

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

5,300

Open access books available

131,000

International authors and editors

155M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Evaluation of Well-Being and Thermal Comfort of the LAD-MA Construction System for Low-Cost Homes

Rodolfo Jiménez Cavieres, Javier Carrasco Eade and Camilo Valdebenito Monsalve

Abstract

This work is part of a research into the state of conservation and behavior of a group of self-built social housing. The construction, which dates from 1990, was carried out with an original low-cost construction system that uses clay and wood bricks called LAD-MA. This was implemented by the NGO Urban Technical Assistance Center “Taller Norte”, in the Peñalolén commune, Santiago de Chile, Metropolitan Region. The study focuses on the evaluation of well-being and thermal comfort in these homes, which is determined through environmental monitoring by meteorological stations installed for six months in 4 homes. It is established that the houses do not comply with the parameters set up by the international standards ISO 7730 and ASHRAE 55. For this, constructive solutions are proposed to thermally improve the current houses, and update the LAD-MA construction system to comply with the thermal Insulation standards stipulated for the Sustainable Housing Certification of the Ministry of Housing and Urbanism.

Keywords: social housing, low-cost construction system, environmental comfort assessment

1. Introduction

In the mid-eighties of the twentieth century, in Chile, around 29,373 families were living in 166 registered irregular settlements (camps), located on the outskirts of different cities in the country [1]. The people who lived in these camps, mainly inhabited houses made of light material, popularly known as “mediaguas”, with an area of approximately 18 m² that, due to their size and materiality, presented habitability problems for families, such as overcrowding, thermal and humidity discomfort, lack of lighting and basic hygiene services [2]. This problem led the authorities of the time to implement urbanization programs that consisted of building basic kitchen and bathroom modules called “sanitary booths” that provided the supply of drinking water, sewage service, and electricity. For that, the inhabitants of Camps had to implement other enclosures such as bedrooms and living room, through self-construction. In this context, an NGO called “TALLER NORTE Urban

Technical Assistance Centre”, in conjunction with organizations from the Peñalolén commune, develops a program called “Building Together” in which various constructive solutions are implemented, the first experiences being the construction with wood and clay. Towards the end of the ‘80s, Taller Norte developed a construction system that uses handmade brick from baked clay and wood for the self-construction of houses attached to sanitary huts called “LAD-MA”. [3] Because it is made up of bricks (**Ladrillo**) and wood (**Madera**), it allows the implementation of 1-level homes, expandable to 2 levels, depending on the needs and possibilities of each family.

Despite the advancement of housing policies in Chile during the last decades, irregular settlements and their consequent habitability problems are far from disappearing. According to official figures from the cadastre carried out by the Ministry of Housing and Urbanism of Chile [4], there are currently 802 camps nationwide in the country’s main cities, with the presence of 47,050 households. Among the reasons that explain the persistence of the camps are the lack of state regulation of the real estate market, the effects of socioeconomic inequality and low salaries, as well as migration [5] from other countries and cities.

The foregoing makes it possible to wonder about the viability of implementing technically assisted self-construction programs, which facilitate efficiently solving the current lack of habitability in the context of irregular settlements. In these programs, there is an opportunity to implement construction systems like LAD-MA, developed 30 years ago, which uses inexpensive materials such as wood and fiscal bricks and is easy to execute.

In this sense, it is worth asking what are the technical gaps in a construction system such as LAD-MA regarding compliance with contemporary standards of habitability, taking into account that in recent years, Chile has presented significant advances in the matter. Specifically, it is interesting to review if the LAD-MA system allows acceptable conditions of thermal comfort according to standards such as ASHRAE 55, as well as, if technically, it is possible to adapt the construction system to achieve compliance with the current Thermal Regulations for homes of Chile [6].

2. Background

2.1 The LAD-MA construction system

The LAD-MA system consists of a set of 4 wall panels (**Figure 1**), which can be arranged in order to solve different architectural solutions. They are made up of a structural framework of upright feet and upper sills of untreated 2x4 “pine wood, braced with 1x4” pine diagonals, which act jointly with a body of prefabricated plates made with ‘fiscal brick’.

The brick plates are fixed to the wooden structure and to each other, using cement mortar of 400 [kg/cm³] and with a horizontal reinforcement for the shear stress, with smooth round iron of 6 [mm], fixed at end of the wall panel with a fold and staples, fixed and tensioned at the other end with nuts and washers.

An 8 [mm] slotted steel bar is used to join the wooden structure with the foundation beam, one at each end of the wall panel, with an upper tie-down with clamps and two bars in the central columns as seen in (**Figure 2**).

On-site, the foundations are made directly on excavation and without molds. The foundation beams are precast on-site using molds containing guides to locate the center columns’ 8 [mm] *Feith* anchors. The foundation beams are mounted on the foundation dice, perfectly level on their upper face. A wooden floor structure is

