TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Environmental Sciences

Title of the dissertation

The Role of Energy Efficiency in the Private Housing Sector
The Case of Santiago de Chile

Dissertation for awarding the academic degree
Doktoringenieur (Dr.-Ing.)

submitted by
M.Sc. José Luis Mercado Fernández
born in 27.12.1975 in Cochabamba.

supervisors:

Prof. Dr. Dr. h. c. Bernhard Müller
Technische Universität Dresden
Faculty of Environmental Sciences, Chair of Spatial Development

Prof. Dr. Waldo Bustamante
Pontificia Universidad Católica de Chile
Faculty of Architecture, Design und Urban Studies

Prof. Clemens Deilmann
Hochschule für Technik und Wirtschaft Dresden
Faculty of Civil Engieneering and Architecture

Dresden, 18.02.2015

Explanation of the doctoral candidate

This is to certify that this copy is fully congruent with the original copy of the thesis with the topic:

“The Role of Energy Efficiency in the Private Housing Sector – The Case of Santiago de Chile“

Dresden, 18.02.2015

……………………………………………

José Mercado

Acknowledgements

I would like to thank the Dresden Leibniz Graduate School (DLGS), for supporting my doctoral research. The framework that underpins the DLGS, a joint activity of the Leibniz Institute of Ecological and Regional Development (IOER), the Technische Universität Dresden (TU Dresden), as well as the Academy for Spatial Research and Planning (ARL), provided me many tools that have enriched my education significantly.

I would also like to thank everyone who has contributed to my work. I would like to thank my supervisor Prof. Dr. Dr. h.c. Bernhard Müller for his support and guidance. Also, I thank Dr. Paulina Schiappacasse (DLGS) and Prof. Clemens Deilmann (IOER) for their support when acting as members of my advisory commission. Moreover, I would like to thank Prof. Waldo Bustamante (Pontificia Universidad Católica de Chile), for evaluating my work and for his selfless support to my research.

I sincerely thank my interview partners in Santiago de Chile, namely the representatives of real estate companies, scholars, and practitioners, for their willingness to contribute to science and to my research and for sharing their knowledge and experience from different approaches and perspectives. Their expertise allowed shedding light on my research and contributing to the scientific discussion on the field of residential energy efficiency.

I thank my friends in Dresden and to my colleges at the DLGS, for walking with me side by side during my staying in Germany. Particularly, I thank Cindy Krause and her family for sharing the warmth of their home with me. I thank Nadia Manasfi and Anne Bräuer, I'm truly grateful for proofreading my work, for their constructive criticism, helpful feedback, and continued support when I most needed it.

I am very grateful with my family in Bolivia, for their unconditional support from afar and sharing the ups and downs in my life during the last years. To my family in Chile, to Dr. Claudia Rodríguez I thank her for supporting me since I started this path, I wouldn't have made it to Germany without her wholehearted support; to Álvaro Román for sharing knowledge and friendship to full hands. At last but not least, I thank Valeria Ramirez who never stopped encouraging me since day one.

José Mercado Dresden, October 2014.

Abstract

In the international context, this research analyzes the state of the art of scientific discussion, the action exerted by national and local governments through regulations, and the opinion of professionals in the field of construction of buildings in relation to the implementation of energy efficiency measures in buildings. In general, the interest in the different areas has been driven primarily by: 1) the worldwide increased energy consumption in buildings, emphasizes by an increasingly urbanized world and the resource scarcity for power generation, primarily fossil fuels; 2) the increase in greenhouse gas emissions related to the buildings' construction and operation; and 3) the thermal behaviour of the building's envelope, which determines the energy demand for thermal conditioning; mainly for heating in winter and cooling in summer.

The foregoing has resulted in the implementation of different types of energy efficiency measures in the building sector around the world. On the one hand, through mandatory measures, driven by national and local governments through building codes; mandatory measures require that when building a new building or refurbishing an existing one, the architects, private developers, or builders must comply with building standards that govern the thermal performance of the different elements of the buildings' thermal envelope. On the other hand, by implementing voluntary measures, such as international certification systems, established by non-governmental institutions, aimed at legitimizing the efforts of building owners, design teams, and builders to design, build, and operate buildings in an environmentally friendly way. The latter has triggered an international trend and an increasing demand for certification of the so-called "*green buildings*". Such independent certification systems seek to reduce the environmental impact of activities in the construction sector. In the Chilean context, this research analyzes the relationship between two main pillars of the Chilean economy, the energy sector and the private housing sector. Particularly, this research focuses on the implementation of energy efficiency measures in the private housing market in Santiago, the Chilean capital.

From the energy perspective, the high vulnerability for power generation by the dependence on the provision of gas from neighbouring countries and periods of drought affecting hydroelectric power generation, has led to the Chilean government intervention. Government intervention is centred on two main lines of action: 1) the diversification of the country's energy matrix, through the implementation of alternative systems for power generation based on non-conventional renewable energy sources; and 2) the implementation of energy efficiency measures. In the construction sector, the latter is

expressed by the entry into force of the New Thermal Regulations for new residential buildings in three stages in the building code since 2000. With the implementation of new regulations in the construction sector in the Chilean context and the growing demand for green building in the international context, private real estate companies and construction companies, which are the backbone of the construction sector in Chile, have reacted by offering energy efficient real estate products in Santiago de Chile.

Based on the foregoing, arises the main question leading this doctoral thesis: How do real estate developers apply energy efficiency in their housing offer in Santiago de Chile? The main research question is further refined by three sub questions: 1) who are the real estate developers that are adopting energy efficiency and why? This is a compound question, first it seeks to identify real estate companies adopting energy efficiency measures in Santiago de Chile's private housing market; then it looks into the motivations for doing so; 2) what types of energy efficiency measures are real estate companies adopting? This sub-research question seeks to identify the adopted residential energy efficiency strategies; and 3) which barriers to further implementation of energy efficiency exist? It seeks to identify the setbacks found by energy efficiency adopters in the implementation process, in order to understand local issues in the adoption process.

The Case Study and Selection of Sub-Cases for the Analysis

The research focuses on the voluntary implementation of residential energy efficiency measures in the private housing market; moreover, it analyzes the case of Santiago de Chile. Therefore, the focus is set on real estate companies that offer energy efficient housing in their offer for real estate products in the metropolitan region.

The selection of embedded sub-cases for the analysis, or sub-cases, was made by applying a criterion sampling strategy known as purposive sampling. For this, a thorough review of 568 private real estate companies' websites, offering different real estate products in the Metropolitan Region of Santiago de Chile between June and July 2011, was performed. Out of this group, a set of 45 companies that offering energy efficient homes mentioned were selected. Later on, personal interviews mainly with general managers of real estate development companies and other actors considered key informants because of their knowledge in the field, such as scholars, representatives from public institutions, other public and private research centres, and practitioners, were conducted between April and May 2012.

Main Methods and Data Analysis

Research is conducted under a qualitative approach, as it focuses primarily on the opinion of real estate companies' CEOs and other key informants considered information rich when helping answering the research questions. The main tool for data analysis was the thematic content analysis.

Main Findings

The main results of this research are structured on the basis of answering the secondary research questions or sub-questions.

Who are the real estate developers that are adopting energy efficiency and why?

As it was mentioned above, the first part of this compound sub-question seeks to identify the real estate companies that are implementing residential energy efficiency measures in their offer in the housing market in Santiago de Chile. A set of 45 real estate companies were identified because they mentioned to be applying some sort of energy efficiency measures. This was a rather small group since, at that time, 568 real estate companies were offering housing products. Based on the empirical findings, a categorization of real estate companies following the Roger's model was conducted. Thus, real estate companies were categorized depending on when they began adopting residential energy efficiency measures in their housing offer. The stages of the New Thermal Regulation (NTR) issued for the housing sector in Chile helped defining the adopter categories. Accordingly, two main adopter's categories emerged following Roger's model. 1) *innovators*, includes real estate companies who adopted energy efficiency measures for the first time before the entry into force of the first stage of the NRT in 2000; and 2) *early adopters*, groups real estate companies who adopted residential energy efficiency measures for the first time after the first stage of the NTR, that is to say between 2001 and 2011 when the selection of cases for this research took place). The empirical evidence suggests that the adoption process of energy efficiency measures has started following the normal development described by Rogers' innovation curve. Therefore, it is expected that the rest of the real estate developers operating in the private housing market in Santiago de Chile will eventually follow the *innovators* and *early adopters.*

The second part of the sub-research question, and probably the most important one, seeks to understand the motivations for real estate companies to offer and implement energy-efficient real estate products in Santiago de Chile's private housing market. This research identifies the motivations of real estate development companies in the opinion of their managers collected in personal semi-structured interviews conducted during fieldwork. Based on the thematic analysis of the abovementioned interviews, four categories of motivations for offering and applying energy efficiency were identified based on the company managers' opinion. These categories, in order of preference are: 1) Market Differentiation Strategies (Competitiveness and Trending); 2) Company Policies (Client-Oriented Policies, Innovation Policies, and Environmentally-friendly Policies); 3) Resource efficiency (Reduction of Household's Expenses and Concerns for Energy Scarcity); and 4) Government Incentive Schemes (Subsidies to the Use of Renewable Energy).

Briefly, the main motivations for adopting energy efficiency measures in the private housing offer are related to marketing strategies. In general, real estate companies operating in Santiago de Chile are looking to distinguish themselves from their competitors by offering energy-efficient housing products. This is mainly because real estate companies are following a trend that is driven by several factors such as: local energy shortage periods, the international influence of green buildings in the real estate market, and the growing demand for international certifications in the Chilean context.

What types of energy efficiency measures are real estate companies adopting?

As mentioned earlier, this research identifies real estate companies offering energy-efficient housing in the private real estate market of Santiago de Chile who implemented a diversity of energy efficiency strategies in their housing supply, as the empirical evidence shows. Although the motivations for implementing energy efficiency measures are diverse (as described previously), energy efficiency measures are mainly implemented in order to reach a comfort temperature inside the dwelling, making all possible efforts to ensure that energy is used efficiently. In the case of the residential buildings, this means looking for the optimal use of energy for space heating or cooling, lighting, hot sanitary water, and ventilation.

In general, depending on whether there is the need to make an additional energy effort in order to achieve optimum indoor comfort conditions, the energy efficiency measures implemented in the private housing sector in Santiago de Chile can be grouped into two main categories of energy efficiency strategies: passive design strategies and active design strategies.

On the one hand, passive design strategies refer to what real estate developers are doing to reduce the energy consumption of their housing buildings. Such strategies include: 1) improving the overall thermal performance of the building envelope; 2) the use of renewable energy, mainly solar thermal and photovoltaic technology, for hot sanitary water and energy conversion respectively; and 3) bioclimatic design and construction principles. As it was mentioned in Section 6.1, a basic characteristic of passive design strategies, distinguishing them from active design strategies, is that in order to operate they rely on the building site and the inherited thermal properties of the building materials used in the different housing building typologies.

On the other hand, active design strategies refer to the technological innovations implemented in order to maintain an optimal indoor thermal conditioning and to reduce the energy used in the different buildings' systems; namely, 1) illumination systems; 2) heating systems; 3) centralized control systems; and 4) air conditioning systems. In general, real estate developers adopted active design strategies as a complement to the use of passive design strategies.

Not surprisingly, real estate developers have mentioned the improvement of the thermal envelope as the most commonly used residential energy efficiency strategy. This results from the fact that building energy regulations in the housing sector were implemented in order to improve the thermal behaviour of dwellings, and therefore, their energy efficiency.

Finally, a third type of energy efficiency strategy adopted by real estate developers in Santiago de Chile is the result of a public-private partnership between the Chilean Government and the Chilectra, the local electricity utility. The initiative is called "*Chilectra – Full Electric Buildings*" and it offers an optional electrical energy tariff for residential consumers. This strategy is further explained in Section 6.3.

Which barriers to further implementation of energy efficiency exist?

Based on the opinion of the various key stakeholder involved in this research, this research shows that most barriers to energy efficiency in the private housing sector in Santiago de Chile interact and strengthen each other. The classification of barriers to further implementation of energy efficiency is not straightforward. Nonetheless, in the opinion of real estate companies' managers, the barriers to adopting energy efficiency measures in the private housing market in Santiago de Chile revolve around the specific characteristics of the local social system. These barriers are: 1) market barriers; 2) organizational barriers; 3) institutional barriers; and 4) behavioural barriers.

In relation to the categorization of energy efficiency adopters identified in the first sub-question, the empirical evidence seems to indicate that, not all the barriers play the same role for all adopter categories. In general, market barriers are most relevant to the *innovators* group. Although most of the real estate developers mentioned that even today the local market and the local construction industry are not ready to provide adequate support (both in the availability of products and services) for further development of the market for energy efficient construction, the deficiency was greater 20 years ago, when the *innovators* first started to implement residential energy efficiency measures in the private housing sector. Moreover, the other barriers encountered (namely organizational and institutional barriers) are transversal to the adopter categories. This seems to be drawn from the organizational and institutional characteristics of the context in which private real estate companies operate. The context remains constant over time and their internal relationships are also maintained, homogeneously affecting all adopter categories. Finally, barriers related to end users and/or clients' behaviour are mainly listed by early adopters, which comprises developers who implement residential energy efficiency measures recently (after 2000). Apparently, this results mainly from the fact that end user are lacking information about the benefits (general and local) to be gained from implementing residential energy efficiency measures.

Contents

List of Figures

List of Tables

List of Abbreviations

ACEEE	American Council for an Energy-efficient Economy
AChEE	Chilean Energy Efficiency Agency (Agencia Chilena de Eficiencia Energética, Chile)
ADI	Real Estate Developers Association (Asociación de Desarrolladores Inmobiliarios, Chile)
APERC	Asia Pacific Energy Research Centre
ASHRAE	American Society of Heating, Refrigerating and Air conditioning Engineers, INC. (US)
BCCh	Central Bank of Chile
BEN	National Energy Balance (Balanço Energético Nacional, Brazil)
BMVBS	Ministry of Building and Urban Affairs (Bundesministerium für Verkehr, Bau und Stadtentwicklung, Germany)
BRE	Building Research Establishment (UK)
BREEAM	Building Research Establishment Environmental Assessment Method (UK)
BTP	Building Technologies Program (Department of Energy, US)
CBECS	Commercial Building Energy Consumption Survey (Department of Energy, US)
CChC	Chilean Construction Chamber (Cámara Chilena de la Construcción, Chile)
CChEN	Chilean Nuclear Energy Commission (Comisión Chilena de Energía Nuclear, Chile)
CDD	Cooling Degree Day
CDT	Technological Development Corporation (Corpotación de Desarrollo Tecnológico, Chile)
CEO	Chief Executive Officer
CEPAL	Economic Commission for Latin America and the Caribbean (Comisión Económica para América Latina y el Caribe)
CER	Renewable Energy Centre (Centro de Energías Renovables, Chile)
CEV	Housing Energy Rating (Calificación Energética de Viviendas, Chile)
CGIEE	Steering Committee Indicators and Levels of Energy Efficiency (Comitê Gestor de Indicadores e Níveis de Eficiência Energética, Brazil)
CLASP	Collaborative Labelling and Appliance Standards Program

CNE	Chilean National Energy Commission (Comisión Nacional de Energía, Chile)
CODELCO	National Copper Corporation (Corporación Nacional del Cobre, Chile)
CSR	Corporate Social Responsibility
CTE	Technical Edification Code (Código Técnico de Edificación, Spain)
CUREN	Conservation and Rational Energy Use Programme (Programa de Conservación y Uso Racional de la Energía, Chile)
DB	Basic Document (Documento Básico, Spain)
DENA	German Energy Agency (Deutsche Energie-Agentur GmbH, Germany)
DER	Dwelling CO_2 Emission Rate
DGNB	German Sustainable Building Certification (Deutsche Gesellschaft für Nachhaltiges Bauen, Germany)
DOM	Municipal Works Department (Dirección de Obras Municipales, Chile)
DSIR	Department of Scientific and Industrial Research (UK)
EE	Energy Efficiency
EEM	Energy Efficiency Measures
EER	Energy Efficiency Requirements
EERE	Office of Energy Efficiency and Renewable Energy (Department of Energy, US)
EG	Energy Performance Certificate for Buildings (Energieausweis für Gebäude, Germany)
ENE	National Energy Strategy (Estrategia Nacional de Energía, Chile)
EPA	Environmental Protection Agency (US)
EPBD	Energy Performance of Buildings Directive (EU)
EPC	Energy Performance Certificate
ERNC	Non-Conventional Renewable Energy Sources (Energías Renovables No Convencionales, Chile)
ETTV	Envelope Thermal Transfer Value
EU	European Union
GB	Green Buildings
GDP	Gross Domestic Product

GFC Global Financial Crisis

GHG Greenhouse Gas

GIZ German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, Germany)

GSBC German Sustainable Building Certificate (Gütesiegel Nachhaltiges Bauen, Germany)

HDD Heating Degree Day

HVAC Heating, Ventilation, and Air Conditioning

HTML Hypertext Markup Language

IC Institute of Construction (Instituto de la Construcción, Chile)

IEA International Energy Agency

IMACON Monthly Construction Activity Index (Índice Mensual de Actividad de la Construcción, Chile)

INE National Statistics Institute (Instituto Nacional de Estadísticas, Chile)

IPCC Intergovernmental Panel on Climate Change

ISO International Organization for Standardization

LBGMA Environmental General Basis Law (Ley de Bases Generales del Medio Ambiente, Chile)

LCOP Public Works Concessions Law (Ley de Concesiones de Obras Publicas, Chile)

LEED Leadership in Energy and Environmental Design (US)

LGUC General Law of Urban Planning and Construction (Ley General de Urbanismo y Construcción, Chile)

LOE Building Construction Law (Ley de Ordenación de la Edificación, Spain)

MEPR Minimum Energy Performance Requirements (EU)

MEPS Minimum Energy Performance Standards (EU)

MINEN Ministry of Energy (Ministerio de Energía, Chile)

MINVU Ministry of Housing and Urban Development (Ministerio de Vivienda y Urbanismo, Chile)

MME Ministry of Mines and Energy (Ministério de Minas e Energia, Brazil)

MNE Spanish Regulatory Framework (Marco Normativo Español, Spain)

MOP Ministry of Public Works (Ministerio de Obras Públicas, Chile)

NCh Chilean Normative (Norma Chilena, Chile)

NM Net Metering

NRT New Thermal Regulations (Nueva Regulación Térmica, Chile)

OGUC General Ordinance of Urbanism and Constructions (Ordenanza General de Urbanismo y Construcciones, Chile)

OLADE Latin American Energy Organization (Organización Lationamericana de Energía)

OPEC Organization of the Petroleum Exporting Countries

OTTV Overall Thermal Transfer Value

PAEE20 Energy Efficiency Action Plan

PD Private Developer

PDUC Conditioned Urban Development Projects (Proyectos de Desarrollo Urbano Condicionado, Chile)

PNCURE National Policy for Conservation and Rational Use of Energy (Política Nacional de Conservação e Uso Racional de Energía, Chile)

PPEE National Energy Efficiency Program (Programa País Eficiencia Energética, Chile)

PPPF Family Heritage Protection Program (Programa de Protección al Patrimonio Familiar, Chile)

PRIEN Programme of Research in Energy (Programa de Estudios e Investigaciones en Energía, Chile)

PROCEL Brazilian Program for Electricity Conservation in Buildings (Programa Nacional de Eficiência Energética em Edificações, Brazil)

PV Photo voltaic

RMS Metropolitan Region of Santiago (Región Metropolitana de Santiago, Chile)

RTTV Roof Transfer Value

SAP Standard Assessment Procedure

SEC Superintendence of Electricity and Fuels (Superintendencia de Electricidad y Combustibles, Chile)

SEF Solar Energy Factor

SERVIU Housing and Urban Planning Regional Service (Servicio de Vivienda y Urbanismo, Chile)

STP	Solar Thermal Panels
TER	Target CO_2 Emission Rate
THR	Residential Hourly Rate (Tarifa Horario Residencial, Chile)
MZT	Thermal Zoning Map (Mapas de Zonificación Térmica, Chile)
UKAS	United Kingdom Accreditation Service
UNEP	United Nations Environment Programme
USGBC	U.S. Green Building Council
WBCSD	World Business Council for Sustainable Development
WGBC	World Green Building Council
ZODUC	Conditioned Urban Development Zones (Zonas de Desarrollo Urbano Condicionado, Chile)

1 Introduction

1.1 Problem Statement

Energy efficiency in buildings is clearly a pressing issue, mainly due to the buildings' impact on the environment and their resource consumption. In this regard, it is estimated that buildings contribute to almost one-third of global annual greenhouse gas emissions, primarily due to the use of fossil fuels during their operations stage (RICS 2013, UNEP 2009). Moreover, according to the World Business Council for Sustainable Development, buildings are responsible at least for 40% of energy use in most countries around the globe (WBCSD 2007, p.4).

Buildings are major consumers of energy within the urban system. According to Santamouris and Asimakopoulos (2001) the worldwide primary energy consumption of buildings is close to 19 million barrels of oil per day and represents almost the entire daily production of the OPEC[1] countries. Not only does the building sector use more energy than any other industry, but its share of energy use is expected to grow ever-more intensely. Therefore, according to the Intergovernmental Panel on Climate Change report in 2007, the eventual aim in terms of energy reduction in the building sector is to mitigate climate change, and reducing energy use in the building sector is considered one of the most important and affordable means to this end (see Mlenick et. al. 2010).

In the international scenario, the discussion regarding the adoption of energy efficiency measures to reduce CO_2 has been addressed by governmental and non-governmental institutions. An example of the foregoing in the relevant literature is the European Union, mainly because the very earliest experiences in implementing national mandatory energy efficiency standards for buildings are to be found in the region. In this context, the European government promotes mandatory targets for energy efficiency across the European Union[2]; later on, achieving the predefined regional energy efficiency goals is sought through the energy demands implemented in the local building codes. In contrast, voluntary energy efficiency initiatives arose immersed in broader green initiatives worldwide; namely: the Building Research Establishment Environmental Assessment

[1] The Organization of the Petroleum Exporting Countries (OPEC) was founded in Baghdad, Iraq, with the signing of an agreement in September 1960 by five countries namely Islamic Republic of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. Nowadays, the OPEC has 12 members.

[2] i.e. the Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.

Method (BREEAM) from the UK; the Leadership in Energy and Environmental Design (LEED) from the USA; and the German Sustainable Building Certification (DGNB) from Germany.

The environmental impacts and energy consumption of the building sector in the Chilean context are not that different from the international scene. The Chilean energy demand showed a sustained growth since the 90's (SERNAC 2005; PEIE 2008). Recent studies conducted by the Asia Pacific Energy Research Centre (APERC) on energy demand, supply data, as well as energy policy information from APEC members[3] – including Chile as a member since 1994 – revealed the Chilean energy production is challenged by its limited energy resources, in particular oil and natural gas. Chile is a net energy importer, and dependent on crude oil imports for energy-generation. In 2009, Chile imported 59.3% of its internal demand; crude oil was 69.1% of the imported energy (APERC 2011, p.33). The high dependency on fossil fuels has negatively affected the electricity generation, leading to episodes of energy scarcity in all the energy consumption sectors (Agostini et al. 2009; Benavente et al. 2005; Chumacero et al. 2000).

The domestic Chilean energy policy is related to the country's economic growth. The Chilean economy grew at a rate of 5.4% between 1986 and 2010 (ENE 2012, p.6). According to the Chilean Ministry of Energy as Chile grows the country demands more energy, stressing a close relationship between economic growth and energy consumption (ENE 2012). Currently, the Chilean government is now addressing the energy challenge through the implementation of national guidelines in the energy policymaking[4]. In connection therewith, the National Energy Strategy 2012–2030 states that, the current Chilean challenge is to have sufficient and competitive energy resources to support the country's development. The lack of access to reliable energy sources and energy networks represents a significant constraint to sustainable social progress, economic growth, and the well-being of the entire population. In this regard, the National Energy Strategy 2012–2030 states: "*The need for greater levels of energy efficiency has never been as clear as it is now. Factors such as the high energy prices, growing concern for*

[3] The Asia-Pacific Economic Cooperation (APEC) has 21 members: Australia, Brunei Darussalam, Canada, Chile, China, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, The Philippines, Russia, Singapore, Taiwan, Thailand, United States of America, and Viet Nam (APERC 2011).

[4] Namely: National Energy Strategy 2012-2030, Energy Efficiency Action Plan 2012-2020 (PAEE20), Energy Efficiency Seal, Minimum Energy Performance Standards (MEPS), Efficient Residential and Street Lighting Programs, The Creation of the Inter-ministerial Commission for the Development of Energy Efficiency Policies.

the environment and energy security in Chile have contributed to a growing awareness of the need for further developing energy efficiency" (ENE 2012, p.16).

In the Chilean context, the relationship between the building sector and the energy challenge is a long-standing issue. According to data released in 2008 by the Programme of Research in Energy (Programa de Estudios e Investigaciones en Energía or PRIEN) and the University of Chile, the building sector should account for 18% of total national energy efficiency potential by 2020, the second after industrial and mining sectors. Moreover, the building sector represents 26.2% of total energy consumption according to the National Energy Balance (MINEN 2012); although the Chilean building sector energy use is relatively lower than the building sector worldwide (40% as stated in the previous sections), the energy consumption of the sector it is still significant. Grounded on this concern, Chilean government implemented measures leaning to reduce buildings' electric energy consumption (EERE 2008). Measures were oriented to reduce households' energy consumption[5].

Santiago de Chile, Chile's capital city, grows and its energy demand grows. Beyond the natural population growth of the city, there are two main migration flows influencing the city development, namely: first, the internal migration from other Chilean regions (INE 2007); and second, the new positioning of the city in global circuits has turned Santiago de Chile into a centre of attraction for foreign population migrating from other countries in the South American region. The latter migratory flow is an outcome of the sustained economic growth of the country due to the economic openness to foreign markets as part of the changes in public policymaking to attract foreign investment (Mercado 2009). According to the Census data, the Metropolitan Region of Santiago (Región Metropolitana de Santiago or RMS) had approximately 1.6 million housing units in 2002; in 2011, approximately 2 million housing units were reported (INE 2012). The increase in almost 25% in the number of existing dwellings in the city represents also an increase in the demand for land, materials, and energy resources, in both the construction phase and operation of housing.

[5] Namely, encouraging the use of energy-saving light bulbs and advertising campaigns to promote the so-called "*good use of the energy* "(see Agostini et al. 2009). Moreover, recent studies have shown that such simple acts, like installing more efficient light bulbs, not only save resources but also pay for themselves in a relatively short time period (IFMA 2010).

As far as the housing sector is concerned, the population growth has led to a greater housing demand to accommodate its growing population[6]. According to the specialists on the field, Santiago de Chile's residential sector has grown steadily since late 1980s (Hidalgo 2010). The private housing stock is distributed and financed across the city mainly in two ways: first, through public-private intervention supported by State subsidies for the construction of high-rise multifamily buildings as an effort to repopulate the city centre; second, through private investment with certain concentration in the north-eastern sector of the city, mainly single-family detached houses in gated communities[7] (see Hidalgo 2004; 2010).

In order to tackle the strained relationship between residential buildings and the energy sector, the Ministry of Housing and Urban Development implemented New Housing Thermal Regulations[8] for all new residential buildings built since 2000 in Chile (MINVU 2009). According to Janda (2009), Chile is a pioneer in implementing mandatory energy efficiency requirements for new residential buildings in South America.

Thus, the discussion about residential energy efficiency has become increasingly important in the Chilean political and institutional discourse and has received wide coverage in the local media, mainly for two reasons. First, the international discussion about the benefits generated from implementing green building design strategies in the real estate sector, which has led to a great demand for international green building certifications worldwide. Second, the Chilean energy challenge, has led to the introduction of national energy policies, implementing two key instruments affecting the housing market: 1) energy efficiency requirements for new residential buildings since 2000; and 2) economic incentives for the implementation of residential solar thermal panels. Given this scenario, the private housing market in Chile has shown interest in the implementation of energy efficiency measures in the variety of products offered in the local real estate market and started offering green-certified buildings.

---

[6] Between 2004 and 2008, nearly 130.000 housing units per year in Chile were sold, representing an increase of almost 30% over the average observed during the 1990s (BBVA 2008)

[7] This process of urban development creating the so-called gated communities it is a phenomena form other Latin American capital cities; namely: Buenos Aires, Lima, and Mexico City (see De Mattos 2002).

[8] The New Housing Thermal Regulations were implemented in three consecutive stages. From a prescriptive approach, the first and second stages established mandatory standards regulating the thermal transmittance (U-value) for the different elements of the building's thermal envelope; they came into force in 2000 and 2007, respectively. In contrast, the third stage defines, from a performance-based approach, an energy performance rate on a voluntary basis since 2013 (MINVU 2013b).

1.2 Rationale and Aims of the Research

According to the mentioned in the previous section, Santiago de Chile has shown an increase in the supply of "*green*" real estate products in the recent past; slogans such as "*energy housing*" or "*energy savings*" are often found in the private real estate offer in Santiago de Chile. Apparently, these slogans are used to promote residential buildings newly built which – in many cases – just meet the minimum standards recently required by local building code. This shows the need to conduct an exploratory research, in order to gain better understanding of the implications for real estate developers for adopting energy efficiency strategies in the private housing sector. Moreover, this research focuses on the private housing sector in Chile because: 1) this sector has shown a significant growth in recent years (see section 2.2.1), therefore its impact on the environment – energy and resources consumption mainly – is also significant; 2) the public sector alone does not construct the so-called "*social housing*"; instead, it hires the services of private construction companies to do so (as described in section 2.2.3).

Recently, scientific research on residential energy efficiency in the Chilean context has focused on quantitative aspects concerning: modelling energy consumption in apartment buildings (Vera and Ordenes 2002, Encinas et al. 2009, Encinas and De Herde 2013), reviewing design and energy performance parameters for buildings in Mediterranean climate (Bustamante and Encinas 2012). In contrast, the qualitative approach is emerging and has focused on the perception barriers of Chilean architects to the inclusion of energy efficiency criteria in buildings (Trebilcock 2011). Therefore, this doctoral thesis seeks to fill in the research gap in the field of energy efficiency.

Specifically, in a scenario where regulations in the field of residential energy efficiency are emerging, where the private sector plays a leading role in the housing market, and considering the growth of Santiago de Chile and its energy demand, research is necessary to inquire about motivations to adopt residential energy efficiency measures and changing paradigms in the construction market. Therefore, the overall goal of this research seeks to generate empirical findings with regard to the private housing sector in Santiago de Chile, more precisely with regard to the motivations and barriers to the adoption of energy efficiency measures in Santiago de Chile,

The main question leading this doctoral thesis is: How do real estate developers apply energy efficiency in their housing offer in Santiago de Chile? The main research question is further refined by three sub questions. 1) who are the real estate developers that are adopting energy efficiency and why? This is a compound question, first it seeks to identify real estate companies adopting energy efficiency measures in Santiago de Chile’s private housing market; then it looks into the motivations for doing so; 2) what types of energy efficiency measures are real estate companies adopting? This sub-research question seeks to identify the adopted residential energy efficiency strategies adopted by private developers in their different housing-products; and 3) which barriers to further implementation of energy efficiency exist? It seeks to identify the setbacks found by energy efficiency adopters in the implementation process in order to understand local issues in the adoption process.

This research uses a case study approach of an exploratory nature (Yin 2009). It investigates the voluntary adoption of energy efficiency measures in the private housing market in Santiago de Chile; at the same time, it seeks to understand the different driving factors behind real estate companies’ decisions to offer and apply energy-efficient housing. More precisely, this research uses a single case with embedded units methodology (Yin 2009); this means a holistic case study – the real estate housing sector in Santiago de Chile – with embedded sub-cases – the energy-efficient housing offer. This would enable the researcher to explore the case while considering the influence of the housing market dynamics on the managers’ decision making. Sub-cases were selected by applying a criterion sampling strategy (Patton 2002), also known as purposive sampling (Flick 2009). The criterion for case selection was: to consider all real estate developers offering energy-efficient dwellings in Santiago de Chile.

Personal interviews were conducted during a six-week fieldwork stay in Santiago de Chile, between April and May 2012. Interviews were conducted until empirical saturation was reached, and when the primary data collection did not shed any further light on the issue under investigation (See Guest et al. 2006). Since the research was enlightened from different institutional and scientific settings, different stakeholders other than the housing sector were taken into account as key informants. The interview partners were carefully selected based on what they may know about the adoption of energy efficiency measures in the private housing sector.

The empirical data accounts for thirty-three personal interviews and a set of documents, including energy efficiency policies, on-line documents available on official websites from Chilean and international institutions. The data analysis was an iterative and reflexive process; this interactivity was applied throughout the process of qualitative inquiry.

Results provide a better understanding of real estate companies' willingness to adopt energy efficiency in their different housing-products. This knowledge may allow researchers, practitioners, and policy-makers to promote energy-efficient housing as path towards the reductions of CO_2 emissions in the housing sector.

1.3 Thesis Structure

This doctoral thesis is divided into eight chapters. The following table provides an overview of the thesis structure.

Table 1: Overview of the Thesis Structure
(Source: own compilation)

Chapters 1 and 2	The Research Gap; Raising Questions
Chapter 3	Main Methods of Data Collection and Data Analysis
Chapter 4	The State of the Art
Chapters 5 to 7	Main Results
Chapter 8	Discussion and Implications

The second Chapter provides an analysis of the close relationship between the construction and the energy sector in Chile and explores the research gap. The first section discusses the role of the private construction sector in the context of the Chilean economic growth. The second section specifically explores the characteristics of the housing market in Santiago de Chile; one of the main contributions of this section is the identification of key players in the real estate sector. The third section discusses Chile's energy challenges sustaining economic development. Policies recently introduced by the Chilean government to tackle the national energy vulnerability, including the implementation of energy efficiency measures, are discussed. Finally, the last section provides emerging questions.

Chapter three presents and substantiate the methodological steps taken throughout the investigation in order to make the research process transparent and traceable. The Chapter is sub-divided into five sections. The first provides a summary of the research design and emphasizes the use of case studies approach of exploratory nature. The criteria and methodology for the selection of sub-cases are reviewed in the second section; sub-cases are selected by conducting a purposeful sampling. The third section presents expert interviews as the main instrument for collecting primary data. Techniques for qualitative data analysis are detailed in the fourth section. Finally, the last section provides a summary of sub-cases selection and main data analysis techniques.

The review of state-of-the-art concerning residential energy efficiency is the main content of the fourth Chapter. The Chapter is sub-divided into six sections. The first section reviews, from a broad perspective, the introduction of the energy efficiency concept in the residential sector, both the academic and institutional discourse are analyzed. Since residential energy efficiency is clearly a normative concept, international experience is reviewed regarding the introduction of mandatory standards for energy efficiency in national building codes; therefore, the second section reviews government-initiated energy efficiency instruments. Nonetheless, in many countries around the globe, non-governmental institutions seem to be dissatisfied with building energy regulations, which are found to set rather low requirements, therefore non-governmental institutions and the academia aim to push the energy and green building standards further. Voluntary energy instruments are reviewed in the third section. The fourth and fifth sections provide a detailed review on the Chilean experience implementing new thermal regulations and the adoption of voluntary instruments in Santiago de Chile, respectively. The final section provides key drivers for understanding how behaviour changes are originated in real estate companies, with the aim of identifying some clues about the motivations for private developer companies to introduce changes in their construction process towards more environmentally friendly attitudes. Although the literature review discusses the factors that influence behaviour change in general, the literature review focuses on the adoption of energy efficiency measures in particular.

In the following three chapters, five to seven, the main results of this research are presented. Chapter five is divided into two main sections; the first identifies and classifies real estate companies in three categories of adopters depending on the time frame that companies first began to innovate in the field of residential energy efficiency; the second, discusses the motivations of real estate companies to adopt residential energy efficiency strategies. Chapter six identifies passive and active design strategies implemented in the private housing market. Chapter seven discusses the main challenges for the broader adoption of energy efficiency in Santiago de Chile's private housing market.

Finally, Chapter eight presents and discusses the results. Based on empirical evidence, shows how the research is successful in shedding light on the major motivations for the adoption of energy efficiency measures in the private housing market in Santiago de Chile, the main barriers for wide dissemination in the market, and the variety of residential energy efficiency strategies adopted in the private housing market in Greater Santiago. Finally, it presents some concerns and open questions emerging from this research that can be taken-up in future research.

2 The Construction Sector at the Heart of the Chile's Energy Challenges.

This Chapter examines the relationship between two important sectors within Chilean economy; on one hand the construction sector and the energy sector on the other. Specifically, the first two sections of the Chapter discussed in detail: the growing importance of the private housing sector in the context of the RMS and its contribution to regional and national economic activity; the dynamics of the regional real estate sector; and the roles of the various stakeholders in the real estate market.

Moreover, the third section reviews the Chilean energy concerns, characterized by high vulnerability in the electricity generation due to production based on fossil fuels, which are imported from neighbouring countries. The above mentioned, has led to major changes in the Chilean national energy policy seeking to diversify the energy generation sources and the recent introduction of policies for the promotion and implementation of alternative solutions based on non-conventional renewable energy sources – such as the local use photovoltaic solar panels – and improving energy efficiency. The latest has generated a broad discussion on the political and academic spheres and has also received extensive media coverage. In parallel, the construction boom of private housing in the recent past of the Chilean capital city, has embraced the slogan of "energy-efficient housing" within the local offer of real estate products.

Finally, the last section of the Chapter presents the raising questions, aiming to understand how the private housing market is adopting the new national energy policy and the energy efficiency standards recently introduced in the Chilean building sector.

2.1 The Chilean Construction Sector

According to Chan et al. (2009, p.3061), the construction industry, a major player around the world, accounts for a sizable portion of most countries' gross domestic product (GDP); the same is given in the Chilean context. According to Central Bank of Chile (Banco Central de Chile or BCCh), the construction sector was the sixth largest in terms of generating GDP, accounting on average 6.6% of economic activity between 2008 and 2011 (see Table 2). Meanwhile, according to projections of the Chilean Construction Chamber (Cámara Chilena de la Construcción or CChC), investment in construction accounted, on average, over 56% of total investment in the Chilean Economy in 2012, creating 8,7% of employment nationwide (CChC 2013a).

Table 2: Sectoral Distribution of GDP (2008 – 2011)
(Source: Own compilation based on banking statistics of the Chilean Central Bank (BCCh 2013))

	Economic Sector	2008	2009	2010	2011
1	Financial and Business services	17,38	17,83	17,98	18,49
2	Mining	14,03	14,03	13,46	12,16
3	Manufacturing	11,19	10,83	10,5	10,68
4	Personal Services	10,13	10,54	10,47	10,47
5	Commerce and Tourism	9,77	9,3	10,1	10,63
6	**Construction**	**7,34**	**7,02**	**6,76**	**6,87**
7	Transport and Communications	6,73	6,45	6,64	6,71
8	Housing Services	4,9	5,13	4,89	4,73
9	Public Administration	4,06	4,37	4,25	4,04
10	Farming and Forestry	2,89	2,79	2,65	2,81
11	Electricity, gas, and water	2,66	3,06	3,15	3,31
12	Fishing	0,43	0,37	0,35	0,37

According to the CChC, the construction sector has grown steadily in recent years, with ups and downs that reflect the influence of the international dynamics (CChC 2013a, CChC 2013b). Moreover, the growth of the construction sector is expected to be affected by four main factors; namely: 1) a greater volatility scenario in the international financial markets, deteriorating the domestic economic expectations; 2) a greater prevailing uncertainty regarding the execution of private productive infrastructure projects; 3) possible delays in budget execution for the construction of public housing subsidy programs; and 4) the lack of resolution with regard to energy (associated with potential increase in the already high energy costs) and the uncertainty as to how and how deeply would the economic proposals be implemented in the upcoming Chilean change of government (CChC 2013b, p.7).

2.1.1 Background and Regulatory Framework

Various stakeholders shape the construction sector in Chile. Among them, construction companies are the central actors working hand in hand with real estate companies, as shown in Figure 1. The various players in the Chilean construction sector operate under a regulatory framework defined by Chilean public policies, aimed at opening up the economy to international trade[9].

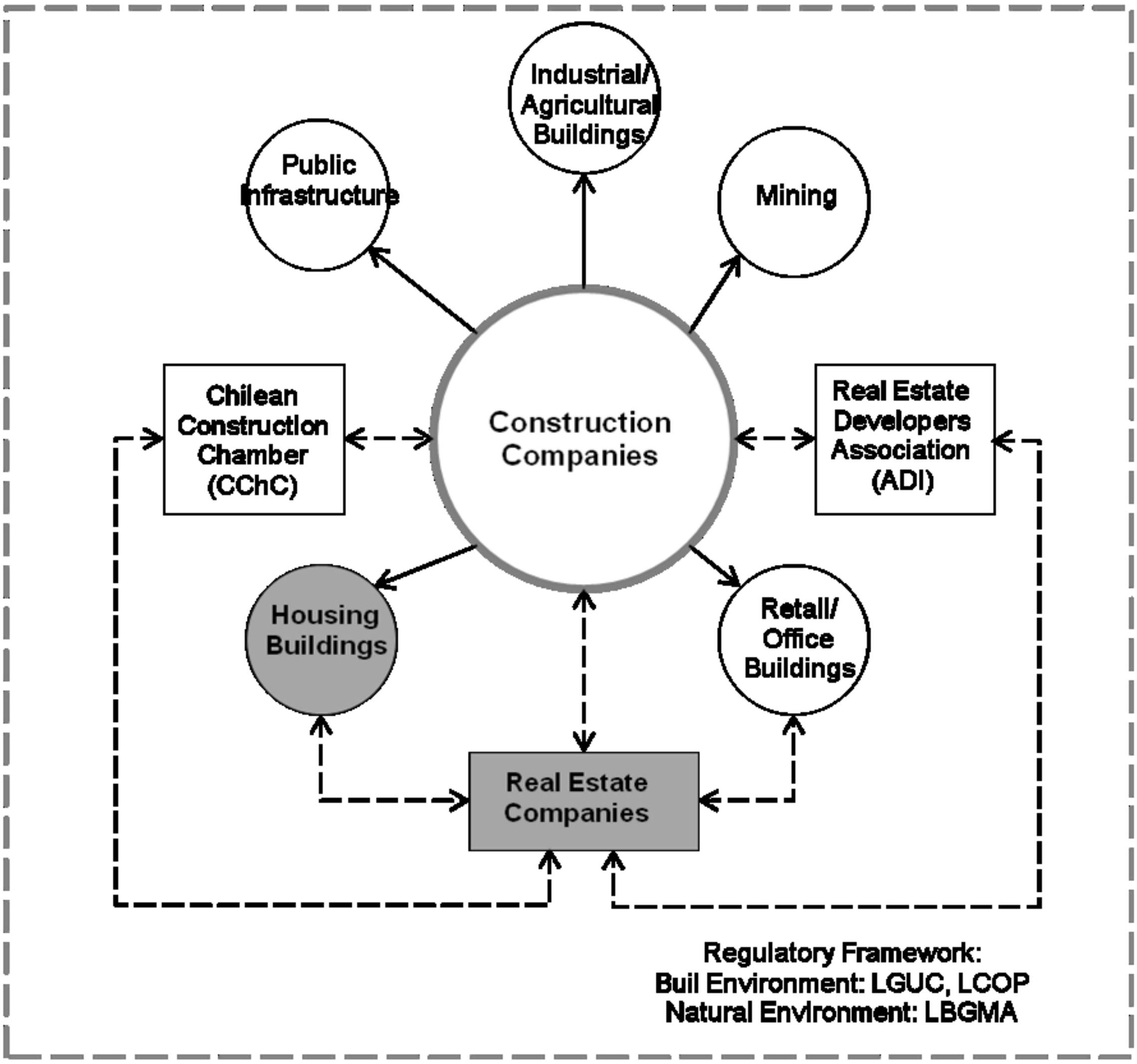


Figure 1: Chilean Construction Industry – Key Stakeholders and Regulatory Framework.
(Source: Own illustration)

The construction industry includes various types of labour activities covered by several regulations. Therefore, the different actors in the Chilean construction industry operate under a national regulatory framework, defined at the central level, and managed at

---

[9] According to Mercado (2009), the Chilean economy has evolved based on two economic models throughout the country's history, leading to the nation's economic growth: first, the industrialization until the early 1970s, and second, the openness of the national economy to international exchange, characterized by a major change in Chilean economic policymaking. Moreover, the economic model change had also brought repercussions all over the country and especially in Santiago de Chile, the capital city. From an urban planning perspective, two main aspects can be noted: first, the growth in demand for services infrastructure; and second, the expansion of cities, reflected in demand growth for urban infrastructure. These two elements reveal a significant pressure to the urban environment, due to the rapid and constant increase in the demand for energy, natural resources, and new land for development (Mercado 2009, p.42).

regional levels for the 15 regions in which the country is divided[10]. The regulatory framework is constituted by a body of laws, decrees and regulations that define minimum construction standards for safety and quality.

In the Chilean context, the regulatory framework within the construction industry operates consists mainly of three Laws. Two governing the built environment, namely: the General Law of Urban Planning and Construction (Ley General de Urbanismo y Construcción or LGUC) and the Public Works Concessions Law (Ley de Concesiones de Obras Publicas or LCOP). And the third one, governing the natural environment, the Environmental General Basis Law (Ley de Bases Generales del Medio Ambiente or LBGMA), also known as the Environmental Law.

The Ministry of Housing and Urban Development (MINVU), through the Urban Development Division, provides all the instructions for the application of the LGUC (MINVU 1975). Moreover, it regulates the urbanization processes and construction of all buildings types and uses, especially residential buildings. The LGUC is an instrument similar to the building code applied in other countries. It defines the minimum requirements that buildings must comply with, among others, in terms of habitability, permitted building heights, land uses, and – since quite recently – the overall thermal transfer values for all new residential buildings constructed since 2000 (MINVU 2009).

Moreover, since the Chilean construction industry draws largely on the construction of road and urban infrastructure (non-residential building) along the entire country under the concessions system[11]. The Ministry of Public Works (MOP) is responsible for the administration of the LCOP (MOP 1991) regulating tenders and concessions in three areas mainly: 1) the exploitation of works or services, 2) the use and enjoyment of national assets for public or government, aiming at developing service areas, and 3) the provision of equipment and/or the provision of related services. The LCOP also defines that granted concessions contemplated the concessionaire's obligation to comply, during

[10] In administrative terms, between 1974 and 2007, Chile was divided into 13 regions. Since 2007 is divided into 15 administrative regions. The capital city, Santiago de Chile, is located in the number 13, also called Metropolitan Region of Santiago.

[11] The success of the Chilean experience in implementing the system of concessions for infrastructure construction constitutes a landmark in the Latin American context. According to Rufián (2002) Chilean experience in road concessions is a very successful example of public-private partnership. The key to this success has been the reliability that has been generated among the public sector, private concessionaire sector, investment financiers, infrastructure users and taxpayers, and the public.

the term of the concession, with the service levels and/or established standards in the tenders' conditions (MOP 1991).

Finally, since all activities related to the construction, operation, and final disposal of buildings, generate an impact on the environment, the activities of the construction industry in the Chilean context are also regulated by the Ministry of Environment, responsible for the administration of the LBGMA (CONAMA 1994). The so-called Environmental Law seeks: 1) to preserve the right of citizens to live in a pollution-free environment; 2) the environmental protection; 3) nature conservation and the preservation of the environment; and 4) to promote sustainable development. This Law includes the general provisions, the tools for environmental management, liability for environmental damage, the design and implementation of environmental policies, plans and programs, as well as the biodiversity protection and conservation, and natural renewable resources and water resources, promoting sustainable development (CONAMA 1994).

2.1.2 Local Supply for Construction Services

Key Stakeholders and Major Players

The central backbones of the Chilean construction sector are construction companies, as shown in Figure 2, construction companies are direct providers of construction services to meet the demand of all the other sectors of the Chilean economy (public infrastructure, industry, mining, housing, trade and services).

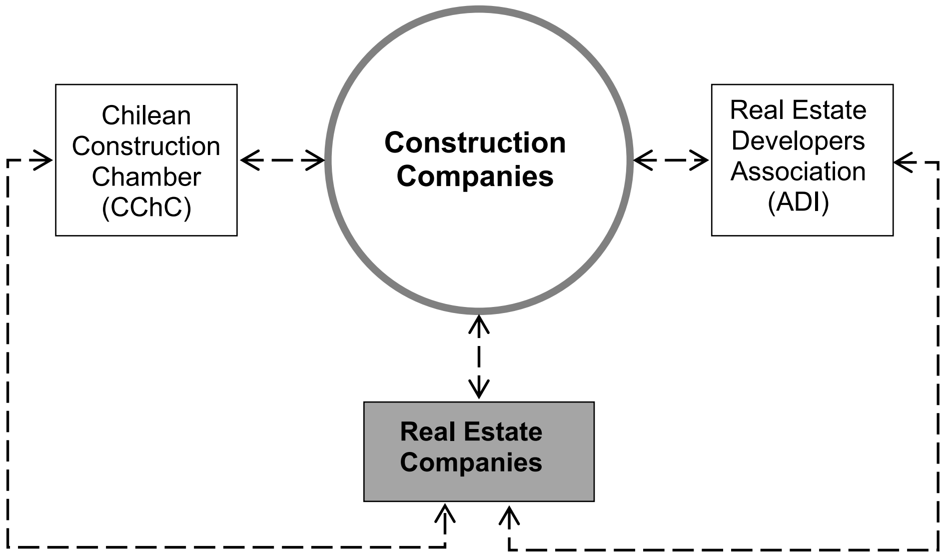


Figure 2: Chilean Construction Industry – Key Stakeholders and Mayor Players.
(Source: Own illustration)

Moreover, construction companies are responsible for the construction of a variety of real estate products and urban infrastructure[12]. Nonetheless, the construction industry relies on larger private development companies moving large national and foreign capital. Side by side with the real estate companies operating along nationwide, the construction companies are the key stakeholders shaping and managing the real estate development in Chile.

Currently, within the Chilean construction industry it has become increasingly common for larger companies to outsource construction services from minor construction companies with highly specialized skills within certain market niches. Similarly, construction companies focused on building housing and office buildings, are closely related to real estate companies responsible for managing several real estate products (single housing, apartment, retail, and offices buildings mainly) which are built directly by the real estate developers – whenever the real estate company owns a construction company – or outsourcing these services to other specialized construction company. Moreover, in order to build different projects, real estate and construction companies require technical inputs, construction materials, provision of specialized professional and technical services, and funding for project implementation. These inputs are provided by other sectors of the Chilean economy, particularly the industrial sector.

In Chile there is no formal record of the number of existing construction companies. However, according to Alvarado and Spolmann (2009) even if there was a formal record, it would still be a relative one. According to the authors, the vast majority of companies are small and medium-sized construction companies tend to form consortia among them; either to develop their own projects or to apply for government-funded project tenders, which makes keeping track of the companies rather difficult. Among the few available descriptions with regards to the number of construction companies operating on the field, is the membership records of the Chilean Construction Chamber (Cámara Chilena de la Construccíon or CChC). This professional association has nearly 1.500 members along the country including: real estate companies, construction companies, consulting firms, building supply dealers, and other service providers for the construction sector; all of them groped within 14 union delegations in the most important cities of the country and

[12] Among the real estate products, construction companies deal with: housing (built with private funding or public subsidy), retail, and offices buildings. Among urban infrastructure: road infrastructure (such as roads, bridges, etc.), industry and mining infrastructure, to name a few.

headquarters in Santiago de Chile. The greatest amount of members are located in the RMS, however, the presence of members in other regions of the country is equally important (CChC 2013c). However, the type and number of members of CChC serve as examples to account relationships and structures that occur in practice in the construction sector[13].

The CChC was founded in 1951 and it represents the interests of private companies involved in the construction industry. Therefore, the CChC has always favoured minimal government intervention in the domain of housing construction (Casgrain 2010). Moreover, the CChC also plays an important role in the sector's policymaking as it is actively involved or is directly responsible for several studies related to the regulation of the construction industry and the residential sector. Within this framework, the Technological Development Corporation (Corporación de Desarrollo Tecnológico de la Cámara Chilena de la Construcción or CDT[14]), has been involved in research in the field of sustainable construction, in general, and residential energy efficiency[15], in particular (CDT 2013).

According to the CChC (2013), the main body of member's involvement are eight trade committees, where members are voluntarily integrated according to their particular interests. These trade committees are grouped in three main areas: housing, infrastructure, and supplies[16]. Finally, the fact that such diverse companies are associated within the same professional organization accounts for the close relationships amongst stakeholders in the production chain within the Chilean construction industry.

---

[13]Based on the membership records of the CChC, it is not possible to draw conclusions about the overall construction industry, as the extent of the members group in relation to all existing construction companies in the country remains unknown. Nevertheless, by the age of the CChC, its presence in the most important Chilean cities, and the size of many of the associated companies, it will be feasible to assume that CChC gathers a significant percentage of construction companies and realtors operating in the sector).

[14] The CDT is a private corporation created in 1989; its mission is to promote innovation, technological development, and productivity of companies in the construction sector through various service areas such as technology dissemination, knowledge management, sectoral studies, technology stakeholder groups' coordination, and technology transfer

[15] Although the contribution of the CDT is analyzed in the section 4.4 of this doctoral thesis, in order to provide a clear example it worth mentioning the Energy Year Book 2012 publication by the CDT. This publication hands in a complete overview of service providers of energy efficiency and renewable energy in the construction sector (CDT 2012).

[16] According to CChC, the Housing Area consists of the Real Estate Committee, which brings together all members interested in housing construction with private financing, and the Housing Committee, which brings together those interested in housing construction with state subsidies. The Infrastructure Area consists of members working in construction with public client. Committees constitute the area of Public Infrastructure and Concessions, as well as those working with large private clients and converging in the General Contractors Committee. Finally, the Supplies Area consists of members manufacturing or acting as intermediaries of building materials, it groups Industrial and Suppliers committees, and those working with complementary facilities and civil works involved in the Committee for Proprietary (CChC 2013c).

These linkages raise common interest amongst industry major players that may eventually lead to potential conflicts in the area of free competition (Alvarado and Spolmann 2009, p.33).

On the other hand, among the most important players in the sector stands out the Real Estate Developers Association (Asociación de Desarrolladores Inmobiliarios or ADI). Its mission is to promote the development and progress of the real estate sector in Chile, in five major areas: housing, commerce, industry, tourism, and services (ADI 2013).

ADI brings together all major companies in the Chilean real estate sector since 2000, with special emphasis on housing issues, covering about 45 % of the market. ADI members share a common vision based on three pillars. First, the responsible growth of cities covering externalities caused; second, generating more and better real estate products, raising the build quality and efficiency of operation, together with create safer environments and neighbourhoods at accessible prices for consumers; and third, the orientation of the real estate management towards the client, through actions to deepen the understanding of their needs. Thus, the ADI is characterized by promoting the development and improvement of real estate activity in Chile, pursuing three objectives: 1) to promote the efficient use of technologies, 2) to build an informed and competitive market; and 3) to ensure a sustainable urban environment (ADI 2013).

Moreover, according to Heinrichs et al. (2009), the relevance of these professional trade associations for the Chilean construction industry – CChC and ADI – is largely due to the strong organizational and political power they exert in the housing market decision making, since they represent the interest the most influential economic groups of the country. Many of the decisions taken at the meetings of these organizations affect the construction sector as a whole and seek favour private interests of influential stakeholders.

Some of the major players in the Chilean construction industry do not deal directly with real estate business, as shown in the *Ranking of the 10 Major Construction Industry and Real Estate Players in Chile* (see Table 3). The construction company with higher sales in 2010, SIGDO KOPPERS, deals with industrial construction, transport, and logistics; it accounts on its own for 1832.4 million Us$ in 2010. Nonetheless, other players do deal with the housing sub sector. Real estate companies like SALFACORP, SOCOVESA, BELSACO, PAZ CORP, or MANQUEHUE in 2010 together accounted for over 2781 million US$ sales in the housing industry; which make them quit relevant players in the construction industry and key stakeholders for the national economy.

Moreover, eight out of the ten major players in the Chilean construction industry are members of the CChC, which shows the importance of the interests of these companies in the decisions taken by the CChC regarding the construction sector.

Table 3: Ranking of Major Construction Industry and Real Estate Players in Chile (Source: Own compilation based on BBVA 2008; America Economía 2011; and Estrategia 2011)

Ranking 2010	Company	CChC	ADI	Sector			Sales 2010 Us$ Mill.
				Construction	Real Estate	Other	
1	SIGDO KOPPERS	(+)		(+)			1832.4
2	SALFACORP	(+)			(+)		1512.4
3	SOCOVESA	(+)		(+)	(+)		550.8
4	BELSACO			(+)	(+)		537.1
5	Claro, Vicuña, Valenzuela	(+)		(+)		(+)	177.8
6	SIPSA				(+)	(+)	132.2
7	Paz Corp	(+)	(+)	(+)	(+)		112.9
8	Infraestructura Dos Mil			(+)		(+)	84.3
9	Fluor Chile	(+)		(+)		(+)	71.4
10	Inmobiliaria Manquehue	(+)	(+)	(+)	(+)		68.4

According to Heinrichs et al. (2009), many of these companies arose from the construction industry, although many have also arisen from other industries and/or from some of Chile’s most prominent wealthy families. Moreover, the large real estate investors in Chile traditionally have strong ties to the country's economic elite, the so-called "*larger economic families*", and have facilitated private sector activities in the real estate sector and the land market (Heinrichs et al. 2009).

Moreover, Zegras and Gakenheimer (2000) argued that three main driving factors have contributed to the emergence of the major players in the Chilean construction industry. First, the accumulation of large sums of capital, a by-product of the Chilean decade of long economic growth and modernization of the financial sector, linked to large investment funds (such as CB Capitales and Fondo Las Américas), pension (via the privatization of the Chilean pension system), and insurance funds. Second, the growth in Chilean purchasing power, leading to a higher demand for larger pieces of land, luxury housing, and the amenities associated with the so-called “*suburban*” life style. And third, the road infrastructure development and motorization, opening up large tracts of land to potential development and the subsequent decline in this land's alternative (typically agricultural) value; and dynamic real estate consumer financing opportunities and favourable tax benefits for housing construction (Zegras and Gakenheimer 2000, p.87).

Apparently, exclusive partnership among large private investors, tending to create private monopolies, is a general pattern followed by the construction industry in several other countries. According to Alvarado and Spolmann (2009) the experience of competition authorities in many other countries shows that collusive agreements are periodically given in the construction sector. The authors refer to this phenomenon as the creation of so-called "Cartels" and claim they are anti-competitive figures that occur more frequently in this area, although there are also abuses of dominant position and other unlawful conduct (Alvarado and Spolmann 2009, p.21). Moreover, the authors identify three main characteristic in the construction sector in Chile that explain the existence of cartels; 1) the difficult detection of cartels, because end users do not have direct contact with the cartel's holders. To the extent that is configured as a market of intermediate goods for the production of other sectors of the economy through the provision of infrastructure, for example; 2) the high level of variability of the construction sector activity, which leads to an extreme competition (or "*ruinous competition*") which is detrimental to the industry because it leads to the disappearance of many small companies in the sector during the decline periods in the economy, encouraging larger companies to build up long-term agreements in order to protect each other; and 3) the creation of barriers for the competitiveness of the foreign companies; this pre-condition of market entry for foreign companies is defined from fixed costs (of various types) that an enterprise must make in order to carry out a project in the Chile (Alvarado and Spolmann 2009, pp.15-21).

Finally, the so-called "*cartels*" are particularly important for two main reasons; first, because the power exercised by the so-called "*cartels*" on the decisions made in the construction sector will affect the sector as a whole; and second, because the decisions made by the directors of the cartels are assumed by the other group members. Therefore, in the field of real estate market these groups of power hold in their hands the ability to introduce new trends in the market and define – to some extend – the design, technology, and even building materials used in constructing the real estate products.

The Importance of the Private Sector

Products developed by the construction industry are highly heterogeneous, due to the diversity of the physical characteristics and the resources requirement for its processing (Alvarado and Spolmann 2009). Factors that explain the relevance of the construction sector for the Chilean economy are threefold: first, it is a crosscutting sector in the national economy; second, it is responsible for the physical infrastructure in almost all economic sectors; and third, on itself has a relevant share in the product and national investment (Alvarado and Spolmann 2009). According to Central Bank of Chile, the participation of the construction sector in the Chilean GDP had an average of 6.6% between 2004 and 2008, being more or less stable over the time (BCCh 2013). Nonetheless, as many other sectors in the Chilean Economy, the construction sector was also affected by the earthquake on February 27th 2010, considered the second strongest one in the history of the country and the fifth strongest in the world.

Moreover, according to BBVA (2008), the real estate sector in Chile has experienced a significant growth in recent years due to increase in bank credit and purchasing power in some sectors of the population seeking to acquire a property for investment or assets. Development of the sector is key to the Chilean, present and future, economic activity. About 8% of employment is generated by the construction sector and this represents 8.5% of total product made in a typical year in the country. Moreover, the building housing attracts a steady stream of investment reached 5 billion in 2007 and, unlike other countries in the region; over 90% of these resources are linked to the private sector (BBVA 2008, p.4).

2.1.3 Demand for Construction Services

As indicated in the previous sections, construction companies providing construction services are the centrepiece of the Chilean construction industry. In Santiago de Chile, the construction companies build a variety of real estate products, namely: residential buildings (private and subsidized housing), office buildings, commercial and retail buildings, urban infrastructure, transport infrastructure (such as roads, bridges, etc.), and mining industry infrastructure. In general, Formoso and Jobim (2003) pointed out that at a time when competition has never been greater among real estate companies, the house-building industry still faces difficulties to improve customer satisfaction. The same seems to happen in the Chilean context. Toro (2009) argued only 5% of the construction companies currently apply real estate-marketing techniques in order to understand what the customer wants and shaping their offer accordingly. In this sense, the real estate companies are responsible for shaping the housing supply according to international trends. Moreover, in order to build their projects, the real estate companies are able to do so either directly, if the real estate company owns a construction company, or by outsourcing these services to minor construction companies specialized in certain construction niches, which is the most commonly used strategy as business model.

The demand for construction services comes from the vast majority of Chilean economic sectors; hence, it results in a wide diversity of product demanded. According to Alvarado and Spolmann (2009), there are three groups within the private sector where the demand is concentrated. First, households demanding new housing; second, private companies demanding infrastructure for the production of goods and services; and third, the public sector demands: non-residential and public buildings, and public infrastructure.

However, considering the overall construction investment figures produced by the CChC (see Figure 3), it can be observed that the greatest demand comes from the private sector. Regarding the demand from the public sector, this is mostly implemented directly by the Ministry of Public Works (Ministerio de Obras Públicas or MOP). It is also possible that the MOP will channel the public work's investments to various government departments, and only the minor amounts and complexity investments are carried out directly by the very same departments (Alvarado and Spolmann 2009).

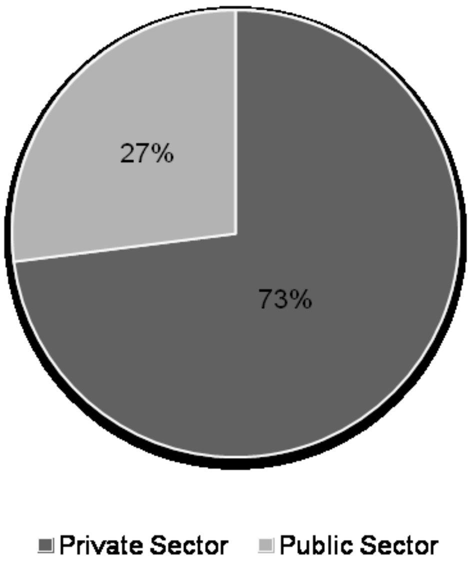


Figure 3: Sectoral Demand for Investment in Construction (2006-2008)
(Source: Informe MACh, Chilean Construction Chamber (CChC 2013b))

Finally, it is worth noting that, the investment in housing construction by the private housing sub sector is significantly higher with respect to the public sub sector, accounting respectively for 75% and 25% of the investment in housing between 2009 and 2013 (see Table 4). According to *Informe MACh* (CChC 2013b) the private housing sub-sector concentrated three quarters of overall investment in construction. These figures have remained stable between 2009 and 2013, showing a slight downward trend (from 78% in 2009 to 74% in 2013). Nevertheless, the difference between the private housing sub sector and public housing sub sector in terms of investment in housing continued to be significant, which highlights a steady demand for private housing in the Chilean construction sector.

Table 4: Construction Investment Expenditure (UF[17] Millions)
(Source: Informe MACh, Chilean Construction Chamber (CChC 2013b))

Sub Sector	**UF Millions**					**Annual Percentage Changes**				
	2009	**2010**	**2011**	**2012**	**2013 (Est.)**	**2009**	**2010**	**2011**	**2012**	**2013 (Est.)**
Housing (1 + 2)	177	178	190,9	200,3	207,6	-11,2	0,5	7,3	4,9	3,7
1) Public Housing (a)	38,3	44,2	47,3	51,1	54,1	28,1	15,4	6,9	7,9	5,9
2) Private Housing	138,7	133,7	143,6	149,2	153,5	-18,1	-3,6	7,4	3,9	2,9
Copayment Social Housing	17,8	30,8	32,6	33,8	34,7	82,9	72,4	6,1	3,5	2,8
Real Estate Without Subsidies	**120,9**	**103**	**111**	**115,4**	**118,8**	**-24,3**	**-14,8**	**7,8**	**4**	**2,9**
Infrastructure (3 + 4)	345	351,2	384	426,4	460,6	-5,1	1,8	9,4	11	8
3) Public Infrastructure	126,3	108,9	122,3	132,6	142,9	3,8	-13,8	12,3	8,4	7,8
Public (b)	99,2	84,6	99,8	106,7	112,2	0	-14,7	17,9	6,9	5,1
Autonomous enterprises (c)	20,3	11,3	7,6	10,8	16	42,6	-44,6	-32,2	42,2	47,6
Concessions Public Works	6,8	13	14,9	15	14,7	-17,6	91	14,6	1	-2
4) Productive Infrastructure	218,7	242,3	261,7	293,8	317,6	-9,5	10,8	8	12,2	8,1
Public (d)	12,6	11,1	12	14,8	19,1	-20,6	-11,5	8,1	22,6	29,6
Private (e)	206,1	231,2	249,7	279	298,5	-8,7	12,1	8	11,7	7
Total Investment In Construction	**522,1**	**529,2**	**575**	**626,7**	**668,2**	**-7,2**	**1,4**	**8,7**	**9**	**6,6**

[17] The Unidad de Fomento (UF) is a Unit of account that is used in Chile. Is an accounting unit indexed to inflation for the immediately preceding month to the period in which it is calculated. The exchange rate between the UF and the Chilean peso is constantly adjusted to inflation so that the value of the UF remains constant on a daily basis during periods of low inflation.

2.2 The Private Housing Market in Santiago de Chile

According to the Housing Finance Mechanisms in Chile report, made by the United Nations Human Settlements Programme (UN 2009), the number of households in Chile grew 25.7 percent in the decade between 1992 and 2002, almost twice as fast as the rate of population expansion. This has had great relevance for the Chilean housing market, since the associated reduction in household size – from 3.98 to 3.57 persons per household between 1992 and 2002 – has meant the additional demand for housing has been met with an increase in housing supply (UN 2009).

