

# Modelling and Methodology for Window Selection with Energy Efficiency Criteria in Chile

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**Abstract** - This article presents the development of a methodology associated with the selection of windows with energy efficiency criteria in Chile. It provides the optimal option in a housing project, according to specific search parameters by region, commune, orientation, materiality, among others options. At the same time, it is possible to download the technical characteristics of the selected window instantly.

According to results obtained on the simulation, S2 showed better energy efficiency performance in the three cities studied (Antofagasta, Santiago and Concepcion). Mainly the transmittance value was slightly smaller than S1 solutions. In general, windows with lower thermal transmission (U) achieve better energy efficiency in homes. However, the selection of optimal windows for a project should always be based on the geographical area, the orientation of the facade or wall, the surface of the light, or the visibility to be projected (dimensions), and the thermal transmittance values (U).

**Keywords** - Sustainability, Energy efficiency, Window, Thermal transmission, Transmittance values.

## I. INTRODUCTION

Currently, Chile has joined multiple sustainable agreement and due to this, Chile actively participate such as a member of the Organization for Economic Cooperation and Development (OECD), Asia Pacific Economic Cooperation (APEC) and the United Nations Framework Convention on Climate Change (UNFCCC). Consequently, a series of national strategies is laid down, for the short and medium-terms, which seeks to favour the transition to a more sustainable and efficient country. [1] [2] [3]

For the development of these, the European reality was studied, which had a successful work program and extensive experience. One of the initiatives that stood out in this area was Directive 2010 / 31 / EU of the European Parliament [4], which is the basis for the energy rating of homes. It also defines the objectives and standards of energy efficiency in buildings by

2020.

Then, the study and analysis of the different energy sectors of Chile began, to know the state of the country in this matter and determine what the gap that exists with high-standard countries is.

In this regard, each the residential and the mining sectors represent 15% of the total national energy consumption. This indicates the magnitude of the context, taking and into account the importance of mining in Chile. [5] [6]

On the other hand, the National Energy Strategy 2012-2030 stipulates an Energy Efficiency Action Plan 2012-2020 that aims to achieve a 12% reduction in projected energy demand in the year 2020 [7] [8]. Additionally, national law No. 20,257 was also enacted, which states that non-conventional renewable energy sources must generate 10% of the energy by 2024 [9].

Notably, the residential sector has sustainable construction standards [10] [11] [12], according to the Handbook of Housing Energy Qualification [13] and the General Law of Urbanism and Constructions of Chile [14]. As a result, there is a need to innovate in this area, creating a methodology that allows selecting windows with energy efficiency criteria.

## II. METHODOLOGY

### A. Study Areas

Three research areas are involved in the study development, namely Laws and Standards, Market Research and Technical Characteristics. The investigative process is detailed in Fig. 1.

#### 1. Laws and Norms

First, all information on national laws and regulations related to window selection was collected, as well as additional information, such as manuals and proposed standards — notably, the General Ordinance of Urban Planning and Construction [15].

On the other hand, the thermal zones of the cities of Chile, they were defined by maps proposed by MINVU [16]. Alternatively, the MINVU update on the communes that have the Air Decontamination Program was incorporated [17] [18]. Also, there is complementary information associated with sustainable construction standards [10] [11] [12] according to the Handbook of Housing Energy Qualification [13], and Climate Explorer [19].

After searching for the applicable legal and regulatory information, the parameters for the methodology were established and defined. Those parameters are necessary to generate an algorithm that allows simulations of different window configurations.

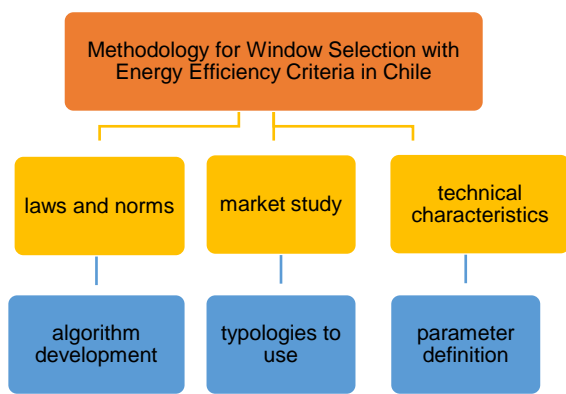


Fig. 1 Flowchart to obtain the methodology for the selection of windows with energy efficiency.

