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Eficiencia energética en edificios municipales de argentina para el programa euroclima+ Energy efficiency in municipal buildings in Argentina for the Euroclima+ program

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Resumen-- **En el marco del programa Euroclima+ se han realizado auditorías energéticas en edificios municipales de Argentina. Para estudiar los edificios se ha utilizado información suministrada por los municipios e información recolectada por los auditores. Luego, se elaboró un programa que permite obtener resultados de demanda de energía según la metodología de la normativa nacional IRAM. A partir de ello se ha encontrado que los edificios no reúnen condiciones adecuadas de confort higrotérmico a pesar de consumir mucha energía. Con las mejoras propuestas se alcanza una reducción de la demanda de energía de al menos un 40%.**

Palabras clave— Energy efficiency; Construction; Sustainability; Audit; Argentina.

Abstract— **Within the framework of the Euroclima+ program, energy audits were conducted in municipal buildings in Argentina. The buildings were studied using information provided by the municipalities and information collected by the auditors. A program was then developed to obtain energy demand results based on the methodology of the national IRAM regulations. Based on this, it was found that the buildings do not meet adequate hygrothermal comfort conditions despite consuming a lot of energy. The proposed improvements achieve a reduction in energy demand of at least 40%.**

Index Terms— Eficiencia energética; Construcción; Sustentabilidad; Auditoría; Argentina.

I. Introduction

A. Euroclima+ program in Argentina

THE Energy Efficiency sector of the Euroclima+ programme aims to contribute to climate change mitigation and adaptation through the implementation of energy efficiency measures. It is part of the Nationally Determined Contributions (NDCs) undertaken by countries to meet the objectives of the Paris Agreement. It is a programme financed by the European Union and co-financed by the German federal government through the Federal Ministry for Economic Cooperation and Development, as well as by the governments of France and Spain Euroclima, 2023.

The objective of Product 6, "Energy-Sustainable Municipal Buildings," is to determine the energy efficiency status of Argentina's municipal building network. Subsequently, it is necessary to propose renovation plans and develop a small sample. The responsible entity in Argentina is the National University of La Plata (Euroclima, 2023).

During 2021 and 2022, 47 energy audits were conducted in 15 municipalities in Argentina. Field trips departed from the city of La Plata, where the university and laboratory are located, along with the necessary equipment.

The buildings analysed are distributed across the national territory, which has 3,694 kilometers from north to south and 1,408 kilometers from east to west (Instituto Geográfico Nacional, 2023). They ranged from very hot climates at latitude -27º to very cold climates at latitude -42º; from sea level to valleys in the Andes mountain range. Buildings with multiple uses and functions were audited: municipal palaces, administrative offices, libraries, museums, schools, health units, hospitals, kindergartens, cultural centers, neighborhood centers, among others.

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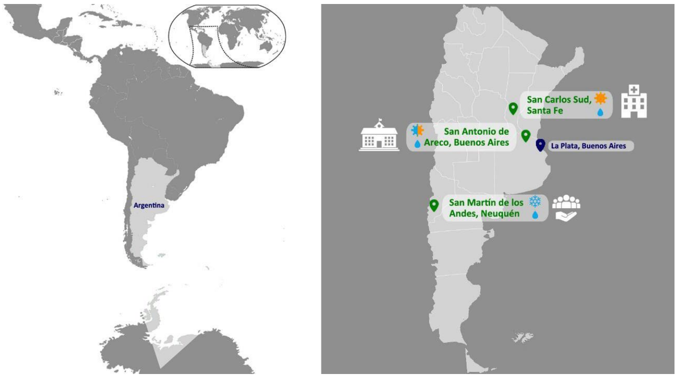


Fig. 1. Processing of photogrammetric information. (Source: Authors).

This paper presents three of the buildings audited for the project. One is the General Manuel Belgrano Municipal School. It is located in San Antonio de Areco, Buenos Aires province, 177 km from the city of La Plata. The climate is warm-temperate and humid (latitude 34° south). Another example is the Selma Kärst Health Center, located in the commune of San Carlos Sud, Santa Fe province. This site is 515 km from the city of La Plata. It has a warm and humid climate (latitude 32° south). The third building is the El Molino Community Center, located in San Martín de los Andes, a municipality in the province of Neuquén, 1,596 km from the city of La Plata. This municipality is located in a valley of the Andes Mountain range, at 640 meters above sea level. The climate there is very cold (latitude 40° south).