Most of the housing construction activity traditionally takes place in the RMS[18] making the City of Santiago de Chile the largest urban centre in the country. However, according to the UN (2009) the housing construction in many other regional centres has been growing faster. Therefore, larger construction companies, with a national reach, compete with smaller local homebuilders for new business opportunities in these younger and less exploited markets (UN 2009).

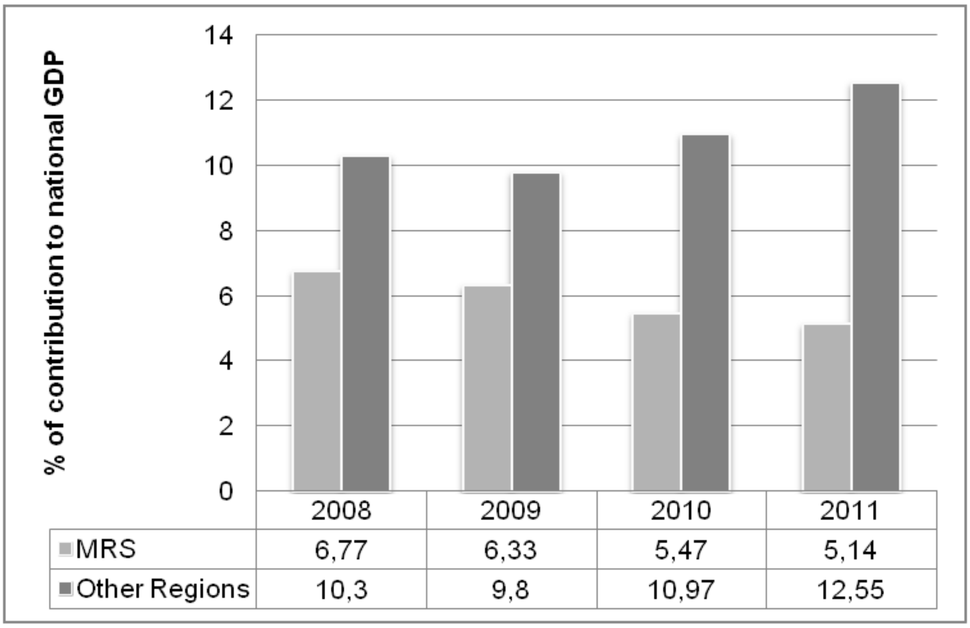


Figure 4: Share of the Construction Regional GDP in the Construction National GDP (2008-2011) (Source: Banking statistics of the Chilean Central Bank (BCCh 2013))

According to the banking statistics of the Chilean Central Bank (BCCh 2013), the growth in the regional housing demand is also reflected in the regional contribution of the

---

[18] The Metropolitan Region of Santiago has an estimated population of 7.069.645 inhabitants and a density of 459 inhabitants per km² (INE 2013).

construction sector to GDP. The contribution of the construction sector from the RMS to the GDP is quite similar to the sum of the contributions of the construction industry in the other fourteen regions to the GDP, as shown in Figure 4.

Finally, while a steady growth can be seen in other regions of Chile – for example the metropolitan areas of Valparaiso and Concepción – the RMS continues to be the country's largest in terms of population, urban extension, and demand for new housing (INE 2013).

2.2.1 Characterisation of the Housing Demand

In the first decade of the century, the city of Santiago de Chile stays well positioned in the worldwide competitiveness rankings. The positioning of the city is a result of the economic growth the region has experienced since the last decades of the twentieth century and the economic openness to foreign markets as part of the changes in public policymaking to attract foreign investment (Mercado 2009). Thus, economic growth has turned the RMS into a centre of attraction for national and international migration in the South American region. This process has led to a greater housing demand to accommodate its growing population.

In general, the housing demand has been fulfilled by public housing initiatives and the private housing sub sector, resulting, unavoidably, in the growth of the city. In terms of building types and housing densities, the housing supply in Santiago de Chile is rather diverse. Such diversity of building types depend on two main factors: the location of the projects within the city and the household’s income. Nonetheless, private supply of housing in Santiago de Chile in recent years has focused primarily on two housing typologies matching two different spatial configurations, as analyzed in the following section.

According to the Central Bank of Chile (Banco Central de Chile or BCCh), based on statistics of the Chilean Chamber of Construction, between January 2010 and August 2012 Santiago de Chile has concentrated more than 50% of the total number of newly-constructed housing in the country per month (see Figure 5). This corresponds to a monthly average of 2.466 housing units (BCCh 2013). This growing housing demands in the RMS it is a response to the rapid increase in the number of households, seen as a long-term tendency of the Chilean market; stressing the importance of the Santiago de Chile’s housing sector within the country.

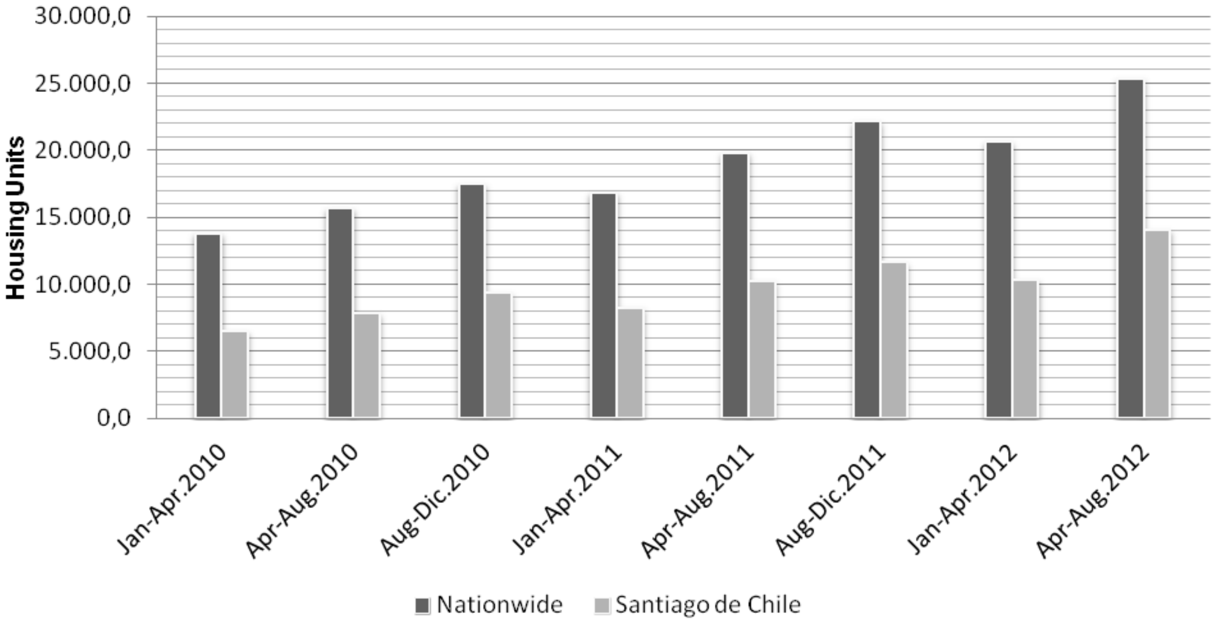


Figure 5: New Housing Sales – Chile and the Metropolitan Region of Santiago (2010-2012) (Source: BCCh 2013)

City Growth Patterns, Socioeconomic Segregation, and Housing

Within the RMS is possible to distinguish residential clusters built in different locations all over the city. Clusters of single-family housing buildings and multi-family housing buildings are located in consolidated areas of the city centre and towards the periphery or urban edge in forms of new development areas, as shown in Figure 6. Furthermore, real estate projects are built outside the so-called "*urban growth boundary*"[19], occupying rural land in municipalities outside the urban perimeter profiting from special development conditions promoted by the National Housing Policy and certain planning instruments developed by the State[20].

The specialized literature identifies two main urban growth patterns in Santiago de Chile. First, the extension growth or horizontal growth of the city*;* characterized by rapid

[19] According to the LGUC (MINVU 1975) there are several territorial planning instruments and urban planning instruments in the Chilean context. In hierarchical order, from the Regional scale to the Municipal scale, these are: Regional Urban Development Plan; Inter-communal Master Plan; Communal Master Plan; Sectional Plan, and the so-called "*Urban Growth Boundary"*. The term "*urban boundary"* refers to the imaginary line that divides urban areas and urban sprawl comprising population centres.

[20] According to Hidalgo et al. (2007) gated megaprojects development in the early 2000s are associated with two new land use management tools. First, the Conditioned Urban Development Zones (Zonas de Desarrollo Urbano Condicionado or ZODUC), born with the Inter Municipal Regulatory Plan of Chacabuco in 1997; and second, the Conditioned Urban Development Projects (Proyectos de Desarrollo Urbano Condicionado or PDUC) enacted in 2003, which allows the construction of large real estate projects in 11 municipalities of the Metropolitan Region of Santiago.

residential expansion towards the periphery (Heinrichs et al. 2009). Second, the densification growth or vertical growth of the city; characterized by the residential densification in the central districts of the city (Hidalgo et al. 2007; MINVU 2007; Contreras 2009). It is important to highlight that a significant part of the growth of the city is due to the expansion of residential areas. In this sense, the UN (2009) argues that the 2002 Population and Housing Census data reaffirmed the long-term tendency of a substantial expansion in the housing stock[21].

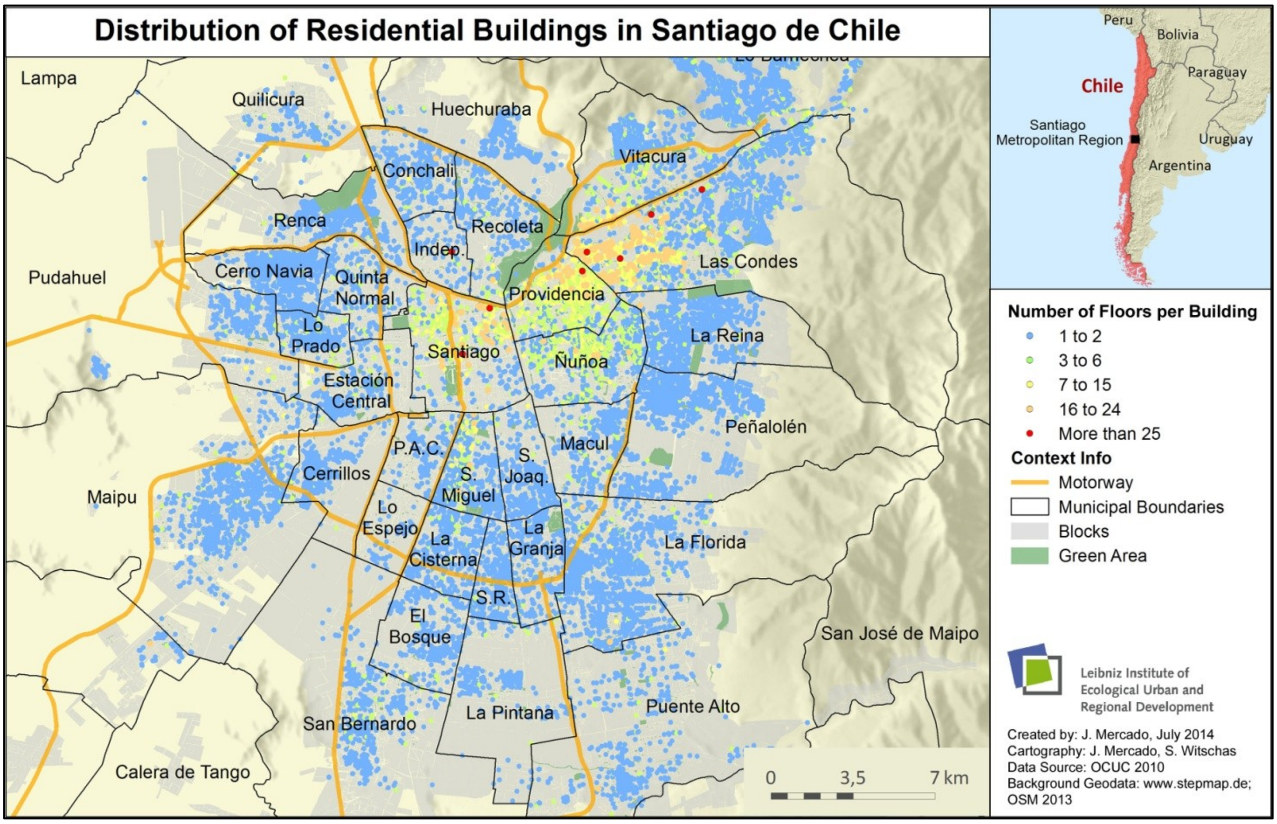


Figure 6: Distribution of Residential Buildings in Santiago de Chile
(Source: Own illustration based on spatial data from Observatorio de Ciudades UC)

For the purpose of this dissertation, it is important to review in detail the urban growth patterns and the related predominant housing types, because there appears to be significant differences between residential energy efficiency measures implemented by real estate companies in different housing types in Santiago de Chile, situation reviewed later on in detail in section 2.2.2 of this dissertation. In the following sections, the urban growth patterns of Santiago de Chile are reviewed.

---

[21] The 2002 Census gathered data for April 24, 2002. The previous census took place in 1992 and the final figures of the 2012 Census were still not available when conducting this research.

The horizontal growth of the City

In recent decades, the horizontal growth of Santiago de Chile, as in the most of Latin American capital-cities, has created a socially and economically fragmented city (see Dammert and Oviedo 2004; Hidalgo 2004). This socio-spatial segregation is characterized by the tendency to grow in extension and the consolidation of more than one urban centre; items daily found in the region (see De Mattos 2006; Link 2008; Green and Soler 2004). Moreover, the work of Rodriguez and Winchester (2004) reveals that the city of Santiago de Chile is clearly segmented in sectors characterized by inhabitants of homogeneous income groups, namely: on the one hand, the high-income groups are found in only six of the thirty-four municipalities of the Metropolitan Area; on the other hand, the lower-income groups in twenty municipalities (p.116).

Since the beginning of the new century, scientific discussion and regional policymaking in the Chilean context had focused on the externalities and drivers of the so-called "megaproject" phenomena, which seem to characterize the private real estate developments in the RMS and other parts of the country (Zegras and Gakenheimer 2000).

The location of the so-called "*megaprojects*" in the urban periphery of the RMS it is grounded on real estate companies' intention to capitalize the potential generated in the gap between the value of undeveloped-land and the maximum economic benefit resulting from land development with higher standards and returns use (Heinrichs et al. 2009). The study by Arriagada and Simioni (2001) on the dynamics of land value in Santiago mentions such potential. While land prices increased annually about 22.5% between 1992 and 1998 in municipal average, in several peripheral districts land prices exceeded 100%. Moreover, the specialized literature identifies two different reasons that explain the horizontal growth of the city. On one hand, the household demand who want to live a suburban life that reflects their preferences and aspirations. From this point of view, the development towards the periphery appears because of the action of private investors, oriented to satisfy that demand (Heinrichs et al. 2009). On the other hand, according to Jackson (1985) the development towards the periphery is a product of government policymaking. From this point of view, the housing development and land use are strongly driven by the alliance of private interests and related public policies.

It seems to be a common agreement amongst the scientific community regarding the impacts of the location of the so-called "*mega-projects*" within the urban fabric; that is the tendency to isolate the new developments from its surroundings, the so-called "*gated communities*" (See Hidalgo 2004; Borsdorf and Hidalgo 2008; Sabatini and Salcedo 2007; Salcedo and Torres 2004).

According to Borsdorf and Hidalgo (2005) considering only aspects such as structure, location, and size, within the RMS it is possible to differentiate three main types of gated neighbourhoods. 1) Urban Gated Communities; are usually groups of attached houses or even towers or skyscrapers that only offer a limited number of facilities. These developments cater for either middle-income or middle lower-income households in intermediate locations (they could even be social housing projects) or middle-high to high-income households in central areas. This concept also involves the massive enclosure of existing areas, in most cases high standing single-family housing areas in central or intermediate locations. 2) Suburban Gated Communities; predominantly cater for the middle-income and higher-income households. They offer oversized single detached houses and share wide areas for common sports facilities. However, suburban gated communities that are located in the periphery and do not include common facilities may be oriented toward lower-middle income groups. And 3) the so-called "*Mega-projects*"; with integrated cultural and educational facilities are still rare. However, this segment is rapidly growing due to the dynamics and the internationalization of the real estate market, as new transnational developers are mostly involved (Borsdorf and Hidalgo 2005, p.7).

The Vertical Growth of the City

The process of vertical growth of the city was strongly driven by government initiatives trying to deal with the process of population decline of the downtown areas and all the related externalities, namely: environment decline and security. The creation of the Urban Renewal Subsidy in 1991 by the Ministry of Housing and Urban Development (MINVU) was the basis for the implementation of the Resettlement Program and the incentive for private developers to invest in the downtown area of Santiago de Chile. The sum of money granted by the government trough the subsidy varies between 300 and 500 UF (11.100 and 18.500€[22], respectively) per housing unit. This subsidy was oriented to

---

[22]Values calculated on November 14th 2012, based on the exchange rates provided by the Central Bank of Chile (www.bcentral.cl).

homeowners who want to buy or build new dwellings with values ranging between 600 and 2.000 UF (22.200 and 74.000€[23], respectively) and a built area not greater than 140 m² (MINVU 2007).

According to the MINVU (2007), between 1992 and 1998 city centre of Greater Santiago[24] concentrated more than 85% of delivered subsidies for URS program. Between 1999 and 2007 to date, this percentage had fallen in favour of municipalities in the urban fringe and some municipalities between the city centre and the urban boundaries[25], where the residential renovation process began in the mid-nineties following the example of the Resettlement Program carried out in the Municipality of Santiago (MINVU 2007). Moreover, according to the Chilean Construction Chamber (Cámara Chilena de la Construcción or CChC) the downtown area gathers the municipalities with the highest concentration of housing production in the private housing market since 2003. Contreras (2009) argues this process relies in four pillars: 1) a strong boost urban renewal subsidy; 2) the marketing strategies of private developers aiming to "clean" the deteriorated image of the downtown area; 3) the increasing regional housing demand; and 4) the land supply granted by the creation of a land bank. Thus, the densification growth of the city or vertical growth of the city it is a transformation process of the city centre and its surroundings.

Is worth noting that, within this accelerated process of high-density housing construction, not just the business models has been replicated in the neighbouring municipalities of the city centre (i.e. Providencia, San Miguel, Independencia), the high-density apartment building typologies have also been replicated. The repetition of such building typologies meets the real estate companies' needs to streamline their administrative and constructive processes, seeking to generate the greatest economic profit, within the shortest period of time and with the least possible investment.

With the exception of apartment buildings built for high-income market segments, the quality of the finishing materials in most of the buildings does not meet high quality

---

[23]Values calculated on November 14th 2012, based on the exchange rates provided by the Central Bank of Chile (www.bcentral.cl).
[24] Including the following municipalities: Renca, Recoleta, Independencia, Quinta Normal, Santiago Centro, Estación Central, Pedro Aguirre Cerda, San Miguel, and San Joaquín.
[25] Including the following municipalities: Colina Conchalí, Lo Prado, Ñuñoa, La Cisterna, La Pintana, San Bernardo, Buin, Talagante, and Melipilla.

standards; therefore, in general the thermal and acoustic behaviour of the elements the envelope is not very demanding (Encinas et al. 2009).

According to the INE (2013), the new residential building permits issued in the RMS between 1990 and 2009 describes a uniform growth in the housing sector, although typically with higher picks and valleys following the national and regional economic trend and the international market influence in the overall development.

Nonetheless, understanding building permits data is not straightforward. The building permits are recorder by square metres of building space, which could be misleading. For example, the Figure 7 shows that in certain years the growth of single-family housing seems to be significantly higher than the multi-family housing (i.e. between 1999 and 2003) which does not necessarily implies that the number of housing units produced is parallel. It is also feasible that within this year bigger houses or smaller apartments were constructed. Unfortunately, more detailed recent comparable data on new home versus apartment sizes was not available when conducting this analysis.

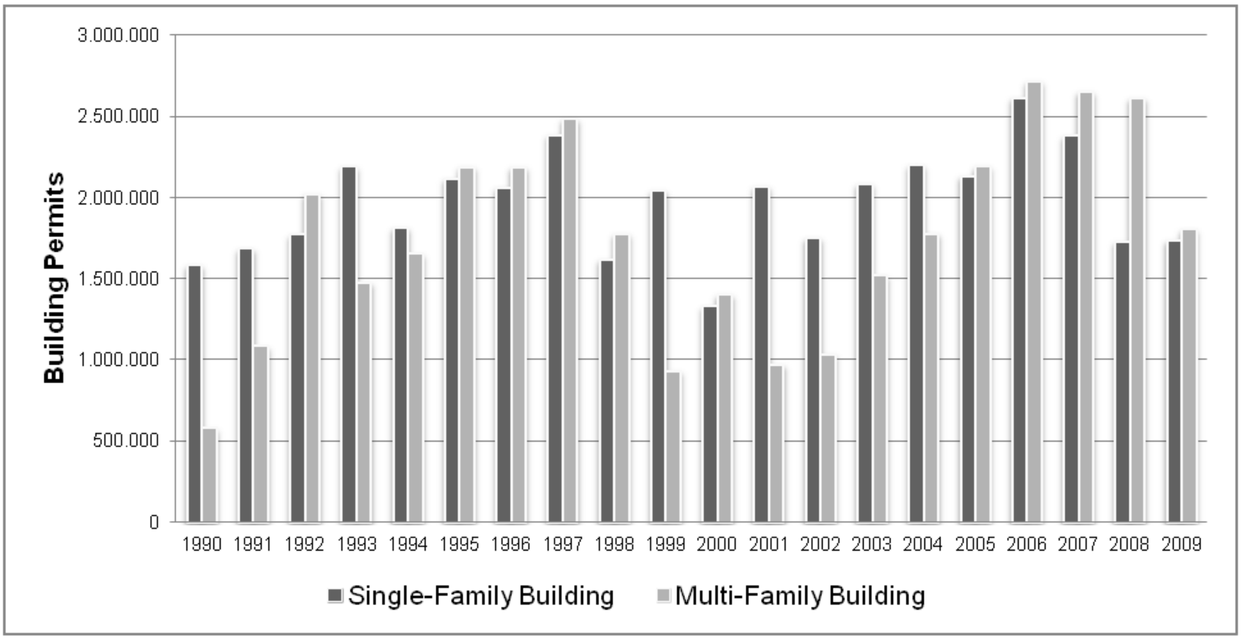


Figure 7: Housing Building Permits in the Metropolitan Region of Santiago (1990-2009)
(Source: Own illustration based on INE 2013)

In summary, the city growth patterns influence on the predominant building types mainly in terms of the physical constrains for the different housing typologies. Such constrains are directly influenced by two main driving factors: regulations, such as building codes and land use regulations, on the one hand; and land prices variation all over the city, on the other. Directly linked with the last one, a determinant of the quality of construction materials of different the building elements is the homeowner's socio-economic status which defines its affordability. Real estate companies usually take the decision about the quality standards of building materials and finishes used in each housing project according to the available budget. The quality of the construction material used is a determining factor of the thermal performance and energy consumption of the dwelling. Moreover, the combination of the household's income and the housing-project's location is a key driver for defining the dwellings' value and the different market segments in the real estate business.

Prior to the earthquake, towards the end of 2009, the construction sector was experiencing a revival after facing the consequences of the Global Financial Crisis (GFC) on 2009 (INE 2012). This revival was due to the Government stimulus package worked its way through the economy and the end of the GFC came into sight. The Chilean Construction Chamber (Cámara Chilena de la Construcción or CChC) the Monthly Construction Activity Index[26] (IMACON), which had experienced three consecutive trimesters of significant falls (-4.2%, -8.6%, and -7.9%), was predicted to grow 7.7% in 2010, 11% in 2011 and 9% in 2012. According to the last available report, the construction activity has remained dynamic during the first quarter of 2012 - evolving beyond its historical average rate of 5% per year. In fact, these features are virtually identical to those reported in many other countries, particularly the developed ones (see OECD 2008) which places the Chilean economy in a competitive position within the Latin-American region and worldwide.

Moreover, according to the INE (2012) between 1990 and 2009 the housing construction (Single-Family Housing and Multi-Family Housing) comprised in average more than 66% of the region's construction industry activity; reaching over 74% in 1997 and over 66% in 2006. Generally follows the national economic growth, although typically with higher picks and valleys (See Figure 8). On the other hand, the construction in the service sector has show a slow but steady growth since the nineties with an important pick in 2007 following the growing trend in the construction sector. This could be explained by the growing demand for strip centres and shopping malls all over the RMS, which goes hand-by-hand with the current process of poly-centricity and urban transformation. In this regard, some authors seem to agreed in ascribing this rapid process of urban transformation to the shift

[26] The Monthly Construction Activity Index (Índice Mensual de Actividad de la Construcción or IMACON) is published in *Informe MACh*: Macroeconomics and Construction. IMACON's composite index is based on surveys that include sales of building materials, number of building permits, jobs, and investment plans.

from a primary accelerated city growth to a functional transformation of the urban space, mainly due to territorial expansion (see De Mattos 2006; Link 2008; Green and Soler 2004).

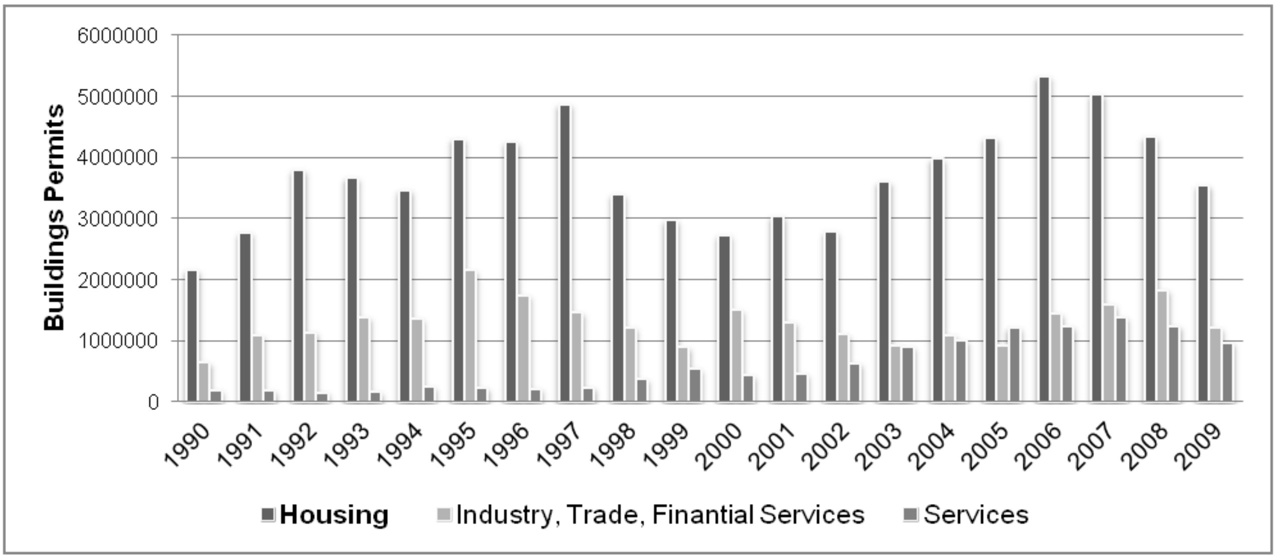


Figure 8: Building Permits in the Metropolitan Region of Santiago (1990-2009)
(Source: Own illustration based on INE 2013)

According to BBVA (2008) between 2004 and 2007, about 130.000 housing units a year were sold in Chile, representing an increase of almost 30% over the average observed during the 90's. Although the economic growth has been moderately lower in the beginning of the new century and the increase in population has decreased considerably, the real estate industry is currently highly dynamic and one of the main drivers of the Chilean economy. Several factors enabled the rapid growth in housing construction, namely: unemployment drop, rising real wages, the development of the financial system, a structural reduction of the interest rates, and the modernization of companies. The latter is evident in the profitability levels faced by the companies involved in the sector (BBVA 2008).

Within this positive scenario, the real estate market in Santiago de Chile is shaped by the combination of several factors, namely: the economic and demographic trends, the various direct and indirect government interventions in the land market, and the urban infrastructure and transport system. Moreover, the real estate market trends can play, in turn, an influencing role in many of the above-mentioned factors (Zegras and Gakenheimer 2000).

The private real estate sector has greatly benefited from the general orientation of the Chilean policy towards liberalization and concession policies, and they themselves exert pressure for that orientation (De Mattos 2002). Thus, thanks to the urban and housing policymaking on the one hand, and the political economy global restructuring on the other hand, there is a new sort of real estate agent who seeks the profitability of capital (usually international) and exploring new opportunities to value the land and develop attractive real estate products (De Mattos 2006). In many cases, this search for developing attractive real estate products has adopted various strategies of innovation in the construction processes of buildings and in the products themselves.

According to Casgrain (2010), the Chilean real estate market existing today owes itself to the specific actions undertaken by the military regime, namely: the sale of large tracts of government owned land, the liberalization of the land market, the elimination of low income squatter settlements in high income municipalities, and the legalization of squatter settlements in other parts of the city. Moreover, according to Zegras and Gakenheimer (2000) these actions contributed to the growth in the importance of the real estate market to the regional economy and the emergence of a growing number of major market players. On the other hand, these market players are linked to the so-called “megaproject” phenomenon (described in the previous sections) and the fast building process within the city centre. Both processes had increasingly characterized real estate developments in the RMS in the last years.

2.2.2 Local Land Market and Housing Market Dynamics

According to the work of Heinrichs et al. (2009) the dynamics of the private housing market in the RMS are a consequence of the interaction of three driving forces: first, the provision and promotion of housing by the private housing sector; second, the support they receive from the public sector policies; and third, the citizens and their preferences. In this study, the role of the public sector is detailed analyzed in the following sections and the citizens and their preferences are captured through the real estate companies perceptions’ regarding the market needs.

Financing alternatives for buying a house are provided by banks and other specialized financial institutions, such as mutual-aid and residential leasing companies. Almost all the credits are granted in UF and terms range from 5 to 40 years. In December 2007, bank lending accounted for 86% of total mortgage lending for housing and the average price of the property is financed around 1800 UF (BBVA 2008). The financial institutions provide financing for dwellings with values over 700 UF, which in practice accounts for financing only private unsubsidized housing. There exists only one state-owned bank in Chile (called BancoEstado) and it provides financing opportunities to lower income segments. It finances housing with a minimum price of 450 UF, covering part of the state-subsidized housing. In addition, this organization provides credit for amounts lower than 350 UF through a subsidiary housing agency, a mutual mortgage company.

The importance of the financing issue is that the majority of real estate companies sell their products before they are actually built-up (the so-called "*in green sale*"). Therefore, real estate companies have various marketing strategies to promote their housing products and help accelerate their sales, i.e. following international trends.

2.2.3 The Role of the State

Although this doctoral thesis focuses on the private housing supply, given the dynamics of the housing market particularities in Santiago de Chile, the subsequent sections provide an overview of social housing policy in the Chilean context. There are two basic reasons for this: firstly, according to what is mentioned in the previous sections, the private sector of the construction industry is also responsible for constructing social housing projects controlled by the state, although with different budgeting; an secondly, state financial incentives in the field of residential energy efficiency are contained within the social housing subsidy programs in the Chilean context. Carefully targeted, upfront government subsidies via vouchers have been the traditional practice of the Chilean government to deal with the housing shortage in the lower-income socioeconomic groups of the country. In fact, sharp focusing on the poorest households traditionally has discouraged the delivery of housing subsidies via alternative subsidy mechanisms such as below-market interest rates as it occurs in other realities around the globe (UN 2009).

The housing sector in Chile comprises housing acquired with the support of a state subsidy (totally or partially) and private housing. The estimated share of the total number of housing units sold in 2007 was 65% and 35% respectively. While private sector builders carry much of the works out, most of the housing units are mandated by the state to be subsequently delivered to low-income sectors in various forms of social programs. The remaining percentage is for private projects developed on their own to be sold directly to third parties, whose main population target is the growing upper middle Chilean class (BBVA 2008).

According to the UN (2009), publicly supported housing programmes in Chile have been crucial in transforming potential demand for housing into actual demand, particularly among low-income families. The fiscal support to the Ministry of Housing and Urban Development (MINVU) social housing programme has been significant over the years. Although the detailed analysis of all the housing financial interventions issued by the state are beyond the scope of this study, it worth understanding the role of the state in the provision of social housing as it is closely linked with the private sector, in which depends for implementing housing projects. When the project meets a private venture, the developer´s activities include site selection along the city, the project development including marketing and financial strategies, and finally the project execution. An important share of this kind of real estate development is done in the form of large-scale megaprojects in the urban periphery, with all the externalities discussed in the previous sections (see Borsdorf and Hidalgo 2005).

The main direct fiscal intervention in the housing market of the RMS is the use of housing subsidies. There are two main types housing subsidies: first, a group of subsidies targeted at aiding specific socio-economic groups (public housing subsidies and DFL2); and second, a group of subsidies oriented at promoting housing development in specific parts of the region like the case of the urban revitalization subsidies applied in the city centre. The direct responsible for overseeing the program nationally is the MINVU, establishing the relevant requirements and providing funding via the Housing and Urban Planning Regional Service (Servicio de Vivienda y Urbanismo or SERVIU).

Since the late twentieth century, housing policy has aimed – by every means possible – at reducing the housing deficit. Furthermore, since 1981, MINVU introduced important changes in their housing programs, when expanding the regulation for the newly created Variable Housing subsidy[27]. This measure originated the Basic Housing Programme, contemplating a variable subsidy system and considering basic housing as the first step towards the social housing. Once perceived, both in the national and in the international scene, the housing policy is being successful in terms of significantly reducing the housing deficit from the quantitative point of view; new concerns about the qualitative aspect of social housing emerged in the housing policy. The so-called "*new housing policy*" applied by the MINVU since 2006 aimed to make progress in improving the quality

[27] A key factor in choosing the beneficiaries of the various subsidies is the score obtained by the applicant in the Social Protection Card, which is the instrument of social stratification that currently uses the State for selecting beneficiaries of social housing programs aim to serve the population living in poverty and social vulnerability in the country (MINVU 2013).

and social integration of housing. At this stage, the built stock of social housing was increased, while also ensuring the quality of construction. It was also sought to reverse the social segregation in the city, improving the stock of existing homes and neighbourhoods, and helping the middle class in need of government support for homeownership. Thus, housing subsidies are not only concentrated on the poorest segments of the Chilean society. There also exist certain subsidies that focus on the middle or so-called "*emerging*" class. In the case of the latter, the subsidy it is not awarded to cover the entire new housing purchasing; instead, it gives the opportunity to complete the value of the dwelling with a mortgage loan or own resources.

Thus, MINVU designs and implements various housing subsidy programs that seek to reduce the deficit of the most vulnerable sectors, reducing inequality and promoting social integration through the delivery of housing solutions (MINVU 2013). To meet this goal, MINVU relies on independent construction companies or real estate companies in order to execute the different housing projects, as the ministry itself is not responsible for the execution of works.

It worth noting that the Family Heritage Protection Program (Programa de Protección al Patrimonio Familiar or PPPF) is the only program that offers some kind of financial support aimed at improving the dwelling in terms of energy efficiency. The Title II of the PPPF, called "*Housing Improvement*" includes two sorts of subsidies. The first one, aimed at reparation and home improvement, looking forward to disrupt the dwelling decay and renew the dwellings of vulnerable families and emerging sectors, supporting the financing of energy efficiency innovations works such as: Solar panels, solar lighting, water separation treatments, or similar. The second one refers to housing's thermal conditioning and it aims to improve the housing's insulation, so that the household has some heating savings and minimize condensation inside the dwelling (MINVU 2013). The implications of the relationship between residential energy efficiency and housing subsidies availability are detailed discussed further on in the section 5.2.4.

2.3 Chile's Energy Challenge

The country's continued economic expansion has led to significant pressure on Chile's energy grid, spread unevenly throughout the country's harsh geography. According to Chile's National Energy Strategy, the country must add over 8 GW of new electricity generation by 2020 in order to meet expected energy demand increases (ENE 2012, p.7).

According to the National Energy Efficiency Program (Programa País Eficiencia Energética or PPEE), based on statistical data collected by the Chilean National Energy Commission (Comisión Nacional de Energía or CNE), the final energy consumption in Chile it is grouped for statistical porpoises in four groups: transport, industry, mining, and commercial-residential-public. The commercial-residential-public sector accounts for more than 26% on average of final energy consumption between 2001 and 2011 (APERC 2009). Moreover, according to the CNE (2007) the energy consumption of the residential sector accounted for over the 20% of the energy consumption of the construction industry as shown in the Figure 9.

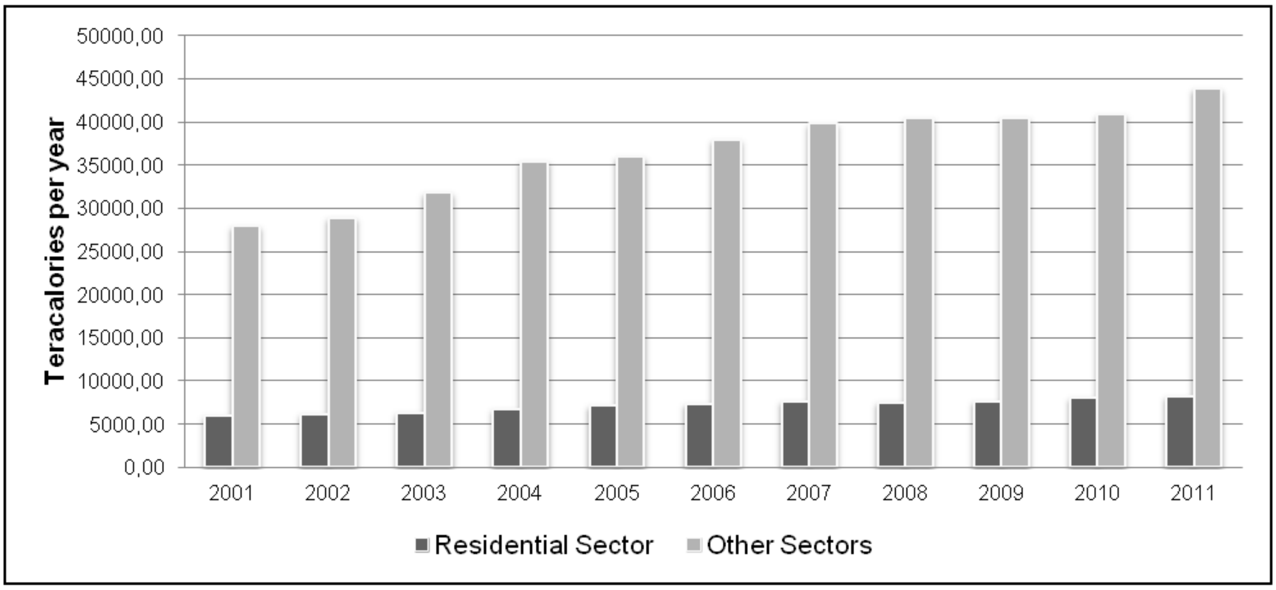


Figure 9: Final Energy Consumption of the Residential Sector vs. Other Sectors of the Chilean Economy (2001-2011)
(Source: Own illustration based on the National Energy Balance, Ministry of Energy (MINEN 2012))

In most of the southern regions of Chile[28], the largest energy source in the residential sector is firewood, used mostly for cooking and heating. It corresponds to 47% of total energy consumption and it creates environmental problems and issues related to sustainable resource management. It should be noted that biomass consumption data are still grossly estimated due to the complexity and informal nature of the biomass market, and is therefore subject to wide margins of error (OECD-IEA 2009). Nevertheless, this concern has recently derived in regional energy efficiency policies and studies for public-housing in the Chilean southern regions (see Vera and Ordenes 2002).

In order to tackle the challenge of achieving sustainable economic growth by meeting the country's energy needs, the Chilean government has recently introduced a series of strategic guidelines contained in the National Energy Strategy 2012-2030 (Estrategia Nacional de Energía or ENE). Since 2012, the ENE is the backbone of the national energy policy. Based on the ENE, weaknesses in the regulatory framework, which became evident when the country had to suffer power rationing primarily by periods of drought in the 90s and the restriction on the supply of natural gas from Argentina in 2004, were identified (ENE 2012, p.10).

In order to reduce energy vulnerability, Chile has based its power generation in coal and diesel energy plants; however, this approach generates a significant impact on the environment, since it implies a significant growth of CO_2 emissions, and does not contribute to reducing the Chilean dependence on fossil fuels for energy production. For all this, the ENE seeks to establish the necessary conditions to permit the diversification of the national energy matrix, through the implementation of non-conventional renewable energy and harnessing the potential of energy savings by fostering the further development of energy efficiency (ENE 2012, p.16).

Energy Efficiency Potentials

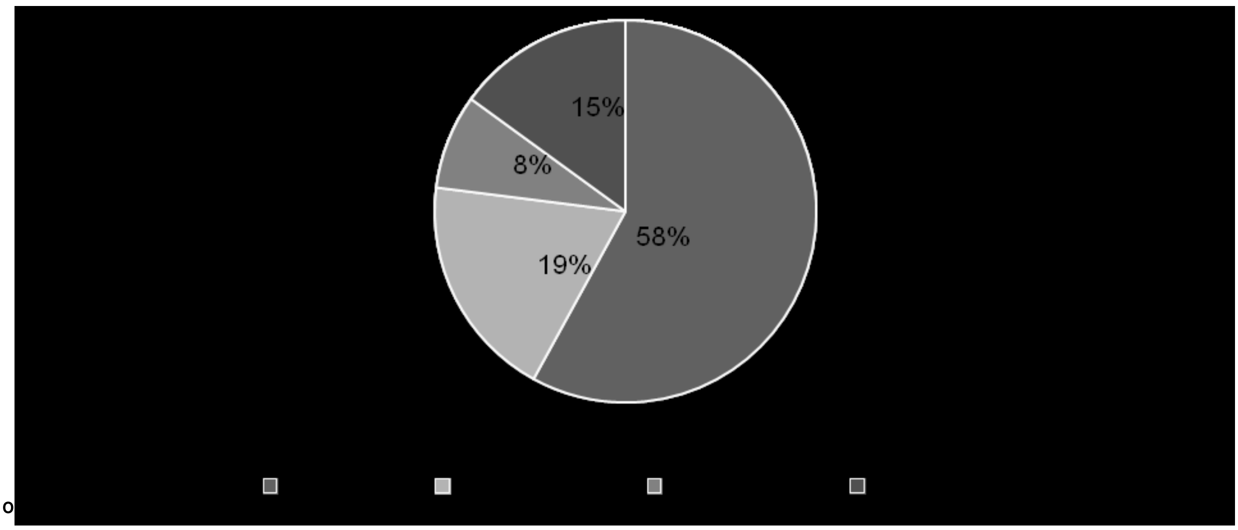
A research conducted by the Programme of Research in Energy (Programa de Estudios e Investigaciones en Energía or PRIEN) at the Universidad de Chile, estimated the potential for energy efficiency (EE) in the largest consumption sectors in the Chilean economy. The purpose of the study aims to establish the relationship between energy efficiency and economic efficiency at the national, sectoral, and sub-sectoral levels, for assessing the evolution of efficient use of energy resources, with two main goals: first, in

[28] The southern regions of Chile are: Bío-Bío, Araucanía, and Los Lagos.

order to establish the theoretical potential for improving EE in the country at these three levels; and second, in order to contribute to designing policies to promote EE use aimed at decouple energy consumption from GDP growth (PRIEN 2008, p.5).

The study is a revision and update of the work done for the National Energy Commission in 2004 and maintains two levels of analysis of the evolution of EE. First, a national macroeconomic analysis considering the Chilean economy as a whole; and second, sectoral and sub-sectoral analysis that considers the key sectors of energy consumption nationwide. Moreover, the energy information basis for the study was provided by the Energy Balance of the National Energy Commission. On the other hand, the economic information was obtained, mostly from the National Accounts of the Chilean Central Bank. For the analysis, there were considered the following sectors: Industrial, Mining, Services, Transportation, and Residential.

Implementing EE is not only a technical problem, but in many cases, involves proper management of energy systems (PRIEN 2008). According to the PRIEN, decoupling between economic growth and energy demand, there has been, to a great extent, by the introduction of EE policies motivated by the scarcity of energy resources and, more recently, by the care for the environment (PRIEN 2008). In this sense, the analysis of the study conducted by the PRIEN highlights the higher energy consumption in the residential sector at national level is much focused on firewood as primary energy, accounting for 58% of total energy consumed by households in Chile (see Figure 10), which means a increased damage to the environment through higher CO_2 emissions.



o

Figure 10: Distribution of Energy Consumption for the Residential Sector (Source: Own illustration based on PRIEN (2008, p.25))

Among the main conclusions of the study, the energy savings potential in the productive sectors of the Chilean economy are highlighted. Based on an analysis of scenarios, the study expects it progressively up to 20% energy savings through the implementation of EE across all economic sectors until 2021 (PRIEN 2008, p.134). Finally, in the residential sector are distinguished some activities with a high potential for improvements in energy use. Those of most interest to this doctoral research are: 1) indoor thermal conditioning; 2) higher thermal quality of construction; 3) water heating; 4) lighting; 5) energy use in kitchens; and 6) electric appliances (PRIEN 2008, p.132).

As in many other countries, energy security concerns and growing energy demand are the grounds for the increasingly importance of EE as part of Chilean energy policy (OECD-IEA 2009). Chile has experienced significant growth in energy consumption over the past few decades, particularly in the electricity sector. Final energy consumption grew by 2.8% per year on average over the past ten years, while electricity consumption increased on average by close to 6% per year (OECD-IEA 2009, p. 89).

Table 5: Energy Efficiency Strategic Guidelines in the Chilean Policy Making
(Source: Own compilation based on Chile's National Energy Strategy 2012-2030 (ENE 2012, pp. 16-18))

Strategic Guidelines	Key Aspects
Energy Efficiency Action Plan 2012-2020 (PAEE20)	Intended to raise the awareness of the public and private sectors on the potential of EE. Aims to: 1) incorporate elements of EE into the different productive sectors; 2) promote low energy consumption for modern appliances.
Energy Efficiency Seal	Applicable to companies leading the way in developing EE on a national level. Aims to make this seal the registered trademark for efficient companies.
Minimum Energy Performance Standards (MEPS)	All products, equipment, appliances, materials and other products that utilize any kind of energy, must comply with MEPS for them to be sold in Chile. Aims to incorporating EE into consumer decisions; by increasing the labeling of appliances and informing the public about the energy performance of products on sale.
Efficient Residential and Street Lighting Programs	Complementing MEPS; seeks to accelerate the transition to more efficient lighting technologies for the residential and public sectors. Aims to promote and educate the public on the benefits of adequate energy consumption.
Efficient Residential and Street Lighting Programs	Achieving the estimated energy savings by means of coordinating public organizations. All EE-related measures or agreements adopted will be integrated into the policies of each participating entity or institution.

The statements in the preceding sections have been hosted in the implementation of strategic guidelines in the field of EE contained in the National Energy Strategy 2012-

2030 (Estrategia Nacional de Energía or ENE). According to the ENE, the need to achieve higher EE levels has never been as clear as now (ENE 2012, p. 16). Factors such as high energy costs and the growing awareness about environmental issues and energy security, have contributed to a greater awareness of the need for further development in the field of EE. Therefore, the ENE includes a set of specific strategic guidelines in the field of EE, as detailed in the Table 5, and directly affecting the residential sector.

Finally, the national energy problem has been introduced in various levels of policymaking, the academic discussion, and everyday conversation of the Chilean population. In the specific case of the construction sector, the energy problem is installed through three relevant factors; namely, 1) the recent implementation of the strategic guidelines in the national energy policy; 2) the implementation of new EE regulations in the residential sub-sector (which is reviewed in detail in section 4.4); and 3) the growing importance of green building in the international arena.

2.4 Raising Questions

In the preceding sections a close relationship between two cross-cutting topics that affect Chilean sustainable development has been established. On the one hand, the growing importance of the construction industry for the Chilean economy and the role of private housing construction in the significant growth of the RMS it was stressed. On the other hand, the country's energy vulnerability – mainly related to the country's dependence on fossil fuels for power generation – was also highlighted. The latest, has motivated the implementation of new guidelines in the national energy policy with two main focuses: first, the search for alternative sources for energy provision; and second, the recent positioning of the concern for improving the energy efficiency of new housing across the country in the Chilean public policy and the regulatory policy. Both topics are developed within the particularities of the Chilean regulatory framework, where there is a constellation of leading actors playing different roles, both when it comes to discussing and generating public policies and strategies, and when it comes to transforming strategic guidelines into regulations.

With regards to the Chilean construction industry, the leading role of groups of construction companies and real estate companies that significantly concentrate construction investment has been emphasized. Moreover, it has been shown that in the Chilean context, the demand for construction services are mainly twofold; first, the public sector`s demand for public infrastructure (i.e. urban infrastructure, road infrastructure, etc.) for the operation the public system and the provision of services; second, the private sector's demand different types of buildings (i.e. commercial buildings, office buildings, residential buildings and a large variety of real estate products).

As for the supply of construction services in the Chilean context, there is a significant universe of private construction companies that form the backbone of the construction industry; construction companies work closely related to real estate companies that handle the marketing of various real estate products. Finally, within the Chilean construction industry, there are – among others – two professionals' associations that group a large number of construction and real estate companies. These associations are the Chilean Chamber of Construction and the Association of Real estate developers, both institutions represent the interests of the members they represent and exert an important pressure on the decision and policy-making in the sector.

One of the sub-sectors of the construction industry that has had a significant growth in the Chilean economy is the construction of new residential buildings in the RMS. The variety of real estate products offered in the private housing sub-sector is a result of the particular dynamics that characterize the Chilean capital city, Santiago de Chile, located in the RMS[29].

The high vulnerability in energy generation – associated with dependence on fossil fuel supply from neighbouring countries for power generation – stands out as one of the most important problems in the Chilean context, mainly when providing a support to the development economic of the country. To date, the Chilean government – with the support of various international agencies and academic institutions specialized in the fields of energy and construction – has introduced the topic in the discussion of public policy and has implemented new regulations in the housing sector[30].

Given this scenario, where the private housing construction sub-sector in the RMS has a wide range of real estate products, which must comply with relatively new and undemanding energy efficiency standards, the main research question of this dissertation doctoral is: ***How do real estate developers apply energy efficiency in their housing offer in Santiago de Chile?***

In order to guide the research in further detail, the following secondary research questions or sub-questions are posed:

Who are the real estate developers that are adopting energy efficiency and why?

Given that the supply for energy-efficient real estate products in the private housing market in the RMS has showed a steady growth, this sub-research question seeks to shed light on two important issues. First, regarding the real estate companies that are implementing residential energy efficiency measures in their housing offer in Santiago de Chile; and second, regarding the motivations of such companies to offer and apply residential energy efficiency in their offer. The second part of this compound sub-question

---

[29] Broadly speaking, two predominant buildings types can be identified in the RMS. On the one hand, high-density multi-family buildings located generally towards the city centre; on the other hand, low density single-family housing, detached or grouped, located generally towards the outskirts of the city. Both building types corresponding two different growth patterns of the city: vertical growth and extension growth.

[30] The new regulations aim to reduce households' energy consumption by improving the thermal performance of different elements of the building envelope.

is critical, because it seeks to understand the underlying reasons of the real estate companies' decisions to implement energy efficiency measures and to offer real estate products with these characteristics in the private housing market.

What types of energy efficiency measures are real estate companies adopting?

Since energy efficiency regulations for new housing buildings in the Chilean context are relatively new, this sub-research question seeks to identify as far as possible all the residential energy efficiency strategies that real estate developers are applying in the various real estate products of the current offer. This sub-question seeks to identify and analyze the universe of residential energy efficiency strategies that are being applied in the private housing supply and the reasons for companies to implement any given energy efficiency strategy or the other. This knowledge enables the understanding of the main reasons for applying an energy efficiency strategy or another. Mainly, this sub-question seeks to draw an imaginary line to differentiate those energy efficiency strategies that go beyond the requirements of the new energy efficiency regulations – partially defined by the new thermal regulation in the Chilean context – from those that energy efficiency strategies that only comply with the regulations.

Which barriers to further implementation of energy efficiency exist?

Finally, once a group of real estate companies interested in implementing residential energy efficiency in the private housing supply have been identified; this group of key informants has the practical knowledge gained through experience in implementing energy efficiency strategies. Therefore, it is important to collect this empirical knowledge in order to understand which have been the main constrains they have had encountered for the implementation of different energy efficiency strategies. Therefore, this sub-question seeks to identify the main constraints (economic, social, organizational, etc.) to further implementation of residential energy efficiency within the regulatory, social, and economic context; within the particular characteristics that define the private housing market housing in Santiago de Chile.

3 Research Design and Methods

Each research project is unique in nature, because it responds to a precise set of motivations and attempts to answer a precise set of research questions. Furthermore, the specifics of the location where the research is conducted, such as the availability of information, the access to key informants, etc., plays an important role when deciding the research's methodological approach. Thus, the aim of this Chapter is to present and substantiate each one of the methodological steps taken throughout the investigation, in order to make the research process transparent and traceable.

The Chapter is divided into five sections. The first provides a summary of the research design and emphasizes the use of case studies of exploratory nature. The criteria and methodology for the selection of sub-cases are reviewed in the second section, which is done through purposeful sampling criterion. The third section presents expert interviews as the main instrument for collecting primary data. Techniques for qualitative data analysis are detailed in the fourth section. Finally, the last section provides a summary of the results of the Chapter that relate primarily to the selection of sub-cases and techniques for qualitative data analysis.

3.1 Research Design

As described in the Table 6, this research uses a case study approach of an exploratory nature (Yin 2009). This methodology originates from human and social sciences as well as evaluative research and focuses on contemporary events (Creswell 2007, p.8). Case study methodology[31] was selected among alternatives because it is useful when a "*how*" or "*why*" question is being asked about a contemporary set of events where the investigator has little or no control (Yin 2009).

The research investigates the implementation of voluntary energy efficiency measures in the private housing market in Santiago de Chile; at the same time, it seeks to understand the different driving factors behind real estate developers' decisions to offer and apply energy efficient housing. More precisely, this research uses a single case with embedded

[31] A range of terms are used to describe different types of case studies and include: storytelling and picture drawing, theory seeking and theory testing (Bassey 1999); intrinsic and instrumental (Stake 1995); theory-led, theory-generated, evaluation and ethnographic (Simons 2009); descriptive, exploratory and explanatory (Yin 2009). Moreover, Yin (2009) in addition refers to single and multiple-case study design either of which may have a single or multiple unit of analysis. Case study described by Yin follows a more positivist epistemology, while the others (Stake 1995; Bassey 1999; Simons 2009) describe case study from an interpretive perspective (Pretty et al. 2012, p.2).

units methodology (see Yin 2009); this means a holistic case study – the private housing market in Santiago de Chile – with sub-cases – the supply of energy-efficient dwellings – would enable the researcher to explore the case while considering the influence of the housing market dynamics on the managers' decision making. This approach enables the possibility to look at the various sub-units – all the companies adopting energy efficiency measures – that are situated within a larger case – the private housing market in Santiago de Chile.

Table 6: Overview of the Research Design and Methods
(Source: Own compilation adapted from Meyer 2011, p.73)

Overall Research Design	Qualitative case study approach of an exploratory nature (no hypothesis testing). Single case study with embedded sub-cases (Yin 2009).
Sub-Cases Selection / Sampling Strategy	Criterion sampling strategy (Patton 2002, Flick 2009). Real estate developers offering energy-efficient housing in Santiago de Chile during 2011 (45 out of 568 real estate developers).
Interview Partners	39 experts (22 real estate developers + 17 other key stakeholders) Interview partners were carefully selected on the basis of their knowledge/expertise in the field of: Energy, Energy Efficiency, and/or the Housing Sector.
Main Methods of Data Collection	33 semi-structured interviews with real estate developers, regulators, and other key stakeholders in the housing and energy sectors, etc.
Main Methods of Data Analysis	Primary data: Thematic content analysis (Fereday 2006). Secondary data: Document analysis (Bowen 2009).

Moreover, according to Yin (2009), this methodology is suitable when considering various scales of data analysis, namely: data can be analyzed within the subunits separately (within case analysis), between the different subunits (between case analysis), or across all of the subunits (cross-case analysis). This capacity, to get deeply involved with such rich data analysis, only serves to better illuminate the case (Baxter and Jack 2008, p.550).

There seems to be a consensus amongst case study researchers with an important feature of the case study research is the ability to combine multiple methods with the purpose of illuminating the case from different angles, that means: to triangulate by combining methodologies and sources; thus, the essence of case study methodology is triangulation, the use of different techniques, methods, strategies, or theories (Yin 2009; Stake 1995; Miles and Huberman 1994). Furthermore, in qualitative studies, in order to deepen the understanding of the case, a variety of data may be collected including: interviews, observation, and document analysis. No particular method of data analysis or data collection is directly linked with case study methodology; therefore, the researcher has certain degree of freedom to choose from a broad range of methods and the selection will be guided by the focus of the case study and research question (Pretty et al. 2012).

The Figure 11 outlines the research's consecutive methodological steps, the procedure or techniques, and aims of each methodological step.

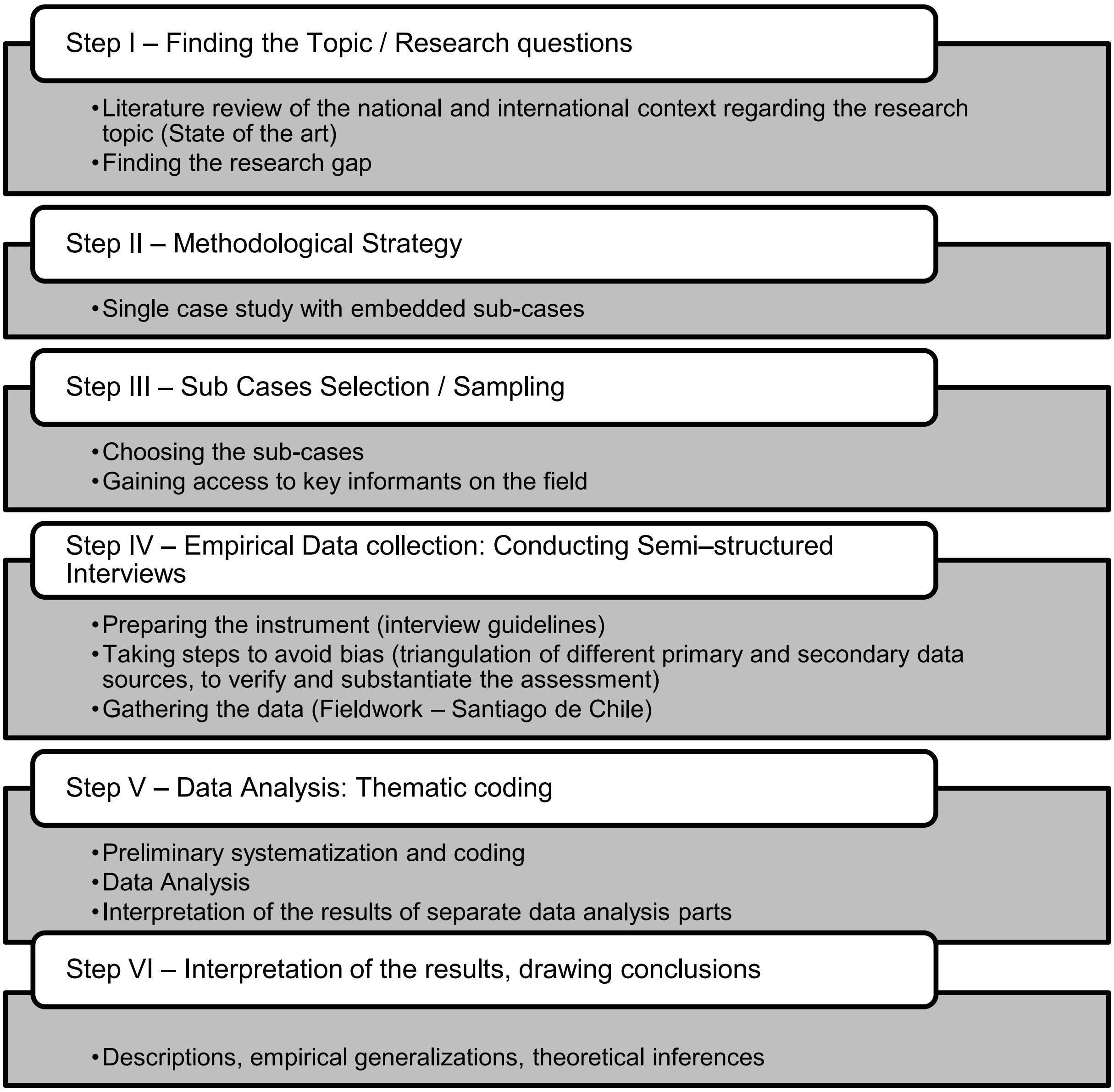


Figure 11: Outline of the Methodological Steps
(Source: Own illustration)

3.2 Sampling and Sub-cases Selection

This research seeks to understand real estate companies' motivations when offering and applying energy efficiency measures in their housing supply. It was intended that selected sub-cases were interesting information providers and illuminative – that is, they offer useful manifestations of the phenomenon of interest (Patton 2002, p.40). Hence, a set of real estate companies, amongst the real estate market of Santiago de Chile, was selected because they were information-rich and they could be helpful to determine why and how real estate companies are applying energy efficiency measures in their real estate products. Consequently, the sub-case selection in this research does not seek representativeness from a sample to a population, because cases are not sampling units and should not be chosen for this reason. Rather, following Yin (2009), individual cases are to be selected as: "*a laboratory investigator selects the topics of a new experiment. Multiple cases, in this sense, resemble multiple experiments*" (Yin 2009, p.38).

As seen on the previous chapters, the literature review on residential energy efficiency regulations in the Chilean context reveals certain weaknesses regarding energy efficiency standards defined in the building code[32], particularly when comparing them with the international experiences. Briefly, Chilean energy efficiency regulations is reduced to National Thermal Regulation which came into force since 2006 (see MINVU 2009), while in the international context the adoption and implementation of specific energy-efficiency regulations started on early 70s. Thus, it is important to gather empirical evidence regarding what motivates the real estate market to go beyond the energy efficiency regulations.

Following a qualitative research approach, sub-cases were purposefully selected by means of applying a criterion sampling strategy (Patton 2002), also known as purposive

---

[32] As seen on Chapter 2, the National Thermal Regulation in Chile is the only mandatory regulation dealing with residential energy efficiency.

sampling[33] (Teddlie and Yu 2007, Flick 2009). This sampling strategy implies: "*to review and study all cases that meet some predetermined criterion of importance*" (Patton 2002, p.238).

This sampling strategy was chosen among alternatives because it aims at the insight of the phenomenon; an empirical generalization from a sample to a population was not sought (Patton 2002; Teddlie and Yu 2007). Moreover, the selection of sub-cases was based on the assumption that all real estate developers, offering energy-efficient housing in Santiago de Chile, are advertising the different real estate products online in order to reach a large number of potential homebuyers. Thus, for the specifics of this research, the criterion for case selection was: all private housing developers currently offering energy-efficient dwellings in Santiago de Chile. In order to select the sub-cases, a systematic review of the real estate developers' websites was conducted between June and July 2011, as a preparatory stage for the data collection during fieldwork in Santiago de Chile between April and May 2012.

In order to cope with the web-based data collection, information was collected about the real estate companies operating in the housing market in Santiago de Chile. Given that there is no formal record of the number of existing real estate companies operating in Chile (Alvarado and Spolmann 2009), a real estate companies database was compiled by the author by adding up the information provided by two sources in order to ensure that the big majority – if not all – of the real estate companies were taken into account. The sources are: the Chilean Construction Chamber (Cámara Chilena de la Construcción or CChC) and the Ministry of Housing and Urban Development (Ministerio de Vivienda y Urbanismo or MINVU).

On the one hand, the CChC[34] is a trade association aiming to promote the construction industry; it holds a complete database of companies working on the construction sector

[33] Qualitative researchers also refer to Purposive Sampling as Selective Sampling or Purposeful Sampling. The work of Coyne (1997) analyses critically the underlying differences between purposeful and theoretical sampling and provides a detailed overview on the various sampling techniques used in Qualitative Research. Moreover, the work of Patton (2002) detailed analyses 15 different strategies for purposefully selecting information-rich cases which may be listed as: 1) extreme or deviant case sampling; 2) intensity sampling; 3) maximum variation sampling; 4) homogeneous samples; 5) typical case sampling; 6) stratified purposeful sampling; 7) critical case sampling; 8) snowball or chain sampling; 9) criterion sampling; 10) theory-based or operational construct sampling; 11) confirming and disconfirming cases; 12) opportunistic sampling; 13) purposeful random sampling; 14) sampling politically important cases; and finally 15) convenience sampling. What this illustrates is the complexity of sampling in qualitative research. In any case, the underlying principle that is common to all these strategies is selecting information-rich cases, that is, cases that are selected purposefully to fit the study.

all over the country. On the other hand, MINVU monitors the real estate activity and presents a quarterly report about the dynamics of the housing market in Santiago de Chile – which is the main focus of this research. The outcome of information overlap was a database created by the author gathering in total five hundred and sixty-eight real estate companies working in the private housing market in Santiago de Chile between June and July 2011.

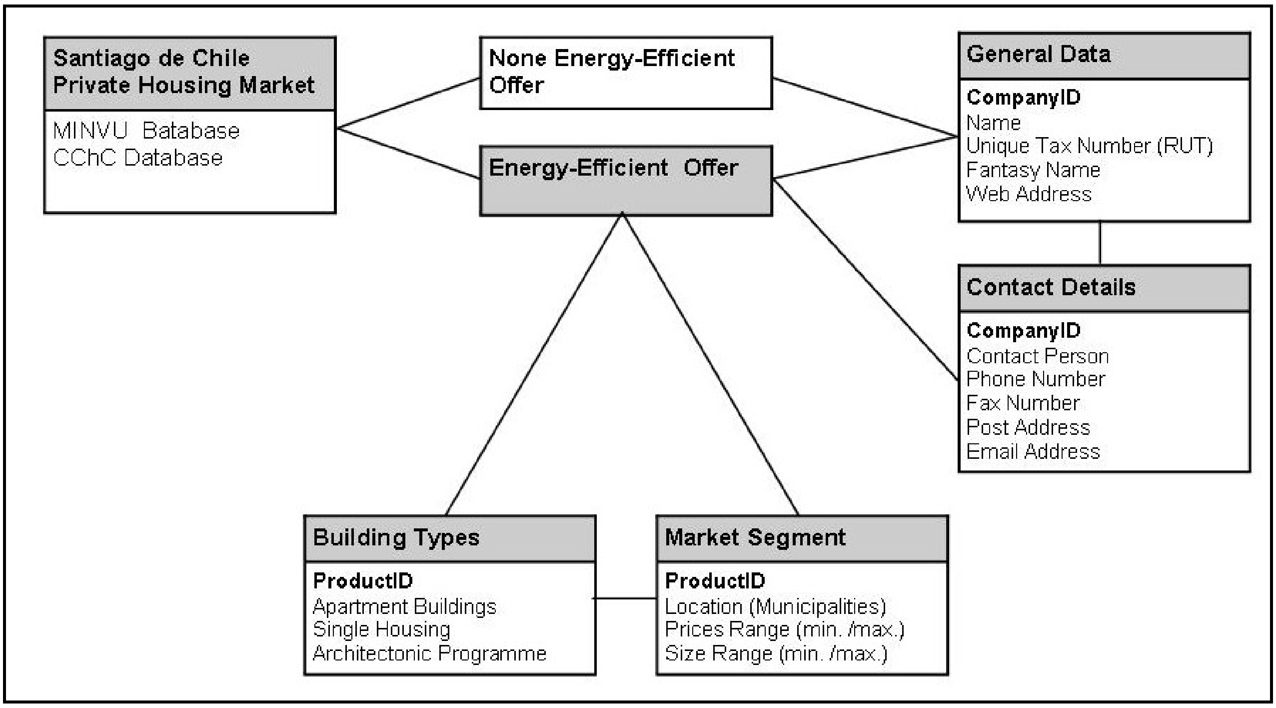


Figure 12: Real Estate Companies – Database Schema
(Source: Own illustration)

The Figure 12 shows the real estate companies database created by the author. After consolidating the database on the basis of the information provided by MINVU and CChC, a debugging process took place. The criteria used for debugging the records are the following: 1) companies not operating in the residential building sector; 2) companies not working in the RMS; 3) websites under construction and/or broken links; 4) subsidiary companies from a parent company; and 5) duplicated entries.