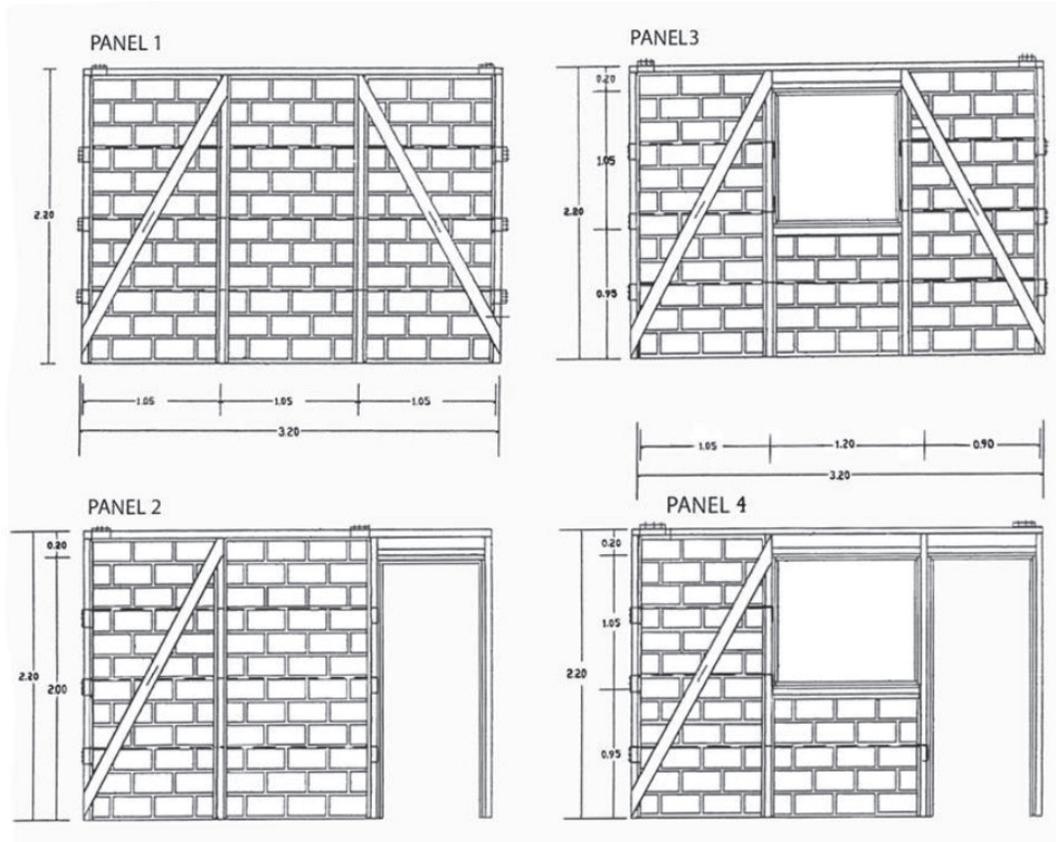


Figure 1.
 LAD-MA set of wall panels.

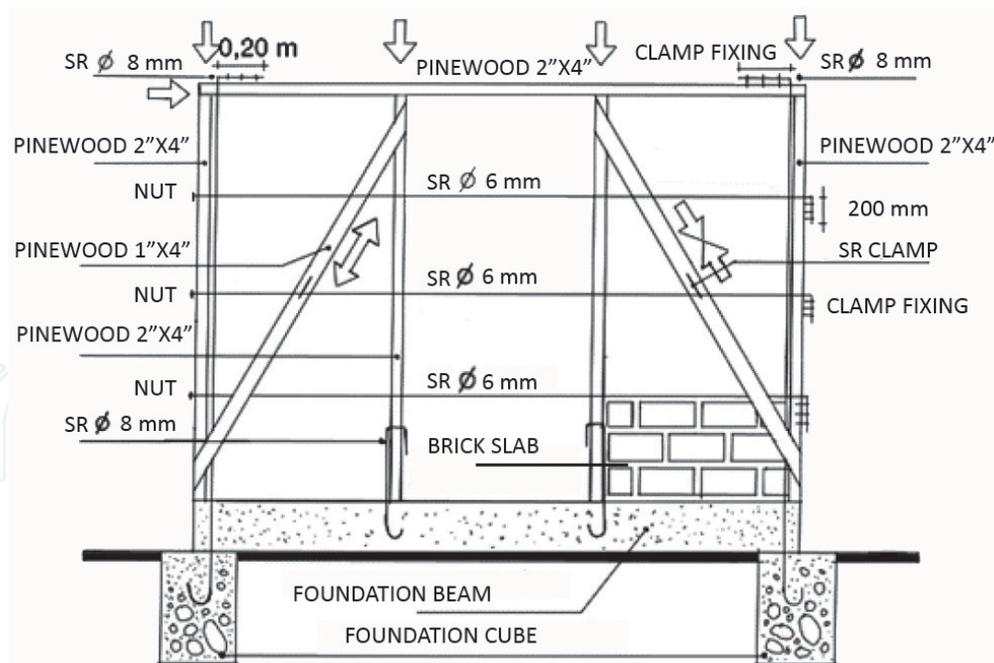


Figure 2.
 Schematic detail of the parts and components of the LAD-MA construction system.

arranged on the LAD-MA structure, to enable a second floor, which is entirely resolved with a traditional wooden structure that in many cases comes from the recycling of precarious homes (**Figure 3**).

This construction system was designed with a purely social and non-profit objective, it is low cost, enables and facilitates self-construction work, is based on the prefabrication of components, uses low-cost local materials and recycled

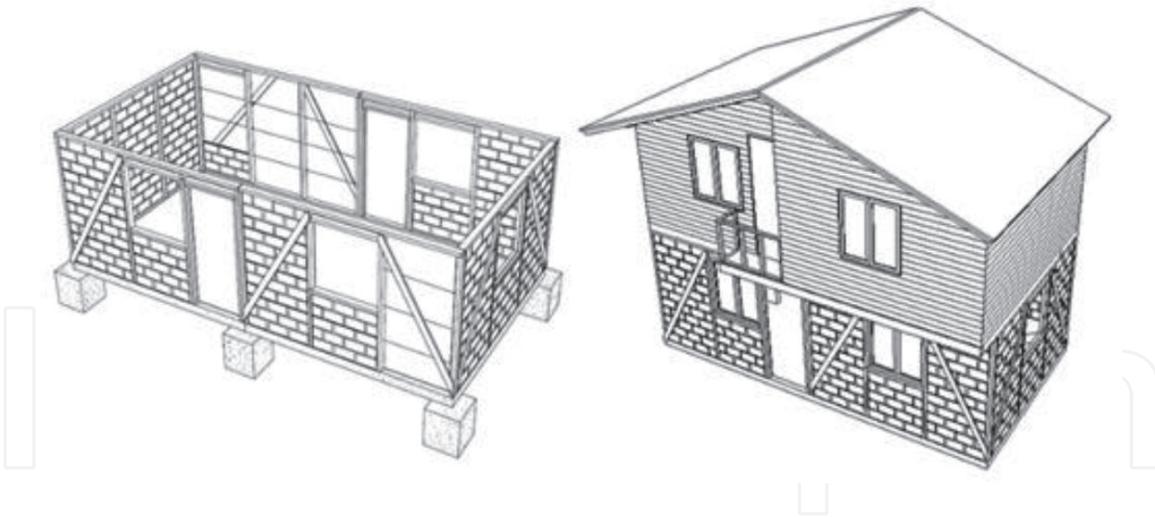


Figure 3.
LAD-MA Architectural Module.

materials, and is intensive in unskilled labor, with technical support that guarantees its proper implementation.

In addition, the LAD-MA construction system was conceived considering that it provides a positive perception in the beneficiaries of a “solid” home, using brick as a material commonly used in permanent homes, giving the feeling of durability, thermal comfort, and structural stability. In contrast to the “mediaguas” units in which the beneficiaries of the construction system previously lived.

