders' concern and stakeholder impact analysis (Mitchell et al., 1997). These phases are described below.

The building industry is mainly based on the relationship between the owner of the building and the constructor. However, many people interact in the process and influence choices and adoptions of traditional and innovative technologies (Pries & Janszen, 1995; Cooke et al., 2007; Entrop et al., 2008). The stakeholder's power, commonly defined as the strength to influence decisions, differs among stakeholders (Svenfelt et al., 2011). Consequently, each stakeholder has a different influence over the adoption of different technologies.

The analysis which follows considers construction processes in Italian case studies. The main stakeholders of a construction process are reported in Table 6.1, together with their main foci and objectives. For convenience, stakeholders are divided into four categories which correspond to different sides respective to the project: client, design, construction, and public side. This division revises the classifications adopted in other recent studies (Williams & Dair, 2007; Entrop et al., 2008; Yip Robin & Poon, 2009). Stakeholders in each side share the main focus. For example, stakeholders from the client side invest in the building to use it after construction; they are interested in the value of the building, but internal comfort and energy consumption are among their main objectives. Stakeholders from the design and construction side work in the design and building process respectively, and look at a technically and economically successful construction. Stakeholders from the public side have a regulative role for the project and defend social equity among everyone, even among people not involved in the construction. As shown in Table 6.1, the specific objectives of each stakeholder are different. In addition, objectives among stakeholders on the same category the interests can conflict (Williams & Diar, 2007; Winch, 2010).

Construction stakeholders are internal if formally and directly connected to the project, and are external if simply affected by it (Winch, 2010). Internal

Table 6.1 Stakeholders of the building sector classified for categories, main foci and most common objectives.

Category	**Main Foci**	**Stakeholders**	**Objectives**
Client side	Building Value	User	Usability, energy consumption, internal comfort
		Owner	Reliability, quality, economy
		Financier	Successful completion, time, quality
Design side	Technical Functionality	Architect	Quality, reliability of owner needs, aesthetics
		Consultant Engineer	Specific functionality according to the specialisation
Construction side	Economic and Successful Construction	Project manager	Stakeholder integration, resources coordination
		General Contractor	Quality, profit and workmanship
		Subcontractor	Work in construction
		Product manufacturer	Sale of subcomponents and material products
Public side	Social equity	Local Government	Local development
		Regional Government	Healthy environment, local conservation
		National Government	Healthy environment, energy saving, climate change
		Neighbour & NGOs	Local conservation, minimisation of project disturbance

stakeholders generally are on the client, design and construction sides, while external stakeholders are often on the public side. Anyone who has a stake in the project, but who is not directly related with construction activities, is an external stakeholder and could be considered to be on the public side. Among stakeholders on the public side, the local government is a key stakeholder for any project, as it has the power to allow the construction and has a large influence on typological and technological choices in the building.

Construction stakeholders discharge different functions and duties in the construction process (Yip Robin & Poon, 2009). Therefore, it is not surprising that they have different concerns. Conflicting objectives among construction stakeholders often revolve around long-term versus short-term objectives, cost efficiency versus jobs, quality versus quantity, and control versus independence (Mlecnik et al., 2010). Conflicts are particularly evident if external stakeholders are considered, given the large territorial and economic impact of construction activities. However, simply considering internal stakeholders, many potential conflicts exist as well (Mohsini & Davidson, 1991).

Relationships among internal stakeholders are ruled by contracts, which are generally signed for every project (Miozzo & Dewick, 2002). The most investigated of these relationships is that between the general contractor and its sub-contractors (Costantino & Pietroforte, 2002). In fact, given the fragmentation of the sector, a large number of these relationships exist. This fragmentation constitutes a limit for the adoption of innovations.

Many studies have pointed that new laws continually regulate in new ways the construction activities: this increases the uncertainty and makes more difficult deciding about innovation adoption (Lutzenhiser, 1994; Toole, 1998). The uncertainty about consumer concerns, which are often unknown, represents another barrier for the adoption of innovations. This is particularly valid for residential buildings, as they are generally built before being sold and, consequently, they rarely adopt innovations that could not merit the sure approval of future clients (Beerepoot & Beerepoot, 2007).

An aspect already described in Chapter 5 regards the unequal distribution of stakeholder power. In fact, stakeholders with crucial power over the process often have low interest towards the adoption of new technologies (Lutzenhiser, 1994). On the contrary, the lack of power of those stakeholders who are interested in sustainable technologies represents a barrier for their adoption of these innovations (Williams & Dair, 2007).

Stakeholders' interest and power are scarcely researched themes, especially in heterogeneous networks of actors such as in construction. Mendelow (1981) stated that the stakeholder's power changes according to context conditions. Later, Johnson and Scholes (1999) developed the power-interest matrix basing on how much interested each stakeholder is in impressing his expectation on project decisions and how much power he has to do this. Stakeholder's power is related to his/her ability influencing the project. On the contrary, his interest is related to factors such as motivations, barriers and expectations. According to the levels of power and interest, several kinds of stakeholders can be indicated. This division has often been adopted in stakeholder management literature, although Walker et al. (2008) proposed that the level of impact for the adoption and its probability are discerning variables for stakeholders' classification.

Stakeholder's influence is given by the combination of power and level of interest (Johnson & Scholes, 1999). As these variables change over time, stakeholders' influence is not static, but it evolves during the construction process (Newcombe, 2003). Entrop et al. (2008), using a qualitative graph, showed the influence of several stakeholders in different phases of building processes to visualise the dependence of stakeholders' influence. The dynamic character of stakeholder influence is often covered by their urgency, defined as the degree to which claims call for immediate attention (Jawahar & McLaughlin, 2001). Figure 6.2 represents a revised version of the bi-dimensional power-interest matrix which allows the reporting of time evolution of stakeholders' influence by the inclusion of a third dimension (time axis). This representation will be used in following sections.

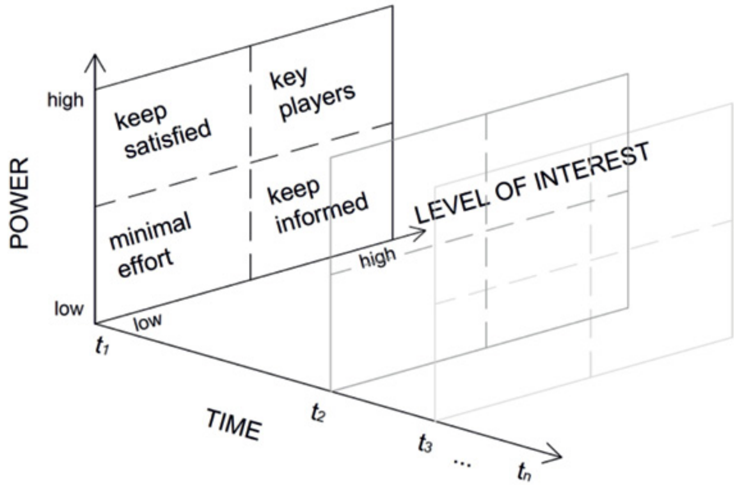


Figure 6.2 Revised version of the bi-dimensional Power-Interest matrix for stakeholder mapping the inclusion of the time dimension to show the evolution of the power and interest (Berardi, 2013).

6.2. Time Analysis of the Process

Section 6.1 has shown that the time in which a stakeholder is involved in the construction process is fundamental for stakeholder mapping. As seen previously, uncertainty about stakeholders' concerns characterise construction processes. Moreover, the fragmentary and temporary organisations of the processes represent barriers for innovation adoption (Miozzo & Dewick, 2002). Generally, stakeholders with high power respond to uncertainties by resisting innovation (Toole, 1998).

Moreover, the time in which a stakeholder starts participating in the process can be a barrier for innovation adoption whenever it is late. In the first phase of the construction process, this is mainly ruled by the municipal and regional governments that have large power over it. Later the project is mainly ruled by design team and general contractor, engaged in design and construction decisions respectively. In particular, the general contractor has significant power for choices regarding technology adoption during building activities given his role of coordination of sub-contractors. Future building occupants often join the construction process after a large majority of the decisions have been made, denying them critical input into the process (de Blois et al., 2011). Some researchers indicated the design team as the key stakeholder for the adoption of innovations (Kubba, 2010), whereas according to others, crucial stakeholders are owners, local governments and contractors (Toole, 1998).

The temporary organisational structure of construction processes represents a barrier for the adoption of innovations also because the fragmentation of the process often provokes the lack of information (Tushman & Nadler, 1978; Toole, 1998; Andreu & Oreszcyn, 2004).

Several studies focussed on barriers and drivers for the adoption of energy-saving innovations (Painuly, 2001; Foxon et al., 2005; Häkkinen & Belloni, 2011). Williams and Dair indicated 12 barriers to the achievement of green choices in buildings (2007). Their findings included, but are not limited to, the technology was not required by the client or was not considered by stakeholders, the stakeholder had no power to enforce the adoption, he was not included or was included too late in the development process and he lacked information, awareness or expertise about the sustainability measures. In different ways, these barriers show a limited influence of some stakeholders over the innovation decisions as a consequence of lack of interest or power.

Williams and Dair (2007) stated that stakeholders' lack of influence of stakeholders for green innovations often happens by avoiding their involvment or delaying the time of their participation. Finally, a recent study has shown that, in the building sector, many stakeholders do not feel they have enough power in implementing innovations (Svenfelt et al., 2011). This obviously constitutes a large barrier for innovation adoption, because it creates a sense of powerless towards the adoption of green innovations.

6.3. Stakeholders' Interest for Green Technologies

The interest in a subject is directly related to both the personal culture and the potential benefits. Culture is attitudinal and behavioural related. It has been categorised into awareness, concern, motivation and implementation (Blank, 1996). These, in turn, refer to the sense of detection of the needs to change an unsatisfied condition, the anxious feelings of an unsatisfied condition, the stimulus to act and the result of behavioural intent respectively. Awareness and concern represent cognitive aspects, while motivation and implementation are related to behavioural actions. In the present chapter, the implementation is considered as a control variable because it represents the outcome of the other three aspects. The focus is on the awareness, concern, and motivation for the adoption of green technologies. In particular, the former two can be composed in the expectation (Blank, 1996). The expectation and the motivation represent the categories to describe the culture. These are strongly related to the interest. Finally, this chapter regards the interest, expectations and motivations for adoption of green technologies in sustainable buildings.

The interest for green technologies of construction companies, local government, design team, financer and clients are briefly discussed below.

In the building sector, construction companies and project managers seldom undertake structured surveys about customer preferences. They generally hypothesise these according to previous experiences and expectations (Pinke & Dommisse, 2009). This was already pointed by Nam and Tatum (1997) who spoke of the "myth" of customer preference. They also indicated that one of the differentiating factors between innovative and non-innovative projects is the overturning of the conventional belief that owners' demands should come first. In fact, in most innovative buildings, the general constructor or the project manager promotes innovations without users' requests (Nam & Tatum, 1997).

The local government is often powerful enough to influence the adoption of green technologies both by implementing tight norms for energy performance and by creating the conditions in which the adoption of green technologies is encouraged (Pinkse & Dommisse, 2009). Although its scope and interest can be limited by regional and national regulations, the local government often owns the land where the building should be sited, or it has the power to decide about the construction. Consequently, its power over decision-making processes is high, especially initially.

Stakeholders from the design side often have a large interest for the adoption of green technologies, also because they generally have the culture and knowledge to assess them (Andreu & Oreszczyn, 2004). However, their power to impose choices is limited. For example, energy consultants have a key role in advising clients about possible sustainable choices but a limited power over the final decision of adoption (Cooke et al., 2007).

The cost of energy-saving technologies is a significant barrier for their adoption worldwide. In some countries, a large attention for sustainable construction is seen among banks and investors. Reversely, in a recent report of the National Association of Italian Construction firms, it emerged that contractors lack a privileged conditions for credit in case of green constructions. This situation represents an important barrier in cases of financial limits, and is recently stopping investments in energy saving technologies (ANCE, 2011).

A stakeholder with an uncertain role for the adoption of technologies is the home buyer. Contractors often experience a lack of customer demand for green technologies (Pinke & Dommisse, 2009). In fact, home buyers do not feel the urgency to choose green technologies and they stay ambiguous, reinforcing the predominantly supply driven status of the residential building market (Pinkse & Dommisse, 2009). Unfortunately, this condition reinforces the predominantly supply-driven status of the residential building market (Madsen & Ulhøi, 2001). In fact, in this situation, construction firms have enough leverage in deciding every technology, and this justifies why the cheapest option is often chosen.

More integrated and informed design and construction approaches have proven crucial for the adoption of green technologies (Hawken et al., 1999, Cole, 2000). In particular, green building experiences have shown the necessity to manage the introduction of innovations through a dynamic coordination among construction stakeholders. In fact, conflicting interests among stakeholders of green buildings have pointed that multi-agent communication, collaboration and support along the construction process are unavoidable for sustainable buildings (Brown & Vergragt, 2008). This is also required because the adoption of energy-saving technologies needs the build-up of specific know-how (Toole, 1998).

The relevance of motivations for the adoption of green technologies not only depends on stakeholders' role, but also varies among projects. This case sensitivity requires looking in-depth at the peculiarities of every project to understand the role and influence played by each stakeholder (Cooke et al., 2007).

6.4. Stakeholders' Influence

The aim of the following case study analysis is to investigate stakeholders' influence on the adoption of energy saving technologies in residential projects. The use of a case study methodology was considered appropriate given the exploratory character of this study. Moreover, the examination of the stakeholders' influence over the dynamic interactions of a building process seemed particularly suited to be analysed through case studies because it allowed better understanding of context specificities. These were hence collected directly through interviews. Case comparison was chosen to better highlight differences in building processes.

6.4.1. Case studies: Italian residential buildings

As we reported in Section 5.6, in 2010, among the 135 M€ invested in the construction sector in Italy, 74 M€ were in residential buildings (ANCE, 2011).

In this high-intensity sector for the national economy, new houses have constituted 38% of the residential sector (ANCE, 2011), and of these, the social housing sub-sector has constituted 30% of the total. These statistics help in understanding the importance that new residential building sector still has.

Case studies were middle size projects. This size was chosen for the larger difficulty introducing green and energy-saving technologies in middle-size projects (Lutzenhiser, 1994; Williams & Dair, 2007).

Any building is a single, unique and unrepeatable case, which made the selection of cases difficult and complicates drawing general conclusions from single-case observations. Reasons behind case selection were their representativeness of the building sector in the context of analysis (the Apulia region in Italy), the possibility to access documents and building site, and the large interest shown by stakeholders to participate in the study. Although these selection criteria implied some biases, it was important to have access to the work site and to be able to interview several stakeholders in each project.

The two case studies are of different kinds: one is a speculative private project and the other is a social housing one. The projects can be described as a supply-driven case and a consumer-driven one respectively. In fact, in the former project, the construction firm realised the buildings to sell houses on the market whereas, in the latter, cooperatives of young families promoted the realisation of the buildings.

Brief descriptions of the projects follow. The first project was a private intervention, which consisted of five new buildings for 100 apartments and rehabilitation of a degraded area. In this project, the general contractor purchased the land from private owners and acted as a project promoter. He accepted an incentive from the local municipality to increase the maximum building volume after having realised public services. The project was of a speculative kind although the agreement was with the local government.

The second project was a social housing intervention that consisted of 96 semi-detached houses. Six different cooperatives bought the land from the municipality and then they obtained the permissions to build houses without taxes and with the conditions to limit the dimensions of the houses (below 95 square meters) and the quality of features (no expensive details). This kind of agreement is common in many OECD countries and aims at giving young families cheaper houses (ANCE, 2011). Each cooperative mandated an architect to design the building, a project manager to coordinate the construction activities and a general contractor to build the houses. Both case studies were realised between 2008 and 2011, following the same regulations and within a distance of a few kilometres from each other.

6.4.2. Stakeholders' Mapping

Stakeholders of each project are mapped in this section. The first project started soon after the general contractor bought the land. The first step was to reach an agreement with the municipality to increase the project volume. This activity took one year. Then, the general contractor commissioned the design team. Features of the project were established by the design team according to its general expectation and wills, and the requests of the general contractor. Before starting the jobsite, the construction firm selected a project manager who was engaged for contracts with material product manufacturers. A sales agency was mandated with sale activities and relationships with clients. Sales lasted during all construction phases, whereas several unsold apartments were put on the market fully built. The main parameter for sale transactions was the floor surface and the location.

The second project was a typical social housing intervention. The Italian law allows young families to organise into cooperatives and to ask the local municipality for a piece of land on which to build new houses. This process is generally slow because the municipality has to find and expropriate the land before selling it to the cooperative. Meanwhile, members of each cooperative discussed house design, they selected a project manager, an architect and some specialised engineer consultants. To each design team, they furnished requests for the building design. The project was then presented to the municipality, which verified the respect of the agreements. After the approval of the blueprint, the project manager invited several construction firms. Then the cooperative evaluated the realisation proposals and selected the construction firm. Construction began and the general contractor chose subcontractors and construction materials mainly on the basis of lowest possible prices. During construction phases, cooperative interests were protected by the project manager and the architect. Limited changes were possible among houses of the same cooperative, as members could personally decide few features only. However, different cooperatives decided to adopt different technologies. For example, one cooperative adopted photovoltaic systems, while the others selected solar thermal panels. Table 6.2 reports for each project the mapped stakeholders and the time of initial involvement in the building process.

The numbers of stakeholders who were interviewed during the study are reported in parenthesis in table 6.2. The owner of the building was the general contractor in the first project whereas in the second project, the users were the owners.

Table 6.2 Mapped stakeholders of the case studies (the number of interviewed is in parenthesis).

	FIRST PROJECT (Speculative Private)		**SECOND PROJECT (Social Housing)**	
	Stakeholders	**Initial Involvement Time**	**Stakeholders**	**Initial Involvement Time**
Client side	Users (3)	During construction or after it (*variable*)	Users (2)	From beginning
	Owner = General Contractor	-	Owner = Users	-
	Financier (1)	From beginning	Financier (1)	Starting point of the construction
-	Sale agency (1)	Before construction	-	-
Design side	Architect (1)	After land acquisition	Architect (2)	After land acquisition
	Energy consultant engineer (1)	Before construction start	Energy consultant engineer (1)	After land acquisition
Construction side	General contractor (1)	From beginning	General contractor (1)	After project approval
	Project manager (1)	From beginning	Project manager (1)	From beginning
	Product manufacture (1)	Before construction start	Product manufacture (1)	During construction
	Subcontractor (4)	During construction	Subcontractor (1)	During construction
Public side	Local municipality (1)	Before construction	Local municipality (1)	From beginning

6.4.3. The measure of stakeholder's influence

Semi-structured interviews with 23 stakeholders were conducted between February and May 2011. Fifteen interviews regarded the first project and eleven regarded the second one, whereas three stakeholders participated in both projects. Each interview lasted 1.5 hour on average, was recorded and then transcribed. Interviews aimed at knowing and assessing stakeholders' power and interest for the adoption of energy-saving technologies.

A semi-structured questionnaire was used to collect answers (the interview is in the Appendix), but the interview always maintained an open character. The questionnaire contained qualitative and quantitative questions: a combination of these has resulted in a better measure of stakeholders' preferences as it is useful to assess the consistency of qualitative answers through quantitative results about sustainability-related choices (Parnphumeesup & Kerr, 2011). Triangulation of results was obtained by comparing stakeholders' answers, checking the coherence of the answers given for each stakeholder by others, and considering secondary information data such as the findings of visits to the jobsite, direct observation of meetings and discussion between stakeholders. Finally, it was possible to analyse the design documents and contracts between stakeholders: these sources were particularly useful to reveal the requests and expectations among stakeholders.

