ARE CONSUMERS WILLING TO PAY MORE FOR RESIDENTIAL ENERGY EFFICIENCY IN EMERGENT MARKETS?

Felipe Encinas
Escuela de Arquitectura; Facultad de Arquitectura, Diseño y Estudios Urbanos; Pontificia Universidad Católica de Chile
El Comendador 1916, Providencia 7520245, Santiago, Chile
felipe.encinas@uc.cl
+56 2 2354 7721

Carlos Marmolejo
Polytechnic University of Catalonia; ETSAB Centre for Land Policy and Valuations
Av. Diagonal, 649, 4, Arq. Legal, Barcelona 08028, Spain
carlos.marmolejo@upc.edu
+34 9 3401 6396

Francisco Sánchez
Departamento Máquinas y Motores Térmicos; Escuela Superior de Ingeniería; Universidad de Cádiz
Avenida de la Universidad de Cádiz, Puerto Real, Cádiz 11519, Spain
+34 9 3401 6396

Carlos Aguirre
Escuela de Construcción, Universidad de las Américas
Manuel Montt 948, Providencia 7500975, Santiago, Chile
caguirre@udla.cl
+56 2 2427 5171

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Abstract

In most of the countries, energy efficiency has been delegated to the dynamics of real estate markets, after regulating a minimum legal (although not optimal) efficiency level. So, it is expected that high efficient housing stock receives a market premium that, at least, equals the over-cost invested in improved thermal insulation and more efficient appliances. Theoretically, under such a mechanism developers are fostered to promote sustainable housing schemes. Nonetheless, the question of whether residential users do pay more for more sustainable housing remains to be explored in emergent markets where green labelling is still not legally implemented. This paper explores the impact of energetic efficiency of housing on demand's willingness to pay in Santiago de Chile. In doing so a contingent valuation approach is used in order to extract the structure of preferences for different levels of energetic efficiency for the residential market of houses. Results reveal that a significant proportion of respondents are willing to pay (WTP) a quantity that surpasses the cost of green investment. The results of a regression model aimed to explain the factors that lay behind WTP suggest that it is positively

influenced by: income level (indirectly measured by the price range of the requested house), educational level and demographics, being households with small children who pay the most. These results have important implications on the design of public policies aimed to improve the energetic efficiency of new housing developments.

Introduction

In most of the countries, energy efficiency has been delegated to the dynamics of real estate markets, after regulating a minimum legal efficiency level. So, it is expected that high efficient housing stock receives a market premium that, at least, equals the over-cost invested in improved thermal insulation and more efficient appliances. In that sense, the relationship between the sales price and the access to the real estate financing determines the maximum to pay for the dwelling, generating a supply curve where the cross elasticity of demand for the different attributes (e.g. improvements of the thermal envelope) is clear, generating a trade-off between them.

This research is focused on the residential real estate market of Santiago de Chile since this constitutes a niche that, despite that it is associated to a very significant segment of the middle-incomes population (in the last years, the private housing supply have been always in a range between 30,000 and 40,000 units) (Ministerio de Vivienda y Urbanismo 2016), has practically not been studied in terms of their energy efficient attributes. A first approach showed - based on data from the *Portalinmobiliario.com*[1] - that the positioning of the attribute of double glazing in windows has increased from 5% in 2007 to 29% in 2014, with respect to the total supply of apartments. On the other hand, the increase in thickness of the thermal insulation in walls has changed from 4% in 2010 to 10% in 2014, for the case of houses (Encinas 2015). In that sense, these attributes are frequently presented as isolated elements without considering the thermal performance of the dwelling as a whole system, in the sense proposed by Directive 2010/31/EU (Official Journal of the European Union 2010) and the Energy Performance Certificates (EPCs).

Then, the question of whether residential users do pay more for more sustainable housing remains to be explored in emergent markets such this, where also green labelling – such as EPCs –is still not implemented as compulsory. This paper explores the impact of energetic efficiency of housing on demand’s willingness to pay in Santiago de Chile. In doing so a contingent valuation approach is used in order to extract the structure of preferences for different levels of energetic efficiency for the residential market of houses.

