HS

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BANCA INFINITA

Durante los primeros noventa días de la pandemia Covid-19, en estado de confinamiento, compulsivamente comencé a dibujar y realizar acuarelas -a partir de fotografías, imágenes de Google Earth y algo de imaginación- de aquellos lugares de Concepción y la región del Bío Bío que están ahí, quedaron ahí y que quería memorizar. Cerca de cincuenta bocetos, dibujos y acuarelas que retratan la arquitectura contemporánea de nuestra región y distintos paisajes urbanos, como también los días de confinamiento. Algunos de estos dibujos son el Consorcio (Browne, 2004)/ Día 7; Pabellón CCP (Rep. Portátil, 2016)/ Día 22; Barrio Cívico Boca Sur (Radic, 2017)/ Día 23; Aiwiñ (Sáez, 2018)/ Día 25; Memorial 27F (Soza y Atanasio, 2013)/ Día 28; Edificio STV (Berríos, 2014)/ Día 31; EL Chiflón N°4 (1880)/ Día 34; Edificio L26 (Belmar y Game, 2014)/ Día 37; Casa Poli (PvE, 2005)/ Día 41; Museo Pewenche (Lobos Arquitectos, 2010)/ Día 43; Vivero Horcones (Aravena, 2015)/ Día 50; Parque Lebu (Soto y equipo, 2015)/ Día 51; Teatro Regional (Radic, Castillo y Medrano, 2018)/ Día 68; y Escuela de Arquitectura de la Universidad del Bío-Bío / Día 72; entre otros.

Al tanto de estos dibujos, Claudia Muñoz, editora de HÁBITAT SUSTENTABLE, me invita a publicar alguna de estas imágenes como portada del actual número de la revista. Gratamente sorprendido por esta inusual invitación, otra vez, como impulso irresistible fue pensar en una portada con varios de estos dibujos o a lo menos con los más representativos de la ciudad de Concepción, pero finalmente decidí proponer una sola imagen que reflejara el espíritu de la revista y los tiempos que corren de pandemia, se trata de la Banca Infinita (2018), una pequeña intervención en el Parque Botánico Alejandro Merino en el Liceo Enrique Molina de Concepción y realizada por la oficina de los arquitectos Carolina Catrón y Ricardo Azocar. Proyecto que evoca tres ideas que me parece destacar. La primera es la continuidad histórica de la propuesta, en términos que reconoce y revaloriza un espacio significativo para la comunidad educacional y la ciudad; segundo, la simpleza de la arquitectura y su materialidad que parece pertenecer al lugar, en armonía con su entorno, acaso la metáfora de la propia existencia del ser humano y su devenir; tercero y final, la geometría circular del proyecto sintetiza un lugar de encuentro por antonomasia, que en estos tiempos de confinamiento por el Covid-19, como decía al inicio de esta nota, está ahí, quedo ahí y probablemente pasará mucho tiempo para volver a re-encontramos en ese lugar o simplemente en la ciudad.

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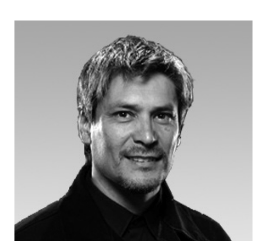

Dra. Claudia Muñoz Sanguinetti
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EDITORIAL

I write this Editorial on day 104 of the Covid-19 lockdown in Chile; a complex existential and painful scenario that nobody could foresee or and that nobody can be indifferent about. Without a doubt, we do not know how much longer we have before returning to a "new normal", but however long it may be, no one should be the same person as when this all began.

This pandemic process not only makes us face how fragile our existence is as a species, but it also places us in the sublime essence of living, relieving with it the sense of sanity, reappraising our homes, encouraging us to consume more consciously and to take care of ourselves as a tribe, just as our ancestral cultures did, where the elderly and children require more attention and protection. This is certainly a favorable scenario for those of us who have been fortunate enough to experience this profound process in a protected way, as this pandemic, just like those of previous centuries, has again uncovered the enormous social divide there is, which make access to the possibility of a more dignified life unattainable for most people. Covid-19 has made us feel smaller on surprising us amid the 21st century, in a scientific and advanced technological era, which we thought had all the answers to everything (even the idea of inhabiting other planets), and showing us how insignificant we are. Thus, reflecting about our current and future condition as a specifies, and about how we relate to each other socially, with the biosphere and our built environment, is crucial. This is a unique opportunity that we should take and nurse, both at a human and at a disciplinary level.

Despite this adverse and uncertain prospect, HS' editorial team continues with a systematic work to contribute to the scientific and academic community with subjects that provide a significant contribution to the built environment and the sustainable habitat, which undoubtedly will be addressed in the future from perspectives and studies arising from the times of Covid-19.

This issue, 10 N1, brings a rich and valuable repertoire of articles from Spain, Mexico and Argentina, that contribute to areas that are so relevant for HS's editorial line like those focused on energy poverty, thermal attributes of construction elements with lower environmental impact, energy efficiency, tools to efficiently use water resources and BIM tools for bioclimatic design, all of them being the results of relevant international research projects.

I would like to end this editorial with a message of optimism, sharing an excellent piece of news for the HS community: as of March, this year, Habitat Sustentable Journal has been accepted in the *SCOPUS* database. This is amazing news that tells us we are on the right path and that encourages us to keep moving forward and improving.

As in every issue, it is necessary to thank the entire HS community that made this all possible: all the authors, reviewers, editorial committee, VRIP-UBB, FARCODI´s Dean, ANID and the esteemed editorial team who issue by issue contribute with their commitment and their skills: Dr. Olga Ostria in correction of style, Ignacio Sáez in diagramming, Jocelyn Vidal in editorial production and Karina Leiva in ITsupport.

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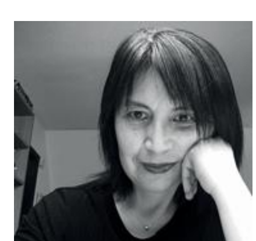

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MIDIENDO LA POBREZA ENERGÉTICA. UNA REVISIÓN DE INDICADORES

MEASURING FUEL POVERTY. A REVIEW OF INDICATORS

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RESUMEN

Identificar aquellos hogares en una situación de vulnerabilidad a la pobreza energética es el primer paso para abordar una problemática social a nivel mundial asociada a la falta de servicios energéticos mínimos, conocido por los términos anglosajones–Fuel Poverty y Energy Poverty, FP y EP, respectivamente. El concepto FP, definido en el Reino Unido como "la incapacidad para obtener un adecuado confort térmico debido a la ineficiencia de la vivienda", mientras que el concepto EP refleja la imposibilidad de tener acceso a un servicio energético mínimo en países en desarrollo. La falta de un consenso a la hora de definir una ruta clara ha originado que algunos países no la reconozcan como un problema social. La investigación se basa en la revisión de ambos conceptos, a través del análisis conceptual de los términos FP y EP, revisión de indicadores utilizados, estudio de la capacidad de los indicadores para identificar y proponer soluciones a la problemática. Todo ello en relación a los objetivos incluidos: infraestructuras disponibles, eficiencia energética, pobreza social y económica, bienestar y salud social. El resultado es la revisión desde una perspectiva técnica en el sector residencial que ayude a desarrollar soluciones que cubran las carencias encontradas.

Palabras clave
eficiencia energética, exclusión social, higiene, pobreza

ABSTRACT

Identifying those households in an energy poverty vulnerability situation is the first step towards addressing a global social problem associated with the lack of minimum energy services, known as Fuel Poverty and Energy Poverty, FP and EP, respectively. The FP concept is defined in the United Kingdom as "the inability to obtain adequate thermal comfort due to the inefficiency of the house", while the EP concept reflects the impossibility in developing countries of having access to a minimal energy service. The lack of consensus when defining a clear path has meant that some countries have not recognized it as a social problem. The research is based on the review of both concepts, through the conceptual analysis of the terms, FP and EP, a review of indicators used, and the study of the capacity of the indicators to identify and propose solutions to the problem. All this regarding the objectives included: available infrastructures, energy efficiency, social and economic poverty, well-being and social health. The result is a review from a technical perspective in the residential sector, that helps develop solutions that cover the deficiencies found.

Keywords
energy efficiency, social exclusion, hygiene, poverty

INTRODUCTION

Energy Poverty (EP), commonly conceived as the inability of a home to satisfy a minimum amount of energy services for its basic needs (Castaño-Rosa, Solís-Guzmán, Rubio-Bellido & Marrero, 2019) like, for example, keeping the dwelling in climatization conditions that are suitable for health (Sokołowski, Lewandowski, Kiełczewska & Bouzarovski, 2020), has stirred the interest of governments and political parties, thus achieving a greater public impact. There have been several definitions and indicators developed by some countries to analyze the situation of the most vulnerable homes, including those of the United Kingdom, Ireland, France, Slovakia, Italy or Austria (Thomson, Snell & Liddell, 2016). It is estimated that almost 20% of the entire European Union population would fall into this category ((EnAct), n.d.). However, there is no official common concept in Europe that allows analyzing the situation of energy poverty in member states and that could facilitate comparing the results obtained, to identify effective measures for an eventual eradication.

The European Commission (EC) uses three basic criteria to evaluate an EP situation: the inability to keep dwellings suitably conditioned, the delay in paying utility bills and living in unhealthy dwellings (leaks in roofs, walls or floors, appearance of mold and rot). This information was collected through the EU Energy Poverty Observatory (European Commission, 2018). The concept of EP is not just the difficulty of keeping a dwelling at a suitable temperature in the different seasons of the year, or to face the payment associated to a given energy consumption or to finance a high price of the energy consumed, but rather is a multidimensional concept that has been evolving. It is currently being defined as a situation that can deprive homes of not just heating or cooling, but also of hot water, electricity and other essential household needs (Bouzarovski & Petrova, 2015).

Currently FP and EP are the two main concepts used to identify one of the major social problems associated to the lack of minimal energy services in homes to cover their basic needs, like food, personal hygiene, comfort areas, safety at home, etc. Ultimately, minimal energy services that guarantee health and social wellbeing, regardless of the area where the dwelling is located, their social and economic situation, health or country of origin (foreigners). The main goal of this work is to review the most used international projects and works to effectively identify those homes at risk or those that are already in a FP or EP situation.

METHODOLOGY

To analyze the concept of EP, the state of the matter needs to be developed from an international perspective, beginning by 1) the analysis of the terms: Energy Poverty (EP) and Fuel Poverty (FP); continuing with 2) the revision of the indicators used to analyze an energy poverty situation; and ending with 3) the identification of the ability of the indicators to solve the issue regarding the proposed goals: available infrastructures, energy efficiency, social and economic poverty, social welfare and health, etc. These goals are set out based on the energy vulnerability factors defined by Bouzarovski, Petrova and Tirado-Herrero (2014). The result is a revision of EP and FP concepts from a technical perspective related to the residential sector, which will allow developing solutions that cover the shortfalls found.

On examining the indicators used to analyze an energy poverty situation, these are grouped into two categories: those based on expenses and incomes of the home and those based on perception surveys and statements of homes. In addition, there are indicators and methodologies that describe the most vulnerable consumers, like the econometric analysis, the overcrowding of shared dwellings, thermal comfort and those based on the energy efficiency rating of dwellings. The indicators gathered in Table 1 will be discussed in the following sections of the article.

REVIEW OF THE RELATED INDICATORS

To analyze EP, it is necessary to develop the state of the matter from an international perspective and, in particular, the analysis of the terms: Fuel Poverty (FP) and Energy Poverty (EP). This article analyzes and reviews the concepts of EP and FP, as well as the most used available indicators, given their capacity to identify homes at risk of EP starting from a technical perspective related to the residential sector. The concept of FP was introduced by Isherwood and Hancock in 1979 after the forced increase of energy prices, due to the oil crisis (1973-1974). However, it is not until 1991 when Brenda Boardman (2010) defines the concept of FP for the first time, referring to the United Kingdom as: “the inability to obtain a suitable thermal comfort due to the inefficiency of the dwelling”, establishing the possibility that those who are energy poor, do not have to be economically so.

Currently, there are different official definitions of FP developed in countries like the United Kingdom,

Category	Type of Evaluation
Based on home's expenses and incomes	Energy consumption expense above 10% of the family income (10%) (Boardman, 2012)
	Energy consumption expense over double the national average (2M) (Schuessler, 2014)
	Family income below the Minimum Income Standard (MIS) (Moore, 2012)
	Family income below the monetary poverty threshold and energy consumption expense above the established threshold (LIHC) (Hills, 2012)
	Family income after fuel cost below the established threshold, where the average fuel cost of the analyzed area is excluded (AFCP) (Romero, Linares, López Otero, Labandeira & Pérez Alonso, 2015)
	Absolute energy consumption expense below the established threshold (HEP) (Rademaekers et al., 2016)
Based on surveys of perceptions and statements of the homes	Possibility of a home to maintain a suitable temperature during the cold season (European Commission, 2014)
	Delays in paying energy bills appear (European Commission, 2014)
	Deficiencies in the dwelling appear, like leaks, damp walls, floors, roofs or foundations, or rot in floors and window or door frames (European Commission, 2014)
	Ability of a home to keep a fresh temperature during summer months (Spanish National Statistics Institute, 2014)
Based on econometric analysis	Influence of given demographic, socioeconomic and physical conditions on suffering EP (Legendre & Ricci, 2014)
Based on thermal comfort	Percentage of hours where the residence is in a thermal comfort situation (Sánchez-Guevara, Neila Gonzalez & Hernández Aja, 2014)
Based on dwelling's energy efficiency	Influence of the quality of the dwelling (energy consumption) with an EP situation. Poor quality of the dwelling causes a higher energy consumption and, at the same time, an EP situation (Fabbri, 2015)decision-makers, technicians, researchers, etc. In Italy, a strategy to solve fuel poverty involves action in order to reduce energy prices, the AEEG (Italian regulatory authority for electricity gas and water
Based on combined criteria	Vulnerable Home Index. Allows assessing a home, whether identified or not in a situation of energy poverty, identifying which variable requires greater attention: economic, energy or thermal comfort. It makes it possible to include the economic and technical viability of energy retrofitting (Castaño-Rosa, Solís-Guzmán & Marrero, 2018)and assesses the home vulnerability situation regardless of whether or not it is in fuel poverty by using three dimensions: monetary cost, energy and thermal comfort. The monetary dimension analyses vulnerability in relation to the available net income to face everyday life. The energy variable assesses the vulnerability related to the constructive characteristics of the dwelling. Finally, the introduction of the thermal-comfort variable enables the evaluation of the vulnerability related to the inner temperature of the dwelling and its perception by occupants. The combination of the different resulting values in each dimension and its relationship to the quality of life of occupants establishes a hierarchy of vulnerable levels. As a result, a multi-dimensional index is defined which relates technical aspects (characteristics of the dwelling
	Fuel Poverty Potential Risk Index. Allows assessing the risk of a home from suffering EP, in relation to the place their dwelling is located in the context of Chile, using the adaptive comfort model (Castaño-Rosa, Solís-Guzmán & Marrero, 2018)and assesses the home vulnerability situation regardless of whether or not it is in fuel poverty by using three dimensions: monetary cost, energy and thermal comfort. The monetary dimension analyses vulnerability in relation to the available net income to face everyday life. The energy variable assesses the vulnerability related to the constructive characteristics of the dwelling. Finally, the introduction of the thermal-comfort variable enables the evaluation of the vulnerability related to the inner temperature of the dwelling and its perception by occupants. The combination of the different resulting values in each dimension and its relationship to the quality of life of occupants establishes a hierarchy of vulnerable levels. As a result, a multi-dimensional index is defined which relates technical aspects (characteristics of the dwelling
	Energy Poverty Vulnerability Index. Applied in Portugal, it provides a spatial analysis of EP by combining several indicators: socioeconomic, climate, energy (Gouveia, Palma & Simoes, 2019)

Tabla 1. Summary of the measures-indicators analyzed.
Fuente: Preparation by the authors.

France, Ireland and Slovakia (Thomson *et al.*, 2016), as well as a diverse set of indicators for its analysis, none of which are officially recognized by the EC. However, while seeking to mitigate this issue, in the Energy Roadmap 2050 strategy (European Commission, n.d.) implemented by the Commission, the vulnerable energy consumer is defined as the family supplied by electricity and formed by people whose age, state of health and low income present a risk of social exclusion, as well as the risk of the supply being cut, and also being benefitted by social protection measures to have the minimum electricity supply required (Peneva, 2016).

The concept of EP has gained relevance thanks to diverse research projects (Bouzarovski y Petrova, 2015; Shonali Pachauri, 2004). This is associated to a lack of energy supply, caused by problems related to distribution infrastructures. The use of the EP concept has allowed identifying areas with limited and old infrastructures and those in an inefficient state, like those of historic hubs, rural areas and/or social exclusion areas, which, together with their limited economic activity, continued depopulation and loss of investor attraction, have led to a continued abandonment, resulting in their residents having a worse quality of life.

A good example of EP is the study carried out in Hungary (Tirado Herrero & Ürge-Vorsatz, 2012), where the buildings analyzed had an excessive expense in energy consumption, complications to change supplier or fuel type due to technical and institutional restrictions, or the impossibility of reducing heating expenses through individual energy efficiency actions. This type of situations causes delays in or the impossibility of paying energy bills, supplies being cut by the energy supplier or the reduction of the use of other needs and basic services, and is mainly associated to poor countries, located especially in central and southern America, Africa and Asia (Bazilian, Sagar, Detchon & Yumkella, 2010; Birol, 2007).

Beyond the notions of FP and EP, the reality is that both define a situation where a home cannot satisfy its basic energy needs (like heating, cooling, lighting or cooking) (Gatto & Busato, 2020), whether this is because of a material or a social matter. From here arises the current trend to identify, more than an EP or FP situation, the vulnerable consumer, which calls upon the concepts of "resilience" – capacity to adapt on facing an adverse situation or status - (Bouzarovski *et al.*, 2014; O'Brien & Hope, 2010; Welsh, 2014) and "precariousness" – lack of sufficient resources or means - (Paugan, 1995). A review is made below of the most internationally recognized and used EP indicators (ASSIST 2GETHER, 2018; Herrero, 2017; Rademaekers *et al.*, 2016; Meszerics, 2016; Thomson *et al.*, 2016), using the European Energy Poverty Observatory (European Commission, 2018), the Mexican Energy Poverty Observatory ("Observatorio de Pobreza Energética en México," n.d.), and the Chilean Energy Poverty Network ("Red de Pobreza Energética (RedPE), Universidad de Chile", 2017) as a base. The analysis of weaknesses and threats of the indicators is made starting from the energy vulnerability factors defined by Bouzarovski et al. (2014).

10% INDICATOR

This indicator defines that a home is in energy poverty if it has to dedicate more than 10% of its income to pay for suitable energy services (like heating, cooling, lighting or cooking) (Boardman, 2010). Defined by Boardman, it is simple indicator, easy to communicate and relatively versatile, which allows establishing a clear political goal. The criticism comes fundamentally from, on one hand, its excessive sensitivity to energy prices, underestimating the scale of the problem when prices are low and overestimating it when these are high, and, on the other, from the arbitrary nature of fixing the threshold at 10%, a threshold which was justified given the socioeconomic situation of the United Kingdom at the beginning of the 90s. Experience of years of application has shown that this 10% threshold included a significant number of homes that were not energy poor, like high-income homes with inefficient houses.

2M INDICATORS

These include: double the median energy expense of the home, double the mean energy expense of the home, double the median energy expense percentage of the home and double the mean energy expense percentage of the home (Schuessler, 2014). Only the third of these indicators has its justification in the pioneering works of Boardman, where it was detected that the median energy expense percentage in respect to the total incomes in British homes was around 5% in 1988. After this, the assessment provided by these indicators indicates that "A home is under energy poverty if, out of their income, more than double the median energy expense percentage has to be used to pay for suitable energy services" (Schuessler, 2014, p. 11). The EP threshold is established in relation to the national mean, making it possible to recalculate it every year. In this sense, it is not a static measurement. As strong points of the indicator, one can highlight: that high-income homes are rarely included as energy poor and it considers the specific features of the country.

MINIMUM INCOME STANDARD (MIS)

MIS, defined by Moore (2012), considers the minimum income of a home as that which allows its members to opt for the opportunities and choices that, at the same time, make an active integration in society possible. The project, "A minimum income standard for Britain", developed by Bradshaw et al (2008),

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represents a good example of what this methodology intends to do. The first thing to underline is that it is limited project, as it establishes an MIS that is always associated to a concrete social collective and it is the people chosen as representatives, who come from diverse social collectives, who will take part in the entire deliberation process and in the preparation of the conclusions. Defining what is understood by an "acceptable minimum income" is the main limitation. This project is based on the UN's Convention of Human Rights and the works of a committee of experts in the US who reviewed the family budgets in 1980, and who developed the concept of Prevailing Family Standard. To keep in mind the particularly vulnerable collectives, a set of socioeconomic parameters of the home were established: the makeup of the home, employment situation, disability, health, ethnicity and accessibility. In this way, "a home would be in a situation of energy poverty if its total income minus its energy costs does not exceed the MIS corresponding to the characteristics of their home" (Moore, 2012, p. 21).

LOW INCOME HIGH COST (LIHC)

Starting from the studies made by Hills (2012), a home is considered as energy poor if its income is below a given poverty threshold and when its energy expenses are above another energy expense threshold. For this, it is necessary to establish both thresholds: the first is defined at 60% of the equivalent income median after discounting the expenses of the dwelling and the energy expenses. For the second threshold, the equivalent energy expense median calculated over all homes was used (see Figure 1).

The strong point of this indicator is based on the possibility of distinguishing between EP and general poverty, clearly reflecting that EP depends on the income of the home. In the same way, the use of this indicator leaves outside of a EP situation, those groups considered as the most vulnerable (elderly, chronically ill, disabled and small children) (Middlemiss, 2016), since the home defined as energy poor is formed by some low income families and an energy inefficient dwelling. This leads to an improvement of the energy efficiency of the dwelling is considered as the main measure to reduce EP, forgetting that low income homes will continue, to a certain extent, having problems to pay their bills and experiencing health issues on living with an inadequate comfort.

AFTER FUEL COST POVERTY (AFCP)

Based on the initial MIS indicator proposed by Moore, the development made by Heindl (2015) and the applications made in Spain by Romero et al. (2015) and in the United Kingdom by Hills (2012), consider that a home is in energy poverty when its income, once the housing and domestic energy expenses are discounted, falls below the minimum income standard (adjusted to the size and makeup of the home by means of the modified OECD equivalence scale). In short, this approach is based on the existence of a minimum income level that guarantees the wellbeing of a person, making it possible that a home is not excluded from society it is part of (social exclusion) by an economic factor.

HIDDEN ENERGY POVERTY INDICATOR (HEP)

HEP identifies those homes whose energy expense is too low, in such a way that where there will be an EP situation if the total energy expense is below the median energy expense (Rademaekers *et al.*, 2016).

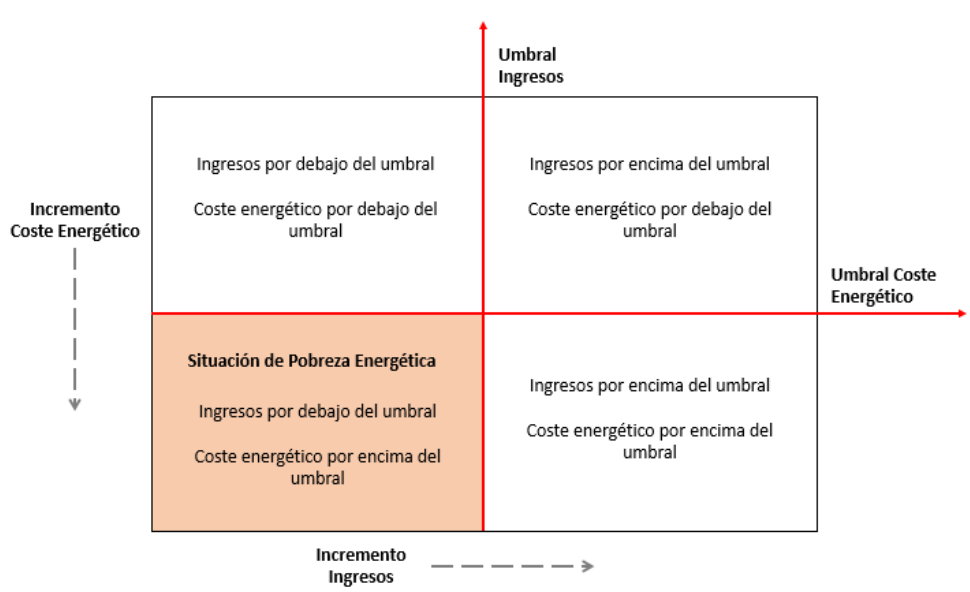

Figure 1. Low Income High Cost (LIHC) Indicator.
Source: Prepared using (Hills, 2012).

This indicator allows distinguishing those homes whose income does not allow having a minimum energy consumption on having to prioritize food expenses, responding to the effect known as "heating or eating". However, it is only valid if the absolute monetary expense is used, as generally high-income homes spend more on energy in absolute terms, but less as a proportional part of their income. On the contrary, homes with a very low expense regarding their income, on having elevated incomes, would be considered in an EP situation. Likewise, the use of the expense in absolute terms allows providing an absolute assessment of the consumption of energy services made, identifying those homes that have an expense below normal levels, abstaining from a basic consumption level. Among its limitations, it is necessary to mention HEP does not consider the characteristics of the dwelling, or its energy efficiency.

PERCEPTION AND STATEMENT SURVEYS OF THE HOMES

The goal of the European Union's survey about income and living conditions (EU-SILC) (European Comission, 2014) is providing a reference source about comparative statistics in Europe about income and social exclusion. From all the aspects of the daily lives of homes that this survey analyzes, the three questions generally used for the EP analysis are related to: inability of a home to maintain a suitable temperature during the cold season; delays in paying bills; and deficiencies in the dwelling, like leaks, damp walls, floors, roofs or foundations, or rot in the floor, window or door frames.

The perceptions and statements of the home surveys (ECV) (Spanish National Statistics Institute, 2014; Tirado Herrero, Jiménez Meneses, López Fernández, Martín Gracía & Perero Van Hove, 2014) study the warm weather situation experienced in countries like Spain, made by the National Statistics Institute, enabling an assessment of the living conditions of people in excessively hot periods, on asking about the ability of a home to maintain a fresh temperature during summer months. The main weakness here is based on its subjective nature, that is susceptible to creating uncertainty in the results.

In brief, it must be clarified that these indicators were not created to analyze the problem associated to EP, so it is necessary to include new variables that allow establishing a difference between the problems associated to the impossibility of a minimum energy consumption and those related to the features of the dwelling or the heating systems.

ECONOMETRIC ANALYSIS

The goal of this analysis is explaining one variable starting from others, as well as the possible disturbances this may be subjected to, analyzing its behavior. Through this, it is intended to identify the collectives that are in a situation of greater vulnerability to experiencing an EP situation, which is why they do not identify an EP situation in themselves. The studies of Legendre & Ricci (2014) for France and of Minaci, Scarpa and Valbonesi (2014) for Italy are good examples of this type of analysis, where the goal is to quantify the influence that given demographic, socioeconomic and physical conditioning factors exercise on the likelihood that a home, that a priori is not in energy poverty, falls below its threshold.

The models developed by Walker, McKenzie, Liddell & Morris (2012) and Walker, Liddell, McKenzie & Morris (2013), which introduce techniques based on Geographic Information Systems to prepare an EP risk, stand out, evaluating: family size, electricity consumption, occupation level, price of the fuel used, etc. (Walker, McKenzie, Liddell y Morris, 2014).

THERMAL COMFORT

Thermal comfort can be understood as "that condition of the mind which expresses satisfaction with the thermal environment" (BS/EN 15251:2007, n.d.). The inclusion of the vulnerable consumer has led to the study of the thermal comfort of the dwelling, mainly due to its close relationship with people's health (Butcher, 2014; Kolokotsa & Santamouris, 2015), as well as its capacity to permit a reduction of the energy consumption of the dwelling (Hatt, Saelzer, Hempel & Gerber, 2012; Martínez & Kelly, 2015; Van Hooff, Blocken, Hensen & Timmermans, 2015), given that a suitable comfort in the dwelling means, in fact, the control of said energy consumption (Vilches, Barrios Padura & Molina Huelva, 2017).