6.4.4. Formulation of the questionnaire

The questionnaire was based on recent researches on attitude and behaviour changes for sustainability. The theory of human behaviour and human decision process (Ajzen, 1991) was considered, whereas aspects about construction culture were mainly drawn from the CIB study in Abeysekera (2002), and by the review of sustainability aspects in Chapter 3. Green technologies were categorised following current sustainability assessment systems in Chapter 4 in water supply efficient technologies (WE), envelope efficiency characteristics (EE), systems for Indoor Air Quality (IAQ), renewable energy technologies (RET) and green materials (GM). The technologies discussed through the questionnaire are reported in Table 6.3

Table 6.3 The energy-saving technologies considered in the questionnaire and in the interviews.

Water Efficient Technologies WE	**Envelope Efficient Technologies EE**	**Heating/Cooling Air Technologies IAQ**	**Renewable Energy Technologies RET**	**Green Materials GM**
Rain water tank Rain water filtration for WC use	Triple-glazed window High performance envelope (roof+ façade)	Condenser boiler Recovery air unit Radiant cooling/ heating	PV panels Solar water heater	Low VOC painting Eco-concrete

The questionnaire regarded expectations and motivations for the adoption of green technologies in buildings. It was divided in four parts in which the interviewed was asked about:

- the construction process, his role, entering time and duration of his activity;
- to rate his and other stakeholders' power for choosing, and to indicate the evolution of his power among the planning, design, construction and utilisation stages of the project;
- energy-saving technologies adopted in the building, specifying technologies for WE, EE, IAQ, RET and GM which have been chosen, and to rate expectation about technologies in any of previous categories;
- motivations for adoption of energy-saving technologies by rating a list of literature-based motivations, and describing what he did to influence a more efficient building, also by rating his power for energy-efficient choices.

Each stakeholder answered for himself, without comparing his point of view with that of the company he worked for. Stakeholders were leaders in their respective roles whereas people who worked on applying decision of others were not interview as they had a limited power in the process of decision making.

Both expectations and motivations were decomposed into five indicators. Expectations referred to the performances of the previous five categories of green technologies. For each of these, the interviewed rated expectations on a Likert scale from 1 (very low) to 5 (very high), in accordance to similar studies (Vermeulen & Hovens, 2006; Olander & Landin, 2005). Moreover, in order to limit the fuzziness of qualitative answers, the interviewed was asked to assess the extra-cost he/she would consider paying for adopting energy-saving technologies in each one of considered categories. He/she was also asking to assess the will to spend a fixed amount of money in each of previous categories of technologies (McGilligan et al., 2010). Questions about extra costs for the adoption of energy-saving technologies regarded stakeholders on construction and client sides only. Finally, the power of each stakeholder was qualitatively assessed on a Likert scale from 1 to 5. The appendix contains the questionnaire which was used for the interview.

6.4.5. Results of the survey

Table 6.4 contains the results given by each stakeholder to the absolute power for project choices, the expectation and motivation for adoption of technologies, and the power for choice green innovations. Whenever more stakeholders were interviewed, the average value of their answers is reported in Table 6.4. The results of interviews with the financiers of both projects, the sale agency of the first project and the product manufacturers of both projects are not reported. These interviews contributed to give a better picture of the decision making process, but both the financiers and the sale agency showed little power to influence the adoption of green technologies. On the contrary, the role of product manufacturers was fundamental and the decision process of adoption was better understood trough them.

As the indicators used to measure the motivations for adoption of energy-saving technologies are related to benefits, the questionnaire implicitly assumed a positivistic point of view according to which, the adoption of technology is favoured by a stakeholder if he/she recognises a benefit. Moreover, the methodology used in the interviews can suffer some biases for limited human capacity of self-evaluation, self-reporting inaccuracy and discrepancy between response and real action. For this reason, the numerical rates were given by the stakeholder after having described both the interest towards each technology and his actions for this. The comparison between qualitative and quantitative answers and the cross comparison among interviews confirmed the validity of answers.

Finally, the interest for the adoption of technology was calculated from the combination of results for expectations and motivations. For simplicity, in order to measure the interest of each stakeholder for different green technologies, the interest was calculated by multiplying the average motivations value with the expectations for different technologies.

6.4.6. Analysis of the results

Results in table 6.4 suggest many considerations. Users in both projects reported similar motivations for energy saving technologies, but their expectations showed lower values in the private speculative project. In this, customers (users) perceived a reduced power over the process and assessed with a low value their project power.

Stakeholders from the design side, both the architect and the energy consultant engineer, had high power for the decision of adoption of innovations. This was true both in the cooperative project and in the speculative one as it clearly emerged during the interviews, when one member of a cooperative affirmed "*the architect is a well-known professional. He always tried to explain possible choices, and after the analysis of the energy consultant, he easily convinced us to adopt PV panels*". On the contrary, the general contractor of the speculative project declared, about the same topic, "*it is a crisis time for construction since 2008, and I have several unsold apartments in the city. Within this market situation there is little justification to invest in solar energy technologies, especially if the houses are unoccupied for long time before being sold. The architect knew this. None of my customers have shown interest in renewable energy technologies, because none of them would pay the difference of price I would ask if I had put*

Table 6.4 Results of the surveys for the two case studies (WE=water efficient technologies, EE=envelope efficiency, IAQ=Indoor Air Quality, RET=renewable energy technologies, GM=green materials).

Stakeholder		POWER			INTEREST									
		Power for general adoption		Power for adoption of green tech	Expectation for adoption of green technologies					Motivation for adoption of green technologies				
		Self rate	Others' Average rate	Self rate	WE	EE	IAQ	RET	GM	Market demand	Higher ROI on sale-rents, subsidy, no tax	Simple to use, technically mature, easy to fit	Reduced environ-mental impact	Image awards publicity
User (U)	I Project	1.7	1.8	3	1	3	2	2	2	3	2	1	2	3
	II Project	3	3.5	3.5	2	3.5	3.5	3.5	2	2.5	2.5	2.5	3	3.5
Architect (A)	I Project	3	3	3	2	3	3	4	3	3	3	4	4	4
	II Project	4	4	4	4	4	4	4	2	3	3	3	4	4
Consultant Engineer (CE)	I Project	3	2	4	2	4	5	5	2	2	4	4	4	2
	II Project	4	4	4	1	4	3	3	3	3	3	4	3	3
General Contractor (GC)	I Project	5	5	4	1	4	2	2	3	2	2	2	2	3
	II Project	3	2	2	1	3	2	2	1	2	1	2	2	1
Project manager (PM)	I Project	4	3	4	1	3	3	3	3	3	3	4	3	3
	II Project	4	4	4	3	4	3	4	4	3	2	4	4	3
Sub-contractor (SC)	I Project	1	1.75	2	1	3	2	4	3	3	2	4	4	3
	II Project	1	1	1	2	2	2	3	3	2	3	4	4	4
Municipal Government (MG)	I Project	3	4	2	2	2	1	2	1	2	1	1	2	3
	II Project	3	4	2	4	4	2	3	4	2	3	2	3	3

photovoltaic systems". Vermeulen and Hovens, (2006) interviewing Dutch managers of construction firms, recorded positive motivations towards green technologies which are easy to fit in and easy to use, but negative motivations for the absence of market demand: this agrees with findings of the present study. Asking the general contractor of the speculative project the motivations of the design team for energy saving technologies, he answered "*I know the market situation and the costs of green technologies, so I limited to the cheapest innovations in the buildings*".

The results obtained interviewing subcontractors of the two projects were similar between the projects, although during the interviews, it emerged that in the speculative project subcontractors had more room for suggestions with the general contractor than in the social housing project. In fact, in the speculative project the general contractor had a larger decision-making power, being also the project promoter. On the contrary, in the social housing project, subcontractors never knew cooperative members and limited their relationships to the general contractor, who preferred to keep the construction costs as low as possible.

The municipal government was considered a powerful stakeholder in both projects. In the speculative project, the municipal government authorized the volumetric increase of the building, while in the social housing project cooperative members recognised the fundamental role for the approval of the cooperative. Although local government was recognised as highly powerful by every stakeholder, the head of the technical office of the local government underestimated his power especially that for the choices related to the adoption of green technologies. Expectations for green innovations of the head of the municipal technical office were slightly higher in the speculative project than in the social housing one. However, questioned about what he had done to promote green technologies, he affirmed "*my role is to control the respect of public regulations and not to influence people's choices. There are so many national laws related to sustainability features that for me, it is sufficient to respect them. The city mayor can request municipal regulations if he wants the technical office to judge and promote stricter sustainability measures in the buildings. However, he had not done this*".

The interviewed were also asked to judge possible modifications of their power and interest along the process. The time evolution of stakeholders' power and interest change during the construction processes. The graphical representation in Figure 6.3 shows differences in the time of action for each stakeholder. The most significant difference between the two processes is represented by the involvement of users of the buildings. In the social housing, users are key players, and have high power and interest for the adoption of green innovations.

Considering the time in which every stakeholder enters the construction process and the duration of his activities, it is possible to assess the interest for

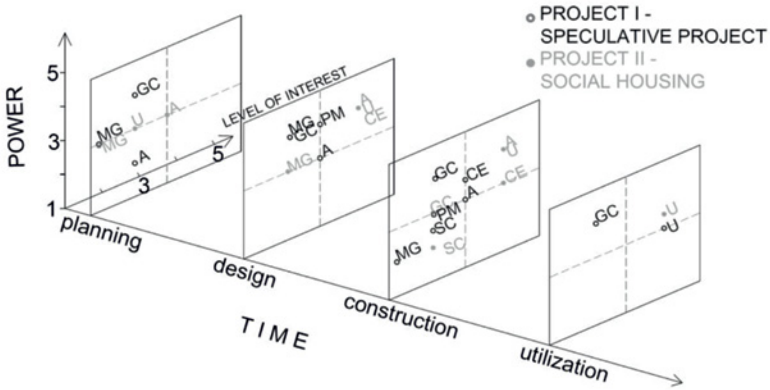


Figure 6.3 Power-Interest matrices with stakeholders' positions towards the adoption of sustainable technologies in the two case studies at different time of the construction process (User (U), Architect (A), Consultant Engineer (CE), General Contractor (GC), Project manager (PM), Sub-contractor (SC), Municipal Government MG)).

the adoption of energy-saving technologies in the construction processes. In the speculative project, the general contractor, the project manager and the local municipality did not discuss adoption of energy efficient technologies at early times, as these stakeholders had low interest in them. The interest increased when the architect was contacted and then, during the construction, when the energy consultant engineer entered the process. On the contrary, in the planning stage of the social-housing project, every stakeholder with an interest for the adoption of green technologies participated in the process. In particular, at the end of the design stage, when also the consultant engineer entered the process, all the interests had already emerged. This difference between the projects underlines that building users in the speculative project entered the process late, when most of decisions about the adoption of technologies had already been done.

Having measured the level of interest and the power for green choices, stakeholders' influence on the adoption of green technologies was determined multiplying them. Obviously, values obtained by multiplication have low meaning and should be considered as qualitative measures of relative influences among stakeholders. Levels of interest largely differ among stakeholders of the same project and among the same stakeholders in different projects. Figure 6.4 reports, for each of the two case studies, the influence of each stakeholder for the adoption of different green features. Influence values can be evaluated as relative values allowing the comparison among stakeholders.

A larger influence of the architect and energy consultant engineer in the adoption of green technologies in the social housing case study emerged. Moreover, results in Figure 6.4 confirm perceptions obtained during the interviews: stakeholders on the client side had a limited power in the speculative project, whereas the general contractor maintained a strong influence over choices.

Finally, the representation of stakeholders' influence in Figure 6.4 permits us to visualise the lower influence for the adoption of green technologies in the speculative project than in the social housing one.

Section 6.3 has highlighted important barriers related to stakeholders' influence for the adoption of energy-saving technologies in Italian houses. In the speculative project, the general contractor anticipated most of the building costs. The financier did not require any guarantee about the adoption of energy saving technologies in the construction, showing a lack of attention for these. At the same time, the general contractor did not perceive consistent availability of higher sale prices in case of adoption of energy saving technologies. In this scenario, general contractors rarely invested in technologies more expensive than law requirements. In fact, the uncertainty about sale time led the general contractor to consider the adoption of energy-saving technologies as a supplementary cost and to reject most of them.

However, differences among technologies emerged as the construction firm was more motivated adopting some technologies than others: expectations for the selection of energy efficient envelope (EE) and green materials (GM) were higher than systems for indoor air quality (IAQ) control or renewable energy technologies (RET). The general contractor indicated that, behind his larger interest for some technologies, there was the preference to limit the costs and

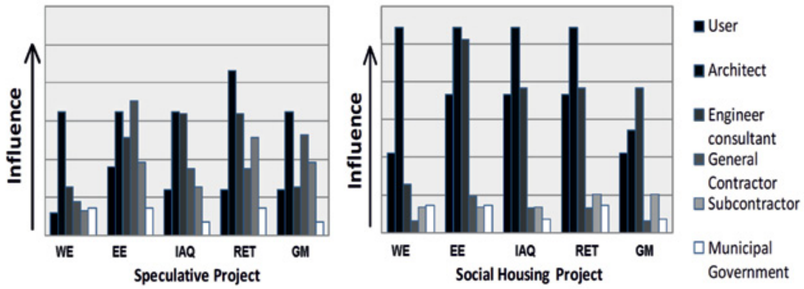


Figure 6.4 Stakeholders' influence for green choices calculated from the level of interest and power (WE=water efficient technologies, EE=envelope efficiency, IAQ=Indoor Air Quality, RET=renewable energy technologies, GM=green materials).

risks of the adoption of innovations, and hence, his preference for simple-to-fit technologies. Highly insulated windows or thermal insulating plasters were hence preferred to more complicated IAQ systems or water depuration (WE) systems, as these were judged to be complex and risky. RET technologies were simply considered expensive.

The results of the study showed the importance of strategies to increase stakeholders' influence towards greener buildings. A home buyer in the speculative project declared "*I would like having some solar energy systems in my house but when the general contractor told that the roof had already been designed without them, I accepted to buy the house because I agreed to the location and the price*". This confirms the supply-driven character of the construction in many speculative projects. On the contrary, in the social housing project, future building users were involved in the green technology assessment and in the decision-making processes. The energy consultant engineer advised them about energy-saving potential, thus furnishing a knowledge power. He was directly linked to future users of the building and the result of his consultant activity positively affected the adoption of green technologies.

Although members of the cooperatives were particularly interested in green technologies, they did not show homogeneous behaviours. In fact, different interests led to different RET adoptions among cooperatives. Reasons for differences can be explained by the different architect's and engineer's suggestions, confirming that the design team can play a large role in the promotion of sustainable technologies. Finally, the case studies have shown that in the context of analysis, there is a very low motivation for WE technologies and GM among all the users.

6.5. Conclusions

The chapter has investigated a main barrier for the adoption of green innovations in the construction sector: stakeholders with power to select green technologies often have no interest in their adoption as they have no evident benefit. The large uncertainty and the lack of information and communication increase the reluctance against the adoption of green technologies in buildings. Moreover, it emerges that while international boards, national and regional governments have put the green building theme on the agenda, local municipalities are making a poor effort to promote the adoption of green innovations. The local government is often an internal stakeholder in construction processes; it has the power to approve the project and it decides on local building regulations. This paper has shown that in the selected case studies, interest of the local government towards the adoption of sustainable technologies was limited, and its efforts were minimal because it mainly focussed on legal and social aspects.

The research suggests that for the promotion of green technologies, it is necessary to favour more integrated relationships between construction stakeholders and to increase circumstances for market demand of green technologies. In particular, process organisations and policies which increase final users' power and allow the growth of emerging interest for the adoption of green innovations should be supported.

Social housing organisations have shown more able than speculative projects in favouring contexts in which stakeholders can push the adoption of green innovations both because the power of the final users is higher and their interest emerges earlier.

Finally, it is important that material suppliers and subcontractors have occasions to show new available technologies to design team and future users to increase the market demand for them. This means to shift the construction sector to a market demand sector. The difficulties of organisations for the management of green innovations and the organisation of the interactions between stakeholders will be the topic of the next chapter.

Chapter 7

Organising the Process of Sustainable Building

This chapter investigates which interactions between firms of the building sector can favour the adoption of green innovations, and hence more sustainable buildings.

The efforts to increase the diffusion of sustainable building are growing at international and national levels, and many products for sustainable buildings already exist (Butera, 2010). In Chapter 1, we have underlined that both the technical and economic potentials for sustainable buildings exist (Hoffmann & Henn, 2008; Svenfelt et al., 2011). However, as emerged from the literature review in Chapter 5, and from the case studies results in Chapter 6, the construction sector is particularly slow in moving towards sustainability (Vermeulen & Hovens, 2006).

In this book, we reviewed researchers about barriers to the adoption of green technologies. An important barrier to the adoption of green innovations has been indicated in the structure of the construction sector (Manseau & Shields, 2005; Williams & Dair, 2007). This is based on temporary relationships between many firms who collaborate side by side within a single-project perspective (Anumba et al., 2005). In this context, the adoption of green technologies is contrasted by an agent vs. agent problem (Howarth & Andersson, 1993; Son et al., 2011).

As seen in Chapter 5, several studies have investigated how construction firms are modifying their practices and their inter-firm organisations in order to adopt sustainable innovations (Rohracher, 2001; Brown & Vergragt, 2008; Bossink, 2011). The main result of available studies is that new organisations of construction processes are necessary; meanwhile, firms have to acquire the knowledge necessary for the transition to sustainability of the sector. However, the evolution of the relationships between firms represents an open topic of research.

Existing studies have focussed on commercial and office buildings and rarely looked at residential buildings. Moreover, the inter-firm organisation in the Italian construction sector has never been considered in literature. Hopefully, the study reported in this chapter will contribute to fill these gaps. This chapter focusses on middle-size residential projects. As already seen previously, the size of the projects was chosen because of the greater difficulties in introducing green innovations in middle-sized projects (Williams & Dair, 2007). In particular, given the representativeness of the Italian construction sector for other European countries and the lack of studies about sustainable buildings in Italy, construction processes of new residential buildings are discussed.

In this chapter, the organisational relationships between firms involved in construction processes are considered. The research aims to investigate how these relationships change as the sector moves towards sustainable practices for green buildings through the adoption of sustainable innovations. This chapter is interested in finding how these relationships evolve. In particular, given the key role played by the general contractor in construction processes (Winch, 2010), this chapter aims to answer this question: *which modifications in the relationships between the general contractor and other firms are there in green buildings?*

This chapter is structured in the following manner: Section 7.1 describes inter-firm organisation in construction processes. Based on literature results, Section 7.2 presents a research model for the analysis of organisational changes of construction processes. Section 7.3 reports the methodology of research and investigates the organisational features in some case studies together with the results of data collection. Section 7.4 discusses the results and tries to respond to assumptions in Section 7.1. To do this, the organisational features are analysed stressing the differences between inter-firm organisation in traditional and green buildings. The chapter ends with some conclusions.

7.1. Organisation of Construction Processes

As seen in Chapter 5, the construction process is the series of activities of planning, realisation, and direction through which materials and equipment are assembled into a building (Walker, 2007). These activities are not limited to those realised on the jobsite. Consequently, firms working at the jobsite, first-order suppliers and other actors of the process, such as the design team or real estate financier, have to be considered when investigating the organisation of construction process (Manseau & Shields, 2005). All the activities and relationships from the urban plan and negotiations for a building to completion of the building are here considered.