The following paragraphs describe each of the three buildings in greater detail. You will learn about the general characteristics of the surroundings, the layout of spaces within the building, its uses, and its materials. The methodology used to obtain the necessary information and calculate energy demand is then described. Finally, the results and conclusions are presented.

B. General Manuel Belgrano Municipal School, San Antonio de Areco, Buenos Aires.

The General Manuel Belgrano Municipal School is a secondary school with a surface area of approximately 1,000 m2 that opened in 2018. San Antonio de Areco, where the school is located, is considered one of the oldest towns in the Province of Buenos Aires. It dates to 1728 and preserves the colonial-style architecture of the period, especially in the downtown area. It is a municipality near the Autonomous City of Buenos Aires with approximately 23,000 inhabitants. It has maintained and cultivated the traditions of gaucho culture and develops significant agricultural and tourism activities. As mentioned above, the climate is warm-temperate and humid.

The building has ten classrooms for 340 students, arranged around a central courtyard, an administrative area near the entrance, another area for management, a storage room, restrooms, and a bar area.

Regarding the building's materials, the exterior roof features black trapezoidal zinc sheets (thickness e = 0.05 cm). These sheets rest on metal profiles from which the ceiling, composed of PVC-coated glass wool panels (e = 2 cm), is suspended. The height to the ceiling is 3.20 meters inside the building. The thermal transmittance coefficient K for this component of the building envelope is 1.35 W/(m^2·K) in winter and 1.23 W/(m^2·K) in summer. (The calculation methodology is mentioned in point two of this article.)

The floors consist of light gray granite tiles (e = 2 cm) on a cement base (e = 2 cm) and a lean concrete subfloor (e = 15 cm). There is no perimeter or surface insulation. The thermal transmittance coefficient K adopted for this component of the building envelope is 1.38 W/m.

The walls are 23 cm thick and composed of concrete blocks (e = 19 cm) with plaster on both sides (e = 2 cm on each side). They have no thermal or acoustic insulation. The thermal transmittance coefficient K calculated for this component of the building envelope is 2.39 W/(m^2·K).

The windows are aluminum-framed, without a thermal break, weatherstripping, and single-pane glass. Some have sunshades, while others have eaves. The adopted thermal transmittance coefficient (K) is 5.82 W/(m^2·K). The doors are made of double-paned steel (e = 0.9 mm each) and are 5 cm thick. The calculated thermal transmittance coefficient (K) is 3.57 W/(m^2·K).

The lighting system consists of LED fixtures. The heating system runs on natural gas. It is distributed through diffusers connected by a network of ducts. There are seven Goodman boilers, model CAPF 363686. In summer, fans, a split-type air conditioning unit, and a Goodman refrigeration unit coupled with a CAPF 363686 unit are used. During January (summer), the building remains closed.

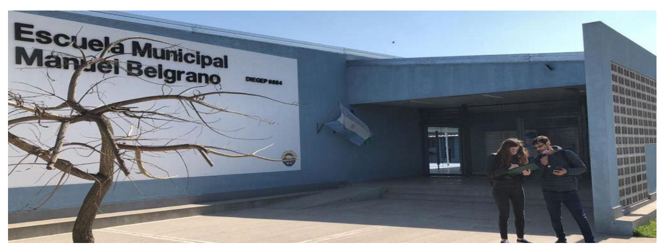


Fig. 2. Building access

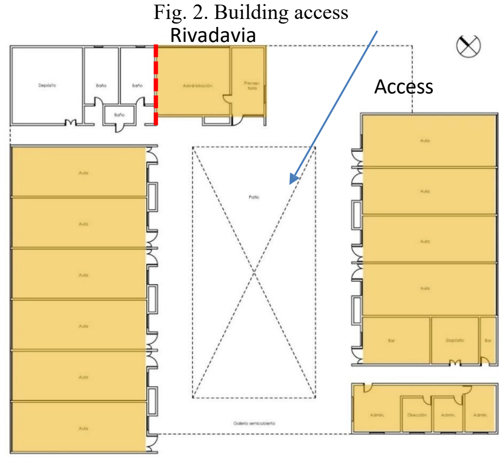


Fig. 3. Floor plan (Source: Julián Basualdo Rapetti and María Belén Birche)