The evaluation of thermal comfort in a dwelling is very complicated (der Perre, Ness, Thoen, Vandenameele & Engels, 2002; Heijs & Stringer, 1988; M. Bluyssen, 2014), mainly because of the great diversity of factors involved (Bienvenido-Huertas, Rubio-Bellido, Pérez-Fargallo & Pulido-Arcas, 2020). In this sense, it is worth highlighting the work of Sánchez-Guevara et al. (2014), where they use the comfort evaluation of dwellings as an indicator of the most vulnerable homes. Starting from the analysis of data obtained from the simulation, and using adaptive models to evaluate thermal comfort (ASHRAE (2013) ANSI/ASHRAE Standard 55-2013, 2013)(BS/EN 15251:2007, n.d.), they identify the number of hours that the home under study is outside

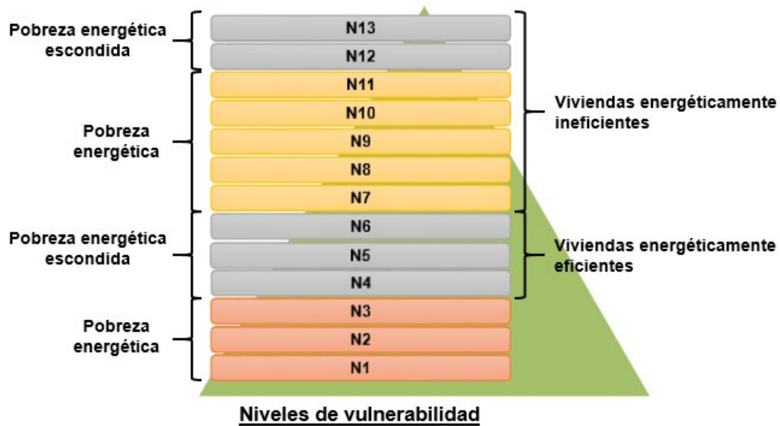

Figure 2. Vulnerability levels from the Index of Vulnerable Homes (IVH).
Source: Castaño-Rosa (2018, p. 55).

the established comfort zone. Those homes with a higher number of hours outside the comfort zone will be considered as the most vulnerable.

ENERGY EFFICIENCY OF THE BUILDING

Due to the relationship established between the energy efficiency of the dwelling, represented by its energy consumption and the EP, there are several researchers who promote reducing this situation by reducing the energy consumption of the dwelling (Braubach & Ferrand, 2013; Rosenow, Platt & Flanagan, 2013; Boardman, 2012). The case carried out in France by Florio and Teisser (2015) follows this line, where an energy efficiency certificate is prepared that, starting from the estimated energy expense of the dwelling, allows evaluating the characteristic housing stock in that country. Another case is the one made in Italy by Fabbri (2015), where an EP indicator is proposed, based on the energy performance of the dwelling using three variables: energy efficiency certification database, monitoring of actual energy consumption and the energy performance standard of the dwelling based on its age. The relationship established between the energy consumption data of the dwellings and the low-income homes (excessive energy consumption and low income), makes it possible to point out the homes in an EP situation that do not have enough income to carry out energy efficiency measures, even when receiving economic incentives. Recently, Porras-Salazar, Contreras-Espinoza, Cartes, Piggot-Navarrete & Pérez-Fargallo (2020), in their latest study on social dwellings in central-southern Chile, demonstrate that a third of those interviewed cannot maintain an adequate temperature in their home and, as a result, have respiratory problems and higher medical expenses. It concludes that improving the energy efficiency of these dwellings to thus reach a suitable temperature during a greater period, would allow reducing the number of families with respiratory issues, and the associated medical expenses.

VULNERABLE HOMES INDEX

The Index of Vulnerable Homes (IVH) (Castaño-Rosa *et al.*, 2018) has been proposed in a combination of the indicators described in the previous sections. This allows making an analysis of the vulnerability situation regarding its consequences and intensity, as well as the possibility of evaluating the optimal energy retrofitting measure to improve the quality of life of the homes. Figure 2 graphically shows the IVH composition: 13 levels (N1: level 1 of vulnerability and least unfavorable; to N13: level 13 of vulnerability and most unfavorable), and the equivalence to a situation of energy poverty or hidden energy poverty. Its latest application, in six neighborhoods in the Northern Hub of Seville, that received financing from the Ministry of Andalusia to carry out an energy efficiency improvement intervention, shows how it is possible to estimate both the cost of the National Health Service associated to an energy poverty situation, and the saving achieved after an energy retrofitting intervention (Castaño-Rosa, Solís-Guzmán & Marrero, 2020). IVH has been adapted and applied to the British context (Castaño-Rosa, Sherriff, Thomson, Guzmán & Marrero, 2019), suggesting that there still is an important margin for improvement in the definition of indicators. IVH is a new tool for the analysis and identification of homes vulnerable to experiencing EP, providing an exhaustive analysis in the identification of the different vulnerability situations that a home may experience (Castaño-Rosa, Sherriff, Solís-Guzmán & Marrero, 2020; Castaño-Rosa *et al.*, 2019).

FUEL POVERTY POTENTIAL RISK INDEX

In order to evaluate the risk a home has of suffering EP, depending on the location where its dwelling is, in the context of Chile, the Fuel Poverty Potential Risk Index (FPPRI) (Pérez-Fargallo *et al.*, 2017) is added. The use of the adaptive comfort model allows, starting from the application of the FPPRI, to consider the relationship between the occupants and the dwelling in the assessment of the risk of suffering from EP, especially for template climates like the central regions of Chile. The use of adaptive comfort covers, in part, the subjective aspect of the interactions of the occupants with the dwelling, reducing the possibility of overestimations. However, the main limitation of the FPPRI is that it must be applied in the design phase of the dwelling and not in already occupied homes. In this context, it is worth highlighting the work done by Bienvenido-Huertas et al. (2020) where the application of the FPPRI is carried out in the three most populated cities of Chile (Santiago, Concepción and Valparaíso), to predict the risk that a home would have of experiencing energy poverty in social housing, depending on the socioeconomic characteristics of the occupants and the technical characteristics of the dwelling (Bienvenido-Huertas, Pérez-Fargallo, Alvarado-Amador & Rubio-Bellido, 2019). This work shows the potential of FPPRI to reduce the risk of a home of suffering an EP situation in the near future.

ENERGY POVERTY VULNERABILITY INDEX

The energy efficiency of dwellings, the possibility of homes to implement measures and the difficulties in heating and/or cooling dwellings, are the different aspects analyzed by the Energy Poverty Vulnerability Index (EPVI), applied in Portugal (Gouveia *et al.*, 2019). In the case study defined for its application, where 3092 districts were analyzed, the potential of EPVI to identify the areas with the highest risk of suffering EP is shown, permitting a later detailed analysis at a local level. Ultimately EPVI is an effective application tool in Portugal, for the preparation of local and national energy efficiency policies. The main limitation of this index is the availability of the data needed for its application, which makes it impossible to apply in other countries where access to information is more restricted.

DISCUSSION

The quality of the dwelling is complex to evaluate and is possibly the most influential factor in the EP of a home, which is why energy efficiency may be a decisive and effective instrument in reducing EP, just as Porras-Salazar *et al.*, 2020 show, having an influence on the energy rating, energy envelope, installations, ventilation level, state of conservation and age of the home. This assessment is made using energy consumption data, so all the analyzed indicators are capable, in one way or another, of establishing a relationship, be this direct or indirect, between the energy efficiency of a dwelling and the EP. Another methodology that allows connecting the quality of the dwelling with EP consists in the thermal comfort assessment, as shown in the works developed by Sánchez-Guevara, Neila González & Hernández Aja (2018); Boemi & Papadopoulos (2019) and Porras-Salazar *et al*. (2020).

One of the most widely used assessment factors is the social impact that EP causes, for example, social exclusion. The relationship between EP and social exclusion is because families reduce social activities with friends and acquaintances on fearing being considered poor and/or on not being able to provide suitable conditions in their dwelling to hold social activities (Longhurst & Hargreaves, 2019). The inclusion of family income by the indicators based on the expenses and income of the home, and those based on surveys of perceptions and statements, allow connecting EP with the situation of economic and/or social poverty.

Health is another important aspect, confirming that living in a house with inadequate temperatures leads to higher hospital admission rates and a higher incidence and severity of asthmatic symptoms (Liddell & Morris, 2010). It has also been identified that the probability of suffering from depression or stress among teenagers who live in an insufficiently conditioned house is greater than 25%, while in homes that do not experience this issue, it reaches only 5% (Howden-Chapman, Viggers, Chapman, O'Sullivan, Telfar Barnard & Lloyd, 2012). Although it is the elderly, children and pregnant women, considered as the vulnerable population, are those who have a higher probability of being affected by these illnesses (Dear & McMichael, 2011). Aside from mental health problems, living in a dwelling with inadequate temperatures in winter is a cause associated to having physical health issues like the flu or colds; it is even accredited with the worsening of the situation of people who suffer from arthritis and rheumatism (Ortiz, Casquero-Modrego & Salom, 2019). Table 2 below, summarizes the capacities identified during the revision of the indicators.

CONCLUSION

The main goal of this document has been to provide a review of the currently most used and internationally recognized energy poverty indicators, following the criteria defined by the European Energy Poverty Observatory, the Mexican Energy Poverty Observatory and the Chilean Energy Poverty Network, with regard to their ability to identify those homes at risk of suffering from this (see

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Analysis	10%	2M	MIS	LIHC	AFCP	HEP	Perception surveys	Econometric	TC CT	EE	IVH	FPPRI	EPVI
Considers the "heating or eating" effect	X	X	✓	✓	✓	✓	X	X	X	X	✓	X	X
Prioritizes low income over high income	✓	✓	✓	X	✓	✓	✓	✓	X	X	✓	✓	✓
Only considers the energy consumption required to achieve a suitable comfort	✓	✓	X	X	X	X	✓	X	X	X	X	X	X
Includes the characteristics of the dwelling in the analysis	X	X	X	X	X	X	✓	✓	✓	✓	✓	✓	✓
Includes the compliance of the minimum thermal comfort	X	X	X	X	X	X	X	X	X	✓	✓	✓	X
Includes the energy efficiency of the dwelling in the analysis	X	X	X	✓	X	X	X	X	✓	✓	✓	✓	✓
Includes the suitable use of the home's facilities	X	X	X	✓	X	X	X	X	X	X	✓	X	X
Considers the income distribution in the study area	X	X	✓	✓	✓	✓	X	✓	X	X	✓	X	X
Includes actual expense and consumption information of the homes	✓	✓	✓	X	✓	✓	✓	✓	X	X	✓	X	✓
Excludes from the analysis the groups considered as the most physically vulnerable (elderly, chronically ill, disabled and young children)	X	X	X	✓	X	X	✓	✓	✓	✓	X	✓	✓
Prioritizes energy efficiency as a measure against EP, hiding the origin of the problem: the home is in a monetary poverty situation	X	X	X	✓	X	X	X	X	✓	✓	X	✓	✓

Table 2. Critical analysis of the analyzed indicators.
10% (10% indicator); 2M (2M indicators); MIS (Minimum Income Standard); LIHC (Low Income High Cost; AFCP (After Fuel Cost Poverty); HEP (Hidden Energy Poverty); TC (Thermal Comfort); EE (Energy Efficiency); IVH (Index of Vulnerable Homes); FPPRI (Fuel Poverty Potential Risk Index); EPVI (Energy Poverty Vulnerability Index). Source. Preparation by the authors.

Table 2). With this in mind, the energy vulnerability factors (available infrastructure, energy efficiency, monetary and social poverty, welfare and health), provided by Bouzarovski et al. (2014) have been used to analyze the effectiveness of current FP indicators, which can be grouped following the indicators they are based upon: income-expenses; self-reported conditions; econometric analysis; thermal comfort; and energy efficiency.

The main weakness of all these indicators is based on the impossibility that a single indicator considers all the possible factors that have an impact on the daily activities of the homes, like thermal comfort, health, and wellbeing. As a result, an incomplete analysis is provided if they are used in isolation, mainly due to inaccuracies of exclusion (reason why the homes that should receive benefits are not recognized by the government strategies) and inclusion (where homes that are not at risk of suffering from energy poverty comply with the eligibility criteria and, therefore receive support). Therefore, it is necessary to combine several indicators and analyze their results to determine whether a holistic analysis is achieved, both of the technical characteristics of the dwelling and the situation of the home.

The discussion presented in this document exposes the weaknesses of existing EP indicators in the identification of homes at risk and leads to the definition of a multiple indicator approach that brings together as many factors as possible. In addition, due to the complexity of extrapolating the indicators defined to other countries, or climate zones, with different social and economic context, the need is argued that each country defines EP considering the circumstances of the context to develop concrete and effective policies. Finally, in the particular case of the European Union, the lack of suitable definitions and indicators in most of the member states leads this research to providing a starting point.

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COMPORTAMIENTO TÉRMICO DE TRES PROTOTIPOS EN SALTILLO, COAHUILA (BLOQUES DE TIERRA, CONCRETO Y TAPA DE HUEVO)

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THERMAL BEHAVIOR OF THREE PROTOTYPES IN SALTILLO, COAHUILA (WITH EARTH BLOCKS, CONCRETE AND EGG CARTONS)

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RESUMEN

El cambio climático se ha ido agravando en el siglo XX, genera modificaciones estacionales a nivel global en el hábitat, se observan variaciones importantes en los factores climáticos, aumentando las temperaturas en las ciudades. En México el acondicionamiento térmico de las viviendas repercute en gran medida sobre la demanda de electricidad, siendo mayor en las zonas norte y costeras del país, el rol de la envolvente es mantener un equilibrio entre el exterior y el interior, refiriéndose a las ganancias o pérdidas de calor, que se logran a través de su transferencia producto de las variaciones de la temperatura. El objetivo del trabajo fue comparar el comportamiento térmico de tres módulos ubicados en Saltillo, Coahuila; construidos de tres distintos materiales: uno experimental y dos de uso común en las viviendas de Saltillo, la metodología es de enfoque cuantitativo, se realizaron mediciones del 2018 al 2019, los resultados muestran que el material experimental con respecto a los otros materiales comerciales no tienen diferencias relevantes en los meses más críticos que son enero y mayo, apenas 1 o 2 grados, por lo que es pertinente seguir experimentando y complementar con un sistema pasivo, como un pozo canadiense, con la meta de mejorar el confort en el hábitat construido.

Palabras clave
Bloque, edificación, temperatura ambiental

ABSTRACT

Climate change has been worsening in the 20th century, causing seasonal changes in the habitat at a global level. Significant variations in climate factors are seen, increasing temperatures in cities. In Mexico, thermal conditioning of houses has a major impact on the electricity demand, which is greater in the northern and coastal areas of the country. The role of the envelope, when referring to heat gains or losses that are achieved by their temperature variation transfer, is to maintain a balance between the outside and the inside. The goal of this work was to compare the thermal behavior of three modules located in Saltillo, Coahuila; built using three different materials, one experimental and two commonly used in Saltillo homes. The methodology has a quantitative focus and measurements were made from 2018 to 2019. The results show that there are no relevant differences between the experimental material and other commercial materials in the most critical months, January and May, with just 1 or 2 degrees. Thus, it is relevant to continue experimenting and complementing with a passive system, like a Canadian well, with the goal of improving comfort in the built habitat.

Keywords
Blocks, edification, room temperature

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INTRODUCTION

Climate change in the 20th century has generated global seasonal changes in the habitat, with important variations seen in climate factors that directly impact comfort inside dwellings. In fact, climates that were previously considered as template, no longer retain this category, so much so that warm climates are more extreme than before, which as a consequence brings the need to adapt the habitat of dwellings to improve comfort.

In the opinion of Delfin, Gallina and López (2014), the habitat has the responsibility of fulfilling suitable conditions for a species, starting from two angles: real habitat, which refers to the presence of a species in a space, and potential habitat, that implies that a habitat may potentially be built in an area where a species is not present.

The Pan American Health Organization (PAHO, 1999) states that the structure of the dwelling for groups in poverty does not have the necessary conditions to act as a shelter, that provides suitable protection from extreme temperatures, noise, among other factors. Múnera (2011) on the other hand, considers that the habitat and, in particular, the dwelling, become “objects” of intervention and manipulation, becoming merchandise, on standardizing the widespread building of social housing by the private sector.

The Energy Secretariat (SENER and CONUEE, 2011) establishes that:

> In Mexico, the thermal conditioning of dwellings impacts, to a great extent, the peak demand of the electricity system, with it being higher in the Northern and coastal areas of the country, where the use of active systems is more commonplace. (p.1).

Along this line, Herrera (2017) states that technical specifications of an obligatory application are established including, among these, the Mexican Energy Efficiency Standard in Buildings and Building Envelopes for Habitational Use (NOM-020-ENER-2011), whose objective is:

> Limiting the heat gains of buildings for habitational use through their envelope, rationalizing the use of energy in cooling systems and improving the thermal comfort conditions inside the spaces of the dwelling (SENER and CONUEE, 2011, p. 1)

García, Kochova, Pugliese and Sopoliga (2010) suggest that a dwelling is like a breathing box since, as it is based on the climate outside, it activates different mechanisms to regulate the heat; but, also, a construction depends on the design, shape and envelope, giving as a result, comfort or discomfort for two constant parameters: temperature and humidity. Both play an important role in the end result. These authors, along with Costantini, Carro Pérez and Francisca (2016), suggest that:

> The choice of construction materials is key for reaching high comfort levels at a low cost. For example, a ceramic hollow brick has very good insulation properties (or high thermal resistance), but there are other materials like thermal clay that have an even better performance (p. 12).

The National Housing Commission (CONAVI, in Spanish), together with the German Technical Cooperation Agency (GIZ) implemented the country-specific mitigation measures program (NAMA) to develop sustainable housing in Mexico. The problem is the shortage of green label materials, based on the thermal capacity and thermal retardation. The latter refers to the time where the heat or cold passes from the outside to the inside (Morris, 2017). to keep a space comfortable without needing to use an artificial system and, therefore without generating a high energy consumption demand (Roux, 2018).

According to Calderón (2019), it is possible to build a sustainable habitat using recycled low-cost materials, without affecting the budget destined for its construction and, at the same time, improving thermal comfort. Likewise, Herrera (2017) states that suitably using construction materials considering their thermal properties allows dwellings to approach comfort levels in each one of the climate zones, affecting the surrounding area less and demanding less non-renewable energy. He especially recommends evaluating the thicknesses of the thermal mass, even the dimensions of the studied materials.

The role of the envelope is maintaining a balance between the outside and inside, regarding the heat gains or losses achieved through its transference as a result of variations in the outdoor temperature. In winter, heat is generated inside the construction and is lost in spaces with low temperatures or is dispersed outside through openings; in summer, the gain is obtained from the outside, due to a lack of protection or of the materials that are good conductors and of the surrounding conditions that do not help reduce the energy increase indoors.

On the other hand, aiming at reaching thermal comfort indoor temperatures, in all building types, airtightness plays a relevant role in contributing towards a reduction or increase of the indoor temperature (Molina, Lefebvre, Horn & Gómez, 2020). Muñoz, Marino and Thomas (2015) consider the orientation of a construction as a factor for the energy consumption needed for its operation, as such, on assessing its behavior, the contributions of the envelope components must be considered (walls, openings and roofs).

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In previous studies made by Molar, Velázquez and Gómez (2018), it is mentioned that:

> In May, the temperatures of dwellings show a thermal behavior that follows the comfort ranges for summer, but in January, there are very low temperatures, with a great thermal amplitude between day and night. As a result, heating is needed to improve indoor conditions (p. 7).

Indoor temperature readings outside these ranges show that heat losses or gains are the result of an unsuitable choice of materials for the envelope. Although, on occasions, this is due to the openings, a given orientation and the materials in general, it has been studied that, by area unit, it is the envelope materials that transfer more heat from the outside to the inside (Huelsz, Molar & Velázquez, 2014; Espinoza, Cordero, Ruiz & Roux, 2017). The heat transfer process happens because of the capture of solar radiation, led inside through the material and released thanks to convection, which affects the environmental thermal behavior inside the building.

In simulation tests using the Ener-habitat program for the climate of Saltillo (Molar & Huelsz, 2017), the total thermal load value of the month of May was compared, following a given thickness. From the different orientations, the one that recorded the highest load was the west. However, in January, under equal conditions, the orientation with the highest load was the north.

Another recommended aspect is annually analyzing a building (Rodríguez, Nájera & Martín, 2018), which means that, if only the summer or winter conditions are studied, it is possible to improve the thermal performance of a single period, which could affect the other, resulting in the neutralization of gains or savings.

Considering this, the Technology in Architecture Faculty Members of the Faculty of Architecture at the Autonomous University of Coahuila's Arteaga Campus, have made a research project with non-toxic and natural industrial waste materials, with the goal of developing sustainable construction systems that improve the thermal comfort conditions of the built habitat. This article presents the results of a project made in this context between 2018 and 2019. It compares the thermal behavior of the envelope of three modules located in Saltillo, Coahuila, built with three different materials: concrete blocks (the most commonly used construction material), compressed earth blocks (typical of the area) and an experimental material that was previously tested as a construction system (Velázquez & Molar, 2016). The objective is to know their results considering given orientations.

METHODOLOGY

The approach of the research is quantitative, performed transversally, with documented work and a field case study. Concretely, measurements were made onsite, following the ASTM Standard Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components, which states that information must be collected of the surroundings of the analyzed habitat to compare this with the data obtained inside the 3 modules.

Thus, two devices were used:

1. An infrared thermometer was used to measure the temperature of the surfaces, which introduces the type of emissivity depending on the material of the horizonal and vertical envelope, always making sure to take the measurement in the same place at an intermediate height of the surface. The temperature measurements were made on the central part of inside and outside walls. In the case of the roof, only the inside was recorded, in the center of the surface.

2. To measure the environmental temperature and the humidity percentage, two datalogger temperature and relative humidity recorders were used. One for the outside and another inside each module. The measurements were made under the shade on the outside and on the intermediate part of the space on the inside.

During the measurement period, the modules were kept in the same conditions. They were uninhabited. Therefore, there was no internal gain, but a solar gain by conduction and convection through the openings was considered.

The measurements were made regularly from May 2018 to May 2019, for one week a month, on the days closest to solstices and equinoxes, every hour, between 9am and 3pm, period of greatest radiation capture. The outdoor data was then compared against the indoor data of the habitats, recording only the daytime data, as the security conditions would not allow making nighttime measurements. The data was input in a format and then processed. As a result, the most critical months were identified, discarding the rest on being inside the comfort zone. In this case, solely the results of May and January are shown.

For the purpose of comparison, the comfort zone was determined for Saltillo, Coahuila, following the criteria of Szokolay (2014) and the ANSI/ASHRAE Standard 55-2010 which the Luna Excel ASHI ASHRAE COMFORT program (2019) provides for summer and winter.

For the calculation of the neutral temperature, Auliciems' formula is used (Szokolay, 2014, p.20) (equation 1).

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$$Tn = 17.6 + 0.31\,Tmm \qquad (1)$$

Where Tn is the neutral temperature and Tmm is the mean monthly temperature.

Tn= 17.6 +(0.31*12.1)
Tn=21.4 °C for the month of January and
Tn= 17.6 +(0.31*22.3)
Tn= 24.5 °C for the month of May

The comfort temperature ranges oscillate between (Tn-2.5) °C to (Tn+2.5) °C, as Szokolay (2014 p.21) suggests, which is why, for Saltillo, in the month of January, whose mean temperature is 12.1°C, the comfort range is from 21.4°C to 23.9°C; while in May, with a mean temperature of 22.3°C, the comfort values are between 22°C to 27°C.

DESCRIPTION OF THE PROTOTYPES

The project was run in the facilities of the Autonomous University of Coahuila. The three modules are located within the university area called Camporredondo, in Saltillo, Coahuila (Figure 1).

The city of Saltillo is located 1,600 meters above sea level, with a latitude of 25°22'35" and longitude of 101°01'00". According to CONABIO (National Commission for the Knowledge and Use of Biodiversity, in English), it has a dry template and warm dry climate with little rainfall throughout the year.

The three habitats (Table 1) are similarly sized in length, height and width (by the size of the blocks) and have the same orientation (NE, SE, SW and NW), making sure to have a separation to not generate shade between them, or obstruct air circulation. The envelope (walls and roof) of each module corresponds to each type of material: compressed earth block (CEB), concrete block (CB) and egg carton block with Thermolite and cement (ECB) (Table 2). None of the modules has a coating on the outside or inside, but they do have two openings, a small window and a door, in a SW orientation (Figure 2).

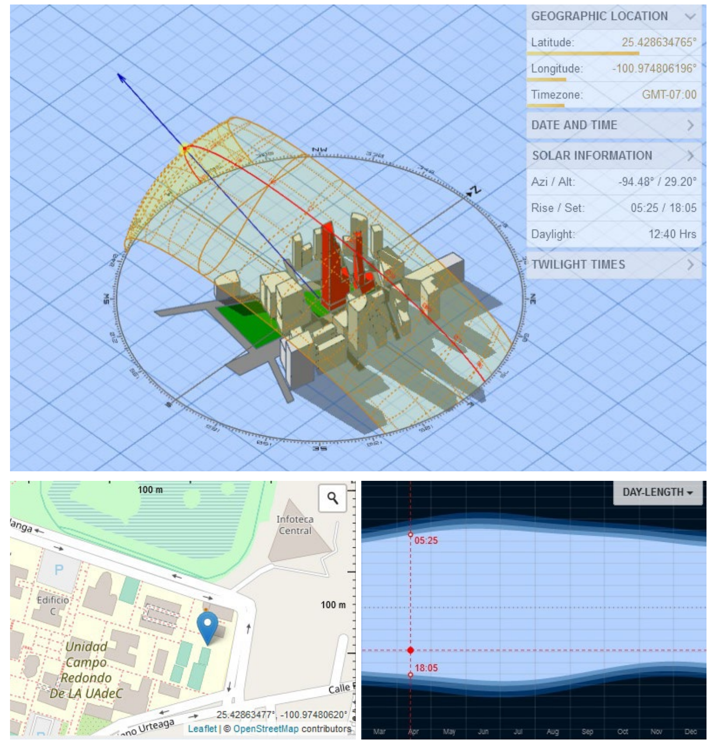

Figure 1. Location of the modules. Source: Andrewmarsh.com. PD: 3D Sun Path.

Figure 2. View of the modules (from left to right: egg carton blocks with Thermolite and cement – ECB, concrete block – CB, and compressed earth block – CEB). Source: Preparation by the author.

Module	Size m (width, length, and height)
Compressed earth block module (CEB)	1.4 x 2.20 x 2.36
Concrete block module (CB)	1.47 x 2.26 x 2.50
Egg carton block module with Thermolite and cement (ECB)	1.57 x 2.21 x 2.45

Table 1. Module size
Source: Preparation by the authors.

Material	Size cm (width, length, and height)
Compressed earth block module (CEB)	20 x 40 x 12
Concrete block (CB)	14.5 x 39.5 x 19
Egg carton block with Thermolite and cement (ECB)t	10 x 69 x 35

Table 2. Sizes of the blocks.
Source: Preparation by the authors.

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The experimental ECB prototype, comprising light materials like Thermolite, Portland cement, sand and egg cartons, was tested in 2015 by Raúl Ernesto Canto Cetina, PhD and Porfirio Nanco Hernández, PhD, obtaining a Conductance of 2.59W/m2°C, with a Thermal Resistance of 386m2°C/W (Velázquez & Molar, 2016).

RESULTS AND DISCUSSION

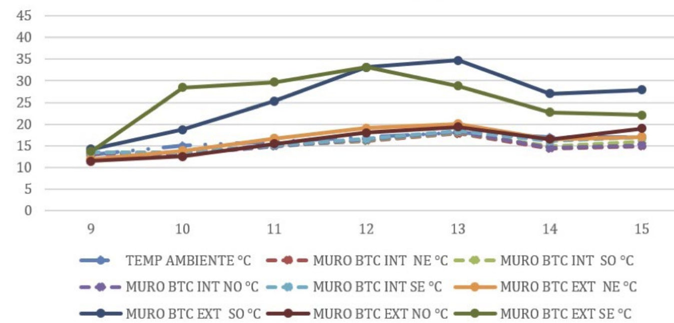
Graphs 1 to 5 correspond to the data obtained in January 2019. It can be seen that the maximum temperature is reached between 12pm and 1pm in the SW orientation. In general, the indoor surface temperature registers around a 10 to 15°C difference compared to the outdoor surface, even with the openings open.