---

[34] According to Alvarado and Spolmann (2009), it is possible to have an approximation of the shape of the sector in the description of the register of members of the CChC, which has nearly 1,500 associates throughout the country. Among CChC members, there are general services construction companies, construction companies specialized in very specific segments, suppliers of industrial supplies and construction materials for the construction sector, consultants and, most importantly for this research, real estate companies.

Once the housing market database was consolidated, all real estate companies' web sites were reviewed one by one to the full extend, in order to select all those offering the implementation of energy efficiency measures in the new housing offer.

Detailed information was collected from all the real estate companies offering energy-efficient housing in the private housing market. Mainly, data was gathered in order to describe each company's real estate products. Primarily, two aspects were considered: first, the type of building (mainly multi-family apartment buildings and single-family housing); and second, the market segment (corresponding to an aggregation of information regarding: the location of the housing projects in the city; the dwelling's price and size ranges). Finally, detailed contact information was collected in order to get in touch with the companies representatives (name of the contact person, phone number, post address, etc.) and starting the interview organization process.

During the web-based data collection, two different website environments were found: 1) Hypertext Markup Language (HTML) where information is written in plain text interspersed with formatting instructions and images, as a document; and 2) flash content, that uses Adobe Flash software for applying advanced animation, music, and video.

On the one hand, websites written in a HTML environment were reviewed using Google Site Search, a search engine used to seek for information on the World Wide Web and FTP servers. The wording of the search query, used to perform the full-text website search, derived from the literature review in order find suitable terms. Thus, Query used during the full-text search corresponds to the Spanish wording as follows: "*eficiencia energética*" Spanish for "*energy efficiency*"; "*energía*" Spanish for "*energy*"; and "*ahorro*" Spanish for "*savings*". The online search results were different paragraphs including any of the words specified in the search query. The selected paragraphs were subject to deeper analysis in order to find out whether the real estate companies were offering energy-efficient housing or not.

On the other hand, websites developed using flash technology, where contents are displayed as images and cannot be analyzed with a full-text search engine, the content of the entire website was reviewed at length; special attention was paid to "about us" section and all the links containing a description of current housing projects of each company.

In summary, forty-five real estate companies offering energy-efficient housing in the private housing market in Santiago de Chile were selected as sub-cases. Once the sub-cases were selected, the main task during the empirical phase of this research was to find out key motivations for offering and implementing residential energy efficiency measures. During the empirical phase, individual semi-structured interviews are conducted with the general manager of each company.

3.3 Primary Data Collection

Due to the nature of the methodological strategy pursued by this doctoral research, the primary source of information is contained in written form, that is, textual data. Therefore, the main body of textual data has been generated from interview transcripts, field notes, memos, or even text fragments from policy documents or other official documents, to name a few. According to Burnard (1996), the point is that what is being analysed is words on paper. The author suggests that such analysis raises its own problems in two main aspects. First, textual data is nearly always divorced from context; therefore, the interview transcript or other pieces of text have no longer very much to do with the interview itself. Second, reading textual data involves interpretation; according to the author, such interpretation may be at a surface level or at a deeper level. In the latest, the researcher has to make sense of the data (Burnard 1996, p.278).

Semi-structured Expert Interviews

During fieldwork, the empirical data collection took place by means of conducting semi-structured expert interviews. This interview method was chosen among other alternatives because it offers some suitable benefits for the research design. According to Cohen and Crabtree (2006) the main benefits for the qualitative researchers are threefold: 1) interview questions can be prepared in advance, allowing the researcher to focus on the particulars of the interviewee’s experience and perceptions; 2) semi-structured interviews allow interviewees the freedom to express their point of views in their own terms; and 3) semi-structure interviews can provide reliable, comparable qualitative data.

Moreover, even though semi-structured interviews are flexible – in the sense that they allow the researcher certain degree of freedom to choose the order in which the questions are asked during the interview – they require rigorous preparation. It is essential to define specific objectives for each interview, in order to adapt the interview guideline to the uniqueness of each interviewee. Furthermore, it is important to devise an interview plan, and draw up a consent form as described in the following sections. Finally, this method allows the researcher to gather information in a relatively short period of time (Taylor and Bogdan 1996).

A feature of case study research is the use of multiple data sources, a strategy which also enhances data credibility (Patton 1990; Yin 2009). Therefore, since the research is a cross cutting interdisciplinary work enlighten from different institutional and scientific settings, different stakeholders beyond the private housing market were taken into account as key informants; namely: public regulatory agents, scholars, and other representatives of organizations currently working on the field of energy efficiency in the housing sector (see Table 7). Although the most important key stakeholders for the porpoises of this research are real estate developers, in order to have a holistic approach to the topic, the interview-partner selection sought for the views of the public institutions, the academy, and non-profit organizations working in the field.

Table 7: Key Stakeholders and their Positions
(Source: Own compilation)

	Institution / Company	Position
Housing Sector	Real estate developers.	General managers and Project Managers, mainly.
	Ministry of Housing and Urban Development.	Representatives of the Construction Technologies Department.
		Coordinator of the Housing Observatory.
	Chilean Construction Chamber.	Representatives of the Energy Efficiency and Sustainable Construction Department.
	Gemines (Real Estate Management).	Representatives of the company.
	Construction Institute.	Executive Director.
Energy Sector	Chilean Energy Efficiency Agency.	Representatives of the Commercial, Public and Residential Department.
	Local Electric Utility (Chilectra).	Representatives of Regulation and Energy Management Departments.
	Integrated Energy Services.	Representatives of the company (Former PRIEN[35] members).
	ArqEnergia (Architecture and Energy Efficiency).	Representatives of the company.
Research	Catholic University of Chile - Faculty of Architecture.	Professors at the Energy Efficiency Department.
	Adolfo Ibañez University - Spatial Intelligence Center.	University Representatives.
	Fundación Chile.	Representatives of the Energy Efficiency Department.

The table 7 presents a summary of the interview partners. They were carefully selected on the basis of what they may know about the research topic – the implementation of residential energy efficiency measures in the private housing sector. Therefore, they could help the researcher to fill in pieces of a puzzle or confirm the proper alignment of pieces already in place (Aberbach and Rockman 2002, p.673).

[35] Programme of Research in Energy (Programa de Estudios e Investigaciones en Energía, or PRIEN).

Prior to each interview, different interview guidelines were drawn up. On the one hand, a general interview guideline for real estate companies' general managers. On the other hand, different interview guidelines for the other key informants who were interviewed during the fieldwork as part of the research. The distinction made between real estate developers and other key stakeholders sought to adapt the interview guideline to the action exerted from various perspectives related to the implementation of energy efficiency measures in the residential sub-sector. This does not meant to exclude the action of one or other stakeholders, but to recognize the diversity of actors and roles in the field.

Moreover, a portfolio analysis[36] of every selected company was conducted prior to the interview, based on the available information on the company's website. This information served to provide an overview of the main characteristics of the companies and to tailor the interview appointment.

Personal interviews were conducted with different key informants during a six-week fieldwork stay in Santiago de Chile, between April and May 2012. Interviews were conducted until a saturation point, when the collection of new data does not shed any further light on the issue under investigation, is reached (Guest et al. 2006).

Most of the interviews were carried out at the workplace of the interview partners, although in one particular case it took place in a coffee shop near the informants' working place. Informants were contacted via e-mail, telephone calls, or personal visits to the informants' working place.

Besides the information of the selected companies, all relevant information about other key informant was collected prior the interview appointment. The information was collected from public websites or from people who know them personally or know their working experience in the field of energy efficiency.

Finally, when visiting the real estate developers for the interview appointment, technical data regarding the implemented energy efficiency strategies was also collected. The aim was to provide an overview to support real estate companies' managers' discourse regarding how energy-efficient their buildings are.

---

[36] The portfolio analysis included collecting data regarding: housing typologies, market segments, price ranges, ranges of built area, and the location of energy efficient housing projects.

The Interview Guideline – Real Estate Companies' Managers

Although this research draws on the opinion of the key stakeholders involved in the field of residential energy efficiency in the private housing sector, the opinion of real estate developers plays a predominant role. Therefore, although a specific interview guideline was tailor-made for each one of the groups of stakeholders, in this section special attention it is given to the interview guideline for real estate companies' managers.

The order and the way of questioning vary according to the flow of the conversation at the time the interview was carried out. Since this semi-structured interview was carried out, the interviewer had the freedom to alter the order of the questions insofar as respondents were providing new information. Therefore, general contents and some ideas as to the formulation of the questions sought to address in each part of the interview are described below.

The interview guideline for private developer companies' managers is divided into five sections. The first section collects some general personal data regarding the interviewees' professional background. Samples of questions asked are: what is your profession? What are your responsibilities in the company? How many years have you been working for the company? How many in your current position?

The second section of the questionnaire inquires about the company's experience in adopting energy efficiency in their housing products. Good examples of the questions asked are: when was the initiative to implement energy efficiency measures born in the company? Since how long have you been implementing them?; What are the determinants for implementing energy efficiency measures in the current housing offer?; Is there any particular reason for the application of such measures?; Are the energy efficiency measures applied to all buildings built by the company? Is there any difference between the energy efficiency measures applied in one building / dwelling or other? Which and Why?; What is the role of the client / end user in the decision to apply one or other energy efficiency measure?; What is your opinion regarding the benefits to implementing energy efficiency measures in residential buildings?

The third section sought to capture companies' general managers' opinion regarding the energy efficiency regulatory framework and to provide insights regarding the energy efficiency strategies adopted. Examples of questions asked are: What is your opinion regarding the implementation of New Thermal Regulation through the National Building

Code? Do you know something about the history or the development process/implementation of it?; Which have been the effects of the implementation of New Thermal Regulation in the company's construction costs of new buildings?; What are the implemented standards that go beyond the demands of the New Thermal Regulation?

The fourth section goes deeper in understanding the residential buildings' energy end-use: heating, ventilation, and air conditioning (HVAC) and lighting. Good examples of the questions asked are: What are the elements of the building in which they are implementing energy efficiency measures and why? (i.e. insulation of exterior walls, high-performance windows, etc.; Do the buildings have some sort of power/heating generation systems of their own? Which ones? (i.e. electricity, natural gas, wood, solar panels); What are the systems with energy efficiency standards? (Heating, ventilation, and air conditioning (HVAC) and lighting.); Does the electrical and electronic equipment operating in the building have any kind of energy performance certificate? Why?

Finally, the following technical data was collected from each company: the amount of m² built by the company; (schematic) blue prints of the apartment buildings and/or housing types, i.e. those more frequently built by the company; construction details, finishing, coatings, etc.

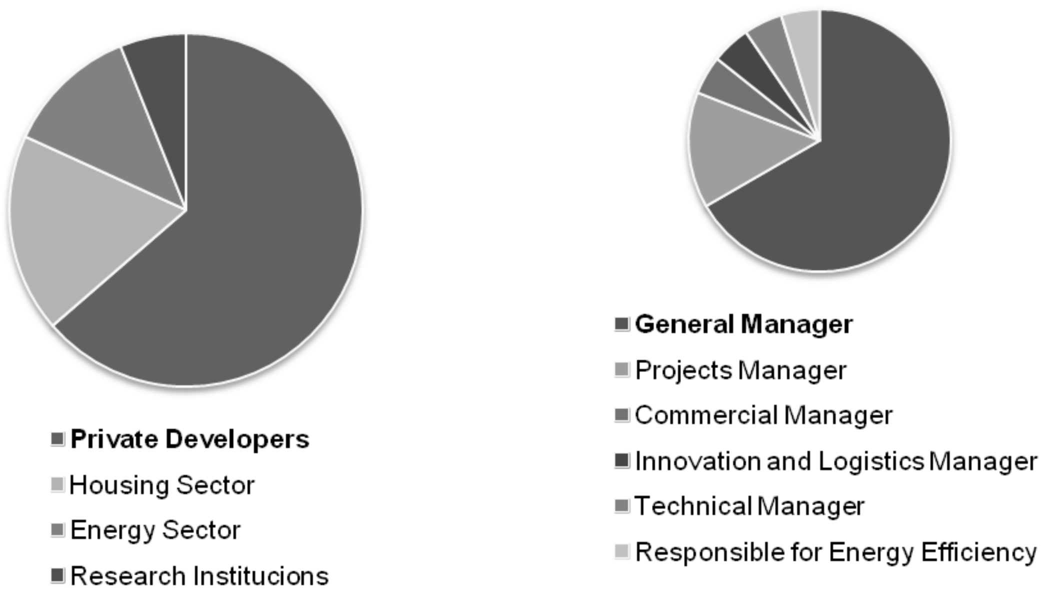


Figure 13: Structure of the Sample
(Source: Own illustration)

In general, every personal interview with companies' managers lasted around 30 minutes, although some have been extended up to an hour and a half. In some cases, the interviews were conducted with various representatives, two or three people simultaneously, mainly in the case of regulators, research organizations, and the academia.

The structure of the sample is shown in the Figure 13. Real estate companies' managers were the larger group in the sample. Therefore, the opinion gathered through interviews reflects the higher-management level perspectives in the companies' decision making. In other words, it was possible to access the point of views of those who are the top of the real estate companies' structure; therefore, their perceptions regarding why and how are they implementing residential energy efficiency measures in their new residential buildings offer are central to this doctoral research.

The second group in the sample is constituted by project managers who have the knowledge and the technical expertise regarding the key features of the housing projects offered by the company. Therefore, their perceptions articulated the main reasons for companies to implement residential energy efficiency measures, as well as the technical features of the various residential energy efficiency strategies implemented in the different real estate products.

Finally, smaller groups in the sample are equally: Innovation and Logistics Managers, Technical Managers, and other Technicians responsible for the implementation of residential energy efficiency measures. These respondents gave fundamental views regarding technical barriers and constraints encountered during the implementation of residential energy efficiency measures[37].

Ethical Considerations

At the very beginning of every interview, the interview partners were informed about the objectives of the research, the reasons why he or she was contacted, and received all the contact details of the researcher and his research institution. It was also mentioned that the interview was voluntary, anonymous and confidential, and that the research pursuits strictly academic purposes within the framework of the doctoral research.

---

[37] The energy efficiency measures are reviewed in detail in Chapter 7.

Furthermore, the respondents were requested to give written consent for the recording of the interview in digital format, which was granted by signing a consent form (see Annex A). The consent form was signed by all of the respondents but one. Only one private developer refused to consent the recording of the interview; in that particular case, detailed minutes of the meeting were hand-written for further transcription and analysis. Moreover, in order to ensure data confidentiality and to protect the empirical data, the interview records and transcripts were properly stored into a password-protected computer, and backed-up on an external hard drive used exclusively by the researcher. Finally, due to confidentiality reasons, the names of the companies nor from key informants are not disclosed.

3.4 Data Analysis

Several qualitative researchers seem to agree that, although the field of qualitative research is divided up into various groups depending on the approaches and schools of thought, what group them back together again is the need to find patterns, similarities and differences in textual data (Leininger 1985 and Hakim 1987, cited in Burnard 1996, p.278).

The main objective of the data analysis is to make sense of the empirical data. The empirical data accounts for thirty three personal interviews and a set of documents, including: energy efficiency policy documents and on-line documents available on official websites from Chilean and international institutions. In general, fragments of the interview transcripts and documents were entered into MAXQDA[38], and a comprehensive process of data coding and identification of themes was undertaken. This process is also known as Thematic Content Analysis. According to Fereday (2006) is a search for emerging themes as being important to the description of the phenomenon under study. The process involves the identification of themes through “careful reading and re-reading of the data” (Rice and Ezzy 1999, p. 258). It is a form of pattern recognition within the data, where emerging themes become the categories for analysis (Fereday 2006).

This process is described as a systematic, step-by-step process in the sections below. The data analysis was an iterative and reflexive process; this interactivity, applied throughout the process of qualitative inquiry, was differentiated in three main stages: transcription, interview analysis, and document analysis.

3.4.1 Transcription

Initially, it was intended to gather respondents' opinions on the basis of handwritten-notes collected by the researcher while conducting the interviews. However, very early during the very first interview appointments, the interviewer – in this case the researcher – realized that this note taking technique was distracting the interviewee’s attention; which prompted the recording of interviews in digital format.

Therefore, in order to understand and analyze interviewees' opinions, in form of textual data, transcription of interviews was the first step towards the data analysis. Specialized

---

[38] MAXQDA is a professional software for qualitative and mixed methods data analysis.

literature on qualitative data analysis, interpretation, and presentation of results, discusses various alternatives regarding the accuracy to perform the process of transcription. According to Flick (2009) the demand on the transcription's accuracy varies depending on both: the objective pursued with the transcription itself and the applied method for empirical data analysis. For instance, in language analyses – or other social branches of anthropology like ethnography – the researcher interest often focuses on attaining the maximum exactness in classifying and presenting statements, breaks, and so on (Flick 2009). Nonetheless, such accuracy standards are beyond the scope of this doctoral thesis.

For the purpose of this research, it was intended to keep a reasonable balance between the transcription's accuracy and the expected outcomes of the data analysis. Keeping in mind that transcribing can involve considerable time and energy, the researcher must be very careful when deciding the standards of exactness in transcriptions. Therefore, it seems more reasonable to transcribe only as much and only as exactly as needed in order to answer the research question (Strauss 1987, pp.266-267). Moreover, the form of transcription used in this study was a standard orthography, based on the norms and accepted usage of the written language (Kowal and O'Connell 2004).

Table 8: Rules for Transcription
(Source: Adapted from Flick (2009, p.301))

Transcripts Layout	
Word processing:	Microsoft Word
Font :	Calibri 11
Margins:	Left 5, Right 1.5
Line numbers:	Assigned automatically – MaxQDA
Lines:	Single-spacing
Page Numbers:	On bottom, right
Interviewer:	I
Interviewee:	IP
Transcription	
Spelling	Conventional
Breaks	Short break *; more than one sec *no of seconds*
Incomprehensive	((incomp))
Uncertain transcription	(abc)
Simultaneous talk	#abc#
Verbal quote	Conventional
Abbreviations	Conventional
Anonymization	Names with °

Nevertheless, in order to achieve greater transparency of the research process and to make it traceable, a set of rules for transcription were adapted from Flick (2009). These rules are detailed described in the Table 8.

Finally, Flick (2009) stated that beyond the above-mentioned transcription rules, the researcher needs to take into account two central features of the transcription procedure before the interview analysis. First, it is important to double-check the transcripts against the original recordings, in order to ensure that all the findings are grounded on the original data. Second, attention is paid to ensuring respondent anonymity and the confidentiality of responses; that implies to guarantee the removal of all the personal data concerning: names, local, and temporal references (Flick 2009, p.301).

3.4.2 Interview Analysis

The overall interview analysis followed a systematic, step-by-step analysis process[39] described by Miles and Huberman (1994) which involves the identification of: codes, themes, and categories; leading to within-case analysis and cross-case analysis

Coding is the organisation of raw data into conceptual categories. Each code is effectively a category or "bin" into which a piece of data is placed. As Miles and Huberman (1994) noted: *"Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study; codes are usually attached to "chunks" of varying size – words, phrases, sentences or whole paragraphs"* (p.56).

The goal of the interview analysis was to isolate a meaningful set of motivations, so that the common and divergent implications can be drawn. The implementation of energy efficiency measures in the private housing offer could respond to different motivations, and these motivations could be expressed in several different ways. Therefore, the emphasis of this research was placed on contrasting empirical findings with key concepts drown from the review of state of the art. This required careful considerations of the subtle differences among interviewees' opinions, in order to stress the relationship between their motivations and the diverse energy efficiency strategies applied in their housing projects.

[39] The work of Mostyn (1985) presents a similar step-by-step process; the author calls it a "Recipe" for the content analysis of open-ended data (p.133). Steps 7 (Categorization) through 12 (Writing) are consistent with the interview analysis conducted in this research.

The main unit of analysis was the information provided by company managers or project managers during the interviews. The most important contents of this information are fourfold; first, real estate developers' motivations for offering and applying energy efficiency measures in their current housing offer; second, external and internal factors that played an important role in the decision to implement energy efficiency measures; third, the energy efficiency strategies and the experience gained in each case; and fourth, the barriers encounter during the implementation process, taken from experience gained.

The data collection and the interview analysis were undertaken consecutively; the data collection during the fieldwork in Santiago de Chile, Chile; and the interview analysis during deskwork in Dresden, Germany. Both stages were carefully reviewed before undertaking further analysis, in order to ensure that the thematic development was grounded in the original data. On the one hand, the primary objective for data collection was to capture the subjective viewpoint of the various stakeholders in form of verbal communications (from their different positions as key stakeholders of the private housing market, the regulators, and other areas of research related to the field). On the other hand, the primary objective of the interview analysis was to make sense of textual data which have been generated as interview transcripts, which are the material for the analysis (Booth 1993, p.204).

Initially, it was intended to carry out the interview analysis on the basis of field-notes and detailed-minutes written down during the interview appointments. However, very early during the fieldwork, the interviewer – the researcher – realized that this technique was distracting the interviewee's attention. Therefore, two decisions were taken in this regard. First, it was decided to take the least amount of hand notes during the interview, simply by noting some new questions arising at the very moment of the interview. And second, it was decided to work based on partial transcript of all the recordings of each interview. All relevant information was recovered from the interview, including the questions formulated by the interviewer, except for the personal stories or anecdotes that were not considered relevant for the purposes of the research.

Finally, it is important to note that the interviews, interview transcripts, and all the data analysis were conducted in Spanish, the researcher's and the interview-partners' native language. Later on, during the writing process of this doctoral thesis, the most relevant quotations were translated into English.

Steps for the Interview Analysis

The activities involved in the interview analysis are organized into series of consecutive steps based on Burnard (1991) and Burnard (1996). Below, a detailed description of each of the steps presented

- *Note Taking*. Handwritten field-notes, regarding the most relevant topics discussed during the interview, are written down shortly after each interview appointments. There are two objectives: first, to identify during the first interviews new insights on the topic in order to modify the interview guide if necessary; and second, to make some notes about the interview partners, i.e.: willingness to provide further information, willingness to participate in a second round of interviews.
- *Screening.* During this step the intensive deskwork and analyze started. The aim of this step is to become immersed in the data as the first raw set of categories emerges from reading the transcripts. The first three to five print outs of the transcripts are read through and handwritten notes are made on general themes founded in the transcripts.
- *Open Coding*. The goal is to let the categories emerge freely through the reading. Transcripts are read through again and headings are written down as many as necessary to describe all content in the interview.
- *Axial Coding.* The list of categories are reviewed and grouped together under higher-hierarchy headings. The goal is to reduce the number of thematic categories, clustering the information by themes and subthemes.
- *Building and Structuring*. The new list of categories and sub-categories is worked through and all repeated or very similar headings are removed to produce the final thematic structure.

All the interview transcripts are worked trough with the final thematic structure. Pieces of the transcripts are coded and placed into a category with the support of MaxQDA, software for qualitative data analysis. One of the most significant benefits of working with this software is that it enables the use of code-and-retrieve technique. The aim of applying such technique is to acknowledge the context in which were said the interview text fragments. Thus, when coding-and-retrieving, the researcher can always go back from the coded sections to the transcripts, in order to avoid the risk of altering the meaning of what was said. Moreover, all the sections coded under the same category are retrieved together, this enables the researcher to make cross-case analysis by comparing interviewees and a contexts.

Finally, information is analyzed in two levels: first, at a thematic level, searching for communalities and/or divergences, and conflicting point of views among the interviewees; and second, over the themes, generating insights between the themes, identifying relations, and building typologies and generalizations.

In summary, all the process involved the identification of all the topics discussed during the interview and reconstructed, through a careful reading and re-reading of the textual data. According to Fereday (2006) this is a form of pattern recognition within the data, where emerging themes become the categories for the analysis.

3.4.3 Document Analysis

As a research method, document analysis is particularly applicable to qualitative case studies, as in the case of this doctoral thesis, producing rich descriptions of a single phenomenon, event, organisation, or program (Stake 1995; Yin 2009). The document analysis involved a systematic examination of instructional documents available in two main formats, namely printed and electronic material (See Bowen 2009). Particularly, documents addressing the topic of residential energy efficiency in the international context, such as regulations, building codes, and national and regional policies were reviewed in detail in order to gain insight into the policy making in the field of residential energy efficiency.

The overall document analysis followed Bowen's perspective of the use of documentary material in a qualitative research (see Bowen 2009). According to the author, documents can serve a variety of purposes. The author considers five specific functions of documentary material as part of a research undertaking, namely: 1) Documents provide historical background related to the research; this information can be very useful in understanding the phenomenon under investigation. Also, the data drawn from the documents may be useful to contrast the information collected during interviews. 2) When carrying out the document analysis prior to fieldwork, the emerging information may raise new questions that should be explored as part of research. 3) Documents may provide relevant complementary research data. In the specific case of this study, information and insights derived from documents added valuable knowledge regarding the quantitative date related to the research on energy efficiency that. Although qualitative analysis is beyond the focus of this research, it is important to acknowledge and understand the data. 4) Tracking change and development is possible trough document analysis. Mostly in the case of policy making analysis, where various draft of a specific policy are available (i.e. National Energy Strategy), the researcher can identify and compare all the changes Finally, and most importantly 5) documents are analyzed as a way to verify the empirical findings and the evidence collected from different sources (i.e. policies contrasted/corroborated with expert interviews). The aim is to afford the readers of the research report greater confidence in the trustworthiness (credibility) of the findings, by providing convergence of information from different sources.

Documents were selected of those countries whose experiences in implementing residential energy efficiency measures fulfilled the following criteria: 1) followed a process similar to Chilean and that to-date they are in a higher degree of implementation; 2) stand out in the international context as best-practice examples; and 3) they are considered as successful cases within the scientific and in institutional discussions. After a detailed screening process of relevant scientific and institutional sources, the experiences of some countries were chosen as good examples. On the one hand, some countries were selected in the European context, namely: The United Kingdom, Germany, and Spain among others. On the other hand, some others in the American context, like the United States of America and Brazil, were also chosen.

In the Chilean context, the document analysis integrated the detailed screening of regulatory instruments on energy efficiency for residential buildings, including: The Chilean Norm[40], the General Law and Ordinance on Urban Planning and Construction, the Housing Thermal Regulation Program, the Strategic Directions in the Energy Sector, and the Energy Policy Guidelines. Moreover, since this research focuses on the specifics of the residential sector, the document analysis also include documents linked to private housing market, both from public and private perspectives. This enabled early recognition of key informants and to develop tailor-made questionnaire for each semi-structured interviews guidelines.

Text fragments of documents in digital format were analyzed in the same way as the interview transcripts with the assistance of MaxQDA. Documents were coded and analyzed following the thematic coding structure (see Interview analysis section). The main categories used for the document analysis were related to the energy efficiency regulations in the housing sector. For example, real estate developers' opinions about the strengths and weaknesses of the regulations were contrasted with regulations documents (laws, regional strategies, policy documents, etc.) and the opinions of those experts and key stakeholders involved in the drafting of energy efficiency regulations.

---

[40] English for "*Norma Chilena*".

Finally, one of the fundamental goals sought with document analysis in this research is the use of data triangulation, which in qualitative research aims to test and maximize the validity and reliability of the study (see Patton 2002). Moreover, triangulation is defined as: "*a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study*" (Creswell and Miller 2000, p.126). In the specifics of this research, data triangulation sought the convergence of theoretical sources and empirical findings, obtained through the document and interviews analysis.

Limitations

Limitations occur for all studies (Fereday 2006, p.28). Because of the nature of a doctoral dissertation, the data was coded and themes identified in the data by one person – the researcher. Later on, as the first groups of codes emerged from the analysis, codes and categories were discussed with peers – other members of the Dresden School Graduated Leibnitz. Once a clearer list of categories and sub-categories was developed, the list was discussed in consecutive rounds with the supervisor of this doctoral dissertation and other members of the advisory committee, who accompanied the process of this dissertation from its very beginning.

This process allowed for consistency in the method but failed to provide multiple perspectives from a variety of people with differing expertise. It is therefore recommended that, following Fereday (2006) when using this method for another study, the coding of data could involve several individuals with themes' being developed using discussions with other researchers, a panel of experts, and/or the participants themselves.

3.5 Identification of Key Stakeholders and Interview Partners

In this Chapter the main research methods for sampling, data collection, and data analysis were reviewed in detail. From a qualitative approach, the exploratory nature of research deals essentially with a case study design with multiple embedded sub-units. This doctoral research deals with the case study of the private housing market in Santiago de Chile and the embedded sub-units of analysis are the real estate developers offering energy-efficient housing.

The main aim of the research is to generate case study empirical findings with regard to the case of the private housing sector in Santiago de Chile and the sub-cases, basically a group of real estate companies adopting energy efficiency measures in their current housing offer. Thus, from a methodological perspective, the first sub-research question seeks to identify what are the real estate developers offering energy efficient housing in the real estate market. Hence, the selection of sub-cases (or sub-units of analysis) involves fulfilling a fundamental criterion: to choose real estate companies that offer energy-efficient real estate products in the private housing market in Santiago de Chile. Thus, a group of forty-five real estate companies was purposely selected from a universe of five hundred and sixty-eight property real estate companies. Such companies were selected because they are considered to be information rich.

Nonetheless, this group of companies is engaged in a broader context in which two sectors of the national and regional economy interact with each other. On the one hand, the construction sector, where the real estate market is inserted. On the other hand, the energy sector, where specific initiatives in the field of residential energy efficiency had arisen. Therefore, in order to have a comprehensive view on the phenomena under study, this doctoral research involves the review and the involvement of a wider range of key stake holder.

The Table 9 summarizes the constellation of actors linked to this doctoral research. It also shows key stakeholders who were personally interviewed during the fieldwork, making a total of thirty-three interviews and thirty-nine interview-partners. In general, the interviewed partners were representatives from the four major sub-sectors related to the implementation of energy efficiency in the private housing supply in Santiago de Chile, namely: 1) regulators; 2) the real estate sub-sector; 3) the energy sector; and 4) research institutions.

Table 9: Key Stakeholders on the Field and Interview Partners.
(Source: Own compilation)

Stakeholders	Institution	Interviews	Interviewees
Regulators	MINVU	1	2
	Housing Observatory - MINVU	1	1
	Construction Institute	1	1
	Chilean Energy Efficiency Agency	1	1
Real Estate Sub-Sector	Real State Companies' General Managers	21	22
	CChC and CDT	1	2
	Housing Market Experts (Gemines)	2	3
Energy Sector	Chilean Energy Efficiency Agency	1	1
	Local Electric Utility (Chilectra)	1	2
	Integrated Energy Services	1	1
	ArqEnergía	1	1
Research Institutions	Universidad Católica de Chile	1	1
	Fundación Chile	1	2
Total		33	39

This research is based, among other stakeholders working on the field, on the opinion of a group of real estate developers' managers, who were selected because their companies are offering energy-efficient dwellings in the private housing supply in Santiago de Chile. The selection of cases sought no statistical representation (see section 3.2). However, it is important to mention that, according to the results of the website review of the private housing offer in Santiago de Chile, most companies do not mention energy efficiency as part of their advertisement on the web (see section 3.3). While there is the possibility that some companies are adopting energy efficiency measures without advertising it, this possibility is very vague because of the growing local media interest in energy efficiency. Therefore, theoretically speaking, within this group of non-adopters are the key informants to understand the reasons for not offering and/or not adopting energy efficiency measures in the residential sector. The perspective of non-adopters is beyond the scope of this research. However, from the perspective of those who do adopt and offer residential energy efficiency measures it is possible to identify: the barriers to the implementation of energy efficiency measures, and the main challenges encountered in the different stages of the innovation process.

Finally, this Chapter provided the main qualitative methods for data collection and data analysis – essentially expert interviews and thematic content analysis – necessary to address the overall aim of this doctoral research, which is the understanding of why and how does real estate developers adopt energy efficiency measures in the private housing sector.

4 Energy Efficiency Standards for Residential Buildings

This Chapter provides a comprehensive review of the existing literature on the implementation of energy efficiency standards[41] for residential buildings. Various sources of secondary information contained in the scientific, institutional, legal, and corporate literature are reviewed. The goal of this Chapter is to provide a systematic and comprehensive state of the art in the related research. The Chapter is divided into six sections as follows.

The first section deals with the still open discussion in the scientific literature regarding energy efficiency as a concept.

The second section analyses the introduction of energy efficiency standards in mandatory basis in the international context, usually through building codes as part of the regulatory framework. It highlights certain experiences of European countries, considered in the specialized literature as pioneers in the implementation of mandatory residential energy efficiency standards. In the construction sector, energy requirements appeared due to the great need to regulate and strengthen the thermal performance of the buildings' envelope due to the climatic adversities that countries of the region must cope with.

The third section focuses on the implementation of voluntary green initiatives, emerging, usually, form non-governmental sectors of the society. Such voluntary initiatives are widely adopted in the real estate market and nowadays, there is a growing demand for third-partly green certifications in the international arena. Overall, these initiatives arise for two main reasons: first, because of the low standards set by local regulations in the field of building construction; second, by increasing need to certify the effort made by private developers to design, construct, and maintain green buildings and energy-efficient buildings and to differentiate them from conventional or standard buildings.

The fourth section reviews the introduction mandatory energy efficiency standards in the Chilean regulatory framework. The Chilean experience stands out as pioneer in the Latin American region and is strongly influenced by the European experience.

---

[41] According to Janda (2009) Energy standards for buildings are used in the relevant literature to refer interchangeably to what also might be called: codes, criteria, guidelines, norms, laws, protocols, provisions, recommendations, requirements, regulations, rules, or standards. Depending on the country, the "*standard*" may be contained in one document, be part of another larger document (such as a general building code), or comprise several documents (p.485). More recently, they are also referred as "*Building Energy codes*" (IEA 2013).

The fifth section discusses voluntary initiatives implemented in the specific case of Santiago de Chile. Although most of the voluntary initiatives are implemented in the commercial sub-sector, the recent interest shown for developing green-residential projects in the local real estate market is also reviewed.

Finally, the last section reviews in detail the relevant literature on the factors which may trigger a behavioural change in real estate developers. It seeks to initiate discussion about the change in attitude from a business-as-usual to an environmentally-friendly approach, following an international trend towards the adoption of green technologies.

4.1 Defining Energy Efficiency – The Wider Context

Patterson (1996) states that: "*Despite the continuing policy interest and the very many reports and books written on the topic of 'energy efficiency', little attention has been given to precisely defining the term*" (p.377). To date, not much has changed in the specialized literature since Patterson's publication.

However, since the implementation of residential energy efficiency measures is a crosscutting concept to different sectors within the construction industry, the concept has been re interpreted from the perspective of different disciplines. According to Herring (2006), the concern on energy efficiency (EE) is discussed amongst environmentalists, arguing that improving the efficiency of energy use will lead to a reduction in energy consumption and hence reduced CO_2 emissions. In contrast, economists seem to belief that the opposite will occur, an assumption based on the economics basics: demand and supply, since the effect of improving the efficiency of a factor of production, like energy, is to lower its implicit price and hence make its use more affordable, thus leading to greater energy use (Herring 2006). The discussion is also addressed from urban planners' perspective, mainly because energy consumed in the building sector constitutes a significant proportion of total energy consumption within the urban system (Tzikopoulos et al. 2005).

In the literature on EE, it is not usual to find concrete conceptual definitions of EE, mainly because the attention is drawn on policy advice, looking for better ways for defining EE standards and technological implementation. Therefore, the discussion regarding EE is still open. In connection therewith, Herring (2006) states: *"Energy efficiency saves people money, but as a solution to the problem of global warming, it is fatally flawed"* (p.19). The author sustained his argument based on the fact that over the past 25 years in Western

Europe, the overall energy use has risen despite great improvements in energy efficiency; therefore promoting efficiency without curbs on consumption (through regulation or taxation) will not tackle the problem of reducing CO_2 emissions. The goal should be less CO_2 emissions and not less energy use; ultimately energy growth needs to be decoupled from CO_2 emissions (Herring 2006).

From a methodological perspective, a definition of the concept and the relation with its measurement can be found in the work of Patterson (1996) who defines: *“Energy efficiency is a generic term, and there is no one unequivocal quantitative measure of ‘energy efficiency’. Instead, one must rely on a series of indicators to quantify changes in energy efficiency. In general, energy efficiency refers to using less energy to produce the same amount of services or useful output (...) Hence, energy efficiency is often broadly defined by the simple ratio: useful output of a process divided by energy input into a process”* (p.377). The previous definition is supported by a later work conducted by Herring (2006) who states: *“Energy Efficiency is simply the ratio of energy services out to energy input. It means getting the most of every unit of energy you buy. It is mainly a technical (and historic) process caused by stock turnover where old equipment is replaced by newer more efficient ones. It is generally a by-product of other social goals: productivity, comfort, monetary savings, or fuel competition”* (p.11).

The international discussion on EE for residential buildings focuses on different approaches to measure EE, in order to establish clear goals and requirements trough building regulations. In the housing sector, the dwelling’s EE is measured in kilowatt-hours per square meter per year ($kWh/m^2/y$). Moreover, due to the worldwide discussion regarding the contributions of the residential sub-sector to carbon dioxide emissions, nowadays the dwelling’s EE is also measured in carbon dioxide per square meter per year ($CO_2/m^2/y$). In either case, building’s energy performance is measured trough different energy standard assessment procedure (SAP), which gives an EE rating based on fuel consumption and the environmental impact rating based on CO_2 emissions (Gann et al. 1998).

In the Latin-American context, the Latin American Energy Organization (Organización Lationamericana de Energía or OLADE) coins a definition of EE following the definition of sustainable development. According to Poveda (2007), EE is a concept that groups actions taken on both the supply and demand sides, without sacrificing the welfare and production, allowing improving the security of supply; achieving further savings in both, energy consumption and general population’s economy. Simultaneously, reductions in emissions of greenhouse gases and improvement energy company's finances are achieved (Poveda 2007, p.5).

In the European context, the Directive on the energy performance of buildings (EPBD) is the Directive 2002/91/EC (EPBD 2002) of the European Parliament and Council on Energy Efficiency of Buildings[42], defines the energy performance of a building as the amount of energy actually consumed – or estimated – to meet the different needs associated with a standard use of the building, which may include, inter alia, heating, hot water heating, cooling, ventilation, and lighting. This amount shall be reflected in one or more numeric indicators which have been calculated, taking into account: insulation, technical and installation characteristics, design and positioning of the building in relation to climatic aspects, solar exposure and influence of neighbouring structures; moreover, own-energy generation, and other factors – including indoor climate – that might influence the building energy demand are also considered (EPBD 2002).

The following sections present a comprehensive review of the different EE standards for residential buildings introduced worldwide. In general, regulatory government-initiated instruments and voluntary instruments, emerging from non-governmental organizations and the private sector, are also reviewed in detail.

---

[42] The Directive came into force on 4 January 2003 and had to be implemented by the EU Member States on 4 January 2006, the latest.

4.2 Government-initiated Instruments – Building Codes and Energy Standards

The buildings' final energy use accounts for a significant share energy end-use worldwide. As shown in Figure 14, according to IEA statistics for the period 2004-2005, the residential sector consumes about 27% of final energy use worldwide; the major share of this energy consumption take place in buildings (OECD-IEA 2008, p.7).

Since energy is it used in residential buildings in many different ways – mainly to control thermal comfort inside the building and the various equipment and building systems, such as lighting and ventilation – the efficient use of energy in the building is an important determinant of energy consumption of the whole sector (OECD-IEA 2008). Moreover, the importance of regulating new buildings' energy performance relies in the fact that buildings are built to last for several decades; therefore its impact on the environment will also be for several decades. Consequently, the importance of regulating building's energy performance from the earliest stages of building design has caught the attention of governmental and non-governmental institutions.

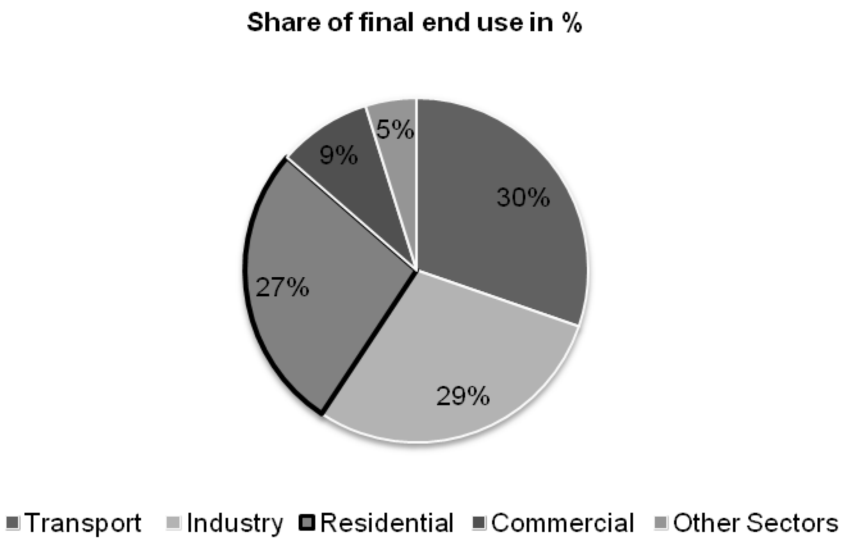


Figure 14: Worldwide Energy Consumption in Different Sectors.
(Source: IEA Statistics for Energy Balance for 2004-2005 (OECD-IEA 2008, p.7))

As noted above, the related literature shows that the implementation of energy efficiency measures in buildings could generate benefits for society as a whole. This is supported by the U.S. Environmental Protection Agency (EPA). According to EPA (2013) the benefits generated implementing energy efficiency by means of building energy codes may be grouped into 3 main groups: 1) energy benefits, such as savings in energy bills, reducing peak energy demand, and improving the system reliability; 2) environmental benefits, related to the reduction of greenhouse gases and air pollution; and 3) economic benefits, due to the creation of new job opportunities thanks to the demands for the installing equipment and monitoring building compliance (EPA 2013).

4.2.1 Regulatory Instruments

The tradition of implementing building codes for new buildings is nothing but new. In Mesopotamia, around 1790 BC, the first examples of buildings codes can be found in Hammurabi's Law (OECD-IEA 2008, p.14). In comparison with the above mentioned, implementation of energy efficiency requirements for new buildings in building codes is relatively new in most countries.

Commanding and Controlling the Thermal Performance of the Building Envelope

According to the specialized literature, the first energy efficiency requirements for new buildings are introduced in countries of northern regions – characterized by very low temperatures during winter periods – before the oil crisis in 1973 (OECD-IEA 2008). Weather conditions in these regions are a major public health concern due to moisture and air infiltration in dwellings with low levels of insulation in walls and floors. For example, due to the European climatic conditions – which generate a high energy demand for space heating during autumn and winter periods – approximately 85 % of the energy consumed in buildings is attributed the provision of these services, which means that the potential for energy savings is significant (BMWi 2014). Moreover, according to the EU Commission, the energy efficiency of the European building stock can be increased by 50 %. Improvements can be made not only to heating systems and other technologies, but also in the area of insulation. Higher targets for energy savings and reduced CO_2 emissions can be achieved by combining perfectly coordinated components to create efficient and fully integrated systems (BMWi 2014).

However, the first real requirements regarding the U-values[43] and R-values[44] and specific demands for implementing insulation material in building's exterior walls and multi-glazing windows – that together comprise the building's thermal envelope – can be found at the

---

[43] According to OECD-IEA (2008): "U-value: thermal transmittance is a technical value describing how much energy passes through one m² of a construction by a difference of one degree in temperature, measured in W per K per m²" (p.14).
[44] According to OECD-IEA (2008): "R-value: thermal resistance describes how well a construction or insulation material resists the penetration of heat, measured in K*m² per W. The (U-value) = 1 / (R-value)" (p.14).

end of the 1950s and early 1960s in Scandinavian countries (OECD-IEA 2008). Since then, improving the thermal comfort inside the buildings was the main driver for implementing thermal requirements for the building envelope through building codes on a national basis. Subsequently, in many countries the oil supply crisis of the 1970s catalyzed the development of requirements for building energy efficiency; mainly, in order to reduce energy consumption and reduce dependence on fossil energy products.

As mentioned in the previous sections, the usage of domestic electricity worldwide has increased rapidly due to the enhancement in the standard of living of households. Under this motivation, the American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE) had originated the Overall Thermal Transfer Value (OTTV) as thermal performance index for the envelope of air-conditioned buildings in 1975. OTTV[45] is considered a better performance index that thermal transmittance index (or U-Value) because it takes into account the impact of direct solar energy on envelope of mechanically cooled buildings (see Hui 1997, Saidur 2009)

The concept of OTTV originates from the energy conservation standards of ASHRAE Standard 90-75, which was later revised as ASHRAE 90A-1980. This standard is applicable to mechanically cooled buildings. OTTV is a measure of heat transfer into the building through its envelope (Hui 1997). Hence it acts as an index for comparing the thermal performance of buildings, provided the same method is used for calculating OTTV (Saidur et al. 2009). The concept of OTTV is based on the assumption that the envelope of a building is completely enclosed. It comprises of two values: Envelope Thermal Transfer Value (ETTV) and Roof Transfer Value (RTTV). ETTV is a measure of heat transfer through the walls or envelope of the building, while RTTV is a measure of heat transfer through the roof of the building. The total sum of ETTV plus RTTV is called as OTTV. The calculations for RTTV is relatively simpler as the roof may not have any glazing, except in the case of skylights.

---

[45] OTTV is an index for comparing the thermal performance of buildings. It is a measure of the average heat gain into a building through the building envelope and consists of three major components: 1) conduction through opaque walls; 2) conduction through window glass; and 3) solar radiation through window glass. The usual practice is to have two sets of OTTV – one for the exterior walls and the other for the roof (See (Hui 1997).

Limitations – OTTV

According to the specialized literature (see Hui 1997, Saidur et al. 2009), the biggest limitation of the OTTV method is that it only deals with the building envelope and does not consider other aspects of building design (such as lighting and air-conditioning) and the coordination of building systems to optimize the combined performance. The use of OTTV as the only control parameter is inadequate and cannot ensure energy is used efficiently in the building. Before other energy codes are implemented, the effect of the OTTV standard on 'real' energy savings is questionable, although it helps to increase concern and awareness of energy efficiency matters. Moreover, the OTTV method has also been criticized for limiting design freedom in architecture and restricting innovations. Although the OTTV approach has made code compliance simple for conventional building designs, it has tended to restrict designers from innovation and more challenging work. If alternative paths for code compliance are not provided, innovative designs that may exceed the OTTV limits but can achieve a higher overall efficiency will be excluded and discouraged. For example, designs employing day lighting to reduce energy consumption of electric lights will be restricted.

As noted above, preceding sections had drawn attention to the importance of the European context on implementing residential energy efficiency regulations worldwide. Thus, it is relevant to review in detail the energy efficiency policy making process within the European Union.

Energy efficiency in the European Context

In the early 1970s the first building energy regulations in the European Union (EU) were issued focusing on the thermal performance of buildings. Certain parameters for controlling the thermal transference trough the building envelope[46] were defined, in order to: 1) reduce heat transfer; 2) control vapour diffusion; and 3) reduce air permeability. This was followed by the introduction of building regulations, in the one hand, and best practice recommendations on design, calculation, and maintenance of building thermal services, on the other hand (Pérez-Lombard et al. 2009).

---

[46] The *Building Envelope* includes all building elements that separate the interior of a building from the outdoor environment; including Windows, walls, foundations, ceiling, intermediate floors, and roof.

Since the establishment of the EU, regional policy making defined guidelines in the different sectors in order to achieve common regional goals across the EU. In agreement with the EU general guidelines, standards, regulations, or normative with specific objectives and goals – at the national and the local scales – are released in each one of the EU Member States. In the field of residential energy efficiency, the leading law is the Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings Directive (EPBD).

According to the EPBD, motivations for the implementation are mainly environmental; namely: 1) compliance with the Kyoto Protocol; 2) the rational use of natural resources; and 3) limit carbon dioxide emissions by improving energy efficiency. Moreover, the directive acknowledges that buildings will have an impact on long-term energy consumption and new buildings should therefore meet minimum energy performance requirements (MEPR) tailored to local climate. Therefore, the EPBD encourages to all Member States to incentive good energy management, taking into account the intensity of use of buildings (EPBD 2002). The objective of the EPBD is to improve the energy performance of buildings within the EU, taking into account outdoor climatic and local conditions (i.e. temperature variation, rainfall regime, wind, sun exposure, etc.), as well as indoor climate requirements (defined by the local culture), and cost-effectiveness.

Setting up energy performance requirements for all EU Member States is one of the most important goals of the EPBD; it further detailed in the Article 4. In summary, it is required that all Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings are established based on the methodology referred to in the Article 3; moreover, such requirements may differentiate between new and existing buildings and different categories of buildings[47] (See Article 4, EPBD 2002). Above all, independently from the building typology, the EPBD makes a clear distinction between the regulations for new buildings and existing buildings; such regulations apply to all buildings with a total useful area over 1.000 m².

The EPBD establishes the obligation to make available to potential homebuyers or home renters an energy performance certificate (EPC) following the guidelines described on the

---

[47] Part 3, Article 4 states: "Member States may decide not to set or apply the requirements (...) for the following categories of buildings: Buildings and monuments officially protected; buildings used as places of worship and for religious activities; temporary buildings with a planned time of use of two years or less, industrial sites, workshops and non-residential agricultural buildings with low energy demand and non-residential agricultural buildings; residential buildings which are intended to be used less than four months of the year; and stand-alone buildings with a total useful floor area of less than 50 m²" (EPBD 2002).

Table 10. This certificate must include objective information on the energy characteristic of the buildings, so that its energy consumption can be valued and compared, pursuing the promotion of buildings of high efficiency and energy saving investments. Considering the importance of final (or end-use) energy consumers, the EPBD states: *"Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years. (...) The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance"* (EPDB 2002, p.4).

Table 10: Energy Efficiency Requirements for Residential Buildings in the EU.
(Source: Own compilation based on EPBD 2002)

New Buildings	Existing Buildings
Member States shall ensure that the technical, environmental and economic feasibility of alternative systems is considered and is taken into account before construction starts; namely: • decentralized energy supply systems based on renewable energy, • combined heat and power, • district or block heating or cooling (if available), • heat pumps (under certain conditions)	When buildings undergo a major renovation, Member States shall ensure that the building's energy performance is upgraded in order to meet minimum requirements as this is technically, functionally and economically feasible. Minimum energy performance requirements should be derived in accordance with Article 4. The requirements may be set either for the renovated building as a whole or for the renovated systems or components when these are part of a renovation to be carried out within a limited time period.

In summary, the relevance of the EPBD lies in four key points; 1) there is a need for a common methodology for calculating buildings' energy performance; 2) it is required that all EU Member States should establish Minimum Energy Performance Requirements (MEPR) for new buildings and for existing buildings that are subject to major renovation; 3) systems for the EPC for new and existing buildings and for public buildings, prominent display of this certification and other relevant information; such certificates must be less than five years old; and 4) regular inspection of buildings' boilers and central air-conditioning systems in addition to an assessment of heating installations when boilers are older than 15 years (EPDB 2002).

This requirement of an EPC has resulted in a broader diffusion of national certification systems amongst EU Member States. Currently, some certification systems are used across Europe and abroad; for example the German Sustainable Building Certificate (GSBC) or the Building Research Establishment Environmental Assessment Method (BREEAM) from the United Kingdom; both certification systems are reviewed in the following sections.

4.2.2 Types of Regulations

According to OECD-IEA (2008) and a recent publication of the International Energy Agency regarding energy building codes (IEA 2013) energy efficiency requirements can be set in different ways; the basic types of energy efficiency regulations are summarized in the Table 11.

Table 11: Basic Types of Energy Efficiency Regulations
(Source: Own compilation based on OECD-IEA 2008, IEA 2013)

Decade	Type of regulation	Key Features
1970	Prescriptive – fixed	Energy efficiency requirements (EER) are set for each building part separately. Individual parts must comply with their specific targets. Most restrictive.
1980	Prescriptive – Trade-off	EER are set for each building part separately. A trade-off can be made between energy performance of the envelope and those of HAVC systems. More flexibility, more complexity.
1990	Model building	EER are set as in the trade-off, and a model building with the same shape is calculated with those values. A calculation has to demonstrate that the actual building will be as good as the model building. Flexible but costly in terms of design.
2000	Energy frame	An overall framework establishes the standard for a building's maximum energy loss. A calculation of the building has to show that this maximum is respected.
2010	Performance-based	Energy performance requirements are based on a building's overall consumption of energy or fossil fuel or the building's implied emissions of greenhouse gas

Most countries have started with prescriptive values. When energy efficiency requirements increased and more elements included, trade-offs or an overall frame allowing adjustments of the individual values was required. Today, energy performance models and computer tools are being developed in many regions. International standardisation has been introduced with the aim of developing and harmonising models to calculate energy performance. At the same time, countries have decided to have several methods for compliance with norms which allow builders and constructors to choose. This is especially the case for small residential buildings where there is a general effort to make simple and comprehensive rules. (OECD-IEA 2008, pp. 26–30)

Prescriptive

According to OECD-IEA (2008), when using the prescriptive method, energy efficiency requirements are set for each component of the building. This could be a thermal value for windows, roofs or walls. The prescriptive method can include efficiency values for technical installation, ventilation, orientation of buildings, solar gains, the number and size of windows. To comply with a prescriptive standard, each part of a building must meet its specific value. A simple version of a prescriptive building code set thermal values for the essential building parts. In the most complicated systems, energy efficiency requirements are set for all parts of building and installations, including heating installation, cooling units, pumps, fans, and lighting. In some cases, these requirements are even adjusted according to size of the equipment or the size of or percentage of windows based on floor area or the outer wall. In general, instructions for the prescriptive method are easy to implement. U-values can be followed by descriptions of typical constructions which fulfil the requirements and requirements for equipment can be combined with the labelling of products. A prescriptive method could require an appliance to be labelled A or B, or rated with energy stars

Trade-off

The trade-off method sets values for individual building parts and / or for parts of the installations, akin to the prescriptive method. However, in meeting a general standard for efficiency, a trade-off can be made between the efficiency of some parts and installations such that some values are exceeded while others are not met. Moreover, the trade-off is generally made in simple terms. Trade-off can be made between U-values for the building shell[48] or between building shell and the energy efficiency requirements for heating and cooling installations. The trade-off model[49] provides more freedom and flexibility than the prescriptive method. The calculations are normally simple and possible to do by hand or in a simple spreadsheet (OECD-IEA 2008, pp. 26–30).

---

[48] For instance, U-values are balanced according to the area, so 10 m² with + 0.2 in one value can be exchanged to 20 m² with – 0.1 in another value.

[49] By trade off models a special attention should be taken for systems with a long lifetime such as insulation and building structures and systems with short or medium lifetime, such as most HVAC systems.

Model Building

According to OECD-IEA (2008) in the model building method, values are set for each building part and / or for the parts of the technical installations. Based on the values and the characteristics of the actual building a model building is calculated with all the set values for losses and efficiency. This calculation follows a clearly defined method. The actual building is then calculated by the same method using the actual values for the individual building parts, heating, cooling, and ventilation systems. The total result of the calculation is compared with the model building and the actual building must perform as well as or better than the model building. The most complicated models include all parts of the technical systems in these calculations, including all parts of heating systems, ventilation, cooling, lighting, built in equipment etc. Renewable energy can be included in the calculations, to make a solar collector, for instance, reduce the general efficiency requirements for the heating system or even the insulation level. The model building gives more freedom and flexibility for building designers and constructors than a prescriptive model. Expensive systems can be changed with improved efficiency in parts of the building or installations where efficiency will be more cost effective.

Energy Frame

The Energy Frame for a building sets a maximum of energy loss from the building. This is usually set as a total frame for the building, a value pr. m^2 building area or as a combination. The energy frame will then be followed by a procedure on how to calculate the energy losses from simple values such as the U-values, temperature, surface and heat gains from sunlight etc. Values for the individual parts are not set in this model but only for total loss or use of energy.

This method enables the constructor to build parts of the buildings that are less energy efficient when other parts are made better than typical constructions. This method can as example also avoid limiting the size window area, as improved windows or increased insulation can adjust for the additional heat losses or larger sun gains by having a larger surface of windows. As long as the overall value is met, the building is approved.

The energy frame can also be defined as an overall thermal value (adjusted u-value), pr. square meter of building floor area or similar. Again it will be the constructor’s decision to document that the building is built up to the standard of the model building given by the overall values. Similar to the model building this gives more flexibility in the fulfilment of the requirements and this can easily be adapted to the most economic solution. On the other hand it increases the need for calculation. (OECD-IEA 2008, pp. 26–30)

Energy Performance

With the energy performance method, a total requirement for the building is set based on the supply of energy or the resulting environmental impact, for instance in form of CO_2 emissions. This method requires a comprehensive method for calculating the energy performance of a building, with standard values for climate and use of the different types of buildings. Constructors are required to use an advanced computer based model for the calculations, which integrate all the different parts and installations of the building.

Values for energy performance are set on the basis of an overall value, consumption pr. m^2 or a mixture, for different types of use or different types of buildings etc. Installations as renewable energy in the building will usually be calculated as improvement in performance, meaning that a solar collector or solar cells can substitute insulation, efficiency in boilers or air conditioners. The performance model requires handling multiple factors as solar gains, recovery of energy losses, shading and efficiency in installations.

In performance calculations, the maximum value is often set for the use of fossil fuels, primary energy use or as a maximum CO_2 emission. Free trade-offs can be made between insulation and installation of efficient equipment, but also based on the selection of fuels, the use of renewable energy, the primary design (form) of the building, use of daylight, and intelligent installations or automatics. Windows with better thermal values can be used to increase the window area or negative losses can be out balanced with positive gains as passive heating.

According to OECD-IEA (2008), energy performance standards give optimal freedom for constructors or designers to reduce energy consumption within the frame. If efficient boilers or air conditioners are more cost effective than improved insulation, the constructors can choose this alternative to improve performance. Similarly, it will be possible to substitute more expensive solutions in the building envelope with efficient renewable energy systems or heat recovery. The model adapts to a change in prices, technical development and allows new solutions and products. There is a need to develop and maintain sophisticated calculation methods and computer tools that take all these important factors into account.

4.2.3 Thermal Zoning

The specialized literature (see Hitchin 1990, Schoenau and Kehrig 1990, Çomaklı and Yüksel 2003, Bolattürk 2008, Martinaitis et al. 2010) shows that one of the most important issues in defining the thermal requirements for the various elements of the thermal envelope of buildings is the influence of the outdoor climate. In general, the degree-day calculation to define the U-values and R-values was the most commonly used method.

With regard to the abovementioned and from a practical experience, the implementation of energy requirements for residential buildings in Brazil constitutes an interesting experience to be reviewed in detail mainly for two reasons: 1) given the diversity of micro climatic conditions – due to the vastness of the territory – has led to the calculation of degree-days for the definition of energy requirements; and 2) because of the importance of reviewing the – rather scare – regional experience on the implementation of thermal regulations in the South American context.

Brazil is divided into five geographical regions. Three coastal regions (North-east, South-east, and South) concentrate the 58% of the national housing stock and they are responsible for about 70% of the electricity consumption (Scalco et al 2012). According to the National Energy Balance[50] (Balanço Energético Nacional or BEN) electricity generation in Brazil reached 454 TWh in 2008. Hydroelectricity represents 80% of the electricity offer in Brazil. The residential sector consumes 22% of the total energy consumption, showing an increase of 5.7% per year between 1976 and 2008 (BEN 2009).

In the Brazilian context, the first measures related to energy conservation emerged during the energy crisis that occurred in 2001. The labelling and inspection mechanisms have been defined as conformity assessment for classifying the level of energy efficiency of buildings after a process that began in 2001 with the enactment of Law. 10.295. This law provides for the National Policy for Conservation and Rational Use of Energy (Política Nacional de Conservação e Uso Racional de Energia or PNCURE), establishes the need for 'technical indicators and specific legislation' aimed at the rational use of energy in buildings (see PNCURE 2001).

[50] Research related to energy offer and consumption published annually and elaborated by the Ministry of Mines and Energy (Ministério de Minas e Energia or MME),

Later on, the Law was regulated by the Decree No. 4059 of December 19, 2001, establishing "maximum levels of energy consumption or minimum energy efficiency for machines that use energy produced or marketed in the country, and constructed buildings". Also showed to the need for "technical indicators and specific rules" for energy efficiency levels in the country.

The Decree created the Steering Committee Indicators and Levels of Energy Efficiency (Comitê Gestor de Indicadores e Níveis de Eficiência Energética or CGIEE) and the Technical Group for Energy Efficiency in Buildings (Secretaria do Grupo Técnico de Edificações – GT Buildings). The GT Buildings regulates and develop procedures for evaluating the efficiency energy of buildings constructed in Brazil seeking the rational use of energy. Furthermore, the Brazilian Program for Electricity Conservation in Buildings (Programa Nacional de Eficiência Energética em Edificações or PROCEL Edifica) aims to build the foundations necessary to rationalize energy consumption in buildings in Brazil. In one of its strand of action, Regulations Subsidies, benchmarks are determined to check the energy efficiency of buildings.

As in other examples, the energy efficiency classification of dwellings in Brazil is based on an evaluation of the thermal performance of the envelope and water heating system. Both individual systems and the overall rating range from level A (most efficient) to E (least efficient)

Brazilian regulations apply a prescriptive method for energy efficiency labelling in the housing sector. The assessment is conducted through energy performance calculations based on the so-called discomfort hour index[51], both for heating and cooling needs. The method consists on linear equations that establish relations between the area for lighting and ventilation, the shade conditions, the solar orientation, and the thermal characteristics of opaque elements. As requirement for the envelope to be evaluated, there are mandatory provisions that establish maximum values of thermal transmittance (so-called U-factor described above) and thermal conductance (C-factor) and certain conditions of natural ventilation according to a national zoning system (see LabEEE s.f.)

---

[51] This index evaluates the impact of heat stress on the individual taking into account the combined effect of temperature and humidity.

Due to the prevailing tropical climate conditions in the Brazilian territory, regulation provides maximum transmittance values as a function of thermal capacity levels and, the so-called, solar absorptance[52] of the walls and roofs; furthermore, minimum percentage for openings for natural lighting and ventilation, according to the bioclimatic zone where the building is located are provided as prerequisites. To this end, the Brazil territory is divided into eight bioclimatic zones. Zones Z1 and Z2 represent the colder regions and Z7 and Z8 represent the warmer regions of the country.

The assessment, rather than considering the dwelling as a whole through the fulfilment of requirements related to the building parameters, is performed considering extended-stay rooms, providing greater flexibility of the method by addressing a range of issues, like the exposure of the external façade and each room's orientation. Thus, the envelope of each room is subject to a detailed energy efficiency analysis and the weighting of each room results in the classification of the dwelling envelope (See Scalco 2012).

4.2.4 Information Instruments

Information instruments aimed at the diffusion of the energy performance of housing, not only for the use of users but for knowledge and the dissemination to the general public. In this regard, several European countries have implemented mandatory instruments to raise public awareness on dwellings' energy consumption and CO_2 emissions. Best examples of these instruments are: labelling, public disclosure, energy rating, and energy certification. Within the European context, the literature highlights the United Kingdom and German experiences in the implementation of information tools. Both experiences are detailed reviewed in the following sections.

United Kingdom

Since 2010, the regulatory framework regarding energy efficiency in the housing sector in the UK is defined by:

- The Energy Performance of Buildings (Certificates and Inspections) (England and Wales) (Amendment) Regulations 2012.

[52] Solar absorptance is a measure of the amount of solar energy that passes into a material. It is defined as the ability of a material to absorb short-wave visible light. Solar absorptance relies on colour no matter what material you use. Dark materials have a higher solar absorptance and will absorb more solar energy.

- The Building Regulations 2010 – Conservation of Fuel and Power, Documents: L1A (Conservation of Fuel and Power in new dwellings) and Document L1B (Conservation of Fuel and Power in existing dwellings).

The above-mentioned regulations have a common body of regulations to define the energy efficiency requirements relevant to new and existing dwellings, namely: *Regulation 29* (energy performance certificates) and *Part L of Schedule 1* (Conservation and fuel power). The main differences between the two regulations are twofold. Firstly, *Regulation 26* (New buildings) of Document L1A requires that: *Where a building is erected, it shall not exceed the target CO_2 emissions rate for the building that has been approved pursuant to regulation 25* (see Documents L1A, p.4). Moreover, in the *Section 3* (General guidance) of Document L1A, some key terms are defined, namely: the Dwelling CO_2 Emission Rate (DER) expressed as $kgCO_2/(m^2.year)$ and the Target CO_2 Emission Rate (TER) expressed as $kgCO_2/(m^2.year)$[53]; both rates (DER and TER) are used in assessing and comparing the energy and environmental performance of dwellings by means of applying the Standard Assessment Procedure (SAP) methodology, developed by the Building Research Establishment (BRE) (DECC 2013).

Secondly, the Regulation 23 (Requirements relating to thermal elements) of Document L1B requires that: where a person intends to renovate a thermal element[54], such work shall be carried out as is necessary to ensure that the whole thermal element complies with the requirements of paragraph L1 (a) (i) of Schedule 1 (see Documents: L1B, p.4). Moreover, the Table A1 (see Documents: L1B, p.22) defines the Cost-effective U-value targets when undertaking improvements in the building envelope; the U-values are expressed as in watts per square-meter per Kelvin ($W/m^2.K$) and the Table A1 provide a detailed description of the construction materials that can be used to achieve the pre-defined U-values.