## 2. Market study

At this point, the market window that includes recurring characterization patterns in different types of windows available. However, the windows present technical information and tests. These are fully available to be selected by the methodology database to ensure effectiveness during implementation. These involve the articles consulted from MINVU [20] [21], as well as suppliers [22]. Moreover, it includes a sample of twenty-eight windows, with all the relevant information.

Subsequently, the windows are added to the methodology and three types are defined; bringing down, sliding and projecting. Each of them has a subdivision according to the frame and thermal background.

Regarding the Chilean window market, it is correct to affirm that investments in the real estate sector have been in a constant growth throughout the years [23] [24] producing an increase in the demand for windows.

However, the products with the most significant presence in the market are Aluminium and PVC. The First is the most frequent for having a lower manufacturing cost, for the number of companies that distribute it and for its age in the market. On the other hand, PVC has only been gaining ground until recently, since public policies use it as a baseline for all their projects in order to generate energy savings in homes, lower maintenance costs, better acoustics [25]. The market distribution is represented by Fig. 2, that reflects an approximation of the growth of both over the years.

Window Type	Amount of money in the window industry per year (M / USD)		
	2017	2018	2019
Aluminium	120,5	126,5	131,5
PVC	31,6	31,0	32,8
Total (M / USD)	152,1	157,5	164,3

Fig. 2 Amount of money in the window industry per year.

Characteristics	Window Type	
	Aluminium	PVC
Corrosion resistance	High	High
Electrochemical corrosion risk	Low	Null
Vulnerability to thermal bridges	Half	Low
Vulnerability to cuts or scratches	Half	Low
Degradation by saline environment	Half	Null
Risk of condensation inside	Low	Null
Difficulty cleaning	Low	Low
Window weight	Low	High
Maintenance	Half	Low

Fig. 3 Factors influencing both durability and window maintenance.

On the other hand, the acquisition of a window brings with it a subsequent installation. Under this circumstance, the Chilean market generally delivers a price to the buyer that includes the installation value. The latter may vary due to the dimensions of the window and the distance or location of the destination. However, the type of window material does not influence this cost, in other words, that a window made up of one material or another will not increase or decrease the installation value.

Nevertheless, in the stage of exploitation or use of the window, there are economic differences related to the material composition. Since the durability and maintenance are not the same in all cases, as shown in Fig. 3. For this reason, has been used the two most recurring window compositions, aluminium and PVC, have been used to identify the variables that can influence the maintenance costs, as well also as in the useful life of them [26]. The latter being an essential factor in determining when to make a replacement.

### 3. Technical Characteristics

The methodology explicitly uses the following types of variables; region, commune, thermal zone, facade surface according to orientation, frame material, window type and thermal transmittance (U) [27] [28] [29] [30]. All of these options allow recreating the conditions of the home better. After entering the information, there is an optimal solution for our case through a technical file, which implicitly contains information such as; glass-framed ratio, glass thickness, inner chamber space, the filling inside the chamber, the rail thickness and air permeability [31] [32]. In summary, have to adjust the data at the beginning, to later know in detail the characteristics of windows.

Additionally, a graphic representation of them allows the user to use as a means for the quotation, manufacture, and implementation of the windows. All this information ensures a correct and quick selection of windows for the case in question.

#### B. Methodology of the Verification Process

According to Fig. 4, the simulation considers housing in different climatic zones (Antofagasta, Santiago, Concepción) to which improvements are subsequently implemented in its windows. It is important to note that energy demand is calculated based on passive systems and does not include equipment (No HVAC). However, the HAP program [33] was used to simulate housing, which uses ASHRAE Std. 62.1 - 2010 [34], ASHRAE Std. 90.1 - 2010 [35] and LEED 2009 [36] as a regulatory framework.