The maximum temperature on the outdoor surfaces, on the compressed earth block module (CEB) (Graph 1), appears on the SE and SW orientation at 12pm and 1pm, reaching 34°C and 35°C, respectively. This is a difference of 15°C regarding the indoor surfaces. The readings of the NE and NW orientations present a similar behavior of the indoor faces, on not having direct radiation. At 2pm, it is seen that, even though the outdoor surface does NOT see a temperature increase on receiving radiation, its indoor face does not increase in temperature, seeing a difference of 4°C between them. At 11am, the temperature increase of the indoor surfaces was 5°C and at 1pm, they began to fall again.

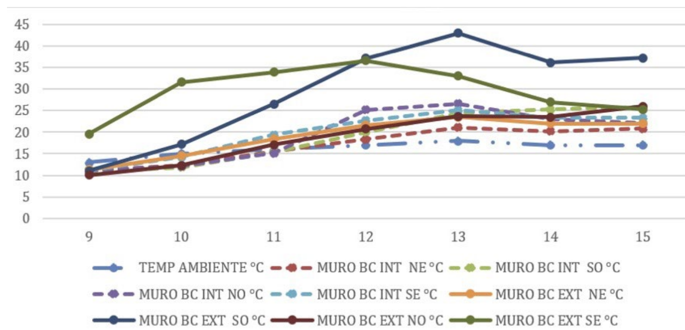
The maximum temperature of the outdoor surface on the concrete block wall module (CB) (Graph 2) is seen in the SW orientation at 1pm, with 43°C, that is to say, a difference of 20°C regarding its indoor surface. In this module, the temperatures of the indoor faces of the surfaces had an increase of 5° to 10°C difference compared with the outdoor environmental temperature at 11am. The NW and NE outdoor surfaces were 5 to 8°C more than the outdoor temperature, even when shaded, reaching 25°C.

The temperature of the module built with egg carton blocks with Thermolite and cement (ECB) (Graph 3) shows that the maximum temperature on the outdoor surface is generated in the SW orientation at 1pm, with 45°C and 20°C of difference regarding the indoor face. The indoor temperatures of the surfaces remained above the outdoor environment temperature, with a difference of between 5°C and 7°C. Meanwhile, the outdoor NW and NE surfaces recorded a difference of 5°C to 9°C, even though there was no direct radiation. However, the indoor temperature of these surfaces stayed 3°C lower.

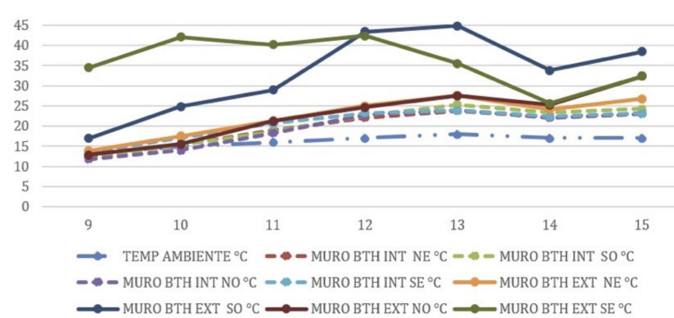
According to Graph 4, in this season, the high temperatures on the roofs are not reached due to contact with the cold air that tends to absorb heat from exposed surfaces. The maximum temperature was



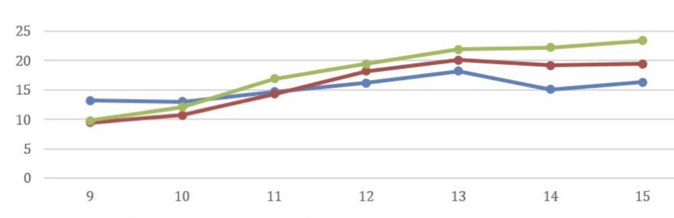
Graph 1: Behavior of indoor and outdoor temperatures of the CEB module (January 2019) Source: Preparation by the authors.



Graph 2. Behavior of indoor and outdoor temperatures of the CB module (January 2019). Source: Preparation by the authors.



Graph 3. Behavior of indoor and outdoor temperatures of the ECB module (January 2019). Source. Preparation by the authors.



Graph 4. Behavior of indoor temperature of the roof of the three modules (CEB, CB and ECB), January 2019. Source: Preparation by the authors.

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reached by the roof with ECB and was 24°C. The lowest of 18°C was achieved with the CEB roof. The CB and ECB begin with the same temperature at the beginning of the recording.

ANSI/ASHRAE 55:2010		
JANUARY		
80% ACCEPTANCE		
LOWER L.	NT	UPPER L.
19.50	22.00	24.50

Figure 3. Comfort limits in January. Source: ANSI ASHRAE COMFORT Program.

Limits were set in the diagram to analyze the results obtained from the measurements, based on the comfort limit corresponding to January, according to Szokolay, 21.4°C to 23.9°C, and what is obtained from the ANSI ASHRAE COMFORT program.

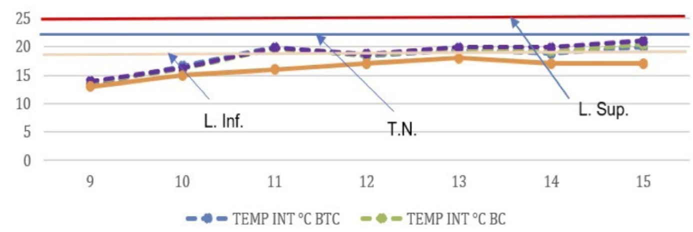
Even though the envelopes of the three modules (Graph 5) have variations in the surface temperatures, the resulting behavior of the three modules was similar to the environmental temperature, reaching the lower limit (Figure 3). Starting from 11am, they capture energy through the envelope, although in the case of the ECB, slightly higher values were obtained, while in the CEB much lower values were recorded.

Graphs 6 to 8 belong to data of May 2019. The maximum temperature of the outdoor surfaces is seen in the SE orientation, at 11am.

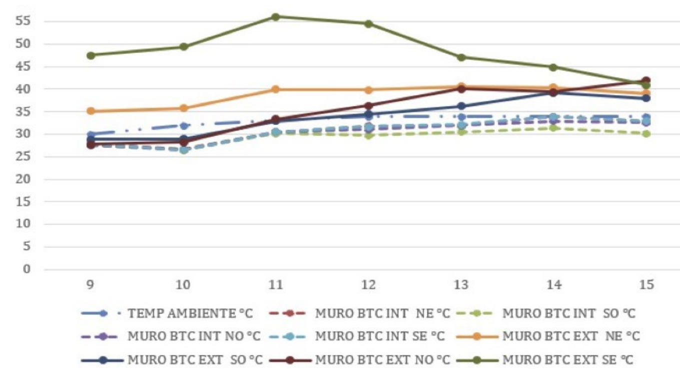
In the compressed earth block wall module (Graph 6), the maximum outdoor surface temperature was recorded on the SE orientation at 11am, with 56°C and 25°C of difference compared with the indoor surface. The temperature of the indoor surfaces increased gradually at 10 am, but remained below the environmental temperature.

In the CB module (Graph 7), the maximum temperature of the outdoor surfaces appears on the SE orientation at 11am, at 56°C, with 20°C of difference compared to the indoor surface. The indoor temperature of the surfaces increased at 10 am, with a difference with the outdoor temperatures of between 1°C and 8°C. At 11am, the NW and SW outdoor surfaces increased their temperature gradually, presenting a difference of between 8°C and 10°C compared to the outdoor temperature, with an oscillation of 5°C compared with the indoor surface.

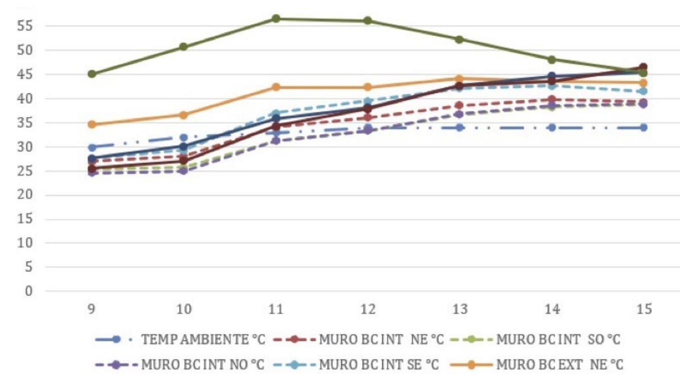
In the ECB module (Graph 8), the maximum temperature of the outdoor surfaces is seen on the SE orientation at



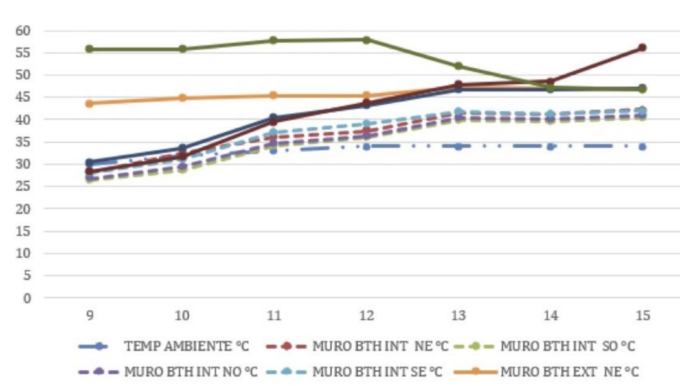
Graph 5. Indoor thermal behavior of the three modules (January 2019). Source: Preparation by the authors.



Graph 6. Indoor and outdoor temperature behavior of the walls of the CEB module (May 2019). Source: Preparation by the authors.



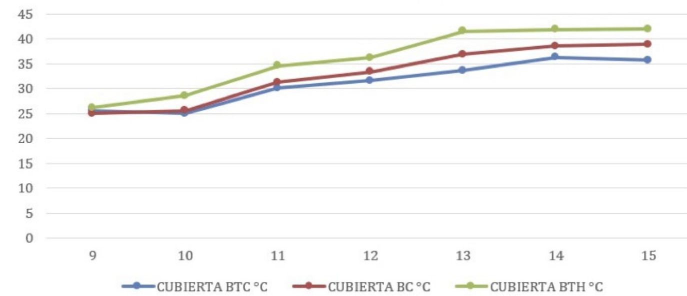
Graph 7. Behavior of the wall indoor and outdoor temperatures of the CB module (May 2019). Source: Preparation by the authors.



Graph 8. Behavior of outdoor and indoor temperatures of the ECB module (May 2019). Source: Preparation by the authors.

11am and 12am, at 57°C with 18°C difference compared to the indoor surface. The indoor temperature of the surfaces increased from 10am on, recording a difference of 1°C to 7°C compared to the outdoor temperature. It was also seen, that the external NW and SW surfaces increased at 10am, maintaining a difference of 5°C to 20°C compared to the outdoor temperature, with an oscillation of 5°C with their respective indoor temperature.

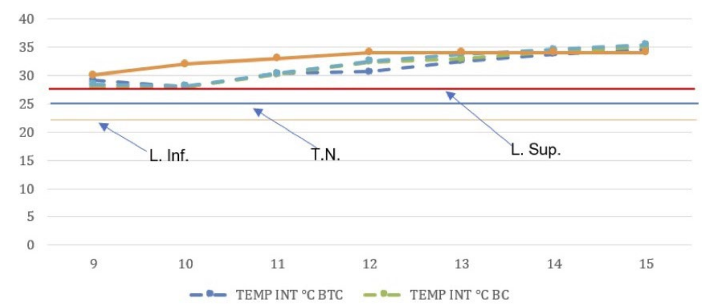
In Graph 9, it is seen that the maximum temperature appears on the ECB roof at 43°C, and the lowest on the CEB is 36°C. In this period, the three roofs begin with similar temperatures at 9am, while at 3pm they keep a difference of 7°C between the lowest and highest value.



Graph 9. Behavior of the indoor surface temperatures of the roofs of the three modules (CEB, BC and ECB) (May 2019). Source: Preparation by the authors.

MAY		
80% ACCEPTANCE		
LOWER L.	NT	UPPER L.
22.70	25.20	27.70

Figure 4: Comfort limits in May Source: ANSI ASHRAE COMFORT Program.



Graph 10. Indoor thermal behavior of the three modules (May 2019). Source: Preparation by the authors.

The limits were defined in the diagram to analyze the results obtained from the measurements, based on the comfort limit corresponding to May, according to Szokolay, 22°C to 27°C, and that obtained with the ANSI ASHRAE COMFORT program.

The resulting indoor temperature of the three modules (Graph 10) has a similar thermal behavior, although at 12pm, the temperatures of the ECB and CB are slightly higher than those of the CEB. The three were outside the upper limit, maintaining a temperature below the outdoor temperature in the first hours.

According to what is said by García et al. (2010), an active envelope activates its regulation mechanisms according to the properties of the material and its exchange with the outside. A key aspect, as Huelsz et al. (2014), Espinoza et al., (2018) and Muñoz et al. (2015) suggest, is the affectation generated by the openings that affect, to a great extent, the heat transfer gain or loss inside the construction. The airtightness is the key to reducing or increasing the indoor temperature (Molina et al., 2020).

CONCLUSIONS

On comparing the thermal behavior in winter of the three modules located in Saltillo, Coahuila, starting from the NE, SE, SW and NW orientations of the walls, it is identified that, in winter, the southwest maintains the highest values during the morning-afternoon, as it receives a higher amount of solar radiation at this time of the day. Likewise, given the composition of the blocks, and starting from the same orientations, the southeast, in summer, has the highest energy transmitted during the morning-afternoon, between 11am and 1pm, period where the surfaces capture the highest amount of radiation. This constitutes an area of opportunity to consider, given that in winter, heat needs to be taken advantage of and, in summer, the intention is having less capture, which would allow proposing some alternative in the design of both orientations.

When comparing the environmental indoor temperatures of January of the three modules with comfort ranges, starting from Szokolay (2014) and the Luna program (2019), the readings begin with values below the comfort ranges, although at 3pm they are found within the comfort ranges. On the other hand, in May, the three modules were above the comfort ranges, which means that the greatest problem to work on would arise in summer.

Regarding the comparison between the surfaces of the experimental materials (CEB and ECB) and the commercial concrete block (CB), these show relevant differences in January and May, which is why it is possible that the thickness of the experimental block is too thin to contribute to the improvement of the indoor conditions. Even so, it is important to continue working on new alternatives and improvements of the material to implement it in building low income dwellings and to improve the built habitat.

The envelope with the CEB in both seasons always keeps temperatures below or similar to the environmental temperature, while the CB and ECB tend to increase the temperature incrementally from 10 and 11am onwards compared to the outdoor temperature. However, the final result was similar to the indoor temperature in the three materials. It is worth stating that the behavior of the surfaces on their indoor faces was diverse, which offers the option to continue working on improvements.

These results may be associated to the lack of protection on the openings, to the thickness of the blocks both on walls and on the roof, or, to the lack of some outdoor and indoor filler that reduces the increase of the environmental temperature inside the construction. This is why it is pertinent to continue making tests with other geometries in the experimental blocks, closing the openings and complementing with a Canadian well as an auxiliary passive system which is viable, according to the mathematical calculations of Molar, Ríos, Bojórquez and Reyes (2020), given the properties of the earth in this location, to help obtain a suitable thermal behavior inside the space. The contribution of this research is focused on improving the habitat inside dwellings of the 20th and 21st centuries, especially in those traditional and vernacular constructions of the location studied here.

ACKNOWLEDGMENTS

We would like to thank UAdeC US for allowing us to make the *Comparative study of the thermal behavior of the CEB, Block and egg carton module* project, and the collaboration of students for the construction of the modules.

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PROPUESTA PARA LA IMPLEMENTACIÓN DE LA METODOLOGIA BIM EN UNA EXPERIENCIA ÁULICA ORIENTADA A LA SUSTENTABILIDAD EDILICIA

PROPOSAL FOR THE IMPLEMENTATION OF THE BIM METHODOLOGY IN AN CLASSROOM EXPERIENCE FOCUSED ON BUILDING SUSTAINABILITY

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Building Information Modeling (BIM) es una metodología de trabajo colaborativo que concentra toda la información de un proyecto en un único prototipo virtual susceptible de ser estudiado a lo largo de su ciclo de vida. Una de las principales dificultades para su implementación es la escasa formación de profesionales en su uso y alcance. Por ello, esta investigación surge con el objetivo de proponer una mecánica de trabajo en tiempo real que, a partir del uso de la metodología BIM desde instancias iniciales del proceso de diseño, constituya un sistema de apoyo a la toma de decisiones en relación con la sustentabilidad edilicia. Con tales fines, se establecen lineamientos básicos para el desarrollo de una experiencia áulica piloto que integre el uso de la metodología BIM, a partir de la realización del Building Energy Model (BEM) de tres prototipos de vivienda social de uso generalizado en San Juan, Argentina. Como resultado, se obtiene el BIM Execution Plan (BEP) para la primera implementación de la metodología BIM en el Taller Vertical de Arquitectura Ambiental (TVAA) de la Facultad de Arquitectura, Urbanismo y Diseño (FAUD) de la Universidad Nacional de San Juan (UNSJ).

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BIM, mecánica de trabajo, experiencia áulica, BEM, BEP

ABSTRACT

Building Information Modeling (BIM), is a collaborative methodology that gathers all the information of a project in a single virtual prototype, which can then be studied throughout its life cycle. One of the main difficulties in its use is the limited training of professionals in its use and scope. Consequently, this research proposes a real-time work procedure where, by using the BIM methodology in the initial stages of the design process, this constitutes a support system for decision-making with respect to Building Sustainability. With this in mind, basic guidelines are set out to develop a pilot classroom experience that integrates the use of the BIM methodology, by making a Building Energy Model (BEM) of three commonly used social housing prototypes in San Juan, Argentina. The result is the BIM Execution Plan (BEP) for the first use of the BIM methodology in the Vertical Workshop on Environmental Architecture (TVAA) of the Faculty of Architecture, Urbanism and Design (FAUD) of the National University of San Juan (UNSJ).

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BIM, work procedure, classroom experience, BEM, BEP.

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Building Information Modeling, or BIM, is a set of methodologies, technologies and standards that allow designing, building and collaboratively and through interdisciplinarity, running a building or infrastructure, throughout its life cycle, in a virtual space (PlanBIM, 2019). Salinas & Prado (2019) sustain that the standout international models for the development of BIM regulations and standards are the United States, the United Kingdom and Singapore. In South America, Brazil and Chile are the furthest ahead in BIM implementation from the public sector. In Argentina, the BIM standard came from the private sector, but with the participation of the public sector. The rest of the region has individual initiatives, without finalizing documents that reflect collaborative work (Salinas & Prado, 2019).

One of the main difficulties detected regarding BIM expansion is the lack of trained professionals. To counter this issue, the role of universities is essential (Orrego, 2017). Regarding the state-of-the-art, it is seen that Piña, Varela, Aguilera & Vidales (2017) propose revising study plans to include more competences related to BIM methodology. For this, they define an organizational chart that establishes the role of BIM agents in the different phases of the project (Design, Construction and Operation), the extent of involvement and the level of knowledge required, so that Construction Engineering students know, beforehand, what the relationships are between said players.

Meana, Bello & García (2017) and Reyes, Prieto, Cortés & Candelario (2017) also analyze the use of the BIM methodology in Industrial Engineering degrees. Meana et al. (2017) suggest the need of adapting the current educational model to the needs of professionals of collaborative models. In this sense, they propose establishing an inter-university commission that leads and unifies goals and competences regarding said methodology. Meanwhile, Reyes et al. (2017) conclude that BIM technology can be used in university teaching with a high probability of success.

Although there is a large amount of research related to the use of BIM methodology in different fields of the construction industry, its implementation in building sustainability-oriented pedagogical practices from the early stages of the design process, has not been addressed. In this line, the aforementioned authors do not outline the use of documents such as the BIM Execution Plan (BEP), or the preparation of a Building Energy Model (BEM). Likewise, the development of standards regarding BIM methodology matches its application in the public sector. However, there are no standards that guide the way this methodology must be implemented in an academic setting.

González Pérez (2015) mentions that the BIM standard is a common framework that must be carried out in the phase prior to starting the project and that it affects the proper performance of collaborative work. In PlanBIM (2019), it is said that a standard is a document established by consensus and approved by a well-known entity which put themselves in the position to help obtain an optimal degree of organization in a given context.

On the other hand, Chong & Wang (2016), Sakin & Kiroglu (2017) and Chaves, Tzortzopoulos, Formoso & Shigaki (2015) agree that BIM constitutes a reliable base to make decisions that lead to the incorporation of sustainable approaches and to the improvement of building performance, on allowing monitoring a project throughout its life cycle. Mercader Moyano Camporeale & Cózar-Cózar (2019) highlight that the consideration of environmental issues during the design stage, represent one of the greatest challenges for designers.

Upon this starting point, of the aim of this article is proposing a real-time work procedure where, from using the BIM methodology in the initial stages of the design process, it makes up a support system for decision-making regarding building sustainability. From that perspective, basic guidelines are initially defined to perform a BEM aimed at analyzing the comfort level of social housing. For this, the thermal characteristics of the materials involved for the construction solutions adopted in three commonly used social housing prototypes in the city of San Juan[2], Argentina, are taken as the starting point. In the same way, foundations are built for the diagramming of a BIM Execution Plan (BEP) directed to the first implementation of BIM methodology in a classroom setting. This will take place in August 2020, in the Environment Architecture Vertical Workshop (TVAA, in Spanish) of the Architecture, Urbanism and Design Faculty (FAUD, in Spanish) of the National University of San Juan (UNSJ, in Spanish), contributing to the development of future BIM standards in education. In short, the intention is to contribute to habitat sustainability, making future professionals aware of the importance that project decisions have throughout

1 City located in the center-west of Argentina, on the Diagonal Árida Sudamericana.

the life cycle of the building. In this regard, specifying the work procedure needed to pass from BIM to BEM allows redefining and improving, in the stage prior to the execution of the works, those technological, construction and design aspects that contribute to a greater sustainability in the building.

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This article proposes a set of documents, capable of structuring a future teaching practice which, based on the BIM methodology, favors the integration of building sustainability variables into the design process for Architecture students. Using this as a starting point, basic directives could be defined to elaborate a Standard aimed at implementing BIM methodology in Architecture teaching in general, and in building sustainability in particular.

From this approach, the proposed methodology is based on two successive stages. In the first of these, the basic guidelines for developing the BEM are defined; then, the comfort level of the three commonly used social dwelling prototypes in the city of San Juan, Argentina, are analyzed. Here, it is important to consider that, although EnergyPlus is the standout analysis model, other software for building information modeling, like Revit and ArchiCAD, are easier to use, which favors their application for assessment in early design stages. The development of this stage includes determining the work procedure needed to go from BIM to BEM. General aspects related to the Basic Information Delivery Manual (IDM) are also mentioned, while the importance of the BIM Information Requests (SDI – BIM) is determined. In addition, the content of the evaluation reports obtained, namely, the possible output variables related to the data input in the BEM, is analyzed. From this, it is possible to determine the similarities and differences associated to the use of each software. This is interesting, so that the teacher can guide the student towards the correct interpretation of the results and, as a result, towards the determination of bioclimatic design strategies that contribute to improving the comfort level obtained in the simulation. The contents of each assessment report are analyzed following six variables (transparency, traceability, processing, comparability, complexity, and possible output variables).

In the second stage, general guidelines are established for the classroom implementation of the BIM methodology. With this purpose, a workflow is proposed, destined to incorporate sustainability variables in the initial stages of the design process. Finally, a role matrix and the Offer PEB, that guides the teaching process, are built. Figure 1 summarizes the proposed research methodology.

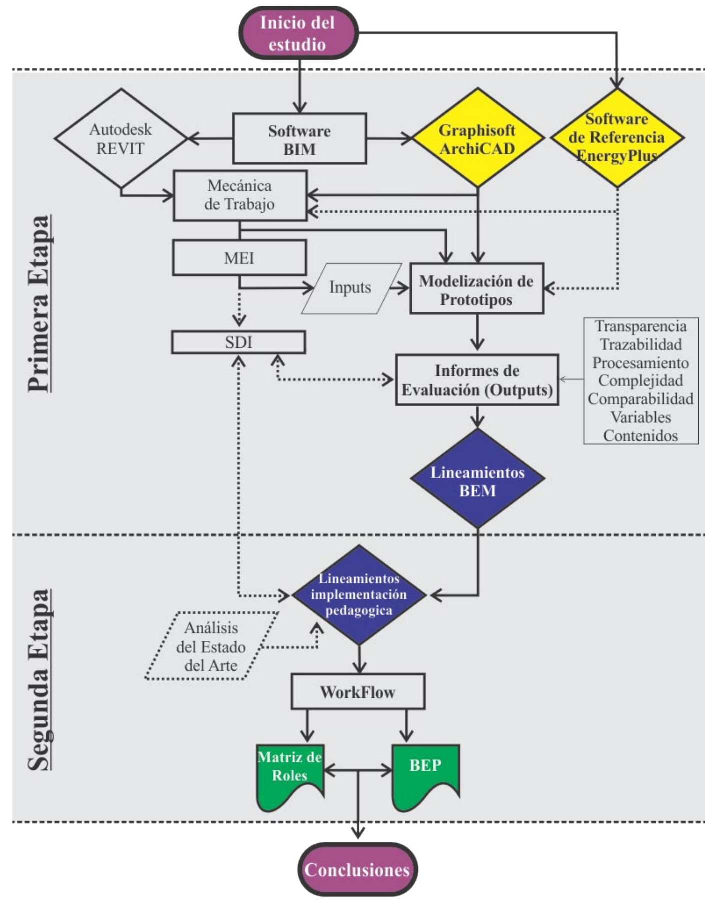

Figure 1. Flowsheet of the proposed research methodology Source: Preparation by the authors.

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Both for Lu, Wub, Changa & Lib (2017) and for Martin, Franco, Broock, González & Assef (2014), traditional design methods are limited in terms of sustainability analysis because of the fragmentation of the information they handle. As a result, including energy assessment in the architectonic design workflow, facilitates the creation of projects that fulfill and, even, exceed energy efficiency standards (Soltani, 2016). However, generating a parametric model requires software management skills that go beyond the three-dimensional representation and implies knowing the way in which parameters to build a functional and useful BIM model must be allocated (Mojica, Valencia, Gómez & Alvarado, 2016).

The term BEM refers to a simulation tool to calculate the thermal load and energy use in buildings, that allows predicting their use based on the architecture and the cooling, heating and air-conditioning systems (Jiménez, Sarmiento, Gómez & Leal, 2017). Therefore, to perform a correct energy assessment, the building's 3D model has to, at least, contain the envelope and carpentry structures, as well as all the main internal structures that represent a significant heat storage volume (Graphisoft, 2017).

According to Llave Zarzuela, Arco Díaz & Hidalgo García (2019), internationally, Revit and ArchiCAD are the modelling tools of building information, that include the energy assessments most used by construction professionals. They also mention that the integrated energy assessment tool of Revit is insight 360 and ArchiCAD's is Ecodesigner. In addition, they mention that insight 360 is an analytical tool lacking sufficient testing; however, the Green Building Studio tool can be used. Finally, they highlight that Ecodesigner is considered one of the most accurate energy simulation software, as it has an error range of less than 5% in energy performance assessments (Llave Zarzuela et al., 2019). Meanwhile, Blat Tatay (2016), characterizes the aforementioned software starting from their main qualities and concludes that Revit and ArchiCAD are powerful and equivalent tools that have reached sufficient maturity to be representative of the moment the BIM methodology is experiencing.

Considering the goals proposed for this research, it is necessary to highlight the importance of using tools that allow assessing building sustainability from the initial moments of the design process. Along this line, it is relevant that the software used in the development of the classroom experience, is easy to use for the students. Based on this, and looking at setting the basic guidelines to perform the BEM, the proposal is made to use the Revit, ArchiCAD and EnergyPlus software to obtain their similarities, differences and scopes, both at a user/interface level and in terms of their output variables.