Methodology

Definition of building typologies by means of cluster analysis

In the field of the real estate analysis, submarkets are usually defined according to price ranges with the aim of establishing supply niches. However, this kind of approach – exclusively defined as a function of supply prices – forgets that real estate markets can compensate the lack of some specific attributes with other attributes or amenities. Therefore, a multidimensional approach is required allowing for the integration of a series of indicators and attributes with the

[1] *Portalinmobiliario.com* is the most important search engine for property, apartments and houses for sale and rental in Chile.

aim of being developed at the level of their value chain. This paper proposes a methodology based on clustering methods, which was implemented based on the *Portalinmobiliario.com* database. According to this procedure, 8 house typologies were defined by means of a hierarchical cluster analysis using the Ward's method, and considering the factor scores of a previously conducted Principal Component Analysis (PCA) as input variables for the clustering process. PCA was applied considering both supply price and area [m^2], and also 4 energy efficient attributes: double glazing in windows, the increase in thickness of the thermal insulation in walls, thermal solar collectors and water-efficient appliances. For the aims of this paper, 3 house typologies that represent the whole range of prices of the real estate market (Figures 1 to 3).

Figure 1. Floor plans and isometric view for typology 1 (Houses with price range lower than 98,000 €)

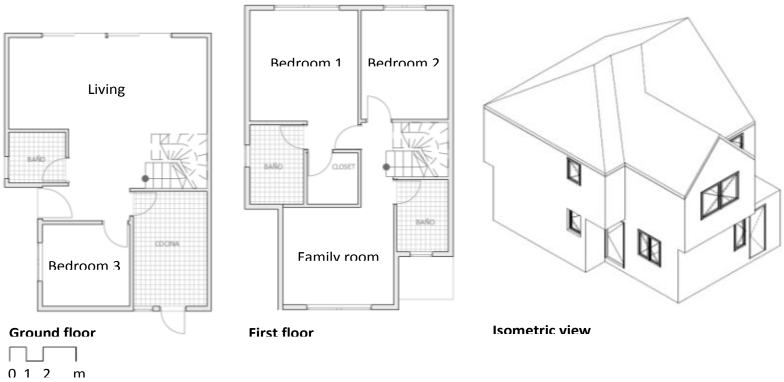


Figure 2. Floor plans and isometric view for typology 2 (Houses with price range between 131,000 and 164,000 €)

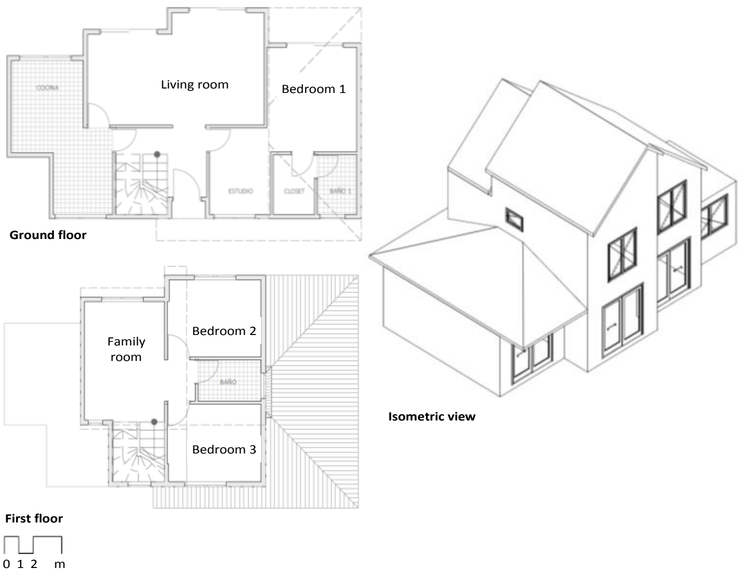
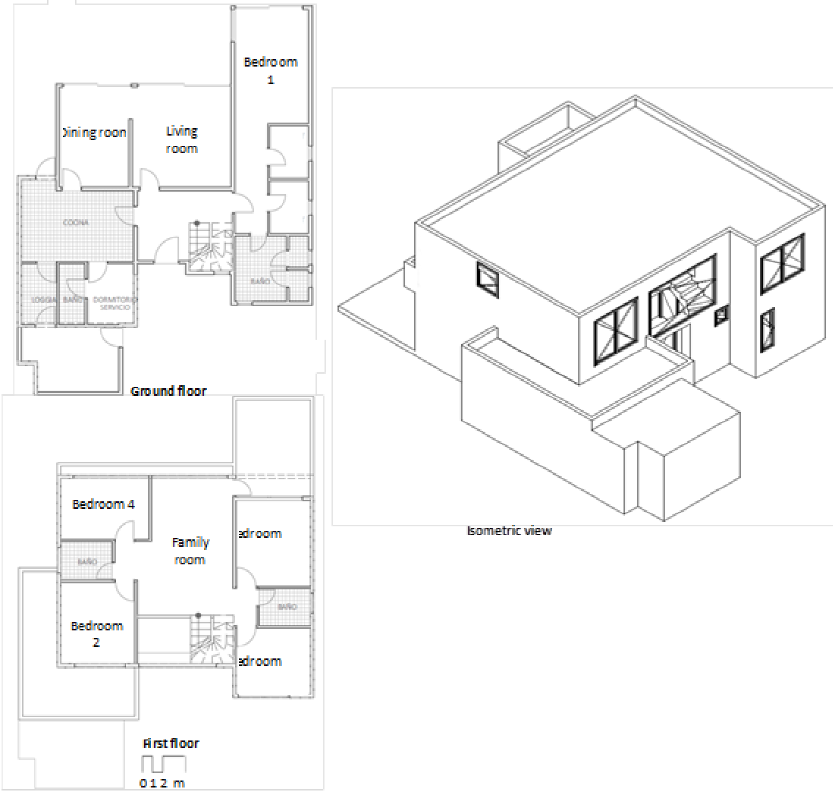


