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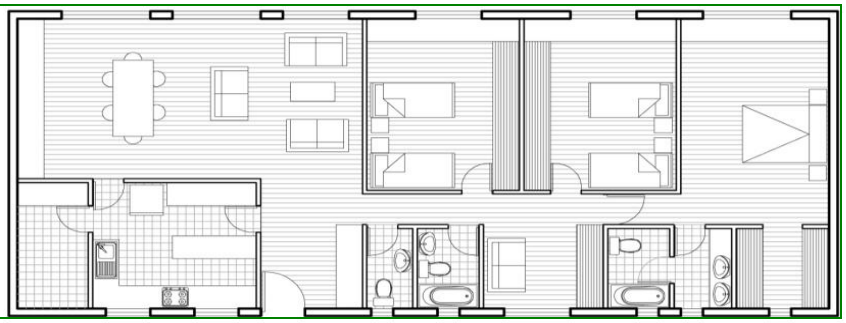

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Key Words
Thermal comfort
Liveability
Public policies
Energy efficiency

ABSTRACT

The objective underlying the present study is to present the performance of existing dwellings in Región Metropolitana of Chile, which were constructed before 2000. Consequently, the study proposes a public-private policy to improve the thermal conditions of the dwellings.
To evaluate the performance a matrix containing thirty two dwelling typologies was made and analysed in terms of: absolute energy consumption, relative energy reduction and payback period. As well, the evaluation was made in three different scenarios; Base Case, Regulation Case and Energy Efficient Case. Finally, the results were analysed in terms of three different income economic groups.
The results demonstrated that an Energy Efficient Refurbishment is more cost-effective than a Regulation Refurbishment. At the same time, increasing the energy efficiency in houses could contribute to: decrease health problems, fuel poverty and also the energy demand of the country. It was also concluded that a public incentive for the high income economic group, would generate a large private investment. Therefore have a big decrease in fuel import and production savings, with this saving it is possible to pay 66% of the total public subsidy for the refurbishment programme.

Palabras clave:
Bienestar Térmico

RESUMEN

El objetivo de este trabajo es presentar el rendimiento energético de viviendas existentes en la Región Metropolitana de Chile, construidas

antes del año 2000. El estudio propone una política pública-privada para mejorar las condiciones térmicas de las viviendas.
Para realizar la evaluación se elaboró una matriz de treinta y dos tipologías de viviendas y se analizó en términos de: consumo energético, reducción de energía y periodo de recuperación de la inversión. A su vez, la evaluación se hizo para tres escenarios diferentes: Caso Base, Caso Regulación y Caso Eficiente Energéticamente. Finalmente, los resultados fueron analizados en función de tres grupos de ingresos económicos.
De los resultados se pudo desprender que el Caso Eficiente Energéticamente resulta más rentable que el Caso Regulación. A la vez, que la eficiencia energética en viviendas podría contribuir a disminuir: problemas de salud, inaccesibilidad económica a la cantidad de combustible requerido y demanda energética del país. También se concluyó que un incentivo público para renovación eficiente energéticamente al grupo económico de ingresos altos, generaría una gran inversión privada. Esto derivaría en una disminución en la importación y producción de combustibles, alcanzando un ahorro que podría pagar el 66% del subsidio necesario para el programa de renovación.

Habitabilidad
Políticas Públicas
Eficiencia Energética

1. Introduction

Chile is currently in an energy crisis produced by the substantial increase in international fuel prices it depends on, as most of the supply consumed in the country is imported.

Consequently, the country has large energy import costs in and puts the country in an unstable scenario from an energy viewpoint. This means that it is advisable to reduce the energy demand to decrease the energy import costs.

On the other hand, in low income sectors the percentage of the family budget available for heating the house is not sufficient to achieve reasonable temperature conditions during winter; this translates into fuel poverty.

In addition, the poor energy efficient quality of construction in Chile is a fact. Before the Thermal Regulation for construction in 2000 (MINVU, 2012a), there were no mandatory standards that would ensure a certain level of thermal performance. This results in low thermal comfort dwellings and high cost heating and cooling, using too much energy to try to obtain adequate temperatures.

Increasing the energy efficiency in houses is the best alternative to achieve adequate internal temperatures. It could also contribute to decreasing health problems, fuel poverty and also the energy demand of the country.

The aim of this study is to present an information analysis for future studies and public policies use directed at increasing thermal conditions of the dwellings and stimulate the energy efficiency in space heating in existing Chilean dwellings located in Región Metropolitana, identifying the most cost effective scenarios.

2. Development

2.1 Background

2.1.1 The energy sector

Chile has a lack of natural gas resources, 80% of all gas supplies depends on imports (CNE, 2012a) and the price of the gas and the electricity has increased notoriously during the years (CNE, 2012b) (Fig.1). Therefore, Chile must anticipate now a severe energy crisis that could occur in the future (Bustamante, Cepeda, Martínez, & Santa María, 2011).

The residential sector has not been an important subject of energy efficiency reduction in government policies even that heating represents about 11 per cent of the country's energy consumption (Collados & Armijo, 2009).

No restrictions apply in terms of fuel use for houses. However, if the house is located in a "saturated urban area" such as Santiago; open fires are prohibited and only double chamber wood or biomass burners may be used unless air

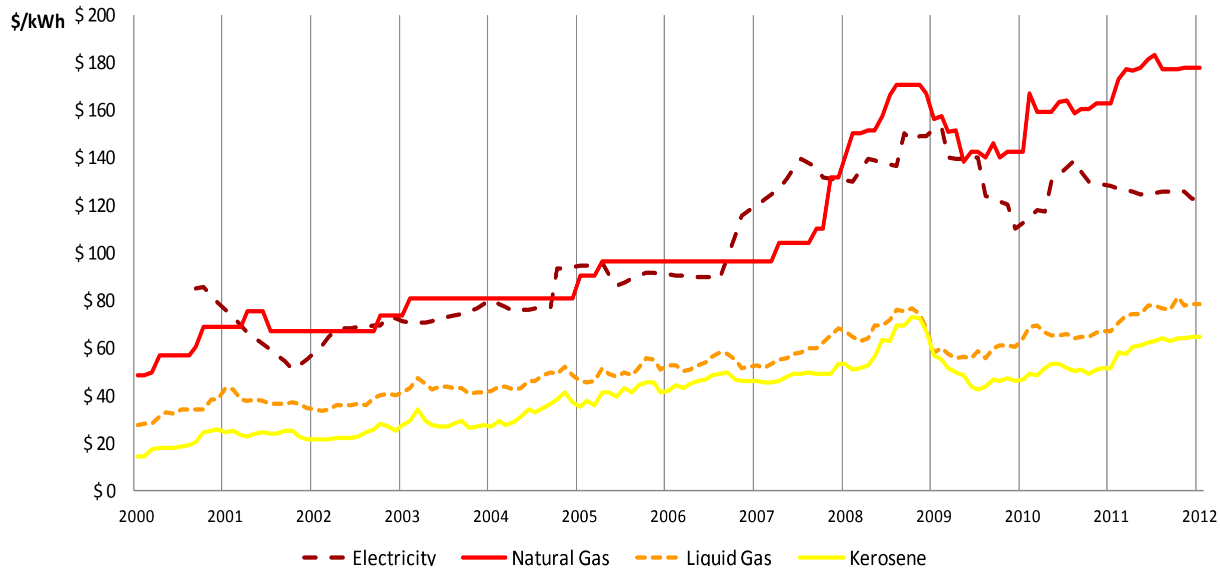

Figure 1: Chilean Historical Energy Prices in chilean pesos by the author**.** Source: CNE, 2012.
Figura 1: Precios Históricos de Energía en Chile en pesos chilenos, por el autor. Fuente: CNE, 2012

pollution rises, and "pre-emergency"[1] is declared.