ArchiCAD, version 21 (demo), Revit 18 (demo) and EnergyPlus 8.4.0 were used to make the models. The prototypes modeled are A-13, B-13, and A-12 (Figures 2, 3 and 4). The graphical information was provided by the San Juan Provincial Housing Institute (IPV, in Spanish-San Juan). In all cases, the prototypes are considered as located in a north-south facing lot with a main access their south face. This constitutes a simplification that allows considering the results using the same location conditions. Table 1 summarizes the thermal characteristics of the materials used to build the dwellings.

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Blasco Gutiérrez, Parant, Olivier, González Redondo & García (2017) state that the BIM methodology constitutes an evolution in collaborative work in all parts of a project and, therefore, university teaching must adapt to the current digital profile of the student, to help them distinguish the different roles of their profession, from the very beginning. In other words, BIM

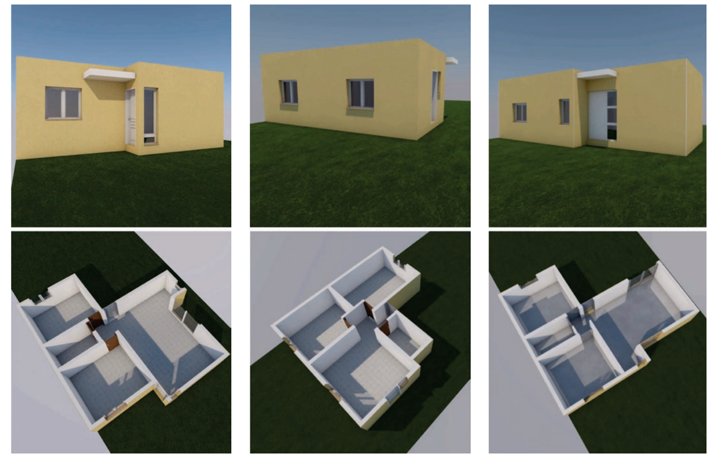

Figure 2. Prototype A-12-
Figure 3. Prototype A-13.
Figure 4. Prototype B-13.
Source: Preparation by the authors based on the information from IPV-San Juan.

Element		Layers of the construction element	R (m^2K/W)	K (W/m^2K) Winter	K (W/m^2K) Summer
External Walls		Mortar	0.01	2.374	2.374
		Brick	0.22		
		Mortar	0.02		
Internal Walls	1	Mortar	0.02	2.36	2.36
		Brick	0.22		
		Mortar	0.02		
	2	Mortar	0.02	3.46	3.46
		Brick	0.09		
		Mortar	0.02		
Roof		Asphalt membrane	0.01	0.647	0.619
		Leveling cover	0.04		
		Pomeca (natural pumice stone)	1.25		
		Reinforced concrete slabs	0.09		
		Lime coated ceiling	0.02		
Floor		Subfloor	0.1	3.29	2.67
		Cover	0.03		
		Tiling	0.03		
External Doors		MDF 18mm Air MDF 18mm	Adopt: 3.50		
Internal Doors		MDF 5mm Air MDF 5mm	Adopt: 3.50		
Windows		3mm transparent glass	Adopt: 5.82		

Table 1. Thermal Characteristics (Resistance and Transmittance) of the materials used in the analyzed dwellings. Source: Preparation by the authors.

References: Comfort levels in W/m2K from IRAM 11605 (Bioenvironmental zone III)
Summer condition: ■ A (Walls: 0.50 Roof: 0.19) ■ B (Walls: 1.25 Roof: 0.48) ■ C (Walls: 2.00 Roof: 0.76) ■ Not reached
Winter condition: ■ A (Walls: 0.286 Roof: 0.246) ■ B (Walls: 0.758 Roof: 0.642) ■ C (Walls: 1.31 Roof: 1.00) ■ Not reached

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education must focus on improving the communication flow and the work sequence (Latorre, Sanz & Sánchez, 2019). For Granero & García Alvarado (2014), teaching architecture considers an essential dedication to design workshops. As a result, BIM implementation finds, in these curricular spaces, favorable conditions for its development.

Along this line, for Piña et al. (2017), running a pedagogical practice based on the BIM methodology requires identifying the different phases of the BIM project simply. These opportunities can be summarized as: Design, Construction and Operation. Reyes et al (2017) implement an Experimental Device that, starting from group work, the determination of roles, conditioning factors, and regulations to comply with, allows students to develop competences that facilitate their integration into the working world.

Likewise, the Argentinean Chamber of Construction (CAMARCO, in Spanish, 2020) mentions that BIM implementation requires planning how the transition of work will be done, as well as how to choose and develop a pilot project. At the same time, they highlight that this project must be on a small scale, with medium complexity and respond to a construction typology that the work team knows well.

Concretely, BEP is a document where the strategies, processes, resources, techniques, tools, systems, etc., which must be applied to guarantee compliance of the BIM requirements requested by the client in a given project, converge, following the life cycle phases related to this (ESBIM, 2018). Following the PlanBIM (2019), two BEP must be developed: one of the Offer (Tender) and another Definitive one (Awarded Supplier). The difference between them is based on the level of detailed information each one contains. The Offer BEP contains basic information of the project, goals and uses of the BIM, technological infrastructure and competences of the team, general deliverables, and overall collaboration strategy. The Definitive BEP, apart from having a greater specificity in the information, includes the standards and conventions that will be used.

Regarding the determination of the roles of the different participating agents, Piña et al, (2017) identify the following intervening agents in the BIM projects:

- BIM Manager: responsible for managing the team and developing and applying the BEP.
- BIM Coordinator: executive party of the BIM Manager, also responsible for developing, applying, and managing the PEB of a project.
- BIM Modeler: in charge of handling the modeling of the project.
- BIM Operator: in charge of managing the deliverables and the exchange of files.
- BIM Analyst: in charge of making simulations and analysis of the BIM models.
- Content Manager: performs the information management tasks the model contains.
- Facility Manager: carries out the building's management in the operation and maintenance phase in a BIM environment.

In this way, a role matrix, following the characteristics of a classroom implementation of the BIM methodology, must make the roles defined by the BIM standards compatible with the functions, characteristics and capacities of teachers and students, in particular. It is worth adding that, as a result of its main characteristics, it is feasible to develop an Offer BEP that allows structuring the teaching practice; while the Definitive BEP will emerge regarding the final presentation of the project, being able to include indicators that facilitate its evaluation considering the percentage compliance of the proposed goals.

Following on from this, it is proposed to hold, in August 2020, a BIM implementation classroom experience in the Environmental Architecture Vertical Workshop course of FAUD-UNSJ which, based on what has been set out by CAMARCO (2020), will consist in the development of a social dwelling (typology known by the students, with a small scale and medium complexity). Given that the analysis is focused on building sustainability, it is considered pertinent that the students in the pilot project work team have prior knowledge in the matter. For this reason, it is better that the experience is carried out with advanced students. In addition, to select the work team, it is proposed to make a survey beforehand, aimed at determining the level of knowledge among the workshop's students regarding BIM methodology and building sustainability.

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The first stage of development of the research consists in making the BEM models corresponding to the chosen case studies. The different prototypes were prepared following the commonly used construction solutions in the housing of IPV-San Juan that, as can be seen in Table 1, do not reach the C level (minimum) established for the Bioenvironmental Zone to which San Juan belongs (IIIa), in accordance with the IRAM 11605 standard. Therefore, from a perspective focused on hygrothermal comfort, these construction solutions must be revised to respond to the current standards in Argentina, in general, and to building sustainability, in particular.

However, the importance of running these models in Revit, ArchiCAD and EnergyPlus, lies in that the basic guidelines that allow passing from the BIM to BEM model can be obtained from this task, as well as the scopes associated

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to each software.

In this sense, according to PlanBIM (2019), the Information Delivery Manual (IDM, in Spanish) constitutes a guide to prepare the BIM models. In other words, it structures the information to guarantee quality BIM deliverables and to ensure the availability and possible reuse of the information. In this direction, the development of the IDM implies:

- The same language, in order to remove inefficient tasks.
- OpenBIM IFC
- Same structure. It relates with the information systematization and coding (coherent and uniform file naming, coordinated position, matching the names corresponding to the BIM model levels, as well as the correct use of entities).
- Availability of information for future uses, resulting from the suitable use of the properties and set of properties defined in IFC.

It must be underlined that the importance of using IDM is the possibilities of improving interoperability, increasing effectiveness of task development, facilitating information systematization and, therefore, its availability for future use.

On the other hand, Tables 2 and 3 present the differences and similarities detected in the assessment reports obtained with each one of the pieces of software used in the research. In this regard, it is highlighted that, in Table 2, the content of these reports is qualified using a scale of high, medium and low, depending on the transparency and traceability of the results obtained and the possibility of running later relational analysis. Based on the purposes of this research, the complexity of the interpretation of results and the possibility of establishing model buildings that benefit assessing sustainability conditions that, at the same time, act as the basis to determine compliance indicators related to teaching practice, are also analyzed. Finally, the possible output variables in each piece of software are considered. Table 3 also shows a list of the contents observed in the assessment reports obtained.

On examining Tables 2 and 3, it is seen that ArchiCAD places emphasis on data transparency, referencing their origin. Likewise, the software studied present the possibility of making a comparative analysis of different construction or design options. Revit accentuates economic aspects, the use of photovoltaic energy and analysis by orientations. Based on this, it is inferred that this software highlights bioclimatic design variables. On the other hand, EnergyPlus and ArchiCAD present the results of different variables without establishing hierarchies, leaving to the criteria of the researcher, the use and establishment of data priorities. Revit presents, in addition, an analysis strongly focused on energy costs, while ArchiCAD shows an evaluation that is analog to that of EnergyPlus. Likewise, according to the bibliography consulted, Revit does not address the analysis of thermal bridges. Following on from this, Table 4 summarizes the general guidelines that allow passing from the BIM model to the BEM.

Variable de Análisis	Software: ArchiCAD (Ecodesigner)	Revit (Insight 360)	EnergyPlus
Transparencia	🟩	🟥	🟩
Trazabilidad	🟩	🟥	🟩
Posibilidad de procesamiento posterior de datos	🟩	🟥	🟩
Complejidad en la interpretación de los resultados	🟨	🟥	🟥
Comparabilidad (Posibilidad de establecer edificio de referencia)	🟩	🟩	🟩
Cantidad y Pertinencia de variables de análisis para la simulación energética	🟨	🟨	🟩

Table 2. Analysis of the assessment report content (general characteristics).
Source: Preparation by authors based on simulations made in Revit, ArchiCAD & EnergyPlus.

References: : 🟩 High 🟨 Medium 🟥 Low

Results Analysis	Software: ArchiCAD (Ecodesigner)	Revit (Insight 360)	Energy Plus
Project Data Summary	●		
Results by Zones	●		●
Energy balance of the project	●	●	●
Temperature	●		●
HVAC Performance	●	●	●
Energy Consumption	●	●	●
Energy Consumption by Source	●		●
Environmental Impact	●		●
Energy Certifications	●	●	●
Base Performance	●	●	●
Base Energy Cost	●	●	●
Performance Rating	●		●
Energy savings and consumption	●		●
Leaks	●	●	●
Renewable energy usage	●	●	●
Lighting	●	●	●
Warning Reports	●		●

Table 3. Analysis of the content of the assessment reports (specific characteristics)
Source: Preparation by authors based on simulations made in Revit, ArchiCAD & EnergyPlus.

Modeling Opportunities	Item	ArchiCAD *Ecodesigner)*	Revit *(insight 360)*	EnergyPlus	Observations
1	Integrated 3D Modeling	•	•	– –	EnergyPlus uses SketchUp and OpenStudio.
2	Determination of thermal zones	•	–	• ?	
3	Definition of materials	•	•	• ?	ArchiCAD and Revit have integrated Calculation engines that take the data From the model. EnergyPlus uses IDFEditor.
	Determination of building packages	•	•	• ?	
	Configuration of thermal Blocks / Climatization Systems	•	•	• ?	
4	Personalized User Profiles	•	–	• ?	Revit has use profiles by default .
5	Selection of climate file	•	–	• ?	ArchiCAD and EnergyPlus accept Climate files: (*.epw). Revit obtains data of closest meteorological season
	Output variables	•	•	• ?	In EnergyPlus, the *"fatal errors"* require the revision of the model. In Revit, session must be started in Autodesk and be in the 3D window ArchiCAD, requests the correction of inconsistencies before simulating EnergyPlus and ArchiCAD, have compatible output variables. Revit makes an analyzed based on energy efficiency and use of renewable energies.
6	Results for later processing	•	–	• ?	ArchiCAD and EnergyPlus allow the later data processing
	Results Report	•	•	– –	Revit, does not permit later analysis of the results

Table 4. Similarities and differences detected in the different modelling instances, of the software analyzed.
Source: Preparation by authors based on simulations made in Revit, ArchiCAD & EnergyPlus.

The guidelines for running the BEM are obtained from the analysis of Table 4, as well as the particularities inherent to its process, following the characteristics of the software chosen for the task. In this context, it is relevant to clearly establish the goal the model is made for. Thus, if the valuation of the building sustainability emerges in the design stage or, as is the case of this research, to set up a decision-making support system from the early stages of the projection process, it is better to use Revit or ArchiCAD due to their easy application and the speed results are obtained. Now, if the project requires an in-depth analysis about the energy behavior of the building, the use of specialized software, like EnergyPlus, is suggested.

Regarding the results obtained in the second stage, it is highlighted that, for Mercader Moyano et al. (2019), the environmental, social, and economic sustainability has the design stage at its core. For this reason, the proposed teaching practice to be held during August

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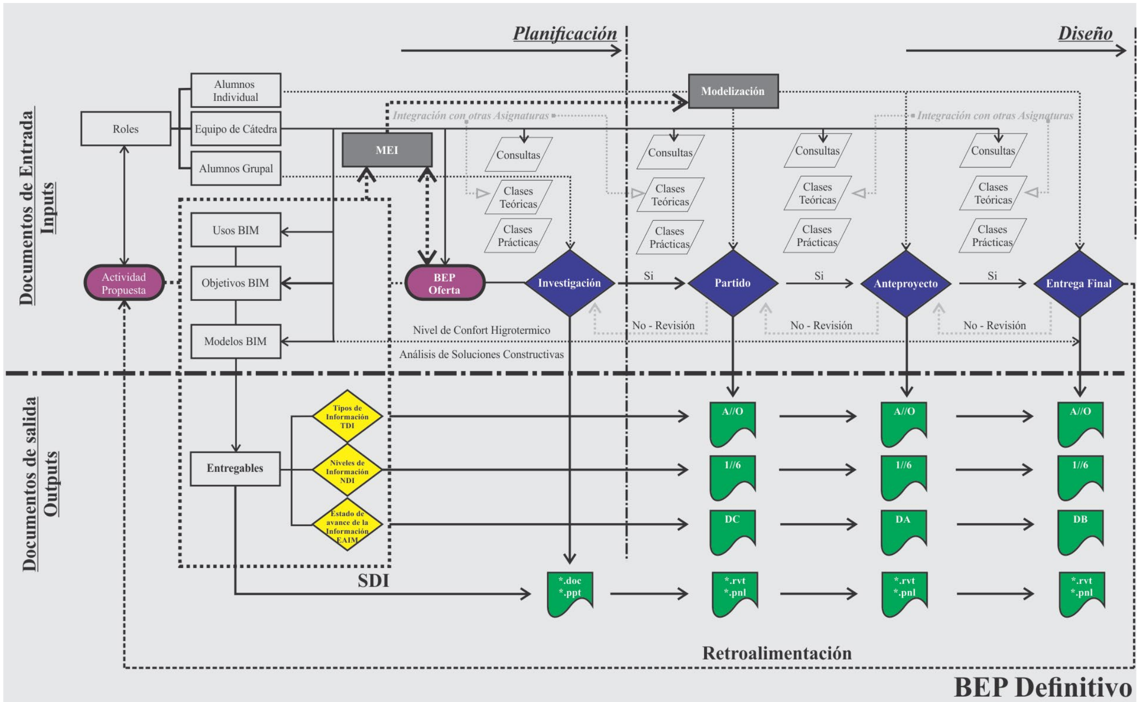

Figure 5. Workflow of classroom experience based on BIM methodology.
Source: Preparation by the authors.

Phases of the Life Cycle	Role		Planning	Development	Construction	Operation	Lead	Revise/ Evaluate	Model	Coordinate	Manage
			Project Stages				Function				
Design	BIM Manager	Course Head	●				●	●		●	●
Design	BIM Coordinator	Course Team	●				●	●		●	●
Design	BIM Modeler	Student		●	•	•			●	•	•
Design	BIM Operator	Student		●	•	•			●	•	•
Design	BIM Analyst	Student		●	•	•			●	•	•
Design	Content Manager	Student		●	•	•			●	•	•
Design	BIM Information Manager	Student		●	•	•			●	•	•
Construction	Construction BIM Manager	Student		•	•	•			•	•	•
Operation	Facility Manager	Student		•	•	•			•	•	•
End of Life	Facility Manager	Student		•	•	•			•	•	•

Table 5. Tentative roles matrix for the classroom implementation of the BIM methodology.
Source: Preparation by the authors based on Piña et al. (2017).

References: ● Main Role • Role subject to model's target

2020, in the Environmental Architecture Vertical Workshop (TVAA), takes as a starting point, a social dwelling design phase. The goal here is providing students with knowledge that allows them to suggest a sustainable design by checking the results, from the beginning of the classroom experience.

From that point of view, apart from the work procedure and the IDM, the following general pedagogical guidelines are suggested: forming work groups; making the sustainable design of social housing (simplified design experience) using a BIM software; brainstorming; comparison of the experience with the traditional design practice; determination of benefits and difficulties in the implementation of the BIM methodology during the design process; and preparation of group conclusions. It is pertinent to mention that the BIM Information Requests (SDI BIM), known in European standards as EIR (Employer's Information Requirements), are documents that include: targets, uses, type and levels of information (TDI and NDI), deliverables, collaboration strategies (Shared Data Setting – CDE), state of progress of the information (EAIM), and organization of the models (PlanBIM, 2019). As a result, their definition prior to the preparation of the BEP, is advisable.

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BEP Tentativo de Oferta				
	Ítems	Característica	Variables	% de Cumplimiento
A. Información de Proyecto:	Llenar con la Propuesta Pedagógica		Nivel de competencia	
B. Introducción	Listado de Alumnos/ Equipo de Trabajo - Declaración de sus competencias previas	Arquitectura	●	
		Estructura	●	
		Instalaciones	●	
		Otros:		
C. Información del Modelado	Objetivo	Ej. Vivienda Social Bioclimática	Recursos / Capacidades / Experiencia Previa	
	Usos BIM	Ej. Consumo Energético	Recursos: ● / Capacidades: ● / Experiencia Previa: ●	
	Desafíos del Modelado		LOD 100 / LOD 200 / LOD 300 / LOD 400 / LOD 500	
	Oportunidades del mode			
	Nivel de Desarrollo		LOD 300: x	
	Estrategias de modelado			
	Verificación del Modelado			
	Verificación de Interferencias		BIM / CAD / PDF / JPG / XLS / GIS / Otro / Planificación / Desarrollo / Construcción / Operación	
D. Información de Referencia (INPUT)	Nombre del Archivo	Contenido principal	BIM: x; Planificación: x	
E. Roles y Funciones	Jefe de Cátedra		Dirigir: x; Revisar/ Evaluar: x; Coordinar: x; Gestionar: x	
	Equipo de Cátedra		Dirigir: x; Revisar/ Evaluar: x; Coordinar: x; Gestionar: x	
	Alumno (Individual)		Modelar: x	
	Alumnos (Equipo)		Modelar: x	
F. Cronograma	Ej. 10-06-2020	Ej. Diseño Urbano	Investigación / Esquicio / Idea Partido: x / Anteproyecto / Entrega Final / Otro	
G. Información a producir/ Entregables			BIM: x / CAD / PDF / JPG / XLS / GIS	
H. Sistema coordinado para la Recopilación/ Gestión e Intercambio de Datos (CDE: Entorno de Datos Compartidos)				
I. Conclusiones				

Table 6. Offer Tentative BEP
Source: Preparation by the authors based on PlanBIM (2017) and SIBIM (2019).

Bearing this in mind, Figure 5 is prepared, which summarizes the proposed workflow for developing a classroom experience based on the BIM methodology. From its analysis, it is inferred that holding said experience requires the determination of the roles each one of the players involved in the design process fulfills (Table 5), as well as the documents prior to the presentation of the Offer BEP (Table 6) and later Definitive BEP. In addition, it presents the inherent complexity for the implementation of the BIM methodology in a teaching practice, given that this requires the prior establishing of documents that structure its development. In this sense, the collaborative work of the course's team and of the work team represented by the students, is essential.

The main structure of the tentative Offer BEP proposed in this research (Table 6) was prepared based on the BEP, for the public sector of the BIM standards, developed by SIBIM (2019) and PlanBIM (2019). The items indicated in red correspond to contributions that must be completed following the characteristics of the academic practice being implemented. Given that this is a double entry table, the columns corresponding to "Variables" indicate the degrees of specificity that the model must reach to fulfill the suggested targets. To complete said variables, the traffic light method, as applies, is used, or the desired characteristic is indicated for the item with a cross. According to the state-of-the-art, in the case of using methodology for pedagogical ends, the indicators used correspond with the percentage compliance reached. In response to this, the BEP incorporates a column that allows the BIM Manager/Course Head to assess the level reached by the student or work team in each item considered. In this way, the use of this BEP, apart from contributing to structuring the pedagogical practice and fostering collaborative work, facilitates the evaluation, and as such provides traceability and transparency.

It must be underlined that the proposed classroom experience corresponds to one of the first implementations of the BIM methodology in FAUD-UNSJ. Therefore, its results contribute to the preparation of professionals with competences related

Propuesta para la implementación de la metodologia bim en una experiencia áulica orientada a la sustentabilidad edilicia
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to the BIM methodology and collaborative work, in what González Pérez (2015) characterizes as Big BIM, apart from the handling of BIM tools (Little BIM). Likewise, on focusing on building sustainability, it contributes to the use of the methodology as a support system for decision-making that places a value on this variable in the early stages of the design process.

Among the main limitations for the implementation of the BIM methodology in a classroom experience aimed at building sustainability, is the human capital one has for this. In fact, the determination of the level of previous knowledge students have is essential to guide the goals of the pilot project and the environmental and compliance indicators being evaluated. For this, before holding the classroom experience, a survey must be made that makes it possible to determine said level. It is important to give feedback about the pedagogical practice, identifying positive experiences and those that can be improved. From this, the guidelines are obtained to standardize positive practices, redefine those needing improvement and detecting deviations or inefficient ways to work on over time, which leads to the continuous improvement of the teamwork (CAMARCO, 2020).

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The study above allows inferring that the use of the BIM methodology in an academic setting is not only necessary for the preparation of professionals with specific competences in this but it is also highly feasible. The proposed BEP, whose structure follows the BIM standards developed in Argentina and Chile, facilitates planning a teaching experience aimed at incorporating building sustainable variables in the initial stages of the collaborative work-based design process.

From this perspective, simulating three commonly used social housing prototypes in San Juan, Argentina, allowed determining the work procedure needed to pass from BIM to BEM. In this task, the particularities of the use of a given software are obtained, which benefits that both the teacher and the student quickly detect errors made while making the model. In parallel, getting to know the scope of the results obtained in Revit, ArchiCAD and EnergyPlus allow the student to carry out the proposed activity (pilot project) in the software of their choice without compromising the validity of the results.

The role matrix, BEP and proposed workflow generate a structure that facilitates the transition from the current educational model to collaborative models. In addition, focusing on the analysis of the BEM development, there is a positive contribution to the use of the methodology as a support system for decision-making related to sustainability variables from the initial stages of the design process.

In this sense, the BEP presented in this article contributes to the development of specific standards that guide the way the BIM methodology is implemented in academic settings which, at the same time, guarantee that the student, regardless of the academic team and the BIM software, develops competences in a way that increases productivity and contributes to the sustainability of the construction industry. In this way, it helps to make future professionals aware of the importance that decisions made during the design process have on the future energy behavior of projects, as well as their environmental impacts, or on the level of indoor comfort of their spaces and, with that, the quality of life of their occupants.

For the purposes of feedback of its structure, in the second stage of this research, the proposal presented in the TVAA of the FAUD-UNSJ will be validated. Likewise, it must be underlined that the classroom implementation of the BIM methodology, as an active part of the design process, requires determining the documents that exceed the scope of this first research stage. In this regard, and looking into the future, the need is outlined of addressing analyses that include the determination and characterization of the human capital one has, as well as the definition of the possible assessment indicators considering the interests and targets of each design subject, the normative study (ISO 19650), or the development of documents other than those mentioned in this article like: AIR (Asset information requirements), CDE (Common data environment), OIR (Organizational information requirements), PIR (Project information requirements), among others. Later, work in more depth must be made in the development of the IDM, SDI and BEP, guidelines in line with the academic level of the student, which involve in their structure, the exchange of information with other courses and laboratories. With regards to the latter, it is of interest to look further into the interoperability between BIM and GIS, to prepare a City Information Model (CIM, in Spanish), that contributes to decisions regarding the urban environment. With this, the pedagogical practice would be enrichened as a result of addressing the course concepts like “urbanism” or “installations”.

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TRANSICIÓN ENERGÉTICA ARGENTINA. EL NUEVO ESTÁNDAR DE EFICIENCIA ENERGÉTICA EN LA EVALUACIÓN DE LA VIVIENDA SOCIAL. CASO DE ESTUDIO: VIVIENDA DE BARRIO PAPA FRANCISCO

ARGENTINEAN ENERGY TRANSITION. THE NEW ENERGY EFFICIENCY STANDARD IN THE EVALUATION OF SOCIAL HOUSING. CASE STUDY: DWELLING IN PAPA FRANCISCO NEIGHBORHOOD

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RESUMEN

El sector edilicio es responsable del 40% de la demanda energética a nivel internacional y el 37% en Argentina. La climatización constituye el ítem más representativo. Los países instituyen medidas para el uso racional de la energía y persiguen estrategias a fin de provocar la transición energética. La aprobación del estándar IRAM 11900 en Argentina promueve la Eficiencia Energética (EE) en el sector edilicio residencial que se pretende, sea inclusivo y conduzca a la transición al 2050. El objetivo del trabajo es la evaluación termo-energética de un prototipo existente de vivienda de interés social del Barrio Papa Francisco y sus variantes mejoradas *"retrofit"* y *"ex ante"*, desde el enfoque de la norma. Para ello se relevan dimensiones, sistemas constructivos, componentes de la envolvente y equipamiento para cubrir demandas de calefacción, refrigeración, agua caliente sanitaria e iluminación. Como resultado relevante, el índice de prestaciones energéticas (IPE) del prototipo existente alcanza un valor de 132 $kWh_{Prim.}/m^2$.año. Además, las variantes mejoradas *"retrofit"* y *"ex ante"* conducen a ahorros económicos considerables en la inversión inicial. De aquí que se valora la importancia de implementar software de análisis en la etapa de proyecto para cuantificar los recursos energéticos y el ahorro de emisiones en una transición energética planificada.

Palabras clave
indice-ipe, vivienda social, norma iram-11900:2017, etiquetado energético

ABSTRACT

The building sector is responsible for 40% of the energy demand internationally, and for 37% in Argentina. Heating and cooling are the most representative item. Rational energy usage measures are being introduced in countries throughout the world, as well as strategies that pursue energy transition. The passing of the IRAM 11900 standard in Argentina promotes energy efficiency (EE) in the residential building sector, and it is expected to be inclusive and lead to the transition by 2050. The aim of this work is to perform the thermo-energy evaluation of an existing social dwelling prototype in "Barrio Papa Francisco" (Pope Francisco Neighborhood), as well as in its two improved variations: "*retrofit*" and "*ex ante*". For this, information is collected about the dimensions, construction systems, building envelope components and equipment to meet demands for heating, cooling, domestic hot water and lighting. As a relevant result, it is reported that the energy supply index (IPE, in Spanish) of the existing prototype reaches a value of 132 $kWh_{Prim.}/m^2$.year. In addition, the *retrofit* and *ex ante* variations lead to considerable economic savings in the initial investment. This is why the importance of implementing software analysis at the design stage is considered as important in order to quantify energy resources and emissions savings in a planned energy transition.