Given the large number of firms in construction processes and the non-integrated structure of the sector, the organisation of the processes is fundamental. The uncertainty and fragmentary nature of construction processes have been suggested as reasons for the high transaction costs for innovations in the building sector (Williamson, 1991; Hobbs, 1996). Moreover, the instability of the production environment has been accused to fragment the supply chains and determines low efficiency and high unpredictability (Black et al., 2000).

A controversial aspect for the adoption of green innovations in buildings is the size of firms. Most firms operating in the sector are small and medium enterprises (SMEs) with a low degree of specialisation (Manseau & Shields, 2005). These firms, instead of considering the adoption of green technologies, refuse them or prefer simple ones. Presently construction firms often replace traditional components with green ones without a calculated systemic approach to sustainable building (Vermeulen & Hovens, 2006). Looking at the transition to sustainable buildings and given the non-integrated structure of the construction sector, the organisation of construction processes is studied by investigating inter-firm relationships and characteristics of the firms which are involved.

7.1.1. Inter-firm relationships in construction processes

Nonlinear models centred on inter-firm relationships have been shown to be appropriate in analysing the transition to sustainability of the sector (Pagell & Wu, 2009; Grin et al., 2010; Loorbach et al., 2010). Previous methodologies are appropriate to study the transition of the building sector too, as this requires a re-organisation of the process (Walker, 2007). Researchers have studied inter-firm approaches by analysing primary firms together with sub-contracting, manufacturing and service companies (Bossink, 2007, Baas, 2008). Inter-firm relationships had received a lot of attention in construction management literature before the movement for a transition to sustainability (Albino et al., 1998, Bossink, 2002). However, given the interest in green buildings, studies about changes in inter-firm relationships are now particularly urgent (Bossink, 2007).

In the building sector, inter-firm relationships are fragmented but frequent. Having looked at homebuilders in the U.S., Eccles (1981) found a low number of subcontractors considered for performing each trade in the project, a long-term business relationship between each homebuilder and the subcontractors, and a low frequency of formal competitive bidding procedures for the selection of subcontractors. Later, Dioguardi (1983) defined the concept of macro-firm to indicate the large stable network of contractors and subcontractors. Finally, Dahl and Dalum (2001) defined the construction cluster to stress the frequent relationships between construction firms.

The key firm when considering the relationships in construction is the general contractor, as it manages the sub-contractors, material and service suppliers, design consultants and customers (Winch, 2010). Different relationships between a firm and its suppliers have been recognised in the literature, spanning basic trading negotiation to partnering (Bresnen & Marshall, 2000) and comakership (Lamming, 1993). Cooper and Ellram (1993) stated the differences between traditional trading relationships and supply chain management in terms of information sharing, coordination, joint planning, and amount of shared risks.

In the construction sector, relationships between firms are often far from the criteria of supply chain management given the low levels of integration with suppliers (Hobbs, 1996; Bresnen & Marshall, 2000; Bossink, 2002). Focussing on supplier sourcing, Vrijhoef (2007) identified four relationships with suppliers:

price-focussed incidental sourcing, quality-focussed sourcing, collaborative integral sourcing, and integrated chain sourcing focussed on early supplier involvement and transfer of responsibilities. This last selection strategy has been shown to be propaedeutic to increasing the rate of innovation of a process and to building a comakership with the supplier (Womack et al., 1990; Lamming, 1993; Pagell & Wu, 2009).

Comakership has been largely investigated in the literature on organisation. It is defined as a mutually intensive and integral relationship based on openness and trust (Compton & Jessop, 1995). Lamming (1993) indicated that, when considering levels of cooperation with suppliers, comakership is the most powerful strategy because it encourages a joint approach to problems; the active involvement of suppliers in a partnership allows opportunities for innovation to be identified by exploiting suppliers' strength and expertise.

Looking at the evolution of networks of firms involved in sustainable innovation adoption, Foster and Green (2000) described several successful relationships between partnering firms. They found that to speed up the development of greener products and services, supply companies with the capacity and will to innovate need room to push their sustainability-related abilities.

The importance of supply chain management in the production of sustainable goods has received increasing attention (Seuring & Muller, 2008; Seuring, 2011). Green building process partnerships with suppliers have been described by Dahl and Dalum (2001) and Vermeulen and Hovens (2006). In both papers, which were reviewed in Chapter 5, the integration of the general contractor with suppliers proved to be a key factor to the adoption of innovations.

An important inter-firm relationship in construction processes is between the general contractor and the design team. Although the latter often acts as a service supplier for the general contractor (Bossink, 2007), its power and influence over the final construction are much more important than those of any other supplier. In fact, material and design choices are mainly the responsibility of the design team, which is consequently a primary actor for changes in the organisation of processes for green building (Maciel et al., 2007).

Finally, the relationship between the general contractor and material and equipment suppliers, and between the general contractor and the design team have to be considered analysing the characteristics of inter-firm organisation.

7.1.2. Characteristics of firms for sustainability partnerships

When analysing changes in the organisation of construction processes adopting sustainable innovations, it is important to consider a few characteristics of the firms involved. In particular, their specialisation is fundamental for partnership selection and for building innovative environments (Kemp et al., 1998; Grin et al., 2010).

The characteristics of firms have been shown to determine the success of integration of sustainable innovations in many sectors moving to sustainability (Runhaar et al., 2008, Nill & Kemp, 2009, Loorbach et al., 2010).

Albino et al. (2009) showed the importance of the sustainability specialisation of firms which are involved in the development of green products. In particular, looking at sustainability-driven companies, they found a high correlation between the development of green products and the existence of environmental strategies. A similar finding has also recently been proven in the construction sector, where firm specialisation and sustainability strategy have been discussed both for the general contractor (Son et al., 2011) and the suppliers (Brown & Vergragt, 2008).

Sustainability specialisation can be related both to previous experience and to specific qualifications in sustainability. Unfortunately, the building sector is seldom able to recognise firm specialisations. Gluch (2005) has shown the great importance that sustainability-related experience can have for suppliers of green buildings. In fact, their knowledge about green issues has proved fundamental in solving the unexpected problems of sustainable buildings.

Considering the high influence that the design team has in managing innovations in construction, some studies have focussed on the sustainability specialisation of the design teams involved in innovative construction projects (Maciel et al., 2007). This has shown that the sustainability-related experience of the members of the design team is fundamental for the integration of sustainability principles into the building.

Another way to allow the specialisation of a firm to emerge is by looking at its sustainability certification. Poor knowledge of certification programs has been recorded in Europe (ANCE, 2011). For example, in Italy, inter-firm relationships are often based on labour subcontracting and cheapest option only. Both these approaches discourage the certification of firms. However, in the last twenty years, the spread of the sustainability paradigm worldwide has favoured the diffusion of certification systems to assess the sustainability of buildings and the competences of the actors (see Chapter 3). Consequently, in many countries, certifying associations have been created both to assess the buildings and to recognise expertise and leadership in sustainable construction. These systems represent a new factor for inter-firm relationships in the building sector, and are becoming a marketable skill for firms involved in sustainable projects. In this way a clearer process of specialisation in sustainability topics has been recorded worldwide. Previous sustainability certification systems have been used as labels to show experience in sustainable projects (Maciel et al., 2007).

Finally, it is important to consider the level of specialisation of the firms involved in construction processes (general contractor, suppliers and design team), and their sustainability qualifications to analyse the organisational changes related to the sustainability transition of the construction sector.

7.2. Research Model and Features of Analysis

The discussion of organisational characteristics in construction processes has shown the importance of considering both inter-firm relationships and the characteristics of the firms involved. Based on literature findings in Section 6.1, four features have been selected for the analysis of construction processes. They are:

- the level of integration between the general contractor and its suppliers;
- the level of integration between the general contractor and the design team;
- the degree of specialisation in sustainable buildings of the firms involved in the process;
- the qualifications related to sustainable buildings of the firms in the process.

One or more proxy variables are chosen for the assessment of each of the above features. Before describing these, it is important to remember that the study adopted a qualitative methodology. Consequently, previous variables have been considered qualitatively as themes of analysis more than quantitative variables.

The variables which were selected to describe the level of integration between firms (relationships between general contractor and supplier, and between general contractor and design team) are the phase of the process in which the relationship started, the reasons for the selection and the frequency of transactions between the firms.

The variables for the degree of specialisation of the firms involved in the construction process (the general contractor, the design team and the suppliers) are the proportion of their portfolio that involves sustainable projects, and the presence of environmentally-related qualifications.

The units of analysis for the four features are different, considering the dyadic relationship between the construction firm and its suppliers when the integration relationships are assessed (Unit of Analysis 1 and 2, in Figure 7.1), and the firms and their activities when portfolio and environmental certifications are evaluated (Unit of Analysis 3 and 4, in Figure 7.1). Figure 7.1 shows the framework and the unit of analysis used to analyse construction processes. The adoption of the units of analysis should not be interpreted analytically, because the research was qualitative and used a "case study" methodology (Myres, 2008). Consequently, the units of analysis have been considered as elements of observation.

This research assumed that mutual relationships exist between the previous organisational features and the "greenness" level of the building. This does

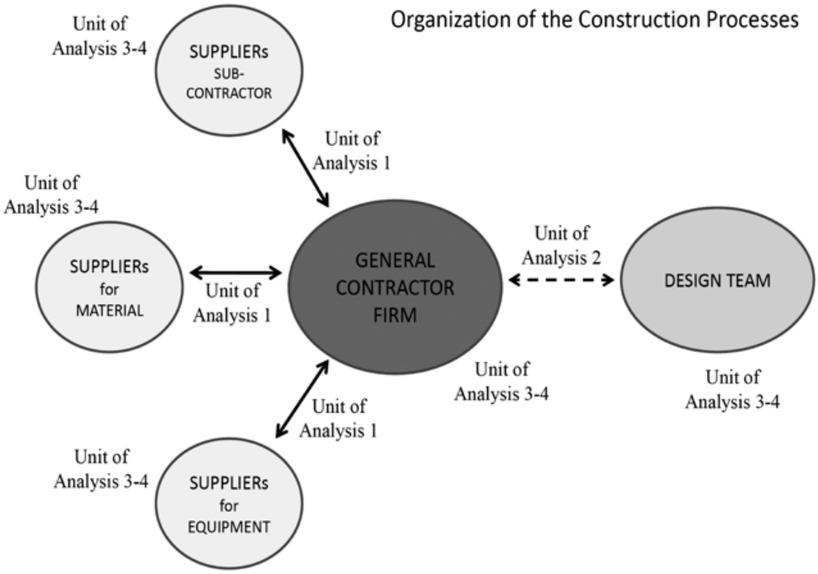


Figure 7.1 Organisational relationships of the construction processes and units of analysis of the research (Albino & Berardi, 2012).

not mean that the proxy variables and sustainability level of the building act similarly to (in)-dependent variables, but they reciprocally influence each other. In fact, construction activities are often unplanned and many adjustments and choices are made during construction, depending on the possibilities created by the actors themselves.

The hypothesis of this chapter is that the variables described above show how buildings with different sustainability levels can be realised differently. This study aims to compare the features of traditional and green building processes with the hope of identifying the organisational relationships which could be adopted in the construction of green buildings. With this aim in mind and considering the units of analysis, this research was designed to understand whether the construction of a green building requires:

- a high level of integration between the general contractor and its suppliers.
- a high level of integration between the general contractor and the design team.
- involving firms with a specialisation in sustainable building.
- involving firms with certification in sustainable building.

As the recognition of a sustainable building is often a difficult task, the number of green innovations is considered a qualitative proxy indicator. Moreover, in order to classify the innovativeness of the project and to evaluate the awareness of sustainability related topics, the integration level of each green innovation in the building is considered according to the classification in Table 5.3. Finally, among other variables which can influence the organisation of a construction process (Bossink, 2007), the size and location of the building and the structure and size of the general contractor should be considered.

7.3. Case Studies

The previous section presented the model of analysis to study the modifications which are occurring in construction processes during a transition to sustainability. Using this framework, a "case study" methodology was selected.

As already seen in Chapter 6, the adoption of a "case study" methodology was justified by the exploratory and interpretative characters of the study (Yin, 2009). Moreover, the examination of the interactions in complex and variable organisations such as construction seemed particularly suited to be analysed through case studies (Halinen & Tornroos, 2005). In fact, case studies allow better understanding of context specificities by collecting direct information about organisational relationships through interviews.

The theories of interest for this analysis were network analysis (Kenis & Oerlemans, 2008) and decision analysis (Mintzberg et al., 1979). However, the above theories were not used as analytical tools. In fact, the research used qualitative methodology in order to better investigate organisational relationships for the adoption of green innovations.

7.3.1. Research methodology

Three construction projects were selected. The organisational features previously described were captured through semi-structured interviews with the most involved stakeholders. For each case study, the project manager of the general contractor, the head of the design team and the main suppliers of the general contractor were interviewed.

After having interviewed the project manager of the general contractor, the design team and suppliers were then asked selected questions. In this way, multiple interviews allowed triangulation of the answers, especially those which regarded the relationships between the firms.

The interviews were conducted between February and May 2011. Each interview lasted 1.5 hours on average, then it was recorded and transcribed.

The aim of the interviews was to know and assess the organisational practices of the construction firms. A semi-structured questionnaire was used to collect answers (appendix). The interviews maintained an open character, allowing new dimensions not identified in the analytical framework to emerge. In the case of discrepancies between responses, the interviewees were re-contacted to clarify and eliminate the discrepancy. Several situations required further dialogue with the general contractor and with the suppliers. Additional information was also collected through these informal and less structured interviews.

The semi-structured interview has been shown to be particularly useful in collecting data about the organisation and innovation of firms involved in construction projects (Slaughter, 1993; Bossink, 2008; Bossink, 2011). The interviews consisted of both descriptive and numerical answers. The collection in a qualitative study of few quantitative questions has been shown to be useful to assess the consistency of qualitative answers with corresponding quantitative values (Myres, 2008). A similar method was successfully applied in a recent study about stakeholders' preferences for the adoption of green technologies (Parnphumeesup & Kerr, 2011) and has been already extensively justified in Chapter 6.

Triangulation of results was obtained by checking secondary information such as the findings of visits to the jobsite, direct observation of meetings and discussion between firms. Moreover, the design documents and contracts for all three projects were analysed. This source was particularly useful to reveal the performance requests which the general contractor made to suppliers.

At the end of the interviews, a report for each case study was created to present the evidence (Yin, 2009). This report was shown to the general contractor and discussed with him.

The interviews, together with the documental materials, focussed on the management of the construction activities, the organisation of inter-firm relationships and the way in which the green issue affects them. The interview was structured in the following parts:

- general information about the project, and activities and involvement of the interviewee
- the sustainability related qualification of the interviewee and of the suppliers
- the level of integration of the general contractor with suppliers
- the green innovations which have been adopted in the building
- the drivers and barriers for the adoption of green innovations.

After a descriptive response, the interviewee ranked a list of drivers and barriers for the adoption of green technologies.

7.3.2. Selection of the case studies

The main difficulties of studies about organisational aspects in the construction sector are site specificities. Any building is a unique and unrepeatable case. This makes the selection of cases difficult and complicates drawing general conclusions from single-case observations.

In order to limit the influence of regulations and context specifics, three case studies were selected in a medium-sized city in the Apulia region in Italy. The general contractors of the three projects were small firms with less than 20 employees and with two to four qualified people in charge of technical duties. The selected firms represent the local construction industry SMEs firms constitute 96% of that group (ANCE, 2011). This high percentage is a barrier to the introduction of sustainable innovations in many European countries. In fact, in other countries such as the United States, a number of very large firms dominate the residential market and their management structure has been shown to be better able to manage the sustainable transition of the construction sector (Son et al., 2011).

Looking for cases, projects in which construction firms guaranteed unrestricted access to information were selected. Although this selection criterion implied some biases, it was important to guarantee access to the work site and to all the contracts between firms.

During case study selection, the evaluation of buildings of different typologies showed widely different organisational schemes, according to the findings of de Blois et al. (2011). In fact, the organisational aspects between the firms involved in office, residential or other building typologies are very different. Consequently, the selected case studies did not significantly differ in architectural and typological design.

Only residential buildings were selected, following the reasons reported in Chapter 6: the size and importance of the sector make its "greening" up unavoidable, whereas the complexity and the fragmentary nature of the residential sector make the adoption of green technologies more difficult.

As the size of project is an influencing factor over firms' organisation, selected case studies were medium-size projects with 50 apartments on average. This size was considered representative of the building sector in the Apulia region.

7.3.3. Description of the case studies

All the case studies were private projects in which the general contractor owned the land and acted as real estate developer and general contractor. This overlap of roles often characterises average-size residential projects in Italy, and in many other European countries (ANCE, 2011).

As the study aimed to focus on organisational diversities related to the "greenness" of the building, in sampling the case studies, contrasts in green characteristics were preferred. The case studies that do not coincide with those used in previous chapter are presented below.

Project I was a social housing intervention. Construction was not originally allowed on the land where the buildings were to be sited. The general contractor applied for a program to provide "social housing", and following a specific agreement with the regional and local governments, he received permission to build 32 detached houses. This situation gave a lot of power to the local government, which used this power to limit the sale price of the houses. In fact, the agreement expressly constrained the general contractor on the future price, but did not report any conditions on the characteristics of the houses, such as their sustainability level.

Project II was an urban regeneration in which the general contractor built houses of different dimensions, quality, and sale prices. In order to increase the number of houses which he could build, the general contractor signed an agreement with the municipal government. This agreement was voluntarily signed by both parties (the general contractor and the municipal government), and it focussed on the possibility to increase the building surface after having built some public services for the community (a few public toilets and a garden).

Project III was a private intervention in which the general contractor was free from constraints and could build and sell the houses while deciding on all the features. He bought the land and submitted the building project to the local government for approval. In this case, the power of the municipal government was limited to the simple authorisation for building according to the law.

All three case studies were conducted between 2008 and 2011, following the same regulations and within a distance of a few kilometres from each other. Moreover, they affected each other: general contractor III revealed that he had decided to adopt many green technologies to mark the difference between his houses and those in other projects such as the low-price houses in project I.

The three projects had different rates of innovation adoption. Table 7.1 reports some of their green technologies. Project I did not have any significant innovations. Project II adopted some innovations and, in particular, some green ones: for example, rainwater harvesting system for irrigation purposes. Project III adopted, among others, a rain water filtration system, a highly efficient ventilated façade, and active air conditioning radiant systems. Table 7.1 reports a classification of the case studies as traditional or brown building for project I and innovative or green ones for projects II and III. Moreover, according to the kinds of innovations adopted in the projects, the two green projects have been classified as modular and architecturally innovative projects, respectively (Henderson & Clark, 1990; Slaughter, 1993). Innovations in project III have been considered architectural innovations because they changed the traditional configuration of the building sub-components or the order of construction activities.

Residential buildings Croci, Foggia, Italy (case study 2)

This complex has been designed to introduce several energy-saving measurements within a traditional design. Over a traditional (for the site) concrete structure, wooden lines are used to raise the final layer to build a ventilated roof. This allows the integration of solar panels and PV panels. The inclination of the roof on the South side has been optimised in order to have a surface available to integrate panels sufficient for the demand of the houses. This demand is reduced thank to the use of a high-insulating envelope, where the total transmittance is 0.20 W/m^2K. The windows contribute to the high-energy performance having a U value of only 1 W/m^2K.