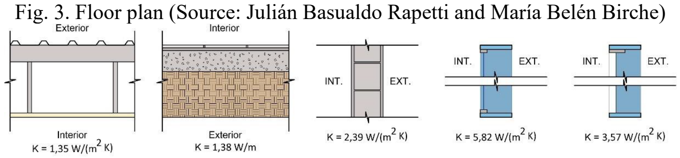


Fig. 4. Building's constructive system. (Source: Authors)

C. Selma Kärst Health Center, San Carlos Sud, Santa Fe

Starting to describe the following case, the Selma Kärst Health Center was inaugurated in 2015 and offers care for various specialties such as dentistry, pediatrics, clinical medicine, psychology, and occupational therapy. It has a covered area of approximately 165 m2. It is in San Carlos Sud, a commune surrounded by crop fields with intensive use of agrochemicals (Ministerio de la Nación, 2023). The climate there is warm and humid, highly influenced by its proximity to the Paraná and Salado rivers, which often cause recurrent flooding in the region (Ministerio de la Nación, 2023). The population is 2,102 inhabitants, who have settled in the city in search of green spaces on their own land and to enjoy the tranquility of suburban areas. However, they continue to carry out their daily activities in other locations, mainly in the city of Santa Fe (Ministerio de la Nación, 2023).

The building has four consulting rooms, restrooms, a kitchen, a storage area, a pharmacy, and an administrative and reception area. The number of people using the building varies, but it is estimated that 18 people use it at a time.

Regarding the building envelope, the roof consists of 20 cm thick reinforced concrete slabs and a 12 cm lean concrete subfloor with a liquid waterproofing membrane on the exterior. Inside, a 2 cm thick plasterboard ceiling suspended 50 cm from the slab can be seen. The ceiling height is 2.70 m, and 4.20 m in the consulting and nursing rooms. The calculated thermal transmittance coefficient K is 1.01 W/(m^2·K) in winter and 0.94 W/(m^2·K) in summer.

Fig. 5. Building access

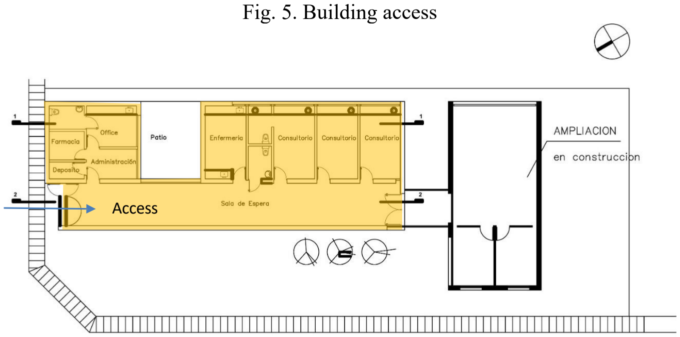


Fig. 6. Floor plan (Source: Julián Basualdo Rapetti and María Belén Birche)

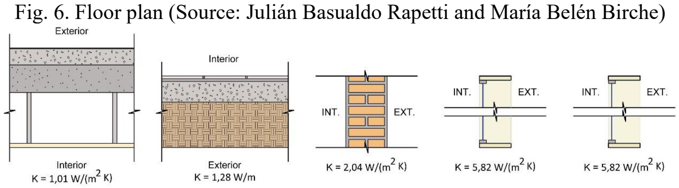


Fig. 7. Building's constructive system. (Source: Authors)

The floors consist of light-colored granite tiles (2 cm thick) on a cement base (2 cm thick) and a lean concrete subfloor (15 cm thick). There is no perimeter or surface insulation. The thermal transmittance coefficient K is 1.28 W/m.

The walls are 30 cm thick and made of solid load-bearing bricks (12 x 24 cm) with plaster on both sides. The calculated thermal transmittance coefficient K is 2.04 W/(m^2·K).

The openings are made of aluminum frames without a thermal break, sealed with weatherstrips, and laminated single-pane glass (3 mm + 3 mm). Some have bars. The adopted thermal transmittance coefficient K is 5.82 W/(m^2·K).

The lighting system consists of LED fixtures and some low-energy lamps. Regarding the thermal conditioning system, the building has a hot-and-cold air conditioner in each office, another in the administration room, and a similarly sized unit in the kitchen (six units with approximately 3.4 kW of power). The waiting room has a higher-power unit (10.4 kW) and is also equipped with fans.