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The main fuel energy used for domestic heating in the Region Metropolitana shows a clear inclination for gas and kerosene fuels (Hormazabal, 2010) (fig. 2).

2.1.2 Thermal Comfort and Fuel Poverty

Energy consumption in the poorer sectors in Chile is not sufficient for achieving reasonable temperature conditions during the majority of the wintertime.

Also, the current high prices of energy in Chile and the low family incomes for the poorest sector, result in fuel poverty. "The inability to afford adequate warmth in the home" (Lewis, 1982). It refers to households that would need to spend more than 10% of their annual income on fuels in order to achieve satisfactory indoor heating. The concept refers to what people need to spend, not what they actually spend (Collados & Armijo, 2009).

According to Miguel Márquez (Márquez & Miranda, 2009), the increase in the cost of energy has a direct implication in the family budget. Low income families by 2009, spent around 12% of the family budget in heating and it could represent up to 20% of the household income.

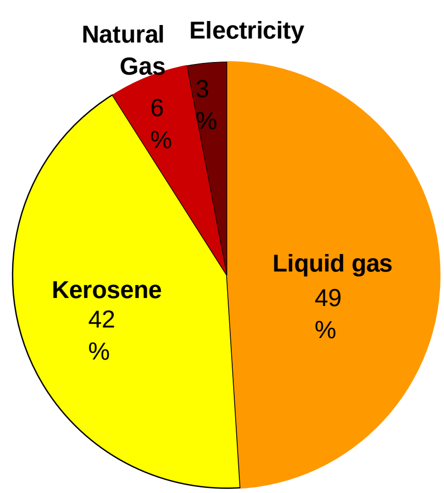


Figure 2: Main energy use for domestic heating in Santiago. Made by the author. Source: Hormazabal, 2012
Figura 2: Principales energías utilizadas para calefaccionar hogares en Santiago. Realizado por el autor. Fuente: Hormazabal, 2012

[1] There is a critical event when the PM10 air quality levels exceed the 200 of ICAP or, equivalently, to 195 ug/m3 concentration (SINIA, 2001). The regulation is supposed to change in 2014.

Table 1: Chilean Building Code regulation. Source: MINVU, 2011.
Tabla 1: Regulación Térmica Chilena para la edificación. Fuente: MINVU, 2011

Thermic Zone	Degree Days Base 15°C	Reference City	Roof	Walls	Ventilated Floors	Windows		
						Single Glazing	Double Glazing	
			U	U	U		3.6 >U<2.4	U>2.4
			W/m²K	W/m²K	W/m²K	Max. % of glazing with respect to the total perimeter wall surface		
1	<500	Antofagasta	0.84	4	3.6	50%	60%	80%
2	500-750	Valpariso	0.6	3	0.87	40%	60%	80%
3	750-1000	Santiago	0.47	1.9	0.7	25%	65%	80%
4	1000-1250	Concepción	0.38	1.7	0.6	21%	60%	75%
5	1250-1500	Temuco	0.33	1.6	0.5	18%	51%	70%
6	1500-2000	Puerto Montt	0.28	1.1	0.39	14%	37%	55%
7	>2000	Punta Arenas	0.25	0.6	0.32	12%	28%	37%

The inadequate thermal conditions of the existing dwellings affect the living standard, and low temperatures in winter have a negative impact on health. In addition, a considerable amount of pollution and humidity are produced indoors due to kerosene and liquid gas heating systems. Health services are oversaturated during winter due to respiratory diseases mainly in children and elderly people.

2.1.3 Chilean Thermal Regulations

Chile has been a pioneer in Latin America in the implementation of mandatory standards in the thermal performance of the new housing envelope. The thermal regulation was established in 3 stages, with the first one starting on 2000 (Table 1).

For improving the energy efficiency in existing dwellings; in 2006 a "Subsidio para Acondicionamiento Térmico de la Vivienda" (Thermal Subsidy) was established (AChEE, 2011). It consists of 100-130 UF subsidies for improvements aimed at decreasing the energy consumption, and the houses should have a maximum value of 650 UF[2] (AChEE, 2012).

2.1.4 Dwellings in Región Metropolitana

The total amount of dwellings in Chile according to the last pre census 2011[3] is 5.581.876 (INE, 2012a). The dwellings are heavily concentrated in the Región Metropolitana, with 37% of them.

From the amount of dwellings considered in the last pre census 2011, 20% of them were built after the year 2002 (INE, 2012a). For the remaining 80%; the quality, warmth and health are far from being satisfactory. Nowadays, more apartments than houses are being built in Región Metropolitana. However, before 2002, 73% of the total dwellings in the Región Metropolitana were houses (INE, 2002) (Table 2).

Table 2: Amount of dwellings in the Región Metropolitana per Census. Source: INE, 2012a
Tabla 2: Cantidad de viviendas en la Región Metropolitana por Censos. Fuente: INE, 2012a

Census	Región Metropolitana
1992	1.286.492
2002	1.639.373
2011	2.045.896

2.2 Methodology

The sample studied is made up of 1.145.702 houses located in the Región Metropolitana and constructed before 2002 (INE, 2002). The houses typologies are analysed in terms of energy consumption in three steps; one with typical construction materials used before the Thermal Regulation, the second one with Thermal Regulation Standards and the third one with Energy Efficiency Standards propose by the author. The typologies for the houses studied were defined according to the data obtained from the INE and MINVU.

First, five groups were set according to the total amount of rooms in a house (INE, 2002). For each group, a surface related to the number of rooms was defined (INE, 2002). The dwelling

[2] The "Unidad de Fomento" (UF) is a unit of account used in Chile, indexed according to inflation. (1 UF = $22.559 CLP 30/08/2012)

3 The Pre-census 2011 is a survey (prior to Census 2012) that was used to update database with the number of blocks, buildings, houses and homes in the country.

surfaces defined to analyse were 50m^2, 70m^2, 150 m^2 and 300 m^2.

The three different income economic groups were established according to the MINVU subsidies requirements. To obtain a low income subsidy; the price of the house should be less than 650 UF, and for medium income subsidies; less than 2.000 UF [4] (MINVU, 2012b) (Table 4). In addition, high income families were defined as the group with no government dwellings subsidies. These costs were linked with the INE dwellings average sizes.