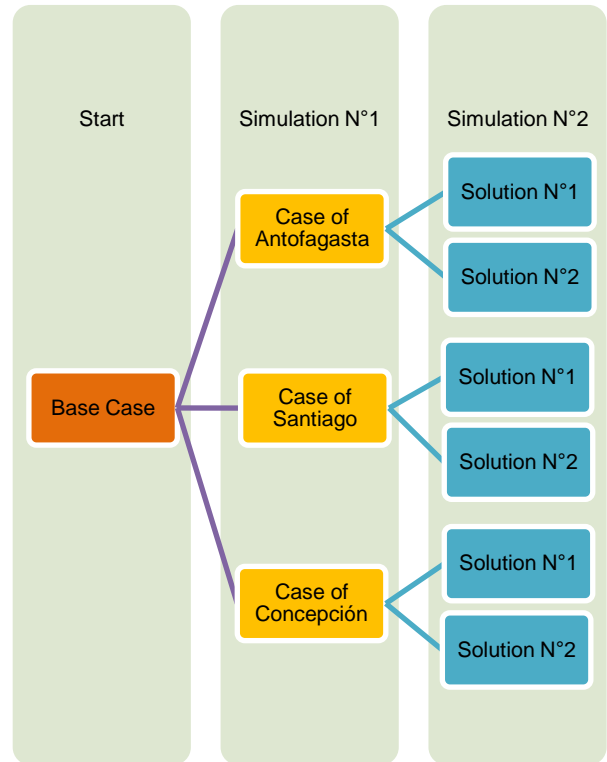


Fig .4 Flowchart to obtain case analysis.

#### 1. Characteristics of Base Cases

The base cases are made up of the technical specifications exemplified in Figs. 5, 6 and 7.

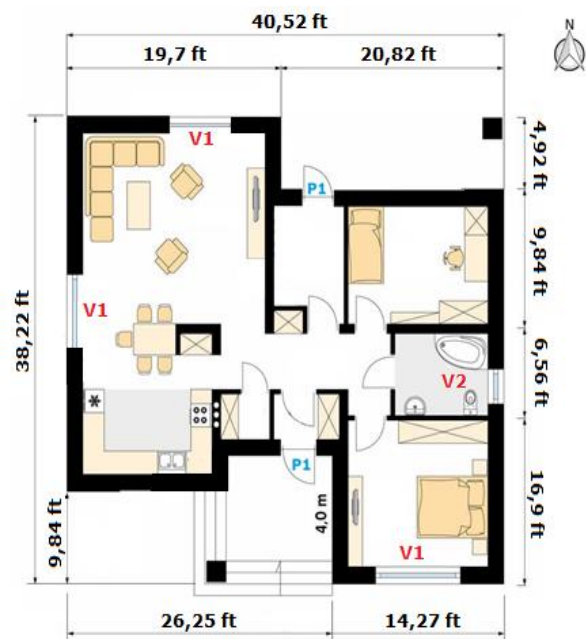


Fig .5 General architecture plant for base cases.

City	Element	High (ft)	Surface (ft <sup>2</sup> )	U (BTU/hr/ft <sup>2</sup> /F)
Antofagasta	Facade N	7,55	304,62	0,29
	Facade S	7,55	292,78	0,29
	Facade E	7,55	248,65	0,29
	Facade W	7,55	249,72	0,29
	Roof	-	1337,95	0,06
	Floor	0,49	1145,28	0,52
Santiago	Facade N	7,55	304,62	0,29
	Facade S	7,55	292,78	0,29
	Facade E	7,55	248,65	0,29
	Facade W	7,55	249,72	0,29
	Roof	-	1337,95	0,06
	Floor	0,49	1145,28	0,52
Concepción	Facade N	7,55	304,62	0,29
	Facade S	7,55	292,78	0,29
	Facade E	7,55	248,65	0,29
	Facade W	7,55	249,72	0,29
	Roof	-	1337,95	0,06
	Floor	0,49	1145,28	0,52

Fig .6 Structural elements of the base cases.

City	Element	High (ft)	Width (ft)	Surface (ft <sup>2</sup> )	U (BTU/hr/ft <sup>2</sup> /F)
Antofagasta	P1	6,6	2,8	18,3	0.32
	V1	5,2	5,2	27,6	1,02
	V2	1,6	1,6	2,7	0,53
Santiago	P1	6,6	2,8	18,3	0.32
	V1	5,2	5,2	27,6	1,02
	V2	1,6	1,6	2,7	0,53
Concepción	P1	6,6	2,8	18,3	0.32
	V1	5,2	5,2	27,6	1,02
	V2	1,6	1,6	2,7	0,53

Fig .7 Non-structural elements of the base cases.