The Figure 15 presents the rating systems applied in the UK based on the SAP methodology (DECC 2013). According to the regulations described above, in order to

---

[53] See paragraphs 4.2 to 4.6, Documents L1A.
[54] According to the Section 3 of the Document L1B, in this Regulations "thermal element" means a wall, floor, or roof (but does not include windows, doors, roof windows or roof-lights) which separates a thermally conditioned part of the building from: a) the external environment (including ground); or b) in the case of floors and walls, another part of the building which is: 1) unconditioned; 2) an extension falling within class VII in Schedule 2; or 3) where this paragraph applies, conditioned to a different temperature.

calculate the SAP Rating for a dwelling, most of the required information is found on the dwelling's plans and specifications, which should include floor plans, sections, and construction details including the details of the preferred insulation. The site orientation in relation to North is also required. Other specific information that is essential would be the type of the proposed heating system including fuel (it is not necessary to state the actual boiler at this stage). The TER and DER rates (described above) have to be calculated prior to the Building Regulation drawings are submitted to Building Control. The DER cannot be greater than the TER and, in order to achieve this goal, some U-values may have to be adjusted.

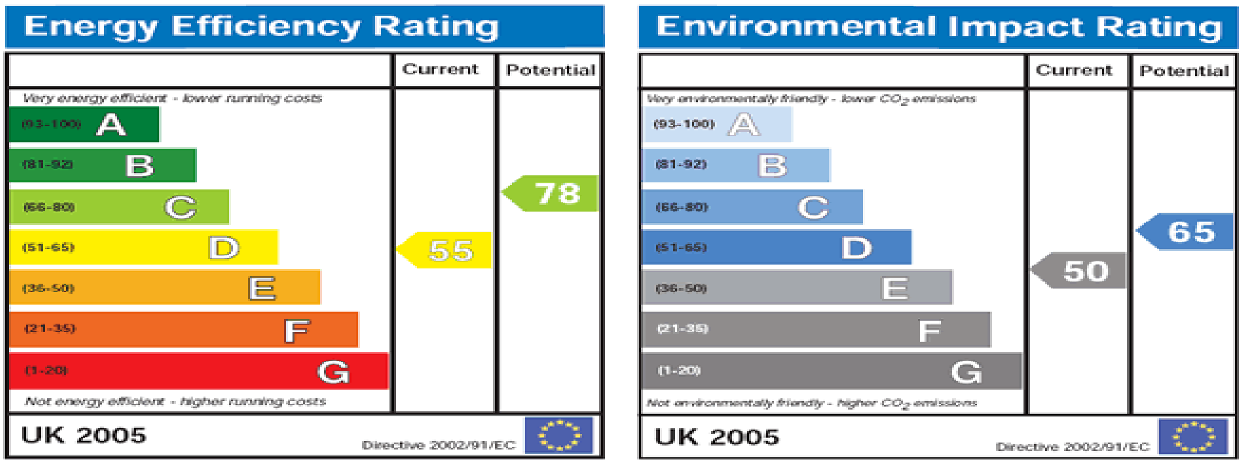


Figure 15: Standard Assessment Procedure (SAP) used in the UK.
(Source: DECC 2013)

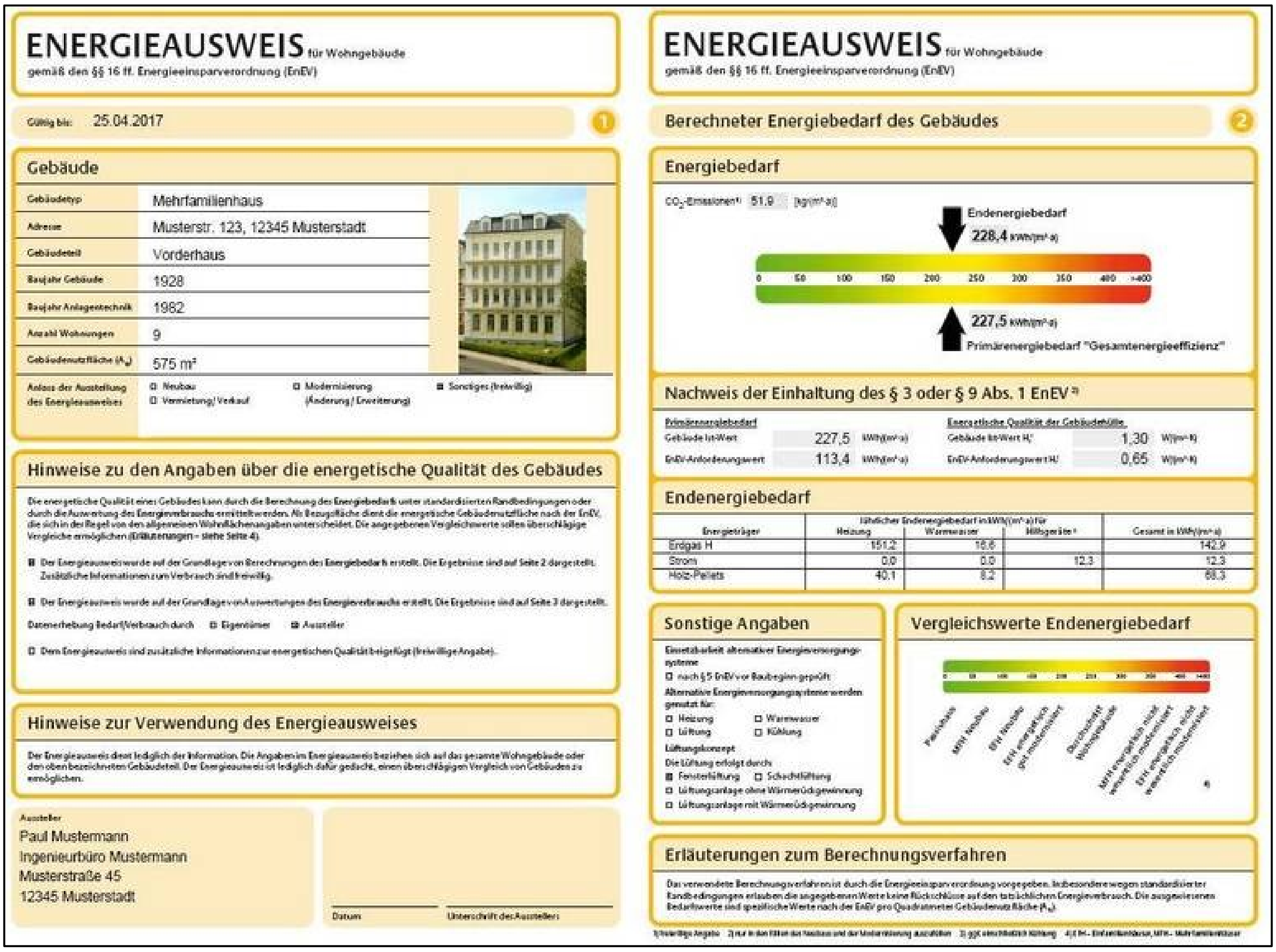
In addition, the Housing Act 2004 requires that all home-sellers and their agents to include an EPC to a file that containing all the information of the dwelling (building plans, building permits, certificates, etc.); this file must be delivered to the new owner (DECC 2013).

Germany

Germany has been effectively addressing residential EE since 1976, with the announcement of the Saving Energy Law (Energieeinsparungsgesetz or EnEG) in order to face the 1973 world oil crises. Germany has managed to reduce in 32 years the primary energy demand of the constructions from 350 up to 70 kWh/m² per year; which is the German average energy consumption value.

The German process has been slow on its implementation when comparing it to other countries in the region; from the first regulations in 1976 to the energy certification it is been a long time, where solid bases in the energy efficiency market has been formed. The professional enabled, specialized manpower, construction materials, etc. already exist in the German context and numerous technological investigations have been conducted with the intention of defining the German energy efficiency standards.

The German Law provides for a general identification obligation that applies not only to citizens but also to buildings. Homeowners that are willing to sale or rent houses to new tenants are required to provide a valid Energy Performance Certificate for Buildings (Energieausweis für Gebäude or EG), the Figure 16 shows an example of the EG applied to a residential building in Germany.


ENERGIEAUSWEIS für Wohngebäude
gemäß den §§ 16 ff. Energieeinsparverordnung (EnEV)

Gültig bis: 25.04.2017

Gebäude

Gebäudetyp	Mehrfamilienhaus
Adresse	Musterstr. 123, 12345 Musterstadt
Gebäudeteil	Vorderhaus
Baujahr Gebäude	1928
Baujahr Anlagentechnik	1982
Anzahl Wohnungen	9
Gebäudenutzfläche (A_N)	575 m²

Hinweise zu den Angaben über die energetische Qualität des Gebäudes

Hinweise zur Verwendung des Energieausweises

Aussteller
Paul Mustermann
Ingenieurbüro Mustermann
Musterstraße 45
12345 Musterstadt

Datum | Unterschrift des Ausstellers

ENERGIEAUSWEIS für Wohngebäude
gemäß den §§ 16 ff. Energieeinsparverordnung (EnEV)

Berechneter Energiebedarf des Gebäudes

Energiebedarf

CO_2-Emissionen 51,9 [kg/(m²·a)]

Endenergiebedarf 228,4 kWh/(m²·a)

227,5 kWh/(m²·a) Primärenergiebedarf "Gesamtenergieeffizienz"

Nachweis der Einhaltung des § 3 oder § 9 Abs. 1 EnEV

Primärenergiebedarf			Energetische Qualität der Gebäudehülle		
Gebäude Ist-Wert	227,5	kWh/(m²·a)	Gebäude Ist-Wert H_T'	1,30	W/(m²·K)
EnEV-Anforderungswert	113,4	kWh/(m²·a)	EnEV-Anforderungswert H_T'	0,65	W/(m²·K)

Endenergiebedarf

Energieträger	Heizung	Warmwasser	Hilfsgeräte	Gesamt in kWh/(m²·a)
Erdgas H	151,2	16,6		142,9
Strom	0,0	0,0	12,3	12,3
Holz-Pellets	40,1	8,2		68,3

Sonstige Angaben

Vergleichswerte Endenergiebedarf

Erläuterungen zum Berechnungsverfahren

Figure 16: German Energy Performance Certificate for Residential Buildings (Energieausweis). (Source: EnEV 2014)

The German Energy Agency (Deutsche Energie-Agentur GmbH or DENA) advises prospective homebuyers and tenants to take a good look at this certificate. It shows the degree of EE of the dwelling and provides an overview of any refurbishment measures that may become necessary in the future. The certificate facilitates comparison between different dwellings and helps to estimate the future hot water and heating costs. Based on the rating provided by the EG, specific renovation measures are proposed to improve the

EE of existing buildings. The EG is an inexpensive way for owners to obtain initial information about how to renovate their buildings. It records the most important details of the building, provides information about its current level of EE and indicates whether renovation would make sense in each case. Furthermore, specific recommendations for renovation in the EG provide a starting point for renovation planning or for a further, detailed energy consultation (BMVI 2013).

For potential buyers and tenants, energy performance certificate provides a higly appreciated point of comparison and decision-making tool for selecting a building or apartment based on projected energy costs. These standards and those for new buildings are regulated by the Energy Saving Ordinance (EnEV).

Since 2002, the EE Estimation and Energy Certificate (Energypass) exist in Germany as part of energy regulations – prior Directive 2002/91/EC – trough Energy Saving Regulation (Energieeinsparverordnung or EnEV). There are two kinds of energy certificates: Energy Demand for New Buildings and Consumption Certificate for Existing Buildings. This regulation establishes the maximum requirements of power consumption including: limit values of thermal transmittance (the so-called U-values described in the foregoing sections) for the building envelope, the heating systems efficiency demands, etc. (BMVI 2013)

In the case of new housing, the Energypass includes an overview of the housing and the evaluator, the identification of the evaluation indicators of housing, and the obtained in the evaluation. It includes an indicator of the final energy demand, an indicator of the primary energy demand, and indicator of CO_2 emissions. For existing housing, comprehensive summary energy consumption is also included. The housing energy consumption is calculated on the basis of the bills for heating and hot sanitary water and is classified according to the amount of energy used and energy source (diesel, gas, etc.), taking into account a climate correction factor.

Finally, it is worth emphasising at this point that all buildings that meet the low-energy house standard in Germany have an annual energy requirement between 30 and 70 kWh/m². The term “passive house”, on the other hand, refers to particularly efficient buildings that do not require an active heating system to achieve a comfortable room temperature. To meet this standard, the annual energy requirement per square meter for room heating must be reduced to less than 15 kilowatt-hours, while the building must also be equipped with ultra-efficient ventilation and heat recovery systems (see BMWi 2014).

United States of America

In the United States of America (USA), unlike the EU countries, there is no mandatory energy labelling; instead, there are regulations on the Minimum Energy Performance Standards (MEPS) that buildings must comply. At the same time, there are voluntary certifications like Energy Star, LEED, and others (voluntary measures are detailed analyzed in the following section), which have been developed and implemented because rising energy prices and government incentives focused on improving energy efficiency in buildings. All this, with the primary purpose of ensuring the country's energy supply.

In the USA context, there is great diversity of energy efficiency regulations in the residential sector. This diversity is given because the country has different administrative levels (federal, counties, etc.), regulations are handled differently in each level. Several private initiatives address different programs in order to promote the implementation of energy efficiency measures in the residential sector. For instance, the Energy Efficiency and Renewable Energy (EERE) promotes the Building Technologies Program (BTP), which collaborates with the residential building industry to improve the energy efficiency of both new and existing dwellings. By developing, demonstrating, and deploying cost-effective solutions, the BTP strives to reduce energy consumption across the residential building sector by at least 50% by 2030. The BTP focuses on three topics: Research and Development; Market Simulation; and Building Codes and Equipment Standards.

According to the American Council for an Energy-efficient Economy (ACEEE), a non-profit organization that acts as a catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviours, in order to ensure that energy efficiency is integrated into all new buildings state-wide, the building codes are a foundational policy. The ACEEE argues that once a construction is completed, the installation of energy efficient measures and equipment is both difficult and expensive; there is a risk of losing opportunity of energy savings in the new building stock if energy efficiency is not incorporated at the time of construction. Therefore, mandatory building energy codes are one way to target energy efficiency by requiring the compliance with MEPS for all new residential and commercial buildings in every state. Finally, in the USA context it is believed that enforcing the compliance with building codes can be difficult and costly, but a concerted effort to fund and train code officials has the potential to generate significant energy savings for a state, helping consumers to save money on their energy bills and thereby making businesses more viable and homes more affordable.

Finally, the USA had been focusing in actions to introduce and encourage EE and to secure national energy supply for the past 30 years. One of the most important acts is the Energy Efficiency Policy issued on 2005, which offers certain stimuli to those federal agencies and consumers willing to purchase electric hybrid vehicles, construction and building renovation, EE products and devices.

4.2.5 Economic Incentive Schemes

According to Nelson et al. (2010), a multitude of measures affecting the real estate sector has been implemented already around the globe. For example, many governments in Europe subsidize the use of renewable energy sources and support actions to improve insulation. Most European countries have also tightened environmental regulation for new buildings and refurbishments of old buildings. Buildings complying with high energy-efficiency and other environmental standards decrease CO2 emissions and are often referred to as “green buildings”

The Spanish experience in applying economic incentive schemes has been successful since the new millennium. Therefore, it has been a benchmark in the European and Latin-American context and it worth a detailed review.

Spain

The transposition of Directive 2002/91/EC in Spain was realized by means of introducing changes within the Spanish Regulatory Framework (Marco Normativo Español or MNE). New energy efficiency requirements in the construction sector were included in the MNE, namely: energy consumption, illumination, isolation, heating, air conditioning, sanitary hot water and use of solar energy.

The Technical Edification Code (Código Técnico de Edificación or CTE) (MINVI 2006), establishes in the Spanish context the new regulatory framework that buildings must fulfil with regard to the basic requirements for security and habitability, defined in the New Building Construction Law (Ley de Ordenación de la Edificación or LOE). It orders and completes the previously existing technical regulation, and it tries to facilitate its application and fulfilment, all this in harmony with the EPBD mentioned in the previous section. The CTE includes a so-called Basic Document (Documento Básico or DB) for energy saving within the so-called habitability section. The DB establishes five energy efficiency and renewal energy requirements that new buildings and buildings that undergo a renovation must fulfil, namely: Limitation of the energy demand; performance of thermal facilities; Energy efficiency of illumination facilities; minimum solar contribution to sanitary hot water; and the minimum photovoltaic contribution to electrical energy (MINVI 2006).

In the Spanish context, there are two options to calculate the energy rating of a building. The first one called “simplified option”, has a prescriptive nature and develops the methodology for calculating the buildings’ energy efficiency in an indirect way. To do this, the building thermal envelope it is evaluated in order to measure whether it meets the thermal transmittance values (also called U-Values) and solar energy factor (also called SEF[55]), both defined within the regulations. The second one called general option; it is performance-based assessment and evaluates energy efficiency comprehensively. Generally, it is carried out through the use of software designed specifically for this porpoise within the Spanish context; the software is called CALENER (Calificación Energética) and is available to the public for free.

The Energy Performance Certificate contains, among other, the following information: building rating; it is mentioned the current energy legislation applied at the time of its construction; type of certificate (Certificate of the Project or Certificate of the Completed Building); primary energy consumption annual estimates (kWh/year) and carbon dioxide emissions (kg CO_2/year). The process for obtaining a certificate has three fundamental instances. The first one is the certification of the building in the design phase in which a specialist certifies that the building meets the energy saving requirements defined in the DB (described above). The second instance is performed during the construction phase of the building through the inspection of the works by an inspector designated by the community. Finally, a third party makes a final inspection of the completed building and issues the Energy Efficiency Certificate of Completed Building.

Based on the foregoing, it follows that a key factor in countries that have shown developments in the field of energy efficiency is the basis of political decision. The European Union – which brings together a significant number of countries in the region – provides a good example regarding the policy engagement. It has been shown that through the creation of institutions responsible for the implementation of programs, the policy implementation could be sustained over time (Poveda 2007, p.17)

[55] The solar energy factor (SEF) is defined as the energy delivered by the system divided by the electrical or gas energy put into the system. Solar energy factors range from 1.0 to 11. Systems with solar energy factors of 2 or 3 are the most common (see USDE 2013)

4.2.6 Heating, Ventilation, and Air Conditioning (HVAC) Systems

HVAC systems maintain a building's comfortable indoor climate through Heating, Ventilation and Air Conditioning (Cooling). These systems profoundly influence energy consumption in buildings. Without heating, cooling and ventilation systems there would be no energy consumption in the building, since it would be totally dependent on outdoor conditions. There is an inverse correlation between the efficiency of the building and the need for HVAC systems: highly efficient building envelopes reduce the need for heating and cooling systems. Good and intelligent designed buildings can reduce or even avoid the need for heating and cooling and reduce the need for ventilation.

Efficiency improvements in HVAC systems can lead to substantial savings, but these savings will also depend on the efficiency of the building in general. If, for instance, energy efficiency is improved in a heating boiler or an air-conditioner, total savings will depend on the total need for heating or cooling in the building. Higher requirements for the building envelope might reduce the potential for savings in HVAC systems. Finally the HVAC systems need to be in a good balance with the buildings in general and they need to be of a proper size which fits with the actual heating, cooling and ventilation needs. (OECD-IEA 2008, pp 22–23)

Ventilation

According to OECD-IEA (2008), well-insulated, airtight buildings often require active ventilation to remove used air and introduce fresh air for occupants. Natural ventilation, like the flow of air through open windows, and mechanical ventilation both circulate air. Ventilation can also be included in air-conditioners which combine simultaneous heating and cooling. There are many technologies to improve the efficiency of ventilation systems, including heat exchangers and heat pumps. For ventilation systems there is a need to be aware of both the energy use in ventilation system itself for fans and preheating of the air etc. but there is also a need to take concern for the heat losses which comes with the exchange of the air. Ventilation systems should hence effectively ensure the necessary air exchange, not more and not less.

Heating systems

Many possible systems can heat a building. Collective heating can include a combined system based on a heating supply in the building such as a boiler or on an external supply in the form of district heating or heating from combined heat and power production. Buildings can also draw heat from individual systems such as electric heaters, heat pumps or individual ovens. Finally, heating can be integrated in the ventilation and air-conditioning systems. Centralised heating systems include a distribution system in the building such as pipes, ducts, tanks, pumps, fans, or exchangers. The efficiency of the overall system depends on the efficiency of all its components, and an efficient boiler can become an inefficient heating system if parts are poorly connected and badly calibrated. In individual systems, the efficiency often depends alone on the efficiency in the heating source only. Building Codes will often address the efficiency in the system in general and in the components of the system. Some buildings might have multiple systems with a mix of functions, which should all be addressed (OECD-IEA 2008).

Cooling

According to (OECD-IEA 2008) in order to maintain a comfortable and healthy indoor climate, the heat must be removed from overheated buildings. Cooling systems can be centralized or decentralized into small units installed in every room for instance with small split units which are installed in each room. For split units, it is mostly the efficiency of the cooling device and the control system which are of importance for the overall efficiency. Within centralized systems, the dimensions and control of the system itself and the distribution ducts both determine energy efficiency. Air tightness is especially important for building cooling, as air leakage can substantially reduce the efficiency of mechanical cooling. Some buildings work with natural cooling or with night cooling, both of which reduce the need for active cooling.

Air Conditioning

Air conditioning (AC) systems generally combine the capacity to ventilate, cool, and heat the dwelling’s indoor environment in order to improve its comfort conditions. In a basic definition, an AC system will supply the building with heated air if outdoor temperatures are cold, with cooled air during hot days, and with plain air if the building requires only ventilation. For AC systems, it is primary the efficiency of the overall system and/or the components which are regulated, including the heating, cooling and ventilation components.

Hot Sanitary Water

Many housing buildings' users require hot sanitary water (HSW) for hygiene, food preparation, and cleaning purposes. The central heating system can provide this water, as a separate system using electricity, oil, gas, solar thermal energy, heat pumps or district heating may do it as well. Given the importance of the HSW systems on the energy performance of the housing, efficiency regulations often address HSW in order to achieve optimum standards.

Automatic Controls - Domotics

Automatic controls of systems might largely determine or influence the efficiency of the energy used by all the systems in the dwelling. Individual housing energy systems as heating, cooling, ventilation or lighting systems may have individual automatic controls in order to achieve higher energy performance. On the other hand, it is also possible that the overall system can be controlled by one central system, which controls all the functions. If the systems are controlled by individual systems this may in some cases lead to conflicts between for instance heating and cooling systems. Good and efficient automatic controls can ensure the optimal use of the HVAC systems.

4.2.7 Renewable Energy

While government-initiated implementation of alternative local energy generation systems in residential buildings is relatively recent, its implementation on a voluntary basis is longstanding.

The use of local sources of renewable energy can be either passive or active. In passive systems the renewable energy is used to reduce the dwelling's energy demands from the local electricity grid the need for heating or cooling while the active systems will transform the energy from, for instance the sun or the wind, into electricity, heat or cooled energy carriers from which energy is used, as if it came from a non renewable HVAC system.

With a decreasing energy demand in buildings, these sources become an important part of the energy performance of the buildings and the more advanced standards include these sources.

Requirements for energy efficiency in buildings and the calculation of energy performance can both address integrated renewable energy systems. These requirements can either be set for the renewable energy sources themselves – for example, in a demand for solar heating of sanitary water, as in the case for Spain - or as part of an overall energy performance (see below), where the demands are set for the maximum delivered energy.

Passive Solar

In a building heated by passive solar energy, glazed areas are oriented and arranged so as to optimise the capture of solar light and heat during the day. When buildings are highly insulated and energy efficient, passive solar energy can meet a substantial share of the heating demand, even in cold climates.

Because a building's exposure to solar energy varies over the year and during the day, constructions must be able to store and balance solar energy. Buildings capturing too much heat may require cooling, offsetting the efficiency gains of passive heating. Passive solar heating of buildings requires good models for balancing heating in multiple zones 29 to provide even temperatures throughout the building.

Passive Cooling and Ventilation

In passive cooling systems natural cool resources for instance in water or in the ground can be used to reduce the need to cool the buildings. Passive cooling systems can also use the fact that the temperature might be colder at night or use different phenomena's which will cool air or building parts.

In natural or passive ventilation different options are used to avoid active ventilation systems. Natural ventilation is often used in small residential buildings and often these buildings are constructed with out or with very limited use of active or mechanical ventilation. In larger buildings and in particular in service buildings the use of natural ventilation requires a high emphasis in the design phase.

When natural ventilation or passive ventilation is used in large buildings natural sources of wind or airstreams because of difference in temperatures are used to drive the ventilation. This is typically achieved through an intensive design phase where the shape of the building is adjusted or where specific elements such as special designed windows are introduced.

Passive cooling and ventilation can reduce energy consumption substantially but is difficult and complicated to address in building codes or standards for new buildings.

Active Renewable Energy Systems

In active renewable energy systems the energy from the renewable energy sources are actively transformed into heating, cooling or electricity and the used as energy supply which comes from non renewable HVAC systems. Some of these systems can often be integrated in the buildings or in the building shell.

Solar water heaters are one of the most commonly used renewable energy supplies in buildings and in these systems water is heated by the sun and the heat is stored until used. Similar systems can be used to heat the building but this increase the need for storage and sometimes even from one season to another.

Photo voltaic (PV) is another example on active use of solar energy in buildings, where solar energy is transformed into electricity and used for the buildings supply of electricity. Solar energy can also be transformed directly into cooling and used as a cooling source. These systems will often require little storage, because they produce when needs for cooling are high. Other renewable energy sources in building can be small building integrated windmills or systems that use biomass or waste products from the buildings and heat pumps can be used (OECD-IEA 2008).

Is noteworthy that residential energy efficiency regulations in the international context, do not apply only for new buildings, but also requirements for existing buildings are included trough the local building and energy codes. Energy requirements for existing buildings are introduced whenever the buildings are the subject of a major renovation.

4.3 Voluntary Instruments – Beyond the Building Codes

In addition to initiatives undertaken by governments to introduce energy efficiency requirements in new residential buildings on mandatory basis – as reviewed in the previous sections – a host of non-state actors have also initiated to engage in promoting energy efficiency in buildings (Janda 2009). In the following sections, the so-called "*green*" initiatives emerging from non-governmental sectors of society introduced in a voluntarily manner in the real estate market are reviewed in detail. Usually, such initiatives were born in the international arena and have been introduced recently in the Chilean market. In the long run, voluntary initiatives seek to generate market transformations aiming towards achieving greater sustainability in the construction sector; therefore, energy efficiency is not addressed in isolation, but is part of the broader set of sustainability initiatives, as shown below.

4.3.1 The Shift Towards Green Buildings

According to Lockwood (2006, p.130) the influential factors causing a shift in thinking towards green buildings (GB) are threefold, namely: 1) the creation of reliable building-rating and certification systems for new construction and renovations[56]; 2) in the international context, recent studies have proven the financial advantages for tenants of going green[57]; and 3) GB materials, mechanical systems, and furnishing have become widely available, and their prices have dropped considerably – in some cases below the cost of their standard counterparts[58].

Green Buildings Definitions in the Relevant Literature

According to Nelson et al. (2010), green, sustainable, and low-energy buildings are just some of the definitions available in the specialized literature for concepts that are "*green*" in the broadest sense and, therefore, the authors argued that further classification of the existing concepts is needed. Moreover, the authors stated that the diversity of terms in

---

[56]For example, in 2000 the U.S. Green Building Council (USGBC) launched its rigorous Leadership in Energy and Environmental Design (LEED) rating program. The program is reviewed in detail, amongst other GB certification systems, in the following sections.

[57] Well designed green buildings have lower utility costs, it was argued; for example, in its first year of operation, the LEED-certified Genzyme Center used 42% less energy and 34% less water that standard buildings of comparable size (Lockwood 2006, p.130)

[58] According to Turner Construction, four industry studies of more than 150 sustainable buildings across the U.S. show that, on average, it cost only 0.8% more to achieve basic LEED certification than to construct a standard building.

the relevant literature are used to define green buildings[59] which exhibit more and better features than standard buildings, built to the local building regulations defined in the building codes.

An analysis and a comparison of the range of existing concepts to define what "green" buildings are it is provided in the work of Lützkendorf (2009). According to the author, the range of concepts goes from *low-energy buildings*, which only consider energy efficiency, to *sustainable buildings*, which cover all aspects listed in Table 12.

Table 12: Green Building Definitions and Main Components
(Source: Own compilation based Lützkendorf 2009)

Aspect	Concept / Term				
	Low Energy Building	**Low Emission Building**	**Green Building**	**High Performance Building**	**Sustainable Building**
Functionality				+	+
Energy Efficiency	**+**	**(+)**	**+**	**+**	**+**
Resource Intensity	(+)	(+)	+	(+)	+
Environmental Compatibility	(+)	+	+		+
Health	(+)	(+)	+	(+)	+
Socio Cultural			(+)		+
Life Cycle Costs					+
Value Earnings					+
Technical Quality					+

As shown in table above, energy efficiency is one of the cross-cutting issues to the whole range of GB definitions; other aspects are resource intensity and health. In contrast, the concept of “*sustainable buildings*” is the only concept that covers all desirable aspects for achieving a GB. Therefore, from this perspective it is valid to argue that achieving energy efficiency in buildings is a step – probably the first and most important one – towards achieving sustainability in building construction; situation discussed further in the conclusions of this doctoral thesis.

[59] According to McCartney (2007) and Nelson (2008) (cited on Nelson et al. 2010, pp. 3–4), the main Features of GB include: 1) Efficient use of natural resources; 2) Waste minimization; 3) Eco-friendly construction materials, 4) Incorporation of local climate conditions; 5) Less energy required to transport building materials; 6) Limited impact on surroundings (e.g. lower emissions, noise, smell); 7) Consideration of life cycle costs; 8) Health; 9) Location near population centres and close to public transportation facilities; 10) Efficient building management and commissioning; 11) Social capacity and building user’s comfort; 12) Convenient indoor environment.

Benefits of Green Buildings

Beyond the still open debate about the different concepts and features of GB, the relevant literature seems to agree in a variety of benefits for designers, developers, builders, homeowners, and householders that might be achieved through the implementation of green design. These benefits can be direct or indirect.

According to Kats et al. (2003), the direct benefits of green buildings are much greater than the costs throughout the life cycle of the building. According to the authors, the cost of obtaining platinum and silver LEED-certified buildings are respectively 2% and 6.5% higher than a normal building, respectively. However, LEED-certified buildings reduce their energy consumption on average by 30%, not to mention the benefits associated with water use, reduced CO_2 emissions, and reduced maintenance costs.

Moreover, according to Edwards (2003) indirect benefits generated by the GB for private developers, owners, and tenants are threefold. 1) GB are healthier to use; mainly because natural climate conditioning techniques are used (mainly lighting and ventilation) and organic materials are preferably used for building construction. 2) GB provide a psychological advantage; this advantage is mainly related to the use of internal spaces of buildings, since a major effort in the implementation of green space is made, creating a sense of wellbeing indoors. 3) GB enhance the corporate image; since the decision to implement green design strategies among the building design represents the involvement and a close relationship between a design team of specialists and client; the mere decision to opt for such effort is already reflected in the image of the company that implements green design.

Factors Influencing a Broader Adoption of Green Buildings

The preceding section stresses the ongoing discussion in the relevant literature regarding the variety of benefits – direct and indirect – that the so-called GB may generate for developers, homeowners, and tenants. However, the literature also emphasizes that, compared with other sectors of society and the business world, the real estate sector has been relatively slow in embracing green initiatives (Nelson et al. 2010).

The work of Nelson et al. (2010) identifies a group of four main factors influencing the slow adoption of green initiatives specifically in the housing market. First, it is argued that at the beginning of the so-called "*green movement*", the lack of awareness among investors and the lack of experience among real estate developers were the most important factors to slow the process of innovation in GB. Second, it was mentioned that the lack of transparent and reliable data, regarding the real estate market, has limited the demonstration and reliable comparison of the financial behaviour of GB against conventional buildings, especially in the European context. Third, A misalignment between costs and benefits for tenants and owners – according to economists, the so-called "*agency problem*" – it was mentioned as a relevant preventing factor for owners and investors to decide for green strategies; mainly because for them, applying such strategies means making a higher initial expenditure whilst the benefits will be perceived by tenants or other end users of buildings. And fourth, the difference in the investment horizon for GB and conventional buildings; it was argued that homeowners usually consider the only initial construction costs, while they should considered the investment over the entire life of the property – the so-called "*life cycle costing*" – although the GB have a slightly higher initial cost than in conventional buildings, they are usually less expensive to maintain and to operate, which eventually makes that – in the long run - the total cost of the property is actually lower.

4.3.2 Green Building Certification Systems

As noted in the previous sections, a wide range of initiatives aiming to improve the building features is currently available on the market. Such improvement seeks to modify design criteria and traditional construction techniques, in order to change construction industry paradigms through technological innovation, resulting in buildings that have better energy performance than buildings constructed with traditional techniques and, therefore, have a less impact on the environment – the so called GB reviewed in the previous sections. Moreover, according to Nelson et al. (2010), the lack of comparability between regulations, technical guidelines, and the green performance of buildings has already sparked much interest among non-governmental actors, real estate developers, and tenants in GB certification systems.

In general, such initiatives are voluntarily implemented by developers, building designers, architects, real estate companies, and/or construction companies in order to achieve higher building standards beyond the increasingly-demanding requirements local building code, improving therefore buildings' energy performance and reducing its environmental impact. In general, such initiatives are: implementing bioclimatic design and construction criteria (i.e. investing in high-performance construction materials and efficient technology). Moreover, once the design team involved in the planning and execution of any given real estate project has voluntarily made an additional effort to improve the building features and an effort has been made in order to significantly reduce the building's operation and maintenance costs and its environmental impact – thus obtaining a GB – then there is an emerging need to asses and certify all this effort by evaluating the building performance and to report it to the society and to various stakeholders. Moreover, from the aesthetic point of view or image of the building, it is not possible to judge the internal features of the building in terms of technological innovations or construction materials, to name a few. Furthermore, sometimes the seemingly disproportionate amount of glass in facades - which is often the characteristic image of these buildings - might suggest that these buildings actually consume more resources than the buildings next door. According to Reed et al. (2009), at this instance, the problem lies in knowing how to distinguish the level of sustainability achieved in a building, enabling the comparison between "*green*" buildings and standard buildings.

In order to address this concern, the international market offers a variety of assessment methods to measure how sustainable a building, which evaluates the building features in detail, and issuing a certificate, a label, and in some cases a rating[60] (Münch 2009). These assessment methods function as voluntary market place instrument and use the requirements set by local environmental and building standards from the country in which the building is located as a baseline for the assessment.

Münch (2009, pp.20-23) provides a detailed review of the sustainability assessment methods in building construction and the various tools that help in the process. In the following sections, some concepts are summarized in order to highlight the differences between the different assessment tools.

---

[60] Nonetheless, according to Nelson et al. (2010, p.15) a rating system do not award a formal green building label; instead, the goal of rating system is to assist private developers and builders in the planning, construction, and operation of green buildings by providing clear standards for green construction.

Certification, Labelling, and Rating

The International Organization for Standardization (ISO) defines certification as a written assurance (a certificate) that certain product, service, or system in question meets specific predefined-requirements; such certificate should be provided by an independent organization. Certification is also known as third party conformity assessment (ISO 2013).

Moreover, Münch (2009) suggested that certification may be applied to end-products (like housing units in apartments-building or private offices in offices-buildings), processes (i.e. housing construction), and systems (like management systems). The author also states that the main benefit of a certificate[61] is it enhances the credibility of a service or product in the eyes of the client or user, given that it is an extern and independent agency who conducted the assessment and provides the certification (Münch 2009, pp.20–23).

A variety of regulatory and market-based concepts are currently being discussed in an effort to meet proposed greenhouse gas reduction targets (Fuerst 2009, pp.285–286).

In the absence of a unified carbon tax regime or carbon-trading scheme, eco-certification labels play a key role in promoting innovative products. In the real estate market, eco-certificates provide information on the environmental performance of a building to investors and tenants. As it is typically not possible or feasible for market participants to directly measure the desired characteristics, for example the degree of energy efficiency of a building, eco-certifications provide signals that facilitate the matching of the so-called "*eco-consumers*" to products carrying the desired characteristics. Gradually, a body of empirical evidence is emerging in real estate research that confirms eco-consumers' willingness to pay a premium for certified products. The majority of these studies have been conducted on Leadership in Energy and Environmental Design (LEED[62]) Green Building Rating System and the Environmental Protection Agency ' s Energy Star system, which are two schemes that have been developed for the commercial real estate sector in the United States (Fuerst 2009).

---

[61] Among other benefits, the International Organization for Standardization highlights the following: 1) providing consumers with added confidence; 2) giving the company a competitive edge; and 3) helping regulators ensure that health, safety or environmental conditions are met (ISO 2013).

[62] LEED is an acronym for Leadership in Energy and Environmental Design; an internationally recognized green building certification system, providing third-party verification that a building or community was designed and built by using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, and CO_2 emissions reduction.

Labelling

A label demonstrates a graphical and/or written mark on a product that bears a certain distinctive quality. This quality is specified and defined through a criteria catalogue and checked by an acknowledged extern body that will assign the label. Further characteristic of a label is that it is a multiple used and standardized quality award for products of a homogeneous group, like a group of different washing agents.

Labels arouse trust and achieve a recognition value, similar to the mechanism of branded products. They attest at the same time, through a third party certification, that a predefined quality standard is achieved. Consequently the label can be seen as a crossbred of brand and certificate. Crucial for its mechanism is the positive allocation and the degree of publicity of the label and its responsible organisation. The benefit from a label is information at a glance. Since the product has to fulfil a certain aspiration level, the relevant product property level is above average compared to other products (Münch 2009).

Assessment Methods

According to Münch (2009), the assessment methods result in a label or a certificate. Labels can be used as instrument for marketing and communication of commitment to sustainability. They are often thought of as market based instrument that link consumer demand for environmental quality and social responsibility with the firms' decision making process. 64 In the case of building labelling and certification especially, this is an incomplete picture that ignores various concerned parties in construction and real estate.

On one hand the certificates serve as a communication tool for owners and users of a building. It makes the quality of a building tangible to them and signals a performance-enhancing work environment as well as higher user satisfaction. On the other hand the labels can be used to provide information to other interested stakeholders like banks, investors, insurance companies and governmental regulators and influence their behaviour. This can benefit the stakeholder obtaining the label in ways like increased market access, easier access to credit, access to public funding, lower insurance premiums, higher stock valuations and simplified permission process by governmental regulators (Münch 2009, pp.20–23).

Although there are a wide variety of certification systems currently available on the market, the evidence points towards a tendency to adopt certain systems with preference by local real estate markets in some countries, as shown in Table 13. This signals a growing international demand for two things: on one hand, the demand for independent systems to assess how green (or sustainable) buildings are; and, on the other hand, the demand to compare GB among them in order to distinguish them from standard buildings.

Table 13: Green Building Certification Systems Adopted Worldwide
(Source: Own compilation based on Reed et al. 2009; RICS 2013; Green Globes 2013; DGNB 2013; BREEAM 2013; LEED 2013.)

Europe	Americas	Asia, Africa, and Oceania
BREEAM (UK, Germany, Netherlands, Norway, Spain, Sweden, Austria) LEED (HQE DGNB (Germany, Switzerland, Bulgaria, Denmark, Austria)	LEED (U.S., Canada, Mexico, Chile) U.S. DOE (U.S. Department of Energy) Design Guide (U.S.) WBDG (Whole Building Design Guide) (U.S.) HOK Sustainable Design Guide (U.S.) BREEAM Canada (Canada) Green Globes (U.S. & Canada) DGNB (Brazil)	Green Star (Australia) BEAM (Hong Kong) LEED (China, India, Korea, Turkey, United Arab Emirates) Greenmark (Singapore) GBTool (South Africa) DGNB (China, Rusia, Turkey, Thailand)

Among the rather increasing and broad variety of voluntary-implemented building certification systems[63], none of the most commonly implemented systems aims to assess – exclusively – the buildings' energy performance. Although the common assumption has been that a LEED building is necessarily an energy-efficient building (Scofield 2009, p.1386). Rather, the aim of independent assessment systems is to analyze how "green" buildings are. In a broad sense, the idea behind GB rating is to conduct a detailed sustainability assessment along the entire building's life cycle (meaning: design, construction, operation, reuse or refurbishment, and demolition). Therefore, the building's energy use is just one among several features[64] considered in both the assessment and certification processes.

[63] The literature accounts for a variety of terms used interchangeably; namely: Rating tools (Reed et al. 2009); Building Certification Systems (DGNB 2013); Environmental Assessment Method and Rating System for Buildings (BREEAM 2013), Rating System (LEED 2013).

[64] Depending on the certification system, the building features taken into consideration are: use of existing landscapes; use of energy efficient and eco-friendly equipment; use of recycled and environmental friendly building materials; indoor air quality; efficient use of water; use of non-toxic & recycled materials; use of renewable energy; effective controls and building management system; waste management; to name a few.

In order to understand how the building certification methods were developed and adopted by the real estate sector, and to what extent does the building certification methods promote energy efficiency in the housing sector, a comprehensive review of the building certification systems implemented in the international experience was conducted. However, a detailed comparative analysis of the most-commonly adopted building certification systems (see Table 13) in the real estate sector on the international scenario was conducted. The selected certification systems for the comparative analysis are: the Building Research Establishment Environmental Assessment Method (BREEAM) from the UK; the Leadership in Energy and Environmental Design (LEED) from the USA; and the German Sustainable Building Certification (DGNB) from Germany.

Independent Third Party Assessment

Since the nineties, several independent organizations were founded in the search for promoting sustainable buildings (accounting for ecological, economical, and social aspects) by developing implementation strategies in the form of independent certification systems (Eberl 2010). In general, most of these certification systems were created in foundations, in some cases within a joint research-cooperation with local governments (i.e. the Building Research Establishment at an early stage, see BRE 2013), but not depending directly from them.

The interaction between independent organizations and local governments is reflected in the British and German experiences (see the British Building Research Establishment and the German Green Building Council). In both cases, there is a close relationship between the involved actors, where local governments implement building standards obtained through the research conducted by the specialized agencies in several areas of the construction industry. On the other hand, the North American experience raises the perspective of non-profit independent organizations concerned about sustainability in construction (see U.S. Green Building Council). The experiences are reviewed in detail in the following sections.

Nonetheless, it worth mentioning that this strategic position of certification organizations, between the government and the private sector had enabled them to operate as an independent third party evaluator. Therefore, certifications can well be seen as very useful for regulators, because they can provide an independent assessment regarding the building standards achieved.

Building Research Establishment Environmental Assessment Method – UK

The history of the Building Research Establishment (BRE) could be traced back to 1917, when the then Department of Scientific and Industrial Research (DSIR) proposed the creation of an independent organisation to investigate various building materials and construction methods, suitable to use in new housing following the First World War (BRE 2013).

In 1921, BRE was founded in Watford, UK, as an independent research and certification institution subsidiary of the BRE Trust. Since then, the research conducted by this institution has focused on studying and creating different standards for construction materials[65] and certification of processes associated with the construction industry, as the fire prevention in buildings for example (BRE 2013). Thus, the research conducted by BRE has been closely linked to the creation and updating of standards for building construction in the UK. BRE is accredited by the United Kingdom Accreditation Service (UKAS) and brought the first certification systems to the market in 1990 (RICS 2013).

The British Building Research Establishment Environmental Assessment Method (BREEAM) was created by BRE in 1990. At the moment of its creation, it was the first commercially available environmental assessment tool for buildings. Since then, it has been used by many other rating systems as basis for their development (Rivera 2009). According to the BRE Global report (2009) BREEAM is used widely, with over 116,000 buildings certified and nearly 714,000 registered all around the world by 2009 with a growing tendency.

The aims of BREEAM are: 1) To mitigate the negative environmental impacts of buildings; 2) To enable buildings to be recognized according to their environmental benefits; 3) To provide a credible, environmental label for buildings; and 4) To stimulate demand for sustainable buildings (BRE Global 2009, p.9)

BREEAM addresses wide-ranging environmental and sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties. Moreover, BREEAM offers many benefits, including the following: the use of a straightforward

---

[65] According to BRE, the studies on building materials since 1921 included: the behaviour of reinforced concrete in floors and the development of the UK's first standard for construction materials: the British Standard for bricks (BRE 2013).

scoring system; a positive influence on the design, construction and management of buildings; and the definition of a robust technical standard with rigorous quality assurance and certification. Currently, there are available in the market a set of four environmental assessment methods provided by BREEAM internationally; namely: 1) BREEAM International New Construction (NC); 2) BREEAM International Refurbishment; 3) BREEAM In-Use International; and 4) BREEAM Communities Bespoke International (BREEAM 2013).

BREEAM is used for a wide range of formats from various country-specific certification systems, for example: UK, Netherland, Spain, Sweden and Norway, was designed to suit international schemes for the certification of individual projects anywhere in the world. It consists of 10 categories and 59 different criteria for the assessment. Each category has certain weighting for the overall rating and finally the performance of the whole building can be defined[66]. For the purpose of this research, the most relevant category accounted in the assessment is Energy (up to 21 out of 112 possible points), which accounts for: CO_2 emissions, low or zero carbon technologies, energy sub metering, and energy efficient building; (BREEAM 2013).

Finally, the importance of BREEAM in UK is remarkable. BREEAM is behind the implementation of The Code for Sustainable Homes (CSH); an environmental assessment method for rating and certifying the performance of new homes based on BRE Global's EcoHomes scheme. It is a Government owned national standard intended to encourage continuous improvement in sustainable home building (BREEAM 2013).

Leadership in Energy and Environmental Design – LEED

As in the other cases reviewed in this section, the Leadership in Energy and Environmental Design (LEED) assessment system was born under the frame of a non-profit organization. The U.S. Green Building Council (USGBC) was established in 1993 as a non-profit organisation located in Washington D.C. The USGBC aims to promote: construction and sustainable development; technological innovation and certification of sustainable buildings; the efficient use of energy and the use of renewable energy; the

---

[66] These categories are: Management, 10 possible points; Health and Wellbeing, 14 possible points Energy, 21 possible points; Transport, 10 possible points; Water, 6 possible points; Material, 12 possible points; Waste, 7 possible points; Land Use and Ecology, 10 possible points; Pollution, 12 possible points; Innovation, 10 possible points (BREEAM 2013).

efficient use of water; the use of building materials from renewable, recyclable, and non-toxic resources; and to improve the quality of life and health of people and communities. Quickly, the initiative was expanded globally. Since 1998, national Council representatives had met to review global activities and offer support for each other's efforts. This has led to the founding meeting of the World Green Building Council (WGBC) in November of 1999 in California, US, with eight countries in attendance[67]. Moreover, the formal incorporation of the WGBC followed in 2002.

The primary function of WGBC revolves around to the diffusion of GB initiatives internationally, by means of: formalizing international communications; helping industry leaders accessing emerging markets; disseminating best practices worldwide; and supporting GB systems (USGBC 2013).

LEED is an internationally recognized GB certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving the building performance across all the metrics that matter most: energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. Broadly speaking, it is a system for sustainable construction assessment.

Moreover, LEED provides building owners and operators a concise framework for identifying and implementing practical and measurable GB design, construction, operation, and maintenance solutions. LEED is flexible enough to apply to all building types – commercial as well as residential buildings. It works throughout the building life-cycle – design and construction, operations and maintenance, tenant fit out, and significant retrofit. LEED for Neighbourhood Development extends the benefits of LEED beyond the building footprint into the neighbourhood it serves. The first version of the LEED system for new buildings was announced in 2000 (RICS 2013) the last available version is from 2009 (USGBC 2013).

According to USGBC (2013) LEED-certified buildings are designed to: 1) lower operating costs and increase asset value; 2) reduce waste sent to landfills; 3) conserve energy and water; 4) be healthier and safer for occupants; 5) reduce harmful greenhouse gas emissions; 6) qualify for tax rebates, zoning allowances and other incentives in hundreds of cities; and 7) demonstrate owner's commitment to environmental stewardship and

[67] The countries are: Australia, Canada, Japan, Spain, Russia, United Arab Emirates, United Kingdom, and the United States (LEED 2013).

social responsibility. On the other hand, LEED for Neighbourhood Development integrates the principles of smart growth, urbanism and GB into the first national system for neighbourhood design. LEED certification provides independent, third-party verification that a development's location and design meet accepted high levels of environmentally responsible, sustainable development. LEED for Neighbourhood Development is collaboration among USGBC, Congress for the New Urbanism, and the Natural Resources Defence Council.

Finally, buildings can qualify for four levels of certification according to the overall score: Certified: 40 to 49 points, Silver 50 to 59 points, Gold 60 to79 points, Platinum 80 points and above.

The German Sustainable Building Certification – DGNB

The German Sustainable Building Certificate (GSBC) that awards the so-called "*Seal of Quality for Sustainable Building*" was developed by the German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen e.V. or DGNB) together with the Federal Ministry of Transport, Building, and Urban Affairs (Bundesministerium für Verkehr, Bau und Stadtentwicklung or BMVBS). These two institutions developed the certification system which is applied voluntarily. According to ENERBUILD (2009), the GSBC was developed by experts from the complete value chain of the construction and real estate sector and gives a clear orientation for this future-oriented economical sector.

The DGNB was established in 2007 by experts from various disciplines and backgrounds from within the construction industry and real estate sector. The first DGNB certificates were awarded in 2009 (RICS 2013). It is a non-profit organization and it is also a member of the World Green Building Council (WGBC) with members all over the world, including Chile in the Latin-American context.

The aim of the GSBC certificate is to be used as a tool for the planning and evaluation of buildings with a comprehensive perspective on quality. The GSBC covers all relevant topics of sustainable construction and it is meant to be a rating system easy to understand. As in other rating systems, energy efficiency is just one of many other variables taken into account by the certification, as it is analyzed below.

Initially, the 2008 GSBC version was available for office and public buildings; nonetheless, the 2009 version applies to other buildings types like hotels, schools, factories or retail, and – more importantly – housing. In this sense, since 2011 the DGNB together with representatives from the residential building sector, architects, project developers, companies, and other experts from the construction and real estate sectors, developed a specific certification system for residential buildings. The certificate was designed for new buildings with more than six housing units. Nonetheless, the aim is to create a version for smaller residential buildings and single-family housing, in order to address new housing districts. Additionally, in the short-term it is expected that the certification system will be adapted to evaluate existing buildings and not only new (DGNB 2013).

The certificate is based on the concept of integral planning and its goal is to define, at an early stage, the aims of sustainable construction (DGNB 2013). In order to assess how sustainable buildings are, the certificate evaluates six topics, namely: ecology, economy, social cultural and functional topics, techniques, processes, and location. Nonetheless, it worth mentioning that the concerns for energy, in general, and energy efficiency, in particular, are only partially considered within the Criterion N°10 of the certification system called "*Non-Renewable Primary Energy Demands*" and Criterion N°11 named "*Total primary energy demands and proportion of renewable primary energy*"; altogether accounting just for 20 points out of 490 available points. In this sense, energy efficiency assessment is not the main goal pursued of the GSBC, but it will provide valuable information on this regard.

Therefore, the DGNB assesses buildings and urban districts that demonstrate an outstanding commitment to meet sustainability objectives. The sustainability concept of the DGNB system is based on three-pillar sustainability model (ecological, economical, and social aspects). It covers key aspects of sustainable building, namely: environmental, economic, socio-cultural and functional aspects, technology, processes and site. The first four quality sections have equal weight in the assessment. This means that the DGNB System is the only one that gives as much importance to the economic aspect of sustainable building as it does to the ecological criteria. The assessments are based on the entire life-cycle of a building. Nonetheless, the focus is always also on the wellbeing of the user. Therefore, the DGNB does not assess individual measures but instead the overall performance of a building or urban district. The DGNB differs from other assessment systems through its holistic international approach – it is can be applied internationally. Since the system can easily be adapted to the climatic, constructional, legal and cultural peculiarities of other countries, the DGNB is in a position to certify worldwide. The aim of achieving high quality remains in place in all cases.

From a critical point of view, Münch (2009) argues that the GSBC is remarkably much more based on quantitative measures and making use of the life-cycle approach, than other assessment methods on the field. Moreover, the author claims that the certification process requires considerable effort to verify and, therefore, criticism from opponents maintains the method is way too complex and it can only be applied on high-budget projects where external expertise can be afforded.

Finally, this scheme provides a similar category weighting as the British BREEAM but it is additionally based on a weighting system for each criterion. Each criterion can receive a maximum of 10 points. At the same time, it is possible to increase the weighting of each criterion. Buildings can be qualified in 3 categories: 50% bronze, 65% silver, 80% gold.

Comparative Analysis

Table 14 summarizes the comparative analysis of the certification systems adopted in the housing market worldwide.

The overall aims pursued by the certification systems are similar: all of them aim to perform a sustainability assessment over their entire building's life-cycle. Moreover, the certification systems are not only concerned on the stand-alone building or housing unit, but they also deal with multi-family housing buildings or urban districts, regardless of the existing different building uses and building types. The latter, has widen-up the range of existing certifications and increased the flexibility of assessment methods.

Since each of the certification systems has a proper understanding of what sustainability means in construction, the different weightings on each system clearly express the sustainability approach of each of the systems. Likewise, the concern for energy in the overall assessment systems makes itself clearly expressed in the different weightings and corresponding sub-sections. On one hand, BREEAM and LEED certifications, the energy variable is integral within the sustainability concept. On the other hand, in DGNB system energy efficiency is part of the Environmental Quality – Resources and Waste section.

Table 14: Comparison of BREEAM, LEED, and DGNB Certifications.
(Source: Own compilation based DGNB 2013; BREEAM 2013; and USGBC 2013)

	BREEAM	LEED	DGNB
Launch Date	1990	1998	2008
Goals	To develop tailor-made systems for every type of building and use over the building's entire life cycle. In addition to the standalone building certificate, city districts, users, and companies can also become certified.	To get people to redefine how they think about the impact on the entire life cycle of the buildings in which they live, work, and learn. Identifying and implementing practical and measurable GB strategies for planning, construction, and operation.	To develop occupancy profiles for every type of building and use over the entire life cycle of the building, both for national as well as international application. Individual buildings as well as city districts can become certified.
Ratings	Pass /Good/ Excellent/Outstanding	Certified/ Silver/Gold /Platinum	Bronze/ Silver/ Gold
Weightings	Management Health and Wellbeing Energy Transport Water Materials Waste Land Use and Ecology Pollution Innovation	Sustainable Sites Water Efficiency Energy and Atmosphere Indoor environmentally Quality Innovation Design Regional Priority	Ecological Quality Economical Quality Socio-cultural and Functional Quality Technical Quality Process Quality Site Quality (extra)
Information Gathering	Design/Management Team or Assessor	Design/Management Team or Accredited Professional	Design/Management Team or Accredited Professional
Certification Labeling	BRE	USGBC (United States Green Building Council)	DGNB (German Sustainable Building Certificate)
Update Process	Annual	As Required	N/A
Governance	UK Accreditation Service (UKAS)	USGBC	DGNB

Finally, each system uses a different rating scheme. Therefore, comparability between certification systems and standards is not straightforward. Furthermore, the ratings of each certification system corresponding to a range within which the subject building is located according to the points obtained in the evaluation. In connection therewith, Nelson et al. (2010) argued that, a global agreement upon standards and measurements for GB and certification systems is missing. According to the authors, the climatic and historical differences could partially explain the lack of a global agreement. More comparability would improve transparency in the real estate sector and could make informed choices and quicker adoption of GB easier (Nelson et al. 2010, pp.3–4).

Criticism to Green Building Certification Systems

Recent evidence in the scientific and specialized literature has thrown into question the real benefits accrued by GB certification holders. Although the analysis and criticism focuses on LEED-certified commercial buildings, the criticism also cast doubt on other certification systems and building types. The scientific evidence focus on LEED certifications mainly because to two main reasons: first, the availability of reliable scientific data; and second, the wide dissemination of the LEED certifications around the world, which has aroused the interest of the scientific community and practitioners more than BREAM, DGNB, or other certifications systems, that are less widespread as shown in the previous section.

A significant body of diverse criticism can be found in the work of Lstiburek (2008). According to the author, in 2008 the U.S. Green Building Council (USGBC) wanted to see how well LEED-buildings were performing on energy compared to regular buildings. A comparative analysis of two datasets was conducted; first, the New Buildings Institute (NBI) was asked to do the analysis for the USGBC; and second, the information on regular buildings was provided by the Commercial Building Energy Consumption Survey (CBECS). The findings were reported by Turner and Frankel (2008); the report is called: "Energy Performance of LEED for New Construction Buildings".

Based on this Turner's and Frankel's report, Lstiburek's work plotted the two data sets, NBI–LEED data against CBECS 2000–2003 data, and noted that the two distributions looked pretty much the same. This showed that LEED buildings did not conclusively save energy compared to typical buildings built at the same time (Lstiburek 2008).

Nonetheless, Lstiburek's main criticism does not refer to the LEED system itself, but to the local standards on which certification systems are based. Thus, what is critical is that certification systems taken as "floor" the minimum values of local regulations, for example the local building codes use ANSI/ASHRAE/IESNA Standard[68] to establish a "floor" or minimum for energy performance; which is taken up by LEED. Therefore, what is being

[68] ANSI/ASHRAE/IESNA Standard 90.1-2007. Energy Standard for. Buildings Except. Low-Rise Residential. Buildings. Approved by the ASHRAE Standards (See ASHRAE 2013)

certified is the compliance with the minimum requirements defined by the local building code (Lstiburek 2008). Moreover, all those considerations are not taken into account by local regulations, through building codes and/or energy codes (i.e. such as the air-tightness of the buildings' envelope) are not considered by the certification systems; meaning, no points are received for making such improvements. In the same line, Maldonado (2011) argues that, according to specialists in the application of GB certifications, if all the points considered in the certification system weigh the same, applicants will only choose those with lower implementation-cost, regardless the benefit they may have on the environment or the energy savings generated. This is the case of the bicycles parking, for example, where there is just requested to paint a few extra lines to get the points.

Based on the same data set (NBI/USGBC LEED-certified buildings and CBECS commercial building stock), two correlative studies analyze, compare, and discuss the energy-consumption of LEED buildings in the stock of commercial buildings in the United States. Both studies provide critical results regarding a fundamental question: "*Do LEED-certified buildings save energy?*"; while Newsham et al.'s answer is "*Yes, but...*", Scofield's answer is "*Not really ...".*

On the one hand, Newsham et al. (2009) published a re-analysis of energy-consumption data for LEED-certified commercial buildings supplied by the New Buildings Institute (NBI) and US Green Building Council. They concluded that: first, on average, LEED buildings use 18−39% less energy per floor area than their conventional counterparts, consistent with and adding clarity to conclusions originally reached by NBI; second, 28-35% of LEED buildings used more energy than their conventional counterparts; and third, The measured energy performance of LEED buildings has little correlation with certification level of the building, or the number of energy credits achieved by the building at design time (Newsham et al. 2009, p.904).

On the other hand, Scofield (2009) criticizes Newsham et al.'s work (2009) and argues that Newsham et al.'s conclusions hang on a particular definition of the mean energy intensity of a collection of buildings that is not related to the total energy used by those buildings. Furthermore, site energy considered by Newsham et al. and NBI, unlike source energy used for the EPA's building Energy Star rating, does not account for the energy consumed off-site in generating and delivering electric energy to the building, whose inclusion is crucial for understanding greenhouse gas emission associated with building operation. Here I demonstrate that both the site energy and source energy used by the set of 35 LEED office buildings and Newsham et al.'s matching CBECS office buildings are statistically equivalent. Hence, Scofield (2009) argued that Newsham et al. offered no evidence that LEED-certification has collectively lowered either site or source energy for office buildings. Finally, Scofield stated that this should worry those concerned with national energy policy and global climate change (Scofield 2009, p.1390).

A frequent criticism leveled at the LEED-certification program is that the lower certification standards, particularly the 'certified' level make no serious contribution to tackling climate change and other environmental problems, and instead may lead to complacency on the part of owners having achieved LEED certification albeit at the lowest level (a phenomenon called 'green washing' by eco-certification critics). Advocates of the LEED system emphasize, however, that certification standards have evolved considerably over the last years to accommodate more stringent and effective standards regarding the environmental performance of a building. In the context of this debate, it is interesting to note that the number of buildings certified at the lowest level has steadily decreased over the ten years since the inception of LEED, reaching its hitherto lowest level in 2008 (Figure 4). Conversely, the shares of gold-and silver-certified buildings have significantly increased whereas the share of platinum has remained relatively stable over time. This may be taken as an indication of generally lower public acceptance of 'barely green' buildings and/or more ambitious goals set by organizations seeking certification (Fuerst 2009, p.290).

A further point of criticism concerning eco-certification programs is that they are 'big government' initiatives disguised as market-oriented, industry-led organizations. Opponents of eco-certification argue that both the supply of and demand for eco-certification predominantly originates from the public sector and that there is no evidence of a "green" business case in the real estate and construction industries (Fuerst 2009, p.292).

Apart from the recent studies indicating that eco-certified programs do indeed achieve rental, price and occupancy rate premia, the share of corporate clients and real estate developers seeking LEED certification has increased steadily since its inception. Figure 6 provides an analysis of clients seeking LEED certification by type of organization. The share of real estate developers and corporate clients has increased considerably from 46 per cent in the 2000-2002 to 60 per cent in the most recent 2006-2008 period. The growth of the share of real estate developers from 3 to 26 per cent is particularly encouraging as this indicates that certification appears to be seen as a valuable investment by an increasing number of developers. Given the exponential growth of certified buildings described above, this trend becomes even more impressive when considered on an absolute basis (that is, number of projects certified for real estate developers in each period) (Fuerst 2009, p.292).

4.4 Regulatory Instruments in the Chilean Context

The concern for implementing energy efficiency requirements in Latin America began in the nineties (Rozas 2002). Thereafter, several research and international cooperation agencies have reviewed the Latin American situation[69] in order to analyze the state of the art of National Energy Plans in their close relationship with the implementation of renewable energy (see Altomonte et al. 2003; Carpio et al. 2009; Horta 2010). In this context, Rozas (2002) argues that in most of the cases, this process assigns an active and participatory role to the State and designing energy efficiency is an inalienable right of citizens must be guaranteed by the State. Moreover, according to the author, this central premise is based on the fact that in most of the Latin American constitutional frameworks, it is stipulated that the natural resources, renewable or not, are a national heritage and that within this legal requirement for the State to define the preservation policies and the sustainable use of natural resources, while at the same time protecting the environment (Rozas 2002, p.10).

In this sense, energy production and energy end-use are central to consider national strategies for achieving sustainability, in a context of increasing energy demand; especially in developing countries where the growth of energy demand appears to be correlated with economic development (see the Brazilian experience as an example). This scenario is reflected in the Chilean case, where residential energy consumption, as the other economic sectors, has shown a steady growth (Marshall 2010).

4.4.1 Energy Efficiency in the National Energy Policy Making

According to Janda (2009), Chile is the first country in the Latin American context that has mandatory energy efficiency regulations for new residential buildings implemented in the building code, as shown in the Figure 17.

Other countries in the region have other voluntary initiatives, usually immersed in programs emerging jointly by the public and private sectors (i.e. Brazil and Argentina). However, these initiatives are either not mandatory or affect non-residential buildings. For example, Argentina has not adopted regulations at the building level; instead – as 26

[69] The most important are: the Economic Commission for Latin America and the Caribbean (Comisión Económica para América Latina y el Caribe or CEPAL); the Latin American Energy Organization (Organización Latinoamericana de Energía or OLADE); and the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH or GIZ.

other countries – it had adopted the Collaborative Labelling and Appliance Standards Program (CLASP) which implies participating in standards and labelling activities for appliances (Janda 2009, p.2299).

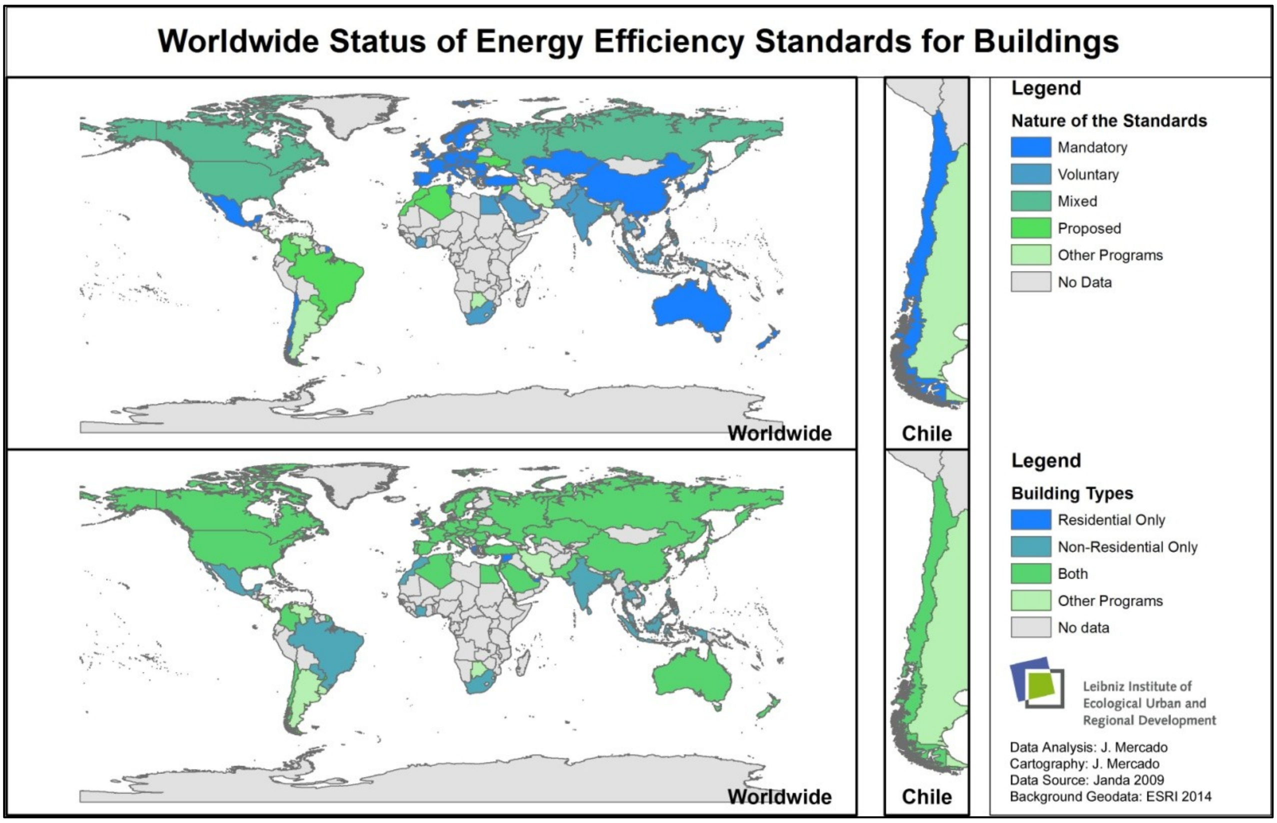


Figure 17: World Status of Energy Standards for Buildings
(Source: Own illustration based on Janda 2009)

Systematic and structured search for EE in the Chilean policy-making started when trying to cope with country's energy needs, characterized by a strong dependence on fossil fuels for energy production (see section 2.3). Therefore, it seems that external factors – such as international agreements or the need to reduce CO_2 emissions – had played a less relevant role than internal factors in the Chilean experience on implementing energy efficiency standards for new buildings. Nevertheless, this could change in the short term because of Chile's recent inclusion in the OECD which defines higher standards for all member countries (see Carpio et al. 2009).