Table 3: Income economic group's definition by the auhor. Source: MINVU, 2012
Tabla 3: Definición de los grupos económicos por el autor. Fuente: MINVU, 2012

Social Class	House Value	House Surface
High	> 2000 UF	150
		300
Medium	650 – 2000 UF	70
Low	< 650 UF	50

Second, a layout was defined for each of the surfaces of both; one-storey and two- storey dwellings (Fig.3).

Third, each one of these models was divided into two different orientations; north-south and east-west.

Fourth, every model was catalogued as either an attached or a detached typology.

Finally, each of the 32 models obtained was built in TAS software (EDSL, 2012), in order to simulate energy consumption.

In addition, for the public policy analysis the results were grouped according to the three different income economic groups.

2.3 Modelling

TAS software (EDSL, 2012) was used to evaluate the energy consumption (kWh/year) per dwelling.

The houses contemplate 2 adults and 2 kids, based on the average family members of Chile (3.6 persons per household) (INE, 2002).

The thermal comfort is set as a minimum of 20°C and a maximum of 27°C, 24 hours a day throughout the whole year.

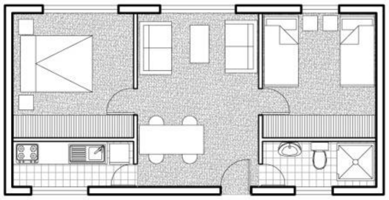
[4] The "Unidad de Fomento" (UF) is a unit of account indexed according to inflation, used in Chile. (1 UF = $22.559 CLP 30/08/2012)

The internal gains were calculated based on CIBSE guide A (CIBSE guide A, 2006) (Table 4).

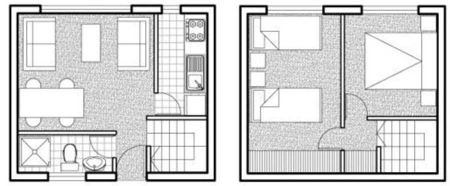
Table 4: Elements Configuration. Source: CIBSE guide A, 2006
Tabla 4: Configuración de elementos. Fuente: CIBSE guide A, 2006

Element Configuration				
Code	**Type**	**Thickness (mm)**	**Material (Out. to Ins.)**	**Emissivity Ext/Int**
01	External Wall	140	Brick	90/90
02	External Wall	140	Brick	87/90
		1	Moisture barrier	
		20	Polystyrene	
		8	Net+Render	
03	External Wall	140	Brick	87/90
		80	Polystyrene	
		1	Moisure Barrier	
		8	Net+Render	
04	Internal Wall	10	Gypsum	87/87
		20	Cavity	
		10	Gypsum	
05	Ground Floor	300	Earth	85/90
		80	Sand	
		70	Concrete	
		1.4	Ceramic Tile	
06	Floor	70	Concrete	85/90
		1.4	Ceramic Tile	
07	Ceiling	10	Gypsum	87/87
08	Ceiling	80	Glass Wool	87/87
			Gypsum	
09	Ceiling	160	Glass Wool	
			Gympsum	
10	Roof	5	Fiber	90/90
11	Door	5	Plywood sheet	
		20	Aire	
		5	Plywood sheet	
12	Door	5	Plywood sheet	90/90
		20	Polystyrene	
		5	Plywood sheet	
13	Glass	10	Glass	84/84
14	Glass	6	Glass	84/84
		12	Cavity	
		6	Glass	
15	Window Frame	4	Aluminium	216/216
16	Window Frame	5	Wood	90/90

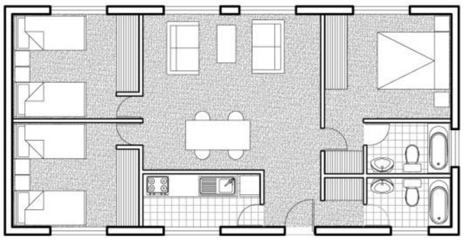
The schedule is set for a seven-day period, with bedroom use between 23:00 and 08:00, kitchen use between 10:00 and 13:00 and 19:00 and 20:00 and Living Room use between 17:00 and 23:00.



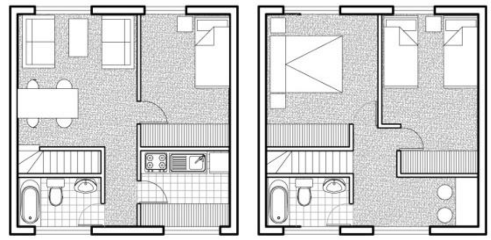
50 m² dwelling (1 floor)



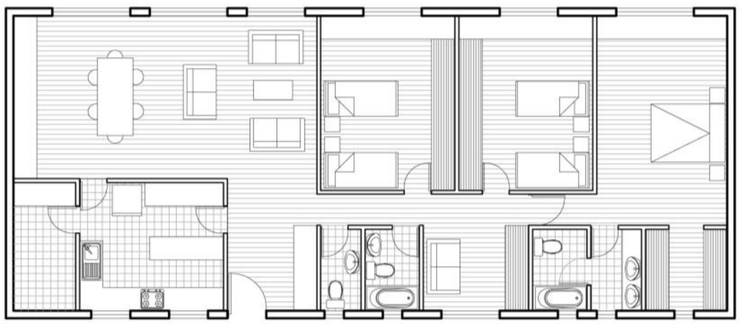
50 m² dwelling (2 floors)



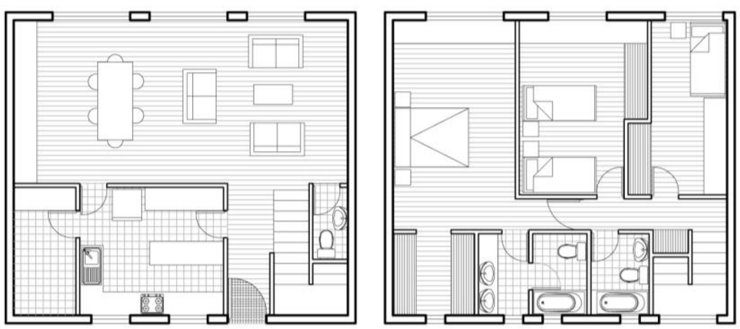
70m² dwelling (1 floor)