Figure 3. Floor plans and isometric view for typology 3
(Houses with price range greater than 262,000 €)



Life-cycle cost analysis as tool for reaching the optimum building envelope

Life-cycle Cost (LCC) analysis is a framework that was originally developed to provide designers with cost information to guide them by specifying the estimated total incremental cost of developing, producing, using, and retiring a particular item (Asiedu and Gu 1998), and has been more recently when an application to the whole building design has been proposed. Thus, a technique used to estimate the total cost of ownership has been developed under the name of Life-cycle Costing, with an interesting contribution to sustainable construction, since it proposes a long term vision in opposition to the traditional perspective that aims the immediate profitability along with a minimum investment, and ignoring their future economic and environmental impacts (García-Erviti, Armengot-Paradinas, and Ramírez-Pacheco 2015). This technique allows comparative cost assessments to be made over a specific period of time, taking into account relevant economic factors both in terms of initial capital costs and future operational and asset replacement cost.

LCC analysis has recently received a new impulse by the European Union thanks to the directive on the energy performance of buildings, Directive 2010/31/EU (Official Journal of the European Union 2010). According to this regulation, the requirements for energy performance and building elements should be set with the aim of achieving the cost-optimal balance between the investments involved and the energy costs saved throughout the lifecycle of the building, without prejudice to the right of Member States to set minimum requirements which are more energy efficient than cost-optimal energy efficiency levels.

This directive was complemented by a Commission Delegated supplement to establish a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements. Among other concepts, the most important one that is defined in this document is the LCC, which represents the sum of the present value of the initial investment costs, sum of running costs, and replacement costs (referred to the starting year), as well as disposal costs if applicable (UNE-EN15459 2008; Official Journal of the European Union 2012):

$$LCC_\tau = C_i + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \cdot R_d(i) \right) - V_{f,\tau}(j) \right]$$

where:

τ	means the calculation period
LCC_τ	means life cycle cost (referred to starting year τ_0) over the calculation period
Ci	means initial investment costs for measure or set of measures j
$C_{a,I}(j)$	means annual cost during year I for measure or set of measures j
$V_{f,\tau}(j)$	means residual value of measure or set of measures j at the end of the calculation period (discounted to the starting year τ_0)
$R_d(i)$	means discount rate for year I based on discount rate τ to be calculated