The construction phases in project II were similar to those in project I. In fact, the innovations adopted mainly regarded modular changes. The interviews showed that most of these changes were not planned, and the decision for adoption was made during construction. For example, the general contractor of

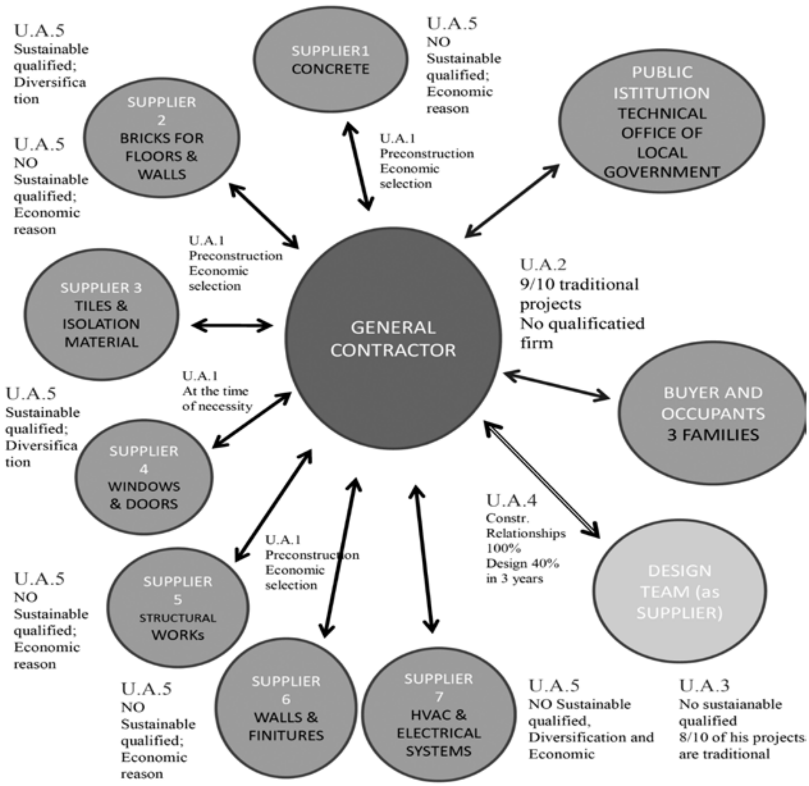


Figure 7.2 Network of stakeholders and firms in Project I, and results of interviews.

Table 7.1 Classification of case studies according to adopted innovations.

	Classification for Adopted Innovations		**Green Innovations**	**Adopted Green Innovations**
Project I	Brown Project	Traditional Project	None	-
Project II	Green Project	Modular Innovations	Few	Water harvesting system, Condensation boiler, Highly insulated envelope
Project III		Architectural Innovations	Several	Water filtration system, Ecological plaster, Thermal bridge correction, Photovoltaic Integrated panels, Active radiant systems with indoor quality control

Table 7.2 Division in categories of sustainable innovations in the three projects.

	WATER EFFICIENCY WE	ENERGY PRODUCTION RET	EFFICIENT ENVELOPE EE	GREEN MATERIAL RESOURCES GM	INDOOR AIR QUALITY IAQ
BROWN BUILDING (traditional building)	Rain water is thrown away	No energy production or just according to law requirements	Standard envelope by law or as common practice	Material selection follows traditional reasons (economic or previous experience)	Law requirements window/envelope and traditional air conditioning systems
GREEN MODULAR INNOVATIVE BUILDING (modular sustainable innovations)	Rain water is reused for grey applications 	PV and solar panels introduced as new elements in the building design 	Highly efficiency envelope: larger isolation, energy saving windows with double glazing 	Bio Materials are selected but used in a traditional way and for the same applications 	Natural ventilation design with control of air/humidity quality 
GREEN ARCHITECTURAL INNOVATIVE BUILDING (architectural sustainable innovations)	A system of water filtration and distribution, purification for reuse 	Total energy/heat water production, and integration of the systems in the design 	Active envelope which integrate different components (i.e. double skin, balcony thermal bridge) 	Selection and integration of local or eco materials. Modularity of the design for integration of material and minimum waste 	IAQ sensors, VMC centralized systems to control air quality. Cooling floor or UFAD for better IAQ 

project II declared that he had always utilized traditional boilers, and during construction, the design team proposed adopting condensation boilers. The general contractor evaluated the possibility with the equipment supplier and decided the adoption of this system in all the houses. This sustainable innovation changed the equipment of the air conditioning system, but it did not provoke any change in the series of construction phases.

On the contrary, some innovations adopted in project III required significant changes in the order of construction activities. For example, the water filtration system was realised during the realisation of the foundations of the building. This overlap of functions required the presence of plumbers and carpenters on the jobsite at the same time. Similarly, the highly efficient ventilated façade was produced and installed by a specialised firm. This required the other subcontractors to leave the jobsite while the specialised firm was working.

Finally, the realisation of active radiant systems required the air conditioning tubes to be embedded in the structural floor slab, and consequently anticipating the construction of the air conditioning system during that of the building structure. A similar change in construction phases was caused by the adoption of photovoltaic panels on the roof in project III. In fact, the adoption of photovoltaic panels was decided since building design, and the roof was designed with the best inclination for the photovoltaic panels. Interviewed about this, the design team of project III declared themselves to have been excited at the idea to adjust the inclination of the roof for such a reason.

7.3.4. Results

Having described green innovations in each case study, it is possible to look at organisational relationships between the firms involved in the construction processes. Table 7.3 summarises the findings of the interviews, grouping them according to the model described in Section 7.2. The results of the study have been condensed following these parameters: level of integration between the general contractor and suppliers, level of integration between the general contractor and the design team, sustainability specialisation, and sustainability qualification of firms.

Looking at the reasons for supplier selection, availability and economic convenience were the main reasons declared by the general contractors of project I and II. On the contrary, supplier selection in project III was based on experience, know-how and specialisation of the supplier and on transfer of responsibilities. This case demonstrated the necessity felt by the general contractor to limit risks in relation to the adoption of innovations. Moreover, early involvement in the project was recorded for several suppliers. Involvement was considered early as the supplier was contacted earlier than in traditional buildings, and possibly, already at the design stage. For example, the supplier of the ventilated façade

Table 7.3 Case studies results according to the features of analysis (Χ = present into the project, ~Χ = slightly present into the project).

Feature	**Integration level of general contractor & suppliers**						**Integration level of general contractor & design team**						**Sustainability specialisation**			**Sustainability qualifications**		
Proxy of analysis	Early involvement	Reason for selection				Previous relationship	Early involvement	Reason for selection				Previous relationship	Portfolio			Certification		
		availability	economic	know-how	risk transfer			availability	economic	know-how	risk transfer		general contractor	design team	supplier	general contractor	design team	supplier
Project I		Χ	Χ			Χ	Χ	Χ		Χ		Χ	nun	nun	nun			
Project II	~Χ	Χ	Χ			Χ	Χ	Χ		Χ		Χ	nun	nun	nun			
Project III	Χ	Χ		Χ	Χ	Χ	Χ	Χ		Χ	Χ		nun	high	low		Χ	Χ

declared having been contacted at the beginning of the design phase to judge the feasibility of the façade. From that time, he was always in contact with the general contractor, and he exchanged plans and documents almost every two weeks for the whole year from the first contact to the realisation of the façade.

As shown, the relationship between the general contractor and the design team is fundamental in construction processes. Previous collaborations with the design team proved to be the most important parameter for selection in projects I and II. On the contrary, the general contractor of project III chose a famous architect with whom he had no experience, but who was well-known in the sustainable construction industry. In contrast to other suppliers, during the selection of the design team, economic considerations had no importance in any of the three case studies. The involvement time of the design team was also independent of the innovativeness of the project, as early involvement was recorded in every project. An interesting aspect of project III was the necessity to select, together with the design team, several specialised consultants. A specialised consultant for the energy systems in the building and a sustainability assessor took part in project III only. In this way, more designers and consultants participated in the project, which adopted more sustainable innovations.

In every case study, no members of the design teams had a sustainability qualification, and the three general contractors also lacked sustainability qualifications. Moreover, the general contractor of project III had no experience in green buildings. Interviewed about the adoption of green technologies in the project, he declared that since the beginning of the project, he had decided to realise an innovative building with sustainable features. He thought this was the only way to reduce the competition which other projects were exercising over his sales. For this reason, he contacted suppliers looking at their capacity to satisfy the necessity and he selected the architect for his visibility and experience in sustainable projects.

Finally, the general contractor of project III applied for and was awarded a sustainability certification label (ITACA) for the building. This label was used for signalling purposes in marketing material, and represented the distinctive element to differentiate his project from other buildings around.

7.4. Discussion of Results

Case study results showed several differences between the organisations of the three construction processes. Some differences were specifically related to changes necessary to adopt green technologies in the building.

In project III, a high level of integration between the general contractor and several suppliers occurred. Many suppliers were involved in the building activities earlier than in traditional buildings. New sequences of activities were necessary, as shown by the presence of plumbers during the realisation of the foundations. These changes in the relationships between the general contractor and suppliers were related to the architectural essence of the green innovations which were adopted in project III.

Among the reasons for the selection of suppliers in project III, there was the necessity for the general contractor to limit risks. For example, during the interview, the general contractor expressed fear in managing the problems of the highly innovative façade, so he transferred the responsibility for proper assembling and functionality of the façade to the supplier. This also clearly emerged in the contract related to the façade, in which the supplier guaranteed the building component for 10 years. The supplier of the façade declared that they guarantee their products for long time as they control all the phases of construction, and they are specialised in it. In project III, the risk of improper operation was also transferred by contract to the supplier for the water filtration system. Figure 7.3 shows a façade similar to the one adopted in project III, and allows understanding that an architectural innovation may be difficult to perceive.

In project III, the prolonged and intensive relationships between the general contractor and suppliers often assumed the characteristics of comakerships. In fact, these suppliers realised the executive plan of the innovative technologies

Figure 7.3 Intelligent façade which incorporates architectural innovations that reconfigure the subsystems by integrating several components and functions. In this picture, the fenestration for the National Renewable Energy Laboratory (NREL) Research Support Facility (RSF) which was designed to provide excellent daylighting while controlling glare and solar thermal gain through the use of shading devices, recessed windows, and electrochromic glass.

and discussed the design realisation at length with both the general contractor and the design team. This management was necessary to overcome the difficulties raised by the adoption of the green innovations. Risk limitation is a typical feature in home construction (Slaughter, 1993). All three project managers ranked it as a significant barrier to the adoption of sustainable innovations. Coherently, in project III, the general contractor selected suppliers of the green innovative technologies considering their ability to entirely manage and build the subcomponent. The choice to externalise risky activities resulted in changes of construction practice and also in the necessity of new relationships. The general contractor of project III revealed the lack of sustainability specialisation among its traditional suppliers. He was obliged to select a few new firms and to start different kinds of relationships with these specialised suppliers. These realised the design, supply, and mounting of the subcomponent integrally. Consequently, their power was significantly greater in the green innovative project, where they were asked to integrate their knowledge both in products and in processes. The integration of suppliers' knowledge led to mixed paths in knowledge sharing between firms (Nonaka, 1994). In particular, both the general contractor and the suppliers were obliged to externalise their know-how and to communicate to each other the desires and problems related to the green innovative technology. The co-design between the design team and suppliers of building subcomponents revealed an externalisation process of knowledge creation. This reinforces the idea that a comakership relationship emerged in the organisational process of a sustainable building (in the units of analysis 1).

Albino and Sivo (1992) stated that comakership is rare in residential building projects. The results of the present study partially contradict this because the comakership level showed to be more related to the "greenness" of the project than to the building typology. Consequently, residential buildings can show high comakership levels, as in the green innovative project.

In all the case studies, supplier selection seemed little influenced by specialisation of suppliers in sustainable projects. Table 7.3 shows that also in the most innovative project, the ratio of sustainable over non-sustainable portfolio for several suppliers had a low value. The general contractor of project III declared that for suppliers with high technical skills and high specialisation, their previous experience in sustainable projects was lacking. This confirmed Eccles's findings (1981) about the lack of specialisation in the construction sector.

The reasons for the selection of the design team of project III represent an interesting thought process. Limited experience and risk adversity of the general contractor led him to prefer a design team with experience in green building projects. Consequently, the degree of specialisation and the experience of the design team played an important role in the selection of the design team for the green innovative project.

The interviews revealed that difficulties had emerged with suppliers' competencies and specialisations in all the case studies. The general contractor of project I declared that previous collaborations and affordability were by far the main parameters for the selection of suppliers. He said he personally knew all the people working on the jobsite and all the material and equipment suppliers, so he did not ask the suppliers for (sustainability) certifications. Obviously, in traditional projects, the lack of formal competitive bidding procedures limits the room for specialisation. However, the selection of specialised firms for green innovative subcomponents, such as the water filtration system in project III, represented a new element in supplier selection in building processes.

The sustainability qualification of firms had a limited influence over the "greenness" level of the project and their selection. In fact, no environmental qualification was recognised in the case studies despite their different green levels. This contrasts with results of other studies (Bossink, 2007). In fact, in the context of analysis, the sustainability qualification was not common, and suppliers were selected more for their capabilities than for their level of qualification. This outcome means a low penetration of certification programs related to sustainability in the context of analysis.

Finally, the achievement of a sustainability label for project III represented a signalling element for the general contractor. The label was considered a distinctive element for the project, and many suppliers during the interviews remarked on the presence of the green label in the project. This confirms that the promotion of green buildings can be supported by sustainability labels.

7.5. Conclusions

This chapter has presented the research model and the features of analysis which were selected to study the organisational changes in building processes which adopt sustainable innovations.

Basing on previous chapters, the general hypothesis of the research was that a transition to sustainability of the construction sector corresponds to new relationships between firms in the construction organisation. Inter-firm relationships and the characteristics of the firms involved have been considered to understand pathways for a transition to sustainability.

This chapter has shown the importance of new organisation of construction processes for the adoption of green innovations in residential buildings. The results of the analysis suggest that to realise sustainable buildings, a higher level of integration between the general contractor and suppliers is required. A level of integration up to the level of comakership can be favourable to engage the ability of the suppliers for green innovative technologies. Comakerships have also proven necessary to engage suppliers' responsibility for the sustainability of the final product.

This chapter has shown that the selection of a design team with experience in sustainable buildings is particularly important, especially when the general contractor wants to realise a sustainable building and has no specialisation in residential construction. The study has shown how difficult is for suppliers' sustainability specialisations to emerge. However, the case studies have demonstrated that a sustainable building requires specialised suppliers, especially when risks for the green innovation are transferred to them. Sustainability certification has proved uncommon among all the firms involved in the three case studies. In fact, suppliers were selected more for their cheapness, capability and experience than for their qualifications.

The results of this study agree with many literature findings in other sectors. However, the adoption of a qualitative case study methodology prevents generalisations from being made about the results of the study outside of Italian medium-size projects. The study has contributed to the understanding of how organisational relationships change when sustainable innovations are adopted in constructions. This provides an insight into the Italian green building sector. However, in order to incentivise the transition to sustainable buildings, a more in-depth analysis of the effects of different green technologies over the organisation of construction processes is necessary.

This study has avoided discussing the influence of tools of communication between firms. However, these are promising instruments to investigate the evolution of inter-firm relationships between the general contractor and other firms.

Finally, an aspect which has been neglected in this chapter is the role of local governments. In every case study, the local government had the opportunity to promote sustainable construction, but its main attention was directed towards other aspects. This decouple between international and national policies, and local government activities needs to be recomposed, and will be analysed in detail in the next chapter.

Chapter 8

Policies for Sustainable Buildings

More and more countries are enacting policies to increase the sustainability of the building sector through the adoption of green innovations in buildings. In previous chapters, the progressive reduction of energy consumption of buildings has been pointed. Recent actions to increase the sustainability of buildings have largely been due to national and international policies. Many of these have been stimulate the diffusion of sustainable buildings worldwide in the last years. The present chapter reviews existing policies.

The first energy efficiency standards were set in Poland and France in the 1960s. Other countries followed previous standards in the 1960s (della Cava et al., 2001). However, these standards were often poorly implemented, and therefore did not have significant effects in the building industry. The first energy efficiency codes for building were set in the 1970s (Deringer et al., 2004). Since then, the variety of policies has considerably grown from regulatory and voluntary instruments in the initial phase towards financial incentives and economic instruments in the last years (IEA, 2010).

Since the 1990s, with the increasing awareness on climate change, more and more countries have introduced appliances standards, building codes, and sustainability requirements (Deringer et al., 2004). For various reasons, the effectiveness of these policy measures in reaching their goals varies significantly depending on countries, situations and policy instruments. For example, building codes have reduced energy consumption of new dwellings in U.S. by about 30%, but a shift to sustainable buildings is still far to be reached. Similarly, sustainable buildings policies are often ineffective in developing countries (Deringer et al., 2004). In general, little understanding exists about the impact of the various policy instruments. Basing on the conclusions of previous chapters, the present chapter aims to review available policies and answer the following question: *which policies could favour the adoption of green innovations in sustainable buildings*?

8.1. Review of Policies

In the building sector, policies have often promoted through standards and codes. In Chapters 1 and 3 we discussed the recent trends for energy saving in buildings as mostly ruled by national and international policies. Table 8.1 lists some European and American acts that are actually regulating the building sector and which aim to change buildings in the next years.

Table 8.1 European and American actions that are actually regulating the building sector.

Standard and code	**Requirement**
European Directive 2010/31/EU *recast* (European Commission, 2010)	As of 31 December 2020, all new buildings are nearly zero-energy buildings; After 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.
Energy Independence and Security Act 2007 (EISA, 2007)	As of 2025, all new commercial buildings must be zero net energy; As of 2050, all US commercial buildings must be zero net energy including retrofits of pre-2025 buildings.
Presidential Executive Order 13514 Federal Office, 2009	As of 2020, all planning for new Federal buildings requires design specifications that achieve zero net-energy use; As of 2015, large government buildings have to show progress; As of 2015, at least 15% of any Federal agency's existing buildings and building leases above 500 m^2 must conform to zero net energy and on-going improvements are required.

However, energy codes represent only one of the policies that are actually implemented to moving to sustainable buildings. This chapter presents an overview of many other policies. Following a recent publication of the SBCI (2007), policy instruments for sustainable buildings can be classified in four categories:

- Regulatory and control mechanisms;
- Economic or market-based instruments;
- Fiscal instruments and incentives;
- Information and voluntary actions.

These policy instruments are categorised in Table 8.2, together with emission reduction efficiency of GHG, cost efficiency and special conditions for their success. Instruments are hence analysed below for their use and effectiveness.

8.1.1. Regulatory and control mechanisms

Control and regulatory policies are probably the most common instruments in the buildings sector (UNEP, 2007). They can be defined as institutional rules that aim to directly influence the sustainability performance by regulating processes and products used and by prohibiting or limiting the discharge of some pollutants.

Table 8.2 Classification of Policies for sustainable building (re-adapting UNEP, 2007).