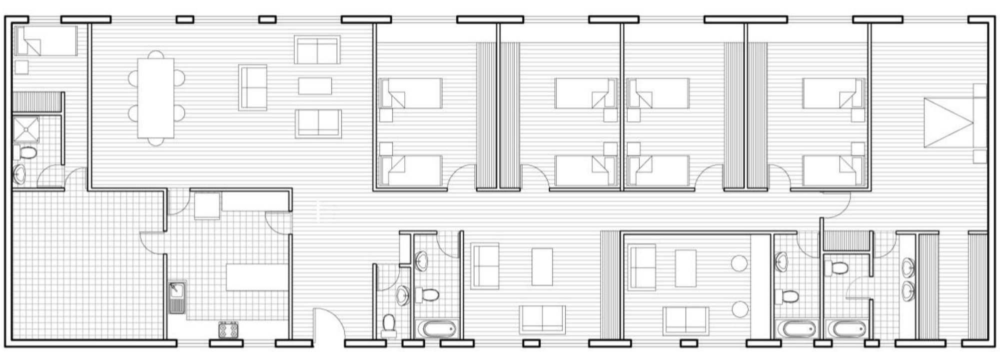
70m² dwelling (2 floor)



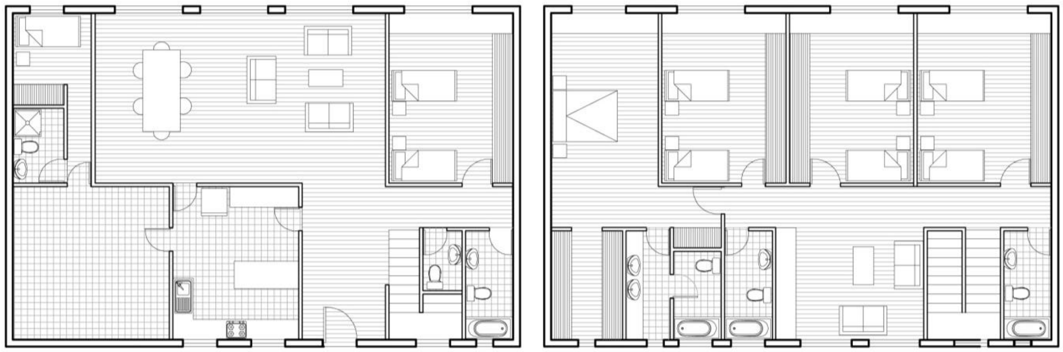
150m² dwelling (1 floor)



150 m² dwelling (2 floors)



300 m² dwelling (1 floor)



300 m² dwelling (2 floors)

Figure 3: Dwellings surface proposed plans. Made by the autor. Source: INE, 2002b (amount of rooms per dwelling).
Figura 3: Planos propuestos y superficie de viviendas. Realizados por el autor. Fuente: INE, 2012b (cantidad de habitaciones por vivienda

The weather data used is from Meteonorm 4.0, Santiago.

The air changes per hour were considered 1.9 ach[5] for the Base and Case and 1.0 ach[6] for the Regulation and Energy Efficient.

The construction material values used are explained below.

For the Base Case the dwellings are based on the typical construction materials used before the Thermal Regulation (2000). The houses are constructed of brick (C01) in all external walls and the windows are single glass (C13), with aluminium frame (C15). The ceiling consists of gypsum board with no insulation (C07) and the roof is made of corrugated fibre cement sheets (C10). The ground floor and floor is made of concrete with ceramic tile as finishing (C06).

For the Regulation Case the dwellings are based on the typical construction materials used with the actual Thermal Regulation. The houses are constructed in all external walls of brick, moisture barrier, polystyrene and render (C02). The windows are single glass (C13) with aluminium frame (C15). The ceiling consists of gypsum board with glass wool (C08) and the roof is made of corrugated fibre cement sheets (C10).

The ground floor and first floor are made of concrete with ceramic tile as finishing (C06).

For the Energy Efficient Case the dwellings are based on a selection of fabrics according to an evaluation made in terms of cost benefit of each material. The houses are constructed in all external brick walls, moisture barrier, polystyrene and render (C03). The windows are double glass (C14) with wooden frame (C16) and wooden external shadings. The ceiling consists of gypsum board with glass wool (C09) and the roof is made of corrugated fibre cement sheets (C10). The ground floor and first floor is made of concrete with ceramic tile as finishing (C06).

The results are in terms of kWh/year and kWh/m^{2}year to analyse the energy consumption and energy reduction according to each improvement. The analysis per heating and cooling was done separately. The liquid gas; as the most common system for heating in Región Metropolitana, was calculated with 75.9 $/kWh [7].

On the other hand, the cooling is calculated with an electric supply of 121.5 $/kWh [8].

Finally, an economic analysis is set according to the payback period of each improvement per typology and case. The payback period was calculated with a discount rate of 3.5% according to the HM Treasury.

[5] According to a study made in the physical laboratory of University of Bio Bio Chile for brick houses (Bustamante et al., 2011).

7 Bases on a study made in the University of Concepcion based on the proposal for the 2nd stage of Thermal Regulation (Bustamante et al., 2011).

[7] Chilean pesos, price based on the market price at March 2012 (CNE, 2012b)

[8] Chilean pesos, price based on the market price at March 2012 (CNE, 2012b)

"The recommended discount rate is 3.5%. Calculating the present value of the differences between the streams of costs and benefits provides the net present value NPV) of an option. The NPV is the primary criterion for deciding whether government action can be justified" (Treasury, 2003).

In addition, each improvement was calculated with a reinvestment according to the lifespan of each material. The construction budget was done according to the Chilean prices and workers' social laws for May 2012.

2.4 Results and analysis

Each case was analysed separately and represented in three general graphs: absolute energy consumption (in terms of kWh/year) (Fig.4), relative energy consumption (in terms of kWh/m2year) (Fig.5), and the improvements' payback period (in years) (Fig.6) which explains the total modelling results.

2.5 Macroeconomics

2.5.1 Total investment

The total investment for the Regulation Refurbishment for all the houses located in Región Metropolitana and constructed before 2002 is 7 billion pesos, and for the Energy Efficient Refurbishment is 8.45 billion pesos.

The figure 7 shows the total investment for the Energy Efficient Case for Región Metropolitana, for the three different income economic groups.

2.5.2 Total energy consumption

The total amount of annually energy consumption for the sample, considering the different percentages of dwellings per size is 15,200 Gigawatts for the Base Case, 9,400 Gigawatts for the Regulation Case and 5,300 Gigawatts for the Energy Efficient Case.

For the Regulation Case total sample, the proportion of cooling consumption from the total is higher than for the Base Case and for the Energy Efficient.

The total absolute energy consumption for the sample by income economic groups shows that the high income houses consume more energy than the medium and low income altogether (Fig.8) (Fig.9).

2.5.3 Total energy reduction

The energy consumption for the whole sample is reduced by 38% for the Regulation Case and by 65% for the Energy Efficient Case. The average in reduction for the Regulation Case is 48% in heating and 0% in cooling, with a standard deviation of 3% and 14 % respectively. According to the Energy Efficient Case, the average reduction for heating is 62% and for cooling 67% with a standard deviation of 2% and 3% respectively (Fig.10).

2.5.4 Total reduction in fuel import and production

The total amounts of energy savings for the Refurbishment can be calculated by money reduction from the import of liquid gas or production of electricity. The total amount of money investment saved annually in gas imported, for this sample, is $127.021 (Table 5) million pesos and $80.072 (Table 6) million pesos for electricity production. The 60% of the total amount of reduction in fuel imports is from the high income economic groups[9] (Fig.11).