Recently, there has been a growing interest in reducing the energy consumption and the associated greenhouse gas (GHG) emissions on all sectors of the economy. The energy consumption in the residential sector accounted for over 24% of the total energy consumption in Chile in 2008 (Marshall 2010). Although this figures are not as high as in other countries[70], most of scientific literature and institutional research focuses on different modelling techniques to assess the energy consumption in the residential sector (i.e. see Vera and Ordenes 2002; Encinas et al. 2009); in accordance with the international research trend (i.e. see Hass 1997; Swan and Ugursal 2009). In any case, the raising concerns in relation to government procurement, and the preservation to energy resources are similar (Pérez-Lombard et al. 2009).

In Chile, the overall EE concern emerged from the State, where Chile has several government institutions working to achieve higher levels of EE[71]. The body directly responsible for promoting, developing, and implementing EE policies and programs is the National Energy Commission (Comisión Nacional de Energía or CNE). One of the most important recently approved policies is the creation of a Ministry of Energy in 2009, an entity that will centralize the functions of developing, proposing, and evaluating public policies in this area (see APERC 2010). As a part of the establishment of the new Ministry, the Chilean government also created the Chilean Energy Efficiency Agency (Agencia Chilena de Eficiencia Energética or AChEE), a public-private organization in charge of the implementation of the energy efficiency programs; with the overall goal to contribute to the sustainability of Chilean energy development (APERC 2011).

According to CNE, EE is understood as “a set of actions that reduce energy consumption, without neglecting the ability to achieve higher profits with fewer resources with the least impact on the environment” (SERNAC 2005, p.12). This definition was inspired in the World Summit on Sustainable Development in Johannesburg in 2002, and the submission of The Kyoto Protocol, in 1997; taking into account both, the sustainable development goals and the world-leader’s commitment to limit and reduce emissions of GHG responsible for global warming. Furthermore, EE concept in the Chilean context aims to reduce energy consumption by improving productivity levels for the provision of certain goods or services (CNE 2005).

[70] Where the energy consumption of the housing sector is by far the greatest share of total energy consumption, ahead of transport sector and industrial production (i.e. over 40% in Europe according to BMWi 2014)

[71] Namely: Chilean Energy Efficiency Agency (Agencia Chilena de Eficiencia Energética, or ACHEE); Renewable Energy Center (Centro de Energías renovables, or CER); Chilean Nuclear Energy Commission (Comisión Chilena de Energía Nuclear, or CCHEN); National Energy Commission (Comisión Nacional de Energía, or CNE); Electricity and Fuels (Superintendencia de Electricidad y Combustibles, or SEC).

In order to achieve this goal, the proposed action lines aimed to improve EE are three fold: 1) technological improvements; 2) changes in the energy use patterns; and 3) improving the economic efficiency of production processes (SERNAC 2005). While the definition of EE coined at the CNE reflects the national concern about the use of the scare energy resources, the concept is very broad and has certain weaknesses; mainly, the definition of clear goals for all sectors of the Chilean economy, in terms targets for the short and medium terms, are missing.

4.4.2 The Institutional Framework

Chilean National energy policy, since the late 1970s, has been structured around two central pillars: economic efficiency and the subsidiary role of the state (APERC 2011). Following the 2004 Argentine gas crisis and the 2007–08 electricity shortage, the Chilean government developed a new long-term energy policy. The government, through the CNE, published new energy policy guidelines in 2008, which set out six energy priorities[72] (CNE 2008).

The general approach to EE changed in 2005, when the government began to develop an Energy Efficiency Policy and included it as one of the central elements in its strategic priorities for energy (OECD-IEA 2009). This was reflected in the inclusion of EE as one of the central elements of the government's energy policy, and the creation of the National Energy Efficiency Program (Programa País de Eficiencia Energética, or PPEE). In the year 2005, the Chilean government organized and brought together a group of public and private stakeholders and places the Ministry of Economy, Development and Reconstruction in charge of starting up and implementing the PPEE. Currently, PPEE is the main mechanism whereby the Government of Chile’s energy efficiency policy and programs are developed and implemented. To develop PPEE, a committee was created including representatives from the most relevant State institutions, the private sector, local governments, and civil society. Thus, the PPEE Commission was created by a supreme decree signed by the ministers of Economy and Energy; the Secretariat General of the Presidency; Public Works; Transport and Telecommunications; Education; Housing and Urbanism; and Mining (see APERC 2011).

[72] The energy priorities set out by the CNE are: 1) strengthening institutions, 2) promoting energy efficiency, 3) optimizing diversification, 4) ensuring sustainable development, 5) supporting equal access, and 6) contingency planning (CNE 2008).

With the aim of strengthening the organisation of the energy sector in Chile, a bill to create the Ministry of Energy (MINEN) was presented to the Chilean Parliament in 2008, and was approved in November 2009. In February 2010, the new MINEN started working. It centralises the functions of developing, proposing, and evaluating public policies in the area of energy, including the definition of objectives, the regulatory framework and strategies to be applied, and the development of public policy instruments (APERC 2011).

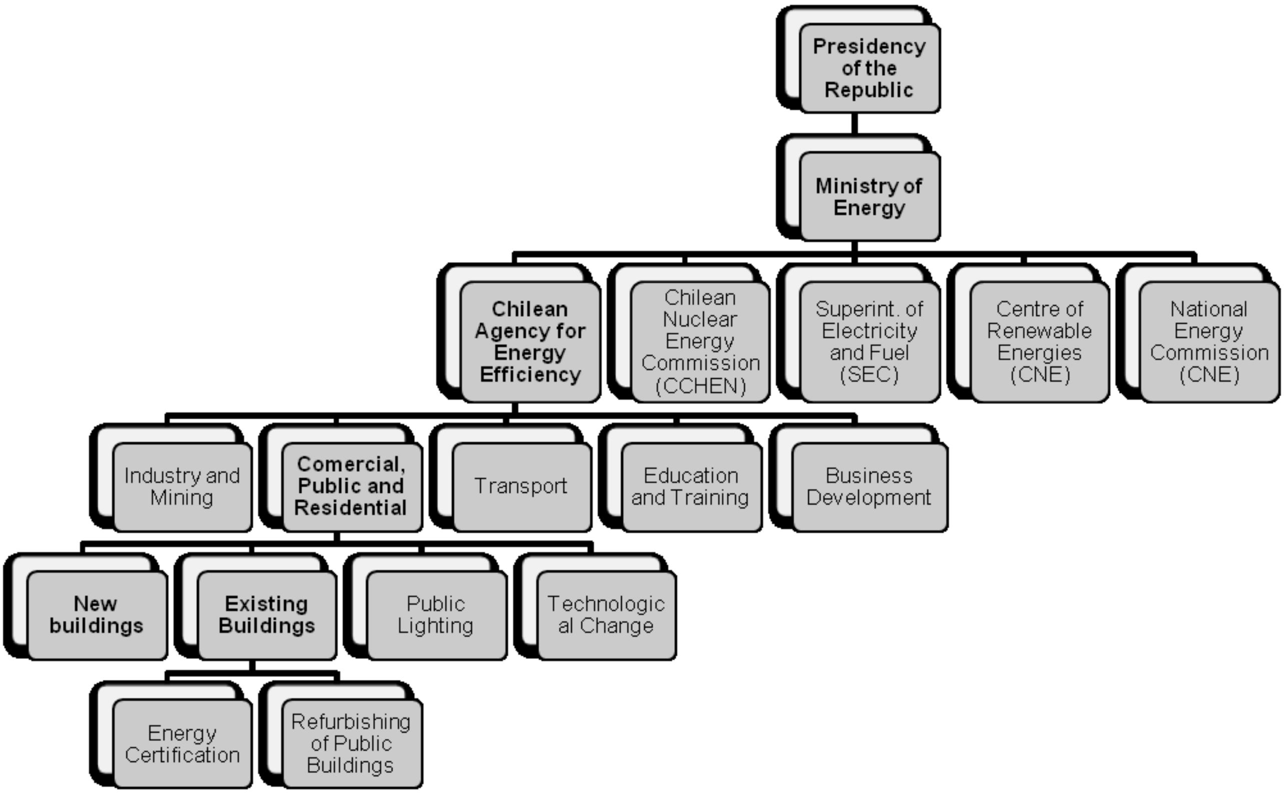


Figure 18: The Institutional Framework of the Energy Sector
(Source: Own illustration based MINEN 2013)

All public services in the energy sector are now overseen by the MINEN, including the CNE, the Superintendence of Electricity and Fuel (Superintendencia de Electricidad y Combustibles or SEC), and the Chilean Commission on Nuclear Energy (Comisión Chilena de Energía Nuclear or CChEN). In 2010, the MINEN created two important institutions: the Renewable Energy Centre (Centro de Energías Renovables or CER) and the Chilean Energy Efficiency Agency (Agencia Chilena de Eficiencia Energética or AChEE). At the same time, the MINEN is responsible for developing directives and policies, for delegating the functions related to: implementation of policies and instruments to other organisations which are not directly subordinate to the MINEN but are closely connected to it (see Figure 18). These public institutions will be responsible for implementing national programs and specific work plans, technical regulation, enforcement, and many other functions related to policy implementation. The activities of these agencies are integrated with other government agencies, and also involve public–private cooperation (APERC 2011, pp.35-36).

Under this institutional framework, is worth noting that the AChEE, a public–private organisation (a foundation), was designed as a joint corporation in where the State and the private sector will participate. In this sense, the decision making it is shared between energy users and promoters of efficient use of energy. This model of public-private participation is used in various countries around the world (such as the United Kingdom and Germany) where the experience has been successful. It is based on the existence of a common interest of the State and private parties in energy efficiency (APERC 2009).

The public-private nature of the AChEE is consistent with what was proposed in the government modernization agenda. Its structure seeks to include a board of directors with various key stakeholders in the area of energy efficiency (EE); contributing in this way to the efficiency and transparency for energy users and for the general public. AChEE functions are centred on activities with a comparative advantage, such as technical assistance and the implementation of programs which require logistical expertise and flexibility for action.

The mission of AChEE is to consolidate EE in a way that contributes to Chile's sustainable energy development. This mission is achieved by following the AChEE strategic objectives are: 1) to establish the institutional foundations and regulatory framework for energy efficiency; 2) to develop incentives and support tools for energy efficiency; 3) to develop useful and accessible information for public and private decision-makers, as well as collective and individual ones; 4) to position and introduce energy efficiency in all levels of training, both formal and informal; 5) to take advantage of international experiences and instruments to accelerate the development of energy efficiency and measure the reduction of GHG emissions; and 6) to strengthen institutional management through quality control processes (ISO).

Although the Chilean government's approach for promoting EE has changed over time, there has not been a priority, nor have they been included in State policies (APERC 2009). Until a few years ago, the main instrument for the government to encourage EE was to ensure that energy pricing mechanisms were as efficient as possible. The main focus was that a competitive market and fully cost-reflective energy prices would result in an optimally efficient use of energy (see OECD-IEA 2009). Moreover, the Chilean government made occasional attempts to promote EE through the implementation of specific measures; Namely: the implementation of the Conservation and Rational Energy Use Programme (Programa de Conservación y Uso Racional de la Energía or CUREN) and the implementation of subsidies to supply energy-saving light bulbs to lower income population on 2008. Nevertheless, the implementation of such measures was not long-lasting and did not have a significant effect (see OECD-IEA 2009, APERC 2009).

Apparently, the prospect of the Chilean government from implementing energy efficiency measures has sought to let the market take care to take the initiative in implementing EE measures. The evidence suggests that this has not been the case. Therefore, other key players involved in the Chilean context have been protagonists in the dissemination of the initiatives. The main interest and actions towards encouraging EE came from the non-governmental sector and the scientific community; namely: the Programme of Research in Energy at the Universidad de Chile; international institutions working in the Chilean context, like the German Society for International Cooperation (GIZ) and the Economic Commission for Latin America (CEPAL); certain energy-intensive companies like the National Copper Corporation (CODELCO) and other institutions (see APERC 2009).

Among other initiatives, Chile has established a product labelling program equivalent to the European comparative labelling scheme, this breaks-down all similar models of a product into one of seven efficiency categories: A (most efficient) through G (least efficient). Product labelling is currently applied to five lines of products in Chile[73], with another five to six planned for to be implemented in 2011[74] (APERC 2011). Products under this initiative are mostly residential applications. In the near future, it is expected to extend the labelling program to small commercial applications.

[73] Incandescent and compact fluorescent light bulbs, one- and two-door refrigerators, and microwaves.
[74] Motors, heating, ventilating and air-conditioning, housing, automobiles, television sets, and decoders.

4.4.3 Energy Efficiency Standards in the Chilean Housing Sector

For over thirty years, many developed countries have established strict energy efficiency (EE) regulations and progressive energy demands for buildings trough the building codes; as well as on the thermal behaviour of the envelope elements of residential and non-residential buildings, indoor air quality, and the efficiency of heating equipment (Janda 2009). Nowadays, the worldwide energy demands in the housing sector are assessed trough mandatory certification systems in order to regulate the maximum energy demands for buildings. This process enables the delivery of relevant technical information in a useful and clear language for the entire population (MINVU 2009).

Following an international trend that started in the 80s, when governments in both industrialized countries and the global south have initiated policies to reduce energy consumption in buildings (Janda 2009), and the strategic policy making in the field of EE within the Chilean context, the Ministry of Housing and Urban Development (MINVU) incorporated EE demands for new residential buildings into their building codes and other EE related incentive programs since 1994. The main objectives were threefold: 1) to improve people's quality of life through better dwelling's thermal comfort and the implied benefits (higher livelihood, better health, less pollution, and greater housing durability); 2) to optimize and / or to reduce fuel consumption for housing heating and cooling; and 3) to promote and encourage applied research on the field of EE from different perspectives, namely the productive process, the industrial process, and the academic research (MINVU 2009). Moreover, in order to accomplish the above-mentioned objectives, a regulatory strategy has been defined following three sequential actions: 1) to decrease housing energy demands to the minimum possible; 2) to use and optimize housing internal and external heat gains; and 3) in the case of requiring housing heating or cooling systems, to use clean, efficient, and low cost systems (CDT 2010). The listed objectives and actions to implement them are simple and practical guidelines, supporting national and international standards in technical, social, and economic terms (MINVU 2009)

The implementation of specific EE standards in the Chilean residential sector is relatively new. They are twofold: the Chilean Normative (Norma Chilena, or NCh) and the General Ordinance of Urbanism and Constructions (Ordenanza General de Urbanismo y Construcciones or OGUC). The main difference between them is that compliance with OGUC is mandatory, since it is equivalent to the building code in other countries, and compliance with NCh is voluntary, because it is a set of best practices guidelines and recommendations for the energy requirements for households' appliances, mainly (see Annex B).

Nevertheless, Chile claims to be the first Latin American country that has incorporated into its building codes the requirements for thermal conditioning for all new dwellings, as part of a policy to improve people's quality of life, beyond current comfort conditions and low housing energy demands achieved in developed countries. According to the MINVU, it can be ensured that the progress in this area will allow living in better and more sustainable way (MINVU 2009). Already in 1996 the MINVU established a Regulatory Programme on Housing Thermal Conditioning, also known as New Thermal Regulations (Nueva Regulación Térmica or NRT); this programme consists of the implementation of three consecutive stages (MINVU-IC 2006; MINVU 2009).

As shown in the Table 15, the first two stages of the NRT were defined from a prescriptive approach, since they set a minimum requirement for each building component. In contrast, the third stage, related to residential energy rating, it is defined from a performance-based approach (Encinas et al. 2009). The third stage of the NRT is approached form a user-oriented perspective. It is intended that home owners – and/or prospective homebuyers – are able to find out about the energy performance of the dwelling, by means of an energy performance rate. A certificate should be issued by a competent and impartial third-party energy certifiers listed in the official records of the MINVU. The overall aim of the third stage of the NRT is to enable the end-user to have a better judgment when choosing among the broad offer of real estate products and take an informed decision in favour of energy efficient housing.

Table 15: Stages of the New Thermal Regulations for Residential Buildings in Chile (Source: Own compilation based on MINVU-IC 2006; MINVU 2009, MINVU 2013b)

Stage	In force since	Approach	Key issues
1st	2000	Prescriptive	Thermal Transmittance of the Building's Roof
2nd	2007	Prescriptive	Thermal Transmittance of the Building's Exterior Walls and Ventilated Floors; Maximum Glazing Surface
3rd	2013	Performance-based	Energy Rating System

The objectives of the first two stages of the NRT are twofold: first, to reduce the current housing energy consumption to the minimum; and second, to utilize and optimize internal and external energy gains (CDT 2010).

In March 2000 the first stage of the NRT came into force, while the second one in January 2007, both through amendments to the Article 4.1.10 of the General Law of Urban Planning and Construction (Ley General de Urbanismo y Construcción or LGUC).

The second stage of the NRT was implemented following the guidelines provided by a technical committee comprising: government institutions responsible for the policymaking in both energy and construction sectors, research institutions and the academia, and private sector's stakeholders. The second stage of the NRT defines the thermal transmittance of exterior walls and ventilated floors, and the maximum glazing surface (see MINVU-IC 2006).

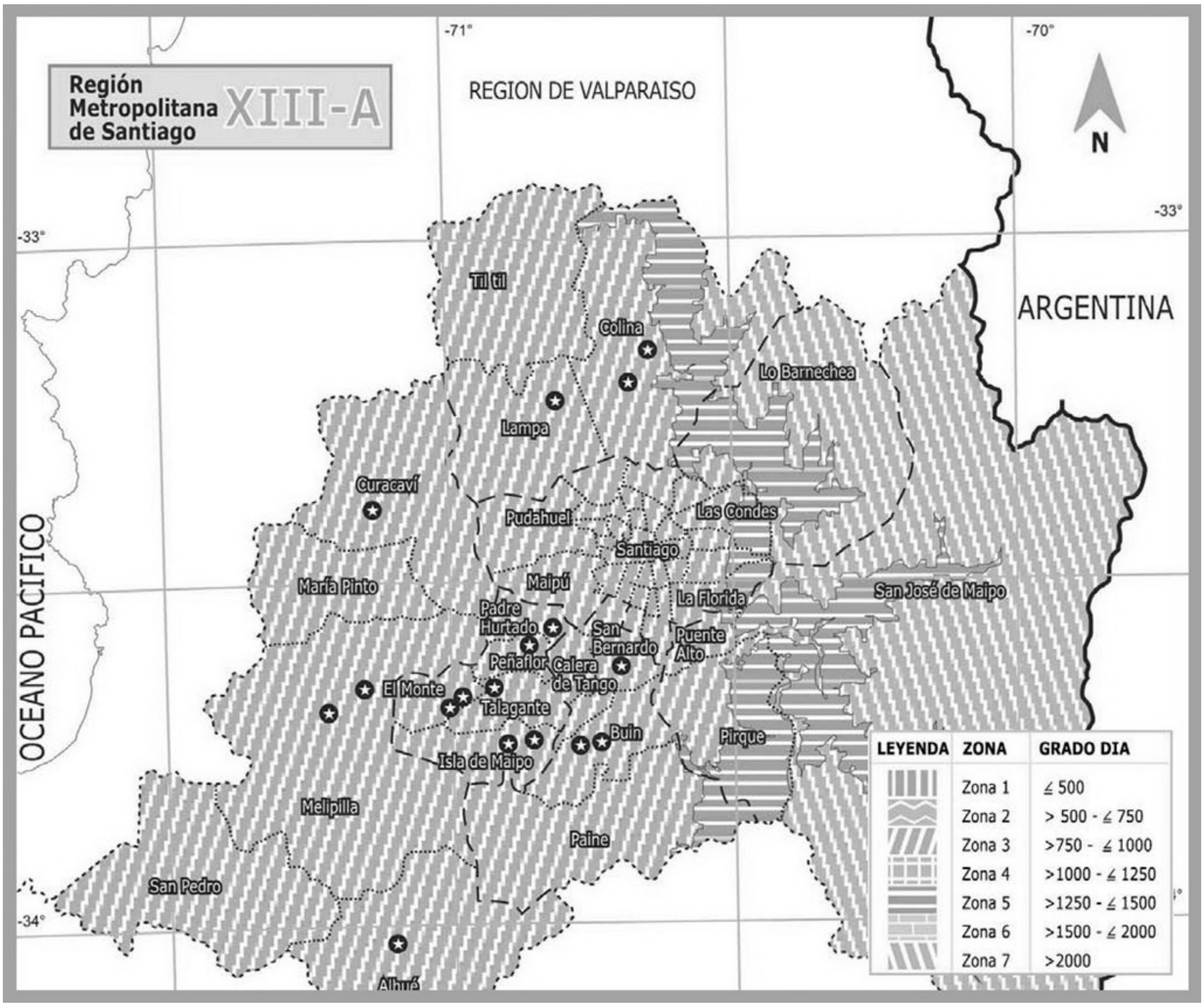


Figure 19: Thermal Zoning Map – Metropolitan Region of Santiago.
(Source: MINVU-IC 2006)

However, the definition of thermal requirements for the elements of the building envelope in the Chilean territory has been laborious. The greatest difficulty lies in two main factors: 1) the geographical aspects of the Chilean territory, and 2) its location on the South American continent. The Chilean territory has a unique elongated shape, with 4,329 km long and an average width of only 180 km (UCh 2013). Moreover, the natural borders of the Chilean territory are La Cordillera de Los Andes to the east and the Pacific Ocean to the west. Given these the abovementioned conditions, the climate system – with its atmospheric, oceanic, and terrestrial components – is extremely complex (DGF 2006). Therefore, since the climatic variations throughout the country are considerable, the thermal requirements for the elements of the building envelope in the Chilean territory are defined based on a Thermal Zoning Map (Mapa de Zonificación Térmica or MZT) which divides the Chilean territory in seven thermal zones, as described in Figure 19.

The MZT was defined in 2006 based on the Heating Degree Day (HDD) method, which is derived from measurements of outside air temperature for a given period of time. The HDD method is commonly used to reflect the demand for energy needed to heat a building. Moreover, the heating requirements for a given structure at a specific location are considered to be directly proportional to the number of HDD at a given location. In contrast, the Cooling Degree Day (CDD) method reflects the energy consumption required to cool the building structure and living spaces in order to maintain a comfortable indoor temperature (see MINVU-IC 2006).

Since 2000, the compliance with the NRT for all new residential buildings in the Chilean territory is required by the Municipal Works Department (Dirección de Obras Municipales or DOM) in every municipality, all over the country. In this way, concepts regarding housing thermal insulation are introduced in the field of architects, builders, and realtors, generating knowledge about insulation of building elements, its application regulated by the DOM.

The third stage was originally designed to require that the dwelling energy demand, on the design phase of the building process, would be equal or lower than the energy demand of a reference building with similar characteristics. Thus, the individual values of thermal conditioning of each one of the building's elements will meet the thermal conditioning requirements for each element of construction described in the previous stages. In order to assist housing owners and practitioners to calculate the dwelling's energy demand, software (called CCTE_CL V2) was developed by MINVU and it is available (MINVU 2009).

Nonetheless, since it was conceived in 2000 until its entry into force in 2013, the third phase of the NRT – also known as Housing Energy Rating (Calificación Energética de

Viviendas or CEV) has undergone two major changes. First, it was thought to be implemented in mandatory basis to all new dwellings; nowadays it is implemented in voluntary basis. Second, it has changed from being a housing energy performance certification system to a housing energy rating system (see MINVU 2013b). This change implies that the provision of a document certifying the energy performance of housing, as part of the transaction documents when sailing a dwelling, it is not mandatory anymore. The latest has two main implications; firstly, it implies that the provision of information to the homeowners or tenants is not longer promoted by the Estate, in contrast to the worldwide trend (see section 4.2 of this doctoral thesis); and secondly, somehow it promotes conventional housing construction, meeting the minimum standards defined by the regulations, limiting innovation and wider adoption of energy efficient housing.

The CEV implies the fulfilment of two consecutive types of energy performance certificates: first, a provisional certificate for the architectural design on the design stage of the dwelling; and second, a certificate of completed building once the construction of the building is finished. The certificate of architectural design indicates the energy performance score obtained by the dwelling on the design phase; it has a provisional character since it is valid just during the construction of the building. It is determined based on the architectural plans, technical specifications, and architectural specialties for hot sanitary water and heating, ventilation, and air conditioning systems. The completed building certificate, it is the final and definitive housing energy performance certificate; it describes the dwelling's final energy rate. The project is rated according to the plans and final technical specifications (as it was built) and additional documentation as described in the Handbook on Implementation of Thermal Regulations issued by the MINVU (see MINVU-IC 2006). The result is expressed in indicators ranging from "A" to "G·, being "A" the best rating. Additionally, in order to obtain scores for A+ and B+, a measurement of infiltrations should be performed, by applying a pressurization method (MINVU 2009, p.20; MINVU 2013b).

In line with the international standards in the field of residential EE (see GreenGlobes 2013; BREEAM 2013; DGNB 2013), the focus of the third stage is to create the an energy rating of dwellings, which is a formal procedure MINVU intended to be applied to all new housing buildings in Chile. As a result of this procedure, the Energy Rating Manager Institution, representing the MINVU, issues a certificate that assess certain parameters to describe dwellings' energy use. Although its application is voluntary, is necessary to meet the full rating procedure in order to obtain the official certificate. The purpose of the certification procedure and housing labelling is the promotion of EE by providing objective information from developers to homebuyers. Thus, homebuyers will be able to find out the building's energy performance. In this way, a comparison between buildings with different energy behaviours is possible (MINVU 2009, MINVU 2013b).

Moreover, following the international experience, the main guidelines related to EE in the Chilean housing sector are focused on improving the thermal quality of low-income new and existing housing, and to increase the EE of domestic appliances. Among other initiatives, a periodic review of thermal standards for housing will be conducted, extending these standards to other areas of the construction industry (MINVU 2013b). An important work in coordination with the MINVU has been done resulting on the implementation of several initiatives in the field of EE. Such initiatives have been recently launched, namely: a voluntary energy rating programme of dwellings; several subsidy programs for thermal renovation of 10,000 existing low-income housing units between 2009 and 2010, and the construction of 400 new low-income housing units' standards even further than the current thermal standard (Carpio et al. 2009).

Finally, it is fair to believe that the implementation of thermal regulations for residential buildings has already generated benefits for the households, because it is quite likely that thanks to the NRT, some improvements have been made in the new housing units (i.e. better insulation in roofs since 2000 and for walls, windows and floors ventilated since 2007), especially when compared with conventional housing units built before 2000. Moreover, the success of the information instruments, like CEV, in raising homeowners' awareness on the dwelling energy performance is yet to be seen. Nevertheless, there are a large number of housing units without the adequate thermal insulation, because before the implementation of the NRT there were no regulations that required meeting the minimum thermal resistance in the envelope. According to the CDT, by 2010 74% of dwellings were not entitled to any thermal requirement, which represents all dwellings built before 2000. Moreover, only 19% of the building stock, the dwellings built between March 2000 and February 2007, comply with the First Stage of Thermal Regulation (CDT 2010). Therefore, there is a large share of the existing housing stock that does not comply with any stage of the NRT; these dwellings may improve their thermal insulation with the support of subsidy programs held at the AChEE.

4.5 Voluntary Instruments in Santiago de Chile

4.5.1 Existing Certification Schemes

Although in the Chilean context there are some non-governmental institutions currently offering, developing, and providing green buildings certifications (i.e. the *IC- Sustainable Building certification* from the Construction Institute), the international certification systems (globally recognized and detailed analyzed in section 4.3.2), have been broadly adopted by the local real estate market.

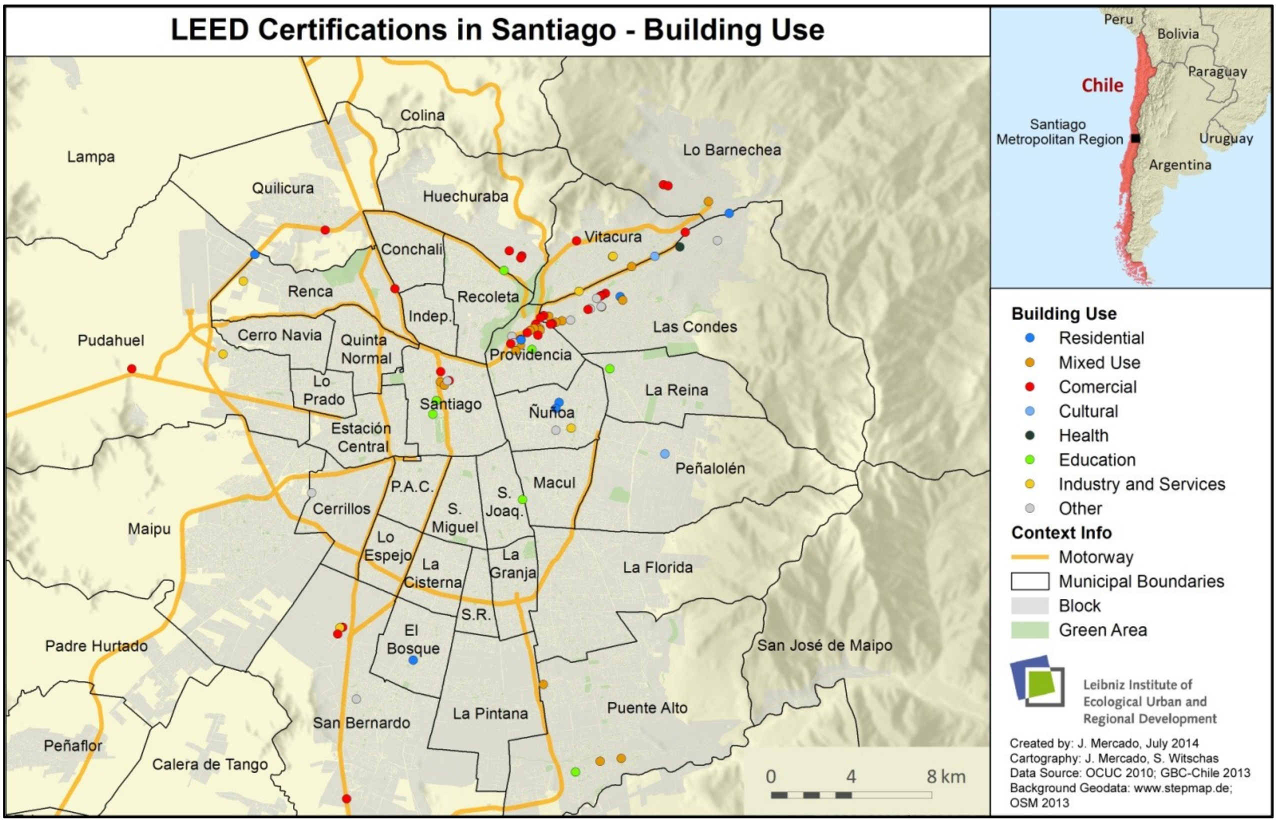


Figure 20: LEED-certified Building in Santiago de Chile – Building Use.
(Source: Own illustration based on GBC-Chile 2013)

As in other countries, LEED certifications have also been introduced in the Chilean market since 2006 (GBC-Chile 2013). Figure 20 shows the distribution of buildings with LEED certification across the RMS. It can be seen that the predominant building-type of LEED-certified buildings are commercial buildings, although there are some residential buildings located in traditional residential areas of the city, where the higher socioeconomic groups are located.

It is important to note that most of the buildings are concentrated in the municipalities of: Providencia, Vitacura and Las Condes. These municipalities concentrate medium-high and high income-segments of the regional socioeconomic structure. Therefore, it is valid to say that LEED-certificated buildings in the RMS have a higher demand amongst higher socioeconomic status. It is also important to mention that most of LEED-certified buildings are located in the Avenues that carry the same name as the abovementioned municipalities, which define one of the most important commercial axes in the structure of the city. These avenues constitute a major attraction for the location of office buildings in which they are installed – traditionally – the headquarters of internationally active firms that have very high standards for the installation of its offices around the world. Therefore, international companies generate significant demand for international standards, which the local real estate market seeks to fulfil.

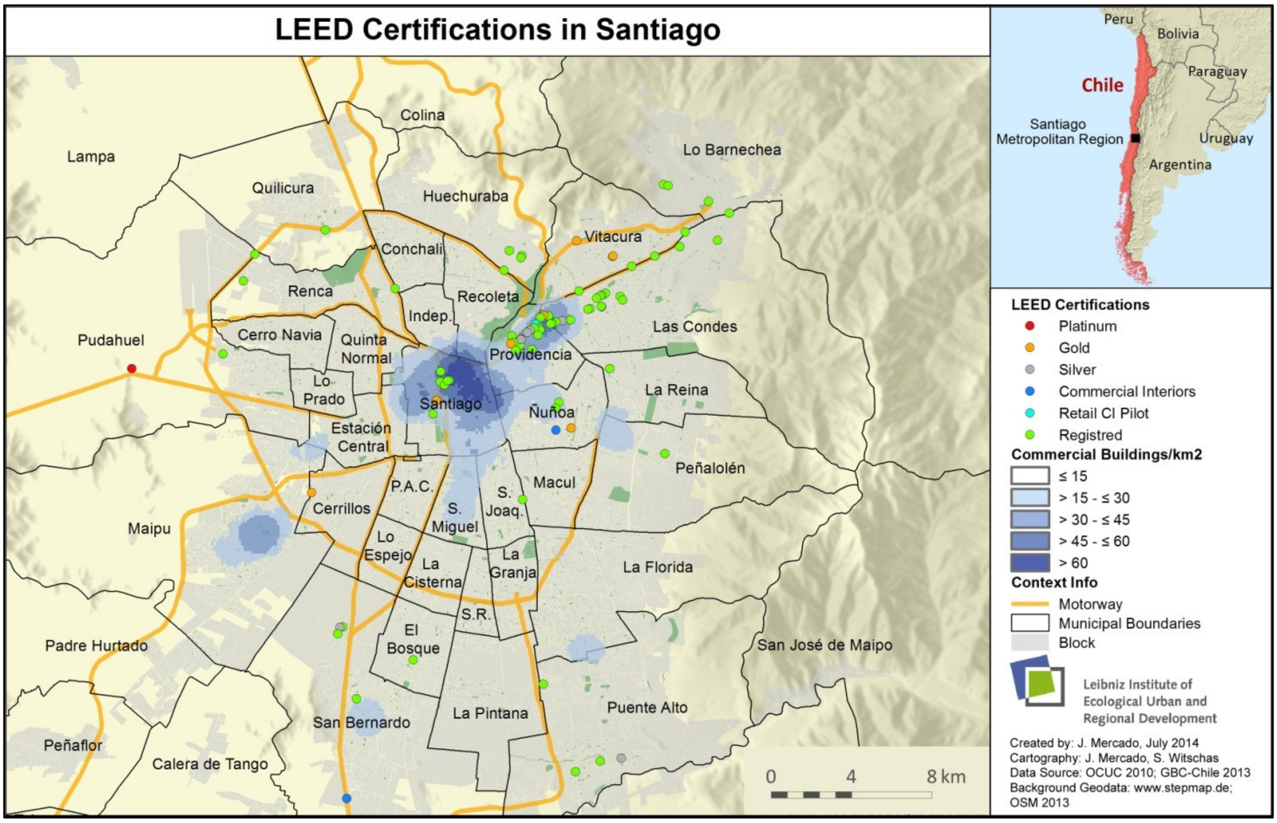


Figure 21: LEED-certified Building in Santiago de Chile – Levels Achieved.
(Source: Own illustration based on GBC-Chile 2013)

Figure 21 shows a map of the RMS overlapping two different data sets. First, the point map shows the spatial distribution of LEED-certified buildings; second, the density of commercial buildings (expressed in buildings per km²) is displayed. The first layer of information shows, on the hand, buildings currently in the LEED certification process are shown; the level achieved by those buildings that already completed the certification process is also shown[75], on the other hand. Since most of LEED-certified buildings are commercially used, LEED-certified buildings are located in most densely commercial areas in the city, as reflected by the second layer of information.

In general, the building owners of LEED-certificated buildings in Santiago de Chile are private owners, as shown in Figure 22. In the case on residential buildings, this seems to be related to the fact that most of multi-family apartment buildings are owned by the real estate company who applied for the certification; which, generally, is also responsible for the building administration. This suggests that the decision to opt for a LEED certification is an initiative of the company (in order to have an overview about the motivations to implement certification systems, see the section 5.2).

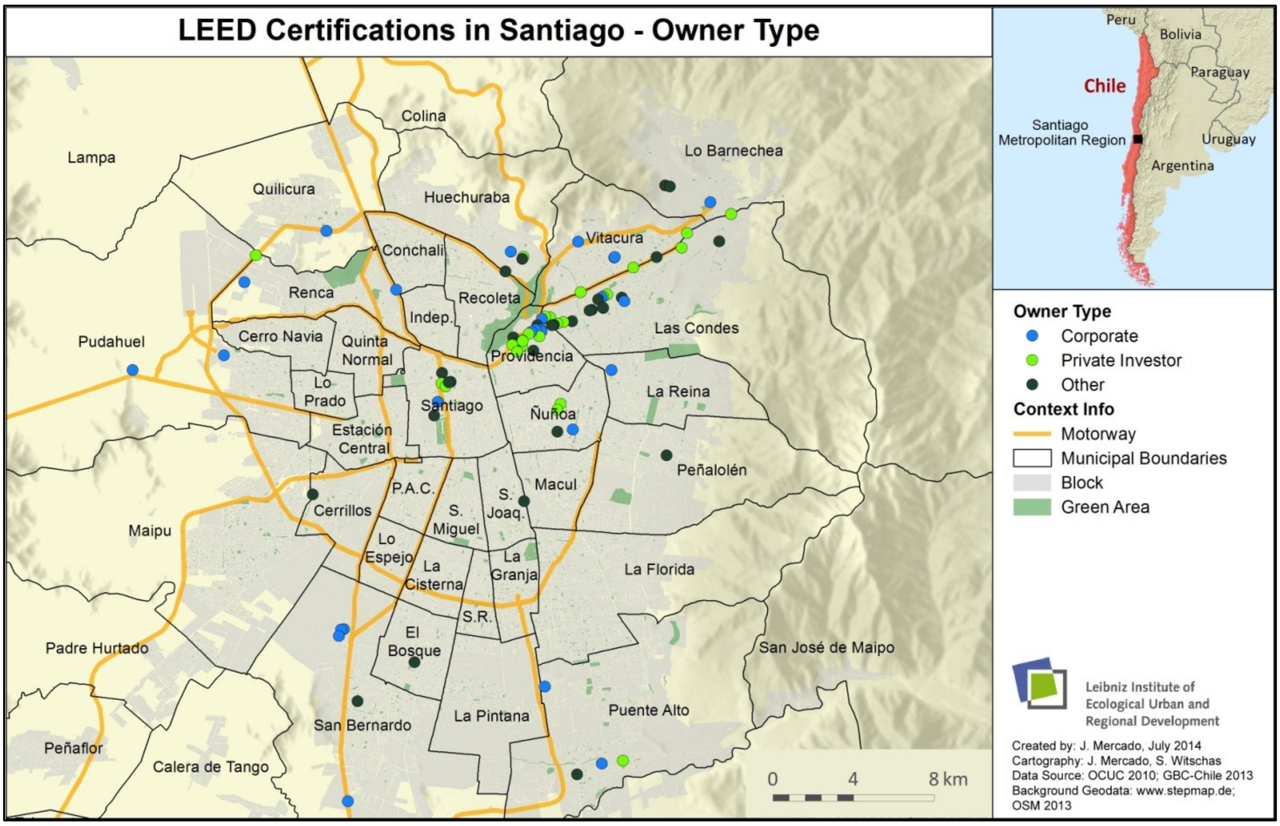


Figure 22: LEED-certified Building in Santiago de Chile – Type of Ownership.
(Source: Own illustration based on GBC-Chile 2013)

Moreover, as shown in Figure 22, there seems to be a balance in the building ownership of LEED-certificated buildings, between private investors and corporate ownership. This suggests that issues of corporate image play an important role in making the decision to certify a building under voluntary schemes. As it was shown in the previous section,

[75] The commercial density was elaborated by the author based on the Building Permits for commercial buildings. The spatial data was provided by the Observatorio de Ciudades UC in 2010.

LEED-certified buildings are mainly located in the most important commercial axes in the structure of the city, in order to cope with an increasing demand for offices in high performance buildings. Therefore, private investor owned buildings are located along the commercial focus of attraction of the city. This seems to reflect the interest of private investors to capture the growing demand for GB in the capital city of Chile.

4.5.2 Public-private Partnership

The so-called "*Chilectra's Full Electric Buildings*" is an initiative developed under the framework of public-private partnership between Chilectra, the local electric utility in Santiago de Chile, and the National Energy Commission (Comisión Nacional de Energía or CNE).

This initiative is the outcome of the stakeholder engagement of institutions responsible for the domestic electricity service in the RMS. On the one hand there is Chilectra, the nation's largest electric distribution utility; on the other hand, there is the National Energy Commission (Comisión Nacional de Energía or CNE), the institution in charge of energy regulation in Chile.

The so-called "*Full Electric Building*" is a concept that stands as a major innovation in the field of residential energy efficiency in the Greater Santiago context. The innovation was achieved through stakeholder engagement with environmental and energetic concerns. In a broader context, the success of the public-private partnership within the Chilean context is no novelty. There are several successful examples of win-win situations achieved through public-private partnership (also called concessions) within the Chilean experience[76].

According to Chilectra's representatives, the bases for this innovation are partly environmental concerns and partly energy concerns. The environmental concerns revolve

---

[76]Briefly, according to Ibarra-Coronado (2011) at the beginning of the 1990s Chile urgently needed to overcome the deficit of infrastructure to ensure economic development. Faced with this problem, it was decided during Patricio Aylwin's administration (1990-1994) to implement the system of concessions of public works and to invite the private sector to participate in developing the productive infrastructure. The aim was to get private capital to finance the infrastructure, who would recover their investment by charging a fee directly to users. Thanks to this initiative was achieved the construction of urban infrastructure projects, such as the case of the subway and some urban highways in the Metropolitan Region of Santiago, and road and airport concessions in other Chilean regions. Finally, it is considered that the Chilean concession system has been successful and that this experience stands out in Latin America. Ibarra-Coronado (2011) reported that by the year 2010, 67 projects had been awarded with an investment of approximately U.S. $ 11,700 million.

around the elimination of air pollution generated by burning fossil fuels inside dwellings in order to support heating, cooking, and hot sanitary water systems. The energy concerns are twofold: first, it was sought to offer and implement higher energy efficient electric appliances in order ensure better use of electricity. Second, it was sought to make better use of the period when the households use electricity, taking into account peak hours of high electricity consumption and valley hours of low electricity consumption.

Through this strategic alliance an optional electricity consumption fee for residential customers called the Residential Hourly Rate (Tarifa Horario Residencial or THR) was officially established in November 2008 (personal communication from Chilectra representatives during fieldwork, March 2012).

4.6 Why Would Real Estate Companies Act Green?

The previous sections provided the analysis of specialized literature on the implementation of residential energy efficiency standards in the field of new building construction. It was shown that initiatives arise primarily from two areas: 1) regulations implemented by national, regional, and local governments through building codes, which must be compulsorily implemented by architects, designers, engineers, and real estate development companies in the different building projects; and 2) initiatives arising from non-governmental sectors which are implemented in the real estate market voluntarily. The latest define – apparently – higher standards than the base line defined in the building codes; moreover, the voluntary schemes are addressing a broader extend than just energy efficiency; they focus on analyzing the level of sustainability achieved by the buildings along the entire life-cycle of the building. The final result of the assessment is given in the form of a rating for comparing the building with other buildings in order to show how "green" buildings are.

Given that the decision to go beyond local building regulations and voluntarily adopt green building strategies depends on the real estate developers. Therefore, this section reviews the literature related to factors that may trigger behavior changes in companies, going from a business-as-usual to an environmentally-friendly perspective.

From a broader perspective, understanding the motivations for behaviour change of organizations – for the purposes of this doctoral thesis case real estate companies – begins by analyzing why companies would act more environmentally friendly.

Initially, the work of Bansal and Roth (2000) examines: "*why companies "go green" and, in doing so, to refine a model that explains corporate ecological responsiveness by identifying motivations for adopting ecological initiatives and the underlying factors that lead to each motivation*" (p.717). Based on key informants' opinions (environmental managers of companies working in different industry realms) the model suggested the basic motivations for the so-called "*ecological responsiveness*" are threefold: 1) competitiveness; as the potential for ecological responsiveness to improve long term profitability; 2) legitimization; referred to the desire of a company to improve the appropriateness of its actions within a established set of regulations, norms, values, or beliefs; and 3) ecological responsibility; viewed as a motivation that derived from the concern that a company has for its social obligations and values (Bansal and Roth 2000, pp.724-728).

A later work, McWilliams and Siegel (2001) introduced the discussion regarding corporate social responsibility (CSR). According to the authors, CSR is defined as: *"actions that appear to further some social good, beyond the interest of the firm and that which is required by law"* (p.117). This definition underscores that CSR means going beyond the law; in this doctoral thesis, real estate companies offering thermal isolation for building's roofs and envelope as energy efficiency measures in Santiago de Chile are not engaging energy efficiency or other green concerns; it is merely complying with the building code. Therefore, it is important to generate deeper understanding about those developers going beyond the requirements of the NBC in terms of energy efficiency.

According to Székely and Knirsch (2005), the adoption of sustainability within a company is much more than a mere public relations exercise, it may take place only when there is an active leader/manager within the company who champions this approach. Thus, the influences of the decisions made by managers of companies are critical to the adoption of sustainability in a broad sense.

Moreover, since this doctoral thesis draws substantially the opinion of managers of private companies that offer energy efficient homes in Santiago de Chile in their role as company leaders, it is interesting to review the literature on organizational management and responsible leadership.

Székely and Knirsch ´s work identifies some characteristics that managers of companies must possess[77] in order to manage determining factors for the performance of their companies. The Table 16 summarizes the factors determining the company's behaviour; these factors can be internal (mainly managerial and organizational) or external (stakeholders' demands). According to Székely and Knirsch (2005) addressing these factors is not an easy task; there are several barriers that need to be overcome, mainly time and market barriers. However, the authors claim that the most critical success factor for sustainability is true leadership within the organization. Leadership means securing the commitment of management (starting at the very top) and developing a system of incentives to reward leaders at all levels who develop and push for the adoption of

[77] This individual needs to be both a good leader and a good manager. His/her sustainability work starts by carefully examining all the factors that determine the sustainability performance of his/her company and its suppliers (Székely and Knirsch 2005, pp. 629-630).

sustainability practices. It also refers to the ability to respond flexibly to change and to engage in dialogue and partnerships with different members of society (Székely and Knirsch 2005, p.629).

Table 16: Factors Determining Company's Behavior
(Source: Own compilation based on Székely and Knirsch (2005, pp. 629-630))

Internal Factors	External Factors
Internal factors favouring the adoption of a sustainable approach toward business operations.	Factors outside the company that compel managers to act in a certain way or to respond to society's expectations and demands.
Managerial Factors • Assessment of all internal organizational structures and management procedures. • Development and implementation of incentive mechanisms • Early identification of potential business opportunities • Recognition of emerging risks, potential threats and management failures • Better risk management, lower risk levels • Improvement in workers' safety and the quality of labour recruitment and retention **Operational Factors** • Identification of environmental problems • Minimization of environmental footprint • Reduction of material inputs • Achievement of energy efficiency (eco-efficiency) • Operating licenses **Economic Factors** • New market opportunities • Cost savings • Technological innovation.	**Market Factors** • Product differentiation • Customers' values (e.g. green consumers, human rights) • Access to new markets • Industry competition • More competitive labour markets • Increased consumer interest in ethical and socially responsible business conduct • Socially-oriented investors • Ratings agencies • Improved company reputation **Government Factors** • Increased regulatory intervention • Operating licenses **Stakeholder expectations** • Full transparency and access to information • Internalization of negative externalities (pollution and waste) • Demands for reduced material consumption • Adoption of international labour codes (human rights groups) • Transparent reporting (investors and authorities).

Finally, Székely and Knirsch (2005) claimed that the importance and scope of factors determining the firm behaviour will vary reflecting the context in which a company operates (Székely and Knirsch 2005). Therefore, the task of identifying these factors in the local social system of the RMS plays a fundamental role in this research.

A later work, also based on the model described above, focused its attention on the growing awareness in the real sector and policymaking in the role that the commercial real sector could play in mitigating the harmful environmental fallout of energy consumption by office buildings in the US. In the work of Eichholtz, Kok, and Quigley (2010), the authors develop four underlying factors that go into the making of CSR in the real estate decision making. They develop hypotheses as to which types of companies and industries will be most likely to rent offices in green buildings. Among the conclusions of the study, authors suggested that literature regarding organizations and the natural environment has been silent on the decisions by corporations to intertwine their consumption of space into their overall environmental strategy. Yet the impact of real estate on the environment makes corporate housing decisions directly relevant for such strategies (Eichholtz, Kok, and Quigley 2010, p.38).

To sum up, the scientific evidence found in the related literature shows that there are certain benefits for companies that conduct business in an environmentally friendly way. Moreover, both the factors that encourage as the factors that limit such behaviour are highly dependent on the context in which such companies operate. This context involves the regulatory framework, the social context and the dynamics of the local market.

5 The Adoption of Energy Efficiency in the Private Housing Market in Santiago de Chile

The aim of this Chapter is to answer the first sub-research question: ***who are the real estate developers that are adopting energy efficiency and why?*** which serves to two essential purposes. Firstly, to identify real estate companies adopting energy efficiency in the private housing market in Santiago de Chile; and secondly, to understand which are their main motivations for doing it. Therefore, this Chapter is structured into two main sections. The first section identifies and classifies the adopters of residential energy efficiency in Santiago de Chile, following the adopters' categories proposed by Rogers[78] (2003). The second section explores the motivations of real estate companies for adopting residential energy efficiency measures in their housing offer, reflected on general managers' opinions received in personal interviews. Figure 23 describes three main categories that emerged through thematic analysis of interviews and that structure the sections of this Chapter; namely: 1) motivations for the adopting energy efficiency measures; 2) energy efficiency measures implemented in the private housing market, and 3) barriers to adoption of energy efficiency measures.

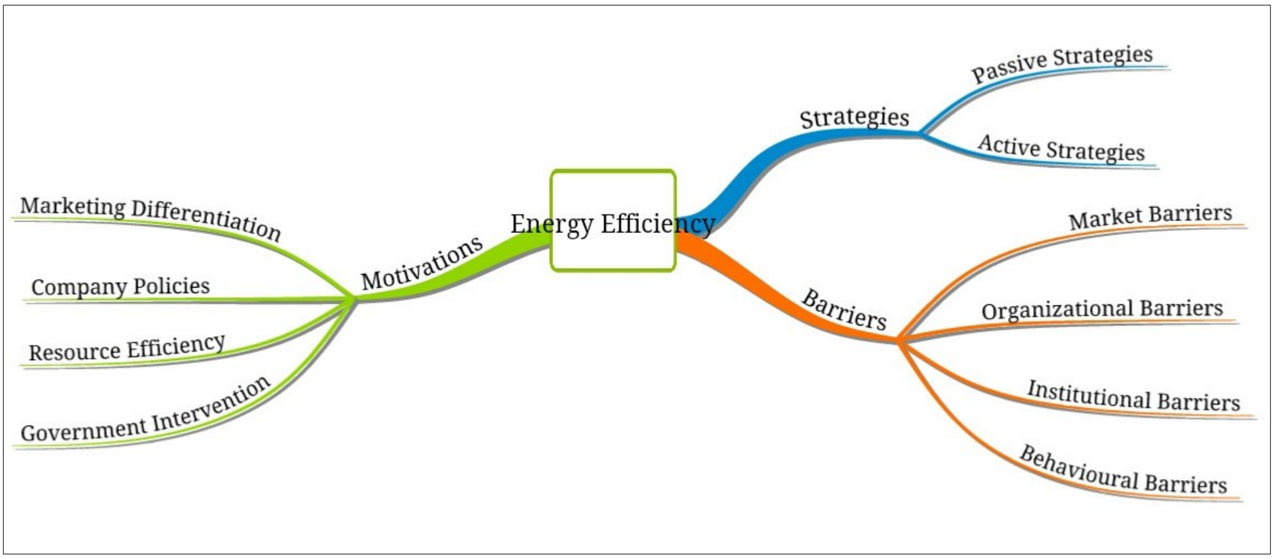


Figure 23: Thematic Structure Emerging from the Analysis
(Source: Own illustration)

[78] Briefly, Rogers' Diffusion of innovations (2003) seeks to explain how, why, and at what rate new ideas and technology spread through cultures. For the purposes of this research, the innovations are new ideas and technology applied by real estate developers in the housing sector in order to create energy efficient housing.

5.1 Energy Efficiency Adopters in the Private Housing Market

This section presents the categorization of energy efficiency adopters among real estate developers offering residential buildings in Santiago de Chile. This categorization was developed following Rogers' diffusion of innovations, where the adoption units are classified based on their innovativeness. According to Rogers (2003) innovativeness is the degree to which an individual or other unit of adoption – for the purpose of this research, real estate companies adopting energy efficiency measures in the private housing sector in Santiago de Chile – is relatively earlier in adopting innovations[79] or new ideas than the other members of the system[80]. Therefore, following the categories defined by Rogers (see Table 17); the categorization of adopters was conducted based on the promptness with which they began to implement residential energy efficiency measures.

Table 17: Innovation Adopters Categories
(Source: Own compilation based on Rogers (2003))

Category	Key Features
Innovators	Brave people, pulling the change. Innovators are very important in communication
Early Adopters	Respectable people, opinion leaders, try out new ideas, but in a careful way
Early Majority	Thoughtful people, careful but accept change more quickly than the average
Late Majority	Skeptical people, will use new ideas or products only when the majority is using them
Laggards	Caring for the 'old' ways, are critical towards new ideas and will only accept them if the new idea has become mainstream or even tradition

In this research, categorizing the adopters of energy efficiency followed a time sequence based on when real estate developers first began to apply energy efficiency measures in there housing offer.

The process of adoption of energy efficiency measures (EEM) in the private housing market of Santiago de Chile it is related to the implementation of the New Thermal

---

[79] Rogers defines an innovation as "*an idea, practice, or object that is perceived as new by an individual or other unit of adoption*" (Rogers 2003, p.11). Rogers' diffusion of innovations theory seeks to explain how, why, and at what rate new ideas and technology spread through cultures. For the purposes of this research, the innovations are new ideas and technology applied by real estate developers in the housing sector in order to create energy efficient housing.

[80] Rogers (2003) claims that rather than describing an individual as "*less innovative than the average member of the social system*", it is more efficient to refer to the individual as being in the "*late majority*" or in some other adopter category (p.22).

Regulations (NRT) issued by the Ministry of Housing and Urbanism (MINVU) for the housing sector in Chile. Therefore, the three stages of the NRT[81], implemented successively since 2000, helped structuring the categorization of energy efficiency adopters in Santiago de Chile, as shown in the Figure 24.

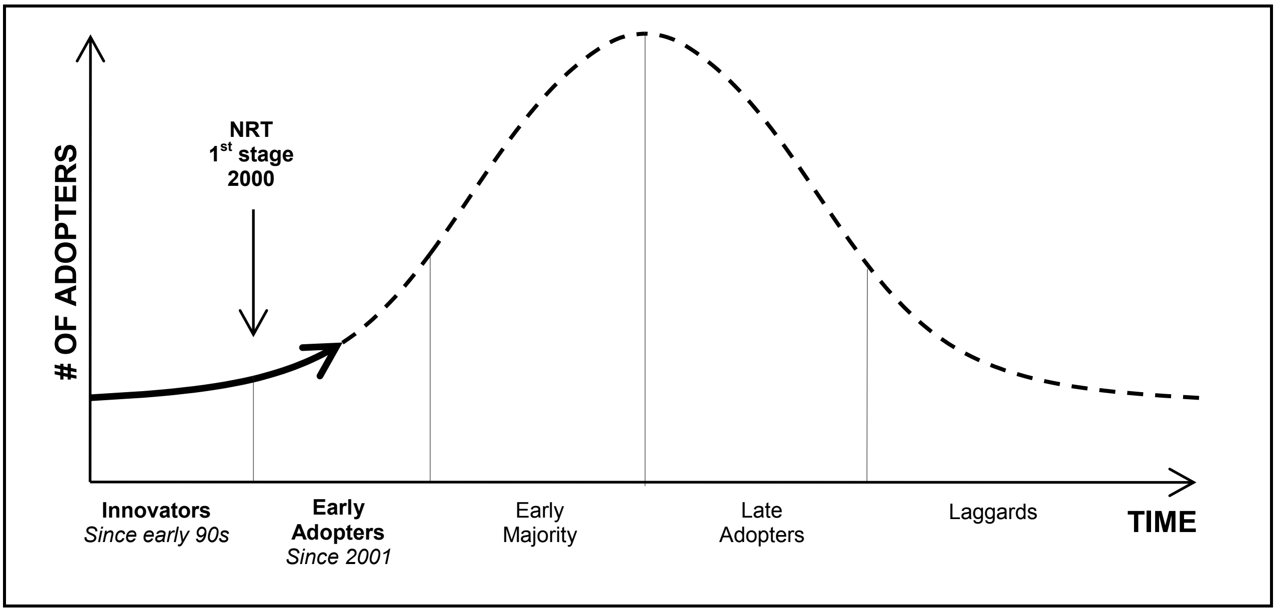


Figure 24: Schematic Representation of the Adoption of Residential Energy Efficiency Strategies in Santiago de Chile
(Source: Own illustration based on Rogers 2003)

This research considers a relatively small fraction of the private housing market of Santiago de Chile: the adopters of energy efficiency measures in the private housing market[82]. As a result, *early majority*, *late majority* and *laggards* categories, described in Rogers' model, are not covered within this research. The theoretical perspective shows that early in the diffusion process, relatively few individuals adopt innovations in each time-period. However, it is expected that the rate of adoption speeds up gradually until all, or almost all members of the system adopt the innovation (Ryan and Gross 1943 cited in Rogers 2003). It appears that to date, the process of adoption of energy efficiency in the private housing sector in Santiago de Chile started recently; therefore, a greater diffusion is expected in the long term.

The first category, called *innovators*, considers real estate companies who adopted EEM for the first time before the entry into force of the first stage of the NRT in 2000. This

---

[81] Briefly, the three consecutive stages considered in the NRT are: the first stage since 2000, the second stage since 2007, and the third stage since 2013 (MINVU-IC 2006; MINVU 2009, MINVU 2013b).

[82] In this research, the units of analysis (or sub-cases) were selected by applying a *Criterion Sampling* strategy. Forty-five real estate companies offering energy-efficient housing in the Greater Santiago area were selected out of five hundred and sixty eight real estate companies working in the Greater Santiago's residential sector in 2011 (see Chapter 3).

stage defines the first institutional requirements in the residential area aimed at improving the thermal behaviour of the building envelope and thus the energy efficiency of the dwellings (see section 4.4.3). The second category, called *early adopters*, brings together real estate companies who adopted energy efficiency measures in their housing offer for the first time after the entry into force of the first stage of the NRT in 2000; that is to say, between 2001 and 2012.

5.1.1 Innovators

Among innovators in the field of residential energy efficiency in Santiago de Chile, there is a significant time variation between establishing a company and the beginnings of the EEM implementation in the different housing-products. In one case, the motivations were born together with the company, meaning that energy efficiency measures were adopted from the start. This is not surprising in this particular case, because that particular company it is a subsidiary of a bigger company overseas. The parent company's policy and business model[83] were replicated in Santiago de Chile; therefore, the time which elapsed before the EEM implementation can be traced back some years before. Amongst the oldest companies working in the housing market in Santiago de Chile, the time between the companies' creation and the adoption of EEM is around sixty years. Amongst innovators, the motivations for applying energy efficiency measures are grounded in environmental and energy shortage concerns, undergoing at the time that the decision to adopt energy efficiency innovations was taken.

Motivations for *innovators* adopting EEM are focused on three main issues; namely: 1) concerns regarding energy scarcity (at the time of the early implementations, there was a rising concern regarding the energy shortage that the country was facing); 2) the reduction of the household's operational cost, with a view to reducing energy expenses to a minimum; and 3) improving habitability and comfort in the house by reducing the heating costs.

[83] Blomström and Kokko (1998) argued that when firms establish affiliates abroad and become multinational, they are distinguished from the already established firms in the host country for two reasons. Firstly, they bring with them some amount of the proprietary technology that constitutes their firm-specific advantage and knowledge to of local markets, consumer preferences, and business practices. Secondly, the entry of the multinational corporation affiliate disturbs the existing equilibrium in the market and forces local firms to take action to protect their market shares and profits. Both these changes are likely to cause various types of spillovers that lead to productivity increase in local firms.

Multi-family low-density apartment buildings were the market segment where the innovation was initially adopted. The target groups are middle and middle-high socioeconomic sectors.

Among energy efficiency strategies implemented in the private housing offer, the first experiences with double-glazed windows and internal wall insulation were cited by interviewees. Some isolated experiences in application of renewable energy were mentioned; namely, solar thermal panels and geothermal (to cool the building structure). Most of the innovations followed a trial-and-error strategy, as the market was not yet able to seriously support the innovations[84].

Within the *innovators*' group, there was no common agreement regarding the barriers for energy efficiency adoption. The lack of information on the users' side and the lack of incentives from the regulators were mentioned extensively. Lack of support from the construction industry's back-office was marginally mentioned. Both topics are closely related to the novelty which meant implementing EEM in Santiago de Chile before 2000. The little support from the government is due to the regulations in the field of residential energy efficiency were under development since the early nineties. Similarly, the back office of the construction industry was not ready to deal with an emerging issue. Therefore, the high degree of uncertainty involved in adopting emerging issues (in this case residential EEM), is reflected in initial slow implementation process and the caution with which the real estate companies adopted residential EEM.

5.1.2 Early Adopters

As mentioned in the previous sections, the category *early adopters* brings together real estate developers who mentioned to be implementing energy efficiency strategies in their residential real estate products after the enactment of the first stage of the thermal requirements for new residential buildings in Chile.

The market segment targeted by real estate companies among *early adopters* of energy efficiency is mainly the middle-class, although some of the companies target higher income groups as well. The building types are diverse, mainly multi-family apartments in a high-density configuration for the middle-class and single-family housing in low-density configuration for the upper-middle and upper class.

[84] The discussion about barriers to implementing energy efficiency measures in the private housing market, are thoroughly discussed later in Chapter 7. Moreover, section 7.1 discusses the main market barriers.

The energy efficiency strategies adopted by members of this group are heterogeneous, although they seem to be slightly concentrated on the implementation of passive strategies, mainly bioclimatic design. A significant share of *early adopters* also applies in most of the apartment buildings designed and constructed by the different companies, the so-called "*Full Electric Buildings*" concept developed by Chilectra since 2008 (see section 6.1). A feasible explanation is that the initiative became a trendsetter when first implemented in 2002, leading most of the companies to apply it. Furthermore, within the group there are two companies that claim to be creators of the initiative (PD.15 and PD. 17). In any case, environmental concerns seem to be the grounds for the implementation of such initiative. There was a growing concern among the heads of these two companies regarding the indoor air pollution caused by gas emissions from both cooking and heating.

The energy efficiency measures applied were mainly related to improving the standards defined by the new thermal regulations and (more noticeably in this group compared to *innovators*) using the government subsidies for solar thermal panels. This might be a normal reaction to the enactment of the second stage of the new thermal regulations (envelope and windows, in force since 2007) and to the entry into force of the subsidies to the implementation of solar panels (see section 4.4). It is worth noting that there were some attempts to venture into the renewals beyond the use of solar thermal panels; some managers claimed to be applying photovoltaic panels for energy conversion (PD.12, PD.2) and geothermal energy (PD.14).

Many interviewees amongst *early adopters* cited resource efficiency and market differentiation as the most important motivations for implementing residential EEM in their private housing offer. Offering energy efficient housing as a market differentiation strategy, in order to cope with energy efficiency as a trending topic gaining traction internationally in the real estate market at the beginning of the century, was cited repeatedly among the adopters in the early adopters' category.

Cross-cutting Issues

In summary, the empirical evidence shows that the process of adoption of residential EEM began in a small group of real estate companies – the *innovators* – early in the nineties, prior to the implementation of new thermal regulation by government. It appears that the economic factor – mainly related to an increased availability of resources to venture into a process of technological innovation – has been decisive in the adoption of EEM. Initially, energy efficiency was adopted in multi-family apartment buildings in upper-middle socioeconomic group, generally under a process of trial-and-error, mainly because of two factors: first, a high level of uncertainty about the real benefits that may be achieved through the adoption of EEM. Second, the lack of support from the construction industry, both in product supply and the provision of services support. According to Rogers (2003) these two factors are related to his definition of technology[85], which is composed of two parts: hardware and software; products to support energy efficiency and local knowledge enabling the proper use and maintenance, respectively. While hardware is understood as "*the tool that embodies the technology in the form of a material or physical object*", software is understood as "*the information base for the tool*" (Rogers 2003, p.259).

Following the *innovators*, a group of *early adopters* was identified in the process of EEM adoption in Santiago de Chile's private housing market. While *innovators* first started applying EEM on a voluntary basis in the early 90s, *Early Adopters* started adopting EEM after the first stage of new thermal regulations for residential buildings became effective in 2000. The empirical evidence shows a continuous growth of energy efficiency adopters in the private housing sector, covering different building typologies and targeting broader housing market segments.

The empirical evidence shows that the diffusion process of EEM in the private housing sector in Chile has started and is developing slowly[86]. Literature on the diffusion of innovations mentions that Rogers' model (2003) is useful to predict the behaviour of a vast majority of innovation processes. Although it would also be feasible to expect that the termination period of innovations on EEM might end up in a failure[87], this does not appear to be the case of the adoption of EEM in the private housing market. The empirical evidence suggests that the innovation process has started following the normal development described by Rogers' innovation curve. Therefore, it is expected that the rest of the private developer companies operating in the private housing market in Santiago de Chile will eventually follow the *innovators'* and *early adopters'* categories.

---

[85]Rogers (2003) defines technology as: "a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome" (p.13).

[86] It has been shown that only a relatively small group of real estate companies are offering energy efficient housing; just 45 out of 568 real estate companies offering private housing in Santiago de Chile in 2012. See the Research Design and Methods chapter.

[87] If there is no further adoption by any other member of the housing market, the termination period of the innovation will be a failure (see Van de Ven et al. 2008, p. 183).

This is mainly due to the recent introduction of thermal regulation by the government and because it is a highly competitive market, in which none of the players can be left behind.

The empirical findings are also supported by the scientific literature. As members of a target group adopt an innovation, the innovation diffuses into the target group market. It is generally accepted that diffusion starts with the *innovators* and *early adopters* of the market. The *early* and *late majority* then will follow, and finally the *laggards* complete the adoption process (Rogers, 1995, 2003). Furthermore, Moore (1999) points out that, although the adoption of innovations starts in the so-called "*early market*", the "*mainstream market*" follows only if certain conditions are met. In other words, the mainstream market members differ from the early market in their willingness to accept innovations. While the early market is more strategic and visionary, the mainstream has a much more pragmatic attitude. To effectively influence the decision-making behavior of these target groups, their differences in accepting new circumstances or adapting their behavior to new situations must be taken into account. In his diffusion theory, Rogers describes these groups as having "*different rates of adoption*" (Rogers, 1995, 2003).