It is worth mentioning that for this research, it was analyzed the evolution over time of 4 homes built in the LAD-MA system, which are located in the Peñalolén Commune, in Santiago de Chile. In some of the observed cases, the owners made modifications, making extensions and plastering the interior and exterior of the walls with cement mortar, and painted the outside and the inside.

2.2 The current standards of habitability of housing in Chile

The regulation of building standards in Chile arose in 1992 with Decree No. 47 that created the General Code of Urbanism and Constructions [7]. The first topics that were regularized through this document were the fire resistance standards of buildings and the requirements for sewage and rainwater systems. Then, in the year 2000, the first stage of prescriptive Thermal envelope regulations for housing was added to the General Code, to establish a minimum insulation standard for the roof of the dwelling, according to the climatic zone of the country.

Then, in 2007, the second stage of prescriptive Thermal envelope regulation expanded the requirements to other building components, such as exterior walls, ventilated floors, and windows of the dwellings.

A third stage of the Thermal envelope Regulation is pending, however, it is known that it will consist of an adjustment and reduction of the prescriptive U-Value of some of the building components, for some of the climatic zones of the country. These adjustments have already been applied on a mandatory basis for new homes in cities of Chile that currently have Atmospheric Decontamination Plans (PDA), as well as in a voluntary way, through the Certification System for Sustainable Housing [6].

The following **Table 1** presents a comparison between the current thermal envelope standards of the Chilean Regulation and the thermal envelope standards from the Certification System for Sustainable Housing in Chile:

Table of comparison. Current Chilean Building regulation for thermal insulation standards and Minimum thermal insulation standards complying with the Sustainable Housing Certification

Roofs				
City of reference	Current Chilean Building regulation for thermal insulation standards		Minimum thermal insulation standards complying with the Sustainable Housing Certification	
	Thermal Zone	U Value (W/m ² k)	Thermal Zone	U Value (W/m ² k)
Arica	1	0,84	A	0,84
Iquique				
Antofagasta				
Copiapó			B	0,47
La Serena			C	0,47
Valparaíso	2	0,6	D	0,38
Santiago	3	0,47		
Rancagua				
Talca	4	0,38	E	0,33
Concepción				
Temuco	5	0,33		
Valdivia			F	0,28
Puerto Montt	6	0,28	G	0,28
Coyhaique	7	0,25	I	0,25
Punta Arenas				

Walls

City of reference	Current Chilean Building regulation for thermal insulation standards		Minimum thermal insulation standards complying with the Sustainable Housing Certification	
	Thermal Zone	U Value (W/m ² k)	Thermal Zone	U Value (W/m ² k)
Arica	1	4	A	2,1
Iquique				
Antofagasta				
Copiapó			B	0,8
La Serena			C	0,8
Valparaiso	2	3	D	0,8
Santiago	3	1,9		
Rancagua				
Talca	4	1,7	E	0,6
Concepción				
Temuco	5	1,6		
Valdivia			F	0,45
Puerto Montt	6	1,1	G	0,4
Coyhaique	7	0,6	I	0,35
Punta Arenas				

Table of comparison. Current Chilean Building regulation for thermal insulation standards and Minimum thermal insulation standards complying with the Sustainable Housing Certification				
Ventilated floors				
City of reference	Current Chilean Building regulation for thermal insulation standards		Minimum thermal insulation standards complying with the Sustainable Housing Certification	
	Thermal Zone	U Value (W/m ² k)	Thermal Zone	U Value (W/m ² k)
Arica	1	3,6	A	3,6
Iquique				
Antofagasta				
Copiapó			B	0,7
La Serena			C	0,87
Valparaíso	2	0,87		
Santiago	3	0,7	D	0,7
Rancagua				
Talca	4	0,6		
Concepción			E	0,6
Temuco	5	0,5	F	0,5
Valdivia			G	0,39
Puerto Montt	6	0,39		
Coyhaique	7	0,32	I	0,32
Punta Arenas				

Source: Own elaboration based on Art. 4.1.10 of the O.G.U.C and the Sustainable Housing Construction Standards, volume II, Energy [6].

Table 1.

Comparative table of thermal transmittance standards for ventilated roofs, walls, and floors.

2.3 Thermal Comfort

Considering thermal comfort as one of the main variables in building design, standards such as ISO 7730 and ASHRAE 55 have been developed. These Standards are used as a reference to determine the performance of buildings, through measurement tools. In the case of Chile, the ASHRAE standard has been used as a reference for the design of the housing energy-rating tool [8].

2.3.1 Standard UNE-EN ISO 7730: 2006

The purpose of the standard is to predict the thermal sensation and the degree of discomfort within a built environment, by calculating a Predicted Mean Vote (PMV) and an Estimated Percentage of Dissatisfied (PPD), taking into account levels of clothing and metabolic activity of people, as well as wind speed, turbulence percentage, among other parameters.

The PMV is an index that reflects an average of votes cast by a large group of people concerning a 7-level thermal sensation scale, which is expressed in **Table 2**.

The PMV index can be estimated for different combinations of metabolic rate, clothing insulation, air temperature, mean radiant temperature, relative air

velocity, and air humidity; for the effect of the purpose of the standard, the following simplified expression is used:

$$PMV = aT + bPv - c$$

Where T is the ambient temperature in [°C] and Pv the pressure of the water vapour in the environment in [kPa].

The constants a , b and c are constants that relate the physical quantities of temperature and pressure to obtain the PMV which is a dimensionless variable and these are obtained from the following table, depending on the time of exposure to the indoor environment and depending on the gender of the subject (**Table 3**).

On the other hand, the PPD index is determined based on the PMV expressed in the following equation:

$$PPD = 100 - 95e - (0.3353PMV^4 + 0.2179PMV^2)$$

2.3.2 ASHRAE 55

This standard determines the influence of environmental variables on human comfort. Although these variables are the same used in the ISO 7730, the difference is that ASHRAE 55 seeks to determine the comfort temperature ranges and then determine the PMV-PPD values, thus deriving in two ways of determining the thermal comfort based on De Dear's studies.

The ASHRAE Standard provides two approaches to thermal comfort on buildings. The first approach focuses on buildings with centralized HVAC systems,

+3	hot
+2	warm
+1	slightly warm
0	neutral
-1	slightly cool
-2	cold
-3	chill

Table 2.
 Scale of 7 levels verbalized according to thermal sensation, PMV (UNE-EN ISO 7730: 2006).