2.6 Recommendations: Public policy a possibility

With the information from this study, a progressive government, banks and homeowners mixed investment programme in the Región Metropolitana, is proposed.

The implementation of the Energy Efficient Refurbishment programme instead of the Regulation Refurbishment programme was decided, due to its better results in efficiency in terms of energy reduction, capital costs and payback period. The existing thermal subsidy gives a maximum of 100 UF ($2.255.900) [10] for the zone that is closer to the Región Metropolitana and the lowest investment for a low income house, to get the Energy Efficient Refurbishment standard is $4.020.640.

The programme is designed to be implemented in 26 years with 3 different steps, and divided in 3 different types of subsidies according to the income groups.

[9] Common OLADE conversion factors for energy units

[10] 1 UF = $22.559 chilean pesos (30/08/2012)

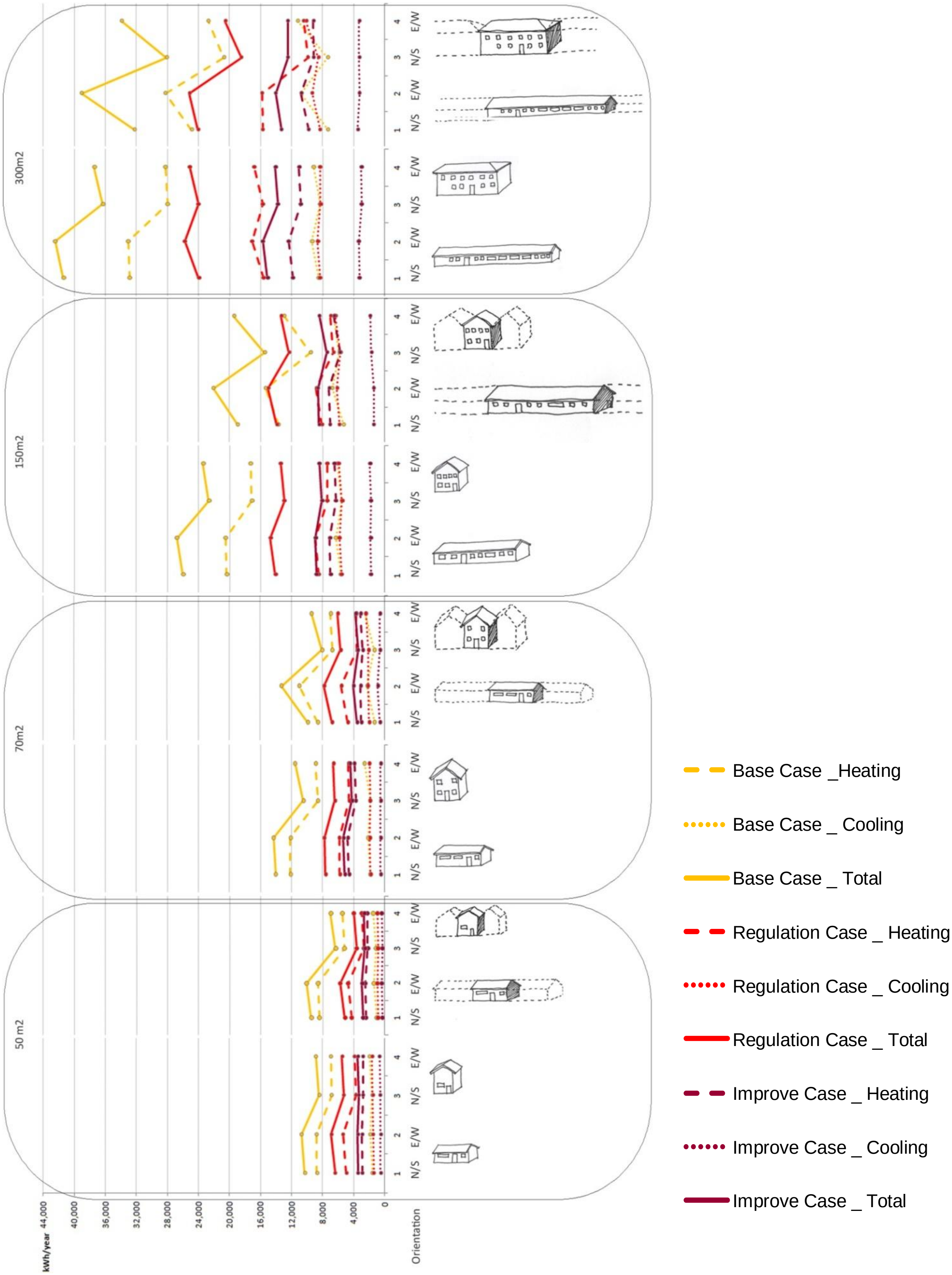


Figure 4: Absolute Energy consumption per dwelling typology (kWh/year). Source: Own Elaboration.
Figura 4: Consumo absoluto de energía por tipología de vivienda (kWh/año). Fuente: Elaboración Propia.