Keywords
ipe-index, social housing, iram11900:2017 standard, energy labeling

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INTRODUCTION

At an international level, energy transition actions differ depending on the economies and social structures of countries. STET Models or Socio-Technical Energy Transition Models, allow detecting foci and dynamics that guide countries in their transitions, raising the discussion about the participation of technologies in their economies and the carbon emissions and targeted energy demand values (Li, Trutnevyte & Strachan, 2015). Emerging economies prioritize changes in biomass use for modern energy vectors. Strategies in developed countries, like the United Kingdom, France and The Netherlands, range from retrofit models for the building envelope in energy conservation, through *ex-ante* energy efficiency planning, to territorial development models for the sustainable growth of new neighborhoods. Germany, a pioneer in energy transition, has developed, for almost two decades, the ENOB - Energie Optimiertesbauen – program, (or Optimized Energy Construction, in English), which focuses on reaching a primary energy demand for lighting, heating/cooling and ventilation of 100 kWh_{Prim}./ m^2y, based on *ex-ante* planned models (Kuchen, Plesser & Fisch, 2012). Today, they are moving forward with the Ministry of Economy and Energy's *ENERGIE WENDE BAUEN 2020* program (Program for Energy Transition in Construction)[1], called *Energieoptimierte und klimaneutrale Gebäude der Zukunft* (Building planning with energy efficiency and neutral environmental impact in English), promoting models of low primary energy demonstration projects, with renewables, and emissions reduction in the 4 phases of the service life.

The Argentine transition pursues, by 2050, the diversification of the energy mix with renewables, Energy Efficiency (EE) in the dwelling, electrification of the end energy, digitalization of data and the change of strategies to lower emissions in industry, forestry and farming (Fernández, 2019); a plan that brings together contributions from international experience. The residential sector, responsible for almost 80% of the consumption of resources within the building sector for the caloric demand (Chevez, 2017), as well as having the highest potential action, is subject to becoming the Achilles heel in the transition, due to its diversity and extension (Riavitz, Zambon & Giuliani, 2015).

The goal of the National Housing Labeling Program in Argentina is introducing the EE Label as a tool that provides users with information about the energy performance of the dwelling (Alonso Frank & Kuchen, 2017). The standard, which highlights the approach models of *ex-ante* and *retrofit* situations, intends on also generating added value to properties (Energy Secretariat of the Nation – SEN, 2020). The purpose of the label is becoming a decision-making tool on carrying out, with environmental awareness, a property development operation: assessing a new project or intervening in existing dwellings (SEN, 2020).

The method to obtain the energy performance index (IPE, in Spanish), standardized in the reference standard (IRAM 11900, 2017), represents the "primary energy" requirement by unit of surface and year [$kWh_{Prim.}/m^2year$], to satisfy the heating, cooling, sanitary hot water and lighting needs of the dwelling. According to Risuelo (2010), labelling should provide information about different measures and investments, at a technological level, of the management and the cultural habits of the citizens.

The initial decisions at the projects' conception are the most determining factors and offer a better balance in the cost-benefit ratio. Correctly deciding on the orientation of a building and the degree of compactness, sizing glazed surfaces based on the climatic characteristics of the location, *ceteris paribus*, should not be more demanding than negligent practices. In addition, any correction during the works themselves tends to be extremely difficult (Kozak, Evans, Adamo, Abálsamo & Romanello, 2017).

In the same way, the choice of structural materials and design operations regarding openings, the location of edges and offsets of the glazed surface, has a strong impact on the equation of economic costs versus the energy-environmental and thermal comfort benefits (Evans, De Schiller and Kozak, 2015).

As the project and construction progress, opportunities close and to achieve a balanced thermal-energy performance, more money must be invested. The same occurs with sustainability-related decisions, like the choice of a material considering its environmental impact, starting from the energy involved in its production and that used during its transportation, or the degree of environmental health of the industrial process during its manufacturing (Brent & Petrick, 2007).

This work presents the study of given construction strategy alternatives, possible options to be implemented in a domestic energy transition, where the economic costs and performance are assessed. As a rule of thumb, the earlier EE and sustainability strategies are included in an architecture project, greater benefits will be achieved at lower costs.

1 Energie Wende Bauen. Energieoptimierte und klimaneutrale Gebäude der Zukunft. Bundesministerium für Witschaft und Energie. BMWE 2020. Retrieved from https://projektinfos.energiewendebauen.de/forschung/forschungsfoerderung/energieoptimiertes-bauen/

METHODOLOGY

As a first step, in methodological terms, a representative unit of the Papa Francisco Neighborhood is identified. Then field work takes place to collect the data to be analyzed. Features like geo-referential characteristics, technical-constructive characteristics (wall, flooring, roof and openings), proximities, solar obstructions, thermal areas, non-climatized or uninhabitable rooms are collected, as well as the equipment to cover heating, cooling, sanitary hot water and lighting demands and the contribution of renewables. To evaluate the energy performance of the unit, the requirements of the IRAM 11900: version 2017 standard are considered, and for the calculation, the Housing Labeling reference IT application (software) is used. Depending on the results obtained from the reference unit, improvements are made to the construction components of the opaque (solid) and transparent (windows) envelope in the *retrofit* applications, that is to say, the retroactive adaption of the finished dwelling and *ex-ante*, namely, simulating the draft stage prior to building the dwelling. Apart from the energy advantages of addressing different strategies, in a process leading towards an energy transition applied through this type of models, the economic and environmental suitability are assessed.

a) Progress of the works, 2019.

b) Location of the object of study.

Figure 1. Intervention of social housing in the Papa Francisco Neighborhood.
Source: City Housing Institute (IVC, in Spanish). Buenos Aires.

a) Unit identified with hashed red line.

b) Finished facade and commercial boulevard on Ground Floor.

c) Indoor Surface finish and aluminum opening

Figure 2. Apartment block chosen for the thermo-energy evaluation
Source: City Housing Institute (IVC). Buenos Aires.

Transición energética argentina. El nuevo estándar de eficiencia energética en la evaluación de la vivienda social. Caso de estudio: Vivienda de Barrio Papa Francisco
Ernesto Kuchen, Daniel Kozak
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IDENTIFICATION OF THE CASE STUDY

27,000 people live in Villa 20, in 4,581 dwellings (48 hectares). The "neighborhood integration" proposal (City Housing Institute – IVC, 2016) consists of generating 1,700 new habitational units (Figure 1a). An existing prototype is chosen as a social housing case study for the relocation of Villa N° 20 to the Papa Francisco Neighborhood, in Villa Lugano, Province of Buenos Aires, in bioenvironmental zone III-B. This has a warm-humid template climate, as per the IRAM 11603 standard's rating (2012), with a mean winter temperature of 12.8°C (min of 9.7°C and max of 16°C) and of 23.3°C in summer (min of 19.6°C and max of 27°C), with an environmental relative humidity of 77% in winter and 69.3% in summer. The heating energy demand based on a 20°C comfort, as per IRAM 11603 (2012), is 1249 degrees/day. The "compact typology" prototype is the standard, within the set of other buildings with similar characteristics (Figure 1b).

TECHNICAL-CONSTRUCTION CHARACTERISTICS

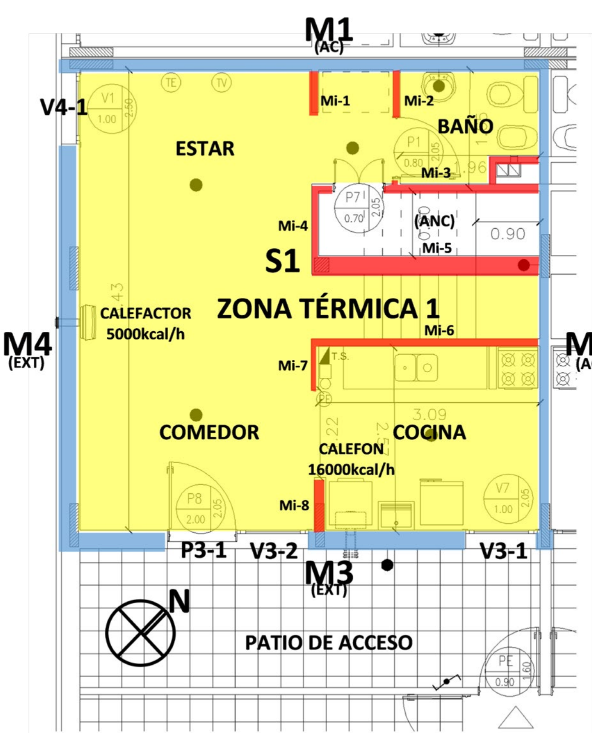
The property under study is located on the third floor of a block of apartments, which is reached by stairs. It is grouped into 8 apartment sub-blocks of 5 floors each (Figure 2a), with a commercial boulevard on the Ground Floor and one-floor apartments on the 1st and 2nd floors (Figure 2b).

The prototype is a duplex with a 78.6m^2 floor plan, an indoor height of 2.6m (Figure 2c) and a volume of 204.5 m^3. The program comprises an exterior access hall with that leads to a living-dining room, a kitchen and bathroom on the ground floor and 3 bedrooms with a full bathroom on the top floor (Figure 3).

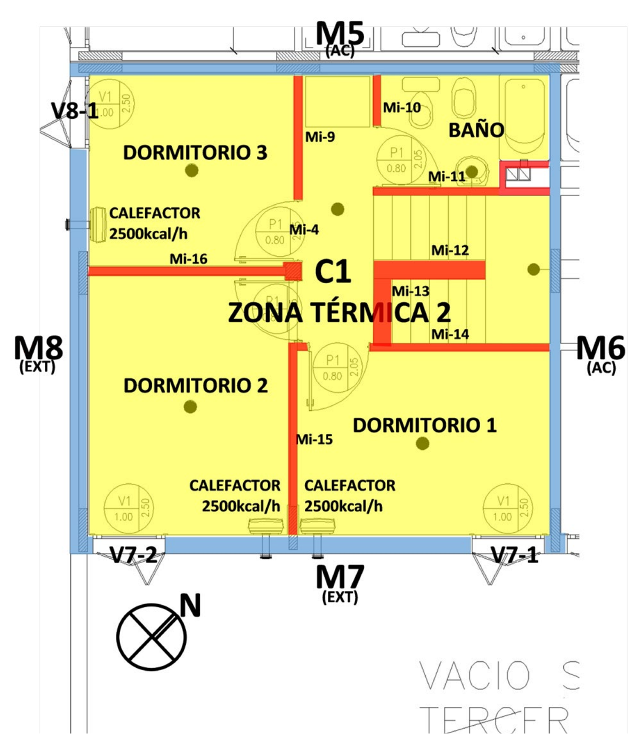
The envelope comprises 18 cm ceramic hollow block walls, with a 3 cm Isolteco type heat-insulating external white plaster, internal 2 cm Revear type plastic indoor plaster (white), with a transfer coefficient of *K=1 W/m²K*; galvanized sheet roof, insulated with 5 cm of glass wool and ceiling with 1.5 cm (white) plasterboard, *K=0.72 W/m²K* and beige tiled flooring *K= 2.9 W/m²K* (floor-to-ceiling). The openings, 1m in width and 2.10m in height which can be opened, are made of white aluminum, with double contact and simple glazing. As a solar protection, they have PVC white roller blinds, with roller blind box above the top frame, at the height of the door-head (Figure 2c), *K=3.68 W/m²K.*

EQUIPMENT

This is meant to cover the requirements to ensure quality of life, keep indoor temperature >20°C in winter and <26°C in summer, hot water (42°C) and lighting in indoor rooms >300 Lux. For heating, it has an installed power of 5.82 kW, in balanced draft heaters, 1 of 5000 kcal/h and 3 of 2500 kcal/h. For Sanitary Hot Water (ACS in Spanish), a 16000 kcal/h boiler (see Figure 3), in lighting, LED lights with a total of 72W. It does not have installations for cooling. There are no Renewable Energies present.



a) Ground floor of the duplex prototype.



b) Top floor of the duplex prototype

Figure 3. Unit floor plan. Identification of equipment, envelope elements: walls and openings; floor and roof; thermal areas and orientation.
Source: Preparation by the authors

RESULTS AND DISCUSSION

By implementing the calculation application software (Housing Labeling, 2020) that the Energy Secretariat of the Nation promotes (SEN, in Spanish, 2020), following the requirements of the standard (IRAM 11900, 2017), the dynamic characteristics, requirements and thermal-energy behavior indicators are calculated, to analyze decision variants for the efficiency and energy restructuring of dwellings.

DYNAMIC ENERGY CHARACTERISTICS

The dynamic energy characteristics refer to the relationship between the contributions and losses of each period where there is additional energy demand. Starting from the simulation, it is noted that, from all the free contributions, 30% is captured in winter and it is possible to take advantage of almost all of it (97%). Conversely, the loss percentage through ventilation and thermal energy conduction from the envelope in summer (thermal dispersion) is 48%, of which less than half can be taken advantage of (47%). The location of the prototype has unfavorable sunlighting conditions regarding the "free contributions" and effective ventilation for "thermal dispersion".

The degree of compactness of the property may be beneficial. In this aspect, the ratio between the envelope area and climatized volume *"A/V"*, measured in [m^{-1}], is 1.5 m^{-1} (good). The "heat transfer factor" is added to this benefit. This refers to the location of a unit over the whole, with a non-dimensional value of 0.36 (low) on a scale of 0-1. From this, it is seen that the location is beneficial in winter. The ventilation strategy of the dwelling plays a fundamental role in the "thermal dispersion", this having to be assured in summer, especially during the night when outdoor temperatures fall, due to cross ventilation.

The "heat transfer factor" is reflected in the "global heat transfer coefficient (H)" value, which indicates that for each degree of indoor-outdoor temperature difference, an energy requirement must be guaranteed in accordance with the seasons of the year. For this prototype, H is 106 W/K in winter (low) and 2.6 times higher in summer, 274 W/K (high). A low H coefficient indicates better "time constant" levels, measured in hours [h], that is to say, the thermal capacity of the envelope to absorb the indoor-outdoor thermal jump, being 28.5 h for winter and 11 h for summer.

ENERGY PERFORMANCE INDEX (IPE)

The IPE represents the primary energy value [$kWh_{Primary\ Energy}/m^2.y$] regarding the environmental impact of the energy use required, and its value shows the energy efficiency level. Table 1, regarding the evaluated prototype, shows

Type of Energy measured in [kWh / m2 . year]	Useful	Net	Primary
Heating	47	72	90
Cooling	12	5	18
Sanitary Hot Water Production	12	16	20
Lighting	-	1	4
Global specific energy requirement			132
Specific contribution of renewable energies	0		
Energy Performance Index, IPE. [kWh / m2 . year]	132		

Table 1. Total energy required to cover thermal and lighting demands of the dwelling.Source: Preparation by the authors.

"useful, net and primary energy" values which must be provided to the system, by useful [m^2] of the property in one year. The resulting IPE in Table 1, of 132 $kWh_{Prim.}/m^2.y$, is a reference value of the primary energy requirement and that, in relation to the average, in the label corresponds to Category D (yellow), that is to say, "mean or standard quality" as per IRAM 11900:v.2017.

The "useful energy" is the thermal energy that will allow maintaining the indoor temperature ≥ 20°C in winter with Heating (47 kWh/m^2.y), ≤ 26°C in summer with Cooling (12 kWh/m^2.y) and the Sanitary Hot Water ≥ 42 °C (12 kWh/m^2.y). These energy values found for this 78.6 m^2 property will vary by climate zone, shape, sunlighting, compactness, infiltrations and insulation, among other factors. The "net energy" represents the energy the dwelling requires to cover the thermal and lighting demand (electricity and/or gas). This indicator allows reflecting the performance of the installed equipment. The "primary energy" is the energy that needs to be obtained, before being transformed and/or transported, to be provided as thermal or light energy to the room. To calculate it, "reduction factors to primary energy" are used and its value will depend on the type of energy matrix. For the case of Argentina, the gas to primary energy vector reduction factor will be 1.25, and for electricity, 3.3.

HEATING

"Balanced draft gas heater" heating is reflected on observing that, to provide 47 kWh_{Useful}/m^2.year, an additional amount of energy is needed, which is lost through the ventilation of the combustion gases. 72 kWh_{Net}/m^2.year must be consumed (see Table 1), that is to say, 65% more, without obtaining the thermal benefit. In the case of the "gas grid" vector, 90 $kWh_{Prim.}/m^2$.year is needed to cover the thermal demand, that is to say, an additional 25% over the net energy provided.

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COOLING

The unit studied does not have cooling equipment, which does not mean that it is not needed. According to the calculations, to keep the indoors ≤ 26°C, 12 kWh_{Useful}/m^2.year are required. Unsuitable thermal conditions would lead the user to install, for example, a Split. The COP performance coefficient, EE class "A", in Argentina is COP=3.3. This means that each unit of electricity provides 3.3 units of thermal energy. On not knowing the COP, the application provides a hypothetical value of COP=2.4 (Category C or D), requiring 5 kWh_{Net}/m^2.year (see Table 1). 18 $kWh_{Prim.}/m^2$.year are required for the electricity supply.

SANITARY HOT WATER

The useful thermal energy that has to be added to water to increase its temperature to 42°C is 12 $kWh_{Useful.}/m^2$.year, a value that depends on the useful surface of the dwelling and that will vary depending on the performance of the equipment. A gas boiler with instantaneous ignition and automatic pilot will be 30% more efficient than one which keeps the pilot on. The installed power in Sanitary Hot Water production (16000 kcal/h) covers the useful energy demand based on the conventional system that requires 16 $kWh_{Net.}/m^2$.year (30% more) and that, on being supplied through the gas grid, will require an additional 25%, namely, 20 $kWh_{Prim.}/m^2$.year.

LIGHTING

LED technology allows transforming almost all the net energy into useful, although the impact of using the electricity grid will continue to be high, as to provide 1 $kWh_{Net.}/m^2$.year, 4 $kWh_{Prim..}/m^2$.year will be required.

RENEWABLE ENERGIES

The dwelling does not have renewable energies available. The assumption of including these technologies (solar, wind, biomass, geothermal, etc.) implies that the fraction generated for thermal or electrical self-consumption will reduce the total primary energy demand.

TOTAL ENERGY REQUIREMENT (GAS AND ELECTRICITY)

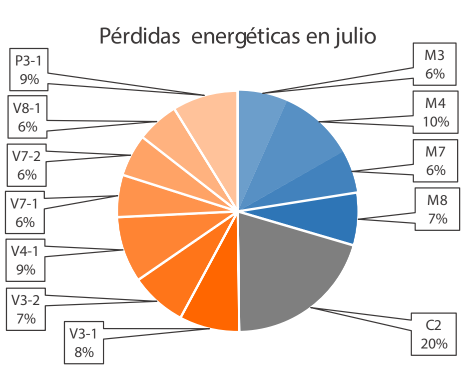
From the total energy requirement of the electricity 394 $kWh_{Prim.}$/year and gas 4187 $kWh_{Prim.}$/year vectors, the ones with the highest demand are heating 2944 kWh_{Prim}/year and Sanitary Hot Water, 1243 kWh_{Prim}/year. The cooling demand reaches 299 kWh_{Prim}/year and the lighting demand is negligible.

TOTAL ENERGY REQUIREMENT BY THERMAL ZONE

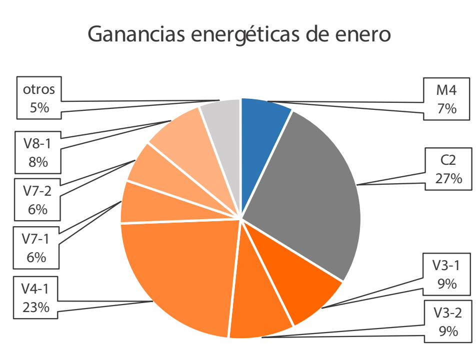
On considering a duplex, two thermal zones must be identified (Figure 3): Zone 1 (Z1) on the Ground Floor and Zone 2 (Z2) on the Top Floor. There are no significant differences in the heating thermal demand in winter. Z1 has an energy requirement of 1779 kWh_{Useful}/year and Z2 of 1914 kWh_{Useful}/year. In summer, thermal dispersion is not effective, being 287 kWh_{Useful}/year in Z1 and more than double in Z2, reaching 687 kWh_{Useful}/year. This difference can be attributed to the low level of insulation and the high degree of exposure of the roof.

BEHAVIOR OF THE ENVELOPE

The energy differences seen in zones Z1 and Z2 lead to making a particular evaluation of the envelope, with its opaque components: wall (*M*), floor (*S*) and roof (*C*);



a) Losses



b) Gains

Figure 4. Identification of construction elements involved in energy losses and gains. Nomenclatures as per floor plans of Figure 3.
Source: Preparation by the authors.

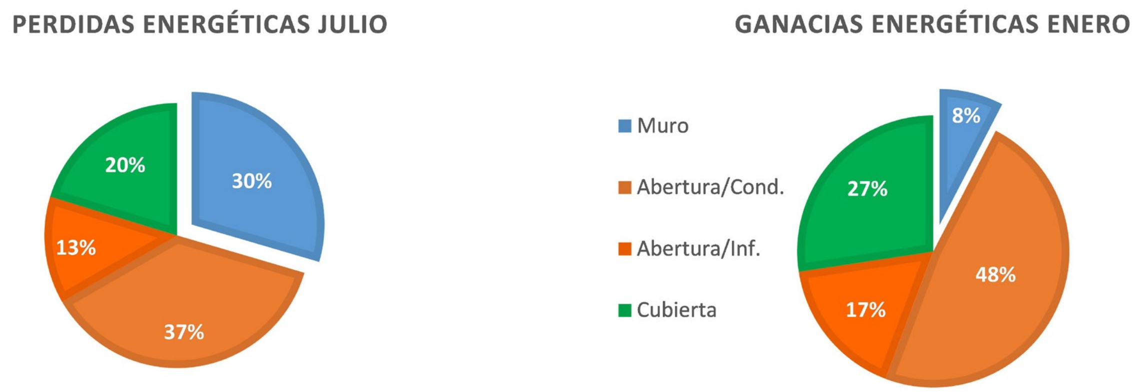


Figure 5. Losses and gains through the envelope, in July and January. Source: Preparation by the authors.

openings: window (*V*) and door (*P*). Figure 4 shows the percentage influence of the construction parts, regarding the energy requirement in the periods of highest monthly demand: July, through losses (heating) and January, through gains (cooling).

From the sum total of equivalent losses and gains, it is the roof (C2) in particular that is shown to be the most important, with losses equivalent to 20% in July and gains in January of 27% of the total. In addition, the wall (M4) corresponds to the highest loss in July and, above this, the opening (V4-1), that of highest gain in January (23%).

50% of the losses in July and 65% of the gains in January are due to the openings. If they are discriminated following the heat transfer mode, those that occur through leaks exceed by ¾ the transfer through conduction (Figure 5).

CALCULATION HYPOTHESIS

Improving the levels of delay, or in other words, reducing in hours the level of losses in winter and dispersion in summer, reconsidering the level of thermal transmittance of the envelope on walls and the roof, and of the insulation and leaks of the openings, allows correcting items with the highest impact, "heating and cooling" and conserving beneficial thermal conditions for human comfort at the minimum energy requirement.

Contrasting this hypothesis means analyzing to what extent the existing original project was thought of in terms of sustainability. After calculating and checking the insulation and thermal resistance conditions, as per the IRAM 11601 (2002) and IRAM 11549 (2002 standards – requirements considered in Provincial Law 13059 (2003) -, 3 (three) additional variants are simulated. One, a widespread construction type, called "conventional"; another where the existing dwelling is improved in the post occupation *retrofit* stage; and a final one where, in the architectonic project stage, decisions are made to reach the best EE and the lowest *ex-ante* environmental impact.

CONVENTIONAL

- General walls: 2cm interior plastic, 18 cm ceramic hollow brick, 3 cm external plaster without insulation. *K Value (thermal conductivity) = 1.54 W/m²K.*
- Roof: Finish with 2cm plaster, 12 cm of reinforced concrete slabs without insulation, 0.03 cm asphalt membrane. *K = 4.53 W/m²K.*
- Openings: 50% larger opening than the existing one. Aluminum frame window, simple glazing, single leaf window, without solar protection. *K = 5.8 W/m²K.*
- Equipment: Just like the "existing one".

RETROFIT

The following is added or changed to the existing one's setup:

- Outside wall. 3 cm coated heat-insulating plate. *K = 0.55 W/m²K.*
- Roof: 8 cm glass wool layer added. *K = 0.34 W/m²K.*
- Openings: Change of window frame, PVC and Double Glazed 4+16+4, it can be opened, PVC roller blind. *K = 1.91 W/m²K.*
- Equipment: Just like the "existing one".

EX ANTE

New envelope:

- Outside wall: 1.5 cm plasterboard, 7 cm air chamber, 10 cm PUR heat-insulating panel, outside plate finish. *K = 0.26 W/m²K.*
- Roof: 1.5 cm suspended plasterboard ceiling, 10 cm unventilated air layer, 10 cm PUT heat-insulating panel for roofs. *K = 0.25 W/m²K.*
- Openings: Window with PVC frame and double glazed 4+16+4, single leaf that can be opened, PVC roller blind. *K = 1.91 W/m²K.*
- Equipment: Reduced (4 heaters, 1500 kcal/h.)

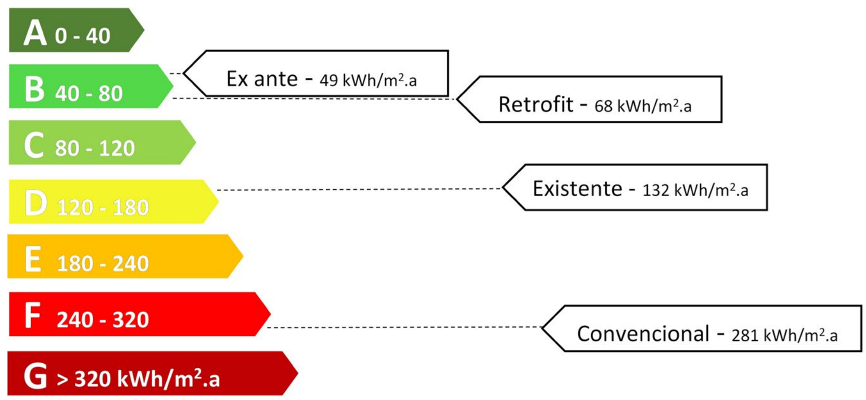


Figure 6. Energy Efficiency Label as per IRAM 11900:v.2017. IPE Values.Source: Preparation by the authors

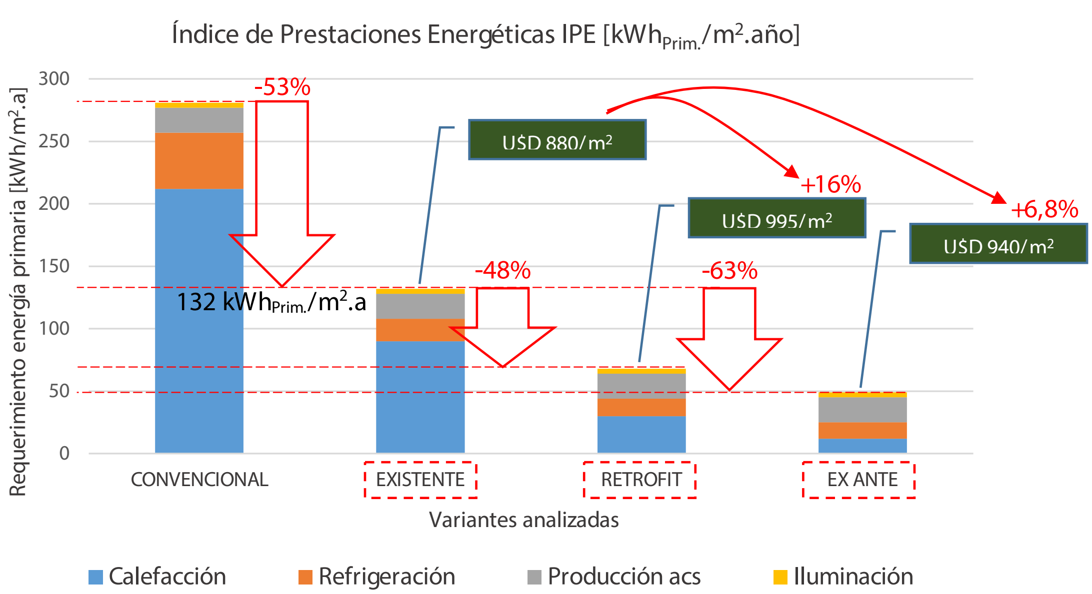


Figure 7. Primary energy requirements by variant and year. Source: Preparation by the authors.