Such analysis requires a whole and complex methodology that includes a building simulation software tool and most cases an optimization method. This paper presents a new methodology based on the combination of a simplified and a detailed building performance software tool, as well as, an LCC analysis method that allows reaching the exact solution in a very low CPU time. ISO 13790 was chosen as the calculation algorithm for the implementation of routines for building energy simulation. This standard gives a quasi-steady simplified calculation method for the assessment of the annual energy use for space heating of a residential or a non-residential building (ISO 13790 2008). This model was adjusted from the results of a dynamic-state building performance tool, carried out by means of TAS software (Environmental Design Solutions Limited 2016). The obtained root mean squared error (RMSE) for the model resolution was 0.13%, 2.09% and 1.16% for typologies 1, 2 and 3, respectively.

Finally, a sensitivity analysis was applied for all the proposed typologies based on this calculation procedure. The uncertainty was propagated on the model from 4 input parameters related to the thermal envelope (U-value of walls, windows and roofs, along with orientation) which were uniformly distributed through a Monte Carlo model. Indeed, a sample matrix of 10,000 samples by typology was defined from the combination of these input parameters and their corresponding distributions, obtaining the annual heating demand per unit area [kWh/m^2/y].

Willingness to pay for residential energy efficiency by means of a contingent valuation method

From a constructive point of view, the housing stock is massively built by masonry and reinforced concrete construction, with 38.6% and 22.5% with respect to the total number of dwellings from the private market in the Santiago Metropolitan Area, according to the statistics from the National Statistics Institute (INE, 2015). However, these building systems traditionally had not incorporated thermal insulation in their building wall envelopes, which should be understood in the context of the current national Thermal Regulation, which defines the requirement of 1.9 W/m²K as a maximum U-value for external walls for this thermal zone. This standard can be reached by means of an increase in the height of the bricks and/or incorporating improved cement mortars (in terms of lower thermal conductivity). Since masonry corresponds to the most common building system applied in houses, in practice, after the introduction of the Thermal Regulation, they are still built without thermal insulation. This situation was also noted for the OECD, which recommended the incorporation of “effective thermal and energy standards” for the Chilean housing market, with the aim of improving the building quality, protect public health and reduce air pollution (Caldera 2012).

In order to assess the willingness to pay (WTP) for a more energy efficient house (in terms of improvements in the thermal envelope of the house typologies), participants of a survey were asked to directly state such a quantity using the contingent valuation framework.

Such a technique builds on the idea that changes in individual’s utility can be expressed in terms of compensatory variation, and thus it is possible to express it in monetary units. Namely, we have used and open ended format in order to extract the WTP for extra benefits coming for an upgraded energy efficiency. One on the main shortcomings of open end formats is the confusion that may produce on respondents the absence of any guide. For that reasons, participants were informed about the marginal costs and benefits in energy expenses for each of the possible energy saving elements (Figure 4).

Figure 4. Willingness to pay for improvements in the thermal envelope for typology 1 as it was asked in the questionnaire survey

Considering that the house you are looking to buy has the minimum building elements according to the national regulation (single glazing in windows and masonry walls without thermal insulation):

Are you willing to pay for incorporating energy efficiency improvements as an extra cost in your new house?

As reference, the following table present some values. For example, upgrading from single to double glazing and adding 80mm of thermal insulation in walls has an additional cost of 1900 €, but, it represents savings on annual heating cost of 270 €.

Type of window	Thermal insulation in walls	Additional cost	Savings on annual heating costs
Double glazing	Without thermal insulation	500 €	80 €
Double glazing	20 mm of thermal insulation	1300 €	190 €
Double glazing	80 mm of thermal insulation	1900 €	270 €
Low-e double glazing	110 mm of thermal insulation	2600 €	320 €
Low-e double glazing	200 mm of thermal insulation	3900 €	360 €

Invitations to participate in the survey – constituted by 11 questions and implemented thorough an online questionnaire – were sent between 21st and 25th August 2015 by e-mail to registered users from the Portalinmobiliario.com database that have been looking new houses to buy in the Santiago Metropolitan Area. The survey framework presents a sample size of 378 respondents, with 5.04% of margin of error and a confidence level of 95%. Due to the characteristic of the survey, these results were considered as appropriate.