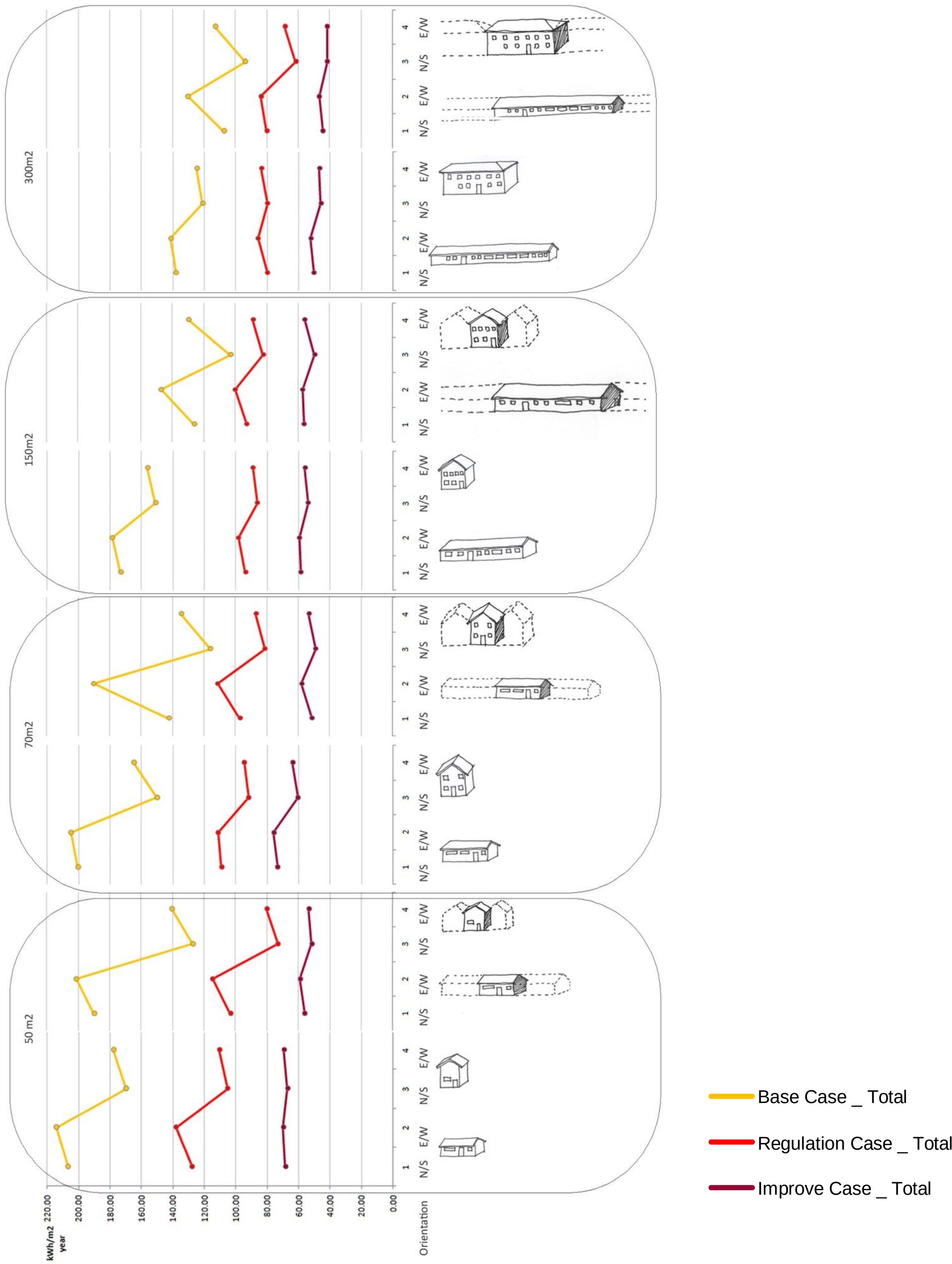


Figure 5: A Relative Energy consumption per dwelling typology (kWh/m²year). Source: Own Elaboration.
Figura 5: Consumo relativo de energía por tipología de vivienda (kWh/m²año). Fuente: Elaboración Propia.

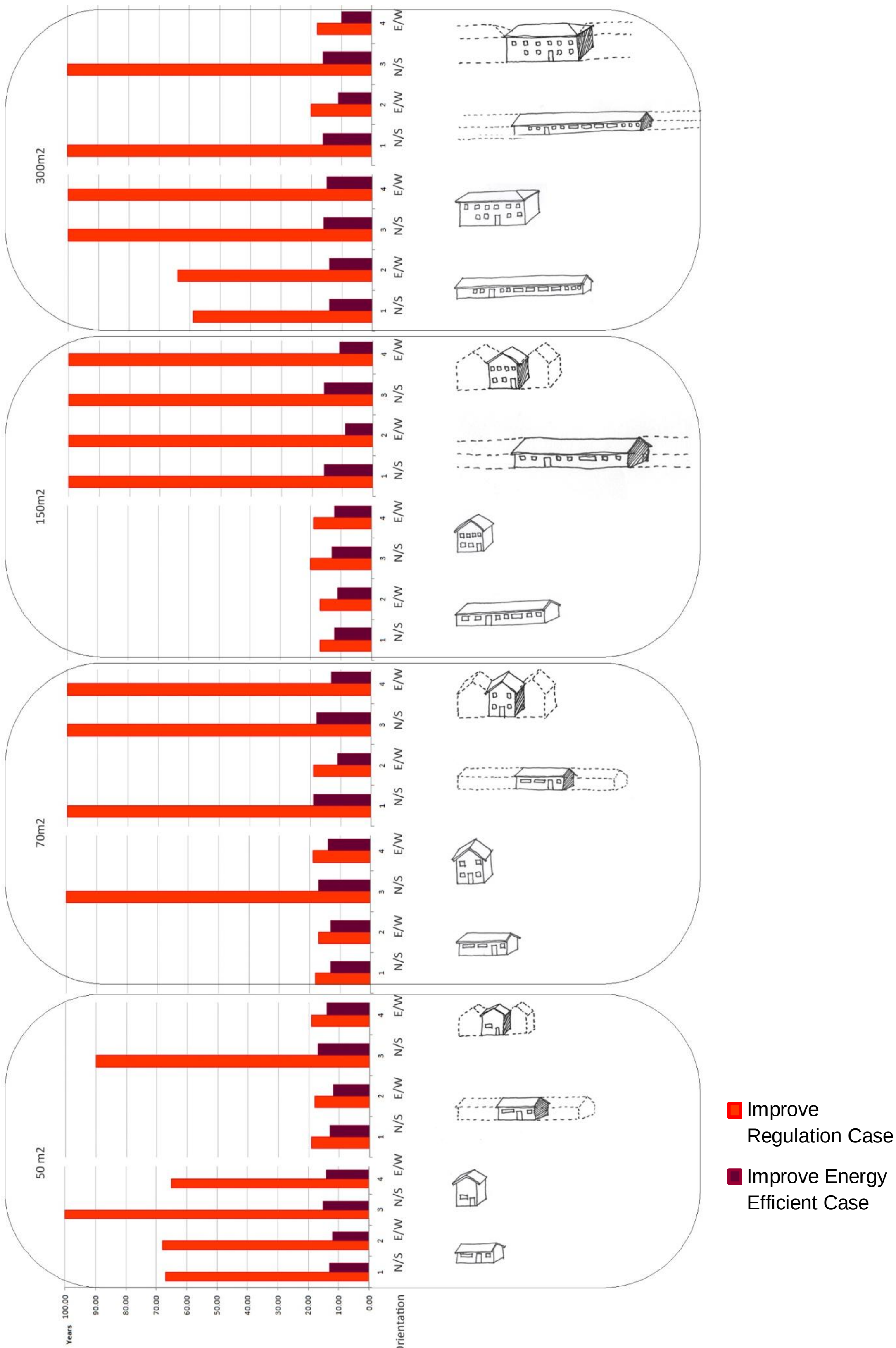


Figure 6: A Payback period per dwelling typology (years). Source: Own Elaboration.
Figura 6: Periodo de retorno por tipología de vivienda) (años). Fuente: Elaboración Propia

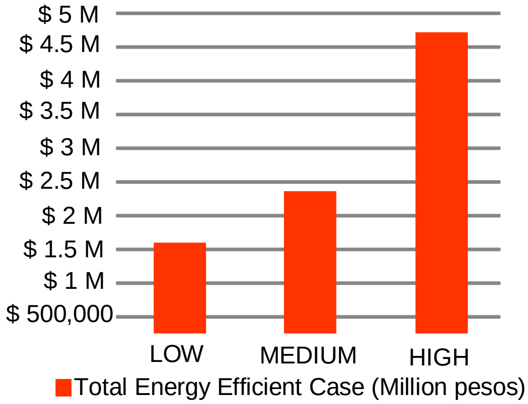


Figure 7: Total investment Energy Efficient Refurbishment. Source: Own Elaboration.
Figura 7: Inversión total en Renovación Eficiente Energéticamente. Fuente: Elaboración Propia