D. 1.4. El Molino Community Center, San Martín de los Andes, Neuquén

Continuing with the last case presented in this article, the El Molino Community Center is located in San Martín de los Andes, a municipality of approximately San Martín de los Andes has a population of 30,000, located in a valley of the Andes Mountain range at 640 meters above sea level. The climate there is very cold (latitude 40° south). With national parks in the summer and ski resorts in the winter, San Martín de los Andes is positioned as an important tourist center in Argentine Patagonia. The economic context and nature foster the Migration from large cities. Following the 2020 pandemic and the spread of virtual work, migration and growth have been even greater.

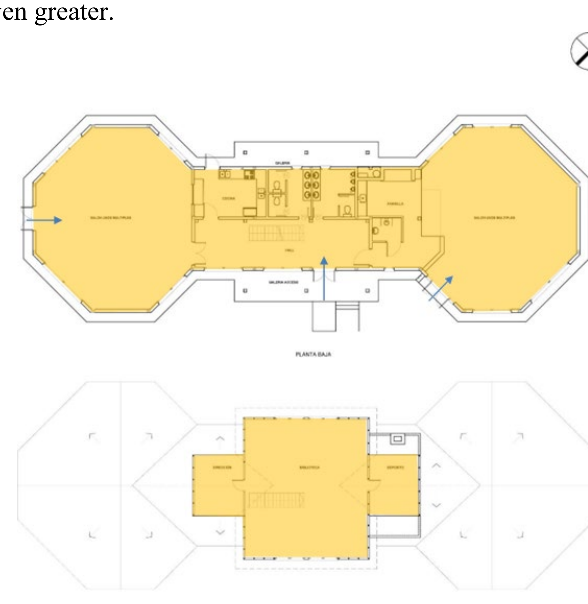


Fig. 8. Floor plan (Source: Julián Basualdo Rapetti and María Belén Birche)

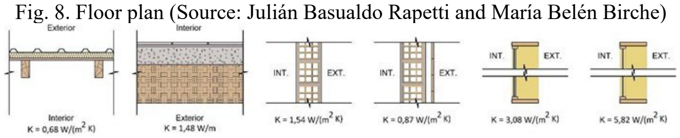


Fig. 9. Building's constructive system. (Source: Authors)

The building has approximately 400 square meters of covered area and two octagonal rooms on each side. One houses activities for senior citizens, and the one on the left houses a gym and non-traditional school. The kitchen is in the center of the ground floor. The upper floor houses a library and the management office. Various activities are held in the building for residents throughout the day, including dance classes and workshops. It has 12 permanent staff members. There are usually 40 more people at the same time, and approximately 120 per day. Plans indicate that the building was built in 2001.

Continuing with the building's materiality, the roof is a lightweight wooden structure composed of trusses on which the rafters support the 3/4"-thick planking. A 200-micron polyethylene film and 5 cm of glass wool were placed over the roof. Black corrugated zinc sheeting is located on the exterior. The thermal transmittance coefficient (K) in winter is 0.68 $W/(m^2 \cdot K)$.

The floors consist of 30 x 30 cm high-traffic ceramic tiles (2 cm thick) on a cement base (e = 2 cm) and a reinforced concrete slab (e = 12 cm). There is no perimeter or surface insulation. The thermal transmittance coefficient K is 1.48 W/m.

There are different types of walls in the building. On the ground floor, they are made of hollow brick (e = 18 cm) with plaster on both sides (e = 2 cm each). They have stone cladding on the lower part. The total thickness is 22 cm, and the thermal transmittance coefficient K is 1.54 $W/(m^2 \cdot K)$. On the upper floor, they are made of hollow brick (e = 18 cm) with interior plaster (e = 2 cm) and on the outside, a wooden structure with an air chamber (e = 5 cm) covered with ¾" wood (e = 1.90 cm). The total thickness is 27 cm, and the thermal transmittance coefficient K is 0.87 $W/(m^2 \cdot K)$.

The openings are made of wooden frames, and most (except the kitchen and the doors) have double-glazed windows, consisting of two 3-mm clear panes of glass and a 12-mm chamber. Some openings are unsealed, and some doors have ventilation grilles. The windows have light-colored fabric curtains on the inside, but the library has blackout blinds. There is no entrance antechamber. The thermal transmittance coefficient (K) of the windows is 3.08 $W/(m^2 \cdot K)$, and that of single-glazed doors and windows is 5.82 $W/(m^2 \cdot K)$.