Results

One of the main purposes of the LCC analysis is to obtain the case corresponding to the minimum LCC (that can be identified as the "optimum case"), but there are many other cases of interest, especially those in the proximity of the efficient frontier. For the purposes of this paper, LCC was expressed in terms of LCC savings (with respect to the base case), where the higher point in the cloud represents this "optimum". All cases in the also called Pareto front represent the best, i.e. cheapest, combinations for their correspondence final heating demand. Far from the proximity of this efficient frontier are cases that should be avoided, since the same heating demand can be obtained with lower LCC savings. Other points of interest in the efficient frontier are (Figures 5 and 6):

(1) The base case (which complies with the minimum requirements of the Thermal Regulation)
(2) The north-oriented base case (in comparison to the original south-oriented)
(3) An improvement in the type of window (from single to double glazing)
(4) The optimum case
(5) An improvement in the type of window (from double to low-E double glazing)
(6) The best case (from the point of view of heating demand)

Figure 5. Efficient frontier according to the type of window for typology 1

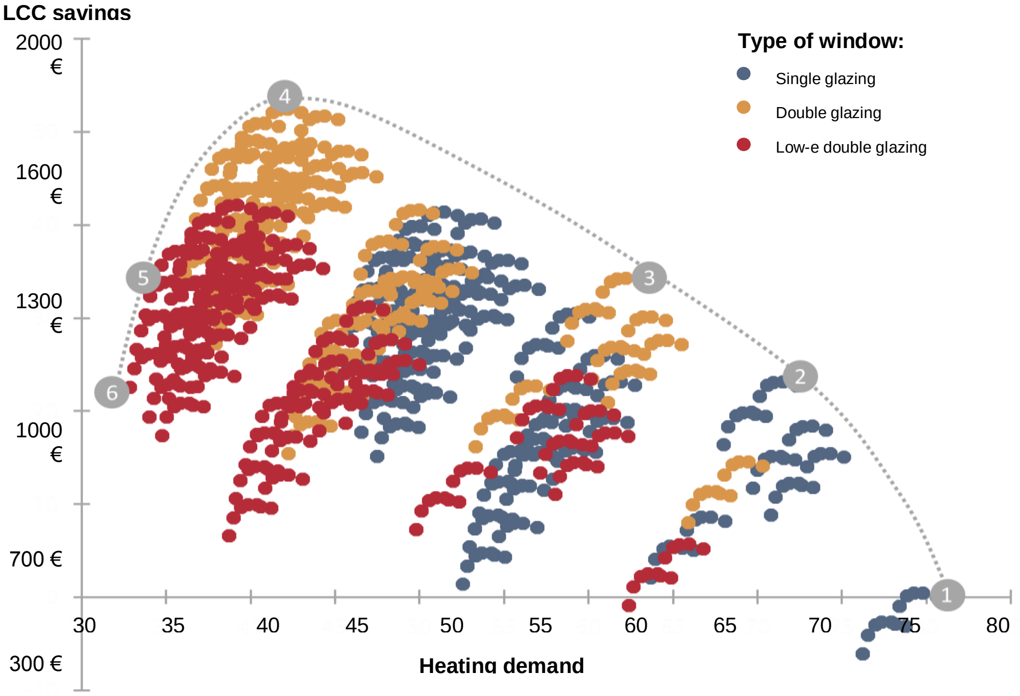
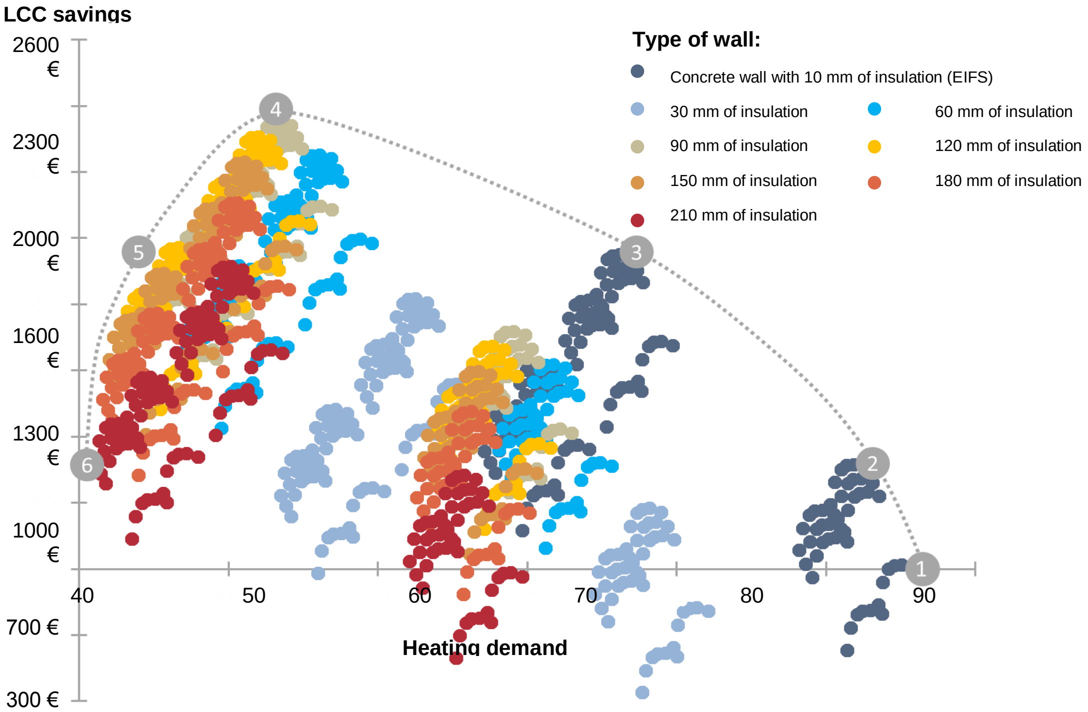