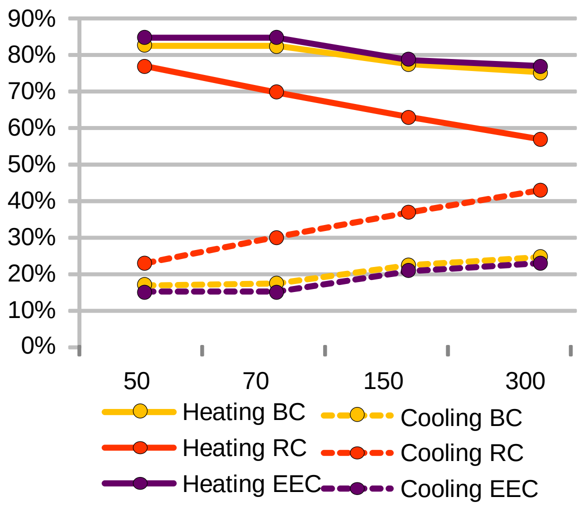


Figure 8: Total sample heating and cooling consumption per size of dwelling. Source: Own Elaboration
Figura 8: Consumo total de la muestra de calefacción y refrigeración por tamaño de vivienda. Fuente: Elaboración Propia

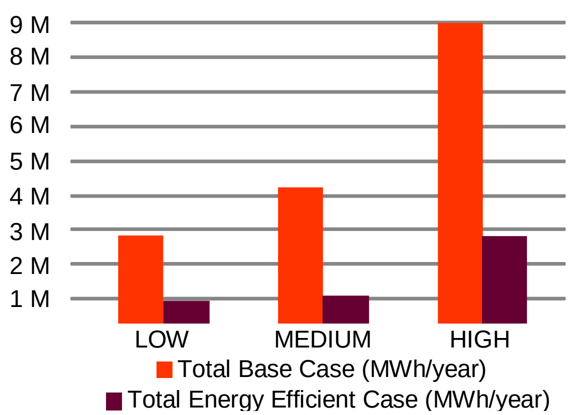


Figure 9: Total sample absolute energy consumption by income economic groups. Source: Own Elaboration
Figura 9: Consumo total de calefacción y refrigeración de la muestra por tamaño de vivienda. Fuente: Elaboración Propia

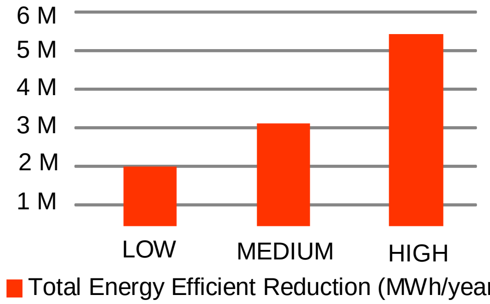


Figure 10: Total absolute energy reduction for the sample by income economic groups. Source: Own Elaboration
Figura 10: Reducción absoluta total de la muestra de consumo de energía por grupos de ingresos económicos. Fuente: Elaboración Propia

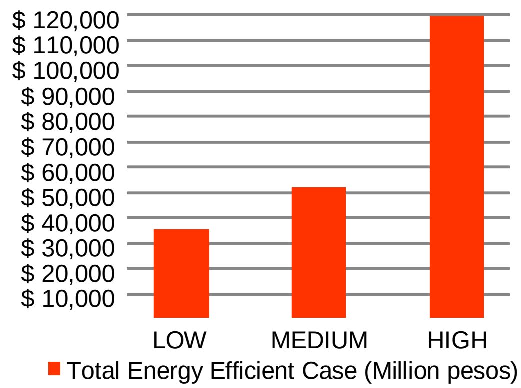


Figure 11: Total yearly reduction of the sample in fuel imports and productions per income economic groups. Source: Own Elaboration
Figura 11: Reducción total de la muestra en importación y producción de energía por grupos de ingresos económicos. Fuente: Elaboración Propia

2.6.1 Step 1 (year 1):

To make a national information programme, it is necessary to make people aware of the various measures that can be taken. From smal things like changing light bulbs, to bigger energy efficient ones like the use of different heating systems and refurbishment opportunities.

In addition, the temperature, humidity, energy consumption and indoor air quality should be monitored in selected different houses in Región Metropolitana during one complete year to analyse the internal conditions and the fuel expenditure.

2.6.2 Step 2 (years 2 and 3):

To make a trial run of the Energy Refurbishment programme in the same selected

Table 5: Annual savings in production of Electricity. Source: Own Elaboration
Tabla 5: Ahorro anual por producción de Electricidad. Fuente: Elaboración Propia

ELECTRICITY		
Annual Consumption before the Refurbishment (MWh)	**Annual Consumption after the Refurbishment (MWh)**	**Saving (MWh)**
3,429,723	1,611,970	1,817,753
Convertion factor: MWh in KWh 1 MWh = 1000 KWh		
Annual Consumption before the Refurbishment (KWh)	**Annual Consumption after the Refurbishment (KWh)**	**Saving (KWh)**
3,429,723,000	1,611,969,810	1,817,753,190
Cost ($/(KWh)*	$44.05	
Annual Consumption before the Refurbishment (million pesos)	**Annual Consumption after the Refurbishment (million pesos)**	**Saving (million pesos)**
$ 362,918	$ 235,897	$ 127,021

** International parity price defined by INE (National Institute of Stathistics)*
** Average 2011 price*

Table 6: Annual savings in import of Liquid Gas. Source: Own Elaboration
Tabla 6: Ahorro anual por importación de Gas Líquido. Fuente: Elaboración Propia

LIQUID GAS		
Annual Consumption before the Refurbishment (MWh)	**Annual Consumption after the Refurbishment (MWh)**	**Saving (MWh)**
11,743,873	7,633,517	4,110,356
Convertion factor: MWh in m^3 liquid gas 1 MWh = 81.2077 kgGLP 1 m^3 = 552.4 kgGLP So: 1 MWh= 0.15 m^3		
Annual Consumption before the Refurbishment (m^3)	**Annual Consumption after the Refurbishment (m^3)**	**Saving (m^3)**
1,726,454	1,122,195	604,259
Cost ($/($m^3$)*	$210,210.22	
Annual Consumption before the Refurbishment (million pesos)	**Annual Consumption after the Refurbishment (million pesos)**	**Saving (million pesos)**
$ 151,079	$71,007	$80,072

** Average 2011 price*

Table 7: Investment and savings costs per year for the Energy Efficient Programme in billion pesos. Source: Own Elaboration
Tabla 7: Inversión inicial y ahorro por año del Programa de Eficiencia Energética en billones de pesos. Fuente: Elaboración Propia

Social economic group	**Total Investment**	**Total government investment**		**Government energy reduction savings**
	/year	/year		/year
	million pesos			
Low Income	$62,487	98%	$61,237	$0
Medium Income	$97,597	70%	$68,318	$51,641
High Income	$207,208	25%	$51,802	$119,231
Total	$367,292		$181,357	$170,872

**The Government Energy Saving for the Low Income group according to the calculation should be 34,934 million pesos. For this purpose, due to the fuel poverty it was considered 0.*

houses, to analyse the timeframe and prices for the improvements. Also, monitor the houses continuously for a year and measuring the difference in the internal conditions and the savings in energy consumption.