Actors differ in their speed of accepting innovations and differ in adapting their behaviour to a new situation. Rogers (2003) in his diffusions theory, calls this the "*adoption speed*". The adoption of new behaviour within target groups often develops in the following way. A group of "*innovators and early adopters*" (Rogers 2003) or the "*early market*" (Moore 1999) change their behaviour. After this group, the rest follows step by step: Rogers calls this group "*the early majority, the late majority, and the laggards*" and Moore calls them the "*mainstream market*" (Moore 1999).

Finally, according to Egmond et al. (2006), in order to meet the Kyoto CO_2 reduction targets, technical innovations in the field of energy efficiency must diffuse more rapidly into a larger market. However, markets develop gradually, especially if innovations are involved. Diffusion starts with the early market (*innovators* and *early adopters*), followed by the mainstream market (the *early majority* and *late majority*), and ends with the *laggards* (Egmond et al. 2006).

5.2 Motivations for Applying Residential Energy Efficiency Measures

The aim of this section is to understand the motivations of real estate companies' managers behind management decisions to innovate on residential energy efficiency in the private housing market in Greater Santiago.

In the following sections, the results of the expert interviews analysis (following the methodology described in Chapter 3) conducted during the fieldwork are shown.

Table 18: Summary of Motivations for Adopting Energy Efficiency Measures (Source: own compilation)

Interview Results Summary		
Category	**Sub Category**	**Key points**
Market Differentiation Strategies	Competitiveness	Offering energy efficient housing is a differentiator within a highly competitive market.
	Trending	Complying with the international trends for energy efficient buildings in the real estate market.
Company Policies	Client-Oriented Policies	Achieving high level of customer satisfaction Improve users' life quality
	Innovation Policies	Increased quality of real estate products (layout, location) Technological innovation
	Environmentally-friendly Policies	Reducing indoor air pollution Stakeholder engagement and strategic alliances
Resource efficiency	Reduction of Household's Expenses	Lower bills for electricity and gas services (i.e. cost of common area expenses for lighting, heating, and hot sanitary water)
	Concerns for Energy Scarcity	Energy-shortage due to the gas supply outages from Argentina
Government Incentive Schemes	Subsidies to the Use of Renewable Energy	State subsidies for solar thermal panels

The Table 18 summarizes current thought of real estate companies' managers on residential energy efficiency measures. From the expert interviews, it was concluded that the adoption of residential energy efficiency is driven by Market Differentiation Strategies for most of the company managers in the real estate industry. Moreover, corporate policies, resource efficiency, and State subsidies are among the drivers for the innovation.

5.2.1 Market Differentiation Strategies

The specialized literature shows that the implementation of green design strategies (among which energy efficiency is one of them) in buildings construction, generates a variety of direct and indirect benefits for developers, owners and tenants (see section 4.3.1). One benefit highlighted is improving the corporate image of the company that implements such green design strategies. This is because the decision to implement strategies for green design in the construction of a building means early involvement of the stakeholders; namely, private developers, building owners, and a team of professionals, specialists, and experts in the design of green buildings (Edwards and Turrent 2000; Edwards 2003). Therefore, beyond the direct benefits generated by green buildings to the environment (see Kats 2003), the benefits are reflected in the corporate image of the company decides to implement them.

Similarly, the empirical evidence found in this research – reflected in real estate development companies managers' opinion of companies implementing green design strategies in their real estate products offer in Santiago Chile – shows that to offer real estate products with standards that go beyond local building codes' requirements, generates an additional advantage for real estate development companies. This situation is reviewed in detail in the following sections.

Competitiveness in the Housing Market

According to most of managers and senior representatives of real estate companies, the primary motivation for offering and applying energy efficiency measures (EEM) was because it is part of the market differentiation strategies, which have two main goals:

On the one hand, energy efficiency measures are considered a market differentiator, as a way to differentiate an energy efficient building from others in order to increase the product's competitiveness. Many managers claimed to be applying energy efficiency measures in their current housing offer because it is a way of differentiating the company itself from competitors within a highly competitive market, as described below.

> *"...first, and on that you have to be super honest, ours [the private housing market] is a very competitive market, with many actors; [applying energy efficiency measures] is a way to differentiate and to add attributes to these projects that make them commercially more attractive. It is also a way to generate competitiveness by having products that one can show the customer that they will be cheaper to operate ..." (PD.20: par.17)*

Moreover, it was mentioned that companies adopting EEM, or any other technological innovation, are at comparative disadvantage with companies that do not. It was mentioned that the costs of implementing energy efficiency measures makes the final prices of the housing units are older. Therefore, when comparing the supply of real estate products at prices equal, energy efficient dwellings have a higher cost. Moreover, interviewees noted that applying residential energy efficiency measures results in a significant increase in the price of the dwellings. Therefore, potential homebuyers who are interested purely in the dwelling price (or prefer better some other feature of the dwellings, like location, size, layout, accessibility, etc.), they will choose a more affordable housing rather than energy-efficient housing. It appears that, the intention of promoting the energy efficient housing is a tacit way to increase the dwellings price per square metre, since it is a matter of competitive advantage, a matter of corporate image, and it is a matter of attracting prospective homebuyers (PD.5: par 48).

This is also supported by the literature. According to Edwards (2003) the implementation of green design strategies can generate additional benefits for real estate developers; the author argues that, in many cases the shape that buildings designed under sustainable or green principles acquire, allow the green building to be highlight among neighbours, delivering a cachet that attracts potential buyers. Therefore, green buildings will be attractive to a section of the housing market (Edwards 2003, p. 3-4)

On the other hand, the goal is to cover an increasing demand for energy-efficient housing. In the specific case of Santiago de Chile, the demand for housing is strongly influenced by international trends, since the Chilean capital is a city that has been positioning itself in a global circuit due to the relative success of Chile in international competitiveness rankings (see De Mattos 2007). The interview extracts below provide some impressions on how managers are tackling the international trend.

> *"... [the company has] some instinct, a sixth sense to say in which direction the market is moving, and some requirements are also given by the international standards, this topic [energy efficiency] has been seen for many years in Europe and the U.S…." (PD.4: par.14)*

> *"...we understand that this [energy efficient housing] is where the world is heading to, and the user is going to ask for that later on ..." (PD.9 : par.29)*

In the construction sector, as in many others, the international trend requires more and more stringent energy efficiency standards. For example, in the commercial sector, multinational companies and institutions from all over the world are seeking that all their local offices worldwide comply with international standards: Usually, complying with worldwide accepted standards means complying with internationally recognized certification systems[88]. The same occurs in the residential sector, where prospective homebuyers are strongly influenced by the mass media and the benefits of energy efficient housing[89] are widely discussed.

5.2.2 Company Policies

According to the CEOs, a relevant motivation for applying energy efficiency measures (EEM) in the housing offer is because in general energy efficiency is central to company policy. The company policies mentioned by the CEOs when referring to their motivations for applying energy efficiency, in order of preference, could be grouped as follows: client-oriented policies, innovation policies, and environmentally-friendly policies.

Client-Oriented Policies

As regards the first set of client-oriented company policies, it was mentioned that real estate companies are committed to provide a high level of customer satisfaction with the offered products; moreover, it was mentioned to be part of the company's mission, as stated below.

> *"Energy efficiency is understood as a corporate policy in the company, is a vocation of the company for developing projects that provide the greatest satisfaction to customers..." (PD.14: par.3)*

Moreover, a clear goal among the client-oriented company policies is to improve customers' life quality. In this sense, implementing energy measures (mainly improvements to the thermal envelope and the acoustics) is linked with the search for greater user comfort. Thus, offering housing with higher comfort conditions than the competition is a form of differentiation. In some cases, it was mentioned that the commitment with the improvement of users' quality of life is even above the pursuit of economic benefit to the company, as described below.

> *"…at least I've always wanted, more than to do real estate business, [to improve] the quality of life of the people who will ultimately enjoy our product, that's what I've always*

---

[88] Namely: LEED, BREEAM, or DGNB Certifications. See section 4.3.
[89] Energy savings and reducing greenhouse gas emissions, mainly.

prioritized, I would rather earn less but make us famous because the people are living in a product with good quality, good comfort ..." (PD.16 : par.7)

In most of the cases, the motivations as part of the company policies, usually emerged following a "top-down" approach; in another words, at the higher levels of decision-making structure within the company. On the one hand, the motivation arose mainly from a decision by the company owner, president, or CEO, as stated below; on the other hand, in only a few cases did the motivation arise from a staff member lower in the company hierarchy, namely the head of the innovation department or an energy efficiency specialist working for the company.

"...[applying energy efficiency measures] was an initiative of the president of the company who is very involved in environmental issues and sustainable development and all that (...) we have followed him on this urge to give it a whirl [to the traditional way of building]. Ours is actually one of the first companies that started with such motivation..." (PD.21: par.16)

In fewer cases, when the real estate company is a subsidiary of a larger multinational real estate company, the motivation for applying energy efficiency was born in the parent company. Thus, company policies, motivations, and knowledge are transmitted to the subsidiaries, regardless of the country where they are installed, as described below.

"...we have gotten into the energy issue because our architects work primarily in the U.S., they are very knowledgeable of all the energy issue and the steps being taken in the U.S. in the construction of buildings and have tried to incorporate in their projects what they are seeing, that is the forefront in the U.S. ..." (PD.3: par.12)

According to the CEOs, the second set of company policies involving the adoption of residential EEM are linked to innovation policies. In general, innovation policies are oriented to provide a better product to their clients. This means offering better products not only in terms of quality - that is, with a higher quality of construction materials, finishes, etc. – but a better product itself, with better quality of architectural design and the whole project. Moreover, the idea of innovation is partly related to differentiation strategies (mentioned above) because, seeking originality and being at the forefront of private housing supply seeks, basically, differentiation through the product, as stated below.

"... our business is real estate, our business is to make housing attractive, innovative, and seek strategic alliances that allow us to move in that direction ..." (PD.17 : par.26)

"...the company's vision is to be a leader and innovative in the market, thus we are always looking and determining which items are more attractive to the public, in order to incorporate them into our projects ..." (PD.4 : p.12)

Innovation Policies

Companies' CEOs mentioned that the implementation of EEM is closely related with the implementation of technological innovations that seek to solve the specific problems of the private housing market. In the case of Santiago de Chile, this means primarily improving the thermal performance of the building envelope that, at the time, was considered innovative by the fact that, until then, it didn't existed in the country. The good example of this kind of technological innovation is the implementation of double-glazed windows (commonly called "thermo panel windows" in the local market) which had a slow process of integration into the market, mainly due to high costs of double-glazed windows and lack of skilled labour force (situations described in more detail in section 7.2).

Moreover, most of the energy efficiency measures implemented by the interview partners followed the technological innovations pushed up by government incentives; namely solar panels and energy saving light bulbs (PD.9).

Environmentally-friendly Policies

Finally, CEOs mentioned a third set of company policies looking for company's activities to be more environmentally friendly. It was mentioned that the use of fossil fuel in housing buildings is problematic. Firstly, , because of the nation-wide shortage of fossil fuels, which implies a high vulnerability because of the dependency on neighbouring countries for the provision of resources (situation described in the Introduction Chapter and discussed in detail in the following sections).

In addition, the combustion of fossil fuels within the dwelling also generates intra-domiciliary pollution. Usually, the devices use liquefied gas in kitchen stoves and hot water heaters, and kerosene in open flame heaters. Thus, coping with intra-domiciliary pollution was an important motivation for seeking a technological turnover and thus significantly reducing the health risk of users, as described below.

"...our [initiative] was born in 2000 and listed as a need for buildings in which there were no risks to people, but especially with the gas issue. Chile had, we still have, regulations on the gas issue which is very precarious (...) we said: we cannot build a building thinking

there is a risk that a person can get poison and may die within a building of ours. Then we have to find alternatives to do it differently given the regulations we had at that time and do something that was 100% efficient, was of very high cost ..." (PD.15 : par.10)

Internationally, the concern for CO_2 emissions is also present in the literature. It has been shown that, among the many benefits of implementing energy efficiency measures in buildings for the society as a whole, one of the most important is the reduction of greenhouse gases and air pollution produced by fossil fuels combustion (OECD-IEA 2008). While the environmental benefits at the local scale are important, the benefits are also reflected beyond the environment, since they also have a significant impact on housing tenants' health, safety, and wellbeing. In the case of Santiago de Chile, is very common to find the use of individual heating systems in dwellings during winter months, where double-combustion firewood stoves and kerosene open-flame stoves are commonly used within the households. Therefore, the implementation of energy efficiency measures, specifically related to the improvement of thermal conditioning and the use of alternative heating systems in residential buildings in Santiago de Chile, can generate broader benefits than the mere reduction of households energy consumption; benefits account also for: the reduction of domestic pollution and CO_2 emissions. The concern aforementioned has led to private developers to seek for innovative alternatives for tackling the domestic pollution problem by implementing alternative strategies that are strengthen by public-private partnership.

According to two different real estate companies' CEOs, who both claim to be the creators of this particular initiative, the need to reduce and eliminate the intra-domiciliary pollution in apartment buildings was the motivation for designing a building in which all appliances work completely on electricity; in other words, to make a full electrical building. In order to accomplish this goal, two important aspects were subject to major innovation. First, from the point of view of technological innovation, all appliances using fossil fuels within the whole building were replaced with electrical appliances: i.e. kitchen-stoves, sanitary hot water heaters, kerosene in open flame heaters. Furthermore, efficient lighting systems in dwellings and common spaces were introduced and regular light bulbs were replaced with energy-saving light bulbs.

Second, engagement of the institutions responsible for both the supply and regulation of the electricity service was sought. In the RMS these institutions are: Chilectra, Chile's largest electric distribution utility, and the National Energy Commission (Comisión Nacional de Energía or CNE), the energy regulator in Chile. Through this strategic alliance, a new optional rate for homeowners was created: the Residential Hourly Rate (Tarifa Horario Residencial or THR), officially introduced to the market in November 2008[90].

5.2.3 Resource Efficiency

The specialized literature shows that in the international context, several countries initiated the implementation of regulations for new buildings construction in response to urban disasters; such as, large urban fires, epidemics, and natural disasters such as an earthquake (OECD-IEA 2008). Therefore, implementation of building codes for new buildings, aims to minimize and prevent future disasters.

In the perspective of real estate companies applying energy efficiency, crisis periods generate needs. For example, it was mentioned the fact that Chile's significant seismic activity has been one of the most important triggers for technological development in the country[91]. Accordingly, it was mentioned that Chile has recently positioned itself as a world leader in seismic developments (personal communication from the Construction Institute representatives during fieldwork, March 2012). As an example, few managers mentioned that the seismic events that took place in the country directly affect the dynamics of apartment sales in high-rise multi-family buildings. It was mentioned that, after a significant seismic event took place in recent Chilean history, the apartment sales in the upper floors of high-rise multi-family buildings was significantly reduced. Over time, as the seismic activity gradually diminish and daily life returns to normal state, prospective buyers' normal preferences for apartments in upper levels of the building (mainly due to the views of the city and towards the Andes) it is restored, thus creating an increased apartment sales rate in upper floors once again.

A similar phenomenon, as the variation in the apartment sales flow in upper floors in multi-family buildings caused by seismic activity, appears to occur in the demand for energy-efficient housing. Real estate developers manager’s mentioned that energy crisis – such as the international oil crisis in 1973, or the historical energy crises in the country, mainly associated with periods of natural gas supply shortages from Argentina (see

---

[90]According to the so-called “*Top Price Decree No. 381*”, set by the Chilean National Energy Commission (CNE). It is an offer valid for customers Chilectra or within the concession area since 2008.

[91] The earthquake in 2010 affected many Chilean regions. Namely, Valparaiso, Metropolitan of Santiago, O'Higgins, Maule, Biobío, and Araucanía.

Chapter 2) – triggered an increased demand for energy-efficient housing, as described in Figure 25.

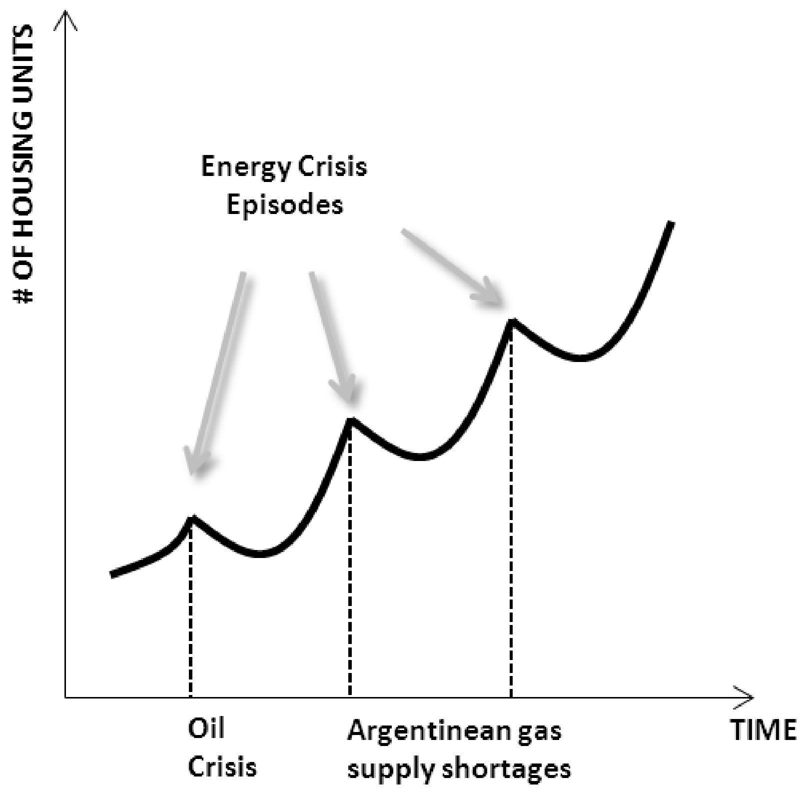


Figure 25: Schematic Representation of the Demand for Energy-Efficient Housing Triggered by Energy Crisis Episodes.
(Source: Own illustration)

Apparently, there is a peak in demand for energy-efficient housing whenever an energy crisis episode occurs in the city or in the country; once the State takes action to restore the supply for energy to normalcy, the demand for energy-efficient dwellings fell. The quotation below illustrates this:

> *"... when Argentina cut off the [supply of] gas 3 years ago …everyone started with the awareness of solar panels, the house had to be more efficient ... that is: crises create needs ... " (PD.10: par.29)*

From this perceptive, such energy shortage episodes tend to raise the concerns for energy consumption in residential users, and may lead to an increase in the demand for energy-efficient housing. The increase in demand slowly returns to a certain stable level, usually through support of government interventions in order to alleviate the energy crisis and the concern fades from daily life. A subsequent event will generate a new increase in the demand and the cycle repeats itself. Finally, from the perspective of real estate companies, the State has the responsibility to intervene in the market in order to create the necessary conditions to foster a stable and permanent demand for energy-efficient housing.

Literature on diffusion of innovations suggests that at times there exist new innovative ideas within an organization[92] that are not yet implemented; that means that some ideas are a fallow potential until some sort of shock occurs. According to Van de Ven et al (2008), shocks served to concentrate attention and focus the efforts of diverse stakeholders in organizations. Moreover, shocks may occur in many different forms and might include new leadership, product failure, a budget crisis, or an impending loss of market share (Van de Ven et al. 2008, pp.28-29).

Furthermore, concrete actions to undertake specific innovations appear to be triggered by shocks from sources internal or external to the organization (Schroeder et al. 1989 cited in Van de Ven et al. 2008, p.29). The empirical evidence seem to suggest that, as regards private supply energy efficient housing in Santiago de Chile, the shocks come from an external source and are related to the occurrence of episodes of energy crisis.

In the context of growing concern of scarcity of energy resources, company's CEOs claimed the decision to adopt EEM in their housing offer is partially motivated by seeking the efficiency of the available energy resources. This decision sought to reduce operating expenditure of households, but also keeping in mind energy resources shortage and thinking about the quality of life for their clients.

As regards reduction of household operational costs, many CEOs mentioned that their motivation for adopting EEM was to generate savings in the monthly budget of their clients through reducing the households expenses related to energy use. This means, on the one hand, to reduce the cost of common area expenses for lighting, heating, and hot sanitary water for all users who live in multifamily buildings, because each household's energy costs are charged simultaneously with the common area expenses. On the other hand, to reduce the bills for electricity and gas services in single-family houses. The quotations below illustrate this:

> *"… [residential energy efficiency measures] basically are just efficiency-oriented measures but directly related to lower the common expenses to the users of the building, is the reason for all this: that someone benefits from the efficiency… " (PD.7: par.8)*

---

[92] In this extend, an organization may be a single company or a broader system.

"We thought to generate savings for the client, because people do not use heating, they [the users] think that it is very expensive, so we thought to generate a financial saving for the user and decided to implement solar panels" (PD.6: par 9)

Furthermore, as mentioned previously in section 2.2 – which analyzes the various alternatives for financing homeownership within the Chilean housing market – a key concern for prospective homebuyers is the cost of the monthly home loan payment. This cost varies according to the characteristics of the dwelling to be purchased (size, location, layout, accessibility, etc.) and is usually proportional to the housing's common area maintenance cost. In general, a larger house requires a proportionally larger maintenance cost; on the other hand, a small department demands lower maintenance costs. Thus, some CEOs say all monthly expenses, fixed and variable, concern them. Therefore, the motivation to implement EEM aimed at reducing energy costs from monthly household budget, as stated below.

"... [energy efficiency measures were adopted] mainly thinking about the user, the homeowner (…) so the user has the common expenses as low as possible…" (PD.9:par.6)

"… and all that [the innovations] is reflected in the tenant's share of expenses; today we are proud to say that we have broken the record for the lowest tenant's share of expenses of the municipality of Providencia, while in most of the housing projects of the municipality the tenant's share of expenses is around 0,05 UF per square meter we are at 0,02 UF per square meter, that means 40% of the municipal average …" (PD.16, par 7).

"...these apartments [in Santiago downtown area] are relatively cheap, so the dividends that they [the homeowners] have to pay for their mortgages are very low. For example, the dividend of a one-bedroom apartment is around 130,000 Ch$ and its common expense is around 30,000 Ch$, which to him [the homeowner] is quite significant with respect to the dividend. Thus, the lower we can make the common expenses the better we benefit him, so he has the solvency to pay such dividend..." (PD.9:par.7)

Moreover, the manager's concerns about the reduction of operational costs points to a broader time horizon. In the long run it seeks to lower household maintenance expenses for end users. Therefore, reducing the dwelling's maintenance costs for the house owner implies a reduction of after-sales service for the real estate companies. Thus, both parties can reap the benefit, as set forth below.

"… with a good thermal insulation system the project has a healthier life, in the sense that the maintenance costs for the owners is lower, and the cost of the after-sales service for us is also lower, which is a benefit for both parties." (PD.4: par.20)

The second factor related to resource efficiency is grounded in energy-shortage concerns. As mentioned in the Introductory Chapter, the Chilean electricity sector is mainly based on thermal and hydropower energy generation. After the gas supply outages from Argentina in 2007, which are necessary for power generation, as well as the long periods of drought that affected hydroelectric generation, Chile began the search for alternative sources for electricity generation to ensure the provision of electric service. Beyond national policies to address this issue, the overall concern for the provision of electrical service was introduced in the daily discussion of Chileans and the property sector was not unfamiliar with this situation. Thus, managers of real estate companies mentioned that the energy shortage episodes were important motivations for implementing residential EEM:

"It started in 2006, 2007 when there was an energy crisis here in Chile, when the Argentineans cut us off from gas or so, then, at that moment we started to look for alternatives, we said this has to change in some way ..." (PD.13 : par.20)

Finally, it appears that the concern for resource efficiency is partially motivated by economics and partially by energy needs. As mentioned above, while on the one hand the real estate companies seek to reduce the pressure exerted by the housing sector on power generation by reducing energy consumption in dwellings; in contrast, the concern for reducing energy consumption in dwellings is grounded on the conviction that the energy cost will increase over time.

"... energy was expensive, it will remain expensive until someone invents something that costs a little less and we are more efficient; also, beyond all that, beyond that we would have cheap energy, we should just keep saving anyhow, the idea is not to waste something that you can, somehow, share in a better way with everyone else..." (PD.2:par.21).

Some managers believe the benefits the diffusion of residential EEM may bring go far beyond savings in residential energy consumption; they may have a significant nationwide impact. According to this perspective, the concern for energy generation and consumption has been introduced in Chilean society gradually.

"…we are all becoming aware that the cost of producing energy, by whichever method, is getting higher and therefore the extent that we are able to save some of that energy and to consume less, eventually will put less pressure on the generation, on the [energy] generation sources, on the [energy] prices, on the economy, etc…" (PD.20: par.17)

5.2.4 Government Incentive Schemes

The implementation of Non-Conventional Renewable Energy (Energías Renovables No Convencionales or ERNC) in the housing sector, through the adoption of government temporary incentive schemes in form of subsidies for the use of solar thermal panels (STP[93]), is the second most commonly used innovation related to energy efficiency in the private housing sector, real estate developers argued. However, in some cases implementing STP goes beyond the mere existence of subsidies. Some managers mentioned that they started applying STP in their housing projects long before the subsidy existed. In some cases it was mentioned that even the cost of implementing the STP was carried by the company and is not transferred to the end users of the homeowner (P.11).

Nonetheless, it seems that real estate companies' opinions regarding government subsidies for the installation of STP in the housing sector are divided. On one hand, in some fewer cases it was mentioned that the decision to implement STP in residential buildings is due to, solely and exclusively, the existence of State subsidies, as outlined below.

"… the only reason that the company had installed [solar] panels here was because of the subsidy, otherwise they would have not been installed. These are company policies." (PD.13: par.39)

On the other hand, those who apply STP as technological innovations since long before the subsidy release, they see as a positive step that the government has released this incentive program.

"…we were just lucky that year the state subsidy was born, the one that subsidizes the solar panel installation, we already had the concern, we never covered the costs on our own because the subsidy came out, then once the subsidy came out a 100 % of our projects have taken advantage of the subsidy and we provided solar panels ..." (PD.7 : par.8)

[93] As described in section 6.1, when using solar thermal panels, solar energy is utilized to heat the sanitary water for the daily use and/or to integrate it to the dwelling's heating system.

Moreover, for this group of real estate companies it would be desirable that government subsidies are extended to other measures promoting energy efficiency in the housing sector; for example, to promote a more intensive use of double-glazed windows or replacing single-glazed windows with double-glazed windows. It was also mentioned that it would be desirable to extend the period covered by the subsidy for solar panels. It is expected that the deadline for the implementation and use of subsidies ends in 2013; this period seems to be rather short and it may imply that the benefits achieved through the implementation of energy efficiency measures[94] are yet to be seen in the medium and long term. The following quotations illustrate this:

> *"This is a subsidy until 2013. I think it should be a permanent subsidy, because it is a savings for the country and being [Chile] a country with energy-generating problems, it directly addresses the problem of energy generation...". (PD.13: par 33)*

> *"... the entire first phase project will go with solar panels on the roof for hot water and that is going to take the subsidy form the government. I say the first phase because I understand the benefit period goes until then, but we are hoping that this period will be extended to incorporate in the other phases, more than 400 housing units, the first 100 would take that system [STP] and if the subsidy does not extend to the other 300 they will not have this system, but we're betting that it will be extended and we will have the 4 stages with solar panels subsidy ...". (PD.4:par 38)*

The Spanish experience was perceived as very influential in the Chilean decision to implement subsidies for STP. While on the one hand the Spanish experience was positively valued and recognized by most of the CEOs, and was considered as pioneering in the field of renewable energy; in contrast, several CEOs mentioned that the underlying reason for the implementation of subsidies in Chile was because there was a stock of STP on the Spanish market; this argument is grounded in the fact that subsidies for STP were removed in Spain in 2008. This means that STP providers in Spain (using Chinese technology, among others) were left with a stock of products due to funding cuts funding from the Spanish government. Thus, providers sought other strategic alliances in other countries, in this case in the Chilean market, in order to commercialize these products elsewhere (PD.5).

---

[94] Energy efficiency measures have the potential to provide significant reductions in electricity use while saving consumers money in the long run.

From the perspective of the CEOs, through the implementation of subsidies for renewable energy the State seeks: first, to help poor people gain access to technology that can reduce energy consumption levels and second, to modify the rate structure so as to be competitive with other power generation systems (PD.5).

From the theoretical perspective on the diffusion of innovations, the work of Rogers (2003) seems to agree with private developer's opinion. According to Rogers, adopter incentives are designed to ensure the adoption of new ideas, primarily with two objectives. First, in order to increase the adoption rate by increasing its relative advantage[95] and triggering therefore a wider adoption of the innovations. Second, to lead to the adoption of an innovation by individuals different from those who would otherwise adopt. When a relatively large adopter incentive is paid to STP adopters, for example, individuals of the lowest socioeconomic status, such as the target of the STP incentive, will adopt the innovation. Finally, such State intervention may have important implications for socioeconomic equality in the diffusion process (Rogers 2003, pp. 236-239).

Finally, CEOs mentioned that there is no clarity about the objectives sought by the government when implementing STP subsidies. On the one hand, there is criticism that the State seeks to reduce residential energy consumption of low-income households through implementing temporary subsidies (which do not introduce major economic and cultural changes) and not intervening at the level of public policy through modifications to the legislative body. As an example, the creation of carbon emissions taxes in the mining sector was mentioned, which may generate a permanent public instrument to address the national energy problem (PD.5).

In contrast, interviewees also mentioned that the way in which the subsidy program for STP has been designed and implemented seems to seek savings for the purchase of new housing and not necessarily promoting energy efficiency or energy savings. Moreover, interviewees mentioned that there should be a detailed analysis of the households' energy consumption in order to determine the prospective subsidy beneficiaries instead of selecting them on the property price. At the moment, the analysis of the prospective subsidy beneficiaries is made based on the property price and the

[95] Rogers (2003) defines relative advantage as the "degree to which an innovation is perceived as being better than the idea it supersedes" (p. 229)

Social Protection Card[96]. Both indicators are closely related to the prospective buyer's ability to pay and, therefore, with their socio-economic status (PD. 13).

From this perspective, there is the need for a dedicated study on the energy consumption profile of households to define State intervention. On this basis, the State may use the so-called "*carrot and stick approach*" to encourage the adoption of residential EEM, either through subsidies (the carrots) to those who need government support in order to access the new technology, or through taxes (the sticks) for those with a higher energy consumption rate.

[96] To allocate the monetary subsidies, the government of Chile developed in the eighties, a social characterization record card, called "Ficha CAS". See Chapter 2.

6 Existing Residential Energy Efficiency Strategies

The aim of this Chapter is to identify and classify the different residential energy efficiency strategies implemented in Santiago de Chile. The Chapter is divided into three main sections. The first section deals with passive design strategies, the second section deals with active design strategies, and the third section deals with public-private partnership strategies.

According to real estate developers, the energy efficiency strategies implemented in their housing supply was diverse (see Table 19). Nonetheless, the implementation of the various energy efficiency strategies[97] sought a common aim: to reach a comfort temperature inside the housing while using the energy efficiently; in the case of the private housing market, this means looking for the optimal use of energy for space heating or cooling, lighting, hot sanitary water, and ventilation.

Table 19: Summary Residential Energy Efficiency Strategies
(Source: Own compilation)

Interview Results Summary		
Passive Design Strategies	Improving the Building Envelope	Double-glazed Windows External Insulation of Walls Internal Insulation of Walls
	Renewable Energy	Solar Thermal Energy
	Bioclimatic Design	Building Orientation Natural Illumination Natural Ventilation Use of Vegetation Green Roofs
Active Design Strategies	Technological Improvement	Illumination Systems Home Automation Systems (Domotics) Heating Systems Air Conditioning Photovoltaic
Public-Private Partnership	Chilectra - Full Electric Buildings	

In general, depending on whether there is the need to make an additional energy effort in order to achieve optimum indoor comfort conditions, the energy efficiency strategies implemented in the private housing sector are grouped into two main groups: passive design strategies and active design strategies. Passive design strategies are those that

[97] The terms "*Measures*" and "*Strategies*" are used interchangeably.

do not demand any additional effort to maintain indoor comfort conditions; for instance, the use of solar strategies for heating. In contrast, active design strategies are those that require some additional mechanical effort to maintain optimal thermal conditioning, for instance heating or air-conditioning systems.

A third energy efficiency strategy adopted to improve the energy performance of housing within Santiago de Chile private housing market, emerges through the public-private partnership between the local electricity distribution utility and the National Energy Commission. This initiative involves a technological change (all heating systems, hot sanitary water, and kitchen-stoves in the dwelling should be electric appliances) and the application of a special rate for the residential electricity consumption.

The following sections analyze and discuss the various residential energy efficiency strategies adopted by real estate developers in Santiago de Chile. In each case, the alternatives are based on information provided by the different actors interviewed during the fieldwork. Moreover, a transversal analysis is performed on the different adopters' categories (discussed in section 5.1), in order to find possible connections between energy efficiency adopters and the implemented energy efficiency strategies.

6.1 Passive Design Strategies

Passive design strategies refer to what it is possible to be done in order to reduce buildings' energy needs and thus reducing also buildings' energy consumption, in general, that means adopting an environmentally friendly lifestyle towards saving energy. A basic characteristic of passive design strategies – distinguishing them from active design strategies – is that in order to operate they rely on inherited thermal properties of materials used in the building and do not require any external energy-operated systems for indoor thermal conditioning.

Nowadays, passive solar heating, cooling, and lighting techniques have reached a high degree of technical maturity. Large scale applications, especially in new settlements, have shown that very high energy gains can be achieved while the thermal and visual comfort, as well as indoor air quality is also very satisfactory (IEA 1997). Following this trend and strongly influenced by the new thermal regulations in the Chilean housing sector, real estate companies in Santiago claimed to be applying various passive design strategies in their new housing offer.

Passive design strategies refer to what real estate developers are doing in order to reduce household's energy needs and thus, the energy consumption of their housing buildings. Such strategies include: 1) improving the overall thermal performance of the building envelope, by using appropriate energy efficient materials, insulation techniques, and double-glazed windows in order to reduce heat lost and, therefore, wasted energy; 2) the use of renewable energy, solar thermal and photovoltaic technology, for hot sanitary water and energy conversion respectively; 3) bioclimatic design and construction principles, are applied in the very early stage of architectural design of the buildings, taking into account outdoor climatic and local conditions in order to optimize the comfort indoors; and 4) using electrical appliances and lighting in an energy efficient manner and, in general, adopting an environmentally friendly lifestyle especially towards saving energy. A basic characteristic of Passive design strategies, distinguishing them from active design strategies, is that to operate they rely on inherited thermal properties of materials in a system and do not require any external energy sources.

Improved Thermal Resistance of the Building Envelope

Improving the thermal resistance of the building envelope is the most commonly adopted strategy by those real estate companies who claim to be applying some kind of energy efficiency strategies in the private housing market in Santiago de Chile. Many general managers mentioned that their aim is to reduce the thermal transmittance of the building elements and materials in order to ensure that, once the desired indoor comfort temperature is reached, it will not be affected by the outside temperature as this may be higher or lower than desired indoors.

The adoption of this kind of energy efficiency strategies in the Chilean private housing market is not a novelty. It appears that thanks to the introduction of new thermal requirements for the building envelope, implemented in the housing sector trough some modifications to the building code in 2000 (see section 4.4.3), an innovation process took place in the construction industry, involving construction systems and materials, followed by intensive marketing campaigns in the housing market.

According to the Chilean Institute of Construction (Instituto de la Construcción or IC), Chile is one of the few developing countries that currently have thermal regulations introduced through amendments to the building code, so they are considered pioneers in the field. However, he mentions that there is some delay compared to international experience, especially when comparing the Chilean experience with European and U.S., where the thermal regulation occurred in the 1970s (personal communication from Construction Institute representatives during fieldwork, March 2012).

Some real estate companies' managers mentioned that the concern for the thermal behaviour of residential buildings envelope was born in their companies before the new thermal regulation enactment (the group called "*pioneers*", see section 5.1.1). Interviewees mentioned they sought to improve the thermal performance of the building envelope (or building enclosure) through the implementation of new construction techniques and materials before the enactment of new regulations for thermal transmittance of the different elements of the building envelope (walls, ventilated floors, roofs, and glazing area; see 4.4.3) form the government's side. According to interviewees, the search for improving the overall thermal performance of the building envelope in their housing supply was carried out making the best of opportunities and following a trial and error strategy. Real estate companies sought making the best of the availability of resources for the design and construction of housing for higher socio-economic groups; which usually have a very healthy budget and give some freedom in terms of decision making; in both technical and aesthetic aspects. These decisions meant to choose and try different strategies and products available in the market to enhance the thermal performance of the building envelope. The quote below illustrates this:

> *"… the concern started in 1998 more or less, with a project in Las Condes [middle-high income municipality in Santiago de Chile], in a slightly more expensive building. Suddenly we were encouraged to do so [to implement energy efficiency measures] because it was justified to make a greater expenditure, and we assumed that the clients who were targeted could afford it, thinking that eventually it would bring them a profit. We are talking about apartments around 140 square meters, between 6000 and 7000 UF or so, we're talking about a C1 group [middle-high income group], very clearly ... " (PD.21: par 16)*

The literature mentions that for many of homebuyers interpret the mere existence of building codes may be assurance enough as to the dwelling energy efficiency of new buildings. However, recent studies (see OECD-IEA 2008) argue that energy efficiency standards specified in building codes rarely represent optimum energy consumption.

Among real estate developers, there seems to be a consensus of conformity with regard to the so-called "*New Thermal Regulations*" (NRT), which encourages the implementation of energy efficiency measures in the housing sector, as it would fill a gap in the housing regulations. Nonetheless, many – not one or a few – general managers think that the requirements of the NRT set too low standards, especially when comparing the requirements of the Chilean standard with international standards, as the following quote illustrates:

> *"... the Chilean standard for thermal insulation basically fills in a gap, accomplishes nothing, all it does is that now there is a thermal standard, which there was not before... and that of course, is a huge step forward but not necessarily the correct one. We make reference to the thermal standard only as a context data, that is, if all that you want is to comply with the thermal standard, the strategy used is the thermal insulation, but it is definitely light years away from achieving energy optimization. The thing is, between having and not having thermal insulation [in the building envelope] is a huge shift in the behavior of the [building] envelope's, but between the Chilean and advanced thermal efficiency standard, at [building] envelope level, both in Chile and Latin America as in Europe and North America, we are light years away. I mean, the thermal standard is just a gesture as if to say: this is an issue that we have to worry about, but for us it is not even part of a theoretical framework..." (PD.5: par 14)*

The representatives of the Ministry of Housing and Urbanism (MINVU), institution responsible for the development of NRT, agreed that initially relatively low requirements were set in the new regulations. According to the representatives, the decision was taken based on two major grounds. First, at the beginning of the implementation of the NRT, many masonry solutions existing in the Chilean market would not have complied with the new regulations[98]; therefore, the masonry solutions necessarily had to be improved by incorporating insulation in the envelope. Therefore, although the initial results of the study demanded higher thermal transference values, it was strategically decided to set less demanding values, because it was necessary to find a joint agreement between the market and the State in order to prevent a break in the industry construction or increase in the costs. Second, there was strong pressure to lower the thermal requirements from key players in the construction industry, especially the brick makers, who exert an important pressure, since a significant share of the dwellings that are built today, are made of brick. However, those responsible for drafting the regulations expected an update of the values set in the NRT during 2013 (personal communication from representatives of the MINVU during fieldwork, March 2012).

---

[98]Especially in the Metropolitan Region of Santiago, the Chilean central zone and southward from Chile, where according to the thermal zoning defined by the NTR, higher thermal transmittance values for exterior walls, are contemplated.

However, according to the specialized literature, the Chilean experience is no exception. A recent study by the OECD-IEA notes that building codes tend to set local standards based on the new buildings available on the local market supply, and not necessarily based on the minimum standards as they were initially defined – theoretically based on technical arguments and energy modelling – by the local authorities responsible for evaluating and implementing the building regulations (OECD-IEA 2008).

Moreover, the work of Koeppel and Ürge-Vorsatz (2007) which evaluates the political effectiveness in implementing energy efficiency in buildings shows that although energy efficiency standards for buildings are frequently used in local regulations, their effectiveness varies widely from country to country, due to the difficulties in implementation and the different local levels of corruption, especially in developing countries. Moreover, the authors argue that a key to achieve real impact on the construction sector is market transformation through a combination of policy instruments (regulatory instruments, information instruments, voluntary agreements, and financial incentives); the idea behind market transformation is the combined use of a number of tools to transform the market in the design, construction, and operation of buildings (Koeppel and Ürge-Vorsatz 2007).

The private housing market in Greater Santiago is highly competitive, with each private developer company competing to establish its distinctive position in the industry. At the same time, however, companies must cooperate to establish the infrastructure required for all industry stakeholders to survive collectively. This seems to be a paradox of cooperation and competition which seeks cooperation to set up an industry whose standards clearly benefit all companies. However, in doing so, each stakeholder tries to ensure that standards that suit it best will be institutionalized (Van de Ven 2008, p.16).

The process for the implementation of the NRT has been very slow. According to the director of the Construction Institute, the institution responsible for developing the NRT proposal, the IC worked on the proposal from late 1999 until 2003. During the preparation of the proposal it sought the involvement of all stakeholders in the construction industry to have a relationship with the topic (i.e. real estate companies, architects, builders, suppliers of building materials, etc.). The purpose of seeking this involvement was to deliver to Ministry of Housing and Urbanism (MINVU) a proposal which already had the technical, economic, and social viability, so it did not face any objections for its implementation (personal communication from Construction Institute representatives during fieldwork, March 2012).

Moreover, Rogers (2003) argues that the adoption of innovation following a trial-and-error strategy is characteristic of the group of "pioneers" in the adoption process. In the specific case of the thermal envelope improvements in residential buildings in Santiago de Chile, managers of real estate companies mentioned that the greatest efforts were made by improving the insulation in walls, ventilated floors, and ceilings. In external walls, mainly in the case of concrete walls, improvements were firstly made by applying the insulation on the inside face of the walls; later on the insulation was applied on the outside face of the walls. At present, there seems to be a consensus among managers and technicians of real estate companies in applying the layer of insulating material on the outside of the walls, because this technique has proved to be more efficient.

There seems to be a close relationship between technological innovations in the elements of the building envelope (both in materials and in technique) and the socioeconomic status of the prospective homebuyers, for whom the buildings are designed for. Several real estate companies mention to be innovating in their projects through the implementation of double-glazed windows instead of single-glazed windows; furthermore, in terms of materials and technical insulation of exterior walls, they mentioned that they were innovating through the application of insulating material on the outside face of the walls. In both cases, in the use of double-glazed windows and exterior wall insulation, the projects target primarily higher economic segments. The following quote illustrates this:

> *"...in the high-cost housing, today we are incorporating several [energy efficient] systems. First, the structure is 100% insulated from the outside, which provides better thermal efficiency to the housing and the envelope. Second, all those houses bear the thermal panel [double-glazed windows], as a way to improve the [housing] thermal efficiency in particular in wintertime. (...). Additionally, in these price segments, in these products, we are evaluating today to incorporated into the thermal panels some kind of thermal insulation or refractive treatment, either by means of incorporating higher refraction layers in the glasses, either interior or exterior, in order to have UV radiation in the housing ... " (PD.20: par 13).*

In this regard, technological innovations involve greater expenses in the construction process itself. The greater expenses are primarily due to the use of significantly more expensive materials, such as double-glazed windows or insulating materials with increased heat resistance, and the use of skilled labour for the application of these materials. In none of the cases were these costs assumed by the private developer companies; instead, the costs were directly transferred to the end user or prospective homebuyer. The prospective homebuyer has a higher purchasing power and a higher socioeconomic status than the population average, which grants them access to these products.

Figure 26: Implementation Trombe Wall in a Single-family Housing in Santiago de Chile. (Source: Own Photograph)

Figure 26 shows a trombe wall applied in a single-family housing as part of a set of energy efficiency strategies implemented. Basically, the trombe wall is a passive solar building technique where a wall was built on the north side of the building[99] – in order to collect as much sunlight as possible due to the solar path in the southern hemisphere –

---

[99] I order to minimize the summer gains when implementing this technique on the west-facing rooms at the external facade, the literature recommends the use of overhangs. However, additional means would be helpful to minimize summer cooling impacts. In both walls, edge effects were minimized with appropriate ground insulation (Torcellini and Pless 2004).

with a glass external layer and a high heat capacity internal layer separated by a layer of air. The staff of engineers in charge of the design and implementation of the energy efficiency strategies in the dwelling, sought to reduce the space heating energy demands. By applying these technique, the heat in close to UV spectrum passes through the glass almost unhindered then is absorbed by the wall that then re-radiates in the far infrared spectrum which does not pass back through the glass easily, hence heating the inside of the building. Trombe walls are commonly used to absorb heat during sunlit hours of winter then slowly release the heat over night.

Renewable Energies

As mentioned in the early chapters of this doctoral thesis, buildings over their life cycle account for a large share of global CO_2.

The European Commission reports that buildings are responsible for a significant share – around 42% – of the EU's final energy consumption and for about 35% of all greenhouse gas emissions (Nelson et al. 2010, p.3). Consequently, a considerable number of measures affecting the real estate sector have been implemented in order to reduce housing energy consumption. According to Nelson et al. (2010), many governments in Europe subsidize the use of renewable energy sources and support actions to improve insulation. Most European countries have also tightened environmental regulation for new buildings and refurbishments of old buildings (as shown in section 4.2.). The Chilean government is not exempt from this type of initiatives to stimulate the private real estate sector through subsidies for the installation of residential renewable energy, as discussed in the following sections.

As discussed in the sections above, when examining the motivations for the adoption of energy efficiency measures in the private sector, most companies adopted the so-called non-conventional renewable energy sources (Energías Renovables No Convencionales or ERNC) in relation to the State subsidies for implementation of solar thermal panels (STP). Certain exceptions exist mainly in the so-called early adopters group, who adopted this technology before government's STP subsidy program started (see section 5.2).

Figure 27: Implementation of Solar Panels in Apartment Buildings in Santiago de Chile (Source: Own Photograph)

The main goal is harnessing solar energy in two systems: solar panels for the heating of sanitary hot water (as shown in Figure 27) and solar electricity systems, known as solar photovoltaic (PV). The first system was strongly encouraged by the government's STP subsidy program; the second one was a less developed private initiative with more experimental uses. Finally, among the adopters of ERNC, there were some cases adopting geothermal systems, which is not yet a well-developed strategy. Nonetheless, it is being applied for cooling high-raise buildings and for heating small gated-communities. Moreover, a project which uses the streams of melt-water from the mountains surrounding the RMS was mentioned as one innovative experience in the use of geothermal energy. These streams have relatively low temperatures, and can thus be utilized by a pumping system to help cool the building:

> *"... now, with the new project we are doing, the main and most important innovation is that we are using geothermal energy. We are using all groundwater threads from [snow] meltdown to cool the building, and the building will save 70% of energy in air conditioning. Thanks to this, it will be as if the building has its legs tucked in cold water, and we will take heat exchangers to reduce the temperature of the building from that. These are glacial waters coming from the mountains". (PD.19: par 24)*

Along with the implementation of ERNC, in the Chilean context the Net Metering (NM) has been introduced. It is a legal instrument used to encourage the development of electricity generation ERNC. The aim of the system is that consumers, in this case residential ones, are able to generate electricity on their own account with ERNC means (usually using wind and solar technologies). After meeting the needs of each housing unit, the idea is that the surplus energy generated by means of residential ERNC can be injected and sold into the network. In order to do this, customers who have generation units should make a monthly balance between the electricity injected and removed from the network. This is achieved by installing bidirectional electricity meters, which should be considered as part of the costs necessary to implement the NM. Therefore, with this instrument, the customer is charged only with the net electricity consumption.

However, the NM implementation has its limitations. In March 2012, law number 20.571 governing the payment of electricity tariffs for residential generators was published in the Official Journal (MEFR 2012). This law establishes the NM, nonetheless, to date the regulations associated with the law have not yet been promulgated. These are supposed to establish: the requirements enabling these generation systems to be able to connect to local networks, the safety measures, the technical specifications and equipment safety, and the mechanisms for determining the cost adjustments to the networks, among other factors.

Finally, pioneering experiences on implementing geothermal energy sources (GES) for domestic heating in pilot projects were also reported. Chosen projects are located in suburban gated communities, which has been an urban development model recently adopted in Santiago de Chile and other Latin American cities (see section 2.2). Private developers implementing GES argue that the housing units were predominantly sold to a segment of society who shares a common life style, characterized by living in close contact with nature. The later, suggests a close relationship between the homeowners' lifestyle, the dwellings they chose to live in, and the technical features of the dwellings. This suggests that, among many other features of the dwelling (i.e. location, size, building typology, etc.), the dwelling's energy performance may or may not be located up on the homebuyer's wish list. Therefore, energy efficient housing may be appealing for some groups of the society and not for others.

Bioclimatic Design

The specialized literature highlights the benefits generated by deploying passive strategies on energy efficiency in buildings. The work of Flores Larsen et al. (2008) highlights the contribution of passive solar strategies to reduce CO_2 emissions in global and local scales. The authors argue that the passive solar design strategies exploit several features of the building such as: orientation, shape, location of windows, materials, and exterior landscape; these considerations accompanied by other energy efficiency strategies can create comfortable environments that are independent of the use of fossil fuels, energy efficient, and accessible to a standard cost[100].

This highlights the importance of considering the elements of the environment as part of the basic criteria in the earliest stages of building design. Passive strategies can contribute significantly to achieve greater comfort inside buildings, while generating significant energy savings. That is why bioclimatic design criteria and passive strategies are offered as part of the basic training of architects in universities worldwide.

An important share of the companies' managers adopting energy efficiency measures are professional architects. This might be an explanation for the emergence of the topic of bioclimatic architecture in the interviewees' discourse. The general concern about the deterioration of the environment has promoted a commitment to ecology among architects and a more responsible attitude in the selection of materials and construction techniques.

Research on ecological and bioclimatic architecture seeks to fill a gap created by misinformation regarding the leading criteria when dealing with design with nature (Yeang 1999) and seeking sustainable architecture and autonomous housing (Hyde 2008).

---

[100] The authors argued that, evidence showing dwellings with passive solar design could generate up to 60% energy savings compared to conventional dwellings in cold, tropical, Mediterranean climates and extreme climate with hot summers and cold winters has been found (Flores Larsen et al. 2008, p.987).

Within this body of literature, it is possible to find different concepts and scopes related to a common concern in seeking a more sustainable architecture[101].

In the field of architecture, implementation of bioclimatic design strategies is considered the best cost-effective alternative. This is mainly because they are implemented from the design phase of the architectural design is when designing a building and incorporating, the micro-climatic conditions of a given site aiming to secure comfortable internal climatic conditions (namely: thermal comfort, heat gains, and use of natural lighting and ventilation) in order to ensure optimum comfort temperature inside the building, and avoid the use of active design strategies for managing and maintaining indoor thermal conditioning.

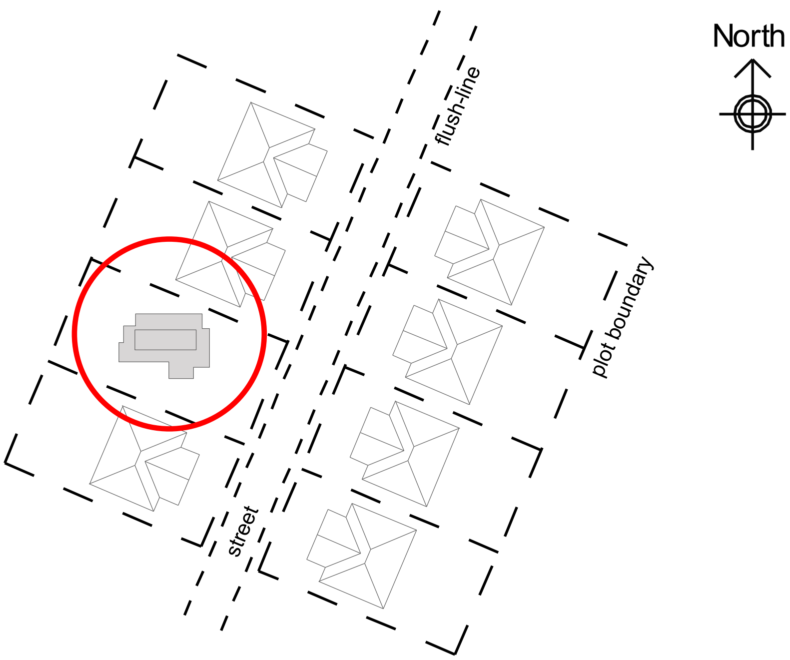


Figure 28: Implementation of Bioclimatic Design Strategies in a Single-family Housing in Santiago de Chile (Source: Own illustration)

According to Lookwood (2006), site-planning is one of the main bioclimatic design strategies to optimize the use of energy in buildings; this strategy is one of the simplest and involves the use of building orientation to take advantage best conditions of sunlight. This strategy is also considered into the residential energy efficient products supply in Santiago de Chile's private housing offer. As shown in Figure 28, the largest facade of

[101]Yeang's work (1999) research focused on ecological and bioclimatic architecture. It introduced into architectural design the ecosystem concept It has also raised the environmental impact analysis of architectural buildings as a segment of a larger flow of interactions, which includes not only climatic factors and resource management, but also the intervention of living organisms. Moreover, the work of Hyde (2008) examines how new priorities in the area of the environment have redefined the direction of housing in order to achieve sustainability. It identifies definitions, concepts and principles, and it shows that bioclimatic principles are a cornerstone of sustainable housing.

the building is oriented on an east-west axis, unlike neighbouring buildings whose main facade is oriented parallel to the flush-line. By orienting the building with the largest facade towards north, the maximum sunlight exposure during the day is collected on the east and north facades, and a smaller part of the building is exposed to the west to the afternoon sun, preventing overheating of the building.

The bioclimatic design strategies most commonly used by the group of real estate developers applying energy efficiency measures in their housing real estate products are: 1) the use of natural lighting through exploiting the orientation and location of the building; 2) the use of natural ventilation, taking into consideration the prevailing winds; and 3) the management and use of the vegetation on site for optimum conditioning of living spaces. However, the company managers mentioned that the use of vegetation has limitations in high-rise multi-family buildings, primarily the use of native species. Nevertheless, some experiences in the use of green roofs were also mentioned.

It is noteworthy that in all cases where the application of bioclimatic strategies was mentioned by interviewees, different bioclimatic strategies are being applied simultaneously. It was mentioned that while the contribution of such energy efficiency strategies is significant, there is still some resistance to its acceptance by customers (situation discussed below in section 7.4).

Finally, as it was shown in Chapter 4 the thermal demands set out in the new thermal regulations (NRT) are closely related to the location of the different housing projects. Fundamentally, the thermal zoning defined in the NRT defines U-values for the various elements of the building thermal envelope. However, the real estate companies' managers claimed that these values are yet very basic and far from being a contribution to achieving the comfort real values (situation discussed below in section 7.3); therefore, bioclimatic design might make a significant contribution to fill the gap created by the thermal regulations because the bioclimatic design strategies work in harmony with the site where the building is located.

6.2 Active Design Strategies

Active design strategies refer to what it is possible to be done in order to reduce buildings' energy needs by means of applying technological innovations in order to support the different housing systems. Real estate companies, which claim to be adopting active design strategies in the private housing sector of Greater Santiago, adopt them as a complement to the use of Passive design strategies. This means that, within the group of companies that are implementing energy efficiency measures, no company makes use solely and exclusively of active design strategies. Yet the other approach is possible, i.e. the mere implementation of passive strategies to improve residential energy efficiency. This is an ongoing discussion in the Chilean market and it is reviewed in detail in the sections below.

Many – not one or a few – managers mentioned to be adopting technological innovations in residential projects. In general, these technological innovations are commonly called "gadgets" and managers use this concept in relation to electronic or mechanical housing systems used to improve the dwelling’s efficiency in the different housing uses of electricity. Among the housing systems where innovation took place, the following technological innovations were adopted: lighting systems, heating systems, centralized control systems, and air conditioning systems. Air conditioning systems enable also the possibility of cooling the living spaces.

Among the different real estate housing products where energy efficiency is adopted in Santiago de Chile, active design strategies are applied in multi-family apartment buildings in middle and middle-high socioeconomic segments. In those cases where such strategies are applied in single-family detached-houses, the housing units belong to middle-high and high socioeconomic segments. This situation seems to reflect a correspondence between the implementation of energy efficiency active design strategies trough technological innovations and high housing prices; mainly, because of the high implementation costs.

Illumination Systems

Many – not one or a few – managers mentioned the adoption of technological innovations in order to improve the efficiency of energy use in the lighting systems of residential buildings. That was mainly the case in multi-family apartment buildings in which these lighting systems in common areas are responsible for a significant share of electricity consumption of the building as a whole. Thus, managers mentioned to be adopting energy-saving bulbs, in some cases LED light bulbs, and the use of motion sensors in order to automatically control light in common areas (mainly hallways, stairways, and basements). The following quote illustrates this:

> *“... we innovate with technology IP telephony and internal phone networks in the building; we also used high-efficiency lighting elements for all common spaces with motion sensors*

in corridors, LED lighting in staircases and emergency exits. We also used timer switches so that energy efficiency is quite high ... ".(PD.16: par.7)

A feasible explanation for the spread of illumination systems innovations, and more specifically the adoption of energy-saving bulbs, are the government campaigns for the replacement of light bulbs in the residential sector (see Chapter 4). While this government initiative was focused on a housing segment that is beyond the focus of this research (as government subsidized housing) the initiative had significant media dissemination, which was able to raise the concern of ordinary people and also the private housing sector.

Heating Systems

In general, it was mentioned that the use of heating systems in residential buildings in Greater Santiago throughout the year is rather low. This is due to fair weather conditions, and it was mentioned that there are few days with low temperatures demanding the use of some sort of heating system.

Heat pumps, under-floor heating systems and heat radiators are the heating systems mostly commonly used among energy efficiency adopters. The installation of heat pumps is directly related to the adoption of the "Full Electric" concepts (discussed in detail in the previous sections).

With regards to under-floor systems, it was mentioned that this technology is imported and its implementation had to overcome several barriers related to back office industry. This situation is discussed in detail in section 7.1.

Finally, there are the heat radiators introduced in residential buildings in combination with the use of high-efficiency water heaters. It was mentioned as an offside remark that this technology is compatible with the use of solar thermal panels, imitating the German and Spanish experiences.

Centralized Control Systems

Figure 30 shows the implementation of centralized control systems in an existing single-family housing located in a high-income area of Santiago de Chile.

It was mentioned by the interviewees that the implementation of centralized control systems were one of the major innovations in the field of residential energy efficiency;

mainly because, at the time of its implementation in a prototype housing project, the technology was not yet introduced in the local residential housing sector. Some managers mentioned that they had some experience in the implementation of centralized control systems in commercial or administrative buildings, but that innovation in the residential housing sector dates back from 2003 (PD.15: par.18).

Figure 29: Use of Centralized Control Systems in a Single-family Housing in Santiago de Chile (Source: own photograph)

Centralized control systems aim to improve residential energy efficiency by controlling and monitoring electrical devices remotely, whether via a user interface, or through an automatic system which is responsible for maintaining the internal conditions within a predefined range of comfort temperature. However, interviewees mentioned that the centralized control systems were not "user-friendly" or easy to understand by domestic users. Therefore, it had not been possible to achieve all possible benefits of adopting these technological innovations. This situation is further discussed in detail when analyzing the barriers for the adoption (see sections 7.1 and 7.5).

Air Conditioning Systems

Finally, the implementation of air conditioning systems was mentioned as the more recent innovation in the housing sector, especially in medium-high and high income market segments due to the high costs of equipment, installation, and maintenance.

Among those implementing air conditioning systems there is consensus that the generation of cold-temperatures inside the dwelling is significantly more expensive than heat generation. However, thanks to recent technological development, air conditioning has being positively introduced in the housing market, generating a high level of customer satisfaction in the Chilean market, mainly due to the versatility in adapting indoor comfort-temperature to local temperature variations. The quote below illustrates this:

> *"... the consumer was positively valuing it, especially in the summer because in the summer it can also get cold, today the clients are 100% users of air conditioning equipment, they cannot imagine living in a dwelling that has no air conditioning, and in Chile they are very useful because in Chile we have a very important change in temperature. There are days in which we can have 5 degrees in the morning and in the afternoon 28°, and if you have a north-facing apartment maybe you have 35° [in the afternoon] when in the morning there were 5°, then an air conditioner helps a lot because you change the temperature quickly, you can heat in the morning and cool in the afternoon... "(PD.15: par. 14)*

6.3 Public-Private Partnership

As mentioned in the previous section dealing with real estate developers' motivations for applying energy efficiency measures in the housing offer in Santiago de Chile (see section 5.2.2), the so-called "*Chilectra – Full Electric Buildings*" is the outcome of the stakeholder engagement of the institutions responsible for the domestic electricity service in Santiago de Chile. On the one hand there is Chilectra, the nation's largest electric distribution utility; on the other hand, there is the National Energy Commission (Comisión Nacional de Energía or CNE), the institution in charge of energy regulation in Chile.

The so-called "*Full Electric Building*" is a concept that stands as a major innovation in the field of residential energy efficiency in the Greater Santiago context. The innovation was achieved through stakeholder engagement with environmental and energetic concerns. In a broader context, the success of the public-private partnership within the Chilean context is no novelty. There are several successful examples of win-win situations achieved through public-private partnership (also called concessions) within the Chilean experience[102].

The bases for this innovation are partly environmental concerns and partly energy concerns. The environmental concerns revolve around the elimination of air pollution generated by burning fossil fuels inside dwellings in terms of heating, cooking, and hot sanitary water systems. The energy concerns are twofold: first, it was sought to offer and implement higher energy efficient electric appliances in order ensure better use of electricity. Second, it was sought to make better use of the period when the households use electricity, taking into account peak hours of high electricity consumption and valley hours of low electricity consumption.

Through this strategic alliance an optional electricity consumption fee for residential customers called the Residential Hourly Rate (Tarifa Horario Residencial or THR) was officially established in November 2008. The THR has the following benefits for residential customers: 1) a 30% discount on the price of electricity registered during the night-time (22:00 to 8:00 hours) all year long; 2) greater control over energy consumption in the household; 3) this rate charges a surcharge of 30% on the price for electricity consumption in peak hours (18:00 to 22:00 hours) except on Saturdays, Sundays, and public holidays; 4) electrical appliances, such as heating pumps or sanitary hot water heaters, can be programmed so that their energy consumption will take place during a less expensive time schedule (personal communication from Chilectra representatives during fieldwork, March 2012).

Real estate companies, who applied the "*Full Electric Building*" concept widely in the middle-income market segments, welcome this initiative. In some instances, independent measurements by local independent research institutions were made in order to verify the savings in electricity consumption achieved by implementing the full electric system and the results are satisfactory, as described below.

---

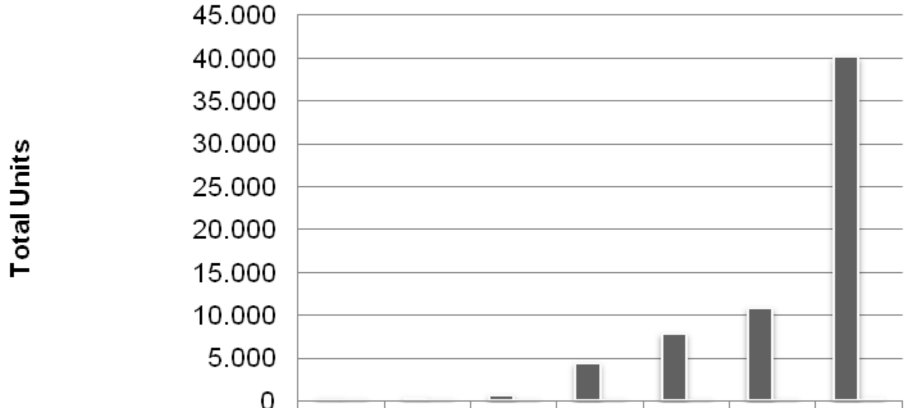
[102]Briefly, according to Ibarra-Coronado (2011) at the beginning of the 1990s Chile urgently needed to overcome the deficit of infrastructure to ensure economic development. Faced with this problem, it was decided during Patricio Aylwin's administration (1990-1994) to implement the system of concessions of public works and to invite the private sector to participate in developing the productive infrastructure. The aim was to get private capital to finance the infrastructure, who would recover their investment by charging a fee directly to users. Thanks to this initiative was achieved the construction of urban infrastructure projects, such as the case of the subway and some urban highways in the Metropolitan Region of Santiago, and road and airport concessions in other Chilean regions. Finally, it is considered that the Chilean concession system has been successful and that this experience stands out in Latin America. Ibarra-Coronado (2011) reported that by the year 2010, 67 projects had been awarded with an investment of approximately U.S. $ 11,700 million.

"…regarding the issues related to electricity and energy savings which nowadays exist in Chile, and I think with good results, there is a special electric rate promoted by Chilectra. It is called "THR Plus" and it privileges or rewards increased electricity consumption in valley hours (...) [in our apartments] we use electric hot water heaters as generation and storage systems, with an electric controller which turns the heater on and off and heats the water only in these valley hours; the heating system uses heat accumulators which also charge energy in these valley hours. I think Full Electric is fairly widespread among most of the real estate companies, especially for middle-income segments, for apartments around the 1500 and 3000 UF [55.594 and 111.187 €, respectively]. Especially in the downtown area of Santiago, nearly all buildings are now being built benefiting from these rates and with these systems. We have measured it and the energy bill of a Full Electric apartment is lower by an average of 30 % when compared with a traditional apartment, so savings are significant..." (PD.11: par 5)

Although the initiative was undertaken with the intention of covering all the housing units within the RMS, the goal later on was to extend the initiative to the whole country. The main difficulty with implementing this initiative countrywide was that not all regions of the country have the same utility provider for the electricity service. However, thanks to the intervention of those who claim to be the authors of the initiative to the Ministry of Energy, the initiative was extended across the country regardless of the utility provider for the electricity service or region in which the building is located. Finally, the extension of the initiative was achieved through the enactment of Decree No. 276/2004 of the Ministry of Economy, Development and Reconstruction and is regulated by the National Energy Commission (see CNE 2008).

According to representatives of Chilectra, nowadays there are more than 43,000 apartments implementing the Full Electric concept in the RMS. This represents around 58% of the total supply of new apartments available until 2011 and shows a sustained demand growth since 2002 (see Figure 29). Until quite recently, Full Electric Chilectra has been implemented mainly in apartments of less than 40 square meters, located mostly in the downtown area. However, the objective is to introduce the concept in other market segments, like bigger apartments and single-family housing (Chilectra 2011).

The so-called "*Full Electric concept*" is framed in the Energy Efficiency Solutions or Eco Energies program (personal communication from Chilectra representatives during fieldwork, March 2012). It involves the use of electricity in all or part of the dwelling's appliances. This implies technological innovations in air conditioning, kitchen appliances, and hot sanitary water systems. Among the air conditioning systems, Chilectra's offer includes: Panel Convector Heaters (portable or wall mounted), Panel Portable Electric Mica thermal Heaters, and Electric Floor Heating Pad (for more details on the products, see Chilectra 2013).