Variant	IPE [kWhp/ m2.y]	Sup. [m2]	Energy [kWh/y]	Year cost [$]	Constr. [U$D/m2]	Investment [U$D/Un.]	Investment [$/Un.]	Tech. Inv. [$/Un.]	Amortization [years]
Existing one	132	78.6	10375.2	30243.708	880.0	69,168.0	5,083,848.0	0.0	
Retrofit	68	78.6	5344.8	15580.092	995.0	78,207.0	5,748,214.5	664,366.5	45.3
Ex ante	49	78.6	3851.4	11226.831	940.0	73,884.0	5,430,474.0	346,626.0	18.2

Table 2. Comparison of the energy costs versus the economic costs of the retrofit and ex ante variants, regarding the "existing" variant.Source: Preparation by the authors. Currency references USD1.00/$73.5 to 01/07/2020, Bank of the Nation – Argentina.

The IPE are obtained from the simulation of the proposed variants, by variant, and the values outlined in the label as per IRAM 11900:v2017, in categories (Figure 6). The "existing" variable with 132 $kWh_{Prim.}/m^2$.year, is located in an average position, corresponding to category D, and ends up being 53% more efficient than the "conventional" variant, with 281 kWh/m^2.year *(Category G)*. The improvements incorporated to the "existing" variant, lead to an increase in EE, reaching an IPE in the ***retrofit*** variant of $kWh_{Prim.}/m^2$.year and 49 $kWh_{Prim.}/m^2$.year in the ***ex ante*** variant, both categorized ***"B"*** in the EE scale.

ECONOMIC IMPACT

Figure 7 shows a general evaluation of the construction cost [U$D/m²] regarding the energy benefit as per the variants analyzed, considering the heating, cooling, sanitary hot water and lighting items in [$kWh_{Prim.}/m^2$.year]. On applying improvements, the ***retrofit*** and ***ex ante*** variants end up being, 48% and 63% more efficient, respectively, than the "existing" variant. The insulation strategies of the envelope and change of openings turn out to be effective. To lower their IPE, renewable technologies must be implemented.

The cost analysis [U$D/m²], regarding the energy benefit [$kWh_{Prim.}/m^2$.year], indicates that the ***retrofit*** variant represents increases of 16% over the "existing" variant. The ***ex ante*** variant ends up being economically and energetically more suitable on meaning increasing of 6.8%, over the "existing", requiring just 49 $kWh_{Prim.}/m^2$.year (Figure 7).

As a summary, Table 2 presents performance values (IPE) and annual energy costs for each variant (*Ref. 2,915 $/kWh, T1-R3, residential up to 400 kWh, EDENOR*) and their relation with the construction costs [U$D/Unit]. These are shown in Figure 7.

In order to estimate an amortization period of the investment, the investment costs in technology [$/Un.] are computed to local values, regarding the potential annual savings by variant [kWh/year]. This makes it possible to determine that, on following the ***retrofit*** variant, the amortization period will be 45.3 years and on opting for the ***ex ante*** variant, it will be 18.2 years.

It must be clarified that this analysis does not contain the affectation that the energy price would experience over time, calculated by Marinozzi (2020) based on an annual monomial price increase factor of 0.672. In this way, it is difficult to confirm a hypothesis of the energy price evolution in the future and, therefore, amortization estimations are unstable.

ASSOCIATED ENVIRONMENTAL IMPACT

The associated environmental impact is directly proportional to energy consumption and will depend on the energy vector involved (see point 3.2). According to the national greenhouse gas inventory (Environment and Sustainable Development – MAyDS, 2017), the residential sector impacts come in 5th place, after farming, transport, forestry, and electricity generation, with 28.41 MtCO2eq/year, which represents 7.7%, without considering the impact of wastewater and solid urban waste (3.8%). Regarding energy consumption, the environmental impact of the Argentine energy mix, by 2018, is 412 gCO2eq/kWh. From the variants, the "existing" option emits 54 kgCO2eq/year.

On considering that the impact of 1700 dwellings in the Papa Francisco Neighborhood over 80 years (service life) could be 0.007 MtCO2eq, reducing the impact associated to the consumption of resources constitutes a fundamental task for the sustainable and inclusive development in the integration of the neighborhoods in an energy transition plan.

CONCLUSIONS

The planned energy resource distribution turns into a *leitmotiv* when it comes to guaranteeing accessibility and equality in the use of the energy service, which, without a doubt, is the motor of a forced energy transition.

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The possibility of referencing admissible energy demand values by surface area and year in the comparison, as well as making the energy, economic and environmental benefits visible, translated into an energy EE label (IRAM 11900, 2017), contribute to the awareness process of an evolving population. The standard represents a change of paradigm for sustainable construction.

Law 13,903 (2017) of Santa Fe promotes its drive so that properties classified with the "A" category receive a 30% bonus of the urban property tax. It is expected that a dwelling which reaches an Energy Efficiency Class – CEE label, is registered in the deed of ownership and is transferred to the General Property Registry to provide value to the unit and motivation to owners and tenants.

The rulings made in the project's conception are the most determining factors and the ones that offer a better balance in the cost-benefit relationship. As the project process and construction move forward, possibilities to seriously modify it start closing. The Energy Performance Index (IPE), as a reference for the comparison with reference values, is a key tool at the time of planning properties from zero.

The Papa Francisco Neighborhood unit responds to better sustainability criteria regarding a widespread conventional variant, although the evaluation of the benefits had started in its initial phase, we would be witnessing a construction solution that is 63% more efficient, with an associated impact to the lower half and just 6.8% more costly, leaving a key impression on the planning of the built environment.

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INCIDENCIA DE LAS ESTRATEGIAS PASIVAS DE DISEÑO ARQUITECTÓNICO EN LA ETIQUETA DE EFICIENCIA ENERGÉTICA EN ARGENTINA

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IMPACT OF PASSIVE ARCHITECTURAL DESIGN STRATEGIES ON THE ENERGY EFFICIENCY LABEL IN ARGENTINA

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RESUMEN

El trabajo presenta un análisis comparativo realizado entre el Índice de Prestaciones Energéticas (IPE), definido por el Programa Nacional de Etiquetado de Viviendas basándose en la Norma IRAM 11900, y las Estrategias Pasivas de Diseño Arquitectónico (EPDA) definidas en dicha norma. La comparación es aplicada a soluciones de rehabilitación energética para la evaluación de mejoras en Eficiencia Energética (EE) en una vivienda en San Miguel de Tucumán, Argentina. Tiene como objetivo evaluar la incidencia de las EPDA en el valor de IPE de la vivienda. Se realiza una valoración con respecto a la importancia que tienen las mismas como punto de partida para lograr una arquitectura más confortable, más eficiente desde el punto de vista energético y más sustentable. Se concluye que las estrategias pasivas no influyen sustancialmente de manera numérica en el IPE el cual determina la etiqueta de eficiencia energética de unidades residenciales en Argentina.

Palabras clave
arquitectura bioclimática, vivienda, renovación arquitectónica

ABSTRACT

This work proposes making a comparative analysis between the Energy Supply Index (IPE, in Spanish), defined by the National Housing Labeling Program based on the IRAM 11900 Standard, and the Passive Architectural Design Strategies (EPDA, in Spanish) defined in said standard. The comparison is applied to energy retrofit solutions for the evaluation of the improvements in Energy Efficiency (EE) in a dwelling in San Miguel de Tucumán, Argentina. Its goal is to evaluate the incidence of EPDAs on the IPE value of the dwelling. An assessment is made regarding their importance as a starting point for achieving a more comfortable, more energy efficient and sustainable architecture. It is concluded that passive strategies do not have a numerically substantial influence on the IPE, that determines the energy efficiency label of residential units in Argentina.

Keywords
bioclimatic architecture, house, architectural renovation

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INTRODUCTION

The reduction of environmental impact is a global concern which has awoken the commitment of many governments, to guide their laws towards sustainable development (Aragón, de Olivera Pamplona and Medina, 2012). The global environmental issue has led many countries to incorporate Energy Efficiency (EE) policies to reduce energy consumption, an aspect that can be seen in measures like EE passports or labels (Alonso-Frank & Kuchen, 2017). Internationally, the residential sector consumes a significant amount of energy. For this reason, it is essential to develop and implement bioclimatic architectonic systems that contribute towards the reduction of energy consumption (Manzano, Montoya, Sabio-Ortega and García-Cruz, 2015). This considers reducing consumption without affecting the building's thermal comfort. In Argentina, to contribute towards reaching the national energy savings goal, the implementation of EE measures in the residential sector is essential, as this sector represents 27% of the total consumption of the country. In addition, this sector can be addressed using multiple approaches, reason why there is a great potential for improvement (Production Development Ministry, 2017).

Energy certification schemes for buildings appeared at the beginning of the 1990s as a key method to improve EE; minimizing energy consumption and providing greater transparence regarding the energy use of buildings (Pérez-Lombard, Ortiz, González and Maes, 2009). These certifications play an important role in EE improvements, as they allow appraising and comparing different buildings and their features vis-à-vis energy consumption and demand (López-Asiain, García, Fernández and de Tejada Alonso, 2020). Energy ratings also appeared as tools to minimize energy consumption and greenhouse gas emissions and to promote greater transparency regarding energy use in buildings (Reus-Netto, Mercader-Moyano and Czajkowski, 2019).

In Argentina, the first legal precedent of a guarantor in the application of EE-related regulations, is the Provincial Law of Buenos Aires N°13.059/03 (2003) and its regulatory Decree 1030/10 (2010). Said law sets out the requirements for all new constructions processed in the province, including checking the hygrothermal performance levels stipulated by the IRAM 11600 series guidelines. Its application has been limited, with the main problems being the variety of construction requirements, the autonomy of municipalities and the decentralized control and inspection system (Chevez, Martini & Discoli, 2016).

In 2007, the "National Program for the Rational and Efficient Use of Energy (PRONUREE, in Spanish) was created through Decree 140/2007. It aimed at achieving an efficient use of energy, which implied adapting the energy production, transportation, distribution, storage and consumption systems, looking to obtain the greatest sustainable development with the technological means available, to lessen environmental impact and optimize energy conservation, thus perceiving a reduction in costs (Ministry of Energy and Mining [MINEM], s.f.).

The first edition of the IRAM 11900 standard: "Heating Energy Efficiency Label for Buildings" was released in 2009. The standard established eight levels of thermal efficiency of the envelope following the household appliance EE label format. It proposed a simplified methodology to calculate the EE level of building envelopes susceptible to being heated (IRAM, 2009).

Later, other legal documents were developed, like Law N°3246 (2009): "Energy Consumption – Reduction and Optimization", of the Government of the Autonomous City of Buenos Aires; Ordinance 8757 of the Municipality of Rosario (2011): "Hygrothermal Aspects and Energy Demand of Constructions"; and Law 4458 (2012) "Thermal conditions standards in building construction", of the Autonomous City of Buenos Aires.

In 2017, a new version of the IRAM 11900 standard was released, which establishes the calculation of energy supplies for residential use properties, integrating a higher number of variables compared to its first version: heating, cooling, sanitary hot water, indoor lighting and renewable energies. The main difference regarding its previous edition is that it considers both passive and active EE strategies.

A year earlier, through an Agreement Act signed between the Ministry of Mining and Energy of the Nation (Undersecretary of Energy Efficiency and Savings), the Government of the Province of Santa Fe (State Energy Secretariat), the Municipality of the City of Rosario and the Professional Colleges of the Province of Santa Fe (Civil Engineering, Specialist Engineers, Architecture and Skilled Workers and Technicians), decided to cooperate in public EE policies in end uses. This document gives rise to, among other goals, the running of a pilot EE certification test in properties destined for housing, during 2017 in the city of Rosario (Agreement Act, 2016).

To implement the first pilot test, professionals were trained in a certification process, to then evaluate already built dwellings. In August 2018, a second test was run in the city of Santa Fe. Starting from both experiences, and an agreement signed with the National Energy Secretariat, the model was rolled out to other cities in the country, to adjust the calculation procedure and IT application using different bioclimatic areas and different construction techniques. The tests were run in the cities of San Carlos de Bariloche, Mendoza-Godoy Cruz and San Miguel de Tucumán. In 2019, it also reached the city of Salta (Government of Santa Fe, 2020).

In 2018, with the goal of introducing the EE label in the country, the National Housing Labelling Program was created, based on the IRAM 11900 Standard. It aims at obtaining an estimation of the primary energy consumption in already built residential homes, to satisfy the demands generated by heating, cooling, sanitary hot water production and lighting requirements, during a typical year. In this way, people can know the EE level of a dwelling, with this new tool becoming a very important piece for decision making when it comes to buying, renting or building a property meant for housing. It is worth highlighting that it is also a useful tool to evaluate a new project or to suggest retrofits for an existing one.

Law 13903 (2019) "Energy efficient labeling of properties destined for housing" enacted by the Legislature of the Province of Santa Fe in November 2019, is the main legal framework and record in the country, which consolidates a specific EE policy. This law regulates the application of the Energy Performance Index (IPE) and the Energy Labeling of properties destined for housing; it creates a Labeling Registry, a Certifiers Register, and a Commission that works as a consultancy entity, and even determines bonuses for its implementation. To date, the compliance to the Law of Districts or Municipalities, and both the IRAM 11900 standard (2017) and the National Housing Labeling Program, do not have an obligatory nationwide implementation, being only a tool for professionals and users.

The goal of this work is comparing the IPE, defined by the National Housing Labeling Program, with the Architectonic Design Passive Strategies (EPDA, in Spanish), established in the first modification to the IRAM 11900 standard (2019), to assess the impact of these strategies on the IPE value of a dwelling.

METHODOLOGY

The methodology used in this research corresponds to a normative analysis and a case study. First, a complete normative analysis of IRAM 11900:2017 and its modification made in 2019 is done. The EE label and the EPDA weight are studied (the latter suggested in the first modification). Then, the web application developed by the Energy Secretariat to obtain an EE label that determines the "Energy Efficiency Class" is analyzed, providing as a result the IPE characteristic value expressed in kWh/m^{2}year. The impact of the passive and active design strategies on the IPE value is examined, to then compare the passive variables that influence the EPDA and IPE. Finally, both variables (IPE and EPDA) are analyzed from a case study. From this, the IPE value is obtained, and consequently, the EE Class through the web app. While, the EPDA weighting is made using the EBioDA calculator (Fernández & Garzón, 2019) for a better understanding of the results. Then, an energy retrofitting proposal is developed using the passive strategies, and the aforementioned values are calculated again, using the same methodology. To finish, the percentage improvement of the IPE and EPDA is compared from the improvements made.

ANALYSIS OF EE EVALUATION MECHANISMS IN DWELLINGS

THE IRAM 11900:2017 STANDARD

The new issue of the IRAM 11900 "Energy Performance in Housing. Calculation Method" was published in December 2017. This document, prepared by specialists and professional sectors that are part of the Subcommittee on energy efficiency in buildings, establishes a change in paradigm regarding EE evaluation (IRAM, 2017). In it, the bases are set for housing labeling. In January 2019, a modification was introduced in the standard, which was defined as: "Energy performance in housing. Energy efficiency labeling and calculation method".

There, a calculation method to determine the energy performance of residential units is outlined, where the notion of "energy performance" refers to the end use of conventional energy that contributes to the dwelling's energy demand through the following services: heating, cooling, indoor artificial lighting and sanitary water heating. The design bioenvironmental strategies are mentioned as an effective way of contributing towards EE, presented, initially, when outlining the calculation of energy performance, as follows:

> Passive design resources included in the architectonic project and the composition of construction elements, effectively contribute to the energy efficiency of housing and to the reduction of energy demand through different mechanisms, like: the reduction of the energy demand required for heating, through heat conservation in periods with low temperatures with thermal insulation; the shape, the compact design and the control of air renewal; the capture of solar radiation at times when its contribution to heating is beneficial; the control of the entry of solar radiation in summer through, thermal insulation; clear-colored roofs and solar protection on glazed surfaces; the incorporation of natural cooling with crossed and selective ventilation. In this context, the bioenvironmental strategies and passive design resources, together with the contributions of

efficient installations and the additional contribution of renewable energies integrated to the project, contribute to improving the energy efficiency of the dwelling (IRAM, 2017, p.11).

It can be seen that IRAM considers the contemplation of passive design strategies as essential.

Immediately after the bioenvironmental strategies, the specific requirement of primary climatization energy (heating and cooling) is mentioned, which consists of the calculation for the thermal evaluation and EE evaluation for air-conditioning. Third is the sanitary hot water calculation, whose purpose is to characterize the systems used and determine their efficiency. Fourth, the indoor artificial lighting; and finally, the contribution from the use of renewable energies, where only solar energy is considered: thermal solar to heat water and photovoltaic, to produce electricity.

The total energy performance of the dwelling is defined from the results of these calculations, as the difference between the specific primary energy requirement (annual energy demand for air-conditioning, water heating and lighting) and the energy contributions generated by renewable sources.

IRAM 11900 ENERGY EFFICIENCY LABEL

As a result of the energy performance calculation (EP) of the dwelling, the EE label is obtained. The variables considered in the label are: the annual primary energy specific requirement for climatization (EP_C); annual primary energy specific requirement for sanitary hot water ($EP_{S.H.W.}$); annual primary energy specific requirement for lighting (EP_{IL}); renewable energy contribution (EP_{REN}); and valuation of the level of Architectonic Passive Design Strategies (EPDA in Spanish).

The EE class is rated from "A" to "G". This is determined from the EP numerical value in kWh/m², which considers in its calculation: contribution of renewable energies, in kWh; primary energy requirement for air-conditioning, in kWh; primary energy requirement for sanitary hot water (SHW) production, in kWh; and primary energy requirement for indoor lighting, in kWh.

Although the standard prioritizes the weight of EPDA passive strategies, these do not have an influence on the result of the label. It is worth noting that passive strategies are mentioned in the norm first, and in the design of the label they are left at the end.

IRAM 11900 - ARCHITECTONIC PASSIVE DESIGN STRATEGIES (EPDA)

EPDA are defined as: "Characteristics of the architectonic design and of the construction elements that adapt the building to weather and environmental conditions, and

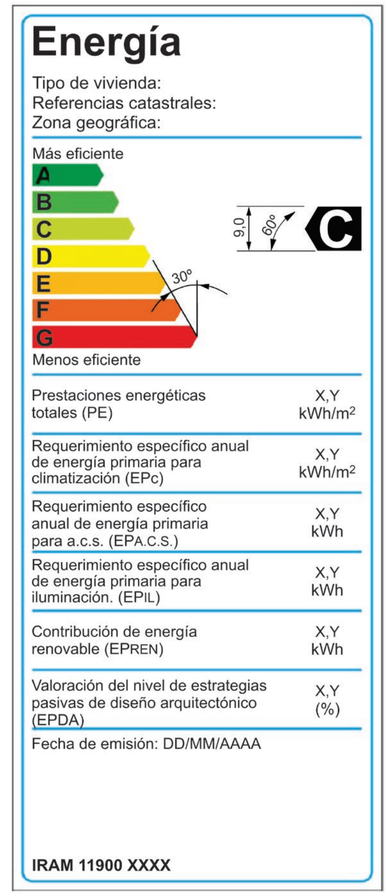

Figure 1. EE Label Model.
Source: Modification N° 1 to the IRAM 11900:2017 standard.

that allow improving the sensation of hygrothermal comfort and reducing conventional energy demand" (IRAM, 2019, p. 2). The EPDA that can be evaluated are thermal insulation; thermal inertia; solar protection; natural ventilation; solar capture; humidification; and surroundings. The weighting of the relevance of the bioclimatic strategies depends on the climate of the region where the building is located.

To determine the weight of the EPDA, a series of characteristic parameters are identified, called "architectonic-construction resources" (RAC, in Spanish), that reduce the energy demand and optimize the hygrothermal comfort through the natural conditioning of the building in summer and winter (IRAM, 2019). The relevance of each RAC varies depending on the climatic characterization of the analyzed area. For example, for the resource, "Thermal insulation of the floor", in a warm climate, the score is one (1) for any type of construction solution, while for a cold climate, this score varies from zero (0), uninsulated floor, to one (1), floor with full thermal insulation. The RAC considered are: roof thermal insulation; outside walls thermal insulation; window thermal insulation; floor thermal insulation; external roof color; outside wall color; window shading; direct passive solar systems; indirect passive solar systems; floor-to-ceiling height; contact with other dwellings; outside obstacles; summer sun; compact shape; window-to-wall ratio; crossed ventilation, selective ventilation, outside ground vegetation; wind breaks; roof window surface; and airtightness level.

The GHabSS (Healthy and Sustainable Habitat Group) task force of FAU-UNT developed a *C-EBioDA* calculator (Fernández and Garzón, 2019), to simplify and systematize obtaining the weight of passive strategies for the city of San Miguel de Tucumán. This carries out a simple systematization, through a calculation spreadsheet, of all the qualitative variables with their corresponding values that influence the EPDA weighting. To do this, the only variables that can be chosen are the qualities of the construction elements for each RAC. The score of said resource is obtained thanks to this process. The advantages of using it are the simplification of the calculation process and the reduction of possible errors due to the number of numerical values involved. Using this calculator, it is also possible to calculate, starting from the total EPDA percentage, the percentage impact of each passive strategy, so that a quick visualization is achieved that allows defining improvement strategies.

NATIONAL IT APPLICATION

The national IT application is an *online* tool, based on the IRAM 11900 standard, designed to carry out the EE evaluation of a dwelling in any place in the country, starting from a survey of it, and to obtain the corresponding Label, following the guidelines established nationwide. Likewise, it contributes towards formulating improvement recommendations and quantifying their impact in terms of potential savings (Ministry of Production Development, s.f.). This application classifies the EE of the dwelling in seven categories.

To validate the application and make adjustments that guarantee its correct adaptation to all construction practices in the entire country, contemplating the particular climatic, socioeconomic and construction practice aspects, tests were run in locations in different provinces and regions of the country. The certification of 1410 dwellings were made, as a pilot test (Ministry of Production Development, s.f.), to weight the current values and, starting from this, to define the different ranges of the label. However, the application is still not available for all locations in the country.

ENERGY PERFORMANCE INDEX (IPE)

The IPE is a characteristic value of the property, expressed in kWh/m^{2}year. It represents the theoretical primary energy requirement to satisfy the heating needs in winter, cooling in summer, sanitary water heating and lighting, during a year and by square meter of surface, under standardized conditions of use (Ministry of Production Development, s.f.).

Different design variables influence the IPE value: These are: orientations; materialization of the envelope; characteristics of the openings; finishing of the outdoor and indoor surfaces; floor-to-ceiling height; shading elements; lighting devices and type of activation; characteristics of the air conditioning equipment; water heating system, use of photovoltaic energy and water heating with solar energy.

These variables, thought of as energy saving strategies, can be classified into active and passive. Passive ones are those that must be implemented initially to reduce energy demands (Martín-Consuegra, Oteiza, Alonso, Cuerdo-Vilches and Frutos, 2014). There are studies that show that the application of passive strategies considerably reduces the energy consumption of a built building (Aguilera, Viñas, Rodríguez and Varela, 2018). It is important to say that said reduction is independent from the energy source used.

The classification of the variables that affect the IPE characteristic value can be seen in Table 1.

Incidental Variables	Passive Strategy	Active Strategy
Envelope composition	•	
Characteristics of the openings	•	
Orientations	•	
Outdoor surface finish	•	
Indoor surface finish	•	
Floor-to-ceiling height	•	
Solar protections	•	
Lighting devices		•
Type of activation for lighting devices		•
Characteristics of the cooling equipment		•
Characteristics of the heating equipment		•
Sanitary Hot Water System		•
Use of photovoltaic energy		•
Water heating using solar energy		•

Table 1. Classification of incidental variables in IPE.
Source: Preparation by the authors.

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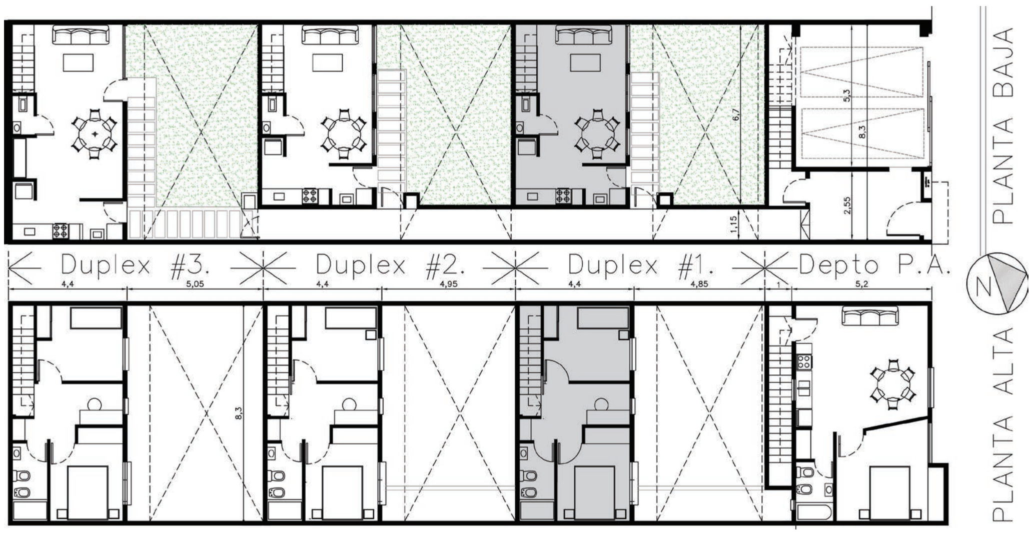

Figure 2. HP ground and top floor plan.
Source: Elsinger & Garzón (2019, p. 250)

COMPARISON OF PASSIVE DESIGN VARIABLES IN IPE AND EPDA

Diverse passive design variables have an impact on both the IPE characteristic value and the EPDA valuation since the active variables are not considered in EPDA. Table 2 below lists all these variables and indicates whether they are considered in each value or not.

According to Table 2, it is seen that there are passive variables not considered in the IPE, and also that the value "Indoor surface color", regarding passive strategy for lighting energy savings, is considered in the IPE and not in the EPDA.

Variable	EPDA	IPE
Thermal insulation of the envelope	Considered	Considered
Thermal inertia of the envelope	Considered	Considered
Outside surface color	Considered	Considered
Inside surface color	Not considered	Considered
Solar protections	Considered	Considered
Natural ventilation	Considered	Not considered
Humidification	Considered	Not considered
Solar capture	Considered	Not considered
Surroundings	Considered	Not considered

Table 2. Passive strategies present in IPE and/or EPDA
Source: Preparation by the authors.

ANALYSIS AND ASSESSMENT OF PASSIVE VARIABLES THROUGH A CASE STUDY

To analyze the correlation of both variables (IPE and EDPA), a case study is used as an application example. The case is located in the city of San Miguel de Tucumán, in the province of Tucumán, in the northwest of the country. It is specifically located in the IIb bioclimate zone, where summer is the critical season, with average temperatures above 24°C, maximums above 30°C and amplitudes of less than 14°C. Winter is drier and has low amplitudes and average temperatures between 8°C and 12°C (IRAM, 2012). The study is applied to a single-family dwelling, whose energy performance had been analyzed previously to generate a thermal-energy retrofitting proposal, which was published in ASADES 2019 by David Elsinger and Beatriz Garzón.

CASE DESCRIPTION

The dwelling is part of a horizontal property. This comprises three "duplex" type units, developed on two levels, and one unit on the top floor (Figure 2). It also has a common access, an easement to reach all the units and a garage for two vehicles. It is north-south facing, with all its openings facing north (Figure 3).