Figure 6. Efficient frontier according to the type of wall for typology 3



According to the results, the optimum case is reached by the incorporation of double glazing in windows and a range between of 80-90 mm of thermal insulation in walls for the 3 house typologies (expressed in the Figures 5 and 6 by the most extreme cases). The characterization of the 6 points of interest from the efficient frontier is also presented for typologies 1 and 3 (Tables 1 and 2, respectively). It is important to notice that the building systems considered in the case of walls for both typologies are different, since they represent also different building quality standards.

Table 1. Characterization of selected cases for the optimization model of typology 1

Cases*	Description	Orientation	Investment	Type of window	Type of wall**	Type of roof***
1	Base case	South	6300 €	Single glazing	Masonry wall without thermal insulation	80 mm of thermal insulation
2	North-oriented base case	North	6300 €	Single glazing	Masonry wall without thermal insulation	80 mm of thermal insulation
3	Upgrading from single to double glazing	North	6800 €	Double glazing	Masonry wall without thermal insulation	80 mm of thermal insulation
4	Optimum case	North	8100 €	Double glazing	Masonry wall with 80 mm of thermal insulation	100 mm of thermal insulation
5	Upgrading from double to low-e double glazing	North	9400 €	Low-e double glazing	Masonry wall with 110 mm of thermal insulation	170 mm of thermal insulation
6	Best case	North	10000 €	Low-e double glazing	Masonry wall with 200 mm of thermal insulation	200 mm of thermal insulation

(*) Corresponding to the points of the efficient frontier from Figure 4

(**) Considering EPS 15 kg/m3 on the inner side of the walls along with 10 mm plasterboard layer as interior finishing

(***) Considering mineral wool 40 kg/m3 along with 10 mm plasterboard layer as interior finishing

Table 2. Characterization of selected cases for the optimization model of typology 3

Cases*	Description	Orientation	Investment	Type of window	Type of wall**	Type of roof***
1	Base case	South	21100 €	Single glazing	Concrete wall with 10 mm of thermal insulation	80 mm of thermal insulation
2	North-oriented base case	North	21100 €	Single glazing	Concrete wall with 10 mm of thermal insulation	80 mm of thermal insulation
3	Upgrading from single to double glazing	North	22500 €	Double glazing	Concrete wall with 10 mm of thermal insulation	80 mm of thermal insulation
4	Optimum case	North	25700 €	Double glazing	Concrete wall with 90 mm of thermal insulation	100 mm of thermal insulation
5	Upgrading from double to low-e double glazing	North	27400 €	Double glazing	Concrete wall with 180 mm of thermal insulation	170 mm of thermal insulation