## 2. Characteristics of the Solutions to Simulate

The solutions for the simulations appear from replacing the initial windows V1 with others with better performance, through the methodology. As a summary of the improvement selection process, Figs. 8 and 9 show all the information necessary to prepare the simulations.

City	Solution N°1			
	Window V1			
	Frame Type	Window opening	Surface (ft <sup>2</sup> )	U (BTU/hr/ft <sup>2</sup> /F)
Antofagasta	Aluminium	Side-hung	19,4	0,63
Santiago	Aluminium	Sliding	17,8	0,63
Concepción	Aluminium	Sliding	12,9	0,63

Fig .8 Summary of solutions No. 1 to simulate.

City	Solution N°2			
	Window V1			
	Frame Type	Window opening	Surface (ft <sup>2</sup> )	U (BTU/hr/ft <sup>2</sup> /F)
Antofagasta	PVC	Side-hung	19,4	0,53
Santiago	PVC	Sliding	24,2	0,42
Concepción	PVC	Sliding	12,9	0,28

Fig .9 Summary of solutions No. 2 to simulate.

## III. RESULTS

Figure 10 shows the cooling or heating energy required by a window V1. Indicating that the cities of Antofagasta and Concepción have cooling gains with their negative statistics. This is not the case in Santiago, whose values show an additional demand for it. As for heating, all windows require other energy input. The window that achieved the best performance was the solution n ° 2 in the city of Concepción. Since it has a favourable contribution of cooling energy (- 16 BTU / hr) and its heating demand is the lowest (126 BTU / hr).

Figs 11 and 12 indicate the amount of variation and heating energy required by the total windows of the house in comparison with the total area of these houses. In particular, the heating demand values are much higher than the cooling figures, with a difference between them that ranges 87 % and 93 %. On the other hand, the window that obtained better performance in both graphics. Is the S2 solution in the city of Santiago because it has the smallest reduction in surface area, 11% compared to the base case. Also, it manages to reduce the cooling and heating needs by 64% concerning its base case.

Figs 13 and 14 it show the heat that flows per unit of time and surface area (U) in the windows compared to the total demand for cooling or heating energy of the house. The cooling demand values are much higher than those required for heating as there is having a difference between them that ranges between 70% and 86%. Moreover, the city that presented the most significant energy demands was that of Santiago — reaching differences of up to 9% in cooling and 56% in

heating. However, the city that shows the lowest energy savings is Antofagasta, decreasing only 1.5% in cooling and having a maximum of 9% in heating. In comparison, the city that achieved the best energy performance was the city of Concepcion with solution S2 since it managed to reduce cooling energy by 3% and 12% for heating.