Policy instruments	**Reduction Efficiency**	**Cost efficiency**	**Special conditions for success, major strengths, limitations, and benefits**
Regulatory and control instruments			
Appliance standards	High	High	Factors for success: periodical update of standards, independent control, information, communication, education
Building codes	High	Medium	Only effective if enforced and periodically updated
Energy efficiency obligations and quotas	High	High	Continuous improvements necessary: new energy efficiency measures, short term incentives to transform markets
Mandatory audit requirement	High, but variable	Medium	Most effective if combined with other measures such as financial incentives
Labelling and certification programs	Medium High	High	Mandatory programs more effective than voluntary ones. Effectiveness can be boosted by combination with other instrument and regular updates
Demand-side management programs (DSM)	High	High	Tend to be more cost-effective for the commercial sector than for the residential sector
Economic and market-based instruments			
Energy savings performance contracting / ESCO support	High	Medium	Strength: no need for public spending or market intervention, co-benefit of improved competitiveness
Cooperative procurement	High	Medium High	Combination with standards and labelling, choice of products with technical and market potential
Energy efficiency certificate or white certificates	Medium	High Medium	No long-term experience. Transaction costs can be high. Institutional structures needed. Profound interactions with existing policies. Benefits for employment
Kyoto Protocol flexible mechanisms	Low	Low	At the end of 2012 a limited number of CDM & JI was considered in projects for buildings.
Fiscal instruments and incentives			
Taxation (on CO_2 or fuels)	Low	Low	Effect depends on price elasticity. Revenues can be earmarked for further energy efficiency support schemes. More effective when combined with others
Tax exemptions/ reductions	High	High	If properly structured, stimulate introduction of efficient equipment in existing and new buildings.
Public benefit charges	Medium	High	Success factors: independent administration of funds, regular monitoring & feedback, simple design
Capital subsidies, grants, loans	High	Low	Positive for low-income households, risk of free-riders, may induce pioneering investments
Support, information and voluntary actions			
Voluntary and negotiated agreements	Medium High	Medium	Can be effective when regulations are difficult to enforce, combined with financial incentives, and threat of regulation
Public leadership programs, procurement regulations	Medium High	High Medium	Can be effectively used to demonstrate new technologies and practices. Mandatory programs have higher potential than voluntary ones
Education and information program	Low Medium	Medium High	More applicable in residential sector than commercial. Best applied in combination with other measures
Detailed billing and disclosure programs	Medium	Medium	Success conditions in combination with other measures

Assessment of Policy Instruments for Reducing Greenhouse Gas Emissions from Buildings – UNEP SBCI - CEU

This publication reviews and assesses the policy instruments available worldwide for greenhouse gas emission from buildings, which contribute on average to 30% of greenhouse gas emissions. There are many proven ways to reduce the energy use in new and existing buildings, but experience shows that this will not happen without intervention from policy makers. This study presents the qualitative and quantitative experiences from different kinds of policy tools applied in countries all around the world.

This category of policies can be divided into regulatory-normative and regulatory-informative instruments. Some of the instruments, such as building codes, prescribe a certain standard for producers whereas others, such as mandatory labelling, stipulate just the provision of information to the users, who may decide not to follow the advice.

Numerous case studies have shown that standards and obligations are usually effective in the building sector. However, their effectiveness can be hampered by poor enforcement, which is a major obstacle to real effectiveness in several countries (Ürge-Vorsatz et al., 2007). Other limits to the effectiveness of these instruments are related to rebound effects.

In order to remain effective, control and regulatory instruments have to be monitored, evaluated and updated or revised regularly in accordance with technological developments and market trends (as recently it has been done for energy-saving policies). Unfortunately, regulatory instruments are much more applicable and easy to enforce in new than in existing buildings, and may be insufficient to promote the adoption of green innovations in existing buildings.

8.1.2. Economic and market-based instruments

Economic instruments for sustainability improvements in buildings are based on market mechanisms and usually contain elements of voluntary action or participation which are often initiated or promoted by regulatory incentives (UNEP, 2007).

As most economic or market-based instruments, they are rather new in the building sector and have been implemented only recently, mostly in developed countries (deCanio, 1998, Häkkinen & Belloni, 2011). Ex-post evaluations are rarely available for these policies.

The instruments in this category of policies differ considerably in their form, aim, and emission reduction effectiveness. These instruments include energy performance contracting, cooperative procurement, efficiency certificate schemes and credit schemes. In addition, flexible mechanisms (CDM and JI) according to Kyoto protocol belong to this category of policies. Unfortunately, the small opportunity of energy saving in the building sector and the fragmentation of the effects of different measures require developing new instruments to fit the characteristics and opportunities of buildings.

8.1.3. Fiscal instruments and incentives

These instruments include energy or carbon taxes, tax exemptions and reductions, public benefits charges, and capital subsidies, grants, subsidised loans and rebates. They target energy consumption and upfront investment costs. Examples of their cost-effectiveness include tax exemptions, public benefits charges, and subsidies.

Taxes can reinforce the impact of other instruments such as standards and subsidies, affecting the building life cycle and making investments for green innovations more profitable. They offer governments the possibility of investing tax revenues into green-building improvements. A challenge in their implementation remains low price-elasticity of demand, and dependence on how households spend their disposable income and the availability of substitute technologies.

Grants and subsidies are well suited to low-income households, which tend not to make investments in energy efficiency even if they have access to capital. By providing unconditional grants and subsidies, governments can provide direct capital rather than access to capital (UNEP, 2009). Grants are also best suited to encourage innovators and small businesses who would like to invest in R&D, but find it difficult to access capital from the market.

For middle- and upper-income households, preferential loans may be more appropriate to carry out sustainability improvements. For example, KfW, a German development bank, launched preferential loans using a double-edged mechanism to finance them through public tax exemption for investments in efficiency projects coupled with direct public subvention (UNEP, 2009). For large-scale "greening" efforts in commercial buildings, the introduction of reduced fees and waivers can significantly help the uptake of sustainable measures.

Ordinarily, construction costs are significant barriers to sustainable innovations as they are non-trivial and have to be paid up-front. Reducing or waiving fees if a building meets certain sustainability criteria helps to stimulate sustainable building. Another effective measure for sustainable building is a reduction in property taxes tied to the sustainability performance of buildings.

8.1.4. Support, information and voluntary actions

This category of instruments includes voluntary certification and labelling programmes, voluntary and negotiated agreements, public-leadership initiatives, awareness raising and education, as well as detailed billing and disclosure programmes. Examples of these are the sustainability assessment labels extensively discussed in Chapter 3.

Appliance efficiency standards and labels are also important in "greening" the building sector (Berardi, 2011). Among the oldest and most comprehensive of these instruments there are the U.S. Federal Minimum Efficiency Performance Standards programme and the U.S. Energy Star endorsement label programme.

The public sector has a leading role in using these kinds of policies to show their effectiveness. Public leadership programmes can reduce costs in the public sector and provide demonstration of new technologies. With respect to education and training, it is evident that the sustainability transition of the building sector necessitates a large number of skilled professionals: this suggests the importance to increase the number of professionals with the expertise in the development and implementation of sustainability codes and standards on green building design, energy auditing, labelling and certification, energy efficient operation and management.

8.2. Efficacy of Policies and their Combinations

The analysis in SBCI (2007) concluded that regulatory and control measures are probably the most effectives and most cost-effectives policies for sustainable buildings. However, grants and rebates have demonstrated to be necessary in any country to overcome the first cost-barrier of sustainable innovations. Tax exemptions appeared to be particularly effective tools among fiscal instruments (deCanio, 1998). However, subsidies, grants and rebates generally have a high cost for the society (UNEP, 2007). Financial instruments are typically more effective if they are applied together with other instruments, such as labelling combined with tax exemptions.

The results of SBCI (2007) have shown the high effectiveness and cost-effectiveness of regulatory instruments compared with economic ones. These findings are probably specific of the building sector, considering its organisational and information barriers for the transition to sustainability (Chapters 5 and 7). In fact, regulatory and control instruments are particularly effective in addressing two main key barriers to sustainability: transaction costs and market failures.

Recent studies have shown the importance of considering combinations of policies to result in synergistic impacts and higher savings. For example, appliance standards are often combined with labelling and rabbet to give incentives for investments beyond the minimum levels required by the standard (UNEP, 2009). Also, labelling of sustainable products can be critical in enabling financial incentives such as loans, subsidies and tax credits to be more effective (Berardi, 2011).

For example, in the U.S. building market, mandatory sustainability regulations have recently been coupled with voluntary labels and tax credits for both manufacturers and consumers (Kubba, 2010). These combinations help eliminating the least efficient products. Similar policies are common in many European countries.

Special enabling factors to support measures for green buildings are:

- Financial assistance or funding mechanisms with technical assistance and training;
- Regulatory measures, such as mandatory audits and incentives together with demonstration projects and information to build trust;
- Monitoring and evaluation continually based on new baseline data;

An integrated policy framework that combines regulatory instruments, such as standards or mandatory audits in certain buildings, capacity-building, training and information campaigns and demonstration projects coupled with incentives can more likely be effective.

8.3. Policies for Sustainable Buildings in Italy

This section describes policies for sustainable building in Italy. The framework of policies for sustainable building which has been reviewed in Sections 8.1 and 8.2 is used to discuss Italian policies for sustainable building. In particular, the effectiveness of Italian policies is discussed below. Later, few suggestions for increasing the diffusion of green innovations in Italian buildings are reported.

Adjusting the priorities of policies to the peculiarities of each context is particularly important. For this, the recognition of barriers to the adoption of green innovations in real case studies is particularly useful. The Italian projects described in Chapters 6 and 7 have highlighted specific barriers to green innovations: low motivation of stakeholders, low request from clients, high transaction costs, difficulties in re-organising the building process and interaction between stakeholders.

As seen in Section 8.2, regulatory and control instruments have shown to be the most effective policies around the world. In Italy, these policies are widely used too and, in fact, national regulations are progressively requiring an increasing energy efficiency level of buildings under the pressure of European policies. The progressive reduction of the energy consumptions in buildings and the progressive increase in their sustainability levels show that European laws are frequently upgrading the requirements in terms of sustainability of buildings.

The requirements of new regulations were frequently cited during the interviews to stakeholders of the case studies considered in previous chapters. All the stakeholders considered new laws about sustainability of buildings as highly stringent. Moreover, in several occasions, stakeholders were confused about the measures to take. In this sense, case studies showed that the performance-based laws which have been adopted in previous years should be supported by notes with practical solutions and examples of sustainable building.

The case studies showed that a low interest within the local government for the sustainability of the buildings existed. In Italy, the distance between national regulations and local regulations should surely be reduced in future policies. This could happen by imposing the local governments to adopt sustainability plans and regulations for green innovations and sustainable buildings in the local communities.

Another aspect related to local regulations and actions is the absence of policies of control for sustainability measures that are effectively adopted in the building and for post occupancy evaluations. This situation should be removed too, as a frequent activity of control over the actions taken in building sites could largely favour the adoption of green innovations in buildings and, hence the transition to sustainability of the building sector. Moreover, requests for energy post-construction assessments are increasing worldwide after the limits of energy simulation and preconstruction modelling have been shown.

Economic- and market-based instruments are actually absent in the building sector in Italy. The recent financial crisis has made more critical the access to subsidies for green innovations for sustainable buildings. Moreover, the disperse consumption which characterises the building sector has prevented the diffusion of Kyoto mechanisms. In fact, as already seen at European level, Clean Development Mechanism or White/Green certificates are not suited for application in the building sector in Europe where the consumption are dispersed and fragmented in many buildings which lack of a common management (SBCI, 2007). The lack of economic and market instruments have been highly criticised during interviews, especially by general contractors who declared their difficulties for the over costs of sustainable innovations.

In Section 8.2, the high public cost of subsidies has been criticised. Considering the international and national crises of recent years, other instruments have hence been considered to help the diffusion of green innovation and the transition towards sustainability of the Italian building sector.

Fiscal instruments are diffused in the Italian building sector. Since 2009, a vast program of fiscal instruments allows homeowners to compensate 55% of the cost of green technologies from annual taxes. This policy has been designed for owners that want to retrofit their houses. The result of this policy has been significant as it allowed substituting 2.5% of heat boilers with high-energy-efficient boilers in 2010 (ANCE, 2011). Between 2007 and 2009, more than 590.000 requalification projects for existing buildings have applied to fiscal incentives (ANCE, 2011), with a total investment of 8 M€. These data show the success of policies of fiscal instruments in Italy. However, looking in detail at the incentives that have been granted, 94% of actions have been taken by single-person owners of single houses. This shows that there is a request for fiscal instruments, which help promote interventions in multi-family buildings.

Moreover, as the construction of new buildings still represents a significant part of the investment in the building sector, a specific fiscal policy should be created to help the general contractors in the adoption of sustainable innovations in new buildings. During the interviews reported in Chapters 6 and 7, fiscal measures emerged that reduce the tax for the general contractor according to the sustainability of the construction; these measures could surely represent an incentive for sustainable buildings.

The last category of policies which has to be considered for "greening" the Italian building sector is that of information and voluntary actions. Public leadership programs are still rare in Europe. An impulse to disseminate a culture of green innovations for sustainable buildings has been due to the sustainability assessment systems. Unfortunately, the low diffusion of sustainability labels in case studies and more in general in many European countries Italy represents a limited driver to the diffusion of green innovations. In fact, it prevents wider recognition of the advantages of sustainable buildings. A difficulty in recognising the experience and qualifications of actors has also emerged in the case studies. This could be solved by incentivising specific programs which signal actors and actions of the increasing "green building economy".

Finally, an increase in communication about sustainable building and more incentives for the diffusion of assessments, labels and certifications related to sustainability are necessary.

Chapter 9

Conclusions

The general framework of this book has been the management of green innovations in sustainable buildings. This book belongs, and hopes to contribute, to the worldwide discussion about sustainable building innovation. In order to respond to the increasing request for sustainable development, international policies as well as national actions are assigning significant importance to the "greenness" of buildings. R&D in the manufacturing sector is offering new products for facilitating the sustainability of the building sector. However, the large-scale sustainability of buildings will still require significant strides by all parties involved.

An important goal of this book has been to investigate the differences in the stakeholders' interactions in traditional and sustainable building processes. The interest and the influence of the different stakeholders of the building sector for the adoption of green technologies have been discussed.

Before answering the previous research questions, the book has clarified the recent interpretations of the concept of sustainable building, in order to avoid misunderstandings about the terminology.

The book has shown that an innovation or a building can be considered efficient or green for its environmental impacts. However, the "sustainable" attribute requires taking into account economic and social impacts as well. This means that sustainability is more difficult than "greenness" to reach.

By examining the evolution of the concept of sustainable development in the last years, this book has shown that many factors compose the definition of what is sustainable in the building sector. In particular, the dependence of the concept of sustainability on time, scale, domain and social constraints has been discussed.

In order to better clarify the current definition of sustainability in the building sector, sustainability assessment systems for buildings have been reviewed. Differences and similarities among systems have been shown. The energy-saving innovations are considered priorities for sustainable building; in fact, insulating materials and renewable energy technologies are particularly evaluated. Moreover, water efficiency technologies or green materials have been increasingly considered.

Later, the book described which green innovations have been adopted in a large sample of sustainable buildings in the U.S. The analysis of assessments of buildings has enabled the discussion on current practices of sustainable building. The study has shown that energy-saving innovations are still adopted relatively rarely in the building sector. Reversely, other technologies such as water efficiency innovations are diffuse. This shows differences in managing different green innovations in buildings, and opens other questions related to the difficulties and differences in their management. Differences among innovations have been reviewed by considering their classification in incremental, modular, architectural, and radical innovations.

Difficulties of the building sector in adopting green innovations have been studied both by reviewing existing literature and by case studies investigations. In particular, the book has shown that:

- Modular innovations are more easily adopted in buildings because they do not modify the way in which the technologies are assembled and integrated.
- Green innovations which are architectural innovations generally require a high level of knowledge and organisational changes in the interactions between stakeholders involved in their adoption.
- Green innovations which imply an architectural integration in the existing technologies of the building imply prohibitively high transaction costs which cause rare adoption.

Previous results show that different green innovations require different strategies for the adoption. In particular, the difficulties in the management of architectural (or radical) innovations in a sustainable building represent considerable barriers to the adoption of green innovations. The book has tried to make alive the complexities and difficulties in managing green innovations by interviewing stakeholders in many case studies. The description of building processes has helped to show the main difficulties that are encountered when adopting green innovations in buildings.

Stakeholders of construction processes have expressed their influence for the adoption of green innovations. Stakeholders' influence has been measured after having evaluated their interest and power for the adoption of green technologies. The case studies showed some predictable results, as the high interest for green innovations from users, and the low interest of the general contractor. Surprisingly, among the barriers to green innovations that case studies have revealed, the lack of knowledge and experience about green innovations have been higher ranked than their cost. Moreover, other findings of the interviews were particularly surprising, for example:

- the design team showed low interest in the sustainability of the building. Design teams generally agreed with the general contractors preferences, and they allowed accepting traditional, no risky and cheap technologies.
- the local government was poorly motivated towards green innovations and sustainable buildings. Although local government had high power to push the adoption, its interest was only focussed on national regulations and local laws, and it rarely considered the sustainability of the buildings.

The interviews showed that a main barrier for green innovations is represented by the late expression of interest during the construction process for the adoption of green technologies. The investigation of the influence of several stakeholders for sustainable innovations has shown the delay between the time in which design and building choices are made, and the time in which the interest for green technologies emerges. In particular, the investigation has showed the minimal influence for the adoption of green innovations of highly motivated but powerless stakeholders, as owners and users of the houses. This suggests that new organisational structures for building processes have to be encouraged. More occasions in which stakeholders can share their preferences and express their doubts are necessary. Organisational aspects among firms involved in the adoption of green innovations have a prime role in moving to sustainable buildings. How inter-firm relationships are changing as the building sector moves to sustainability has been discussed extensively. Organisational aspects in traditional and sustainable buildings have been compared, finding that green innovations for sustainable buildings are associated to:

- a high level of integration between the general contractor and its suppliers;
- a high level of integration between the general contractor and the design team;
- involving firms with a specialisation in sustainable building;
- not necessarily involving firms with certifications for sustainable building.

Inter-firm relationships of comakership between the general contractor and suppliers, and between the general contractor and the design team have shown to favour the adoption of green innovations in buildings. In fact, green innovations require high level of knowledge for the adoption and integration especially when they are architectural innovations. Architectural innovations modify the way in which technologies are assembled in the building and hence, they require actors with higher know-how on sustainability, as previous experiences or specific qualifications.

The importance and effectiveness of policies for sustainable buildings have also been considered. According to the insight of the case studies, new policies have been suggested to promote green innovations in buildings:

- regulatory and control instruments have shown to be the most effective policies, but they should continue to be upgraded frequently;
- performance-based laws should be supported by regulations and notes with practical examples of green innovations in buildings;
- the gap between national and local regulations has to be reduced, increasing the motivations of local governments towards green innovations in buildings;

- controls of the actions taken during the construction activities are necessary;
- post-occupancy evaluation of the performance of buildings is particularly important as a decoupling between predictions and final performances is often recorded.
- fiscal instruments are diffused and effective in the retrofitting of Italian buildings. However, specific fiscal policies should be created to help general contractors during the adoption of sustainable innovations in new buildings.
- occasions for communication and discussion between actors (for example, the general contractor and the users) about the adoption of green innovations should be incentivised.

The book has suggested that to facilitate the management of green innovations in buildings, it is necessary to take into account that sustainability is a complex socio-technical process. In the building sector, stakeholders take part in on-going processes of organising which influence the way they enact and manage (green) innovations.

In order to deal with sustainability issues, it is important to consider how the socio-technical networks of the building sector organise themselves. Interactions among stakeholders and actors of the building processes have to change, and the time, power, motivations and influences of different stakeholders have to be re-considered.

It can be concluded that there is a need to go beyond the prevalent normative and rationalistic technological view of green innovations. This can occur by promoting a perspective that considers green innovations that integrate techno-economic and social-organisational aspects.

Appendix

Questionnaire for the Interview about Building Practices

Answering the following questionnaire, please refer to the way that best reflects your views and indicate the way your firm is behaving. The survey contains questions regarding green innovations. In this interview, you will assess green innovations, i.e. processes or products new to the commonly assumed in your practice or activity which have a particularly high performance for sustainability.