Time	Gender	a	b	c
1 hour	Male	0.220	0.233	5.673
	Female	0.272	0.248	7.245
	Both	0.245	0.248	6.475
2 hour	Male	0.221	0.270	6.024
	Female	0.283	0.210	7.694
	Both	0.252	0.240	6.859
3 hour	Male	0.212	0.293	5.949
	Female	0.275	0.255	8.620
	Both	0.243	0.278	6.802

Table 3.
 Values of constants a , b and c to be used in the PMV estimation equation.

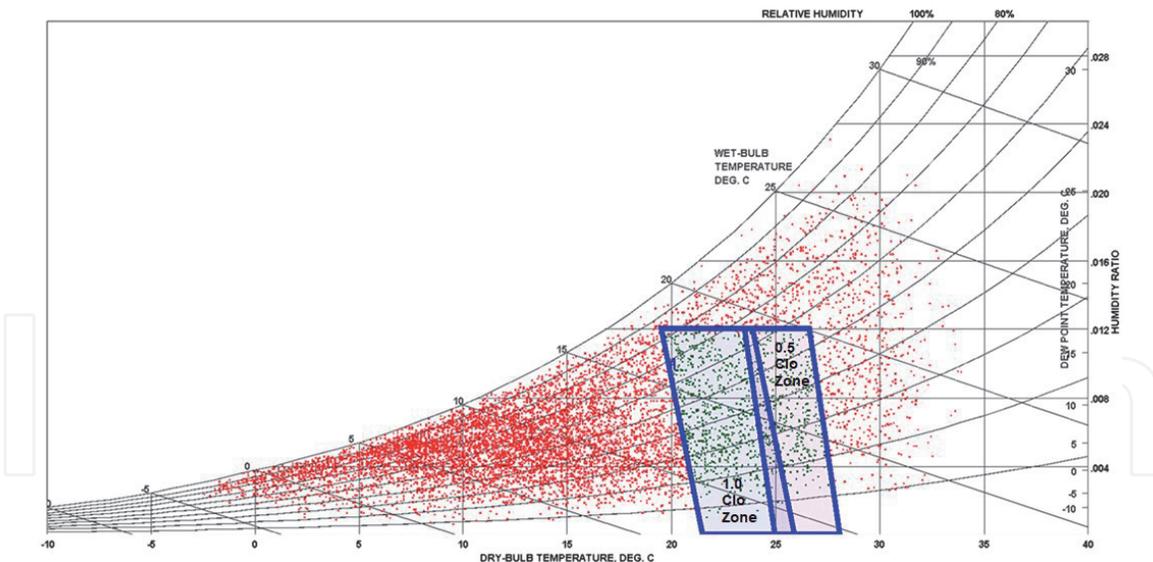


Figure 4. Thermal Comfort Range for Santiago, Chile, based on ASHRAE 55 Standard. Source: own elaboration using climatic data from Santiago (855740 WMO Station Number) plotted on the Psychrometric Chart provided by the software Climate Consultant.

considering an airspeed of 0.2 [m/s], a sedentary metabolic activity between 1 [met] and 1.3 [met], and the option of insulation of clothing varies between 0.5 [clo] and 1.0 [clo], similar to that described above, corresponding to summer and winter respectively. Based on the Fanger thermal balance, a hygrothermal comfort range illustrated in **Figure 4** is determined.

The second method focuses on buildings without centralized HVAC systems, and determines a dynamic comfort temperature based on the average ambient temperature outside the buildings, this continues to maintain a requirement that there be a sedentary metabolic activity between 1 [met] and 1.3 [met], and that people can vary the clothing insulation between 0.5 [clo] and 1.0 [clo]. However this method is valid only if the outside temperature oscillates between 10 [°C] and 33.5 [°C], and that their measurements are greater than 7 days and a maximum of 30 days, thus generating the minimum and maximum comfort temperature equations.

$$T_{\min, \max} = 0.31 \cdot T_{\text{Ext}} + 17.80 \pm 3.50$$

Regarding humidity, the standard establishes a maximum humidity ratio of 0.012, equivalent to the vapor pressure of 1.910 [kPa], and does not determine a minimum. Also, consider an acceptability index of 80%.

3. Methodology

The study set out to determine if the homes built using the LAD-MA system, in the mid-90s, meet the contemporary comfort parameters described in the international standards ISO 7730 and ASHRAE 55. Given the results obtained, possible modifications to the construction system were studied, to optimize its performance and conform to the thermal envelope standards for housing. The above, understanding that the LAD-MA system was conceived as a self-construction method, economically accessible for families in conditions of socioeconomic vulnerability, who require housing solutions that can be extended over time; a problem still in force at the local level.

The study has been composed of two stages. The first stage, of an empirical nature, consisted of measuring environmental parameters in four existing houses

built under the LAD-MA construction system and located in the Peñalolén Commune in Santiago. This measurement was carried out by data loggers that assessed internal and external environmental parameters for six months. The external parameters measured were temperature and humidity, while the internal parameters were temperature, humidity, CO₂ concentration, and noise. The data obtained through these data loggers allowed us to determine if the homes achieve thermal comfort standards, based on the PMV and PPD indicators, analyzing these according to the parameters established in the international standards ISO 7730 and ASHRAE 55. The measurements were analyzed based on periods of continuous occupation (24hrs), and limited periods of occupation (only the hours of occupation) under both standards. It is worth mentioning that some of the houses studied made use of heating systems during the winter period, so the measurement does not strictly reflect passive environmental conditions of the construction.

In the second stage of this study, possible modifications to the LAD-MA construction system were analyzed, in order to adjust the system to comply with the Chilean Thermal Regulations and thus, theoretically improve its compliance with the PMV and PPD indicators. To carry out this part of the study, possible constructive solutions were proposed to reduce the thermal transmittance of the LAD-MA system, using the static energy simulation tool Therm 7.7. The constructive adjustments were then represented in a dynamic thermal model of the LAD-MA architectural module, using the energy simulation tool DesignBuilder 6.1 and the Energy Plus 8.9 calculation engine, thus determining interior temperatures and the variation of PMV and PPD indicators.