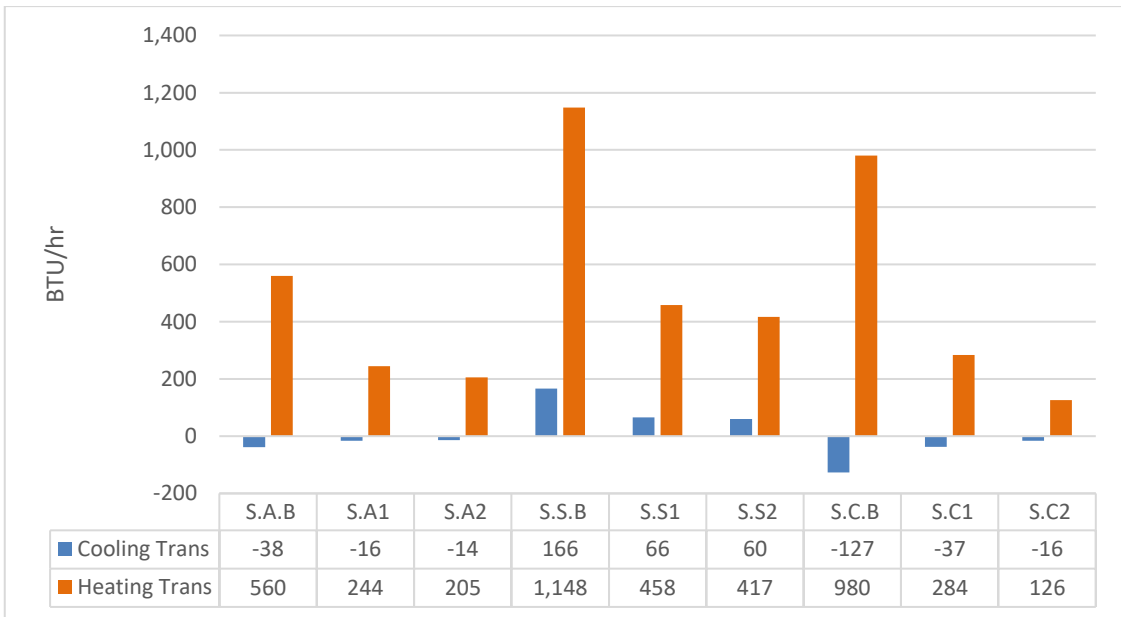


Fig. 10. Cooling vs heating energy required by a V1 window.

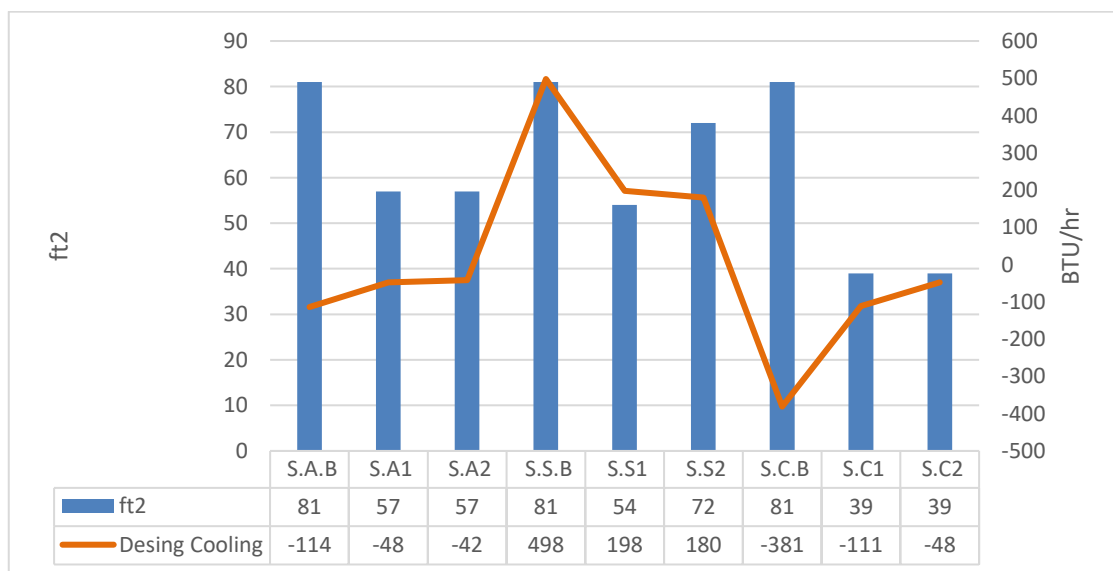


Fig. 11. Total surface of the V1 windows vs energy supply for cooling them.