General info: context of the analysis

The interviewed is asked to answer general questions about his activities

Core competencies (Chapter 7)

Competences are investigated through firm activities and its portfolio

- Which are your firm's core activities?
- How much do you incorporate innovations in your projects?
- Could you give reasons for this?
- How much do you invest for Green Innovations?

Sustainability rating and sustainability qualification (Chapters 3 and 7)

- Do you have an internal environmental training?
- Do you have an Environmental Management System?
- Do you have employees with sustainability qualification degrees?
- Have you ever been involved in buildings that were constructed with sustainability in mind?

Reasons and barriers for green innovations (Chapter 6)

Score the following reasons for your projects in relation to green innovations:

a) Government regulation
b) Reduce environmental impact
c) Awards for the Building
d) Higher ROI on resale
e) Higher rents
f) Subsidies
g) Firm image
h) Benefit from publicity
i) Expanding business with green client

Score the following barriers to projects with green innovations:

a) Increased components costs
b) More complex constructions
c) Position price of green buildings
d) Documentation
e) Difficulty in quantifying benefits
f) Lack of awareness about benefits
g) Awareness of sustainability problems
h) Short-term budget horizon
i) Design fee
j) Lead time in construction
k) Proximity to resources
l) Unsuitable site
m) Communication and language
n) Perceived risks

Following questions are related to a specific medium size and residential project in which you have been involved in recent years

Stakeholders' motivation (Chapter 6)

- Reasons for selection of the project
- Decision about the typology of the building
- How have you decided the quality of the building?
- How have you analysed customer request requirements?

Innovation introduction (Chapter 5)

- How much do you consider your project "innovative"? (on scale from 1 to 5)
- Firms that believe to have an innovative project (score 3-5) are asked to describe their innovations.

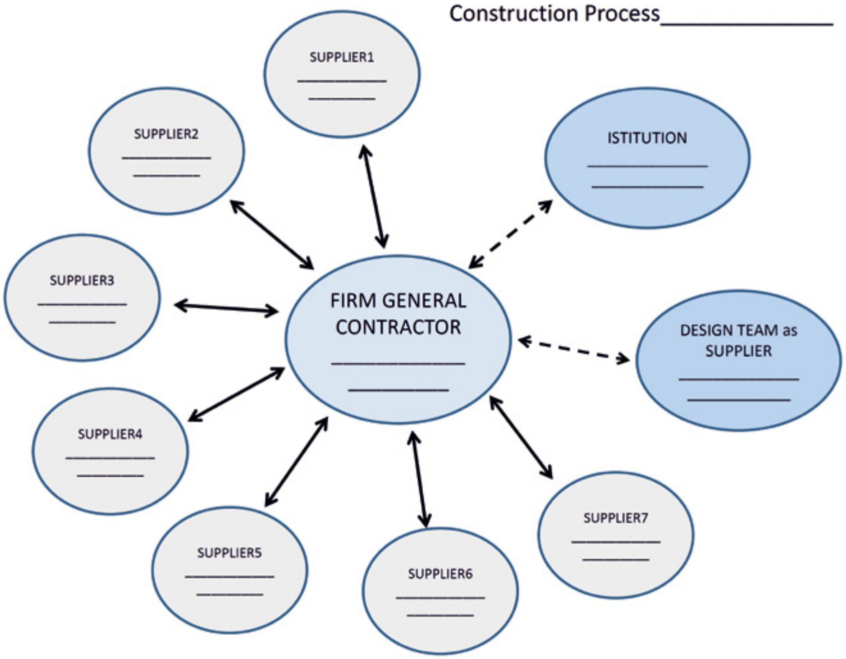
Green introduction (Chapter 5)

- How much do you consider your project "green"? (on scale from 1 to 5)
- Firms which claim to be innovative (results 3-5) are asked to describe their selections.

Which green innovations have you adopted for to the following categories?

	Description of the innovations	**Evaluation of Innovations**	**Modular or Architectural**
Water Efficiency			
Energy Production			
Envelope			
Material Resources			
Indoor Environmental Quality			
others Innovations			

Integration level of construction firm with suppliers (Chapter 7)
Please, fill empty spaces in the figure indicating the main suppliers for general contractor – suppliers network.



	Supplier1	Supplier2	Supplier3	Supplier4	Supplier5	Supplier6
Duration of involvement in the project / over duration of the overall project						
Phase of first involvement along the duration of the project						
Parameters used for supplier's selection: (*5=Very Much, 1=Not at all*) a)Price reduction on average b)Previous experiences c)Time reduction d)Contractual reliability e)Management reliability f)Integration in the project	a) b) c) d) e) f)	a) b) c) d) e) f)	a) b) c) d) e) f)	a) b) c) d) e) f)	a) b) c) d) e) f)	a) b) c) d) e) f)
Power of the supplier						
integrating suppliers' knowledge and competences of product						
integrating suppliers' knowledge and competences of process						
integrating suppliers' knowledge and competences about green product						
integrating suppliers' knowledge and competences about green process						

Core competencies of design team (Chapter 7)

- Specialisation
- Innovative projects in last 3 years
- Green Innovative projects in last 3 years

Design & general contractor firm relationship (Chapter 7)

The dyadic relationship between general contractor and design team is investigated.

- What percentage of your activity is performed jointly with design team
- What percentage of design team activity is jointed with you
- Have you selected one or more design firms?
- Duration of involvement in the project
- Phase of first involvement along the duration of the project
- Have you recourse to environmental or energy engineering?
- Rate the following parameters for suppliers' selection

	Very Much =5	Somewhat	Undecided	Not really	Not at all = 1
Price reduction over average					
Previous experiences					
Time reduction					
Contractual reliability					
Management reliability					
Integration in the project					
Power of the supplier					
integrating suppliers' knowledge and competences of product					
integrating suppliers' knowledge and competences of process					
integrating suppliers' knowledge and competences about green product					
integrating suppliers' knowledge and competences about green process					

Bibliography

Aalborg Charter. (1994). European Conference on Sustainable Cities & Towns in Aalborg, Denmark, Aalborg.

Abernathy, W.J., Utterback, J.M. (1978). Patterns of Industrial Innovation. Technology Review, MIT Press, 80(11), 40-47.

Abeysekera, V. (2002). Understanding 'Culture' in an International Construction Context. CIB Report, Perspectives on Culture in Construction, 275, 39-51.

Ackermann, F., Eden, C. (2011). Strategic Management of Stakeholders: theory and practice. Long Range Planning, 44(3), 179-196.

Agapiou, A., Flanagan, R., Norman, G., Notman, D. (1998). The changing role of builders merchants in the construction supply chain. Construction Management and Economics, 16, 351-361.

Ahmad, I. (1991). Restructuring Responsibility and Reward for More Construction Innovation, Proc. Congress in Preparing for Construction in the 21st Century, ASCE, 453-458.

Ajzen, I. (1991). The theory of planned behavior, organizational behavior and human decision processes. Organizational Behavior and Human Decision Processes, 50(2), 179-211.

Akashi, O., Hanaoka, T. (2012). Technological feasibility and costs of achieving a 50 % reduction of global GHG emissions by 2050: mid- and long-term perspectives. Sustainability Science, 7(2), 139–156.

Albino, V., Balice, A., Dangelico, RM. (2009). Environmental strategies and green product development: the behaviours of sustainability-driven companies. Business Strategy and the Environment, 18(2), 83-96.

Albino, V., Berardi, U. (2012). Green buildings and organizorganisational changes in Italian cases studies, Business Strategy and the Environment, 21(6), 387-400.

Albino, V., Dangelico, R.M., Natalicchio, A., Yazan, D.M. (2011). Alternative Energy Sources In Cement Manufacturing, Network for Business Sustainability, Richard Ivey School of Business of Western Ontario.

Albino, V., Garavelli, C. (1998). A neural network application to subcontractor rating in construction firms. International Journal of Project Management, 16(1), 9-14.

Albino, V., Schiuma, G., Sivo, G. (1998). Firms Networks for Building Maintenance and Urban Renovation: The Technological and Organizational Evolution. European Journal of Purchasing and Supply Management, 4(1), 21-29.

Albino, V., Sivo, G. (1992). The comakership for innovation in large projects of construction engineering. Performance (in Italian).

Ali, H.H., Al Nsairat, S.F. (2009). Developing a green building assessment tool for developing countries – Case of Jordan. Building and Environment, 44, 1053-1064.

ANCE, Associazione Nazionale Costruttori Edili (2011). Trends Observatory On The Building Industry. http://www.ediliziainrete.it/libri/mercato-prezzi/ance2011.pdf.

Andreu, I.C., Oreszczyn, T. (2004). Architects need environmental feedback. Building Research and Information, 32(4), 313-28.

Anumba, C.J., Ugwu, O.O., Ren, Z. (2005). Agents & Multi-agent Systems in Construction. Taylor & Francis, London.

Arditi, D., Kale, S., Tangkar, M. (1997). Innovation in construction equipment and its flow into the construction industry. Journal of Construction Engineering and Management, 123(4), 371-378.

Atkinson, S., Schaefer, A., Viney, H. (2000) Organisational structure and effective envi-ronmental management. Business Strategy and the Environment, 9(2), 108-121.

Baas, L. (2008). Industrial symbiosis in the Rotterdam Harbour and Industry Complex: reflections on the interconnection of the techno-sphere with the social system. Business Strategy and the Environment 17(5), 330-340.

Bagheri, A., Hjorth, P. (2007). Planning for Sustainable Development: a Paradigm Shift Towards a Process-Based Approach Sustainable Development. Sustainable Development, 15(2), 83-96.

Baldwin, C.Y., Clark, K.B. (2006). Architectural Innovation and Dynamic Competition: The Smaller "Footprint" Strategy, Harvard Business School Working Paper, No. 07-014.

Baldwin, C.Y., Clark., K.B. (2000). Design Rules: Volume 1. The Power of Modularity. Cambridge, Mass. MIT Press.

Barrett, P., Sexton, M.G. (2006). Innovation in small, project-based construction firms. British Journal of Management, 17(4), 331-346.

Bauman, R.D., Kracum, J.J. (1995). Innovation – What More Can We Do?, Proc. Constr. Conference, ASCE, 65-69.

Baumann, H. (2004). Environmental assessment of organising: towards a framework for the study of organisational influence on environmental performance. Progress in Industrial Ecology, 1(1/2/3), 292-306.

Bazerman, M., Hoffman A. (1999). Sources of environmentally destructive behavior: Individual, organizational and institutional perspectives. Research in Organizational Behavior, 21, 39-79.

Becchio, C., Corgnati, S.P., Filippi, M., Guglielmino, D. (2009). Rating Systems for green buildings certification: features, applicability, practice. Proc. Aicarr, Rome.

Beerepoot, M., Beerepoot, N. (2007). Government regulation as an impetus for innovation: evidence from energy performance regulation in the Dutch residential building sector. Energy Policy, 35(10), 4812-4825.

Benn, S., Dunphy, D., Griffiths, A. (2006). Enabling change for corporate sustainability: an integrated perspective. Australasian Journal of Environmental Management, 13(3), 156-165.

Berardi, U. (2013). Clarifying the new interpretations of the concept of sustainable, Sustainable Cities and Society, 8(1), 72-78..

Berardi, U. (2013). Stakeholders' influence on the adoption of energy saving technologies in Italian homes. Forthcoming.

Berardi, U. (2011). Organizational process changes and management of architectural innovations for a sustainable development: application to green buildings, EURAM 2011, Tallinn (Estonia), May 30 - June 1, 2011.

Berardi, U. (2011). Beyond sustainability assessment systems: upgrading topics by upscaling the assessment, International Journal of Sustainable Building Technology and Urban Development, 2(4), 276-282.

Berardi, U. (2011). Comparison among sustainability rating systems for buildings, SB11 - World Sustainable Building Conference, Helsinki (Finland), October 18-21, 2011.

Berardi, U. (2012). Sustainability Assessment in the Construction Sector: Rating Systems and Rated Buildings. Sustainable Development, 20(6), 411-424.

Berardi, U. (2012). Books in Sustainable Development And Related Fields. International Journal of Sustainable Building Technology and Urban Development, 3(4), 248-251.

Bernstein, H.M., Lemer, A.C. (1996). Solving the Innovation Puzzle: Challenges Facing the U.S. Design and Construction Industry, New York, American Society of Civil Engineers, 1996.

Biemans, W.G. (1996). Organizational networks: Toward a cross-fertilization between practice and theory. Journal of Business Research, 35(1), 29-39.

Binder, G. (2008). Understanding innovation for sustainability within the Australian building industry: an evolutionary social learning model. Journal of Green Building, 3(3).

Birkinshaw, J., Hamel, G., Mol, M. (2008). Management innovation. Academy of Management Review, 33(4), 825-845.

Black, C., Akintoye, A., Fitzgerald E. (2000). An analysis of success factors and benefits of partnering in construction. International Journal of Project Management, 18(6), 423-432.

Blank, L. (1996). Changing Behaviour in Individuals, Couples, and Groups. Charles Thomas Publisher, Springfield.

Bloom, E., Wheelock, C. (2010). Green Building Certification Programs, Pike Research Report 2Q.

Boland, R.J., Lyytinen, K., Yoo, Y. (2007). Wakes of Innovation in Project Networks: The Case of Digital 3-D Representations in Architecture, Engineering, and Construction. Organization Science, 18(4), 631-647.

Boons, F.A.A., Baas L.W. (1997). Types of industrial ecology: The problem of coordination. Journal of Cleaner Production, 5(1-2), 79-86.

Bossink, B.A.G. (2002). A Dutch public-private strategy for innovation in sustainable construction. Construction Management and Economics, 20(7), 633-642.

Bossink, B.A.G. (2002). The development of co-innovation strategies: stages and interaction patterns in interfirm innovation. R&D Management, 32(4), 311-320.

Bossink, B.A.G. (2004). Managing drivers of innovation in construction networks. Journal of Construction Engineering and Management, 130(3), 337-345.

Bossink, B.A.G. (2007). The interorganizational innovation processes of sustainable building: A Dutch case of joint building innovation in sustainability. Building and Environment, 42(12), 4086-4092.

Bossink, B.A.G. (2011). Managing Environmentally Sustainable Innovation: Insights from the Construction Industry, Routledge, New York.

Bower, J., Howe, J., Fernholz, K., Lindberg, A. (2006). Designation of environmentally preferable building materials – fundamental change needed within LEED. Report, MN, Dovetail Partner.

Bozdogan, K., Deyst, J., Hoult, D., Lucas, M. (1998). Architectural innovation in product development through early supplier integration. R&D Management, 28(3), 163-173.

Brand, R., Karvonen, A. (2007). The ecosystem of expertise: complementary know ledges for sustainable development. Sustainability: Science, Practice, & Policy, 3(1), 21-31.

BRE, British Research Environment. (2008). A Discussion Document Comparing International Environmental Assessment Methods for Buildings. BRE, Glasgow.

Bresnen, M., Edelman, L., Newell, S., Scarbrough, H., Swan, J. (2004). Social practices and the management of knowledge in project environments. International Journal of Project Management, 21, 157-166.

Bresnen, M., Goussevskaia, A., Swan, J. (2004). Embedding new management knowledge in project-based organisations. Organisation Studies, 25(9), 1535-1555.

Bresnen, M., Goussevskaia, A., Swan, J. (2005). Implementing change in construction project organisations: exploring the interplay between structure and agency. Building Research and Information, 33(6), 547-560.

Bresnen, M., Marshall, N. (2000). Partnering in construction: a critical review of issues, problems and dilemmas. Construction Management and Economics, 18(7), 229-237.

Brown, H.S., Vergragt, P.J. (2008). Bounded socio-technical experiments as agents of systemic change: The case of a zero-energy residential building. Technological Forecasting and Social Change, 75(1), 107-130.

Butera, F.M. (2010). Climatic change and the built environment. Advances in Building Energy Research, 4(1), 45-75.

Bythewat, A., Dhillon, G. (1996). Significance of Partnerships in the Management of Interorganizational Systems. International Journal of Information Management, 16(5), 369-380.

Cainarca, G.C., Colombo, M., Mariotti, S. (1989). An evolutionary pattern of innovation diffusion. Research Policy, 18, 59-86.

Capozzoli A., Corrado V., Mechri H.E. (2009). A critical review on forward and data driven methods for building energy analysis. Proc. Aicarr, Rome.

Carbon Trust. (2005). The UK Climate Change Programme: Potential Evolution for Business and the Public Sector. Technical Report. www.carbontrust.co.uk.

Cassidy, R. (2003). White Paper on Sustainability. Building Design and Construction, 11. http://www.usgbc.org/Docs/Resources/BDCWhitePaperR2.pdf

CEDEFOP, European Centre for the Development of Vocational Training. (2010). Skills for green jobs: European synthesis report. European Centre for the Development of Vocational Training. Publications Office of the European Union, Luxembourg.

Chapman R., Hyland, P. (2004). Complexity and learning behaviors in product innovation. Technovation, 24, 553-561.

Charron, R. (2005) A Review of Low and Net-Zero Energy Solar Home Initiatives, NRCan, Natural Resources Canada, pp. 1–8.

Chau, C.K., Tse, M.S., Chung, K.Y. (2010). A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes. Building and Environment, 45, 2553-2561.

Chen, Y., Berardi, U., Chen, J. (2012). A Multi-Integrated Renewable Energy System In A Commercial Building In Beijing: Lessons Learnt From An Operating Analysis. International Journal of Low-Carbon Technologies, in press.

Cheng, C. (2010). A new NAMA framework for dispersed energy end use sectors. Energy Policy, 38(10), 5614-5624.

Cheng, C., Pouffary, S., Svenningsen, N., Callaway, M. (2008). The Kyoto Protocol, The Clean Development Mechanism and the Building and Construction Sector – A Report for the UNEP Sustainable Buildings and Construction Initiative.

Chinyio, E., Olomolaiye, P.O. (2009). Construction Stakeholder Management. John Wiley & Sons, Oxford.

CIB, Conseil International du Bâtiment. (2010). Towards Sustainable and Smart-Eco Buildings, Summary Report on the EU-Funded Project Smart-ECO Buildings in the EU, CIB Secretary, Rotterdam.

Clark, P.A. (1987). Anglo-American innovation, Walter de Gruyter & Co., Berlin.

Clason, C. (2007). Building Information Modeling: Value for Real Estate Developers and Owners, MIT press.

CLASP, Collaborative Labelling and Appliances Standards Program. (2007). Standards and Labelling Programs Worldwide. www.clasponline.org.

Clements-Croome, D.J. (2010). Sustainable Intelligent Buildings for People. Proc. IAQVEC 2010, Syracuse, US.

Cole, R.J. (2000). Cost and value in building green. Building Research and Information, 28(5/6), 304-309.

Cole, R.J. (2004). Changing Context for environmental knowledge. Building Research and Information, 32(2), 91-109.

Cole, R.J. (2005). Building environmental assessment methods: redefining intentions and roles. Building Research and Information, 33(5), 455-467.

Cole, R.J. (2010). Building Environmental Assessment in a Global Market. International Journal of Sustainable Building Technology and Urban Development, 1(1), 11-14.

Cole, R.J. (2011). Environmental Issues Past, Present & Future: Changing Priorities & Responsibilities for Building Design. Proc. SB11, Helsinki.

Cole, R.J. (2012). Regenerative design and development: current theory and practice. Building Research & Information, 40(1), 1–6.