4. Discussion of the results

4.1 LAD-MA housing monitoring

NET ADMO environmental measurement equipment was installed in 4 homes originally built with the LAD-MA system. It is worth mentioning that the 4 LAD-MA homes monitored present differences in their state of conservation and their current architectural configuration due to the different modifications and extensions that users have made since they were delivered. The first and second level extensions that have been adhered to the original LAD-MA modules are wooden structures that have been progressively built by the owners, in general with a low thermal standard. However, they have generated an effect on the environmental conditions of the original module. **Table 4** presents a brief architectural characterization of the 4 monitored dwellings, highlighting in color the location of the original LAD-MA module in each case, the orientation of the dwelling relative north, and the description of the general state of conservation in each a. case.

The results of the environmental measurement of the 4 LAD-MA houses in Peñalolén, showed that they present minimum periods of thermal comfort, which are reduced towards the winter months. The average temperature in the monitored homes during February is 24°C, while the average temperature barely reaches 14°C in July. On the other hand, the indoor relative humidity oscillates within acceptable levels. **Table 5** presents graphs of the average monthly conditions of temperature, and relative humidity, together with some general observations.

Finally, when analyzing the Percentage of People in Thermal Dissatisfaction through the PPD indicator, during the months in which the LAD-MA dwellings were monitored, it is observed that the dwellings present high levels of dissatisfaction. On average, under the parameters of the ISO 7730 standard, the 4 thermally monitored homes have 75% thermal discomfort in the total measurement period

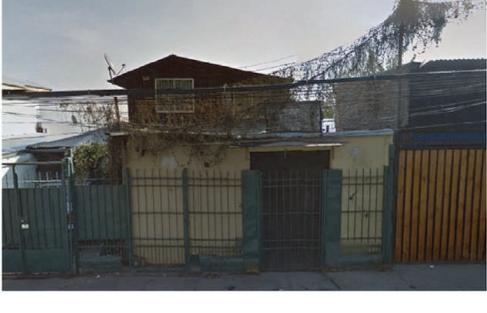
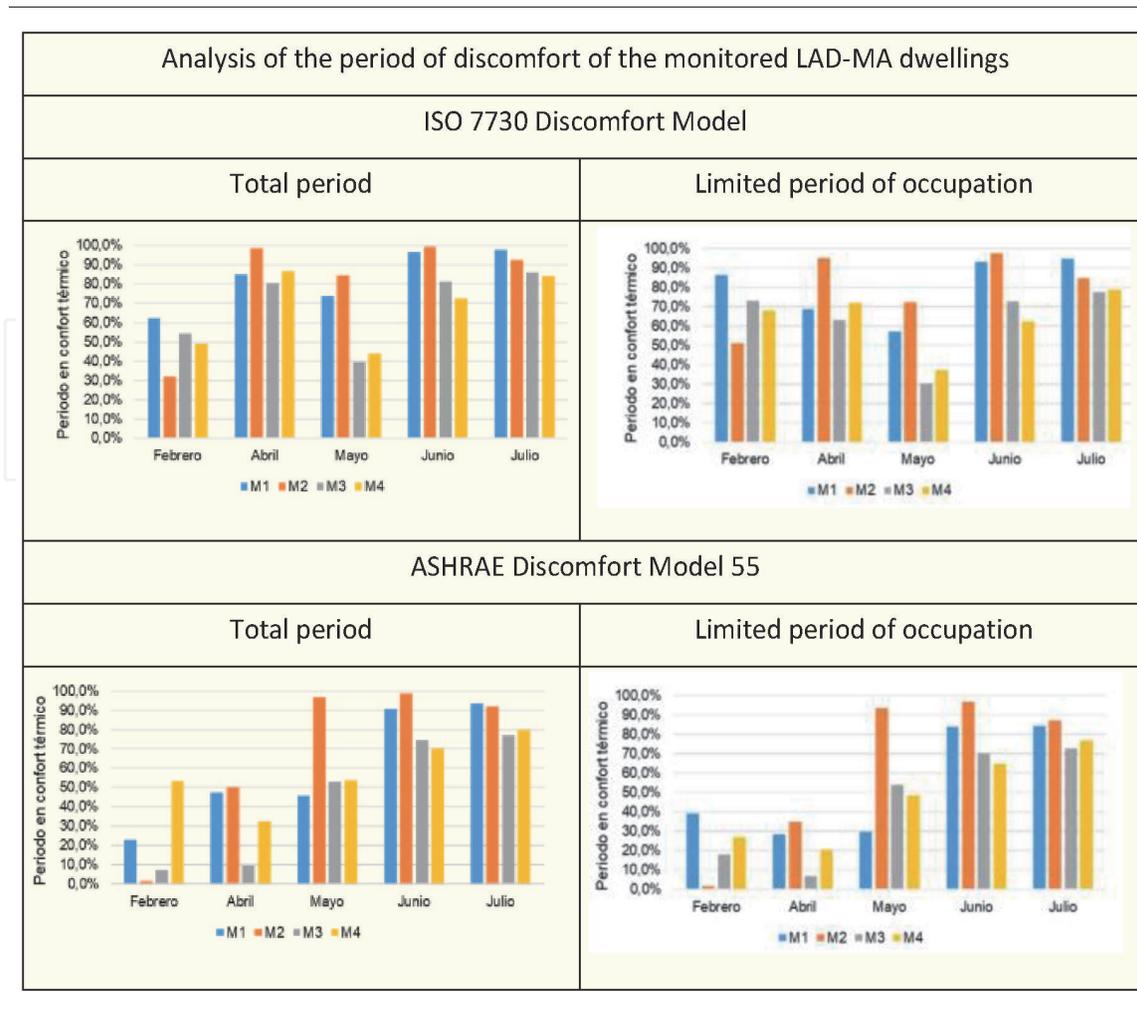
Homes built in the LAD-MA system monitored - Peñalolén, Santiago			
Monitored housing - M1 - Panes Family			
1st level plan	2nd level plan	Exterior view of the house	General description
			It does not have modifications or maintenance of the LAD-MA panels, even generating deterioration of it. The environment of the module is mainly closed, avoiding good ventilation of the space.
Monitored housing - M2 - Sandoval Family			
1st level plan	2nd level plan	Exterior view of the house	General description
			Modifications were made, plastering the inside of the panels with cement, and painting them outside and inside. Maintenance is carried out every 3 to 5 years. Closed environment, avoiding good ventilation Ceramic floor
Monitored housing - M3 – Lopez Family			
1st level plan	2nd level plan	Exterior view of the house	General description
			Modifications were made, plastering the inside of the panels with cement, and painting them outside and inside. Maintenance is carried out every 3 to 5 years. The house has a large patio and large windows, they also left space at the entrance, factors that give it very good ventilation. Ceramic floor
Monitored housing - M4 – Vargas Family			
1st level plan	2nd level plan	Exterior view of the house	General description
			Modifications were made, plastering the inside of the panels with cement, and painting them outside and inside. Maintenance is carried out every 3 to 5 years. The house is higher than the others, having a very good inlet for ventilation, however, the outlet to the patio is smaller, reducing the potential for air exchange. Ceramic floor

Table 4. Characterization of the Homes built in the monitored LAD-MA System, Peñalolén, Santiago. Own elaboration.