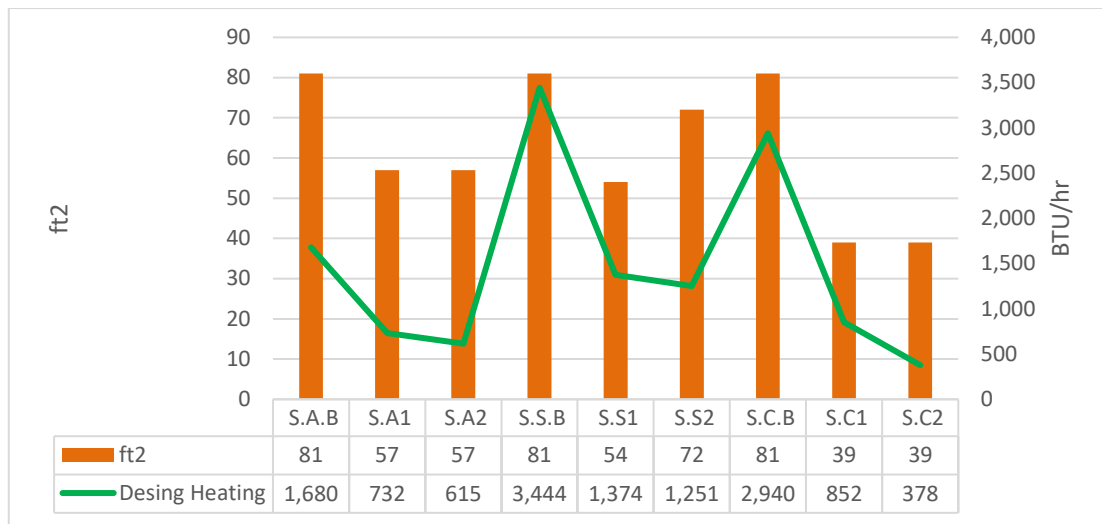


Fig. 12. Total surface of the windows V1 vs energy supply for heating them.

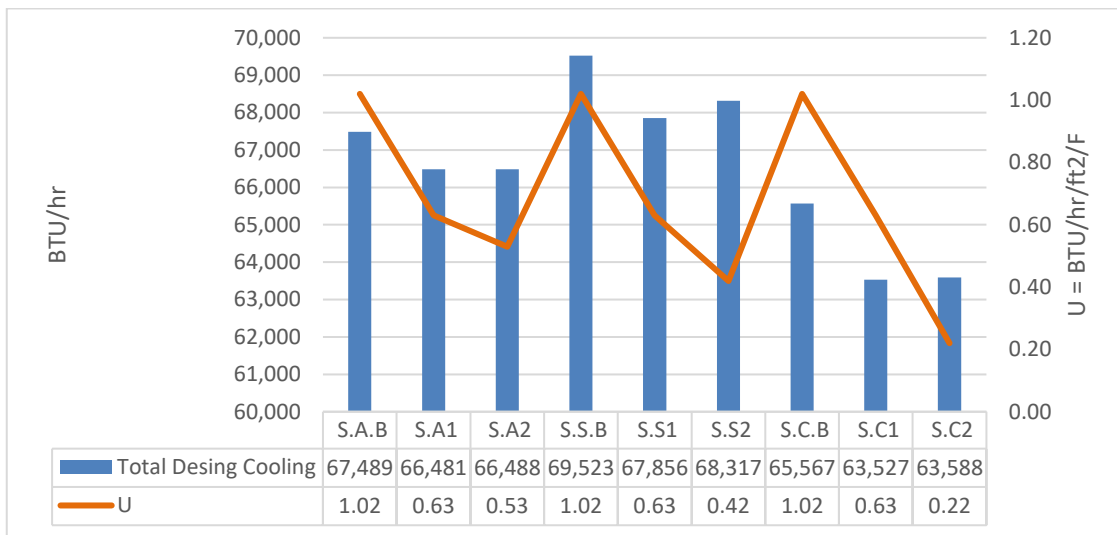


Fig. 13. Thermal transmittance of the window (U) vs total energy demand for cooling.