2.6.3 Steps 3 (year 4 to year 26):

To launch an Energy Efficient Refurbishment programme for every house constructed in the Región Metropolitana before 2000. The policy would be divided in three different types, according to the house values, established by the existing MINVU´s subsidies. It should be implemented during 23 years to achieve the totality of the target group.

The table 8 shows the investments per income economic group divided into the different entities involved. The government investment for the average house is similar for the three groups; however the difference to achieve the total investment is made by the homeowners' savings or by bank loans.

The table 9 shows the total investment of the programme. The largest government investment is for the medium income group and the second one is for the low-income group.

- Low income programme:

Public plus homeowners investment for an Energy Efficiency Refurbishment to maximize thermal comfort, reduce fuel poverty, reduce national health expenses and increase property values.

Table 8: Average Investment per house in pesos for the Energy Efficient Programme . Source: Own Elaboration
Tabla 8: Promedio de inversión inicial en pesos por vivienda del Programa de Eficiencia Energética. Fuente: Elaboración Propia

Average investments per house							
Social economic goup	Government Subsidy		Homeowners Investment		Bank Loan		Total
	pesos						
Low Income	98%	$ 4,940,468	2%	$ 100,826	0%	$ 0	$ 5,041,294
Medium Income	70%	$ 4,559,228	3%	$ 195,395	27%	$ 1,758,559	$ 6,513,183
High Income	25%	$ 4,699,129	0%	$ 0	75%	$ 14,097,386	$18,796,514

Table 9: Total Investment for the Energy Efficient Programme in billion pesos. Source: Own Elaboration
Tabla 9: Inversión total del Programa de Eficiencia Energética en billones de pesos. Fuente: Elaboración Propia

Total investments per programme							
Social economic goup	Government Subsidy		Homeowners Investment		Bank Loan		Total
	Million pesos						
Low Income	98%	₤ 1,408,458	2%	₤ 28,744	0%	₤ 0	₤ 1,437,202
Medium Income	70%	₤ 1,571,315	3%	₤ 67,342	27%	₤ 606,079	₤ 2,244,736
High Income	25%	₤ 1,191,445	0%	₤ 0	75%	₤ 3,574,336	₤ 4,765,781

The government investment would be $61.200 million pesos a year for 23 years. No savings are calculated in energy supply or production due to fuel poverty.

The government investment would be 98% of the total investment and the owners should contribute the other 2%, which is between $100.000 and $200.000 per house. This would make them part of the policy and also responsible for the investment.

The subsidy should be between $4.000.000 and $5.700.000 per house to ensure that the Energy Efficient Refurbishment is made complete and work as a whole airtight improvement.

- Medium income programme:

Public plus private plus homeowner's investment policy, for an Energy Efficient Refurbishment programme for medium income houses; to maximise the thermal comfort, reduction in energy bills, decrease in energy dependence and increase property values.

The medium income economic group has a lack of public policies in Chile; generally the subsidies are aimed at low-income families. However, the medium-income families do not have sufficient income to pay for all the necessities as high-income families do.

The refurbishment average cost per house should be $6.500.000, 70% of it will be subsidised by the government, 3% will be the owner's savings and 27% a bank loan with low charges. If the bank loan is for 3.5 years, the monthly bank fee would be the average in energy saving after the refurbishment; $51.640.

The subsidy will have a total of $68.300million pesos investment a year for 23 years and the production and import saving would be $51.600 million pesos a year.

- High income programme:

Is focused on making a national programme to provide an incentive to private investment in high-income families, to reduce the energy consumption and also decrease the government costs in fuel production and imports.

The subsidy would be 25% of the total refurbishment cost to encourage private investment. The rest of the investment could be made directly by homeowners' savings or by a bank loan with low charges.

If the total cost for the homeowner's investment is made by a bank loan for 10 years, the monthly bank fee would be $136.700 pesos; the average in energy saving after refurbishment.

The total government investment would be $51.800 million pesos a year for 23 years and the total saving in energy supply or production would be $119.200 million pesos a year with a difference of $67.400 million pesos a year saving for the government.

Because the largest amount of energy consumption and energy savings, after refurbishment are in high-income households, this also provides the biggest savings in energy supply for the government. If a public policy is adopted to encourage high-income homeowners' investment, the national saving in energy supply could pay 66% of the total investment of the programme. When adding the medium-income energy supply savings, the total government savings for the production and import of energy could pay 94% of the total investment proposed.

The total investment of the government for the programme would be $4.170.000 million pesos and the total saving in 23 years in energy production and import would be $3.930.000 million pesos. The savings continue after completion of the programme implementation.

It is also necessary to consider that the calculation is made in a conservative way. The budget prices are based on the actual market prices. If a public refurbishment policy is adopted, buying all the materials in a bulk purchase could significantly reduce prices and the total investment for the government and for the private sector would decrease.

Besides, there are other economic factors associated with the programme that should be taken into consideration; such as savings in the public health system and the economic house values increase.

In addition to the refurbishment programme, ventilation regulation and the use of internal combustion heaters should be regulated to maintain the indoor air quality due to the health problems they generate.

Conclusion

The study has analysed a model of 32 dwelling typologies in the Región Metropolitana in terms of energy absolute energy consumption, relative energy reduction and payback period analysis.

The information of the study can be used as a basis for a Chilean public policy with a proposal to enlarge the study for the entire country. It can also be used as a database for further studies and for standards in the Región Metropolitana energy consumption by house typologies.

The study shows how poorly thermally constructions helps to increase the poverty circle with a large percentage of the family budget expenditure being spent on heating in low-income families.

Currently there are government actions being developed to improve the energy efficient construction with regulations and subsidies for new houses and buildings. There is also a necessity to take care of the existing dwellings to make sure that the energy efficient actions cover the whole population.

The Energy Efficient Refurbishment should be accompanied by an upgrade of the existing Thermal Regulation for new houses, in order to increase the thermal regulation standard to a more energy efficient one, such as the one presented as Energy Efficient Standard for Región Metropolitana.

The study proposed an Energy Efficient Refurbishment programme to increase the thermal conditions of the dwellings in the Región Metropolitana. This would contribute to having energy security, a decrease in health problems during the winter, an increase in thermal comfort and a reduction in energy consumption. Also a national programme could reduce the fuel poverty generated by heating expenses.

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