Comparison of Average Indoor Temperature and Relative Humidity in Monitored Homes Built with the LAD-MA System		
February		
Temperature	Relative Humidity	Observations
		The homes have temperatures slightly below the minimum comfort level, with M1 being the coldest home and the one with the highest indoor temperatures during the day. Indoor humidity in all homes is within acceptable levels.
April		
Temperature	Relative Humidity	Observations
		The homes have temperatures slightly below the minimum comfort level, with M1 being the coldest home and the one with the highest indoor temperatures during the day. Indoor humidity in all homes is within acceptable levels.
May		
Temperature	Relative Humidity	Observations
		The dwellings have T° below the minimum comfort level, with M1 and M2 being the coldest dwellings. M1 has higher indoor temperatures during the day. The use of heating is observed in M3 and M4. Indoor humidity is within acceptable levels.
June		
Temperatura	Humedad relativa	Observaciones
		The houses practically do not present T° within comfort ranges. M1 is the coldest dwelling. The use of heating is observed in M2, M3 and M4. Indoor humidity is within acceptable levels.
July		
Temperatura	Humedad relativa	Observaciones
		The houses practically do not present T° within comfort ranges. M1 is the coldest dwelling. The use of heating is observed in M2, M3 and M4. Indoor humidity is within acceptable levels.

Table 5. Comparison of Average Indoor Temperature and Relative Humidity in monitored LAD-MA homes. Own elaboration.

**Table 6.**

Analysis of time of discomfort of the Monitored LAD-MA Homes. Own elaboration.

and 71% during the limited period of occupancy, while under the parameters of the ASHRAE 55 standard, the 4 monitored dwellings have 57.5% of thermal discomfort time in the total measurement period and 54% during the limited period of occupation. Towards the winter months, the period of discomfort increases between 80% and 90% of the occupation time, due to the low temperatures inside the houses. The above is observed in **Table 6**.

4.2 Thermal Transmittance Analysis of the LAD-MA construction system

The next stage of the study analyzes the thermal performance of the wall construction system of the LAD-MA module, together with the adjustments required so that the system can comply with the country's thermal regulations. To carry out this first part of the analysis, the Therm 7.7 thermal transmission calculation simulation tool was used to represent a typical section of the LAD-MA wall, composed of brick plates and wooden studs.

For analysis purposes, some characteristics of materials have been assumed based on the Chilean Standard NCh 853, which presents typical conductivities of materials according to their density. The edge conditions used have been 6.5°C outside and 25 W/m²K of air film coefficient on the outside, and 13°C inside, with 7.69 W/m²K of air film coefficient on the inside.

Thermal analysis of the original construction system was carried out, plus the analysis of 4 variants that represent possible improvements of the thermal

envelope. The summary of transmittance and thermal resistance results of the variants studied is presented in **Table 7**.

The analysis of variants allows us to observe the alternatives for improving the thermal quality for the LAD-MA construction system, to the extent that stucco (variant 1 and 2) and thermal insulation could be progressively added to the walls (variant 3 and 4), in the context of a thermal improvement for said dwellings. From the point of view of thermal resistance, it is evident that the incorporation of thermal insulating materials contributes in a better way to the fulfillment of the thermal regulations for homes. The most recommended solution being the installation of thermal insulation on both sides of the wall, thus which the thermal transmittance of the wall would make it possible to comply with the normative requirements in force in 6 of the 7 thermal zones, and with the normative requirements of the third stage of

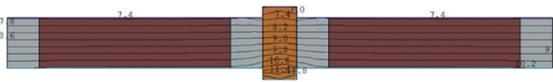
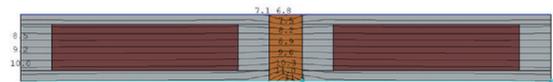
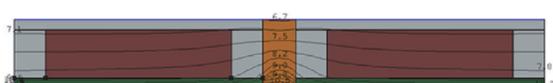
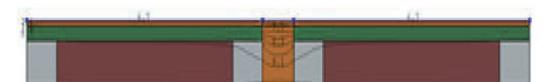
Constructive analysis of variants LAD - MA system		
LAD-MA Original System		
Transmittance U (W / m2K)	Resistance (m2K / W)	Commentary
3,23	0,31	 <p>The original system complies with the Thermal Regulations in force for Thermal Zone 1, in the north of the country. It does not comply with the Third Stage of the Thermal Regulation of Homes, in any of the Thermal Zones of the Country</p>
<p style="text-align: center;">Variant 1- LAD-MA + plus Internal Stucco</p>		
Transmittance U (W / m2K)	Resistance (m2K / W)	Commentary
2,93	0,34	 <p>By adding mortar stucco on the outer face, 15mm thick, the transmittance is reduced by 9%. It complies with the Thermal Regulations in force for Thermal Zones 1 and 2, in the north of the country. It does not comply with the Third Stage of the Thermal</p>
<p style="text-align: center;">Variant 2 - LAD-MA + Stucco both sides</p>		
Transmittance U (W / m2K)	Resistance (m2K / W)	Commentary
2,70	0,37	 <p>By adding mortar stucco on both sides, 15mm thick, the transmittance is reduced by 16%. It complies with the Thermal Regulations in force for Thermal Zones 1 and 2, in the north of the country. It does not comply with the Third Stage of the Thermal Regulation of Homes, in any of the Thermal Zones of the Country</p>
<p style="text-align: center;">Variant 3 - LAD-MA External stucco plus interior Mineral Wool + Wood cladding</p>		
Transmittance U (W / m2K)	Resistance (m2K / W)	Commentary
1,38	0,72	 <p>By adding a 15mm thick thermal insulator, the transmittance is reduced by 57%. It complies with the current Thermal Regulations for Thermal Zones 1, 2, 3 and 4 of the country. Complies with the Third Stage of the Thermal Regulation of Homes, in Thermal Zone A, in the north of the country</p>
<p style="text-align: center;">Variant 4 - LAD-MA Construction System with mineral wool on the outside and inside</p>		
Transmittance U (W / m2K)	Resistance (m2K / W)	Commentary
0,77	1,29	 <p>By adding 15mm thick thermal insulation on both sides of the wall, the thermal transmittance is reduced by 76%. It complies with the current Thermal Regulations for Thermal Zones 1, 2, 3, 4, 5 and 6 of the country. Complies with the Third Stage of the Thermal Regulation of Homes, in Thermal Zone A, B, C, and D of the Country</p>