Lighting is provided by low-consumption LED lights, with tubes and spotlights. The building has natural gas heaters with balanced draft of 9,000 cal/h (five on the ground floor and one on the upper floor). Additionally, the upper floor features a hot-and-cold split air conditioner with a 3.49kW cooling capacity and 3.1kW heating capacity. Regarding cooling, only the library has such equipment. The rest of the building uses natural ventilation.

II. METHODS

The energy audits conducted in each building consist of laboratory work, where the information is processed, and field work within each building.

The laboratory work consists of the following activities:

- Data collection before fieldwork and organization of information in data spreadsheets.
  - Names and location of the buildings to be audited.
  - Determining dates for building audits. Contacting the host.
  - Request for building plans, both sectional and horizontal, in AutoCAD and PDF formats. Analysis of missing information to be collected.
  - Request for historical electricity and natural gas consumption.
- Developing programs in Excel
  - For preparing temperature and humidity graphs.
  - For the preparation of psychrometric diagrams available in (Czajkowski, 2022).
  - For calculating thermal transmittance coefficients for each element of the envelope. Prepared based on national regulations (IRAM, 2022)
  - For calculating energy demand for the original and improved situation. Prepared based on national regulations (IRAM, 2022) available at (Birche et al., 2023).
- Downloading information collected during fieldwork.
- Information processing using the developed programs.
  - Preparation of winter and summer temperature and humidity graphs.
  - Preparation of winter and summer psychrometric diagrams.
  - Calculation of energy demand for the original and improved situation.
- Preparation of the report for each building.

Fieldwork includes the following activities:

- Data collection during fieldwork and information organization. Each building was visited four times: twice in winter and twice in summer. During the first visit, the measuring instruments were deployed, then removed.
  - Surveying the building envelope's materials not indicated in the plans (roofs, walls, floors, openings). Measuring thicknesses and observing materials. Describing them on sheets and taking photographs.
  - Survey of lighting and heating installations.
  - Survey of the number of people using the space and equipment of interest in heat emission.
  - Placement of temperature and humidity meters (Hobo).
  - Conducting perception surveys with building users. This includes perceptions of thermal comfort in winter and summer, lighting comfort, information on building use, ventilation schedules, etc.
  - Reading gas and electricity meters.
  - Taking thermographic photographs.

III. RESULTS

The following paragraphs present the results obtained for each building. First, the winter and summer psychrometric diagrams are shown, displaying the temperature and humidity inside and outside the building, measured over a week. The lines that define hygrothermal comfort are graphed as a reference for understanding the building's situation. Along with the psychrometric diagrams, a graph is presented detailing the energy consumption associated with the same period. The proposed improvements are detailed. The following section continues with the energy demand for the original situation and for the situation with proposed improvements. Finally, some results of the surveys and observations are shared.

A. General Manuel Belgrano Municipal School, San Antonio de Areco, Buenos Aires.

Temperature and humidity measurements were taken between August 19, 2021, and August 26, 2021, using sensors located in a classroom, the principal's office, the tutor's office, and outside. After processing the data, Fig. 10 and 11. were obtained:

For this building, it was found that, both in winter and summer, it operates most of the time outside the hygrothermal comfort zone, despite the energy consumption that maintains interior temperatures. The following improvements were proposed:

Incorporate glass wool over the removable ceiling (e = 10 cm). After dismantling it and replacing the glass wool, it is reinstalled. These improvements result in a thermal transmittance coefficient (K) of 0.31 W/(m2·K) in winter and 0.30 W/(m2·K) in summer. No improvements are proposed for the floor given the complexity of the project.

On the walls, it is proposed to add Base Coat (e = 0.2 cm) to the original package and towards the exterior, followed by EPS 30 kg/m3 (e = 5 cm). Over the EPS, Base Coat with double fiberglass mesh (e = 0.4 cm) and reinforcing washers (4/m2). Then another layer of Base Coat with a smooth trowel (e = 0.1 cm) and finally Finish+Color (e = 0.3 cm). This gives a thermal transmittance coefficient K of 0.50 W/(m2·K).

For the openings, the original window structure is used and transformed into a double-glazed window. This results in a thermal transmittance coefficient (K) of 3.33 W/(m^2·K). The doors remain the same.

Other improvement proposals include installing solar panels for electricity supply and replacing the heating system with heat pumps and geothermal probes.

B. Selma Kärst Health Center, San Carlos Sud, Santa Fe

Fig. 14 were obtained from temperature and humidity measurements taken using sensors located in the waiting room and outside between September 30, 2021, and October 14, 2021.