6	Best case	North	29500 €	Low-e double glazing	Concrete wall with 210 mm of thermal insulation	200 mm of thermal insulation

(*) Corresponding to the points of the efficient frontier from Figure 5

(**) Considering EPS 15 kg/m3 on the outer side of the walls based on EIFS construction

(***) Considering mineral wool 40 kg/m3 along with 10 mm plasterboard layer as interior finishing

Willingness to pay (WTP) for improvements in the thermal envelope of dwellings – as was obtained by the questionnaire survey – was established from the cumulative frequency histograms, dismissing the protest votes (for example, users that are not willing to pay because they think that already pay too much for their house) and establishing associations with the strategies obtained through the LCC analysis model (Figure 7). In this sense, as it can be observed, the maximum WTP varies from 3900 € to 8400 € with respect to the best case (point 6 in Tables 1 and 2) for typologies 1 and 3, respectively.

Finally, between the models that can explain the WTP, a lineal regression with a coefficient of determination (R^2) of 0.4 was selected, which is represented by the following equation:

$$WTP = 2{,}373{,}337\, X_1 + 1{,}563{,}196\, X_2 + 681{,}749\, X_3 + 627{,}160 X_4 + 379{,}598\, X_5 + 300{,}357\, X_6 + 938{,}163$$

where X_i are the independent variables that explain the model and correspond to:

X_1 means houses with price range greater than 262,000 €

X_2 means houses with price range between 164,000 and 262,000 €

X_3 means houses with price range between 131,000 and 164,000 €

X_4 means houses with price range between 98,000 and 131,000 €

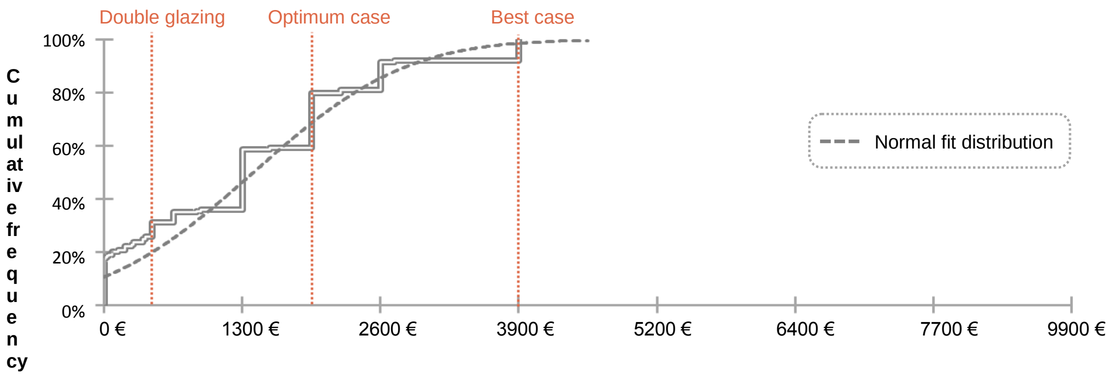
X_5 means users with postgraduate studies and that declare some kind of environmental action