Considine, M., Lewis, J.M. (2007). Innovation and Innovators Inside Government: From Institutions to Networks. Governance, 20(4), 581-607.

Cooke, R., Cripps A., Irwin, A., Kolokotroni, M. (2007). Alternative energy technologies in buildings: Stakeholder perceptions. Renewable Energy, 32(14), 2320-2333.

Cooper, M.C., Ellram, L.M. (1993). Characteristics of supply chain management and the implications for purchasing and logistics strategy. International Journal of Logistics Management, 4(2), 13-24.

Corbett C.J., Muthulingam, S. (2007). Adoption of Voluntary Environmental Standards: The Role of Signaling and Intrinsic Benefits in the Diffusion of the LEED Green Building Standards.

Costantino, N., Pietroforte, R. (2002). Subcontracting practices in USA homebuilding - an empirical verification of Eccles's findings 20 years later. European Journal of Purchasing & Supply Management, 8(1), 15-23.

Crawley, D., Aho, I. (1999). Building environmental assessment methods: application and development trends. Building Research and Information, 27 (4/5), 300-308.

Crawley, E., de Weck, O., Eppinger, S., Magee, C., Moses, J. Seering, W., Schindall, J., Wallace D., Whitney D. (2004). The influence of architecture in engineering systems, The ESD Architecture Committee, MIT ESD.

CRESME, (2010). Rapporto Congiunturale e Previsionale del Mercato delle Costruzioni, CRESME.

Dahl, M.S., Dalum B. (2001). The Construction Cluster in Denmark, in: den Hertog, Bergman, Charles (eds.), Innovative Clusters: Drivers in National Innovation Systems, OECD, Paris.

Daly, H.E. (1996). Beyond growth: the economics of sustainable development. Boston: Beacon Press.

de Bakker, F.G.A., Fisscher, O.A.M., Brack, A.J.P. (2002). Organizing product-oriented environmental management from a firm's perspective. Journal of Cleaner Production, 10, 455-464.

de Blois, M., Herazo-Cueto, B., Latunova, I., Lizarralde, G. (2011). Relationships between Construction Clients and Participants of the Building Industry: Structures and Mechanisms of Coordination and Communication. Architectural Engineering and Design Management, 7(1), 3-22.

DeCanio, S.J. (1998). The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments. Energy Policy, 26(5), 441-454.

DEFRA, Department for Environment, Food and Rural Affairs. (2011). Mainstreaming sustainable development – The Government's vision and what this means in practice. http://sd.defra.gov.uk/documents/mainstreaming-sustainable-development.pdf

della Cava, M., Wiel, S., duPont, P., Phuket, S.R., Constantine, S., McMahon. J.E. (2000). Supporting a Network for Energy Efficiency And Labels and Standards Programs in Developing Countries, Proc. of the 2nd International Conference on Energy Efficiency in Household Appliances and Lighting, Naples, Italy.

Delmas, M., Toffel M.W. (2004). Stakeholders and environmental management practices: an institutional framework. Business Strategy and the Environment, 13(4), 209-222.

Dempsey N, Bramley G, Power S, Brown C. (2011). The social dimension of sustainable development: Defining urban social sustainability. Sustainable Development, 19(5), 289–300.

Deringer, J., Iyer, M., Yu Joe Huang, Y. J. (2004). Transferred Just on Paper? Why Doesn't the Reality of Transferring/Adapting Energy Efficiency Codes and Standards Come Close to the Potential?. Proc. 2000 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA.

Devuyst, D. (2000). Linking impact assessment and sustainable development at the local level: the introduction of sustainability assessment systems. Sustainable Development, 8, 67-78.

Ding, G.K.C. (2008). Sustainable construction - The role of environmental assessment tools. Journal of Environmental Management, 86(3), 451-464.

Dioguardi, G.F. (1983). Macrofirm: Construction Firms for the Computer Age. ASCE Journal of Construction Engineering and Management, 109, 13-24.

Dosi, G. (2000). Innovation, organization and economic dynamics: Selected essays, Edward Elgar Publishing, Cheltenham, Northampton.

du Plessis, C. (2005). Action for sustainability: preparing an African plan for sustainable building and construction. Building Research and Information, 33(5), 405-415.

du Plessis, C., Cole, R.J. (2011). Motivating change: shifting the paradigm. Building Research & Information, 39(5), 436-449.

Dutton, J.E., Jackson, S.E. (1987). Categorizing strategic issues: Links to organizational action. Academy of Management Review, 12, 76-90.

Eagly, A.H., Kulesa, P. (1997). Attitudes, attitude structure and resistance to change, in Environment, Ethics and Behavior, Bazerman, M. (ed.), The New Lexington Press, San Francisco, CA.

Eccles, R.G. (1981). The Quasi-firm in the Construction Industry. Journal of Economic Behaviour and Organization 2(4), 335-357.

Edwards, AR. (2010). Thriving Beyond sustainability: Pathways to a Resilient Society. Gabriola Island: New Society Publishers.

EIA, Energy Information Administration. (2011). International Energy Outlook 2011, US Department of Energy, Washington, DC.

Eichholtz P., Kok N., Quigley J.M. (2009). Doing Well By Doing Good? Green Office Buildings, Working Paper No. W08-001.

Eichholtz, P.N., Kok, J.M. (2010). Quigley, Sustainability and the Dynamics of Green Building.

EISA (2007) CRS Report for Congress: Energy Independence and Security Act of 2007: December 21, US Government, Washington, DC.

EN 15643-1. (2010). Sustainability of construction works. Sustainability assessment of buildings. General framework.

Entrop, A.G., Brouwers, H.J.H., Dewulf, G.P., Halman, J.I.M. (2008). Decision Making processes and the adoption of energy saving techniques in residential and commercial real estate. Proc. SB08, Melbourne.

EPA, Environmental Protection Agency. (2008). Green Building Strategy - Defines green building and explains EPA's strategic role in facilitating the mainstream adoption of effective green building practices.

EPBD, Energy Performance of Buildings Directive. (2010). Directive 2010/31/CE of the European Parliament. Official Journal of the European Union.

Esbensen, T.V. and Korsgaard, V. (1977) Dimensioning of the solar heating system in the zero energy house in Denmark. Solar Energy, 19(2), 195-199.

Ettlie, J.E. (1997). Integrated design and new product success. Journal of Operations Management, 15(1), 33-55.

Eurostat. (2011). Energy consumption by sector in European countries, available at: http://epp.eurostat.ec.europa.eu/

Finch, G., Burnett, E., Knowles, W. (2009). Energy Consumption in Mid and High Rise Residential Buildings in British Columbia.

Fixson, S.K. (2005). Product architecture assessment: a tool to link product, process, and supply chain design decisions. Journal of Operations Management, 23, 345-369.

Foray, W.D., Freeman, C. (1993). Technology and the Wealth of Nations. Pinter Publishers, London.

Foster, C., Green, K. (2000). Greening the innovation process. Business Strategy and Environment, 9(5), 287-303.

Fowke, R., Prasad, D. (1996). Sustainable development, cities and local government: dilemmas and definitions. Australian Planner, 33(2), 61-66.

Fowler, K.M., Rauch, E.M. (2006). Sustainable Building Rating Systems Summary. Pacific Northwest National Laboratory.

Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A., Anderson D. (2005). UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. Energy Policy, 33(16), 2123-2137.

Freeman, C. (1989). The Economics of Industrial Innovation. MIT Press, Cambridge, MA.

Freeman, R.E. (2001). A Stakeholder Approach to Strategic Management. Analysis,1(1).

Freeman, R.E., Harrison, J.S., Wicks, A.C., Parmar, B.L., de Colle, S. (2010). Stakeholder Theory – The State of the Art. Cambridge University Press, New York.

Fuggetta A. (2009). The challenge of innovation, CEFRIEL, Innovision Paper.

Gann, D. (1994). Innovation in the Construction Sector in M. Dodgson and R. Rothwell (eds.) The Handbook of Industrial Innovation, Edward Elgar, Aldershot.

Gann, D.M., Salter, A.I. (2000). Innovation Management in project-based, service-enhanced firms: the construction of complex products and systems. Research Policy, 29, 955-972.

Gaps, S.E. (1998). Barriers and conceptual chasms: theories of technology transfer and energy in buildings. Energy Policy, 26(15), 1105-1112.

Gibb, A.G.F., Isack, F. (2001). Client drivers for construction projects: implications for standardization. Engineering, Construction and Architectural Management, 8(1), 46-58.

Gibberd, J. (2005). Assessing sustainable buildings in developing countries – the sustainable building assessment tool (SBAT) and the sustainable building lifecycle (SBL), Proc. of World Sustainable Building Conference, Tokyo, 1605-1612.

Gibbons, M., Limoges, C., Nowotny H., Schwartzman, S., Scott, P., Trow M. (1994). The new production of knowledge: the dynamics of science and research in contemporary science, Sage, Newbury Park.

Gilijamse, W. (1995) Zero-energy houses in the Netherlands, in Proceedings of Building Simulation '95, Madison, WI, US, 276-283.

Gluch, P. (2005). Building Green Perspectives on Environmental Management in Construction. PhD Book, Chalmers University of Technology, Göteborg.

Grin, J., Rotmans, J., Schot, J. (in collaboration with Loorbach D, Geels FW). (2010). Transitions to Sustainable Development. New Directions in the Study of Long Term Transformative Change. Routledge, New York.

Grosskurth, J., Rotmans J. (2005). The Scene model: Getting a grip on sustainable development in policy making. Environment, Development and Sustainability, 7(1), 135-151.

Hahn, T.J. (2008). LEED-ing Away from Sustainability Toward a Green Building System Using Nature's Design. Sustainability Mary, 1(3).

Hajer, M. (1995). Politics on the move: the democratic control of the design of sustainable technologies. Knowledge and Policy, 8(4), 26-29.

Häkkinen, T., Belloni, K. (2011). Barriers and drivers for sustainable building. Building Research & Information, 39(3), 239-255.

Halinen, A., Tornroos, J.A.K. (2005). Using case methods in the study of contemporary business networks. Journal of Business Research, 58(9), 1285-1297.

Hastings, R., Wall, M. (2007). Sustainable solar housing, vol. 1 - Strategies and Solutions, Earthscan, London.

Hawken, P., Lovins, A.M., Lovins, H. (1999). Natural capitalism: Creating the Next Industrial Revolution. Little, Brown & Company, Boston.

Hellstrom, T. (2007). Dimensions of Environmentally Sustainable Innovation: the Structure of Eco-Innovation Concepts. Sustainable Development 15(3), 148-159.

Henderson, R.M., Clark, K.B. (1990). Architectural Innovation: The Reconfiguration of Existing product Technologies and the Failure of Established Firms, Administrative Science Quarterly, 35, 9-30.

Hill, R., Bowen, P. (1997). Sustainable construction: principles and a framework. Construction Management and Economics, 15(3), 223-239.

Hobbs, J.E. (1996). A transaction cost approach to supply chain management. Supply chain management 2(1), 15-27.

Hoffman, A.J., Henn, R. (2008). Overcoming the social and psychological barriers to green building. Organization & Environment 21(4), 390-419.

Hopwood, B., Mellor, M., O'Brien, G. (2005). Sustainable Development: Mapping Different Approaches. Sustainable Development, 13(1), 38-52.

Howarth, R.B., Andersson, B. (1993). Market barriers to energy efficiency. Energy Ecnomics, 15(4), 262-272.

Hueting, R., Reijnders, L. (2004). Broad sustainability contra sustainability: the proper construction of sustainability indicators. Ecological Economics, 50(3-4), 249-260.

Hugé, J., Waas, T., Dahdouh-Guebas, F., Koedam, N., Block, T. (2012). A discourse-analytical perspective on sustainability assessment: interpreting sustainable develop-ment in practice. Sustainability Science. doi: 10.1007/s11625-012-0184-2

IEA, International Energy Agency. (2010). Key World Energy Statistics, Paris. http://www.iea.org/textbase/nppdf/free/2010/key_stats_2010.pdf

Intrachooto, S., Horayangkura, V. (2007). Energy efficient innovation: Overcoming financial barriers. Building and Environment, 42, 599-604.

IPCC, Intergovernmental Panel on Climate Change. (2007). Summary for Policymakers, Climate Change, IPCC WG1 Fourth Assessment Report, Cambridge University Press, New York, NY.

Iqbal, M. (2004) A feasibility study of a zero energy home in Newfoundland. Renewable Energy, 29(2), 277-289.

ISO standard 14020. (2000). Environmental labels and declarations - General principles, 2000.

ISO standard 15392. (2008). Sustainability in building construction - General principles.

ISO standard 15643-1. (2010). Sustainability of construction works - Sustainability assessment of buildings - Part 1: General framework.

ISO standard 21931-1. (2010). Sustainability in building construction - Framework for methods of assessment for environmental performance of construction works - Part 1: Buildings.

Janikowski, R., Kucharski, R., Sas-Nowosielska, A. (2000). Multi-criteria and multi-perspective analysis of contaminated land management methods. Environmental Monitoring and Assessment, 60, 89-102.

Jawahar, I.M., McLaughlin, G.L. (2001). Toward a descriptive stakeholder theory: An organizational life cycle approach. Academy of Management Review, 26(3), 397-414.

Johns, C.M., O'Reilly, P.L., Inwood, G.J. (2006). Intergovernmental Innovation and the Administrative State in Canada, Governance, 19(4), 627-649.

Johnson, G., Scholes, K. (1999). Exploring corporate strategy. Prentice Hall Europe, London.

Kash, D.E., Rycroft, R.W. (2003). To manage complex innovation ask the right questions. Industrial Research Institute, 29-33.

Kates, R., Clark, W., Corell, R., Hall, J., Jaeger, C., Lowe, I., McCarthy, J., Schellnhuber, H-J., Bolin, B., Dickson, N., Faucheux, S., Gallopin, G., Grubler, A., Huntley, B., Jager, J., Jodha, N., Kasperson, R., Mabogunje, A., Matson, P., and Mooney, H. (2001). Sustainability science. Science, 292(5517), 641-642.

Kavgic M., Mavrogianni A., Mumovic D., Summerfield A., Stevanovic Z., Djurovic-Petrovic M. (2010). A review of bottom-up building stock models for energy consumption in the residential sector. Building and Environment, 45, 1683-1697.

Keivani, R., Tah, J.H.M., Kurul, E., Abanda, F.H. (2010). Green jobs creation through sustainable refurbishment in the developing countries. A literature review and analysis conducted for the International Labour Organisation (ILO). International Labour Office, Geneva.

Kemp, R. (2010). Sustainable technologies do not exist! Ekonomiaz, 75(3), 2-17.

Kemp, R., Martens, P. (2007). Sustainable development: how to manage something that is subjective and never can be achieved? Sustainability: Science, Practice, & Policy, 3(2), 5-14.

Kemp, R., Parto, S., Gibson, R.B. (2005). Governance for sustainable development: moving from theory to practice. International Journal of Sustainable Development, 8(1-2), 12-30.

Kemp, R., Schot, J., Hoogma, R. (1998). Regime Shifts to Sustainability through Processes of Niche Formation. The Approach of Strategic Niche Management. Technology Analysis and Strategic Management, 10(2), 175-195.

Kenis, P.N., Oerlemans, L.A.G. (2008). The social Network perspective: understanding the structure of cooperation, in: Cropper S., Ebers M., Huxham C., Smith-Ring P. (eds.), Oxford Handbook of Inter-Organizational Relationships, Oxford University Press, Oxford.

Kenny, H. (2010). From net energy to zero energy buildings: Defining life cycle zero energy buildings (LC-ZEB). Energy and Buildings, 42(6), 815-821.

Kibert, C.J. (2007). The next generation of sustainable construction. Building Research and Information, 35(6), 595-601.

King, A., Lenox, M. (2001). Does it Really Pay to be Green? The Journal of Industrial Ecology, 5(1), 105-116.

King, A.A., Toffel, M. (2007). Self-regulatory Institutions for Solving Environmental Problems: Perspectives and Contributions from the Management Literature, in Magali Demas and Oran Young (Ed.) Governing The Environment: Interdisciplinary Perspectives

Kua, H.W., Lee, S.E. (2002). Demonstration intelligent building – a methodology for the promotion of total sustainability in the built environment. Building and Environment, 37(3), 231-240.

Kubba, S. (2010). LEED Practices, Certification, and Accreditation Handbook. Butter-woth-Heinemann, Burlington, MA.

Lam, P.T.I., Chan, E.H.W., Chau, C.K., Poon, C.S., Chun, K.P. (2010). Environmental management system vs green specifications: How do they complement each other in the construction industry? Journal of Environmental Management, 92, 1-8.

Lamming, R. (1993). Beyond partnership: strategies for innovation and lean supply. Prentice Hall, New York.

Landau, R., Rosenberg, N. (1986). National Academy of Engineering. The Positive Sum Strategy: Harnessing Technology for Economic Growth, National Academy Press, Washington, D.C.

Lang, G. (2009). Establishment of a Co-operation Network of Passive House Promoters (PASS-NET) International Passivhaus Database. Period of documentation 2007 – 2009, 20000 Passivhaus projects in Europe.

Larsson, N. (2010). Rapid GHG Reductions in the Built Environment under Extreme Conditions. International Journal of Sustainable Building Technology and Urban Development, 1(1), 15-21.

Lassen, A.H., Gertsen, F., Riis, J.O. (2006). The Nexus of Corporate Entrepreneurship and Radical Innovation, Creativity and Innovation Management, 15(4), 359-372.

Laustsen, J. (2008) Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings, OECD/IEA, Paris.

Lawrence, P., Dyer, D. (1983). Renewing American industry, Collier Macmillan Publishers, New York.

Lenox, M., Ehrenfeld, J. (1997). Organizing for Effective Environmental Design. Business Strategy and the Environment, 6(4), 187-196.

Levine, M., Urge-Vorsatz, D., Blok, K., Geng, L., Harvey, D., Land, S., Levermore, G., Mongameli Mehlwana, A., Mirasgedis, S., Novikova, A., Rlling, J., Yoshino, H. (2007). Residential and commercial buildings, Climate Change 2007: Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, U.K. & New York, NY, U.S.A.

Ling, F. (2003). Managing the implementation of construction innovations. Construction Management and Economics, 21(6), 635-649.

Loch, C.H., Huberman, B.A. (1999). A Punctuated-Equilibrium Model of Technology Diffusion. Management Science, 45(2), 160-177.

Lockwood, C. (2006). Building the Green Way, Harvard Business Review, June.

Loorbach, D., van Bakel, J.C., Whiteman, G., Rotmans, J. (2010). Business Strategies for Transitions Towards Sustainable Systems. Business Strategy and the Environment, 19(2), 133-146.

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

Lowe, R. (2007). Addressing the challenges of climate change for the built environment. Building Research & Information, 35(4), 343-350.

Lund, H., Marszal, A. and Heiselberg, P. (2011). Zero energy buildings and mismatch compensation factors. Energy and Buildings, 43(7), 1646-1654.

Lutzenhiser, L. (1994). Innovation and organizational networks Barriers to energy efficiency in the US housing industry. Energy Policy, 22(10), 867-876.

Maciel, A.A., Ford, B., Lamberts, R. (2007). Main influences on the design philosophy and knowledge basis to bioclimatic integration into architectural design - The example of best practices. Building and Environment, 42(10), 3762-3773.

Madsen, H., Ulhøi, J.P. (2001). Integrating environmental and stakeholder management. Business Strategy and the Environment, 10(2), 77-88.

Manseau, A., Seaden, G. (2001). Innovation in construction: an international review of public policies, Taylor & Francis, Books Ltd, London.