	2002	2003	2005	2006	2007	2008	2010
Residential Buildings	210	297	597	4.391	7.853	10.825	40.134
Non-Residential Buildings	2	6	6	28	54	69	256

Figure 30: Growth of Full Electric Residential and Non-residential Buildings
(Source: Own elaboration based on Chilectra 2009, 2011)

Moreover, from the perspective of Chilectra's representatives, the main grounds for the technological innovation on electrical appliances are: 1) high energy efficiency; 2) low noise-pollution and zero toxic gas emissions; 3) efficient use of space through the installation of floor heating pads, for example; 4) user protection, because the appliances reduce the risk of burns on contact; and 5) the ability of programming the appliances in order to make the most of the THR (personal communication from Chilectra representatives during fieldwork, March 2012).

Finally, according to representatives of Chilectra, the Full Electric concept goes beyond the sale and use of appliances. Instead, it has to do with a more fundamental concept, since it is related to the efficient use of energy in all its aspects. In that context, Full Electric is perceived by Chilectra representatives as a success in terms of product and concept (Chilectra 2011).

7 Barriers to Implementing Residential Energy Efficiency Strategies

The aim of this Chapter is to discuss the main challenges for the broader adoption of energy efficiency in Santiago de Chile's private housing market. The Chapter it is structured into five sections.

The first section identifies the market barriers, related to the local market preparedness to provide energy-efficient products and materials to support energy-efficient construction. The second section presents the organizational barriers, related to the financial ceiling depending on each real estate product in every real estate company, mainly. The third section deals with the institutional barriers, with regards to the political agenda and the pressure exerted by the local context on the decision making. The fourth section identifies behavioural barriers, related to the homeowners and home users values and lifestyles. Finally, the last section summarizes the main barriers emerging from the primary data and discusses the main challenges for energy-efficient housing in Santiago de Chile's real estate market.

Table 20: Summary of Central Challenges and Barriers for Wider Adoption
(Source: Own compilation)

Interview Results Summary		
Category	Sub Category	Key points
Market Barriers	Economic Constraints	Expensive ”technology”
	Construction Industry	Lack of industry's back-office support
	Government Intervention	Subsidies distort the market No incentive to reduce energy consumption
Organizational Barriers	Budgeting	Housing-Market segment sets the standard
Institutional Barriers	Policy-making	Technical decisions are made by politicians Regulations respond to market pressures
		Thermal regulation sets low standards
	Information	Lack of diffusion about the benefits of adopting energy efficiency measures
Behavioural Barriers	Client's Values and Cultural Aspects	Mismatch between clients' opinions and their actions
		Skepticism in the consumer's culture

The classification of barriers for the adoption of energy efficiency measures is not straightforward. The related literature mentions that it is not possible to sort and classify the barriers to a wider diffusion of the efficient use of energy[103]. However, there seems to be a consensus among real estate companies' opinions regarding these barriers. In the opinion of managers of real estate companies, the barriers for the adoption of energy efficiency measures in the private residential housing market in Santiago de Chile revolve around the specific characteristics of the local social system (Van de Ven, 2008). In connection therewith, these barriers can be grouped in four main groups as shown in Table 20.

As mentioned in the introductory Chapter, the research on residential energy efficiency in the private housing market in the Chilean context is scarce. However, Trebilcock's work (2011) is a landmark in the research field; it analyzes the main barriers to the integration of energy efficiency from architects' perspective working in the public and private sectors in the major southern and central Chilean cities. Moreover, since the key informants for this doctoral thesis, the company managers, are architects, contractors, or civil engineers, it is not surprising that some of the barriers derived from the empirical evidence of both studies (namely this doctoral thesis and Trebilcock's research) have found some similarities. On the contrary, it is part of the validation process of empirical findings sought by the researcher through the triangulation of sources and methods (see section 3.4.3). The results are discussed in the following sections.

7.1 Market Barriers

Specialized literature shows that the implementation of mandatory requirements seeking buildings to behave more energy efficiently, it could also affect the supply of products that typically buildings are constructed with, generating that the models of products available in the market – like windows , air-conditioning systems, hot water boilers, etc. – will perform also in a more energy efficient way. Once the energy efficient products – considered at the beginning of the adoption process as "*advanced technology*" – have penetrated the market, they will become a standard (OECD-IEA 2008). This argument is

---

[103]According to Weber (1997) there is not a typology as such to describe the barriers to the efficient use of energy. According to the author, each real barrier has its institutional, economic, organizational and behavioral aspects. He claims that it is empirically impossible to find the 'true' reason behind an energy-conserving action which has not been taken. Moreover, he claims that the barriers are real, but not observable. Therefore, they cannot be classified because they are invisible (pp. 833-834).

also valid for the products that improve the acoustic and thermal conditioning of the various elements of the buildings’ thermal envelope.

In this regard, CEOs of real estate companies in the *innovators* category argued that, the most important barriers to greater adoption of energy efficiency measures in the private housing market in Santiago de Chile refer to the lack of preparation of the local market to meet the needs of an emerging market. This situation is discussed in detail in the following sections.

Economic Constraints

From the perspective of socio-economic equality, it is argued on the literature that one of the most significant barriers to market penetration of energy-efficient housing is that, at present, the energy-efficient housing has even higher up-front costs. Accordingly, Marburger (2010) argues that energy-efficient housing must be, above all, affordable to build and to operate. The author claims that this is necessary because without the measures to ensure affordability and cost-effectiveness, energy-efficient housing cannot penetrate into the mainstream of the housing market, creating a gap between those who can afford an energy-efficient housing and those whose dwellings are less safe, less healthy, less sustainable, and more expensive to operate (Marburger 2010, p. 7).

Accordingly, in many – not one or a few – managers working in the private housing market in Santiago de Chile, belonging to *early adopters’* category, mentioned economic constrains as the mayor limitation for the further adoption of energy efficiency measures. In the managers’ opinion, economic limitations exist because their clients are not willing to pay the relatively high costs of products and technology available in the local market that could allow greater energy efficiency in their dwellings. Thus, the price-product relationship seems to be one of the main constraints to the implementation of energy efficiency measures, mainly in those market segments where housing prices are comparatively low. The following quote illustrates this:

> *“… so we put thousands of gadgets, of course nobody paid more, I mean when they [the home-buyers] asked about the value per square meter, we brief them about all these benefits that they could obtain due to the thermal insulation and everything else and nobody paid more, then we were caught by the Asian crisis, so it was quite dramatic ...” (PD.21: par.18)*

> *"…we have studied photovoltaic energy, it is still very expensive to incorporate, the numbers [budget] do not allow us to do so, but in the future, when it is a variable with a reasonable cost, it will be incorporated in our projects." (PD.17: par.7)*

The specialized literature on diffusion of innovations emphasizes that a determining factor for the (higher or lower) speed of adaptation of innovations is the degree of uncertainty associated with the innovation. According to Rogers (2003), a faster adoption rate of innovations can be achieved when the degree of uncertainty related to the success of the innovation is reduced. According to the author, there is a relationship between the degree of uncertainty and the resources available to the adopter of the innovation. The greater the availability of resources, the less certainty the adopter needs about the success of the innovation. Similarly, a reduced availability of resources requires greater certainty about the efficiency of an innovation for adoption to occur.

In this sense, the available budget for the design and construction of different housing products offered by real estate developers in Santiago de Chile is an important determinant in deciding an innovation process in any field. In the specific case of innovation (technology, construction, or design) in the field of residential energy efficiency, there is still a high level of uncertainty (mainly due to the lack of local knowledge and previous experience on adopting energy efficiency strategies). However, as mentioned above, to the extent that there is a greater freedom of action, some companies with a bigger budget have sought to innovate and experiment on their own in the field of residential energy efficiency.

Readiness of the Construction Industry

Apparently, in terms of market availability to provide materials and technologies that enable greater adoption of energy efficiency measures and green technologies, there is a significant contrast between what happens in the international arena and Chile.

On the one hand, the literature states that at present there is a greater diffusion of so-called green buildings (GB) because, GB materials, mechanical systems, and furnishing have become widely available, and their prices of GB have dropped considerably - in some cases below the cost of their standard counterparts (Lockwood 2006, p.130)

In contrast, in the opinion of managers of real estate companies offering energy-efficient real estate products in Santiago de Chile, the local market is not ready to push the market for energy-efficient real estate products any further. That idea seems to be transversal to all adopters' of residential energy efficiency measures in Santiago de Chile. It was argued that, beyond the fact that the available products for building energy-efficient dwellings in the local market are expensive; the construction industry still lacks the necessary support for the scarce products on offer.

The problem of support in the construction industry refers to two specific issues related to the industry's back-office. On the one hand, there is no proper service in terms of product installation in private housing building projects. For example, it was mentioned that initially there was no serious and reliable company that could install double-glazed windows; currently they are still scarce. In contrast, although nowadays there are some companies willing to supply and install the products, they offer very limited warranty conditions. The following quote illustrates this:

> *"…the main obstacle we have, at least in Chile, is that there is not yet the level of providers that allows you to address these issues with more comprehensive solutions, [there are] many trial and error strategies of initiatives in individual projects or within the development units of each project." (PD.20: par.19)*

> *"... we wanted to apply the under-floor heating. About 7 or 8 years ago an Israeli technology appeared (...) it was very efficient, and when I wanted to use this technology, no one would give me the warranty on the installation, but there were people willing to import it. What we still need to develop in the country [Chile], is to have companies taking this [energy efficiency issue] seriously. Progress is being made, more and more now, but we need someone with presence, who accumulates experience and translates it into good future service. [At the moment] it is not stable, because service-companies are born and die very often and they are mere importers who bring the product and are not constant…" (PD.15: par. 26)*

However, according to the specialized literature, once the penetration of energy-efficient homes in the local market is achieved and an escalation in the availability of: components, materials and technologies for energy-efficient buildings, all products and components that to date are not cost-effective in the local market, they will be so in the future, enabling a wider use of these energy-efficient technologies (Marburger 2010).

The Government Intervention

The use of subsidies as government financial intervention mechanisms in the market occur as the State wishes to increase the consumption of the so-called merit goods[104]; in order to obtain the positive externalities of technological innovations in a larger scale. In this specific case, the subsidies were related to the use of solar thermal panels (STP) for hot sanitary water in the residential sector. Within the case study, the market fails because the adoption rate of STP was extremely slow due to the high prices of the technology. Therefore, the government introduced the subsidies in order to reduce the implementation cost of STP. This lower price[105], compared to the free market price increased the quantity of the product in the market.

There seems to be consensus among managers regarding the barriers that affect increased application of State subsidies for implementing STP in the residential sector. These barriers can be summarized as follows:

First, the duration of the benefit period is one of the major barriers for a greater use of subsidies. It was mentioned that subsidies are not designed to be permanent, as they aim to solve an issue temporarily. Therefore, the benefits that can be achieved with the implementation of subsidies will be as permanent as the permanence of the subsidy. It is thought that subsidies are not a solution when addressing greater paradigm shifts such as tackling climate change or reducing the carbon footprint (PD.5: par 36). In this context, the Spanish experience serves as a good example, because when the Spanish government cut its national aid policy, by approving the Royal Decree 1578/2008, this reduction nearly paralyzed the Spanish photovoltaic sector[106]. In this regard, interviewees mentioned that although the Chilean government is planning to extend benefit period until 2013, that extension would not be enough because of the constant increase in demand for energy resulting from the country's continuous growth. With respect to the State subsidies for implementing STP in the Chilean housing sector, MINVU representatives

---

[104] A merit good is a commodity, which is judged that an individual or society should have because of some concept of need, rather than ability and willingness to pay. For a deeper discussion, see Musgrave (1957).

[105] Also called the "*social optimum price*".

[106] Broadly speaking, this reduction has resulted in: 1) stop the market for over six months by the regulatory change; 2) reduce the pay for the energy produced by 30%; 3) introducing a progressive reduction remuneration may exceed 10% per annum; 4) establishing a annual ceiling of 500 MW in the coming years, with a new record for awarding this power which complicates the administrative handling of projects; and 5) dividing the market into two segments, one for solar plants in soil and other facilities incorporated for the construction, when more than 95% market was soil oriented (FVS 2012).

and Real Estate Developers mentioned that the Chilean government is planning to extend the subsidies only until 2013 while the increase in energy demand of the country – and its associated externalities – are a permanent and ongoing concern. Therefore, in the opinion of private developers, the location of the state's efforts is not optimal, given that it does not address the problem in the long run. As an example, private developers mentioned that certain solutions oriented to introduce technological replacement in the housing sector (i.e. full electric buildings described in section 6.1) is actually increasing the energy demand in the housing sector (since full electric buildings considered the replacement of the entire domestic equipment for electrical appliances); in contrast, the commitment to renewable energy sources (as implementing STP) seeks to reduce the overall energy demand and the pressure in the local energy matrix (PD. 13: par 33).

Second, real estate developers mentioned that other complexities involved in the implementation of STP subsidies is the need to guarantee the installation for a period of five years. It was observed that the difficulty revolves around the fact that STP are rather complex systems, in terms of its operation and maintenance (PD.13: par 22; I10: par 38). In the opinion of managers, complexities are grounded on the local cultural context.

On the one hand, managers mentioned that the Chilean market, in general, is governed by customer-oriented protectionist policies and the housing market is no exception. Managers complain that there is no proper use of the after-sales service (which covers adjustments, maintenance, and repairs only), because in many cases the company has to take care of damage caused on the dwelling by the lack of maintenance on end-user's side. The quote below illustrates this:

> *"... I think the most complex part of the [solar panels] subsidy is that it forces you to guarantee the complete installation for a longer time, and today from my point of view the biggest complication in the Chilean construction industry is the issue of the warranty, because it is very badly used, there is no culture, first of maintenance, nobody maintains the apartment (...) and when something goes wrong, he [homeowners] complains to the builder, and if the builder does not fix it, he goes to SERNAC [National Consumer Service] and the government protects him, then this is a point that is widespread in all things and it is hitting the construction industry very hard. We were building before and had no after-sales department (...) today we have after-sales department, engineers, professionals in charge of after-sales department, because they [homeowners] are taking advantage from the after-sales and the government has given a lot of strength to the consumers' rights but they have no duties ..." (PD.15 : par 25)*

On the other hand, the STP system is perceived as a complex system, in terms of its operation and maintenance, especially when the responsibility of the operation and maintenance lies in the community. The quote below illustrates this:

> *"The issue of the solar panels is a complex system, it includes: solar panels on top of roofs, a pumping system, distributions to each one of the dwellings, the thermos, etc. ... and what if at the end it does not work?; What happens with all the investment? At the end [the users] will end up using gas stoves (...). Also, to do the maintenance will cost a fortune; because it is a special water heater ... then all these are barriers to introduce the topic [in multifamily buildings]. However, it worked in single-family social housing, because each user is responsible for the system, not the community ..." (PD.21:par 44)*

Moreover, another complexity of the subsidies system was mentioned, which exerts pressure on the economic capacity of real estate companies. Under current conditions, it is required that the initial investment cost for the installation of STP (purchase and installation of equipment, mainly) are covered entirely by the real estate company. Once the dwelling is built and delivered to the end user, the real estate company will receive a refund of this investment in the tax return. As was mentioned above, the costs of implementing this technology is still high in the local market (see the economic constraints section), which means that each company interested in adopting the subsidy for STP should have available the necessary financial resources to meet the initial investment. This is not a restriction when it comes to the major players in the construction market, but when it comes to small companies; this is a very important constraint:

> *"... [I installed] solar panels for water heating basically because there is a subsidy; the truth is I was quite interested and at this stage I nearly installed them. I did not install them because I am too small, [referring to the size of his company] that's the truth. The subsidy is paid to me much later, so to put the solar panels on 53 houses it meant an up-front payment of cash (...) I would have recovered it later but I would have ran out of funding meanwhile, it hurt in my pocket that's the only reason why I did not put them (...) but I think the idea is very good, of course, corporations [referring to bigger real estate companies] do not have many problems, but for companies like mine that are basically an SME, it is more complicated because you have to get the money out of your pocket and finance houses for a year and then you will recover it through your tax return, there should be a more efficient mechanism ... " (PD.18 : par 8)*

Third, a lack of incentives for other energy efficiency measures in the housing sector was pointed out. One example is the lack of incentives for the replacement of simple-glazed windows for double-glazed windows. It was mentioned that a subsidy for this may bring major impacts to the dwelling's energy performance and it could mobilize an entire area of the economy. As an example, it would create jobs in the areas related to the construction sector due to the increased demand for these products and its installation and maintenance. Moreover, the State would recover its investment through taxes and through less fossil fuel imports for energy generation. Moreover, other positive externalities mentioned are the benefits to the users' health, by reducing indoor air pollution caused by the use of other hot sanitary water systems (PD.8; PD.18).

> *"…because there was [is] no incentive if your building has lower [energy] consumption you will have some benefit, that was our own initiative out of pure love for ecology in that building, but that did not discourage for us from continuing to try to implement some concepts of energy efficiency in the planned buildings." (PD.21: par.21)*

Finally, there was a criticism from general managers regarding the government's intervention through subsidies. It was perceived that subsidies tend to distort the market; the market depends and subsists to the extent that subsidies exist, but they do not necessarily change the market dynamics nor the behaviour and people (PD.5).

In this regard, it seems that the influence of government intervention should go beyond the mere implementation of subsidies or incentive programs to implement energy efficiency measures. In this sense, the specialized literature mentions that implementing new regulations and more demanding energy performance requirements for residential buildings may also influence supply goods in the market in two ways. First, by opening the market for new energy-efficient products; and second, by promoting the elimination of inefficient and obsolete products which are not complying with the new requirements. As examples we can mention simple glass windows and non-condensing gas boilers in the German, Dutch, and Danish markets (OECD-IEA 2008). In the Chilean context, it may be mentioned as an example the introduction of low-energy light bulbs that replace inefficient light bulbs.

7.2 Organizational Barriers

Organizational barriers for a broader adoption of energy efficiency measures in Santiago de Chile's private housing market seem stress the relationship between two key aspects, economic and organizational structure of the company. Both aspects are relevant when defining the characteristics of real estate products offered by the company in terms of location, type of building, user density, layout and design, and the quality of the materials, mainly; several of the mentioned features have a significant influence in the energy performance of the building and, hence, on its energy efficiency. All these aspects are reflected in the available budget for the design and construction of residential buildings.

Budgeting

This issue is related to the availability of resources for the design and construction of the various real estate products offered in the private housing market. In the opinion of private managers, one of the most important constraints for the adoption of energy efficiency measures is the available budget, because it affects the quality of materials, finishes, and even the skilled labour used for construction. The products offered by real estate companies are diverse in terms of types of multi-family buildings and single-family homes; they also vary in terms of price ranges because they focus on different market segments (see section 2.2). It was also mentioned that while there is apparent interest from prospective buyers in the implementation of energy efficiency measures, the issue is no longer interesting for them when discussing the budget for implementing them. The quote below illustrates this:

> *"There is no client whom I would not have offered to make a plan for energy efficiency, most of them think it is interesting and most do not take it. Of course, there are some that do it, but there is an issue of implementing cost of the measures that hampers the development of these projects." (PD.8: par. 16)*

It was argued that income and housing typology market segments are determinants of the degree of flexibility to change the construction paradigms and, therefore, the adoption rate of innovations, in this case, in the field of energy efficiency. In the opinion of real estate companies, the multi-family high rise building segment is very resistant to undertake any changes in the construction systems. This housing segment looks for repetition, modularity, and seeks standardization. Moreover, this is in essence a housing segment that - with few exceptions - does not consist of luxury apartments, so the budget for the design and implementation of the projects are comparatively lower than single-family housing. Therefore, changing the paradigms associated with the operation or design of this type of buildings is more complex than in the single-family housing.

In contrast, it was mentioned that when a private-owner or a single-family decides to design and build a house, it has a much higher purchasing power, therefore the level of flexibility to implement energy efficiency strategies increases (PD.5: par. 8). Clearly, when it comes to houses for low and middle-lower socioeconomic groups, they are governed by similar conditions as the multifamily-housing in height-rise segment (i.e., repetition, modularity, and standardization are sought). Therefore, the flexibility to innovate decreases considerably as the budget for implementing more energy-efficient materials and technology also decreases.

Table 21: The Influence of Predominant Building Types on the Adoption of Residential Energy Efficiency (Source: own compilation)

	Horizontal Growth / Detached Single-family Housing	**Vertical Growth / High-Rise Multi-family Housing**
Design -	Seeks singularity and individualization	Seeks repetition, modularity, and standardization
Market Segments	High-income and middle high-income households living in high-standard gated communities Middle low-income and low-income households living in low-standard overcrowded gated communities	High-income and middle high-income households living in luxury apartments Middle low-income and low-income households living in low-standard small apartments
Innovation	Is sought in the higher-income segments. Higher flexibility to implement energy efficiency strategies and to change operation or design paradigms; due to a higher availability of resources	Offers very few opportunities to innovate in the design and construction processes, mainly because of the economic constraints
Construction Material and Finishes	Homogeneous quality of the material of structural building elements, independently of the income-groups High-income and middle high-income dwellings with high quality construction materials and finishing. Middle low-income and low-income dwellings with low quality construction materials and finishing	Homogeneous quality of material of structural building elements, independently of the income-groups High-income and middle high-income dwellings with high quality construction materials and finishing. Middle low-income and low-income dwellings with low quality construction materials and finishing

Table 21 was built upon the analysis of the private housing market in Santiago de Chile (see section 2.2). It stresses two dimensions of the city growth[107] which, according to real

[107]Namely: the physical growth of the city (Horizontal Growth or Vertical Growth) and the building typologies (mainly detached single-family housing and high-raise multi-family housing).

estate companies, seem to have a strong influence on the level of energy efficiency standards and also on the innovation's adoption rate. In the particular case of Greater Santiago a third dimension, the household socioeconomic status, is closely related to the previous two and plays an important role when deciding the budgeting of the residential projects, and therefore, the freedom to adopt innovations.

7.3 Institutional Barriers

Institutional barriers are policies, procedures, or any other subset of social norms or rules that systematically affect local social system, preventing a greater diffusion of residential energy efficiency measures. In managers' opinion, the institutional barriers revolve around three aspects closely related to the political scene and the political agenda in the sector. Namely: the way policy is made, the flow of information within the local social system, and the regulations governing the housing sector.

Policymaking

Two relevant factors related to how policies are made in the local social system were perceived to be affecting the thermal regulations in the housing sector; namely, the decision-making process and the influence of key market players. In the opinion of real estate companies, the residential energy efficiency standards define technical values. Therefore, the decision about the benchmarks for energy efficiency standards[108] should also be taken on a technical basis. Apparently, this is most frequently not the case and to date decisions are taken rather from a political standing in response to market pressures, which leads to lower benchmarking and to the misallocation of subsidies. As one private developer said,

> *"… the only bad thing about this is that these decisions that are in the hands of politicians are so technical (...) for example the issue of solar panels, the panels are subsidized housing until 2000 UF, then what is being done? Subsidize affordable housing or subsidize energy savings?" (PD.7: par. 38)*

Moreover, according to Trebilcock (2011), the new policies in the field of energy efficiency should focus on economic and tax incentives, in addition to strict regulations with demanding technical basis.

The pressure exerted by private industry in decisions made in the construction sector is not new. In the previous sections, the influence of the brick industry in deciding standards for new homes regulation temperature was discussed (see section 6.1). Correspondingly, real estate companies mentioned that the local brick industry plays an important role in the housing stock construction of the RMS, where around 48% of the houses are built of brick (PD.12: par.18).

---

[108] In this case, the U-values for the elements of the thermal envelope as described in section 4.2.

Lack of Access to Information

Some general managers mentioned the lack of information among the main barriers to greater diffusion and acceptance of innovations in the field of residential energy efficiency. It was mentioned that prospective homebuyers have no clear idea about the benefits that can be obtained when buying an energy-efficient home. The following quotes illustrate this:

> *“... on these issues, there are people who still do not understand when you speak of [energy efficiency] ... and much less when talking about carbon footprint, the people have no idea what they're talking about, therefore I think you have to go little by little, I think that's the process …” (PD.2 : par.25)*

Moreover, one of the biggest gaps in the information is the lack of data available for the end-users, to enable them to understand the difference between energy-efficient housing and housing that does not have any kind of improvements.

> *"The big problem of energy efficiency today is because it is very ethereal, no one lands on numbers, values, today nothing is being measured, so energy efficiency happens mostly because the motivation of someone and there is no actual hard data. " (PD.12: par.2)*

This view is shared by other stakeholders related to the housing sector. The Executive representatives of Chilectra, the local electric distribution utility, stated that the responsibility for greater dissemination of information belongs to the State. The end user should be informed not only about energy saving, but handle energy efficiency as a more holistic understanding, as the following quote illustrates:

> *"The main barriers to the mass use [of residential energy efficiency measures] are related to the education of people and the knowledge of the efficient use of energy. That's where the State plays a key role in disseminating and educating people regarding the use, where they are not only invited to save, given the current contingency, but rather to transform efficiency into something systematic, [incorporated into] daily life and a priority" (Chilectra 2011, p.12).*

Finally, the conclusions of Trebilcock’s work on architects’ perceptions on the barriers for greater diffusion of energy efficiency measures, suggest the need to cover education about energy efficiency throughout the whole application chain, from postgraduate offers to professional courses to training courses for construction workers; including the end user education as well (Trebilcock 2011).

7.4 Behavioural Barriers

Based on interviewees' opinion, barriers concerning the social context in which the private housing market inserts were identified. These barriers are mainly related to the way customers think about product innovations. According to Van de Ven (2008), potential customers find it difficult to compare products because alternatives embody different merits. Moreover, the empirical evidence shows that difficulties in the diffusion of energy efficiency innovations are related to the cultural context of the local social system on the one hand, and with the uncertainty about the real benefits of the innovation on the other.

Client's Values and Cultural Aspects

Regarding the cultural context of the local social system, CEOs argued that they found some cultural barriers that reflect the local idiosyncrasy[109] along the adoption process of energy efficiency measures in their housing projects. Certain social characteristics were mentioned that reflect the way customers think when facing two types of decisions: the decision to purchase durable goods and their stance when facing social responsibility issues.

First, regarding the way customers when facing the purchasing of durable goods, managers mentioned that some of their customers consider the purchase of a dwelling as an element that will give them certain social recognition among social peers. Therefore, the energy performance of the dwelling is not yet one of the attributes of a dwelling that are more interesting when deciding to purchase. Instead customers mentioned factors such as the size of the house or some other features like its design, whether it has swimming pool or a grill, as important features, perhaps because they provide a certain degree of visibility or social recognition. The following quote illustrates this:

> *"... then the guy [homebuyer] always wants to buy the biggest house that the bank is willing to finance him, instead of maybe buying a smaller house but maybe with all these things [energy efficiency measures], it's funny but there is missing ... there is a cultural issue that is not fully inserted into the people. Because if you have a house, maybe a bit smaller but thermally efficient, the guy [homebuyer] will have more savings than when buying a bigger house that will have more heating costs, more spending on the garden ... but the other house is more visible" (PD.18: par.14.)*

[109]Namely: the way of thinking of ordinary people based on their cultural heritage, values and traditions.

Second, regarding their customers' stance when facing social responsibility issues, it was mentioned there is a mismatch in the discourse of the Chilean population, mainly between people's opinions expressed in public communication channels, opinion polls, surveys, etc., and their actions. Some managers mentioned that in the public discourse, there seems to be a significant degree of environmental awareness and knowledge about the shortage of energy resources. However, the environmental commitment does not seem to be deep enough, since the actions taken indicate otherwise. The following quote illustrates this:

> *"... the Chilean talks many things, thinks many things, but finally his actions are not oriented exactly to what is planned, that is, if a person is conscious, if the Chilean were aware of the energy problem, many things would not be happening in Santiago, no one would use so many cars, for example ..." (PD.10 : par.11)*

Moreover, it was mentioned that public awareness reflects a passive and contemplative stance regarding energy shortage. The concerns for energy scarcity will seemingly only be taken into account when the energy scarcity will affect the normal daily life and will make some abrupt changes in household's life-style patterns. The following quote illustrates this:

> *"… when you will have the light cut off and you will have to go buy a candle in the supermarket, then you will be aware of the problem [referring to energy shortage], not before, because now the State is there. Then you say: but this is going to be solved, and you're always expecting someone to fix the problem, not you. So I think this [the demand for energy-efficient housing] will continue to rise, if the problem is the way we think, because of the consumerism culture we have, we have a very paternalistic State ... we think, the Chilean think that the problems must be solved by the authority, not by us, ..." (PD.10 : par.30)*

Complexity of New Technology

With respect to the active design strategies adopted by some real estate companies (detailed reviewed in section 6.2), their implementation such energy efficiency strategies involves the use of technological innovations, mainly to control the indoor temperature and the different housing systems involving energy consumption. In this regard, in real estate companies' opinion, the implementation of technological innovations has not been easy and has encountered resistance in its implementation among users. Therefore, the relative complexity in the use of systems has prevented the expected benefits from being achieved with the implementation. The following quotes illustrate this:

> *"…but in most cases, many times we have implemented some solutions and after thinking about it, we know they are not used, because they complicate people's lives, that is the programming ... then we are quite careful with what we do implement." (PD.17: par.17)*

> *"... there were alternatives that the client can add later, we could not set you all the functionality of the domotic central because our costs would have been too high, and the experience was that the Chilean client was not ready for this kind of product because we made a great investment and we realized later on that people did not use it..." (PD.15: P.18)*

Complexity in the use of innovations is very sensitive attribute of innovations identified in the specialized literature[110], which seek to predict the rate of adoption of innovations. According to Rogers (2003, p.266) complexity is "*the degree to which an innovation is perceived as relatively difficult to understand and to use. The complexity of an innovation, as perceived by members of a social system, is negatively related to its rate of adoption*". This argument is consistent with the empirical evidence, as stated above. Moreover, according to real estate companies, the complexity in the use of the EEM goes beyond the use of new technologies. In the opinion of some managers, the complexity also relates to the appropriate use of some simpler systems related to users' customs and practices[111], such as the habit of ventilating rooms, for example.

Scepticism in the Consumer Culture

Finally, certain barriers were mentioned previously related to the customer scepticism about the benefits that can be obtained in an energy-efficient dwelling. This mainly occurs when information about the supposed benefits is provided by those who sell the products and not by the State or by a third party. The following quote illustrates this:

> *"...If a real estate developer says it, they [the prospective buyers] do not believe it, because [they think] he just wants to sell houses ..." (PD.10: par.36)*

---

[110] Rogers (2003) described the innovation-diffusion process as "an uncertainty reduction process" (p. 232); the author identifies certain attributes of innovations that help to decrease uncertainty about success of an innovation. Attributes of innovations includes five characteristics of innovations: 1) relative advantage, 2) compatibility, 3) complexity, 4) trialability, and 5) observability. Rogers (2003) stated that "individuals' perceptions of these characteristics predict the rate of adoption of innovations" (p. 219).

[111] This is closely related to the concept of social norms and life style patterns (see Weber, 1997)

The specialized literature seems to support the empirical evidence. Rogers (2003) described the innovation-decision process as "an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation" (p. 172).

Therefore, to the extent that the degree of uncertainty in the perception of the benefits that can be obtained with innovations by individuals (or other unit of adoption as real estate companies) is reduced, the relative advantage could be increased and, therefore, the adoption rate of EEM innovations may be accelerated.

7.5 Central Challenges for the Adoption of Energy Efficiency

Under current prevailing conditions in Santiago de Chile, the greatest challenge for real estate companies is to build and to sell energy-efficient dwellings.

As mentioned in the previous sections, under the current market-conditions it is difficult for real estate companies to adopt energy efficiency measures in their housing projects, mainly because the back-office of the construction industry is still weak in terms of: material supply, technical support, and guaranties for the installation.

Moreover, it is also difficult to sell an energy-efficient dwelling, because the potential buyers do not quite understand the topic yet and have other concerns when looking for a new dwelling (i.e. location, final price, and layout).

From an economic perspective, the empirical evidence shows that the socioeconomic status of the different market segments seem to play an important role when deciding the level of energy efficiency standards applied in one housing project or another. The socioeconomic aspect seems to have found common ground among members of all categories of adopters.

On one hand, pioneer adopters of energy efficiency measures (EEM) made no distinction with regard to the level of the energy efficiency standards applied to on housing-project or other. The most common target market segments, in terms of socio-economic groups, ranged from mid-low to high income groups. Regarding the building types, multi-family housing – both in low-density and high-density configurations – have been the focus for energy efficiency innovations. Nonetheless, it was mentioned that in one particular case, where the budget availability for the construction of an apartment building for a higher segment of the housing market was high, it enabled the real estate companies of the project to try (at that moment) new alternatives such as double-glazed windows, new accoustic and thermal insulation systems, etc., because “a more expensive building justified a greater expense” (PD.21, par 16).

On the other hand, for the early-adopters and early-majority adopters of EEM, it seems that the prospective buyers’ income (or willigness to pay for higher energy efficiency standards) is quite relevant when deciding on the level of the energy efficiency standards they will apply. Many – not one or a few – managers claimed that the housing price defines the level of energy efficiency standards. In many cases, it was mentioned that there is a close connection between the finishes and building elements (mainly appliances and windows) and the level of energy efficiency that can be achieved in the house. This means that to a higher level in the quality/price of the construction finishing details and building elements corresponds a higher level of energy efficiency; therefore, the construction costs are higher because it takes more expensive products and the labor cost is also higher and so on. The costs for fine workmanship also plays a role when deciding about the general standards, and more specifically the energy efficiency standards, as one manager stated:

> *"…because the level of construction, the level of detail required in the Dehesa [with a dominant high socioeconomic standard] is different from that required here [Municipality of Santiago with a dominant medium-low socioeconomic standard], then always when focusing on a slightly higher [socioeconomic] level, you build a better standard, for example, the worker knows that if he has to finish a wall in La Dehesa it is finished in a way but you have to finish in Santiago in a differet way because the cost of the department, I mean the sale value of the department is not enough to pay for a house with finishings as in La Dehesa…" (PD.13:par 12)*

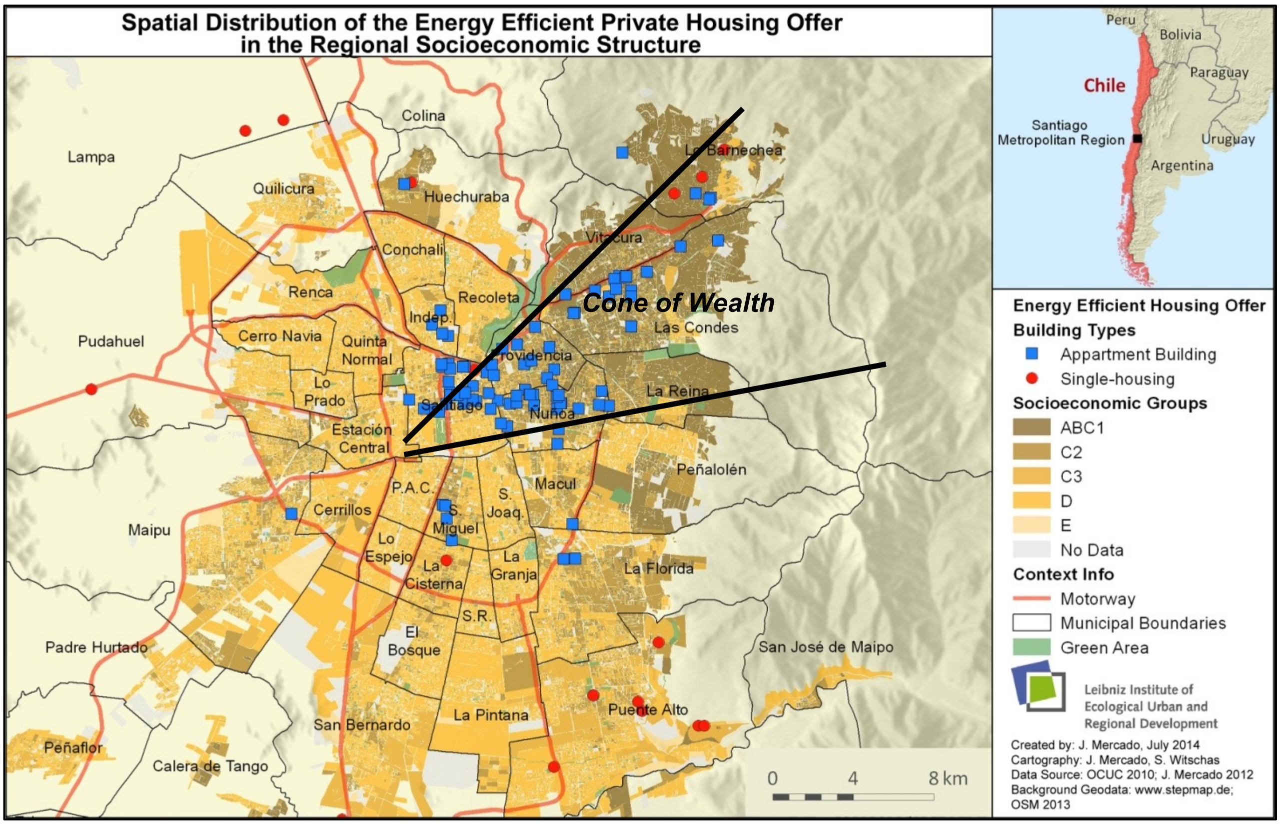


Figure 31: Spatial Distribution of Energy-Efficient Private Housing Offer in Santiago de Chile. (Source: own creation based on fieldwork)

Figure 31 shows the spatial distribution of energy-efficient housing offer in the private housing market in Santiago de Chile in 2012 related to the prevailing socioeconomic structure of the city. On the one hand, the points on the maps represent the energy-efficient buildings offer in the private housing market, grouped into two different building types: multi-family apartment buildings and single-family housing. In contrast, the colour-graded map in the background shows the prevailing socioeconomic groups; darker shades represent a higher socioeconomic group. When analyzing the maps the so-called "*Cone of Wealth*" – which concentrates the higher income municipalities in the RMS – is clearly visible. The later shows that, to date, the process of adoption of residential energy efficiency measures has clearly focused on medium and medium-high socioeconomic groups. Therefore, one of the major challenges for the private housing market is to find creative strategies (described in detail in the following Chapter) to reach the middle-low and low socioeconomic groups with energy efficient housing, without losing the quality of the energy efficiency measures.

Thus, it could be helpful to promote the use of energy efficiency strategies, which do not generate a significant impact on housing prices, such as passive design strategies for energy efficiency (i.e. bioclimatic design, ECNR, etc.) when offering energy-efficient real estate products for middle-low and low socioeconomic groups.

8 Discussion of the Results and Implications

Based on empirical evidence, the final Chapter of this doctoral thesis shows how this research is successful in shedding light on the major motivations for the adoption of energy efficiency measures in the private housing market in Santiago de Chile, the main barriers for wider dissemination in the market, and the variety of residential energy efficiency strategies adopted by real estate developers working in the private housing market in Santiago de Chile.

The Chapter is structured in four sections. The first section provides a summary of the main research findings based on the analysis of Chapters 5, 6 and 7. The second section presents the discussion of the results and their implications to the state of the art of research. The third section meets one of the most important objectives of the research, which is to deliver recommendations for academics and practitioners in order to promote greater adoption of residential energy efficiency in the private housing market in Santiago de Chile, the Chilean context, and the South American context, hopefully. The recommendations emerged from the analysis and discussion of the empirical results, from both primary and secondary sources. Finally, the fourth section discusses open questions and future lines of investigation emerging on the research findings and the conclusions.

8.1 Summary of Findings

The discussion of the results and implications of this research is structured on the basis of answering the secondary research questions or sub-questions, which are a breakdown of the following main research question:

How do real estate developers apply energy efficiency in their housing offer in Santiago de Chile?

Therefore, the main findings of this research answered the following three sub-questions:

Who are the real estate developers that are adopting energy efficiency and why?

The first part of this compound sub-question seeks to identify the real estate companies that are implementing residential energy efficiency measures in their offer in the housing market in Santiago de Chile.

In order to answer the first part of the first compound sub-question, the selection of a sub-set of cases (or sub-units for the analysis) involved complying with a fundamental criterion: all the real estate companies offering energy-efficient housing in the private housing market in Santiago de Chile. In July 2011, when the selection of sub-set of cases was conducted, 45 real estate companies mentioned on their websites that they were applying some sort of energy efficiency measures. This was a rather small group since, at that time, 568 real estate companies were offering housing products.

Based on the empirical findings, a categorization of real estate companies following the model of Rogers (2003) was carried out. Thus, companies were categorized depending on when they started the process of adopting residential energy efficiency measures in their housing offer. The adopter categories in this research were built up following a time sequence based on when real estate companies first started applying energy efficiency measures. The stages of the New Thermal Regulation governing the housing sector in Chile, and implemented successively since 2000, helped defining the adopter categories.

The first category, called *innovators*, includes real estate companies who adopted energy efficiency measures for the first time before the entry into force of the first stage of the NRT in 2000. This stage defines the first institutional requirements in the residential area aiming at improving the thermal envelope and thus the energy efficiency of the housing. The second category, called *early adopters*, groups real estate companies who adopted residential energy efficiency measures for the first time after the first stage of the New Thermal Regulation, that is to say between 2001 and 2011 (when the selection of cases for this research took place).

Although Rogers' model considers five categories (See Rogers 2003); nonetheless, *early majority*, *late majority,* and *laggards* categories are not covered within this research. The empirical evidence shows that the diffusion process of residential energy efficiency measures in the private housing sector in Chile has started and is developing slowly. Therefore, this research found a relatively small fraction of the private housing market of Santiago de Chile who is adopting residential energy efficiency.

Literature on the diffusion of innovations mentions that Rogers' model (2003) is useful to understand the behaviour of a vast majority of innovation processes. Although it would also be feasible to expect that the termination period of innovations in residential energy efficiency measures might end up in a failure, this does not appear to be the case for the adoption of residential energy efficiency measures in the private housing market. The empirical evidence suggests that the innovation process has started following the normal development described by Rogers' innovation curve. Therefore, it is expected that the rest of the real estate developers operating in the private housing market in Santiago de Chile will eventually follow the *innovators* and *early adopters*. This is mainly due: firstly, introduction of mandatory thermal regulations for the housing sector by the Chilean government; and secondly, because the housing market it is a highly competitive one in which none of the players cannot allow itself to stay one step behind from competitors.

The second part of the sub-research question, and probably the most important one, seeks to understand the motivations for real estate companies to offer and implement energy-efficient real estate products in Santiago de Chile’s private housing market. In order to find an answer, this research identifies the motivations of real estate development companies in the opinion of their managers collected in personal semi-structured interviews conducted during fieldwork. Based on the thematic analysis of the abovementioned interviews, four categories of motivations were identified based on the company managers’ opinion. These categories, in order of preference are: 1) Market Differentiation Strategies (Competitiveness and Trending); 2) Company Policies (Client-Oriented Policies, Innovation Policies, and Environmentally-friendly Policies); 3) Resource efficiency (Reduction of Household's Expenses and Concerns for Energy Scarcity); and 4) Government Incentive Schemes (Subsidies to the Use of Renewable Energy).

Briefly, the main motivations for adopting energy efficiency measures in the private housing offer are related to marketing strategies. The real estate company managers are looking to differentiate from competitors by offering energy-efficient housing. This is mainly because private developers are following a trend which is driven by several factors, such as: the local energy shortage periods, the international influence of green buildings, and the growing demand for international certifications. Other motivations on the demand side, related to what buyers' expectations and their lifestyles (i.e. fashion and green trends, greater environmental awareness, increased number of foreign citizens living in Santiago de Chile, etc.) are not discussed in this research; however, they may influence the supply of private developers significantly. Finally, in certain market segments, government intervention through state subsidies for the implementation of solar thermal panels is also a relevant motivation.

What types of energy efficiency measures are real estate companies adopting?

Real estate developers offering energy-efficient housing in the private real estate market of Santiago de Chile implemented a diversity of energy efficiency strategies in their housing supply, as the empirical evidence shows. Although the motivations for implementing energy efficiency measures are diverse (as briefly described in the previous section and in detail in section 5.2), energy efficiency measures are mainly implemented in order to reach a comfort temperature inside the dwelling, making all possible efforts to ensure that energy is used efficiently. In the case of the residential buildings, this means looking for the optimal use of energy for space heating or cooling, lighting, hot sanitary water, and ventilation.

In general, depending on whether there is the need to make an additional energy effort in order to achieve optimum indoor comfort conditions, the energy efficiency measures implemented in the private housing sector are grouped into two main categories of energy efficiency strategies: Passive design strategies and active design strategies. On the one hand, passive design strategies refer to what real estate developers are doing to reduce the energy consumption of their housing buildings. Such strategies include: 1) improving the overall thermal performance of the building envelope; 2) the use of renewable energy, mainly solar thermal and photovoltaic technology, for hot sanitary water and energy conversion respectively; and 3) bioclimatic design and construction principles. As it was mentioned in Section 6.1, a basic characteristic of passive design strategies, distinguishing them from active design strategies, is that in order to operate they rely on inherited thermal properties of the materials used in the different housing building typologies. On the other hand, active design strategies refer to the technological innovations implemented in order to maintain an optimal indoor thermal conditioning and to reduce the energy used in the different buildings' systems; namely, 1) Illumination Systems; 2) Heating Systems; 3) Centralized Control Systems; and 4) Air Conditioning Systems. In general, real estate developers adopted active design strategies as a complement to the use of passive design strategies.

Finally, real estate developers in Santiago de Chile adopted a public-private partnership strategy as the third type of energy efficiency strategy. The initiative is called "*Chilectra – Full Electric Buildings*" and it offers an optional electrical energy tariff for residential consumers. This strategy was the result of a joint venture between the Chilean Government and the Chilectra, the local electricity utility.

Not surprisingly, real estate developers have mentioned the improvement of the thermal envelope as the residential energy efficiency strategy most commonly used. This results from the fact that internationally (see section 4.2) and in Chile (see Section 4.4) regulations in the housing sector were implemented in order to improve the thermal behaviour of dwellings, and therefore, their energy efficiency. In Chile, this implementation is relatively recent and all new residential buildings must comply with the New Thermal Regulations since 2000. Real estate developers claimed that the standards defined in these regulations are rather low; especially when comparing them to international standards.

Which barriers to further implementation of energy efficiency exist?

Based on the analysis of the various key stakeholders' opinion involved in this research (general managers of real estate companies, mainly, but also representatives from the government, the scientific community, and other key informants in the energy sector and the construction sector) this research has shown that most barriers to energy efficiency in the private housing sector in Santiago de Chile interact and strengthen each other.

The classification of barriers to the adoption of energy efficiency measures is not straightforward. Nonetheless, in the opinion of real estate companies' managers, the barriers to adopting energy efficiency measures in the private housing market in Santiago de Chile revolve around the specific characteristics of the local social system. These barriers are: 1) Market Barriers (Economic constraints, the construction industry, and Government Intervention); 2) Organizational Barriers (Budgeting); 3) Institutional Barriers (Policy making, Diffusion of information); and 4) Behavioural Barriers (Client's Values).

In relation to the categorization of energy efficiency adopters identified in the first sub-question, the empirical evidence seems to indicate that, not all the barriers play the same role for all adopter categories. In general, market barriers are most relevant to the so-called *innovators* group. Although most of the real estate developers mentioned that even today the local market and the local construction industry are not ready to provide adequate support (both in the availability of products and services) for further development of the market for energy efficient construction, there was a greater deficiency 20 years ago, when the energy efficiency innovators first started to implement residential energy efficiency measures in the private housing sector.

Moreover, the other barriers encountered (namely Organizational and Institutional Barriers) are transversal to the adopter categories mentioned in the analysis. This seems to derive from the organizational and institutional characteristics of the context in which private real estate companies operate. The context remains constant over time and their internal relationships are also maintained, homogeneously affecting all adopter categories. Finally, barriers related to end-users and/or clients' behaviour are mainly listed by the so-called *early adopters*, which comprises private developers who implement residential energy efficiency measures after 2001. Apparently, this results mainly because the housing end-users are lacking information about the potential benefits (general and local) that can be derived from implementing residential energy efficiency measures.

8.2 Discussion and Implications

The purpose of this research is to generate empirical findings on the adoption of energy efficiency measures in the private housing market in Santiago de Chile. The empirical results were discussed in the light of a theoretical framework based on a thorough review of the state of the art. This enabled analyzing the adoption process of residential energy efficiency measures by real estate developers in Santiago de Chile, their motivations for offering and applying energy-efficient housing products, the energy efficiency strategies most commonly adopted, and the main barriers in the adoption process. The summary of the results given in the following sections highlights the advantages of a case study research of an exploratory nature, which enabled the analysis of an emerging scientific research-topic in the Chilean and South American context. According to the empirical evidence, the adoption process of energy efficiency measures in the private housing market is an undergoing process.

(Small) Steps towards an Energy-Efficient Housing Market

The research findings show that implementing energy efficiency measures in the private housing market Santiago has much in common with the situation in other cities around the globe, mainly because it faces similar implementation barriers at the beginning of the implementation process. Nonetheless, some steps towards a more energy-efficient housing market had been already taken, and the leading role of the national government and the policy-making has been shown. So far, there is a group of real estate developers adopting a variety of strategies to improve the energy efficiency of their real estate products in Santiago de Chile. Thanks to the mandatory implementation of energy efficiency standards for new residential buildings since the beginning of the new century, the Chilean experience is a pioneer in the Latin American context.

As far as the main motivations for real estate developers to embrace the challenge and to include energy efficiency in their housing offer is concerned, the main reasons for the adoption relate to marketing and competitive strategies, not surprisingly. According to the analysis of secondary data, it has been shown that the private housing market is a highly competitive market, so there is a constant quest for differentiation strategies. The managers of real estate companies seek better market positioning through product innovation. Therefore, given the growing local interest in issues of social responsibility (in this case related to the responsible use of energy given the country's vulnerability in electricity generation), real estate companies seek to incorporate energy efficiency into their offer strategies that can set them apart from the competition, or at least that do not cause them to be left behind.

In this sense, the positioning of the city of Santiago de Chile in the global circuits has clearly been a factor for the nascent and growing demand for complying with international certifications[112]. This is mainly because nowadays many transnational companies have chosen Santiago de Chile for locating its regional partner companies. Therefore, these companies seek that all their local headquarters meet international standards. While these standards are generally used for office or services buildings, housing buildings are also designed and built by real estate companies working in Santiago de Chile, so the concerns have been ingrained in the companies' discourse and they are valid for the housing sector as well. According to a small group of energy efficiency measures adopters, the concern about having international certifications in residential buildings are increasing and, in many cases, it is already an ongoing process.

Nonetheless, amongst energy efficiency adopters there are also other motivations besides marketing and competitiveness. A small group of real estate developers are motivated by environmental concerns. In general, these "green" real estate developers have been pioneers in implementing energy efficiency measures because they adopt green design and energy efficiency strategies since early nineties, meaning, long before the thermal regulations for new buildings came into force in 2000 (see section 4.4.3). The residential energy efficiency strategies were adopted by the "green" real estate developers following a "trial-and-error" strategy; this results from the fact that the domestic construction market was not ready to support green initiatives[113]. Therefore, the "trial-and-error" strategy sought to reduce the high degree of uncertainty regarding the success of green and energy efficiency innovations in new buildings.

Finally, the literature and the scientific discussion suggested that, the main barriers to progress towards improving energy efficiency in the housing market and achieving reductions in CO_2 emissions are located in the policy making, the process of

[112] The empirical findings have shown the introduction of LEED and BREEAM certifications amongst private developers. Nonetheless, due to the strong German influence on the institutional research and the definition of local standards in Chile, it is expected that in the near future the DGNB certifications will also enter the Chilean real estate market.
[113] In private developers point of view, the domestic construction industry it is still not ready to provide an efficient support for green initiatives (see section 7.1)

implementing energy efficiency measures, and the availability of human resources, rather than in technology as narrowly defined. In this regard, Lowe (2008) argued that there is a need to improve energy efficiency in dwellings, and to higher levels, if global mean temperature rise is to be held. Nonetheless, the author argues that achieving real reductions in CO_2 emissions in this sector is not straight forward, and that delivering them will require significant changes in the way energy policies are formulated and implemented.

City Growth Patterns, Residential Buildings Types, and Energy Performance

The empirical evidence and the scientific discussion seem to show that regarding the socio-spatial aspect of Santiago de Chile, segregation is also evident between energy-efficient buildings and standard buildings within the private housing offer.

The private housing market in Santiago de Chile contributes with one of the main shares to the regional and national economy (See Chapter 1 and Chapter 2). The existence of few key players that concentrate most of the activity on the construction sector of Santiago de Chile is remarkable (see section 2.1.3). The influence of power groups on the dynamics and the decision making regarding the regulations in the construction sector have influenced the definition of relatively low standards; power groups have managed to set the standards to meet their demands and not precisely an optimum.

The growth of the city is defined by patterns of socio-spatial segregation, reflected in clusters of housing typologies scattered across the city. Accordingly, two predominant residential building types were identified: single-family detached houses and multi-family apartment buildings. They correspond to two city growth patterns; horizontal and vertical, respectively (see section 2.2.1). Moreover, the private housing market is a highly competitive market and the housing supply is steadily growing in all of the housing market segments.

While the private housing market evolves dynamically and steadily, the research findings suggested that the private energy-efficient housing market still has many barriers to overcome. Under current prevailing conditions in Santiago de Chile, the greatest challenge for real estate companies is to build and to sell energy-efficient dwellings. As mentioned in the previous sections, under the current market conditions it is difficult for real estate companies to adopt energy efficient measures in their housing projects. Mainly because the back-office of the construction industry is still weak in terms of material supply, technical support, and guaranties for the installation. Moreover, it is also difficult to sell an energy-efficient apartment, because the potential buyers do not quite understand yet the topic and have other concerns when looking for a new dwelling (i.e. location, final price, and layout).

The energy-efficient real estate products offered by real estate companies are concentrated in certain market-segments of the private housing sub-sector, defined by types of housing, socio-economic groups, or areas of the city (in the particular case of Santiago de Chile, the last two aspects are closely related due to the high degree of segregation within the city). In very few cases the real estate companies offer products in all market segments.

From the financial perspective, the empirical evidence seems to show that the socio-economic status of prospective buyers – in the different housing-market segments in Santiago de Chile – seems to play an important role in deciding the energy efficiency strategies adopted by private developers in one residential building or another. Thus, a factor that slows down and hinders energy-efficient dwellings' sales is the relatively high costs for implementing residential energy efficiency measures. The foregoing was reflected in the views of CEOs of real estate companies adopting residential energy efficiency (see section 7.2).

Beyond the prospective buyers' ability and willingness to pay for energy-efficient housing, the literature supports the research findings and presents some explanatory factors from the perspective of the demand side, that is, from the point of view of potential buyers of energy-efficient dwellings. The related literature indicates that in general the use of energy is physically invisible to consumers (OECD-IEA 2008, p. 18). It also mentioned that only the social status and level of comfort that can be achieved inside the house through the use of energy, will be visible to homebuyers and, more importantly, for others. For example, it is argued that a building that does not require air-conditioning systems can be more comfortable and affordable to maintain; however, from the perspective of the homeowners or private developers, only by installing air-conditioning systems it can be shown to prospective buyers that the levels of comfort inside housing were a priority and it was taken into account in the design. Therefore, the – sometimes unnecessary – installation of air-conditioning equipment, the inefficient use or even the waste of energy can be a sign that the homeowners can afford to have an air-conditioned indoor space and to show certain kind of concern for the welfare of the inhabitants of the building. In relation therewith, the OECD-IEA (2008) mentions that several times even the sound of the air-conditioning equipment can be seen as an added value that makes visible the comfort – or concern for a comfortable space – for building users, building owners and their visitors.

With respect to what it presented in the preceding sections, the research findings and the literature discussion seem to indicate that the socio-spatial segregation, that characterizes the spatial development of the city of Santiago de Chile, is also reflected in the private offer of energy-efficient housing products. It seems clear that the dwellings (in general single-family housing (detached or in gated communities) or low-density multifamily buildings) located in traditional residential areas of the city – which concentrate the higher-income socio-economic groups – are offered and built with higher residential energy efficiency standards than the residential buildings (in general high-density multifamily buildings) built for low-income socio-economic groups. However, although there is the possibility that the same housing building types are inhabited by households from different socioeconomic strata, the location of the buildings within the city is an important indicator of the socioeconomic characteristics of the households and, therefore, the buildings' construction standards. For example, high-density multi-family buildings for middle and upper-middle class in the communes of Providencia and Las Condes, or single-family low-density social housing in the communes of Buin, Talagante, and other communes located in the south west area of the city mainly.

8.3 Recommendations

Based on the findings of this doctoral research, a set of recommendations for the further uptake of residential energy efficiency in Santiago de Chile are suggested in the following sections.

The recommendations emerging from this research are divided into three main subjects. First, the implementation of energy efficiency standards for the existing housing stock; second, some measures to overcome barriers to greater implementation of residential energy efficiency measures; and third, the path beyond energy efficiency in building construction towards achieving sustainability in the sector.

The Existing Housing Stock

The analysis of secondary data has highlighted, among other benefits, the importance of the energy saving potential of new buildings. According to the OECD, this potential accumulates year by year because of the long lifetime of buildings: most buildings constructed today will remain in use until after 2050 (OECD-IEA 2008). Moreover, it was argued that building energy codes are easier to implement in new buildings (IEA 2013). Nonetheless, it was also suggested that new buildings soon will become existing buildings and all existing buildings were once new; hence, will the efficiency of new buildings determine the efficiency of existing buildings over time (OECD-IEA 2008).

With respect to the foregoing, the related literature has shown that, among the most important attributes of the housing market, there is the fact that new housing supply generates only a small portion of the total supply of housing at any given time (Cheshire and Mills 1999). In this regard, Santiago de Chile´s housing market is no different from other housing markets around the globe. The supply of new buildings is significantly small compared to the existing housing stock (around 26% and 74% respectively, according to CDT 2010). Moreover, according to statistics from the last National Census conducted in 2012, the number of households in Chile has increased by 24% in the last 10 years (INE 2013), showing a significant growth in the housing stock.

There is a need for the Chilean government to take the necessary steps in order to substantially improve the thermal behaviour and, consequently, the energy efficiency of the existing residential buildings stock. The above argument is grounded in two relevant aspects: first, the number of existing residential buildings built before 2000[114] is significantly higher than the number of residential buildings built meeting any energy efficiency standards; and second, residential buildings built between 2000 and 2007 met only the first stage of the new thermal regulations. Hence, it is valid to argue that residential buildings built since 2000 onwards present a better thermal performance than buildings constructed meeting no thermal regulation. The foregoing highlights the existence of a housing stock with low energy performance[115].

Moreover, the empirical findings have also stressed the pressing need to take appropriate action on commanding and controlling the energy performance of existing residential buildings. Accordingly, a recurrent criticism in the opinion of key stakeholders (scholars as well as practitioners) working in the field of residential energy efficiency in the Chilean context was found regarding the absence of state intervention in the existing private housing stock; there are no clear public policies or regulations setting energy efficiency standards for the existing housing stock.

As mentioned when analysing the barriers to the adoption of energy efficiency measures (see section 7.3), the research findings have shown that Chile's experience in the implementation of energy efficiency requirements for existing buildings is quite delayed compared to international experience. In the international context, there are policies and regulations designed to regulate the existing housing stock. Clearly defined strategic guidelines, both for new and for existing buildings by the European Union buildings (see Table 10, section 4.2.1) provide a good example of the definition of local energy efficiency standards based on regional objectives and goals. For example, the experience in Switzerland, Germany, and Norway are noteworthy for implementing energy efficiency measures in the renovation of existing housing. Therefore, research is needed for the existing housing stock, mainly regarding its energy consumption by building typology. Based on a detailed diagnosis, strategies for intervention in the existing stock of housing are designed considering scholars and practitioners perspectives.

---

[114] The first stage of the New Thermal Regulations for residential buildings in the local building code was issued in 2000. See section 4.4.3.

[115] According to the Chilean Technological Development Corporation, by the year 2010 74% of dwellings were not entitled to any thermal requirement, which represents all dwellings built before 2000. Moreover, only 19% of the building stock, the dwellings built between March 2000 and February 2007, comply with the First Stage of Thermal Regulation (CDT 2010).

So far, the Chilean government has created public policy instruments to improve the thermal performance of existing buildings in two main areas: social housing and public buildings. Interview partners on the field expected and perceived that the recent creation of the Chilean Energy Efficiency Agency, in 2010, may address the issue of existing buildings. The Chilean Energy Efficiency Agency's line of action is focused on the development of pilot projects in existing public buildings to set an example for other sectors and the promotion of new forms of financing for energy efficiency projects. The Chilean Energy Efficiency Agency has enabled the creation of methodologies for integrated building intervention, consolidated in the Energy Efficiency Program in Public Buildings. The program intended to convert existing public buildings through a national benchmark for energy efficiency standards and indoor environmental quality (including hospital infrastructure). With regards to the social housing, in 2012 the Chilean Energy Efficiency Agency encouraged the development of energy efficiency measures in social housing projects (approximately a total of 438 housing units) located in the metropolitan area. Nonetheless, the State intervention in energy efficiency in the existing housing stock is an issue that, at least to date, is relatively absent on the public agenda.

Besides the above mentioned public policy instruments, while there are some government initiated instruments aiming at improving the social-housing thermal behaviour – subsidies under the so-called "*Protection of Heritage Program*" (developed and administered by MINVU) and some smaller initiatives by the Chilean Energy Efficiency Agency – in general, the private existing housing stock remains absent from the policy-making agenda.

As mentioned in the preceding sections, to date, MINVU subsidies provide the possibility for households to access some resources to improve the thermal conditioning in social housing. However, there is criticism that, under current settings of the subsidy system, most of potential grantee or subsidy-beneficiaries choose not to apply. In the opinion of the interviewees, the challenges for subsidizing housing thermal reconditioning in Santiago de Chile are threefold. Firstly, the amount of the subsidies is rather small, although it is justified because subsidies target affordable or social-housing. In contrast, the real potential to make significant improvements in the dwellings' thermal behaviour is as scare as resources are. Secondly, when choosing any of the subsidies, the grantee is "marked"; that means that he or she would not be able to apply for any other housing-related subsidy. Thus, the home-owner is forced to choose a single subsidy program within the range of subsidies offered by MINVU. For example, if the beneficiary decides to follow the thermal reconditioning subsidy, then he or she cannot apply for the grant for house expansion. For this reason, many people decide not to take up the thermal reconditioning subsidy and prefer other subsidies.

Private developers perceived that the way the government incentives were conceived and are being applied, they seem to be focused on the dwelling’s price instead of its energy performance. Consequently, an analysis of the households’ energy consumption for selecting grant recipients should be performed, instead of selecting them according to the dwelling’s price and the household´s socio-economic situation, which is closely related to their ability to pay. In the opinion of the stakeholders, a recurring demand for government intervention in residential energy efficiency revolves around the need to extend the subsidy programs in two ways. Firstly, to other socio-economic segments, in order to increase the adoption rate of energy efficiency measures among the broad middle class. And secondly, to subsidize other technological innovations in the housing sector beyond the solar thermal panels (i.e. the replacement of single pane windows for double-glazed windows, commonly called "*double pane*"). Real estate companies and other stakeholders mentioned that the replacement of windows is one of the most important steps in improving the thermal conditioning of the housing. However, given the current market barriers (primarily high prices of the products, the lack of supply, and limitations in the back-office service industry), this is not yet one of the most commonly adopted strategy neither by home-owners nor by real estate companies.

According to the argument of the foregoing sections, it is necessary for the Chilean government to implement mandatory energy efficiency requirements for existing residential buildings in the short term.

Coping with System Norms and Barriers for Broader Adoption of Energy Efficiency

According to relevant institutional and scientific studies on the implementation of residential energy efficiency regulations (see OECD-IEA 2008, IEA 2013) given the conditions in which energy efficiency standards are defined in building codes – which are characterized by defining relatively low standards – there is no real incentive for designers, builders, and/or real estate development companies to exceed the energy efficiency standards defined in the local building code, which may further increase the initial production costs of the dwellings for the developers. Therefore it is argued that building codes should provide and ensure a common baseline to guide the process. Also, they should seek to ensure that initiatives considered higher standards for residential energy efficiency for both, new buildings and existing buildings when they are subject to major renovations.

In relation therewith, the rate of adoption of innovations in any field is directly related to the perception of potential innovation adopters (see Rogers 2003). With regard to the adoption of energy efficiency innovations in the Chilean housing sector, it is important that individuals (or organizations) perceive energy efficiency innovations as advantageous. That is determined by the relative advantage of innovations in the field of energy efficiency, defined as the ratio of expected benefits and costs of adoption. In real estate companies' opinion, this relationship is crucial to achieve a wider diffusion of residential energy efficiency strategies. The grounds are twofold: first, the adoption costs are still very high (see section 7.2 on budgeting and financial barriers); and second, the information regarding the expected benefits that can be achieved by adopting residential energy efficiency is still scarce, both for private entrepreneurs and for customers; therefore, the degree of uncertainty is high. This directly affects the adoption rate of residential energy efficiency strategies in the private market of Santiago de Chile, which is still low.

In this regard, this doctoral thesis has stressed the role of the Chilean government in the broader diffusion of residential energy efficiency measures. Based on empirical evidence, it is perceived that government intervention should focus on two key areas: first, on the indirect intervention in the market for residential energy efficiency, through the provision of incentives for reducing costs of products and services, at least in the initial stage of the diffusion process; second, by fostering a greater diffusion of the knowledge about the economic, social, and environmental benefits that may be achieved through the implementation of residential energy efficiency measures. The need to generate local knowledge about the benefits was also stressed by private developers. In connection therewith, according to Yogel et al. (2004), the difference between knowledge and information is that knowledge is essentially a cognitive capacity associated with the ability to interpret and transform information. Information, however, is a set of structured and formatted knowledge, but inert and inactive until interpreted by those who have the skills to handle them (Yogel et al.2004, p.141). Therefore, knowledge generation involves the process of analyzing the information generated by and through the international experience and transferring that knowledge in terms that are useful and understandable for all citizens. This plays a key role when increasing the relative advantage and reducing the complexity of innovations.

According to the research findings, one of the main tools for generating information about the benefits of implementing residential energy efficiency measures is the provision of an energy performance certificate of residential buildings (see sections 4.2.4 and 4.3.2). While the Chilean government has recently implemented the residential energy rating system on a voluntary basis (see section 4.4.3, MINVU 2013b) the international experience shows that in order to ensure successful implementation of this type of information systems, they should be implemented on mandatory basis (as an example, see the German experience discussed in Section 4.2.4). Therefore, in the short term, the Chilean government should require the provision of the energy performance certificate on mandatory basis whenever buying or renting a new dwelling or whenever a major renovation in an existing dwelling is to be carried out.

Looking at the Big Picture – From Energy-Efficient Buildings to Sustainable-Buildings

This doctoral research has highlighted the importance of a paradigm shift in the construction industry (see section 4.3.1). The need for change in the traditional building systems was stressed. The paradigm shift should be achieved through a broader adoption of technological innovations in order to reap, among other benefits, energy savings trough the efficient use of energy in buildings.