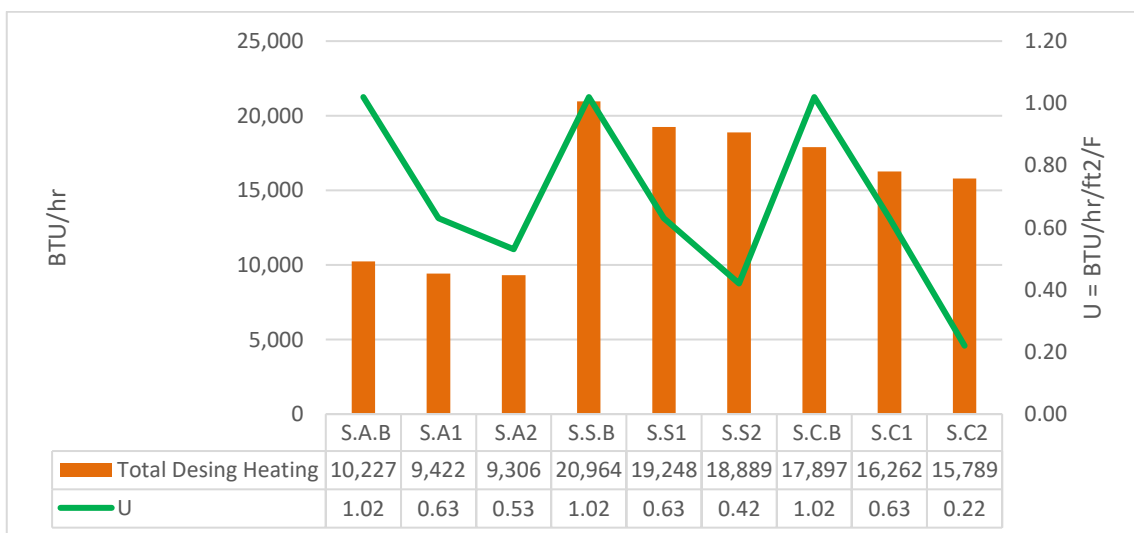


Fig. 14. Thermal transmittance of the window (U) vs total energy demand for heating.

#### IV. CONCLUSION

After evaluating the passive energy performance of homes, it is concluded that the highest energy demands were recorded in cooling and they were much higher than those required for heating. As a result, the double airtight glass allows reducing the solar gain but fails to eliminate overheating in high-temperature seasons.

Other relevant data provided by the simulations correspond to the relationship between the thermal transmittance (U) of the windows and the total energy demand of the house (BTU / hr). Specifically, when using windows with small values of U in geographic areas where high temperatures prevail, great energy and economic performance are not obtained. Radiation control measures are more practical to combat these situations.

In geographical areas where low temperatures are recurrent, the strategy is of using very high-quality windows is not always viable. That is to say, using thermal transmittance values that are very low or close to 1.0 BTU / hr / ft<sup>2</sup> / F. Together with decreasing their dimensions, they singularly favour the heating demand reduction. However, this situation is not entirely profitable because the natural light surface is lost, and the implementation costs are too high.

In temperate climates, it is where the correct selection of the windows has a higher incidence. Because, if windows with U values ranging between 2.0 and 3.0 BTU / hr / ft<sup>2</sup> / F are used, a considerable reduction in the energy demands of the house is obtained, with a reasonable implementation cost. For example, in cold months, the solar radiation decreases, allowing the double airtight glass to limit heat transfers between the interior and exterior of homes in addition to avoiding condensation in the interior glass.

In contrast, in months of high temperatures, the same windows allow cooling through cross ventilation caused by opening them. In the case of having a ventilation, heating and air conditioning system (HVAC) the windows with the indicated characteristics allow encapsulating or retaining the comfortable temperature inside the enclosure, avoiding energy loss.

In general, it is confirmed that windows with lower thermal transmittance (U) achieve better energy

performance in homes. However, the selection of optimal windows for a project should always be based on the geographical area, the orientation of the facade or wall, the surface of light or visibility to be projected (dimensions) and the values of thermal transmittance (U). For example, the simulations showed that the S2 solution obtained a better performance of energy efficiency in the three cities mainly because it had U figures and slightly smaller surfaces than the S1 option.

As for the users of homes in Chile and around the world, the following is inferred; usually, they do not know the energy demand of homes, much less about the selection of doors or windows with excellent performance. Because these responsibilities transferred to government authorities, this means that it is the governments that generate the energy efficiency and sustainability strategies, according to the political, social and economic reality that they live. However, the difference is that Europe, unlike Chile, has more experience and track record on this issue. Instead, Chile is in the process of transition, since its policies and regulations are recent or in the development stage.

About the above and the evidence collected, it is possible to affirm that this methodology can effectively provide support to users, allowing them to know when it is profitable to change their windows for one that has a better performance. On the other hand, the implementation of this in the design stage allows knowing the cost and benefit relationship that exists between the windows, a critical factor in projects where resources are minimal, such as social projects. Furthermore, it favours the country's energy transition process in a transversal manner. In other words, it involves all the stages of a project; design, construction, operation and demolition or replacement in this case. It can be implemented free of charge, with high possibilities of application in the market and with national coverage. However, the successful integration of this in the field depends on the improvement of the current legal and technical framework that surrounds it, a modest initial investment, additionally a process of information and standardization of the market.

#### V. ACKNOWLEDGMENTS

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