The existing construction was built after the demolition of a dwelling; therefore, the existing divides (East and West), using 30 cm thick common solid masonry bricks, were recycled with at least one face plastered (indoor face). The rest of the vertical envelope was built using 20 cm ceramic hollow masonry bricks (18x18x33 cm) with both faces plastered. The building has an independent reinforced concrete structure and

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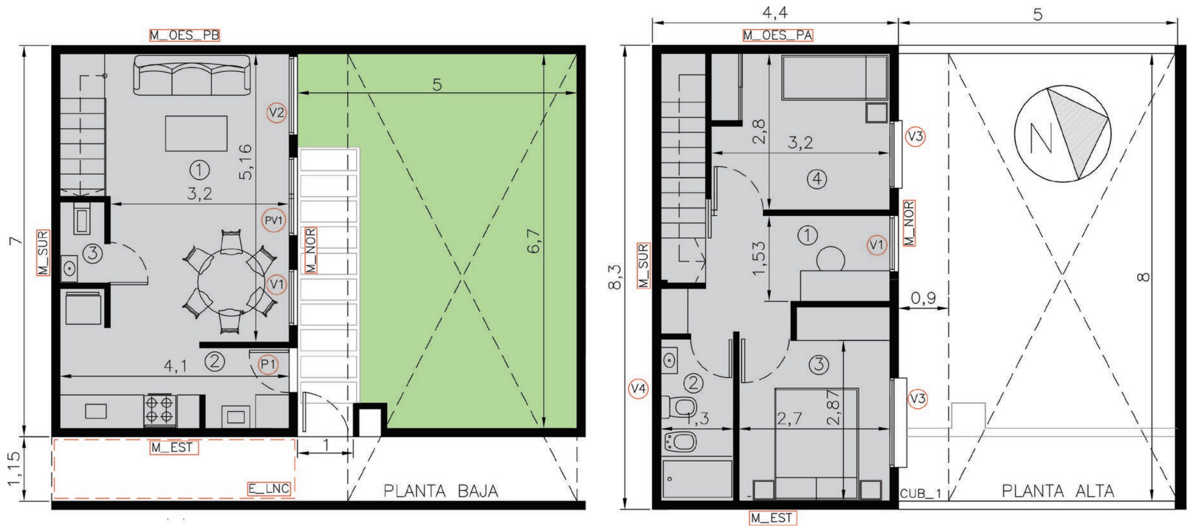

Figure 3. Unit of study - ground and top floor plan.
Source: Elsinger & Garzón (2019, p. 251)

a caliber 24 sinusoidal plate roof, with 5 cm glass wool and a "C" metal profile structure placed on the plates. The roof is formed on a single north sloping gable, which has a 0.90 m overhang towards the internal yard of one of the properties. The indoor divisions are made using different techniques: 15 cm common brick masonry on the ground floor, 8 cm hollow block masonry and cardboard plasterboard sheet partitions with 10 cm thick galvanized sheet metal profiles on the top floor. Both floors have tiled baseboards and floors. The indoor surfaces have a fine whitewash and light color paint and the ceilings are plaster applied on the ground floor's slabs and suspended on galvanized sheet profiles and drywall enclosures on the upper floor. The external vertical surfaces have a thick whitewash with "splatter" finish, which has its own color, in this case, one that is similar to "light beige" (Elsinger & Garzón, 2019).

RETROFITTNG PROPOSAL

The retrofitting proposal considers the following measures:

- Increase of the thermal insulation of the envelope (Table 3).
- Reduction of the glazed surface to reduce solar capture. For this, one of the north-facing ground floor windows is removed (Figure 3: V1-Ground floor)
- Generation of crossed ventilation. This is achieved by opening two transom windows on the south face of the building: one on the ground floor and another on the first floor

Envelope element	Original situation	Retrofitting proposal
Carpentry	Sliding doors with 3 mm thick transparent glass	Opening with double airtight glazing
North Wall	Ceramic hollow brick plastered on both faces (20 cm)	Incorporation of insulation on the outer face: 7 cm of expanded polystyrene + cementitious plate
South Wall		
East Lower Level Wall		
East Upper Level Wall	Solid ceramic brick plastered on the indoor face (30 cm)	Incorporation of insulation on the inside face (on being divides). 5 cm glass wool + 12 mm plasterboard
West Wall		
Roof	Sinusoidal galvanized plate + 5 cm of glass wool + 8 mm plasterboard ceiling	Incorporation of 5 cm more of glass wool (this is placed from the external face removing the roof's plates)
Street Level Slabs – East E_LNC	Pre-tensed joist floor slabs with expanded polystyrene overhangs (17 cm)	Incorporation of a 5 cm glass wool lower face + plasterboard

Table 3. Thermal insulation proposals on the envelope.
Source: Preparation by the authors.

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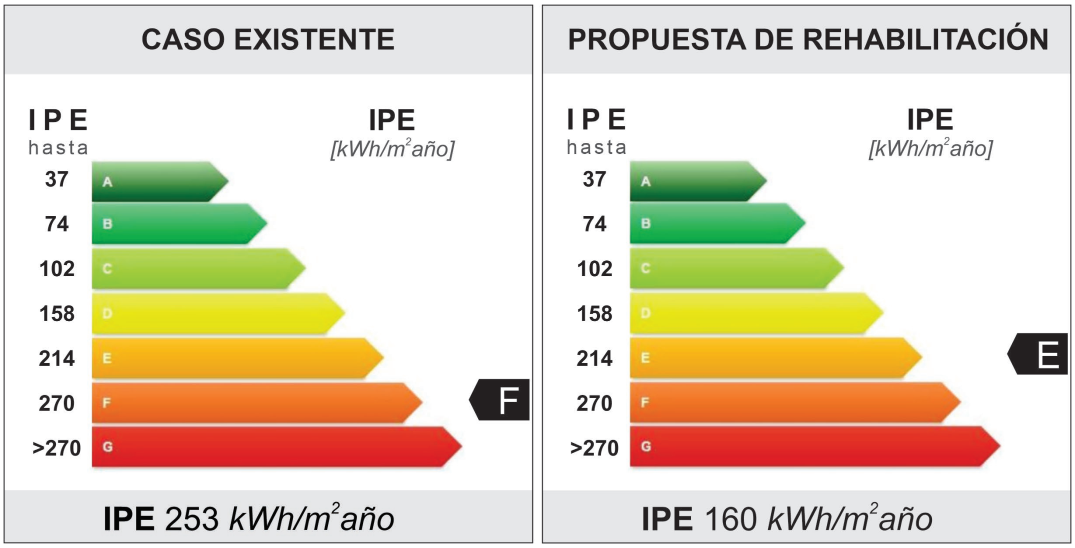

Figure 4. IPE value for the existing case and retrofitting proposal.
Source: Preparation by the authors

EBioDA <		EBioDA >>	
% EPDA	23.76 %	% EPDA	48.69 %
Aislación térmica	28.75 %	Aislación térmica	83.75 %
Inercia térmica	24.90 %	Inercia térmica	24.90 %
Protección solar	30.70 %	Protección solar	30.70 %
Ventilación natural	5.00 %	Ventilación natural	32.50 %
Captación solar	17.20 %	Captación solar	32.20 %
Humidificación	0.00 %	Humidificación	0.00 %
Entorno	35.00 %	Entorno	35.00 %

Figure 5. Determination of the EPDA % using the EBioDA calculator.
Source: Preparation by the authors

COMPARISON OF THE EPDA ASSESSMENT AND IPE RESULTS FOR BOTH CASES

The IPE value is calculated through the web application. The results that are obtained are the following: for the existing situation, 253 kWh/m²year, and for the retrofitting proposed, a total of 160 kWh/m²year. With this, the original prototype is left with an "F" rating and retrofitting proposal, with an "E".

The EPDA valuation was then made for both cases, using the C-EBioDA calculator as a tool (Fernández & Garzón, 2019). The percentage values obtained are 23.76% for the original case, and 48.69% for the retrofitting proposal.

It can be seen in Figure 5, that substantial improvements occur in the thermal insulation (from 28.75% to 83.75%), in the natural ventilation (from 5% to 32%) and in the solar capture (from 17% to 32%). This is the result of the retrofitting strategies implemented. In insulation, the behavior of the entire envelope is optimized (walls, roof, and windows). The natural ventilation is achieved incorporating transom windows on the south wall, which benefits cross ventilation in almost the entire dwelling. Finally, the solar capture is reduced, on reducing the glazed surface, removing a north facing window.

On comparing both values, it is seen that, regarding the passive strategy valuation, the analyzed case improves by 52.1%, while, in terms of the IPE, it only does so by 36.6%. As a result, the optimizations in the passive strategies do not imply an improvement, at the same level, as the energy supplies of the dwelling.

DISCUSSION

It is fundamental to consider that any intervention in a dwelling generates increases in the thermal comfort, which provokes a broad margin of action (Fernández, Rubio & Guevara, 2019). The energy retrofitting of dwellings is focused on improving the building conditions considering the economic possibilities of the user, the characteristics of the building, and other possible limitations (Pérez Fargallo, Calama Rodríguez and Flores Alés, 2016). The commitment of investing in the retrofitting of dwellings as an EE improvement of the residential sector must not fall back on the good intentions of the user, but rather must be accompanied by real public supporting policies and of an amount that is proportional to the cost required so that the thermal-energy modernization process of buildings is sustainable and does not become a social problem (Lizundia, Etxepare, Sagarna & Uranga, 2018).

The energy retrofitting proposal outlined here is feasible from the local socioeconomic and technological point of view. However, there are diverse limitations, among them: the layout of the building at the site (between divides); the lack of specific materials and/or specific products in the local market (thermal insulation, high performance carpentry services, etc.); and technological limitations, related to local construction practice knowledge.

On the other hand, the preliminary conclusions obtained aim at reinforcing the low impact of passive strategies on the building EE label. Given that, in this case, only the variations produced by said strategies have been analyzed, it would be important to also analyze the impact of active strategies on the energy label to carry out a more suitable weighting.

CONCLUSIONS

Starting from the analysis of the IRAM 11900:2017 standard, and from the energy labeling web application, which mainly allowed evaluating the weighting of architectonic passive design strategies, and after the later analysis of a case study and its resulting energy retrofitting proposal based on passive strategies, it is confirmed that, although this type of interventions has an impact, it is not of great importance.

The Housing Labeling Program constitutes, without any doubt, an authentic domestic policy to face the energy conditions of the modern world. On the path to the implementation of a Housing Labeling Program throughout Argentina (Renewable Energies and Energy Efficiency Undersecretary, s.f.), it is necessary to revise the ways in which the data that helps obtain the IPE is weighted, to obtain a label that fits the different socioeconomic realities of the country.

The IPE determines the EE of residential units in Argentina. Even though its implementation is not obligatory, it is expected that it is of collective interest, since, on being recognized by the property market, is constitutes an added value for the purchase-sale, rental or construction of a property destined to housing, regarding its degree of efficiency.

On the other hand, it is valuable to consider that the improvement of the thermal insulation of the envelope implies improvements in the IPE, but this is the only passive measure that leads to this goal, omitting the other variables. It would therefore be very positive, that the consideration of the passive strategies had a more significant role, to generate awareness and greater knowledge about bioclimatism.

It is highly questionable that the fact that improvement strategies which involve energy production costs and generate relevant waste (like the change of air-conditioning equipment or lighting) is considered. The possibility of reaching the highest standards, essential to guarantee a safe and energy efficient habitat, is feasible through passive design that ensures noticeable improvements in the natural comfort and in the reduction of conventional energy use. Therefore, the use of a tool that favorably weighs the passive strategies is required and that does not entail including air-conditioning equipment, renewable energy generation equipment or other active systems, just to reach a better label.

Considering this, and understanding the Energy Label as a tool to suggest dwelling retrofitting processes, the study made ends up setting the following questions: What are the final impacts of passive and active strategies on the Energy Label? Is it necessary to check these impacts to adapt the Label to the diversity of local socioeconomic-technological context of the Argentine Republic?

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VIVIENDA SUSTENTABLE: UNA DISCUSIÓN SOBRE EL MANEJO EFICIENTE DEL USO AGUA EN INSTALACIONES DOMICILIARIAS. CASO DE ESTUDIO: SANTA FE –ARGENTINA

SUSTAINABLE HOUSING: A DISCUSSION ON THE EFFICIENT MANAGEMENT OF WATER USE IN DOMESTIC INSTALLATIONS. CASE STUDY: SANTA FE –ARGENTINA

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RESUMEN

Este trabajo busca exponer una reflexión crítica sobre la eficiencia en el manejo del recurso agua, en el marco del caso de estudio –Ciudad de Santa Fe, Santa Fe (Argentina). Ponderando el rol de las instalaciones sanitarias en la optimización del uso del agua como recurso fundamental, se propone, en términos metodológicos, un análisis en base a tres dimensiones: el sistema hídrico de la ciudad, la normativa vigente en materia de regulación de excedentes y el suministro de agua por red. Se recuperan las propias investigaciones precedentes para mensurar el consumo domiciliario típico, atendiendo a dos variables: uso racional del agua y consideración de tecnologías al servicio de la eficiencia. Como síntesis, se elaboran curvas de abatimiento para caracterizar la eficiencia en tres escenarios. Y, en el terreno de la discusión, se interpelan las responsabilidades de los usuarios y la praxis de los profesionales de la arquitectura, encargados de concebir la sustentabilidad de la vivienda urbana santafesina.

Palabras clave
vivienda, sustentabilidad, eficiencia, agua, curva de abatimiento.

ABSTRACT

This work aims to present a critical reflection about the efficiency of water resource management in the case study - City of Santa Fe, Santa Fe (Argentina). Analyzing the role of sanitary installations in optimizing water use as an essential resource. In methodological terms, a three-dimensional analysis is proposed: the city's water system, the current regulations for surplus management and the water network supply. The author's prior research projects are recovered to measure typical household consumption, considering two variables: rational water use and consideration of service efficiency technologies.In summary, abatement curves are made to characterize the efficiency in three scenarios. As a discussion, the responsibilities of users, and the praxis of architecture professionals, responsible for conceiving the sustainability of urban housing in Santa Fe, are questioned

Keywords
housing; sustainability; efficiency; water; abatement curve.

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INTRODUCTION

Architecture, throughout history, has looked to conceive an efficiently conditioned habitat, both regarding the safety and a location to perform activities. However, it was in the last century when these concerns reached an exponential importance. As a result, the design/technology and project/installations dialectic pairs consolidated a scientific-technological enthusiasm, looking towards reducing emissions, sustainable design and improving efficiency conditions of the habitat.

The "new system"[1], characterized by the depleting of energy resources due to the fossil fuel crisis in the 1970s, along with climate change which results from high emissions levels, forced architecture to reflect about project related practices. As Fernández Rojas states (cit. In Delucchi 2016, p. 23) "more responsible measures regarding the abuse and wastage that the representation of the spectacular in architecture has had, over simple and sustainable application criteria", have become necessary.

Considering this scenario, this work proposes studying water as a limited resource[2] in the city of Santa Fe, Argentina. It sets out as a goal, an analysis that leads towards reflecting about the role of household installations as a project-related resource, oriented to taking advantage of water, and consequently, adapting the dwelling to the environment.

Therefore, the discussion involves professionals, but also users, who with their habits and decisions affect the performance of the resource (Alonso-Frank & Kuchen, 2017). Although background information that describes similar research lines by different authors is acknowledged, this work intends on providing an innovative perspective on studying the case of the city of Santa Fe, in the framework of the recent water regulation standard. In this sense, the essential contribution is based upon a critical revision of the instrumental case regarding the scope of the regulatory framework, even though the methodological nature of previous analyses is used.

In terms of architectonic characteristics, it must be stated that although this article outlines using regular rainfall devices as a core variable, given the current regulation, in order to make a comparative study, the design and construction resolution criteria of buildings directly affect water efficiency. Using this study as a starting point, it is confirmed that the planning of the size and slope of roofs, just like the handling of the absorbance capacity in the cases that include green surfaces, consolidate guidelines to optimize water reuse, compared with those cases that only propose its evacuation.

METHODOLOGY

From the methodological point of view, this work, to reach the final discussion, considers two phases, which are outlined below:

Phase 1: Multidimensional analysis of the case study: City of Santa Fe.

Dimension 1: The drainage basin that endangers the city is characterized, with the goal of weighing the interrelationship between the geographical features of the area and the particular rainfall and water systems. Likewise, the origin of the rainfall control devices is described in the framework of different decisions, which have sought to cover the specificities of the region in terms of its natural conditions.

Dimension 2: The current regulation is characterized considering excess rainfall control.

Dimension 3: The network water supply is quantified in depth, retrieving data from the research of LATEC/FAU/LATMAT/FADU and the FADU-UNL Installations lectures.

Phase 2. Analysis of case study (3 dimensions), starting from the following three scenarios:

1. User efficiency and change in consumption habits (Alonso-Frank & Kuchen, 2017)
2. Change in technology without using harvested rainwater.
3. Change in technology using harvested rainwater.

1 "New climate system" is a term coined by Bruno Latour. In his latest book (2017), he uses this concept by alluding to the end of the Holocene and beginning of the Anthropocene.

2 According to the water company, Aguas Santafesinas S.A., the amount of energy needed, pumping, transportation, treatment and distribution, to obtain 1 cubic meter of water that is suitable for human consumption from a river source, ranges between 0.35 and 0.40 kW/h/m3. In this way, even though this work acknowledges the interrelationship between the water and energy resources in the context of household supply, this aspect is intentionally omitted in the analysis of efficiency of water management as an essential resource.

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Figure 1. Typologies for the analysis. Source: Preparation by the authors.

Figure 2. Aerial photo of the Greater Santa Fe metropolitan area. Source: Preparation by the authors based on Google Earth.

While making the second phase of the analysis, three possible housing typologies are considered with traditional sanitary installations, to service an average of four inhabitants[3], namely: a bathroom, a kitchen, a laundry and a service tap for a small or medium-sized yard (Figure 1). The typologies are:

a. Dwelling with one floor or on the ground floor.
b. Dwelling with two floors or top floors.
c. Dwelling in multi-family or high-rise building.

To prepare a summary of each efficiency scenario, the concept of "abatement" is returned to (Clerc, Díaz & Campos, 2013), where costs are understood as benefits received on replacing technology or traditional use for an alternative one. In this way, a *curve* can be prepared, as a graphical representation of abated costs from a menu of options, along with their reduction percentages.

ANALYSIS

DIMENSION 1: THE SANTA FE WATER SYSTEM

The city of Santa Fe lies at the meeting and floodplain of two rivers: Paraná and Salado. Its physical limits are mainly fluvial, and 70% of its territory is formed by wetlands (lagoons, rivers, and swamps).

According to Sánchez & Sánchez (2004), the sustained increase in demand for water resources is limited, manifesting the need to seek more efficient ways to use them, as well as considering measures that moderate its use in processes or activities.

Santa Fe is also located in the drainage basin of the Paraná River, area that features constant cyclical hydroclimatic events, mainly in summer and fall, like abundant rains, rivers swelling and breaking their

3 The report "Santa Fe, how are we doing" (2019) determines that the average number of members in the census, is four people per dwelling.

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banks. The location of this basin, technically named "Middle Paraná", is affected by all the phenomena that occur in the higher parts of Bolivia, Brazil, and Paraguay (Figure 2).

The Paraná River defines the Eastern side, while the Salado River, the Western, and despite its particular aspects, its floodplain comes into contact with the southern edge of the city, a situation that magnifies the vulnerability of the territory. Thus, and returning to Paoli and Schreider (2000), the Paraná River[4] is, without a doubt, the most important one of the "River Plate" basin, on having a basin surface area of 1,510,000 km^2 and an extension of approximately 2,570 km.

The geographical characteristics of the city have had historic consequences. Since 1905, swollen rivers and floods[5] have been recorded on countless occasions, but it was in 2003 and 2007 when the city went through two significant phenomena that merited the formulation of a *Master Plan*[6]. Structural actions were drawn up in this: consolidation of defenses, construction of new operation points for the city's water extraction, formation of reservoirs to accumulate rainwater and a complex system of drains. Alongside this, legal regulations were implemented for waste treatment that affect sewage, the creation of greenbelts[7], a new soil impermeabilization factor (FIS, in Spanish), modifications to the urban organization regulation – ROU – and surplus rainfall control systems.

It is also necessary to characterize, on one hand, the water system of the rivers and, on the other, the rainfall.

With regard to the former, the entire Middle Paraná system swells due to inflow from higher areas: "[...]

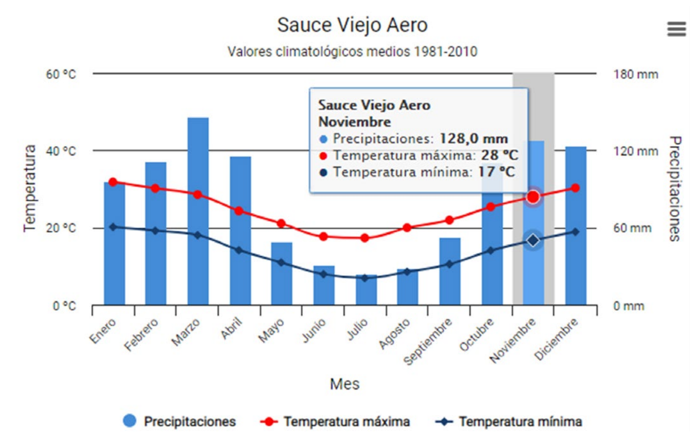

Figure 3. Monthly rainfall in Santa Fe, Sauco Viejo station. Source: National Meteorological Service, 2019.

the origin of the inflow indicates that rains produced in the tributary basins of the High Paraná, Iguazu River and Paraguay River, are the direct causes of overflows in middle or lower sections, with the inflow of these sections having a low impact" (Paoli and Schneider, 2000, p. 72). According to the authors, the Paraná River, at the height of the Province of Corrientes, Argentina, has an annual modulus of 17,000 m^3/s, receiving inflow from the High Paraná and Paraguay, and in the entire middle section, it incorporates some 1,000 m^3/s.

As for the rainfall system, due to the lack of rain in winter and excess in summer, it has an annual average of between 1,000 mm and 1,200 mm (Figure 3). According to the National Meteorological Service (SMN, in Spanish), these are not that far from those mentioned for the entire Basin: with 1,019.80 mm a year and maximum extremes of up to almost 200 mm daily recorded in the month of March 2017.

4 The Paraná basin includes areas of Brazil, Argentina, Paraguay, and Bolivia, covering a surface area of 2.6 million km2 (84% of the fluvial system of the River Plate). It integrates the Brazilian continental platform and the eastern basin of an Andean sector along its route through Brazil, Bolivia, Paraguay, and Argentina. The system comprises three hydrographic areas: the Paraguay, Upper Paraná, Middle Paraná, and Lower Paraná Rivers (Bello, Ballesteros, Buitrago, González & Velasco, 2018).

5 Floods due to the swelling of the Paraná River: 1905, 1966, 1982/3, 1992, 1998; from the swelling of the Salado River: 1914, 1973, 2003; due to extraordinary rainfall; 2007 (Santa Fe 2019 Risk Management Report).

6 Uban rainfall storm drain Master Plan formulated in the framework of the 2010 Urban Plan. Government of the City of Santa Fe.

7 Greenbelts refer to a space with grass and/or trees that must be considered when building a sidewalk and set aside for a better rainwater absorption, reducing the surface area built with paving. In the city of Santa Fe, it is obligatory by ordinance and all cases where the sidewalk or curb width is over two meters. See: Ordinance N°11610. Honorable Municipal Council of the City of Santa Fe de la Vera Cruz. 17/9/2009.

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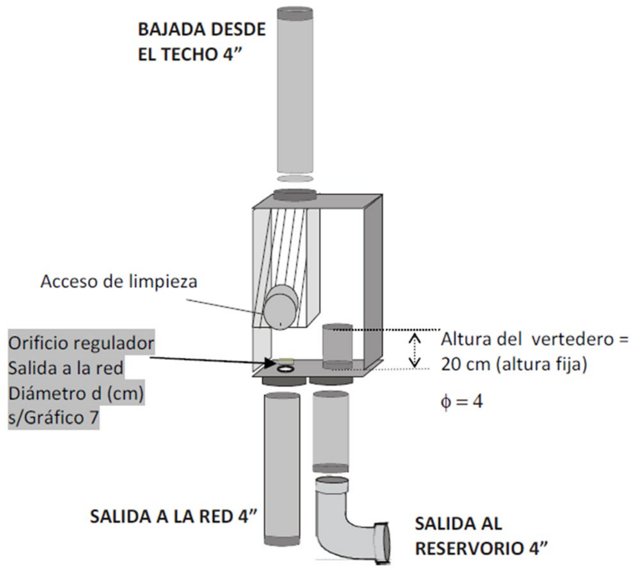

Figure 4. Hydraulic control device. Source: Left: Santa Fe Water Resources Secretariat.
Figure 5. Reservoir designed in the building, SJ-58 Pilay-Capitel, Irigoyen Freyre 2230, Santa Fe.
The ground floor yard is, in itself, the reservoir, and covers its entire surface. Source: Photograph by the authors.

DIMENSION 2: SURPLUS CONTROL AND STANDARDS

In December 2012, Ordinance N° 11959 "Surplus rainfall control system"[8] was enacted in the city. The way it proposes contributing to the optimization of the urban system's operation, consists in the incorporation of hydraulic devices, whose mission would be to control the gradual evacuation of surplus rainfall, delaying the drainage to control its impact on the system. These hydraulic devices must reduce the maximum flow to a minimum of 50%. These comprise two conceptual elements: a "reservoir" and a "regulator".

Regarding household installations, the system works in the following way: the water runs along impermeable surfaces and roofs to gutters and chutes. It is then transported to downpipes where it encounters a "regulator", that leads the rainwater through a duct with a reduced exit hole, into the network, and the rest – overflow, through a standard one that redirects it and stores it in a "reservoir". In this, in the same way, a part is run off to the network through an exit with a regulated hole, and the rest is stored in the cistern. To determine component capacities and diameters, a simple calculation is made that consists of determining the impermeable surfaces of the building and considering the slopes of roofs. With this information, a delay curve of 50% is considered. Then, using the tables, the reservoir volume is obtained, and the exit hole diameter is defined (Figures 4 and 5).

THE HYDRAULIC REGULATOR AS A REGULATORY INSTRUMENT

To establish accuracy in the regulatory analysis framework, a practical example is proposed: a dwelling with a roof [9] of 100 m² and a storm design with an intensity[10] of 180 mm/h, which means that 18,000 liters of water must be evacuated.

The flow to be evacuated for the example cited, considering the equation of Díaz Dorado (2008), is: 5 l/s.

Q (flow) = (S (sup.) x Imax (rain) x e (friction coeff.))/3600

The following graph shows the rainfall curves of the analyzed area, considering the recurrence, where, with a double entry, the duration is indicated on the

8 Ordinance N°11959, Surplus rainfall control system for Santa Fe de la Vera Cruz, Municipal Council, December 13th 2012.

9 The ordinance demands considering all waterproof surfaces, paving, etc. Only for illustrative purposes, a roof is provided as an example.

10 "Rain intensity" is the ratio of height increase that the rain reaches over time. Its unit of measurement is mm/h.

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x-axis and the intensity on the y-axis. From this, the information of 180 mm/h is determined for the later calculations (Figure 6).

Apart from considering the flow to be evacuated by a property, it is necessary to specify another parameter: the rainfall pattern. With that, the amount of water that is stored in a cistern could be quantified, complying with norm N° 11959 throughout a given period. Some data is considered to transform it into sources of information as, according to the SMN, as was already mentioned, the rainfall pattern of the city of Santa Fe, is between 1,000 and 1,200 mm a year (Figure 7).

SMN has rigorous data for two periods (1961/1990 and 1981/2010), where it is seen that 1,000 mm to 1,200 mm a year do not fall in a balanced way, with summer months rainier than winter ones. The number of days in each month and each season with rainy days is also reported. Considering this information, by which it is not feasible to accumulate rainwater in a balanced fashion in all months and seasons, it is proposed, for practice purposes, to evaluate the 1,000/1,200 mm a year pattern with a linear average.

As a result, a dwelling with a roof of 100 m^2 that receives 1,000 mm to 1,200 mm of water a year, will gather 120,000 to 144,000 liters yearly. From this, a monthly average of 10,000 to 12,000 liters is calculated.