Table 7.
 Constructive analysis of variants System LAD - MA. Own elaboration.

the thermal regulation of houses, in 4 of the 8 thermal zones. It is worth mentioning that this thermal solution can be obtained in several ways, among others by using a solution of the STATE type (Exterior Thermal Insulation System). Better known in Chile by its acronym in English EIFS (Exterior insulation finishing system) that incorporate a plastered plaster on the outside, or failing that, by installing a secondary

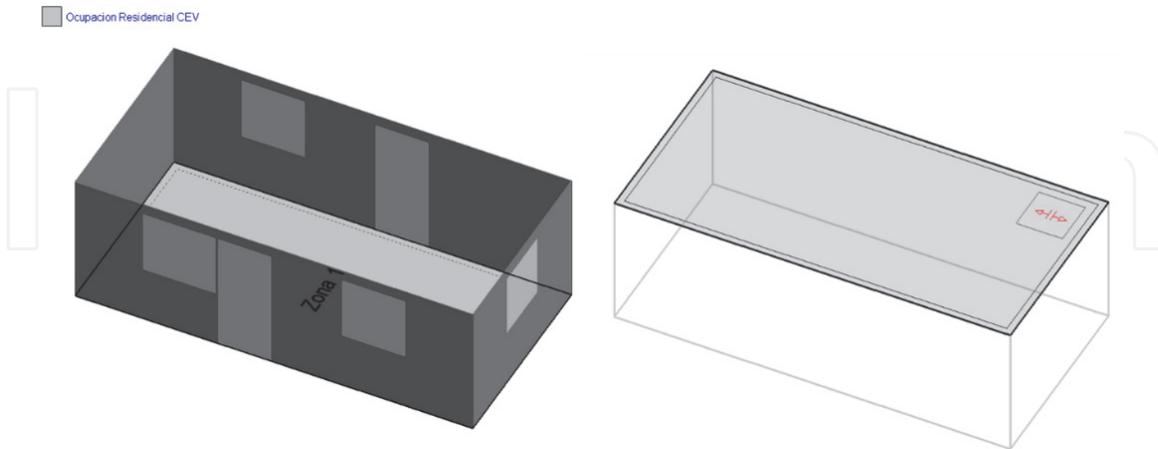


Figure 5. Computational thermal model in Design Builder program. Own elaboration.

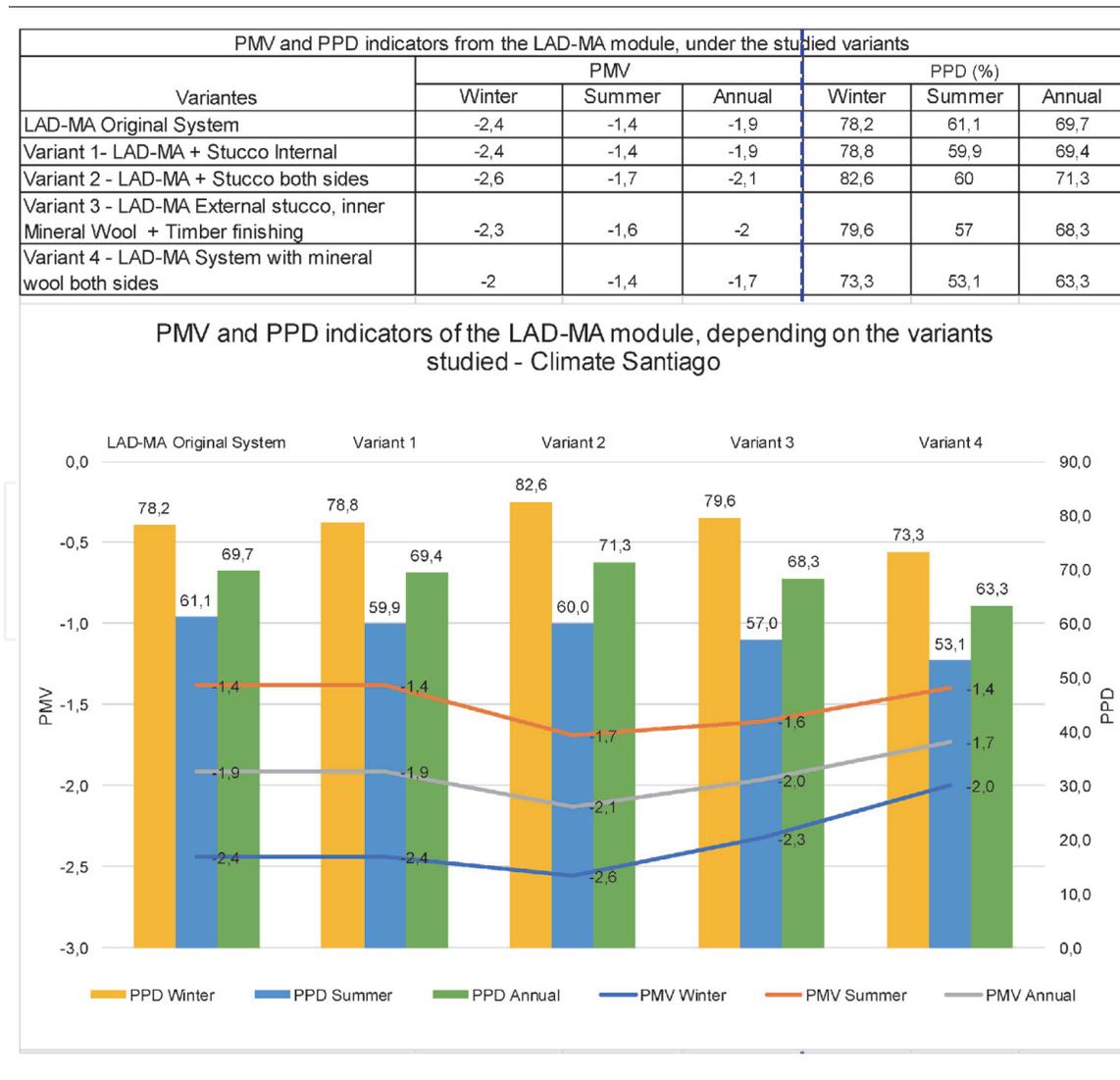


Table 8. PMV and PPD indicators of the LAD-MA module, depending on the variants studied. Own elaboration.

structure that serves to support some thermal insulator in plate or roll format, on which a wooden or similar coating is installed.