From measurements taken at the same sites, between 3/24/2021 and 3/31/2021, Fig. 15 was obtained.

It can be observed that this building exhibits improved hygrothermal behavior. This behavior is possibly due to the inertia of the walls. Gas consumption is zero since it has no gas supply. Improvements shown in Fig. 12 were proposed.

It is proposed to install a root barrier on the roof, over the subfloor's impermeable membrane, followed by a NeotechRoof thermal-drainage panel (e = 7.4 cm), a geotextile layer, and fertile soil (e = 10 cm) with vegetation, after structural

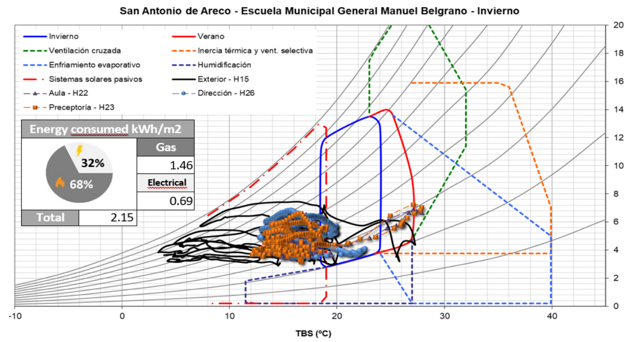


Fig. 10. Psychrometric diagram and energy consumption. Winter measurement. (Source: Authors)

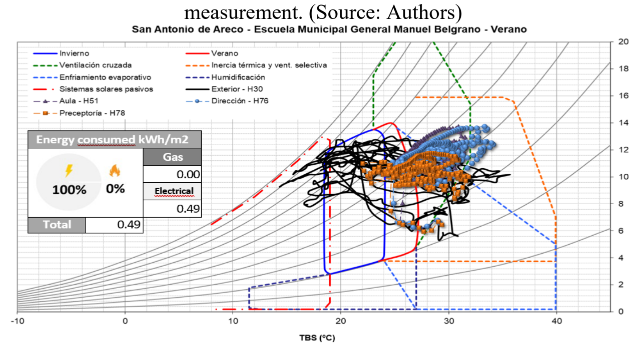


Fig. 11. Psychrometric diagram and energy consumption. Summer measurement. (Source: Authors)

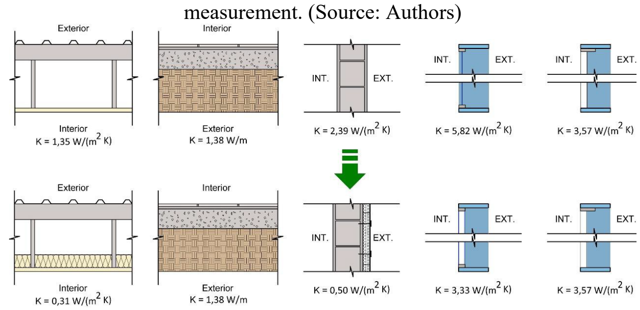


Fig. 12. Constructive systems improvements (Source: Authors).

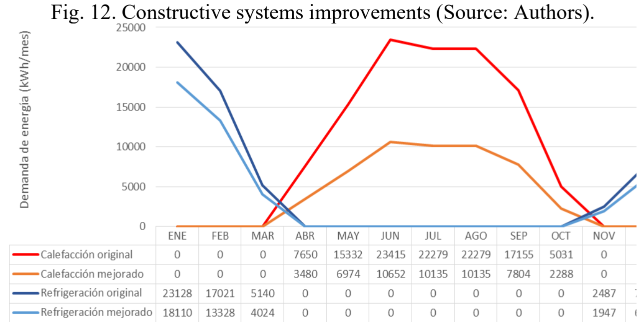


Fig. 13. Heating and cooling energy demand for the original and improved conditions. (Source: Authors)

TABLE I
ANNUAL ENERGY DEMAND. (SOURCE: AUTHORS)

Energy demand	Heating (kWh/year)	Refrigeration (kWh/year)	Total (kWh/year)	Total (kWh/m² y
Original	113,140.96	55,485.28	168,626.25	181.58
Improved	51,468.39	43446.01	94914.39	102.21
Demand reduction	54.51 (%)	21.70 (%)	43.71 (%)	