It remains to be said that, although ordinance N° 11959 considers the storage to attenuate the water impact on the urban system, it does not stipulate its harvesting for use. So, the cistern volumes, to begin with, do not have full capacity to accumulate the amount of rainfall, so it will depend on the seasons, month and days with rain.

DIMENSION 3: WATER SUPPLY AND NETWORK DISTRIBUTION

According to the report, "*Santa Fe, how are we doing 2016, 2017 and 2019*", produced by the city government and the Stock Exchange, as well as the official data of the water company, Aguas Santafesinas S.A (ASSA), more than 92% of the city has a drinking water network that comes from the surface intake on the Colastiné River (part of the Paraná River basin). The rest of the population is supplied with water from community or household wells. The daily water consumption per inhabitant in the location is 397.5 liters, while 100 liters per capita is the recommendation of the WHO (Bartam et al., 2009), some four times the stipulated values. This average consumption indicator appears, according to ASSA, from assuming what is produced and distributed among the users. According to what Franco (2019) confirms, the real consumption must be managed with metering systems and not

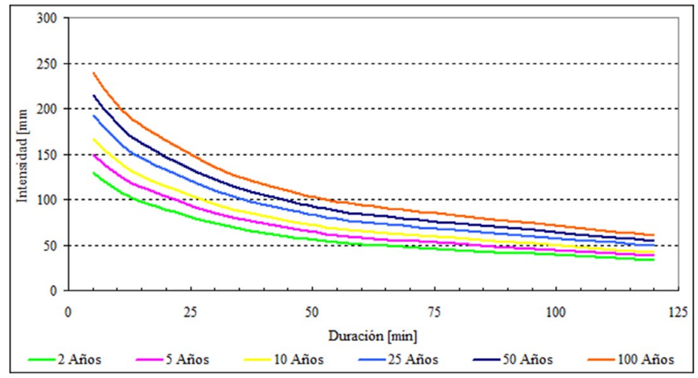

Figure 6. IDF intensity-duration-frequency curves, 1970-2006 series (Bertoni) II – Regionalization Workshop. Source: FICH-UNL Faculty of Engineering and Water Sciences of the National University of the Littoral.

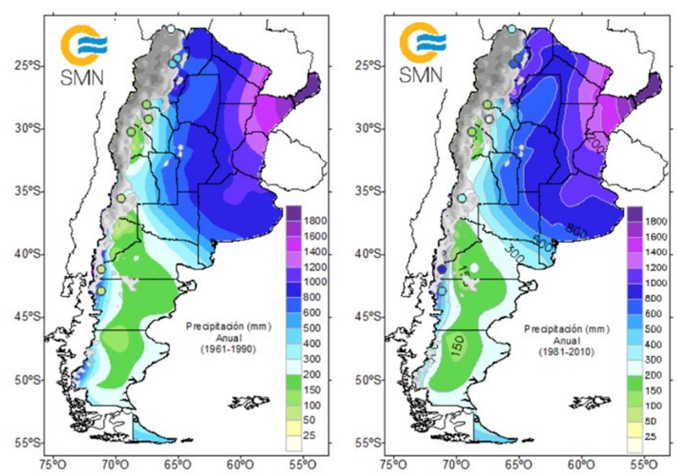

Figure 7. Annual rainfall for the periods of 1961-1990 and 1981-2010. Source: SMN.

by a production distribution among those served. As Calcagno, Mendiburo and Gaviño (2000) say, the average liters/inhabitant/day in Argentina varies greatly between Provinces, ranging from a maximum of 654l/h/d to a minimum of 168l/h/d.

The uncounted water values constitute one of the main efficiency issues in most drinking water services. It is estimated that between 35% and 40% of the water produced is lost in the networks and in illegal connections. In this sense, Jiménez (1994) proposes a classification for efficient water use based on five groups: leak detection, leak repair, tariffs, user education, and regulations.

According to information from the water company, ASSA (2019), 17,380 meters have been installed, which represents 16% of all the connections. This means that a large part of the users pays using the cadastral tariffing system – through the volume allocation. For this reason, most of the tariffing system in the city, is based on the water volume system assigned

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through cadaster and is regulated by Provincial Law N° 11220 "Service Supply Tariffing System"[11]. The users connected to the service have a calculation formula which is expressed as follows:

MF = (CF + P x Q) x FS x TR
MF Amount to be billed ($/period)
CF Fixed charge ($/period)
P Price per m^3 of water ($/m^3$)
Q Water volume to be billed (m^3/period – QM measured, or QA assigned)
FS Service factor
TR Fair control and regulation rate (ENRESS)

The tariff revision maintains the Provincial State user subsidy scheme, which will continue to cover part of the expenses the company must face to provide its services, with treasury funds. The state subsidy in Santa Fe is around 30% (ASSA, 2019). Considering the study made by FADU-UNL, in connections with meters installed by ASSA, the average water consumed, QM, is 188l/h/d, a value that is far off the 397.5l/h/d stated by the company.

Considering this, it is possible to state that the values confirm, on one hand, the overallocation of consumption for unmetered systems and the positive difference between the real consumption per person and that stated by the water company, a gap of between 40% and 50%.

EFFICIENCY IN RESOURCE USE

The National Sanitary Works regulation (OSN, in Spanish) sets reserve tank capacity values considering the average daily consumption assigned to a standard location unit that includes: a main bathroom, a service bathroom, a kitchen sink and a laundry sink (Lemme, 1973). The standard unit was considered with a 4-member family. The Domestic Household Installations Regulation[12] established that for the standard unit, it had to have an 850-liter tank, when this was supplied directly – without a pumping tank -. Meanwhile Title II (household water supply), Chapter III, art. 142, paragraphb 1., indicates: "[...] these shall have dimensions proportional to the amount of water they should provide and their useful capacity shall be, at least, equal to the consumption corresponding to twenty-hours of use". Here is where a stipulated average consumption per person and per day of 212.5 liters of water appears (Table 1 and Figure 8).

Personal hygiene	Consumption	Use	Liters/ Inhabitant/ Day
Shower	8 min	1/day	75 L
Bath	1.70m x 0.75m	1/day	200 L
WC selective flush	3 to 6 L	10 flushes	45 L
WC flush	6 to 10L	10 flushes	80 L
WC valves	1 L/s	10 flushes of 3 s	30 L
Bidet	10 L	1 minute	10 L
Basin	0.16 L/s	3 minutes	30 L
Average			160L
Home cleaning			
Washing plates and utensils	0.16L/s	8 minutes	18.75 L
Automatic washing machine	4 Kg.	1/day	6.25 L
Laundry sink	0.16L/s	5 minutes	12.5 L
Washing machine	50 to 60 L p/ cycle	1 use	13.75 L
House cleaning (e.g. floors)	0.16L/s	Average	12.5 L
Car washing	500 L	1/week	*
Average			45L
Watering			
Watering plants	0.16L/s	Daily	4 L
Water small garden	0.16L/s	Average	18.75 L
Water medium-sized garden	0.16L/s	Average	37.5 L
Average			18 L
Consumption and drink			
Drinking		Daily	1.5 L
Cooking		Daily	1.5 L
Average			3 L
Daily total			226L

Table 1. Household use water consumption considered in liters/ inhabitant/day. Source: FADU-UNL Installations Course (2018).

11 Government of Santa Fe. Provincial Law N° 11220, Transformations of the public drinking water sector, sewers, and sanitation. December 12th, 1994.

12 Decree N° 11877 of the P.E.N. – National Public Works Ministry – National Sanitary Works General Administration – Argentina – 1954 and modifications.

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In this context, this research uses the household water use identification method proposed by Castillo-Ávalos & Roviera-Pinto (2013), so it formulates a comparative calculation between the potential water volumes that can be saved in a dwelling, using the FADU-UNL Techniques and Materials Laboratory (LATMAT)[13], to readapt the method and recalculate water consumption values for dwellings in the city of Santa Fe:

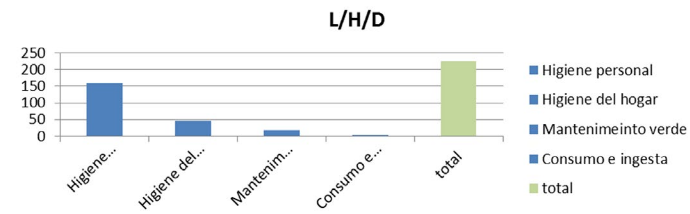

Figure 8. Uses regarding water consumption. Source: FADU-UNL Installations Course (2018). Source: Lecture on installations, FADU –UNL (2018).

ANALYSIS FROM 3 SCENARIOS

Returning to the three dimensions used to build the analysis in the first stage, which characterize the case study in terms of water supply, use and resource management, three scenarios are defined that constitute typical situations to compare, aiming at completing the analysis, obtaining results and provoking the final discussion.

1ST SCENARIO – USER EFFICIENCY LEVEL

The first option, "user efficiency level" (NEU, in Spanish), to use the term of Alonso-Frank & Kuchen (2017), can be included with the following actions: A 10-min shower consumes 100 liters of water, while a 5-min one would consume half. If a glass is used to brush teeth, 0.25 liters of water are used, while leaving the tap open uses between 20 and 30 liters. Shaving, closing the tap, consumes 3 liters, while doing so with the tap open, consumes some 40 liters of water. Keeping yards and gardens green by watering in the afternoon/evening or at sunrise instead of using controlled triggers, allows saving half the water. All this information, taken from the Argentinean Sanitary and Water (2019) (AySA) and LATMAT, FADU-UNL research, show that it is possible to reduce water use by 30%, just by using it rationally and making changes in the users/inhabitants' habits.

If the item, *personal hygiene* is considered (Figure 9), responsible for 70% of the water consumption per inhabitant and per day, the possible efficient use in liters for the different appliances involved can be graphed, where it can be seen that there could see a reduction of up to 30% in consumption, without altering comfort levels. In the item, *home hygiene* (Figure 10), the NEU can reach values of over 20%, for example, by using buckets to clean floors instead of keeping hoses running. Regarding *garden upkeep* (Figure 11), considering small and medium sized yards, the efficient use is not as significant as the aforementioned options, as it reaches values of up to 10% of the NEU thanks

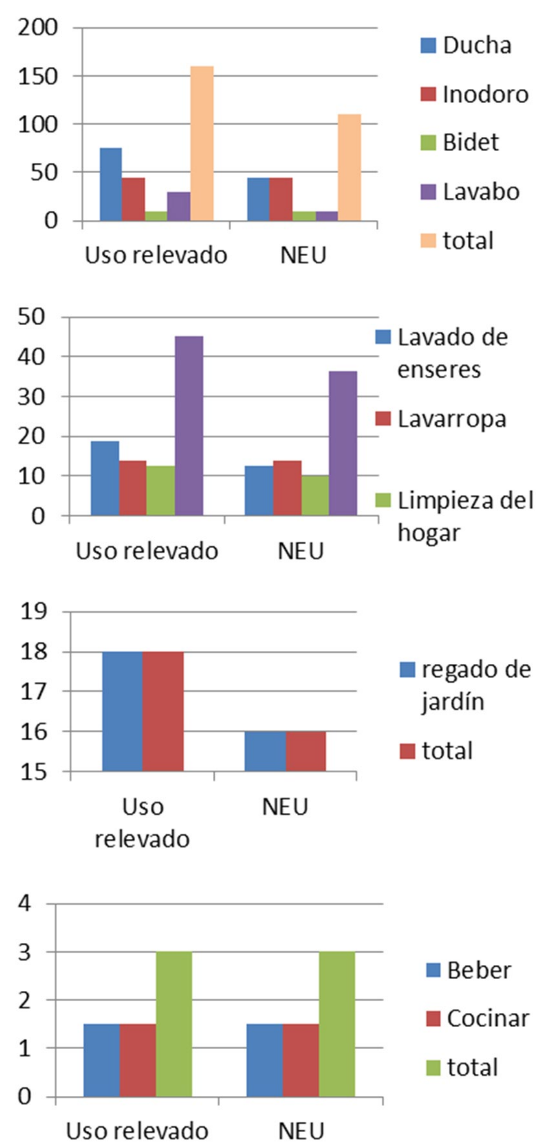

Figure 9-10-11-12 (from left to right and up down). Possible efficiency levels for the different uses. Source: Preparation by the authors based on ASSA, AySA and FADU-UNL Facilities Course database (2018).

13 CAI+D Research (2008) called "Sustainable architecture, experimental development of a habitational module with 0 energy consumption", under the direction of Professor Alberto Maidana, FADU-UNL.

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uses	Personal Hyg.	Home Hyg.	Garden	Cons/ Drink	Pers. Hyg Ab	Home Hyg Ab	Garden Ab	Cons Ab.
liters	160	45	18	3	-50	-8,75	-2	3
	Average collected consumption				Abatement by user efficiency level			

Table 2. Table with collected consumption information (demand) and possible reduction values (abatement) in liters of water, applying user efficiency criterion. Source: Preparation by the authors.

to using dosing triggers or sprinklers. Considering the water consumed (Figure 12) for cooking, drinking and infusions, no NEU is considered.

To make a summary of each efficiency scenario, the concept of "abatement", proposed by Clerc et al. (2013) is used again, referring to the *curve* that shows the impact produced when facing consumption, emission and energy use reduction measures, which allow establishing indicators between the different mitigation and saving decisions, in order to plan the efforts associated to this.

From this perspective, the costs are understood as perceived benefits, on replacing a traditional technology or use for an alternative one. Concretely, an abatement curve can be prepared, as a graphical representation of the costs abated from a menu of options, along with their reduction percentages. In this graph, it is possible to see the different choices organized, as well as relevant information to evaluate and compare the effects of different measures. Likewise, the curves find their main source of knowledge in the abatement of CO_2 and GHG emissions but, with illustrative purposes, the concept is used to prepare a representative graph of the possible abatement in liters of water consumed in the items considered above the NEU.

From the 226l/h/d, applying the NEU, an efficiency of up to 26.88% can be achieved, namely some 60.75l/h/d (Figure 13).

2ND SCENARIO – CHANGE IN TECHNOLOGY WITHOUT USING HARVESTED RAINWATER

The second option, changing technologies without including water harvesting, refers to all the possibilities there are where more efficient appliances and installations can be used, without reducing comfort levels or changing basic consumption needs. An example of these would be using selective WC cisterns[14] or valves, instead of traditional cisterns or,

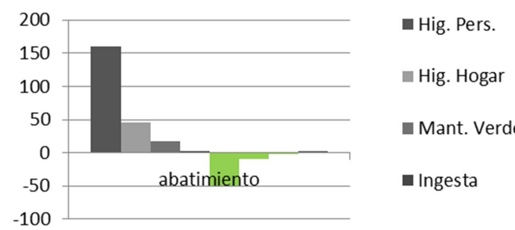
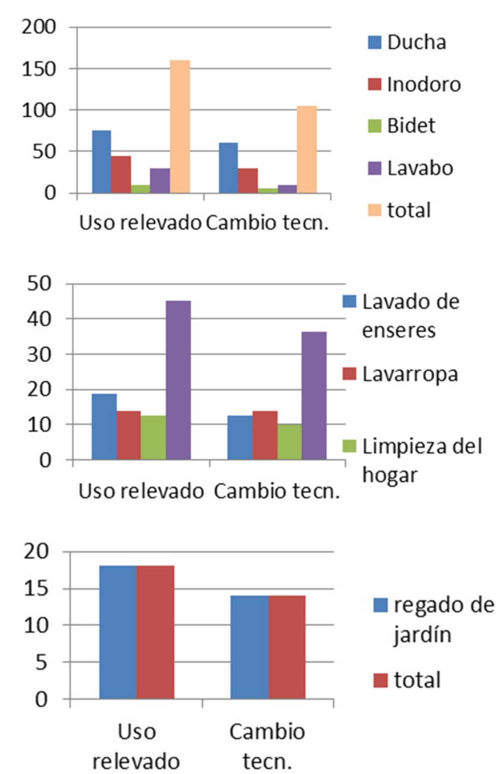


Figure 13: Graph of abatement in liters of water, applying user efficiency criterion. Source: Preparation by the authors.



Figures 14-15-16-17 (from left to right and up down). Bar chart showing the possible efficiency levels for the different uses.
Source: Preparation by the authors based on ASSA, AySa and FADU Installations course database

14 "WC cisterns are known as discharge deposits or tanks with mechanical capacity cleared by pressing them, to release all or part of the water, depending on their capacity.

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uses	Personal Hyg.	Home Hyg.	Garden	Cons/ Drink	Pers. Hyg Ab	Home Hyg Ab	Garden Ab	Cons Ab.
liters	160	45	18	3	-55	-8,75	-4	3
	Average collected consumption				Abatement by user efficiency level			

Table 3. Table with information of collected consumption (demand) and possible reduction values (abatement) in liters of water, applying bathroom technology change criterion. Source: Preparation by the authors.

Cases	Possibility of using harvested rainwater.			
	Personal hygiene	Home hygiene	Garden upkeep	Consumption-drinking
Single-Floor Home	Available with technology*	Available	Available	Not available
Two-floor home	Available	Available	Available	Not available
High-rise building	Not available	Available with limitations **	Available with limitations **	Not available

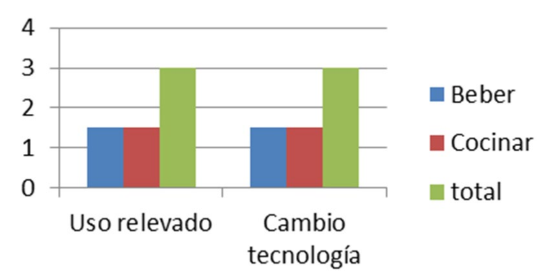
Table 4. Cases and uses of harvested rainwater. Source: Preparation by the authors.
* needs pumping to the reserve tank, to include harvested rainwater in the cistern
** only possible for use in garden upkeep, cleaning sidewalks and common areas (Ground Floor).

using timer-button activated or automatic taps, instead of traditional ones (Figures 14, 15, 16, 17 and 18).

As an illustration, a comparison of some elements is presented here[15]:

- Top brand WC discharge value: $7,646
- Top brand WC cistern: $6,550
- Top brand 4th turn, ceramic, bathroom tap: $8,345
- Top brand automatic bathroom tap: $10,320.

From the 226 l/h/d, and applying the "technology changes" efficiency criterion, without considering using the harvested rainwater, an efficiency of up to 30%, i.e., some 67,80 l/h/d in savings, can be achieved.



Figures 17 (from left to right and up down). Bar chart showing the possible efficiency levels for the different uses. Source: Preparation by the authors based on ASSA, AySa and FADU Installations course database

3RD SCENARIO – CHANGES IN TECHNOLOGY USING HARVESTED RAINWATER

Incorporating the available harvested rainfall into household use, taking advantage of the obligatory nature of its implementation, as per Santa Fe Ordinance N° 11959 "Surplus rainfall regulation", presents a wide range of possibilities, both in types of use and in cases.

Regarding the *building type*: unlike the two efficiency scenarios presented *ut supra*, which do not imply changes of implementation regarding dwelling types, in other words, where it is possible to apply an NEU criterion and

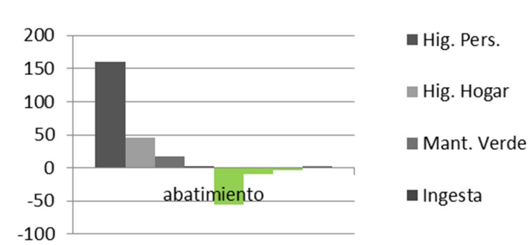


Figure 18. Graph of abatement in liters of water, applying bathroom technology change criterion. Source: Preparation by the users.

15 Reference of research that considers elements available in the local market of Santa Fe and top brands, like FV, Ferrum and Roca. Values in Argentinean Pesos to December 2019. Reference Dollar $62.5 (Argentinean Pesos).

uses	Personal Hyg.	Home Hyg.	Garden	Cons/ Drink	Pers. Hyg Ab	Home Hyg Ab	Garden Ab	Cons Ab.
liters	160	45	18	3	-160	-26,25	-19	3
	Average collected consumption				Abatement by user efficiency level			

Table 5. Table with data of collected consumption (demand) and possible reduction values (abatement) in liters of water, applying rainwater use criterion. Source: Preparation by the users.

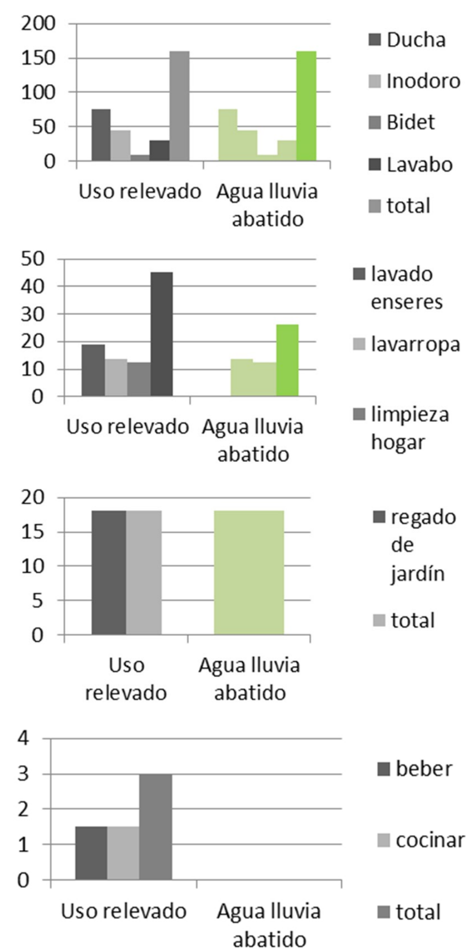
a change in the technology, both in ground floor dwellings and on top floors and in multi-family apartment buildings, in this third scenario, restrictions appear depending on the type of building: single floor dwellings, two-level dwellings and dwellings in multi-family or high-rise buildings. In the first of these, considering the pressure gauge level available in Santa Fe, there is no need for a pumping tank, but they do need a reserve one, and they may have grid water in the kitchen, for example, for consumption and drinking. In the second, buildings built on two levels, the ground and first floor need a pumping and a reserve tank, but with the possibility of direct service consumption. Meanwhile, the third requires a pumping and reserve tank, without the possibility of direct services.

Regarding the *use*: the uses, in terms of taking advantage of harvested rainwater, are characterized into two groups: the first, simple use, i.e., only use from the cistern; and second, complex use, i.e., incorporation of the water collected in the sanitary hydraulic circuit, with the exception of for drinking and consumption. This last one is considered as significant, since an efficiency value can only be achieved in that situation. In fact, if the accumulated water is used, without incorporating it into the hydraulic circuit, only with the extraction of the cistern at the same level, through a tap, its use is limited to cleaning floors, sidewalks and garden upkeep, all consumptions that do not directly impact the main part of the daily average.

The different possibilities considering the three dwelling cases can be summarized in the following table (Table 4)

Pursuant to what has been seen, the accumulated rainwater cannot be significantly used in high-rise buildings, where its use, in the framework of what is set out in the current regulations, Ord. 11595, is restricted to solely small actions: cleaning common spaces, watering green areas, among others. Therefore, we will limit considerations to single-floor and two-floor dwellings (Figures 19, 20, 21, 22 and 23). If we consider a hypothetical and ideal situation, where there were no limitations in the amount of rainfall or in the storage capacity, these could *abate*, in the sense of replacing the grid service consumption with rainwater, as follows:

In the personal hygiene graph, 100% can be abated, that is, 160l/h/d of water consumption. In the home hygiene graph, it is possible to abate 58%, that is 26.25l/h/d.



Figures 19-20-21-22: Abated percentages in liters of water for each use level, personal hygiene, home hygiene, garden upkeep and consumption and drink. Source: Preparation by the authors

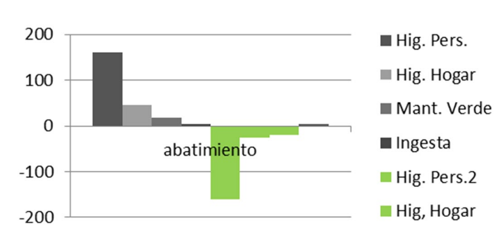


Figure 23. Graph of abatement summary in liters of water, applying rainwater use criterion. Source: Preparation by the authors.

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usos	Consumo nensual	abatimiento s/lluvias Sta. Fe	abatimeinto s/Ord. N° 11595
litros	27120	-12000	-6000

Table 6. Table with monthly consumption data (demand) and possible reduction values (abatement) in liters of water, which considers the annual average rainfall in Santa Fe and the storage capacity of cisterns, as per Ordinance N° 11595, and for the case study used. Source: Preparation by the authors.

Washing up here is considered in the kitchen sink and, as will be explained, it constitutes a network water supplied consumption. In the garden upkeep graph, 100% can be abated: 18l/h/d. Finally, in the water consumption graph, abatement is not possible, as the consumption for drinking and cooking is assumed by default as through the grid, which guarantees the technical suitability (Figure 24). This ideal situation, in the city, has a limitation in both the amount of rainfall and in reserve. To replace this ideal scenario for a real one, it is proposed to refer to the aforementioned example, where "a dwelling with a 100m^2 roof" that receives 1,000 mm to 1,200 mm of water a year, will collect 120,000 lts to 144,000 lts a year. The resulting amount has a monthly average of 10,000 to 12,000 liters. If 226 l/h/d are needed for an average home, 27,120 liters of water are required monthly, in other words, by simplifying each item to a linear abatement function, 44% water use could be achieved. If to this, the fact that Ord. N° 11595 establishes design volumes that, for this standard dwelling with four inhabitants and 100 m^2 of impermeable surfaces, 6,000 liters of harvesting a month are reached, and the possible abatement would be around 22%.

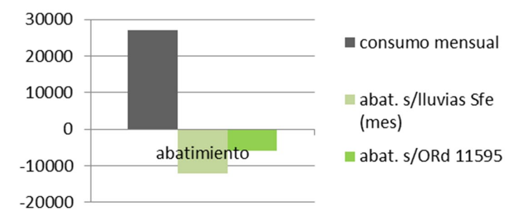

Figure 24. Graph of abatement in liters of water, which applies rainwater use criterion, considering annual average and storage capacity for the example outlined. Source: Preparation by the authors.

On the other hand, through the description of the city's water system, or the way network water is consumed and the current legal regulations for surplus rainfall control, it can be inferred that the rainwater accumulation system is effective, in the sense that it fulfills a purpose. However, thinking that it is intended to achieve the essential, using what is available, this is not efficient regarding the use of resources.

RESULTS AND DISCUSSION

Regarding the results of the study, and in the framework of the three scenarios addressed by the analysis, the following considerations are suggested.

In the first scenario, with a suitable User Efficiency Level (NEU), efficiency values of up to 27% are achieved, which clearly state the importance of the inhabitants regarding the use and the need to inform, train and broadcast the virtues of a rational use of water. In the second scenario, using technologies available in the local market with efficiency criteria and without greater costs, allows abating up to 30%, which indicates, among other aspects, the relevance of the criteria, the responsibility and knowledge of professionals on making projects and carrying out works. The third scenario permits abatements of between 22% and 44%, which implies a commitment of the professional and the user, not just in complying with an ordinance, but with the environment and the resources. From this, it is seen that the rainwater harvesting, apt for different uses, can represent a significant contribution regarding the water consumed from the network, reaching reduction values of around 40%.

CONCLUSIONS

As it has been presented, although the decision to accumulate the surplus and its then gradual later elimination complies with the current legislation, it does not promote margins of efficiency: even when uses overlap, the harvested water does not contribute to reducing network supply consumption. Alongside this, the recent regulation establishes values associated to the morphological aspects of buildings; however, they are presented solely for the purpose of guiding the corresponding calculations: slopes, run-off surfaces, size of downpipes, etc. In fact, there are still no express guidelines which, in design terms, allow optimizing the reuse of water resources, without detriment of its service quality and to satisfy the analyzed demand minimums.

Finally, it is worth stating that the result of the study, without questioning the regulation in the framework of the urban system, tries to provide a reflection about those decisions of the project praxis which, in the framework of infrastructure construction to optimize water consumption in Santa Fe, do not promote efficiency as an added value and, therefore, discourage the conception of the dwelling as a sustainable habitat.

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