X_6 means couples with children less than 5 years of age

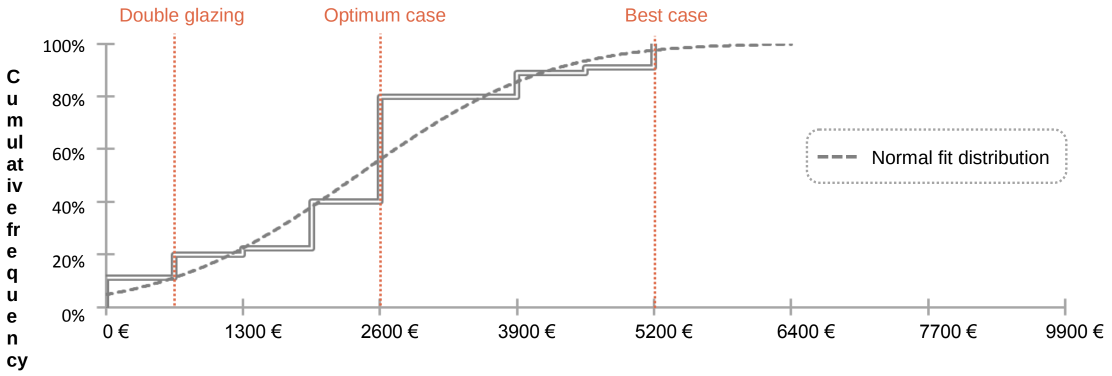
The results of a regression model aimed to explain the factors that lay behind WTP suggest that it is positively influenced by: income level (indirectly measured by the price range of the requested house), educational level and demographics, being households with small children who are willing to pay the most.

Figure 7. Willingness to pay for improvements in the thermal envelope of dwellings with respect to the LCC analysis model of the 3 house typologies

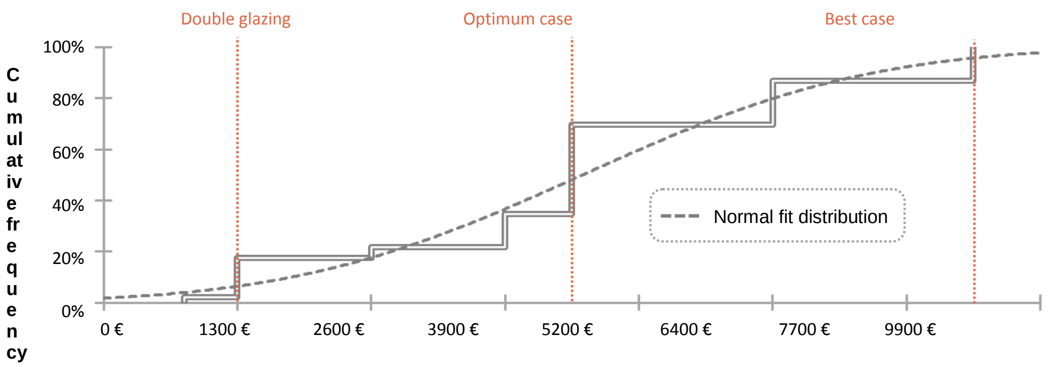
Typology 1 (houses with price range lower than 98,000 €)



Typology 2 (houses with price range between 131,000 and 164,000 €)



Typology 3 (houses with price range greater than 262,000 €)



Conclusions

According to the Energy Ministry of Chile, the residential sector represents 21% of the total energy consumption at the national level. Given this situation, it is clear that housing market represents a very relevant target for reducing its impact in terms of energy consumption, especially in the case of Santiago, which supply has been always in a range between 30,000 and 40,000 units in the last years. One of the methodologies for approaching energy efficiency is known as Life Cycle Cost (LCC) analysis, which has received a new international impulse by the European Union thanks to the directive on the energy performance of buildings. Such analysis requires a whole and complex methodology that includes a building simulation software tool and most cases an optimization method. This paper presents a new methodology based on the combination of a simplified and a detailed building performance software tool, as well as, LCC analysis method that allows reaching the exact solution in a very low CPU time. By means of this method, 3 building typologies - representative of the real estate market of houses in Santiago de Chile – were optimized in terms of their thermal envelope, which was represented by means of an efficient frontier with 6 points of interest. According to the results, the optimum case is reached by the incorporation of double glazing in windows and a range between of 80-90 mm of thermal insulation in walls for all building typologies. In order to assess the willingness to pay (WTP) with respect of the strategies obtained through the LCC analysis model, participants of a survey were asked to directly state such a quantity using the contingent valuation framework. Results reveal that a significant proportion of respondents are WTP a quantity that surpasses the cost of green investment. The results of a regression model aimed to explain the factors that lay behind WTP suggest that it is positively influenced by: income level (indirectly measured by the price range of the requested house), educational level and demographics, being households with small children who are willing to pay the most. These results have important implications on the design of public policies aimed to improve the energetic efficiency of new housing developments

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