4.3 Analysis of the potential for improvement in the PMV and PPD indicators according to the wall variants LAD-MA

The construction variants are represented below, through a dynamic thermal calculation model developed in the DesignBuilder 6.2 program, using the Energy Plus calculation engine. This representation aims to approach the thermal results obtained empirically in the LAD-MA homes built through a representative digital model of the LAD-MA architectural module. For the analysis, an adiabatic condition was considered for the roof of the module. **Figure 5** shows the model represented.

The analysis is carried out based on the climate of Santiago and focuses on the thermal comfort results of the module and the PPD and PMV indicators for each variant studied. **Table 8** presents the results obtained from these indicators, considering the winter and summer periods and the annual total.

It is observed that the representative thermal model of the original LAD-MA system presents 69.7% of the time in thermal discomfort in the annual period. It should be noted that the discomfort conditions increase when applying stucco on both sides (variant 2). The solution with the greatest impact on reducing annual thermal discomfort is clearly variant 4, consisting of the incorporation of thermal insulation on both sides of the wall, with which the time in thermal discomfort is reduced from 69.7% to 63.3%. It is worth highlighting the positive effect of the thermal insulation solution during the summer period, which reduces the transfer of heat into the home, reducing, in turn, the time in thermal discomfort of 61.1% in the home with the LAD system. -Original MA, at 53.1% when thermal insulation is added on both sides.

5. Conclusions

The study allowed observing the performance and thermal comfort of social housing built 30 years ago, which were designed to respond to urgent needs of habitability of vulnerable families in camps, to provide a basic infrastructure, expandable over time, based on the needs of each family, concluding that they fulfilled the objective for which they were built in their time. It is worth mentioning that in this context, the thermal comfort of the dwellings was a secondary aspect given the various shortcomings and challenges of the beneficiary families, who over time put their economic efforts into expanding and providing new spaces to their dwellings. This is clearly observed in the homes studied, which prioritize new spaces over construction quality and the thermal envelope. However, the study also shows that by building new spaces, the beneficiaries have been undermining the performance of the house, from the point of view of its natural lighting and ventilation.

It is observed that the monitored LAD-MA homes present thermal comfort standards below international standards and that they currently do not meet the thermal envelope requirements for homes in the country. Given the above, constructive solutions with low economic impact were studied, using computational methodologies, which could be progressively implemented in the wall construction system, to comply with local regulations and gradually improve interior comfort conditions. In this case, it is concluded that the incorporation of thermal insulation layers in the original wall is the best alternative to reduce the hours of discomfort

inside the home. This involves installing an E.I.F.S system on both sides or installing a clad secondary structure, which serves as a support for the insulation material.

Taking into account what has been described above, and considering the need to implement self-construction programs that help solve the habitability problems in contemporary irregular settlements, it is of utmost importance to emphasize technical assistance that manages to transfer capacities to the beneficiaries in terms of construction and thermal conditioning, so that the beneficiaries can focus their self-construction efforts and progressively improve their thermal comfort standards, achieving healthier indoor environments.

IntechOpen

IntechOpen

Author details

Rodolfo Jiménez Cavieres*, Javier Carrasco Eade and Camilo Valdebenito Monsalve
Universidad de Santiago de Chile, Chile

*Address all correspondence to: rodolfo.jimenez@usach.cl

IntechOpen

© 2021 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Rugiero A. M. Experiencia chilena en vivienda social. 1980-1995. *Revista Invi.* 1993;13;35
- [2] Hidalgo R. La vivienda social en Santiago de Chile en la segunda mitad del siglo XX: Actores relevantes y tendencias espaciales. *EURE.* 2005; 31; 939:108-112. DOI:10.4067/S0250-71612005009300009
- [3] Taller Norte. Descripción del sistema constructivo LAD-MA. 1990
- [4] MINVU. Minvu presenta actualización de catastro y campamentos llegan a 802 a nivel nacional [Internet]. 2019. Available from: <https://www.minvu.cl/noticia/noticias/minvu-presenta-actualizacion-de-catastro-y-campamentos-llegan-a-802-a-nivel-nacional/> [Accessed: 2019-12-03]
- [5] Lopez Morales E, Pineda Flores P, Orosco Ramos H. Inmigrantes en asentamientos en Chile: ¿un mecanismo de integración o efecto de exclusión?. *Revista INVI.* 1994;33;94. DOI:10.4067/S0718-83582018000300161
- [6] MINVU. Estándares de Construcción Sustentable para Viviendas de Chile, Tomo II, Energía [Internet]. 2018. Available from: <https://csustentable.minvu.gob.cl/wp-content/uploads/2018/09/ESTANDARES-DE-CONSTRUCCION-SUSTENTABLE-PARA-VIVIENDAS-DE-CHILE-TOMO-II-ENERGIA.pdf> [Accessed: 2019-11-07]
- [7] MINVU. Ordenanza General de Urbanismo y Construcciones [Internet]. 2020. Available from: <https://www.minvu.gob.cl/elementos-tecnicos/decretos/d-s-n47-1992-ordenanza-general-de-urbanismo-y-construccion/> [Accessed: 2020-11-010]
- [8] MINVU. Manual de Procedimientos de Calificación Energética de Viviendas en Chile [Internet]. 2018. Available from: <https://csustentable.minvu.gob.cl/wp-content/uploads/2018/03/MANUAL-DE-PROCEDIMIENTOS-CALIFICACION-ENERGICA-DE-VIVIENDAS-EN-CHILE.pdf>. [Accessed: 2019-12-08]