According to the literature, local and national governments play a key role in achieving greater sustainability in the construction sector (Nelson et al. 2010). Since energy efficiency is one of the first steps towards sustainability of the construction sector (see section 4.3.2), the role of governments is also critical. The relevant literature assigns an important role to local governments to raise designers', private developers', buyers', and homeowners' awareness of the impacts generated by the construction of buildings, the energy performance of buildings, and the potential energy savings that can be achieved through the implementation of energy efficiency measures.

Therefore, local governments play a leading role in generating information about the real benefits of implementing "*green*" design guidelines and energy efficiency measures. According to Nelson et al. (2010) and IEA (2009, 2013) along with information, the implementation of demonstration projects can make the benefits that could be achieved through the implementation of new technologies, materials, and "*green*" design criteria more tangible and credible. Thus, the reduction of the uncertainty about the success of the adoption of energy efficiency measures, which is one of the most relevant barriers for greater diffusion of energy efficiency measures in the private housing market (see section 7.5), can be achieved.

The work of Nelson et al. (2010) argues that the rating systems are the least expensive way to assist designers, real estate developers, and builders to plan, design, and operate green buildings. Therefore, these systems are also attractive for residential buildings. In the Chilean context, MINVU seems to be following this criteria, since what was initially conceived as a residential energy efficiency certification system – that should be introduced compulsorily as part of the 3rd and final stage of the New Thermal Regulation – has changed from its original design and was introduced as a residential energy rating system, implemented voluntarily and applies only to new dwellings (MINVU 2012).

Finally, it is important to highlight that international experience (see the German and British experiences reviewed in Chapter 4) has shown that international certification systems – both government-initiated and voluntary instruments – consider energy efficiency just as a part of a whole set of criteria which are taken into account in the evaluation (among others it also discusses waste management, efficient water management, etc.). Therefore, the state of the art for international certification systems shows that energy efficiency is only a fraction of the overall sustainability assessment. Although the main benefits of implementing building certifications is that it enhances the credibility of a service or product in the eyes of the client or user (Münch 2009), the overall goal is to assess buildings' sustainability in the design, construction, and operation stages. In the short term, this approach should also find common ground in the Chilean and the South American context; not only by means of adopting voluntary instruments (i.e. certification systems) but also by strengthening the existing government-initiated instruments (i.e. building and energy codes).

8.4 Further Research

One of the major contributions of this doctoral research to the state of the art in the field of residential energy efficiency is the identification of key stakeholders from different areas working in an emerging scientific research area in the Chilean and South American contexts. Among the stakeholders, this research has clearly identified a group of real estate development companies who – through the opinion of general managers and other representatives in the upper levels of the companies' decision-making structure – have shown interest in three important areas related to the research, namely: 1) energy efficiency; 2) the search for sustainability in the construction sector; and 3) the desire to be engaged with the academia and the scientific community. This contribution is rather significant in the sense that it opens up the opportunity for new fields of research related to energy efficiency.

Therefore, based on emerging research findings of this doctoral research, the following sections present the most important further research fields related to the research.

Dwelling Ownership and Willingness to Adopt Energy Efficiency

As reviewed in the discussion of the barriers to implementing green building (see section 7.5), the so-called "*agency problem*" according to Nelson et al. (2010, p.21) is a current issue in Santiago de Chile. This issue describes a misalignment between investment and costs incurred by the buildings' or dwellings' owners and the tenants or users of the property. This means that, on the one hand building or dwelling's owners are not able to capture the benefits generated by the implementation of green-design and energy efficiency strategies. Such benefits are received in the operation stage over the life of the building or dwelling, that is, when the building or the house is occupied by the tenant. On the other hand, the initial cost of a building or property which includes energy-efficient or green criteria is greater than the initial cost of a traditional or conventional building; therefore, the cost to the home-owner or builder are also higher whereas they are lower to the occupant or renter. Moreover, in the case of major renovations, according to the traditional lease arrangement systems, the landlords have to pay for the initial costs of any improvements or renovations in the property (including energy efficiency improvements), and at the end the tenants or building-users will not fully compensate the owner, yet collected all the benefits that might have been generated (i.e. energy savings, proper room-temperature, lower energy bills, etc.).

Following a qualitative approach, this research has focused on the supply side of the private housing market, analyzing the factors that determine the choice of real estate companies to provide energy efficient residential buildings in Santiago de Chile. However, to the best of the researcher's knowledge, empirical research from the point of view of market demand for private housing, i.e. customers or prospective buyers / homeowners, in the Chilean context and Latin America is scarce.

Taking into account that a significant percentage of new buildings constructed to date in Chile are intended for lease (especially in the central districts of the city), it becomes clear that the structure of housing tenure plays an important role when deciding to adopt energy efficiency measures. Generally, the decision to adopt residential energy efficiency measures (or purchasing an energy-efficient housing) is a matter for the homeowner. Regardless of the energy efficiency strategy that is adopted, the decision involves an investment whose economic return period can vary. Whether this means innovating in terms of equipment or materials affecting the thermal performance of the dwelling, the homeowner will have a different decision based on whether it will be the end user of the dwelling or not. This is mainly because the user of the dwelling is responsible for housing maintenance costs and energy consumption.

Therefore, relevant factors to the decision to adopt residential energy efficiency measures can be found by examining homeowners' standpoint and their motivations; it is important to understand this perspective as real estate developers are in a constant search to offer real estate products that meet the demands of potential buyers. The work of Nair, Gustavsson, and Mahapatra (2010) identified several factors that influence the adoption of energy efficiency investment measures and categorized them into contextual factors (i.e. building age, thermal comfort, and location) and personal factors (i.e. education, income, gender, awareness, and attitude). The former factors play an important role for this research since those are under real estate companies' control. The latter factors are beyond the scope of this research because they focus on the demand side. Nonetheless, is important to keep this perspective to explore in future research.

The related international literature currently examines, mainly using a quantitative approach, the relationship between dwellings and ownership structure; for example: tenants of rental housing (Laquatra, 1987); tenants of rental apartments and owners of single-family houses (Banfi et al., 2008); and owners of detached houses (Nair, Gustavsson and Mahapatra 2010). In addition, current literature also addresses these topics: the willingness to pay for energy efficient buildings; mandatory energy-conservation standards (Laquatra 1987); energy-saving measures include air renewal system and different energy-efficiency standards of windows and facade (Banfi et al. 2008); non-investment measures or investment measures (Nair, Gustavsson and Mahapatra 2010). The mentioned topics are well covered in the international context; however, they are not yet exanimate in Chile nor the Latin-American context.

The Non-adopters of Residential Energy Efficiency Measures

As it has been shown in the literature, the challenge of reducing CO_2 emissions in this housing sector requires behavioural changes in life styles and energy consumption patterns of people and the use of more energy-efficient production of housing buildings (Flores Larsen et al. 2008). Although the research findings have shown there is a group of real estate developers engaged with adopting energy efficiency and green design and construction techniques in Santiago de Chile's private housing market, the adoption of residential energy efficiency is still ongoing process on its early stages.

In order to group and categorize energy efficiency adopters, this research followed the adopter's model suggested by Rogers (2003). There are categories, which are not covered in this investigation: *early majority, late majority* and *laggards*. In this research, 45 companies that claimed to be adopting energy efficiency measures in the private housing market of Santiago de Chile were selected and examined. However, the private housing market in Santiago de Chile accounts for more than 500 companies all together (see Chapter 3).

Out of this group of non-adopters of residential energy efficiency measures (*early majority, late majority* and *laggards*), it is yet to be analyzed in further studies: 1) whether they currently have a housing offer on the market or not, and 2) whether they indeed decided not to adopt energy efficiency measures or whether it is just not advertised. Once that differentiation is made, a more detailed study on barriers to innovation can be conducted. Within this group are the key informants to understand the reasons for not adopting energy efficiency measures.

The Real Level of Efficiency Achieved with Adopted Energy Efficiency Strategies

To date, the scientific and serious research regarding the real benefits generated by the implementation of thermal regulations for new residential buildings in the Chilean context (see section 4.4.3) remains absent from the academic and institutional agenda.

This research identifies the main residential energy efficiency strategies adopted by real estate companies in the housing market in Santiago de Chile, expressed in the opinion of managers of the companies. However, this research does not determine the actual standards that may be achieved through the implementation of each of the strategies. In terms of passive design strategies, these include: 1) Improved thermal resistance of the envelope; 2) Renewable Energies; and 3) Bioclimatic Design. In terms of active design strategies, these include: 1) Illumination systems; 2) Heating systems; 3) Centralized control systems; and 4) Air conditioning systems. And the adoption of the so-called "*Chilectra - Full Electric Buildings*". Therefore, a quantitative analysis and classification of the efficiency ranges that can be achieved through the implementation of each residential energy efficiency strategies in the different building typologies in the current private market is needed. Moreover, it is important to know the associated investment cost based on the available products on the market.

The scientific literature shows a considerable amount of studies that apply a variety of techniques for quantitative data collection. Data collection techniques range from modelling energy consumption by dwelling typologies to surveys. This research in Latin America in general and specifically in Chile is scarce. The foregoing plays an important role in setting the goals and objectives to be achieved by implementing energy efficiency regulations. The relevant literature shows the need for quantitative data on building's energy performance, in order to diagnose the current situation and define clear goals and objectives for the future (Lowe 2008, IEA 2013). It is only based on this information that the discussion with the various stakeholders may be initiated and jointly define clear goals in the consumption of housing in terms of $kW/(m^2.year)$ or $kgCO_2/(m^2.year)$, or any another suitable indicator that enables planning and state intervention in the medium and long term.

Finally, serious scientific research in Chile has started exploring the energy and thermal behaviour of commercial buildings (see Bustamante and Encinas 2012, Pino et.al. 2012, Bustamante et.al. 2011), apartment building performance (Encinas and De Herde 2013, Encinas et al. 2009), and social housing (Bustamante et al. 2009). Nonetheless, the rigorous scientific research on the energy performance of residential buildings, comparing those meeting with thermal standards with those that were built before 2000, is still an emerging research field demanding attention in the short term.

References

Aberbach, J. and Rockman, B. (2002), "Conducting and Coding Elite Interviews", *Political Science and Politics*, Vol. 35 No. 4, pp. 673–676.

ADI (2013), Asociación de Desarrolladores Inmobiliarios, available from: http://www.adi-ag.cl/?page_id=93&lang=en (accessed 21.11.13)

Agostini, C., Plottier, M., and Saavedra, E. (2009), "*La demanda residencial por Energía Eléctrica en Chile".* Universidad Alberto Hurtado, Santiago de Chile, available from: http://economia.uahurtado.cl/pdf/publicaciones/inv240esp.pdf (accessed 10.08.10).

Altomonte, H., Coviello, M., and Lutz, W. (2003), "*Energías renovables y eficiencia energética en América Latina y el Caribe. Restricciones y perspectivas*", CEPAL, Serie Recursos Naturales e Infraestructura, Santiago de Chile: Naciones Unidas.

Alvarado, A. and Spolmann, S. (2009), "Análisis de competencia del sector de la construcción chileno y sus procesos de licitaciones públicas de contratos de obras: Estructura, Agentes y Prácticas. Informe final", available from: http://www.fne.gob.cl/wp-content/uploads/2011/03/estu_0001_2009.pdf (accessed 07.11.13)

América Economía (2011), "*Ranking por Sector: Construcción*", América Economía, available from: http://rankings.americaeconomia.com/2011/500-chile/sector-construccion.php (accessed 21.09.11)

ANSI/ASHRAE/IES Standard 90A-1980, Energy Conservation in New Building Design, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1980

Anink, D., Mak, J. and Boonstra, C. (1998), "*Handbook of sustainable building: An environmental preference method for selection of materials for use in construction and refurbishment*", London: James & James (Science Publishers) Limited.

APERC (2009), *"Peer Review on Energy Efficiency in Chile – Final Report",* Asia-Pacific Economic Cooperation, available from: http://www.ieej.or.jp/aperc/PREE/PREE_Chile.pdf (accessed 07.07.11).

APERC (2010), *"Compendium of Energy Efficiency Policies of APEC Economies*", Asia Pacific Energy Research Centre, available from: http://www.ieej.or.jp/aperc/CEEP.html (accessed 03.03.11).

APERC (2011), *"APEC Energy Overview 2010",* Asia Pacific Energy Research Centre, available from: www.ieej.or.jp/aperc/2010pdf/Overview2010.pdf (accessed 08.08.11).

Arriagada, C. and Simioni, D. (2001), *"Dinámica de valorización de suelo en el área metropolitana del Gran Santiago y desafíos del financiamiento urbano"*. Santiago de Chile: ECLAC/CEPAL, Serie Medio Ambiente y Desarrollo, available from: http://www.eclac.org/publicaciones/xml/5/9695/lcl1646e.pdf (accessed 03.03.13).

ASHRAE (2013), *"Energy Standard for Buildings Except Low-Rise Residential Buildings"*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., available from: https://www.ashrae.org/File%20Library/docLib/Public/20091119_90_1_2007_r.pdf. (accessed 03.03.13).

Banfi, S., Farsi, M., Filippini, M., and Jakob, M. (2008), "Willingness to pay for energy-saving measures in residential buildings", *Journal of .*Energy Economics, Vol. 30, No. 2, pp. 503–516.

Bansal, P. and Roth, K. (2000), "Why companies go green: A model of ecological responsiveness", *Academy of Management Journal*, Vol. 43 No. 4, pp. 717–736.

Bassey, M. (1999), *Case study research in educational settings*, Maidenhead: Open University Press.

Baxter, P. and Jack, S. (2008), "Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers", *The Qualitative Report,* Vol.13, No4, pp. 544–559.

BBVA (2008), "Situación inmobiliaria Chile", available from: http://serviciodeestudios.bbva.com/KETD/fbin/mult/080826_SitInmobiliaria_Chile_tcm346-198731.pdf?ts=19112012 (accessed 11.11.12).

BCCh (2013), Banco Central de Chile, "Serie Indicadores Excel, Producto interno bruto por actividad y por región", available from: http://www.bcentral.cl/estadisticas-economicas/series-indicadores/index_aeg.htm (accessed 07.11.13)

BEN (2009), "Balanço Energético Nacional" (National Energy Report). Relatório Final - ano base 2008. (Final Report - base year 2008) EPE, Brazil, (In Portuguese).

Benavente, J., Galetovic, A., Sanhueza, R., and Serra, P. (2005), "El costo de la falla residencial por la electricidad en Chile: estimación usando la curva de demanda", *Revista de análisis económico*, Vol. 20, No. 2, pp. 23-40.

Berelson, B. (1971), *"Content Analysis in Communication Research"*, New York: Free Press.

Blomström, M. and Kokko, A. (1998), "Foreign investment as vehicle for international Technology Transfer", in Barba et al. (eds.) *Creation and Transfer of Knowledge Institutions and Incentives:* Springer-Verlag Berlin Heidelberg.

BMVI (2013), Energieausweise - Wärmeschutz beim Wohnungsbau wird transparenter (auf der Grundlage der derzeit noch gültigen EnEV 2009), Bundesministerium für Verkehr und digitale Infraestruktur, available from: http://www.bmvi.de/SharedDocs/DE/Artikel/SW/energieausweise-waermeschutz-beim-wohnungsbau-wird-transparenter.html, (accessed 30.11.13).

BMWi (2014), Energy Efficiency – Made in Germany, Energy Efficiency in Industry and Building Services Technology, Federal Ministry for Economic Affairs and Energy (BMWi), avalible at: http://www.efficiency-from-germany.info/EIE/Redaktion/EN/PDF/ee-made-in-germany-broschuere,property=pdf,bereich=eie,sprache=en,rwb=true.pdf (accessed 20.05.14).

Bolattürk, A. (2008), “Optimum insulation thicknesses for building walls with respect to cooling and heating degree-hours in the warmest zone of Turkey”, *Building and Environment*, Vol. 43 No. 6, pp. 1055–1064.

Booth, S. (1993), “Computer-Assisted Analysis in Qualitative Research”, *Computers in Human Behaviour*, Vol. 9, pp. 203–211.

Borsdof, A. and Hidalgo, R. (2008), “New dimensions of social exclusion in Latin America: From gated communities to gated cities, the case of Santiago de Chile.”, *Land Use Policy*, Vol. 25, pp. 153-160.

Borsdorf, A., and Hidalgo, R, (2005), “The fragmented City”, *The Urban Reinventors,* Issue 3/09, available from: http://www.urbanreinventors.net/3/borsdorfhidalgo/borsdorfhidalgo-urbanreinventors.pdf (accessed 07.11.13).

Bowen, G. (2009),"Document Analysis as a Qualitative Research Method", *Qualitative Research Journal*, Vol. 9, No. 2, pp. 27 – 40.

BRE (2013), Building Research Establishment, available from: http://www.bre.co.uk/page.jsp?id=1712 (accessed 07.11.13)

BRE Global (2009), “*BREEAM Europe Commercial 2009 Assessor Manual, SD 5966A: ISSUE 1.1”,* available from: http://www.ngbc.no/sites/default/files/SD_5066A_1_1_BREEAM_Europe_Commercial_2009.%20pdf (accessed 02.02.11).

BREEAM (2013), Code for a Sustainable Built Environment, available from: http://www.breeam.org/page.jsp?id=347 (accessed 07.11.13).

Burnard, P. (1991), “A method of analyzing interview transcripts in qualitative research”, *Nurse Education Today*, Vol. 11, pp. 461–466.

Burnard, P. (1996), “Teaching the analysis of textual data: an experiential approach”, *Nurse Education Today*, Vol. 16, pp. 278–281.

Bustamante, W. (2009), “Design guide for energy efficiency in social housing” Santiago. Ministry of Housing and Urbanism, available from: http://www.minvu.cl/opensite_20070402125030.aspx (accessed 11.11.11).

Bustamante, W., and Encinas, F. (2012), “Parámetros de Diseño y Desempeño Energético en edificios de clima mediterráneo”, *Arq - Arquitectura, Diseño y Urbanismo*, Chile, Vol.82, pp.20-23.

Bustamante, W., De Herde, A., Encinas, F. (2011), “Analysis of office building thermal performance in different districts of the Metropolitan Area, Chile”, *Revista de la Construcción*, N° 10, Vol.1, pp.64-77.

Cardoso, M., and Lira, F., (2008) “Situación Inmobiliaria Chile”, *Servicio de Estudios Económicos – BBVA*, available from: http://serviciodeestudios.bbva.com/KETD/fbin/mult/080826_SitInmobiliaria_Chile_tcm346-198731.pdf?ts=10102013 (accessed 07.11.13).

Carpio, C., Coviello, M., Poveda, M., (2009), *“Situación y perspectivas de la Eficiencia Energética en América Latina y El Caribe”,* CEPAL/OLADE, Santiago de Chile: Naciones Unidas.

Casgrain, A. (2010), “La apuesta del endeudamiento en la política habitacional chilena”, *Revista INVI*, Vol.25, No.68, pp. 155-182, available from: http://www.scielo.cl/scielo.php?pid=S0718-83582010000100006&script=sci_arttext (accessed 07.02.11).

CBCh (2010), Central Bank of Chile, “Cuentas Nacionales de Chile 2003-2010”, available from: http://www.bcentral.cl/publicaciones/estadisticas/actividad-economica-gasto/pdf/CCNN2003_2010.pdf (accessed 02.02.11).

CChC (2013a), “*Chile: Sector Construcción”*, Coordinación Económica - Cámara Chilena de la Construcción, available from: http://www.ccs.cl/html/eventos/2013/doc/proyecciones2014-JavierHurtado.pdf (accessed 07.11.13)

CChC (2013b), Informe MACh: Macroeconomía y Construcción Nº 39 Diciembre de 2013, Cámara Chilena de la Construcción, available from: http://www.cchc.cl/publicacion/informe-mach-39/ (accessed 07.12.13)

CChC (2013c), “*Comités Gremiales*”, Cámara Chilena de la Construcción, available from: http://www.cchc.cl/sobre-cchc/comites-gremiales/ (accessed 07.11.13)

CDT (2010), “Manual Técnico Reacondicionamiento Térmico de Viviendas en Uso”, Corporación de Desarrollo Tecnológico de la Cámara Chilena de la Construcción, available from: http://antiguo.minenergia.cl/minwww/export/sites/default/05_Public_Estudios/descargas/Reacondicionamiento_termico_viviendas.pdf (accessed 07.11.11)

CDT (2012), *“Anuario Energético 2012”*, Corporación de Desarrollo Tecnológico de la Cámara Chilena de la Construcción, Santiago de Chile.

CDT (2013), “C*orporación de Desarrollo Tecnológico”*, Cámara Chilena de la Construcción, available from: http://www.cdt.cl/cdt/www/adminTools07/home.aspx (accessed 21.11.13)

Chan, E., Qian, Q., and Lam, P. (2009), “The market for green building in developed Asian cities—the perspectives of building designers”, *Energy Policy*, Vol. 37 No. 8, pp. 3061–3070.

Cheshire, P. and Mills, E. (1999), "Introduction: Applied urban economics," Handbook of Regional and Urban Economics, in: Cheshire, P. and Mills, E. (ed.), Handbook of Regional and Urban Economics, edition 1, volume 3, chapter 34, pp. 1323-1335 Elsevier.

Chilectra (2009), Rafael Caballero, Head of the Energy Management Area at Chilectra "Chilectra´s Energy Efficiency Plan (2005-2009)". Gerencia de Regulación y Gestión de Energía. Santiago, March 2009.

Chilectra (2011), "El sistema Full Electric es un éxito en términos de producto y de concepto", Revista Electricidad, No.135, available from: http://www.chilectra.cl/wps/wcm/connect/20e6e08046e4a00c8cb2fe0e72d9d021/Entrevista_CFM_RevistaElectricidad_135.pdf?MOD=AJPERES&Tipo=DOC (accessed 02.02.11).

Chilectra (2013), *"Productos Full Electric"*, Chilectra, available from: http://www.chilectra.cl/wps/wcm/connect/ngchl/ChilectraCl/Ecoenergias/Solucion+Electrica+Eficiente/Full+Electric/Productos+Full+Electric (accessed 21.11.13)

Chumacero, R., Paredes, R., Sanchez, M. (2000), "Regulación para Crisis de abastecimiento: Lecciones del Racionamiento eléctrico en Chile", *Cuadernos de Economía*, Vol. 37, pp. 232-338.

Chwieduk, D. (2003), "Towards sustainable-energy buildings", *Applied Energy*, Vol. 76 1–3, pp. 211–217.

CNE (2005), "Eficiencia Energética en Chile. Aspectos Generales", Gobierno de Chile, Comisión Nacional de Energía, available from: <http://www.pnud.cl/areas/Energia-Medio-Ambiente/taller_energia_ppt/pto_montt/RubenMunoz.pdf, (Accessed 03.03.11).

CNE (2008), Fijación de fórmulas tarifarias para concesionarios de servicio público de distribución, available from: http://antiguo.cne.cl/cnewww/export/sites/default/07_Tarificacion/01_Electricidad/otros_Vad/vad/descargas_2008_2012/IT_VAD_2008-2012.pdf (accessed 02.02.13).

Cohen, D., and Crabtree, B. (2006), Qualitative Research Guidelines Project, available from: http://www.sswm.info/sites/default/files/reference_attachments/COHEN%202006%20Semistructured%20Interview.pdf (accessed 02.02.13).

Çomaklı, K. and Yüksel, B. (2003), "Optimum insulation thickness of external walls for energy saving", *Applied Thermal Engineering*, Vol. 23 No. 4, pp. 473–479.

CONAMA (1994), *Ley Nº 19.300 sobre Bases generales del medio ambiente*. Santiago: Comisión Nacional del Medio Ambiente.

Contreras, Y. (2009), Movilidad Residencial Centrípeta:El rol del mercado inmobiliario y del nuevo habitante urbano en la recuperación del centro de Santiago de Chile, XII Encuentro de Geógrafos de América Latina "Caminando en una América Latina en transformación", available from: http://observatoriogeograficoamericalatina.org.mx/egal12/Geografiasocioeconomica/Geografiadelapoblacion/25.pdf (accessed 07.11.13).

CORFO (2006), "Elaboración de normas chilenas sobre uso eficiente de la energía en sector industrial y residencial", available from: http://repositoriodigital.corfo.cl/handle/11373/3160 (accessed 03.03.11)

Coyne, I.T. (1997), “Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries?”, Journal of Advanced Nursing, Vol. 26 No. 3, pp. 623–630.

Creswell, J. W. (2007), *Research design: Qualitative, quantitative, and mixed methods* approaches (2nd ed.), Thousand Oaks, CA: Sage.

Creswell, J., and Miller, D. L. (2000), “Determining validity in qualitative inquiry. Theory into Practice”, Vol 39 No.3, pp. 124-131.

Dammert, L. and Oviedo E. (2004), Santiago: delitos y violencia urbana en una ciudad segregada, In de Mattos, C., Ducci, M.E., Rodríguez, A., and Yáñez, G. (eds.) *Santiago en la Globalización ¿Una Nueva Ciudad?* Santiago: Ediciones SUR.

De Mattos, C. (2002), “Transformación de las ciudades latinoamericanas: ¿Impactos de la globalización?” *EURE Revista Latinoamericana de Estudios Urbano Regionales*, Vol.28, No.85, pp. 5-10.

De Mattos, Carlos (2006), “Modernización capitalista y transformación metropolitana en América Latina: cinco tendencias constitutivas”, in: Geraiges de Lemos, Amalia Inés y otros. América Latina: cidade, campo e turismo. San Pablo: Consejo Latinoamericano de Ciencias Sociales (CLACSO).

De Mattos, Carlos (2007), “Globalización, negocios inmobiliarios y transformación urbana”, *Nueva Sociedad,* No 212, pp.81-96, available from: http://www.nuso.org/upload/articulos/3481_1.pdf (accessed 11.11.11).

DECC (2013) Standard Assessment Procedure, Department of Energy and Climate Change (DECC), available from: https://www.gov.uk/standard-assessment-procedure (accessed 30.11.13).

Decreto n. 4.059, de 19 de dezembro de 2001. Regulamenta a Lei no 10.295, de 17 de outubro de 2001, que dispõe sobre a Política Nacional de Conservação e Uso Racional de Energia, e dá outras providências. Lex: Diário Oficial da União, Brasília, 2001b, available from: www.mme.gov.br/ministerio/legislacao/decretos/Decreto%20nº%204.059-2001.html (accessed 02.02.11).

DGF (2006), Estudio de la Variabilidad Climática en Chile para el Siglo XXI, Departamento de Geofísica, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, available from: http://www.sinia.cl/1292/articles-50188_recurso_8.pdf (accessed 07.11.13)

DGNB (2013), The DGNB Certification System, available from: http://www.dgnb-system.de/en/system/certification_system/ (accessed 07.11.13).

Du Plessis, C. (2002), Agenda 21 for sustainable construction in developing countries: A discussion document, Boutek report, Vol. 0204, WSSD ed., CSIR Building and Construction Technology, Pretoria.

Eberl, S. (2010), “DGNB vs. LEED: a comparative analysis”, *Central Europe towards Sustainable Building 2010 (CESB10),* available from: http://cesb.cz/cesb10/papers/5_assessment/031.pdf (accessed 07.11.13).

Edwards, B. (2003), *Green buildings pay,* 2nd ed., Spon, London.

Edwards, B. and Turrent, D. (2000), *Sustainable housing: Principles & practice*, E & FN Spon, London, New York.

EERE (2008), "Energy Efficiency Trends in Residential and Commercial Buildings", *U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy*, available from: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/bt_stateindustry.pdf (accessed 11.11.11)

Egmond, C., Jonkers, R. and Kok, G. (2006), "One size fits all? Policy instruments should fit the segments of target groups", *Energy Policy*, Vol. 34 No. 18, pp. 3464–3474.

Eichholtz, P., Kok, N. and Quigley, J. (2010), "Why Do Companies Rent Green? Real Property and Corporate Social Responsibility", *UC Berkeley: Berkeley Program on Housing and Urban Policy*, available from: http://www.escholarship.org/uc/item/7br1062q (accessed 11.09.11).

Encinas, F. and De Herde, A. (2013), "Sensitivity analysis in building performance simulation for summer comfort assessment of apartments from the real estate market", *Energy and Buildings*, Vol. 65, pp. 55–65.

Encinas, F., De Herdé, A., Nuñez, C. and Marmolejo, C. (2009), "Thermal comfort and market niches for apartment buildings: impact of the current thermal regulation in the private real estate market in Santiago de Chile", *ACE: Architecture, City and Environment [en línea]*, Año IV, No. 11, pp. 45 – 58, available from: http://www-cpsv.upc.es/ace/Articles_n11/PDF/ ACE_11_SA_12.pdf (accessed 03.03.11).

ENE (2012), "National Energy Strategy 2012-2030: Energy for the Future", Government of Chile, available from: http://www.centralenergia.cl/uploads/2012/06/National-Energy-Strategy-Chile.pdf (accessed 07.11.13).

EnEV (2014), "Amendment to the Energy Saving Ordinance", available from: http://www.energieausweis-fuer-wohngebaeude.de/ (accessed 06.10.14)

ENERBUILD (2009), Certification of energy-efficient public buildings - Summary of instruments in the Alpine Space, available from: http://www.itz.ch/__/frontend/handler/document.php?id=330&type=42 (accessed 07.11.13).

EPA (2013), *Building Codes for Energy Efficiency*, Environmental Protection Agency, available from: http://www.epa.gov/cleanenergy/documents/suca/buildingcodesfactsheet.pdf (accessed 07.11.13).

EPBD (2002), Directive 2002/91/EC of The European Parliament and of The Council of 16 December 2002 on the Energy Performance of Buildings, available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:001:0065:0065:EN:PDF (accessed 30.11.13).

Escorcia, O., García, R., Trebilcock, M., Celis, F. and Bruscato, U. (2012), "Mejoramientos de envolvente para la eficiencia energética de viviendas en el centro-sur de Chile", *Informes de la Construcción*, Vol. 64, pp. 563–574.

Estrategia (2011), "*Cómo crecerán las Grandes Inmobiliarias en 2012*", Estrategia, available from: http://www.estrategia.cl/detalle_noticia.php?cod=47047 (accessed 21.09.11)

Fereday, J. and Muir-Cochrane, E. (2006), "Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development", In *International Journal of Qualitative Methods*, Vol. 5: 1, pp. 80-92.

Flick, U. (2009)," An introduction to qualitative research". 4th ed. Los Angeles: Sage

Flores Larsen, S., Filippín, C., Beaschochea, A., Lesino, G., (2008), An experience on integrating monitoring and simulation tools in the design of energy-saving buildings, Energy and Buildings 40, pp. 987-997.

Formoso, C., Jobim, M. (2003), "Customer servicing in the brazilian house-building industry", *Revista de Ingeniería de Construcción*, Vol. 18, No. 1, pp. 23-31.

Fuerst, F. (2009), "Building momentum: An analysis of investment trends in LEED and Energy Star-certified properties", *Journal of Retail and Leisure Property*, Vol. 8 No. 4, pp. 285–297.

FVS (2012), "Situación de la energía fotovoltaica en España (Enero-2012)", Fundación Vida Sostenible, available from: http://www.vidasostenible.org/observatorio/f2_final.asp?idinforme=361 (accessed 07.11.13)

Gann, D., Wang, Y., and Hawkins, R. (1998), "Do regulations encourage innovation? - the case of energy efficiency in housing", *Building Research & Information*, Vol.26 No.4, pp.280-296, available from: http://dx.doi.org/10.1080/096132198369760 (accessed 30.11.13).

García, S. and Solís, J. (2008), "3Cv + 2: Modelo de calidad para la construcción de la vivienda", *Revista Ingeniería de Construcción*, Vol.*23, No.*2, pp. 102-112, available from: http://www.scielo.cl/pdf/ric/v23n2/art05.pdf (accessed 29.10.13).

GBC-Chile (2013), Green Building Council Chile, LEED Certified Projects, available from: http://www.chilegbc.cl/proyectos_leed.php, (accessed 07.11.13).

Glicksman, L., Norford, L. and Greden, L. (2001), "ENERGY CONSERVATION IN CHINESE RESIDENTIAL BUILDINGS: Progress and Opportunities in Design and Policy", *Annual Review of Energy and the Environment*, Vol. 26 No. 1, pp. 83–115.

Green Globes (2013), The Practical Building Rating System, available from: http://www.greenglobes.com (accessed 07.11.13).

Greene, M. and Soler, F. (2004), "Santiago: de un proceso acelerado de crecimiento a uno de transformaciones", en: De Mattos, Carlos y otros. (2004). *Santiago en la globalización ¿Una nueva ciudad? Santiago de Chile: SUR-EURE Libros.*

Guest, G., Bunce, A., and Johnson, L. (2006), "How Many Interviews Are Enough? An Experiment with Data Saturation and Variability", *Field Methods,* Vol. 18, No. 59.

Hass, R. (1997), "Energy efficiency indicators in the residential sector', *Energy Policy,* No 25, nos. 7-9, pp. 789 – 802.

Heinrichs, D., Nuissl, H. and Rodríguez, C. (2009), "Dispersión urbana y nuevos desafíos para la gobernanza (metropolitana) en América Latina: el caso de Santiago de Chile", *EURE*, Vol. 35 No. 104, pp. 29–46.

Herring, H. (1999), "Does energy efficiency save energy? The debate and its consequences", *Applied Energy, Vol.* 63, pp.209-226.

Herring, H. (2006), "Energy efficiency – a critical view", *Energy Vol.31*, pp. 10 – 20.

Hidalgo, R. (2004), "De los pequeños condominios a la ciudad vallada: las urbanizaciones cerradas y la nueva geografía social en Santiago de Chile (1990-2000)" *EURE (Santiago),* Vol. 30 No.91.

Hidalgo, R. (2010), "Los centros históricos y el desarrollo inmobiliario: las contradicciones de un negocio exitoso en Santiago de Chile", *Revista Electrónica de Geografía y Ciencias Sociales*, Vol. 14 No.331.

Hidalgo, R., Borsdorf, A., and Sánchez, R. (2007), La expansión residencial amurallada en la reconfiguración metropolitana de Santiago de Chile. In: De Mattos, C. and Hidalgo. R. ed. *Santiago de Chile: movilidad espacial y reconfiguración metropolitana*. Santiago: GEOlibros 8.

Hitchin, E. (1990), "Developments in degree-day methods of estimating energy use", *Building and Environment*, Vol. 25 No. 1, pp. 1–6.

Hohnen, P. and Potts, J. (2007), "*Corporate social responsibility*. *An implementation guide for business,* International Institute for Sustainable Development = Institut international du développement durable, Winnipeg".

Horta, L., (2010) "*Indicadores de políticas públicas en materia de eficiencia energética en América Latina y el Caribe*", CEPAL/GTZ/BMZ, Colección Documentos de Proyectos, Santiago de Chile: Naciones Unidas.

Hui, S. (1997), *Overall Thermal Transfer Value (OTTV): How to Improve Its Control in Hong Kong*, In Proc. of the One-day Symposium on Building, Energy and Environment , 16 October 1997, Shangri- la Hotel, Kowloon, Hong Kong, HKIE BS Division/CIBSE/ASHRAE/PolyU, pp. 12-1 to 12-11, available from: http://web.hku.hk/~cmhui/bse97a.pdf (accessed: 23.08.13)

Hyde, R. (2008), Bioclimatic Housing: Innovative Designs for Warm Climates, Taylor and Francis.

Ibarra-Coronado, R. (2011), "La Ley de Concesiones de Obras Públicas chilena en el tiempo", 19 International Law, *Revista Colombiana de Derecho Internacional*, pp. 183-222.

IEA (1997), Solar Energy Houses, Strategies, Technologies, Examples, A.G. Hestnes, R. Hastings and B. Saxhof, (Ed.), James and James Science Publishers.

IEA (2009), *Chile Energy Policy Review,* International Energy Agency, available from: www.iea.org/publications/freepublications/publication/chile2009.pdf (accessed 04.11.13).

IEA (2013), *Modernising Building Energy Codes*, International Energy Agency, available from: http://www.iea.org/publications/freepublications/publication/PP7_Building_Codes_2013_WEB.pdf (accessed 04.11.13).

IFMA (2010), "The Economics of Sustainability in Commercial Real Estate", IFMA Foundation, available from: http://www.ifmafoundation.org/documents/public/EcoofSustainability.pdf (accessed 23.08.10).

INE (2007), Migración Interna Regional 1992-2002, Instituto Nacional de Estadísticas (INE), available from: http://www.ine.cl/canales/chile_estadistico/demografia_y_vitales/demografia/pdf/migraciones241107.pdf (accessed 23.08.13).

INE (2012), Censo de Población 2012, Resultados Preliminares Censo de Población y Vivienda 2012, Instituto Nacional de Estadísticas (INE), available from: http://www.cooperativa.cl/noticias/site/artic/20120831/asocfile/20120831161553/resultados_preliminares_censo_2012.pdf, (accessed 23.08.13).

INE (2013), *Compendio estadístico 2013*, Instituto Nacional de Estadísticas INE, available from: http://www.ine.cl/canales/menu/publicaciones/calendario_de_publicaciones/pdf/COMPENDIO_2013.pdf (accessed 07.11.13).

ISO (2013), What is conformity assessment?, available from: http://www.iso.org/iso/home/about/conformity-assessment.htm (accessed 07.11.13).

Jackson, K. (1985), *Crabgrass frontier. The suburbanization of the United States*, New York/Oxford: Oxford University Press.

Janda, K. (2009), “Worldwide status of energy standards for buildings: a 2009 update”, available from: http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2009/Panel_2/2.299 (accessed 29.10.13).

Kats, G. (2003), “The Costs and Financial Benefits of Green Buildings. A Report to California’s Sustainable Building Task Force”, available from: http://www.usgbc.org/Docs/Archive/General/Docs1992.pdf (accessed 29.10.13).

Koeppel, S., and Ürge-Vorsatz D. (2007). *Assessment of policy instruments for reducing greenhouse gas emissions from buildings*. Report for the UNEP-Sustainable Buildings and Construction Initiative. Central European University: Budapest, available from: http://web.ceu.hu/envsci/projects/UNEPP/index.htm, (accessed 07.11.13).

Kowal, S. and O'Connell, D. (2004), The transcription of conversations. In Flick, U., von Kardorff, E. and Steinke, I. (Eds.), *A companion to qualitative research*, London: Sage, pp. 248–252.

LabEEE s.f. Laboratório de Eficiência Energética em Edificações – LabEEE – UFSC. Etiquetagem de Eficiência Energética de Edificações.

Laquatra, J. (1987), “Energy efficiency in rental housing”, *Energy Policy*, Vol. 15 No. 6, pp. 549–558.

LEED (2013), Leadership in Energy and Environmental Design, available from: http://www.usgbc.org/leed (accessed 07.11.13).

Levine, M., Ürge-Vorsatz, D, Blok, K., Geng, L., Harvey, D., Lang, S., Levermore, G., Mongameli, A., Mehlwana, Mirasged, S., Novikova, A., Rilling, J., and Yoshino, H. (2007), “Residential and commercial buildings”, in *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, United Kingdom and New York, NY, USA.

Link, F. (2008), “From polycentricity to fragmentation in Santiago de Chile”. Centro-h, *Revista de la Organización Latinoamericana y del Caribe de Centros Históricos*. No. 2, pp. 13-24.

Lockwood, C. (2006) “Building the Green Way,” *Harvard Business Review*, Vol.84:6, pp.129-135.

Lowe, R. and Oreszczyn, T. (2008), “Regulatory standards and barriers to improved performance for housing”, *Energy Policy,* No. 36, pp. 4475–4481.

Lstiburek, J. (2008), “Why Green Can Be Wash”, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), available from: http://www.pinp.org/pdf/ACF222B.pdf (accessed 30.11.13).

Lutzenhiser, L. (1994), “Innovation and organizational networks. Barriers to energy efficiency in the US housing indusry”, *Energy Policy*, Vol. 22 No. 10, pp. 867–876.

Lützkendorf, T. (2009), Nachhaltiges Bauen – auf dem Weg zum Leitmarkt, In: Sedlbauer, K. and Bauer, W. *Brennpunkt CO_2 Reduktion – Chancen für das Bauwesen*, Stuttgart: Stiftung Bauwesen.

Mahlia, T., Masjuki, H., and Choudhury, I. (2002), “Theory of energy efficiency standards and labels”, *Energy Conversion and Management*, Vol. 43, pp. 743–761.

Maldonado, D., (2011), “*Certificación LEED – Análisis Crítico*”, SustentaBiT,No. 10, available from http://biblioteca.cchc.cl/datapicture/23148-2.pdf (accessed 30.11.13).

Marburger, L. (2010), Metrics for High Performance Affordable Housing, Federation of American Scientists, available from: http://www.fas.org/programs/energy/btech/policy/Metrics%20for%20High%20Performance%20Affordable%20Housing.pdf (accessed 07.11.13).

Marshall, D. (2010), “El Consumo Eléctrico Residencial en Chile en 2008”. Cuadernos de Economía, Vol. 47, pp. 57-89.

Martinaitis, V., Bieksa, D. and Miseviciute, V. (2010), “Degree-days for the exergy analysis of buildings”, *Energy and Buildings*, Vol. 42 No. 7, pp. 1063–1069.

Matthew, B., and Huberman, A. (1994), “Qualitative Data Analysis”. Thousand Oaks: Sage.

McWilliams, A., and Siegel, D. (2001), "Corporate Social Responsibility: A theory of the firm perspective", *Academy of Management Review*, Vol. 26, No.1, pp. 117-127.

Mercado, J. (2009), "Evaluación de la coherencia entre políticas públicas y su aporte a la sustentabilidad regional. Santiago de Chile (1987-2007)", Master's thesis, Pontificia Universidad Católica de Chile.

Meyer, C. (2011), *Planning for an Ageing Population – Experiences from Local Areas in the United Kingdom*, Berlin: Rhombos-Verlag, available from: http://www.ioer.de/fileadmin/internet/IOER_schriften/IOER_Schrift_56.pdf (accessed 07.11.13)

Miles, M., and Huberman, A. (1994), *Qualitative data analysis: An expanded sourcebook* (2nd ed.), Thousand Oaks, CA: Sage.

MINEN (2012), *Balances Energéticos*, Ministerio de Energía, available from: http://antiguo.minenergia.cl/minwww/opencms/14_portal_informacion/06_Estadisticas/Balances_Energ.html (accessed 20.10.12)

MINEN (2013), Organigrama del Ministerio de Energía, Ministerio de Energía, available from: http://www.minenergia.cl/ministerio/organigrama.html, (accessed 07.11.13).

MINVI (2006), *REAL DECRETO 314/2006 - Código Técnico de la Edificación*, Madrid: Ministerio de Vivienda, available from: http://www.codigotecnico.org/cte/export/sites/default/web/galerias/archivos/RD3142006.pdf (accessed 07.11.13).

MINVU (1975), DFL N° 458 de 1975 – Ley General de Urbanismo y Construcciones, Santiago: Ministerio de Vivienda y Urbanismo.

MINVU (2007), "Evaluación de impacto del subsidio de renovación urbana", Estudio del Área Metropolitana del Gran Santiago 1991-2006, División Técnica de Estudio y Fomento Habitacional, Ministerio de Vivienda y Urbanismo – DITEC, primera edición, junio de 2007.

MINVU (2009), *"Sistema de Certificación Energética de Viviendas",* Instituto de Investigaciones Tecnológicas y Asistencia técnica – Universidad de Concepción, Fundación Chile, available from: http://www.acee.cl/576/article-58868.html (accessed 25.01.11).

MINVU (2012), Sistema de Calificación Energética de Viviendas, Ministerio de Vivienda y Urbanismo, available from: http://www.minvu.cl/opensite_20120504133150.aspx (accessed 07.07.12).

MINVU (2013), Programa de Protección del Patrimonio Familiar, Ministerio de Vivienda y Urbanismo, available from: http://www.minvu.cl/opensite_20130226131226.aspx (accessed 07.11.13).

MINVU (2013b), Calificación Energética de Viviendas, Ministerio de Vivienda y Urbanismo, available from: http://calificacionenergetica.minvu.cl/, (accessed 07.11.13).

MINVU-IC (2006), "Manual de Aplicacion Reglamentacion Termica MINVU", Ministerio de Vivienda y Urbanismo. Instituto de la Construcción Santiago, noviembre de 2006.

Mlenick, E., Visscher, H., and van Hal, A. (2010), "Barriers and opportunities for labels for highly energy-efficient houses", Energy Policy, Vol. 38, pp. 4592–4603.

Montalvo, C. (2006), "What triggers change and innovation?", *Technovation*, Vol. 26 No. 3, pp. 312–323.

Moore, G. (1999), Crossing the chasm: Marketing and selling high-tech products to mainstream customers. New York: HarperBusiness.

MOP (1991), DFL Nº 164 de 1991 – Ley de Concesiones de Obras Públicas, Santiago: Ministerio de Obras Públicas.

Mostyn, B. (1985), The content analysis of qualitative research data: a dynamic approach. In Brenner, M., Brown, J., Canter, D. (Eds.), *The research interview: Uses and approaches*, London: Academic Press, pp.115-145.

Münch, J. (2009), "Sustainability Assessment of Buildings. A Comparative Analysis of three Methods: the BRE Environmental Assessment Method, the German Sustainable Building Certificate and the Swan label for Small houses", Master thesis, Management Engineering, Technical University of Denmark, available from: http://etd.dtu.dk/thesis/268962/Julianes_Comparative_Analysis_of_three_assessment_methods.pdf (accessed 07.11.13)

Musgrave, R. (1957), "A Multiple Theory of Budget Determination", *Finanzarchiv/New Series*, Vol. 25 No. 1, pp. 333–343.

Nair, G., Gustavsson, L., and Mahapatra, K. (2010), "Factors influencing energy efficiency investments in existing Swedish residential buildings", *Energy Policy*, Vol. 38 No. 6, pp. 2956–2963.

Nelson, A., Rakau, O., and Dörrenberg, P. (2010), "*Green buildings - A niche becomes mainstream*", Deutsche Bank Research, available from: http://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000256216/Green+buildings%3A+A+niche+becomes+mainstream.pdf (accessed 10.10.13).

Newsham, G., Mancini, S., and Birt, B. (2009), "Do LEED-certified buildings save energy? Yes, but...", *Energy and Buildings,* Vol.41, No.8, pp.897–905.

OECD (2008), *"Roundtable on Competition in the Construction Industry"*, Organisation for Economic Co-operation and Development (OECD). available from : http://www.oecd.org/daf/competition/cartelsandanti-competitiveagreements/41765075.pdf, (Accessed Feb 2011).

OECD-IEA (2008), *"Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings"*, Organisation for Economic Co-Operation and Development and International Energy Agency, available from: http://www.iea.org/publications/freepublications/publication/Building_Codes.pdf (accessed 30.11.13).

OECD-IEA (2009), *"Chile Energy Policy Review 2009"*, Organisation for Economic Co-Operation and Development and International Energy Agency, available from: http://www.iea.org/publications/freepublications/publication/chile2009.pdf (accessed 30.11.13).

Orsato, R., "Competitive Environmental Strategies: When Does It Pay to be Green?", *California Management Review*, Vol. 48 No. 2, pp. 127–143.

Parlow, M. (2008), "Greenwashed?: Developers, Environmental Consciousness, and the case of Playa Vista", *Environmental Affairs*, Vol. 35, pp. 513–532.

Patterson, M. (1996), "What is energy efficiency? Concepts, indicators and methodological issues", *Energy Policy,* Vol. 24, No. 5, pp. 377-390.

Patton, M. (1990), Qualitative Evaluation and research methods (2nd ed.), Newbury Park, CA: Sage.

Patton, M. (2002), Qualitative Research and evaluation methods, CA: Sage.

PEIE (2008), "Aporte potencial de: Energías Renovables No Convencionales y Eficiencia Energética a la Matriz Eléctrica, 2008-2025", available from: http://www.archivochile.com/Chile_actual/patag_sin_repre/03/chact_hidroay-3%2000035.pdf (accesed 03.03.13).

Pérez-Lombard, L; Ortiz, J; González, R; and Maestre, I. (2009), "A review of benchmarking, rating and labelling concepts within the framework of building energy certification schemes", *Energy and Buildings* 41, pp. 272–278.

Pino, A., Bustamante, W., Escobar, R., and Encinas, F. (2012), "Thermal and Lighting Behavior of Office Buildings in Santiago of Chile". Energy and Building, No.47, vol., 1, pp.441-449.

PNCURE (2001), Lei n◦ 10.295, de 17 de outubro de 2001. Dispõe sobre a Política Nacional de Conservação e Uso Racional de Energia, e dá outras providências. In: Diário Oficial da União, Brasília, DF, 2001.

Poveda, M., (2007), *"Eficiencia Energética: Recurso no aprovechado"*, Latin American Energy Organization, available from: http://www.iadb.org/intal/intalcdi/PE/2009/02998.pdf (accessed 01.01.11).

Pretty, N., Thomson, O., Stew, G. (2012), "Ready for a paradigm shift? Part 2: Introducing qualitative research methodologies and methods", Manual Therapy.Miles.

PRIEN (2003), "Estudio de las Relaciones entre la Eficiencia Energética y el Desarrollo Económico" .Programa de Estudios e Investigaciones en Energía, available from: http://www.prien.cl/documentos/GTZ_Eficiencia%20y%20desarrollo.pdf (accessed 12.02.11).

PRIEN (2008), "Caracterización y estimación del potencial de ahorro de energías en las distintas regiones de Chile". Universidad de Chile, available from: http://www.acee.cl/576/articles-59067_doc_pdf.pdf, (accessed 12.02.11)

Reed, R., Bilos, A., Wilkinson, S., and Karl-Werner, S. (2009), "International Comparison of Sustainable Rating Tools", *The Journal of Sustainable Real Estate*, Vol. 1 No. 1, pp. 1–22.

Rice, P. and Ezzy, D. (1999), *Qualitative research methods: A health focus*, New York/Oxford: Oxford University Press.

RICS (2013), Grün kommt! Europäische Nachhaltigkeitsstatistik – September 2013, Going for Green Sustainable Building Certification Statistics Europe – September 2013, available from: http://www.rics.org/Global/Gr%C3%BCn%20kommt!%202013.pdf (accessed 07.11.13)

Rivera, A. (2009), "International Application of Building Certification Methods: A Comparison of BREEAM and LEED." *PLEA2009- 26th Conference on Passive and Low Energy Architecture.* Quebec, Canada.

Rodríguez, A., and Winchester, L. (2004) Santiago de Chile: Una ciudad fragmentada, In Santiago en la Globalización ¿una nueva ciudad?, Santiago de Chile: Ediciones SUR, available from: http://www.sitiosur.cl/r.php?id=372. (accessed 07.11.13).

Rogers, E. (2002), "Diffusion of preventive innovations", *Addictive Behaviors*, Vol. 27 No. 6, pp. 989–993.

Rogers, E. (2003), *Diffusion of innovations,* 5th ed., Free Press, New York.

Roriz, M., Ghisi, E. and Lamberts, R. (2000), "A first step towards the Brazilian standardisation on thermal performance of buildings" . In: Proceedings of COTEDI 2000, Venezuela, pp. 297–302.

Royal Institute of Chartered Surveyors, 2005, Green Value, *RICS Research Report*: London and Vancouver.

Rozas, P., (2002), "*Competitividad, eficiencia energética y derechos del consumidor en la economía Chilena*", ILPES/CEPAL, Serie Gestión Pública, Santiago de Chile: Naciones Unidas.

Rufián, D. (2002), *Políticas de concesión vial: análisis de las experiencias de Chile, Colombia y Perú,* Instituto Latinoamericano y del Caribe de Planificación Económica y Social (ILPES), available from: http://www.eclac.org/publicaciones/xml/1/9751/sgp16.pdf (accessed 07.11.13).

Sabatini, F., and Salcedo, R. (2007), Gated communities and the poor in Santiago, Chile: Functional and symbolic integration in a context of aggressive capitalist colonization of lower-class areas, *Housing Policy Debate,* Vol.18 No.3, pp.577-606.

Salcedo, R., and Torres, A. (2004), "Los nuevos barrios enrejados: ¿muro o frontera?". Sabatini, F., and G. Cáceres, *Barrios cerrados en Santiago de Chile. Entre la exclusión y la integración residencial*. Santiago: Lincoln Institute of Land Policy/Instituto de Geografía, Pontificia Universidad Católica de Chile, pp.147-178.

Sahin, I. (2006), "Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory", *The Turkish Online Journal of Educational Technology – TOJET*, Vol. 5 No. 2, pp. 14–23.

Saidur, R., Hasanuzzaman, M., Hasan, M. and Masjuki, H. (2009), "Overall Thermal Transfer Value of Residential Buildings in Malaysia", *Journal of Applied Sciences*, Vol. 9 No. 11, pp. 2130–2136.

Santamouris, M. and Asimakopoulos, D.N. (2001), *Energy and climate in the urban built environment*, James X James, London.

Scalco, V., Fossati, M., de Souza, R., Sorgato, M., Lamberts, R. and Morishita, C.(2012): Innovations in the Brazilian regulations for energy efficiency of residential buildings. In *Architectural Science Review* 55 (1), pp. 71–81.

Schoenau, G. and Kehrig, R. (1990), "Method for calculating degree-days to any base temperature", *Energy and Buildings*, Vol. 14 No. 4, pp. 299–302.

Scofield, J. (2009), "Do LEED-certified buildings save energy? Not really…", *Energy and Buildings*, Vol. 41, pp. 1386–1390.

SERNAC (2005), Eficiencia Energética – "Comportamiento de Consumo Energético, en familias urbanas tipo del Gran Santiago", Gobierno de Chile – Convenio SERNAC – CNE, Programa País de Eficiencia Energética, available from: *www.sernac.cl/download.php?id=1372andn=1* (accessed 25.01.11).

Simons, H. (2009), *Case study research in practice*, Los Angeles: Sage.

Stake, R. (1995), "The Art of case study Research". Thousand Oaks, London, New Delhi: Sage.

Strauss, A., (1987), "Qualitative Analysis for Social Scientist". Cambridge: Cambridge University Press.

Swan, L., and Ugursal, I. (2009), "Modeling of end-use energy consumption in the residential sector: A review of modeling techniques", *Renewable and Sustainable Energy Reviews,* No. 13, pp. 1819 – 1835.

Székely, F., and Knirsch, M. (2005), "Responsible Leadership and Corporate Social Responsibility", *European Management Journal*, Vol. 23 No. 6, pp. 628–647.

Tashakkori, A., and Teddlie, C. (2010), "*Handbook of mixed methods in social and behavioural research",* (2ed.), Thousand Oaks, CA: Sage.

Tashakkori, A., and Teddlie, C. (1998), "Mixed methodology: Combining qualitative and quantitative approaches" , *Applied Social Research Methods Series*, Vol. 46. Thousand Oaks, CA: Sage.

Taylor, S., and Bogdan, R. (1996), "Introducción a los métodos cualitativos de investigación: La búsqueda de significados", Barcelona, Buenos Aires: Paidós.

Teddlie, C. and Yu, F. (2007), "Mixed Methods Sampling A typology with examples", *Journal of Mixed Methods Research*, Vol. 1, No. 1, pp. 77 – 100.

Torcellini, P., and Pless, S. (2004), *Trombe Walls in Low-Energy Buildings: Practical Experiences*, World Renewable Energy Congress VIII and Expo Denver, Colorado August 29–September 3, 2004, [Online], available from: http://www.nrel.gov/docs/fy04osti/36277.pdf, [accessed 07.11.13].

Toro, C. (2009), *"Aplicación de la metodología de kano para la determinación de un modelo de valor para clientes de productos inmobiliarios",* Master Thesis, Pontificia Universidad Católica de Chile, Santiago de Chile, Chile.

Trebilcock, M. (2011), "Perception of barriers to the inclusion of energy efficiency criteria in buildings", *Revista de la Construcción*, Vol. 10 No. 1, pp. 4–14.

Turner, C., and Frankel, M. (2008), *"Energy Performance of LEED for New Construction Buildings—Final Report"*, New Buildings Institute and U.S. Green Building Council, White Salmon, WA, available from: http://newbuildings.org/sites/default/files/Energy_Performance_of_LEED-NC_Buildings-Final_3-4-08b.pdf (accessed 07.11.13).

Tzikopoulos, A, Karatza, M., and Paravantis, J. (2005), "Modeling energy efficiency of bioclimatic buildings", *Energy and Buildings,* No.37, pp. 529-544.

UCh (2013), *Acerca de Chile*, Universidad de Chile, available from: http://www.uchile.cl/portal/presentacion/la-u-y-chile/acerca-de-chile/8035/presentacion-territorial (accessed 07.11.13)

UN (2009), "Housing Finance Mechanisms in Chile". United Nations Human Settlements Programme. Nairobi.

UNEP (2009), Buildings and Climate Change, United Nations Environment Programme, available from: http://www.unep.org/sbci/pdfs/sbci-bccsummary.pdf (accessed 07.11.13)

USDE (2013), Estimating the Cost and Energy Efficiency of a Solar Water Heater, U.S. Department of Energy, available from: http://energy.gov/energysaver/articles/, (accessed 07.11.13).

USGBC (2013), *LEED Rating Systems*, The U.S. Green Building Council, available from: http://www.usgbc.org/leed/rating-systems (accessed 07.11.13).

Van Audenhove, L. (2007), "*Expert Interviews and Interview", Techniques for Policy Analysis*, SMIT Studies on Media, Information and Information and Telecommunication, IBBT Interdisciplinary Institute on Broadband Technology, available from: http://www.ies.be/files/060313%20Interviews_VanAudenhove.pdf (accessed 10.1011).

Van de Ven, A., Garud, R. and Venkataraman, S. (2008), "*The Innovation Journey*," Oxford University Press, New York.

Vera, S., and Ordenes, M (2002), "Thermal and energy performance evaluations of a social housing in Chile, using building energy simulation software", *Revista Ingeniería de Construcción*, Vol. 17, No. 3, pp. 133 – 142.

Vijayalaxmi, J. (2010), "Concept of Overall Thermal Transfer Value (OTTV) in Design of Building Envelope to Achieve Energy Efficiency", *Int. J. of Thermal & Environmental Engineering*, Vol. 1 No. 2, pp. 75–80.

WBCSD (2007) Energy Efficiency in Buildings, World Business Council for Sustainable Development, available from: http://www.c2es.org/docUploads/EEBSummaryReportFINAL.pdf, (accessed 07.11.13)

Weber, L. (1997), "Some reflections on barriers to the efficient use of energy", Energy Policy, Vol. 25 No. 10, pp. 833–835.

Wright, A. (2008), "What is the relationship between built form and energy use in dwellings?", *Energy Policy*, Vol. 36 No. 12, pp. 4544–4547.

Yeang, K. (1999), "Proyectar con la naturaleza: Bases ecológicas para el proyecto arquitectónico", Arquitectura y diseño + ecología, Barcelona: Gustavo Gili.

Yin, R. (2009), *Case study research: design and methods, (*2nd ed.-), Thousand Oaks, CA: Sage.

Yogel, G., Novick, M., Milesi, D., Roitter, S. and Borello, J. (2004), "Información y conocimiento: la difusión de las TIC en la industria manufacturera Argentina", *Revista de la Cepal*, Vol. 82, pp. 139–156.

Zegras, C., and Gakenheimer, R. (2000), "Urban Growth Management for Mobility: The Case of the Santiago, Chile Metropolitan Region", available from: http://web.mit.edu/czegras/www/Zegras_Gakenheimer_Stgo_growth_mgmt.pdf (accessed 07.02.11).

Annex

A Participant Consent Form

TECHNISCHE UNIVERSITÄT DRESDEN Leibniz Gemeinschaft AKADEMIE FÜR RAUMFORSCHUNG UND LANDESPLANUNG LEIBNIZ-FORUM FÜR RAUMWISSENSCHAFTEN Leibniz Institute of Ecological and Regional Development

Leibniz-Institut für ökologische Raumentwicklung e.V. , Dresden Leibniz Graduate School, Weberplatz 1, 01217 Dresden

José Mercado
Doktorand der Dresden Leibniz Graduate School

Tel: +49/351/463 42351
E-mail: j.mercado@dlgs.ioer.de

Consentimiento Informado

Proyecto de Tesis Doctoral:

"El rol de la eficiencia energética residencial en el sector privado de la vivienda.

El caso de Santiago de Chile".

Se me ha informado que esta entrevista es anónima y confidencial, así como que puedo detenerla cuando lo desee. Estoy de acuerdo en que la entrevista con José Mercado sea grabada en formato digital, a fin de no perder detalles de la misma. La información entregada durante la entrevista podrá ser utilizada como parte del proyecto de doctorado mencionado anteriormente. Por otra parte, estoy de acuerdo con que algunos extractos de la entrevista puedan ser utilizados en documentos destinados a publicaciones científicas relacionados con esta investigación.

Santiago de Chile, ... , ...

Postadresse
José Mercado, DLGS
Leibniz Institut für ökologische Raumentwicklung
Weberplatz 1
01217 Dresden

Besucheradresse
Würzburger Str. 35
2. Obergeschoss
Raum 221
01187 Dresden

Kontakt
Tel: +49/351/463 42351
E-mail: j.mercado@dlgs.ioer.de

Internet: www.dlgs-dresen.de

B Chilean Norms regarding energy efficient use in industrial and residential sectors (source Own compilation based on CORFO 2006)

Chilean Norm – Housing Appliances	
Norm Number	**Title**
NCh3000.Of2006	Eficiencia energética - Refrigeradores, congeladores y refrigeradores-congeladores de uso doméstico - Clasificación y etiquetado
NCh3010.Of2006	Eficiencia energética - Lámparas incandescentes de uso doméstico - Clasificación y etiquetado
NCh3020.Of2006	Eficiencia energética - Lámparas fluorescentes compactas, circulares y tubulares de uso doméstico - Clasificación y etiquetado
NCh3037.Of2007	Consumo de energía - Equipos de audio, video y equipos relacionados - Método de ensayo
NCh3038.Of2007	Eficiencia energética - Televisores - Clasificación y etiquetado
NCh3041. Of2007	Eficiencia energética - Monitores de computador - Clasificación y etiquetado
NCh3042. Of2007	Artefactos eléctricos de uso doméstico - Medición de potencia del modo en espera
NCh2582/1.Of2007	Eficiencia energética - Lavadoras de ropa - Parte 1: Método de ensayo para medir el comportamiento
NCh2582/2.Of2007	Eficiencia energética - Lavadoras de ropa - Parte 2: Clasificación y etiquetado
NCh3081.Of2007	Eficiencia energética - Equipos de aire acondicionado - Clasificación y etiquetado
NCh3107.Of2008	Artefactos eléctricos de uso doméstico - Eficiencia energética en modo de espera - Etiquetado

Chilean Norm – Solar Panels	
Norm Number	**Title**
NCh3096/1.Of2008	Energía solar - Sistemas solares térmicos y sus componentes - Colectores solares - Parte 1: Requisitos generales
NCh3096/2.Of2008	Energía solar - Sistemas solares térmicos y sus componentes - Colectores solares - Parte 2: Métodos de ensayo
NCh3120/1.Of2008	Energía solar - Sistemas solares térmicos y sus componentes - Sistemas prefabricados - Parte 1: Requisitos generales
NCh3120/2.Of2008	Energía solar - Sistemas solares térmicos y sus componentes - Sistemas prefabricados - Parte 2: Métodos de ensayo
NCh3088/1.Of2007	Energía solar - Sistemas solares térmicos y sus componentes - Sistemas hechos a medida - Parte 1: Requisitos generales
NCh3088/2.Of2008	Energía solar - Sistemas solares térmicos y sus componentes - Sistemas hechos a medida - Parte 2: Métodos de ensayo
NCh3088/3.Of2008	Energía solar - Sistemas solares térmicos y sus componentes - Sistemas hechos a medida - Parte 3: Caracterización del rendimiento de acumuladores para sistemas solares de calefacción
NCh3146.Of2008	Energía solar - Sistemas que utilizan colectores solares - Recomendaciones para su instalación

Chilean Norm – Sustainable Construction	
Norm Number	**Title**
NCh853.Of2007	Acondicionamiento térmico - Envolvente térmica de edificios - Cálculo de resistencias y transmitancias térmicas
NCh1079.Of2008	Arquitectura y construcción - Zonificación climático habitacional para Chile y recomendaciones para el diseño arquitectónico
NCh1973.Of2008	Características higrotérmicas de los elementos y componentes de edificación - Temperatura superficial interior para evitar la humedad superficial crítica y la condensación intersticial - Métodos de cálculo
NCh3048/1.Of2007	Sustentabilidad en la construcción de edificios - Métodos para el desarrollo de indicadores de sustentabilidad - Parte 1: Edificios
NCh3049/1.Of2007	Sustentabilidad en la construcción de edificios - Métodos de evaluación del comportamiento ambiental de los trabajos de construcción - Parte 1: Edificios
NCh3045.Of2007	Guía para determinar condiciones de medición de consumo energético
NCh3055.Of2007	Directrices para la determinación de la calidad ambiental interna en edificios de uso comercial
NCh849.Of2007	Aislación térmica - Magnitudes físicas y definiciones
NCh850.Of2008	Aislación térmica - Determinación de resistencia térmica en estado estacionario y propiedades relacionadas - Aparato de placa caliente de guarda
NCh851.Of2008	Aislación térmica - Determinación de propiedades de transmisión térmica en estado estacionario y propiedades relacionadas - Cámara térmica calibrada y de guarda
NCh3076/1.Of2008	Comportamiento térmico de puertas y ventanas - Determinación de la transmitancia térmica por el método de la cámara térmica - Parte 1: Puertas y ventanas
NCh3076/2.Of2008	Comportamiento térmico de puertas y ventanas - Determinación de la transmitancia térmica por el método de la cámara térmica - Parte 2: Ventanas de techumbres y otras ventanas sobresalientes
NCh3077.Of2007	Materiales y productos de construcción - Determinación de los valores térmicos declarados y de diseño
NCh3078.Of2008	Comportamiento térmico de edificios - Coeficiente de pérdida por transmisión de calor - Método de cálculo
NCh3117.Of2008	Comportamiento térmico de edificios - Transmisión de calor por el terreno - Métodos de cálculo
NCh3136/1.Of2008	Puentes térmicos en construcción de edificios - Flujos de calor y temperaturas de superficie - Parte 1: Métodos generales de cálculo
NCh3137/1.Of2008	Comportamiento térmico de ventanas, puertas y contraventanas - Cálculo de transmitancia térmica - Parte 1: Generalidades
NCh3137/2.Of2008	Comportamiento térmico de ventanas, puertas y contraventanas - Cálculo de transmitancia térmica - Parte 2: Método numérico para marcos
NCh3149.Of2008	Diseño ambiental de edificios - Eficiencia energética - Terminología

Chilean Norm – Illumination	
Norm Number	**Title**
NCh3082.Of2008	Eficiencia energética - Balastos de lámparas fluorescentes - Clasificación y etiquetado
NCh3083.Of2008	Método de medida de la potencia total de entrada de los circuitos balastos-lámparas
NCh3110.Of2008	Balastos para lámparas de descarga (excluyendo lámparas fluorescentes tubulares) - Requisitos de comportamiento
NCh1101.Of2008	Lámparas fluorescentes de casquillo doble - Especificaciones de comportamiento
NCh2681.Of2008	Lámparas fluorescentes de casquillo simple - Especificaciones de comportamiento