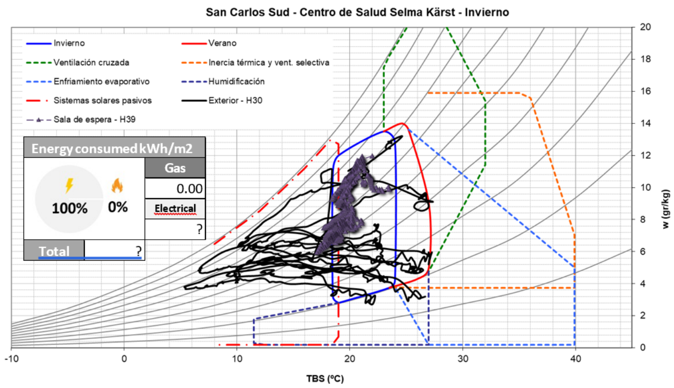


Fig. 14. Psychrometric diagram and energy consumption. Winter measurement. (Source: Authors)

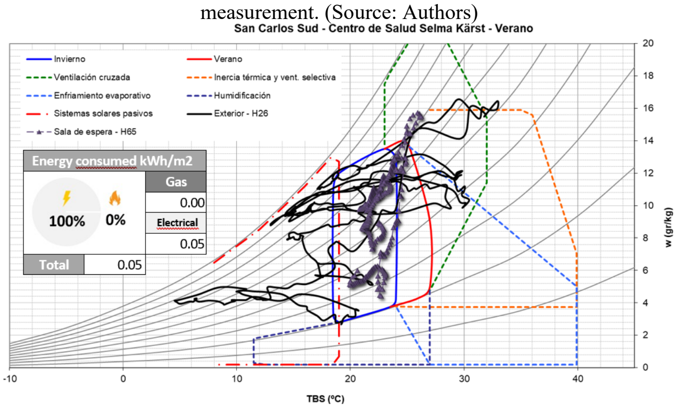


Fig. 15. Psychrometric diagram and energy consumption. Summer measurement. (Source: Authors)

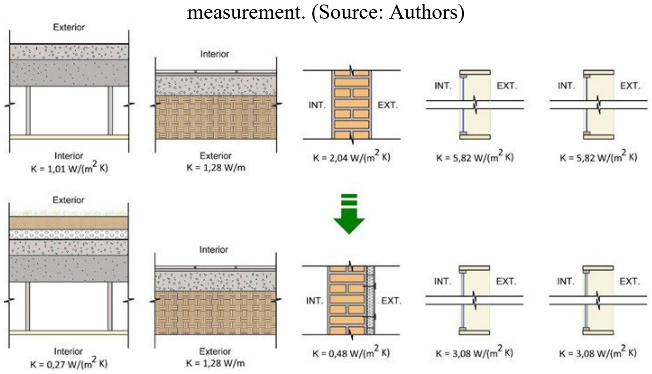
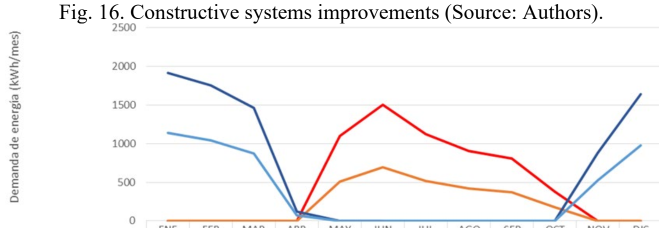


Fig. 16. Constructive systems improvements (Source: Authors).



	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
Calefacción original	0	0	0	0	1095	1498	1119	905	806	381	0	0
Calefacción mejorado	0	0	0	0	507	693	518	418	373	176	0	0
Refrigeración original	1915	1753	1462	122	0	0	0	0	0	0	878	1638
Refrigeración mejorado	1138	1042	869	72	0	0	0	0	0	0	522	974

Fig. 17. Heating and cooling energy demand for the original and improved conditions. (Source: Authors)

TABLE I
ANNUAL ENERGY DEMAND. (SOURCE: AUTHORS)

Energy demand	Heating (kWh/year)	Refrigeration (kWh/year)	Total (kWh/year)	Total (kWh/m^2 year
Original	5803.95	7768.36	13572.31	82.61
Improved	2684.64	4617.15	7301.80	44.44
Demand reduction	53.74 (%)	40.56 (%)	46.20 (%)	

verification. If the impermeable membrane is not in good condition, a new layer should be installed. Incorporating these improvements results in a thermal transmittance coefficient (K) of 0.27 W/(m^2·K) in winter and summer. No improvements are proposed for the floor given the complexity involved in the project.