Manseau, A., Shields, R. (2005). Building Tomorrow: Innovation in the Construction and Engineering. Ashgate Publishing, London.

Martens, P. (2006). Sustainability: science or fiction? Sustainability: Science, Practice, & Policy, 2(1), 36-41.

Martin, E.R. (1997). Understanding the diffusion of energy efficiency technology in Residential Buildings, MIT.

McCool, S.F., Stankey, G.H. (2004). Indicators of sustainability: challenges and opportunities at the interface of science and policy. Environmental Management, 33(3), 294-305.

McDonough, W., Braungart, M. (2002). Cradle to Cradle, North Point, New York, NY.

McGilligan, C., Sunikka-Blank, M., Natarajan, S. (2010). Subsidy as an agent to enhance the effectiveness of the energy performance certificate. Energy Policy, 38(3), 1272-1287.

McGraw Hill Construction. (2005). Green Building Smart Market Report. 2006 Green Building Issue. New McGraw Hill Construction.

Meadows, D.J., Randers, J., Meadows, D.L. (1972). Limits to Growth. New York: Universe Books.

Mendelow, A. (1981). Environmental scanning: the impact of stakeholder concept. Proc. II International Conference on Information Systems, Cambridge, MA.

Mertz, G.A., Raffio, G.S. and Kissock, K. (2007) Cost optimization of net-zero energy house, in Proceedings of the Energy Sustainability Conference, 2007, 477-488.

Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A. (2007). IPCC - Summary for Policymakers, Climate Change, Cambridge University Press, Cambridge, NY, USA.

Miller, T. (2012). Constructing sustainability science: emerging perspectives and research trajectories. Sustainability Science. doi: 10.1007/s11625-012-0180-6

Mintzberg, H. (1979). The Structuring of Organizations. Englewood Cliffs, Prentice Hall.

Miozzo, M., Dewick, P. (2002). Building competitive advantage: innovation and corporate governance in European construction. Research Policy, 31(6), 989-1008.

Mitchell, G. (1996). Problems and fundamentals of sustainable development indicators. Sustainable Development, 4(1), 1-11.

Mitchell, R.K., Agle, B.R., Wood, D.J. (1997). Toward a theory of stakeholder identification and salience: Defining the Principle of Who and What Really Counts. Academy of Management Review, 22(4), 853-886.

Mlecnik, E., Visscher, H., van Hal, A. (2010). Barriers and opportunities for labels for highly energy efficient houses. Energy Policy, 38(8), 4592-4603.

Moffat, S., Kohler, N. (2008). Conceptualizing the built environment as a social - ecological system. Building Research and Information, 36(3), 248-268.

Mohsin, R., Davidson, C.H., (1991). Building procurement - Key to improved performance. Building Research & Information, 19(2), 106-113.

Mokhlesian, S. (2010). Knowledge generation and business model changes: the case of green construction, Research workshop on technology and innovation in construction, Lulea.

Moore, G. (1991). Crossing the chasm: marketing and selling disruptive products to mainstream customers, Harper Business Essentials.

Murakami, S., Kawakubo, S., Asami, Y., Ikaga T., Yamaguchi, N., Kaburagi, S. (2011). Development of a comprehensive city assessment tool: CASBEE-City. Building Re-search & Information, 39(3), 195-210.

Myres, M.D. (2008). Qualitative Research in Business & Management. Sage Publications Ltd, London.

Nam, C.H., Tatum, C.B. (1989). Toward Understanding of Product Innovation Process in Construction, Journal of Construction Engineering and Management, ASCE, 115(4), 517-534.

Nam, C.H., Tatum, C.B. (1997). Leaders and champions for construction innovation. Construction Management and Economics, 15(3), 259-270.

Nelson, R.R., Winter, S.G. (1982). An Evolutionary Theory of Economic Change. Harvard University Press.

Newcombe, R. (2003). From client to project stakeholders: a stakeholder mapping approach. Construction Management and Economics, 21(8), 841-848.

Newsham, G.R. Mancini S., Birt, B.J. (2009). Do LEED-certified buildings save energy? Yes, but..., Energy and Buildings, 41, 897-905.

Nijkamp, P., Rietveld, P., Voogd, H. (1990). Multicriteria Evaluation in Physical Planning. North-Holland, New York.

Nill, J., Kemp, R. (2009). Evolutionary approaches for sustainable innovation policies: From niche to paradigm? Research Policy, 38(4), 668-680.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. Organization Science, 5(1), 14-37.

OECD, Organisation for Economic Co-operation and Development. (2003). The measurement of scientific and technological OSLO MANUAL. http://www.oecd.org/dataoecd/35/61/2367580.pdf

Olander, S., Landin, A. (2005). Evaluation of stakeholder influence in the implementation of construction projects. International Journal of Project Management, 23(4), 321-328.

Pagell, M., Wu, Z. (2009). Building A More Complete Theory Of Sustainable Supply Chain Management Using Case Studies Of 10 Exemplars. Journal of Supply Chain Management, 45(2), 37-56.

Painuly, J.P. (2003). Barriers to renewable energy penetration: a framework for analysis. Renewable Energy, 24(2), 73-89.

Parnphumeesup, P., Kerr, S.A. (2011). Stakeholder preferences towards the sustainable development of CDM projects: Lessons from biomass (rice husk) CDM project in Thailand. Energy Policy, 39(6), 3591-3601.

Parr, A., Zaretsky, M. (2010). New Directions in Sustainable Design. London: Taylor & Francis.

Peine, A. (2009). Understanding the dynamics of technological configurations: A conceptual framework and the case of Smart Homes. Technological Forecasting & Social Change, 76, 396-409.

Perez-Lombard, L., Pout, J.O.C. (2008). A review on buildings energy consumption information. Energy and Buildings, 40, 394-398.

Peschiera, G., Taylor, J.E., Siegel, J.A. (2010). Response–relapse patterns of building occupant electricity consumption following exposure to personal, contextualized and occupant peer network utilization data. Energy and Buildings, 42, 1329-1336.

Petts, J., Herd, A., Gerrard, S., Horne, C. (1999). The climate and culture of environmental compliance within SMEs. Business Strategy and the Environment, 8(1), 14-30.

Pinkse, J., Dommisse, M. (2009). Overcoming Barriers to Sustainability: an Explanation of Residential Builders' Reluctance to Adopt Clean Technologies. Business Strategy and the Environment, 18(8), 515-527.

Pisano, G., Verganti, R. (2008). Which kind of collaboration is right for you? Harvard Business Review.

Pisano, G.P. (1996). The Development Factory: Unlocking the Potential of Process Innovation. Boston: Harvard Business School Press.

Pohoryles, R.J. (2007). Sustainable Development, Innovation and Democracy, Innovation. The European Journal of Social Science Research, 20(3), 183-190.

Poole, M.S., Van de Ven, A.H. (2004). Handbook of Organizational Change and Innovation, Oxford University Press, New York.

Porritt, J. (2007). Capitalism as if the world matters, Earthscan, London.

Pries, F., Janszen, F. (1995). Innovation in the construction industry: the dominant role of the environment. Construction Management and Economics, 13(1), 43-51.

Reed, B. (2007). Shifting from 'sustainability' to regeneration. Building Research and Information, 35(6), 674-680.

Revell, A., Blackburn R. (2007). The Business Case for Sustainability? An Examination of Small Firms in the UK's Construction and Restaurant Sectors. Business Strategy and the Environment, 16, 404-420.

Rinzin, C., Velthuis, D.N., Vermeulen W.J.V. (2007). The 'successful failure' of the sustainable development agreement between the Netherlands and Bhutan. Sustainable Development, 15(6), 382-396.

Robinson, J. (2004). Squaring the circle: on the very idea of sustainable development. Ecological Economics, 48(4), 369-384.

Roe, E. (1998). Taking Complexity Seriously. Policy Analysis, Triangulation, and Sustainable Development, Kluwer Academic, Boston.

Rogers, E.M. (2003). Diffusion of innovations, 5th ed, Free Press, New York,

Rohracher H. (2001). Managing the Technological Transition to Sustainable Construction of Buildings: A Socio-technical Perspective. Technology Analysis & Strategic Management, 13(1), 137-150..

Ross, P.F. (1974). Innovation Adoption by Organizations. Personnel Psychology, 27(1), 21-47.

Runhaar, H., Tigchelaar, C., Vermeulen, W.J.V. (2008). Environmental Leaders: Making a Difference. A Typology of Environmental Leaders and Recommendations for a Differentiated Policy Approach. Business Strategy and the Environment, 17(3), 160-178.

Schumpeter, J.A. (1976). Capitalism, Socialism, and Democracy, Allen and Unwin, London.

Seuring, S. (2011). Supply Chain Management for Sustainable Products – Insights From Research Applying Mixed Methodologies. Business Strategy and the Environment, Forthcoming.

Seuring, S., Muller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production, 16(15), 1699-1710.

Sev, A. (2009). How can the construction industry contribute to sustainable development? A conceptual framework. Sustainable Development, 173(3), 161-173.

Sexton, M., Barrett, P. (2003). Appropriate innovation in small construction firms. Construction Management and Economics, 21(6), 623-633.

Sharma, S. (2000). Managerial interpretations and organisational context as predictors of corporate choice of environmental strategy. Academy of Management Journal, 43(4), 681-697.

Slaughter, E.S. (1993). Builders as sources of construction innovation. ASCE Journal of Construction Engineering and Management, 119(3), 532-549.

Slaughter, E.S. (1993). Innovation and Learning During Implementation: A Comparison of User and Manufacturer Innovations. Research Policy, 22, 81-95.

Slaughter, E.S. (1997). Characteristics of Existing Construction Automation and Robotics Technologies. Automation in Construction, 6, 109-120.

Slaughter, E.S. (1998). Models of Construction Innovation. Journal of Construction Engineering and Management, 124(2), 226-231.

Slaughter, E.S. (1999). Assessment of construction process and innovations through simulation. Construction Management and Economics, 17(3), 341-350.

Slaughter, E.S. (2000). Implementation of Construction Innovations. Building Research and Information, 28(1), 2-17.

Slaughter, E.S., Eraso, M. (1997). Simulation of Structural Steel Erection to Assess Innovations. IEEE Transactions on Engineering Management, 44(2), 196-207.

Slaughter, E.S., Shimizu, H. (2000). Clusters of Innovations in Recent Long Span and Multi-Segmental Bridges. Construction Management and Economics, 18(3), 269-280.

Smith, T., Fischlein, M., Suh, S., Huelman, P. (2006). Green Building Rating Systems - A comparison of the LEED and Green Globes in the US.

Son, H., Kim, C., Chong, W.K., Chou, J.S. (2011). Implementing Sustainable Development in the Construction Industry: Constructors' Perspectives in the US and Korea. Sustainable Development, Forthcoming.

Stenberg, A.C., Räisänen, C. (2006) The interpretative flexibility of "green" in the building sector: Diachronic and synchronic perspectives. International Studies of Management & Organisation, 36(2), 32-54.

Steurer, R., Hametner, M. (2011). Objectives and indicators in sustainable development strategies: similarities and variances across Europe. Sustainable Development, Forthcoming.

Suzuki, M., Oka, T. (1998). Estimation of life cycle energy consumption and CO2 emission of office buildings in Japan. Energy and Buildings, 28(1), 33-41.

Svenfelt, Å., Engström, R., Svane, Ö. (2011). Decreasing energy use in buildings by 50% by 2050 - A backcasting study using stakeholder groups. Technological Forecasting & Social Change, 78(5), 785-796.

Swan, L.G., Ugursal, V.I., (2009). Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. Renewable and Sustainable Energy Reviews, 13(8), 1819-1835.

Tangkar, M., Arditi D. (2000). Innovation in the construction industry. Dimensi Teknik Sipil, 2(2), 96-103.

Tatari, O., Kucukvar, M., (2011). Cost premium prediction of certified green buildings: A neural network approach. Building and Environment, 46(5), 1081-1086.

Tatum, C.B. (1986). Demands and Means for Construction Innovation, Constr. Innovation: Demands, Successes and Lessons, ASCE Convention, Seattle, Washington, ASCE, 31-43.

Tilley, F. (1999). The gap between the environmental attitudes and the environmental behaviour of small firms. Business Strategy and the Environment, 8(4), 238-248.

Toole, T.M. (1998). Uncertainty and Home Builders' Adoption of Technological Innovations. Journal of Construction Engineering and Management, 124(4), 323-332.

Torcellini, P., Pless, S., Deru, M. and Crawley, D. (2006) Zero Energy Buildings: A Critical Look At the Definition. NREL/CP-550-39833, National Renewable Energy Laboratory (NREL), Golden, CO.

Turner Construction Company. (2005). Green Building Market Barometer. Turner Construction. http://www.turnerconstruction.com/greenbuildings/content.asp?d=2199.

Tushman, M.L., Nadler, D.A. (1978). Information Processing as an Integrating concept in Organizational Design. Academy of Management Review, 3(3), 613-624.

UIA. (2009). Sustainable by Design Declaration, available at: http://www.uia-architectes.org/cop15_en.html

Ulrich, K. (1995). The role of product architecture in the manufacturing firm. Research Policy, 24, 419-440.

Ulrich, K.T., Eppinger, S.D. (2000). Product design and development. Irwin McGraw-Hill.

Ulrich, K.T., Seering, W.P. (1990). Function sharing in mechanical design. Design Studies, 11(4), 223-234.

Ulrich, K.T., Tung, K. (1991). Fundamentals of product modularity, MIT Sloan School of Management, Cambridge, MA.

UNEP, United Nations Environment Programme. (2003). Sustainable building and construction: facts and figures. Industry and Environment, 5.

UNEP-SBCI, United Nations Environment Programme - Sustainable Buildings & Climate Initiative (2009). Buildings and Climate Change: a Summary for Decision-Makers, UNEP-DTIE Sustainable Consumption & Production Branch, Paris.

Urge-Vorsatz, D., Mirasgedis, S., Harvey, D., and Levine, M. 2007. Mitigating CO2 emissions from energy use in the world's buildings. Building Research and Information, 35(4), 458-477.

Vakili-Ardebili A., Boussabaine A.H. (2007). Design eco-drivers, The Journal of Architecture, 12(3), 315-332.

Vallance, S., Perkins, H.C., Dixon, J.E. (2011). What is social sustainability? A clarification of concepts. Geoforum, 42(3), 342–348.

van Zeijl-Rozema, A., Cörvers, R., Kemp, R., Martens, P. (2008). Governance for Sustainable Development: A Framework Sustainable Development. Sustainable Development, 16(6), 410-421.

Verganti, R. (1997). Leveraging on systemic learning to manage the early phases of product innovation projects. R&D Management, 27(4), 377-392.

Vermeulen, W.J.V., Hovens, J. (2006). Competing explanations for adopting energy innovations for new office buildings. Energy Policy, 34(17), 2719-2735.

von Hippel, E. (1988). The source of innovation, Oxford University Press.

Vrijhoef, R. (2007). Supply chain integration in construction - Co-makership in Construction, Delft University of Technology Press, Delft.

Walker, A. (2007). Project management in construction, 5th ed. Wiley-Blackwell, London.

Walker, D.H., Salt, D. (2006) Resilience Thinking. Sustaining Ecosystems and People in a Changing World, Island, Washington, DC.

Walker, D.H.T., Bourne, L.M., Shelley, A. (2008). Influence, stakeholder mapping and visualization. Construction Management and Economics, 26(6), 645-658.

Watson, E. (2007). Who or What Creates? A Conceptual Framework for Social Creativity, Human Resource Development Review, 6(4), 419-441.

WCED, World Commission on Environment and Development. (1987). Our Common Future, Oxford University Press, New York.

Williams, C.C., Millington, A.C. (2004). The diverse and contested meanings of sustainable development. The Geographical Journal, 170(6), 99-104.

Williams, K., Dair, C. (2007). What Is Stopping Sustainable Building in England? Barriers Experienced by Stakeholders in Delivering Sustainable Developments. Sustainable Developments, 15(3), 135-147.

Williamson, O.E. (1991). Comparative economic organization: the analysis of discrete structural alternatives. Administrative Science Quarterly, 36(2), 269-296.

Winch, G. M. (1998). Zephyrs of creative destruction: understanding the management of innovation in construction. Building Research and Information, 26(4), 268-279.

Winch, G.M. (2010). Managing construction projects, 2nd ed. Wiley-Blackwell, London.

Winston, N. (2010). Regeneration for sustainable communities? Barriers to implementing sustainable housing in urban areas. Sustainable Development, 18(6), 319-330.

Womack, J.P., Jones, D.T., Roos, D. (1990). The Machine That Changed the World: The Story of Lean Production. Harper Perennial, New York.

Wu, P., Low, S.P. (2010). Project management and green buildings: Lessons from the Rating Systems. Journal of professional issues in engineering, 136(2), 64-70.

Yanarella, E., Bartilow, H. (2000). Dreams of Sustainability: Beyond the Antinomies of the Global Sustainability Debate. International Journal of Sustainable Development, 3(4), 370-389.

Yao, R., Li, B., Steemers, K. (2005). Energy policy and standard for built environment in China. International Journal of Renewable Energy, 1-16.

Yin, R.K. (2009). Case Study Research: Design and Methods, 4th ed. Sage Inc, Thousand Oaks, CA.

Yip Robin, C.P., Poon, C.S. (2009). Cultural shift towards sustainability in the construction industry of Hong Kong. Journal of Environmental Management, 90(11), 3616-3628.

Yu, W., Wu, C., Huang, T. (2009). Development and application of a systematic innovation procedure for construction technology. Proc. 26th Intern. Symp. Automation and Robotics in Construction, ISARC.

List of Abbreviations

CED	Cumulative energy demand
CPD	Construction Products Directive
EC	European Commission
EPA	Environmental Protection Agency
EPD	Environmental Product Declarations
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel of Climate Change
NGO	Non-governmental Organisation
LCA	Life cycle analysis
NIST	National Institute of Standards and Technology
OECD	Organisation for Economic Co-operation and Development
SBCI	Sustainable Buildings & Climate Initiative, Buildings
TQA	Total quality assessment
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
WCED	World Commission on Environment and Development

Index

E

F

G

H

I

Author's Biography

Umberto Berardi is an Assistant Professor in the Civil & Environmental Engineering Department at the Worcester Polytechnic Institute (MA, USA). He teaches sustainable construction, architectural engineering systems and building physics.

He earned a degree in Building Engineering and Architecture at the Politecnico di Bari, and he received a Master's degree in Engineering from the ISVR of the University of Southampton (UK). He attended the PhD course in Building Engineering at the Politecnico di Bari and the Scuola Interpolitecnica, in Product Development and Innovation Management.

Before joining the Worcester Polytechnic Institute, he had research experiences in the Faculty of Architecture of Valencia (S), the Syracuse University in U.S. and at the International Centre for Integrated assessment and Sustainable Development of the University of Maastricht (NL).

He has attended and given speeches in several specialised courses and conferences worldwide. He is collaborating with the UNEP-SBCI in writing the "The State of Play Report of Green Buildings in Italy".

Recently, Umberto has been studying sustainable innovations for buildings. His studies have covered areas such as innovation diffusion, sustainability assessment, energy efficiency technologies, and green buildings. Umberto is taking an active role within the WG 116 (Smart and Sustainable Building) of CIB - International Council for Research and Innovation in Building and Construction.

He has published more than twenty articles in peer-reviewed journals, including *Renewable & Sustainable Energy Reviews*, *Sustainable Development*, *Business Strategy and the Environment*, and the *Journal of Low-Carbon Technologies*.