On the walls, Base Coat (e = 0.2 cm) is proposed to be added to the original package and towards the exterior, followed by 30kg/m^3 EPS (e = 5 cm). Over the EPS, Base Coat with double fiberglass mesh (e = 0.4 cm) and reinforcing washers (4/m^2). Then another layer of Base Coat with a smooth trowel (e = 0.1 cm) and finally Finish+Color (e = 0.3 cm). This improves the thermal transmittance coefficient to K = 0.48 W/(m^2·K)

It is recommended to replace the openings with double-glazed windows. This will result in a thermal transmittance coefficient (K) of 3.08 W/(m^2·K).

The energy demand obtained for the original and improved conditions was as follows. It is important to clarify that the energy demand calculation does not consider the thermal inertia of the elements.

Additional recommendations include paying special attention to vegetation. Considering that San Carlos Sud is a community surrounded by fields cultivated with agrochemicals, preserving vegetation, especially trees, could help reduce the negative effects of these chemicals. They contribute to reducing the heat load in summer, improving air quality and biodiversity. Mobile awnings and insect screens could be added to the interior patio. Solar panels could be installed for electricity supply and geothermal heating. In the surveys, users focused on other building problems, such as mold and sewage odors. Therefore, adequate sewer ventilation is proposed to address the problem. It is important to mention that the proposed improvements are based on budget constraints and avoiding complex projects or projects that would affect operational performance.

C. El Molino Community Center, San Martín de los Andes, Neuquén

From temperature and humidity measurements taken using sensors located in the library, office, gymnasium, SUM, and outdoors, between June 27, 2022, and July 4, 2022, the following psychrometric diagram was obtained.

With measurements taken at the same sites, between 02/09/2022 and 02/16/2022, the following psychrometric diagram was obtained:

From the graphs above, during the winter, outside temperatures are low, but inside the building, temperatures can even exceed 30°C. Gas consumption is much higher than electricity consumption. In the summer, outside temperatures are closer to comfort, and the low-energy building manages to achieve its performance within the comfort zone. The following improvements were proposed for this building:

The roof is proposed to be covered with 10 cm thick glass wool beneath the wood planks and between the braces. Below the glass wool, another 3/4" thick wood plank is added. Incorporating these improvements results in a thermal transmittance coefficient of K = 0.25 W/(m^2·K).

Considering the comfort of the elderly, it is proposed to install 25 mm of 20 kg/m^3 EPS insulation over the existing floor. This is followed by an electro-welded steel mesh, to which the underfloor heating coil is secured with cable ties. Above this, 6 cm of concrete and ceramic tiles are placed. This solution will be applied on the ground floor. The underfloor heating coil will be installed only in the two living rooms at the ends of the ground floor. Incorporating these improvements, a thermal transmittance coefficient (K) of 1.00 W/m^2 is achieved.

Regarding the walls, on the ground floor, it is proposed to add Base Coat (e=0.2 cm) to the original package and towards the exterior, then EPS 30 kg/m3 (e=5 cm). Over the EPS, Base Coat with double fiberglass mesh (e=0.4 cm) and reinforcing washers (4/m^2). Then another layer of Base Coat with a smooth trowel (e=0.1 cm) and finally Finish + colour (e=0.3 cm). If desired, stone cladding can be replaced. With these improvements, the thermal transmittance coefficient K is 0.45 W/(m^2·K).

For upper-floor walls, the wood cladding is removed, then the air cavity is filled with sprayed cellulose or glass wool, and the wood cladding is replaced. The thermal transmittance coefficient K improves to 0.48 W/(m^2·K).

In the improved version, it is proposed to replace the single-pane window with one like the other double-pane windows. For the doors, an entry chamber should be incorporated to prevent the entry of cold outside air. The thermal transmittance coefficient K for this door position is 1.99 W/(m^2·K).

In surveys, older adults indicated that every time someone enters from outside, they are hit by very cold air. Incorporating entrance chambers would prevent this discomfort. Users indicate they are cold even though measurements show temperatures sometimes reach 30°C. This may be due to poor heat distribution, some users are elderly with limited mobility, and mainly due to the entry of cold air through openings. The library also has problems with smells coming from the kitchen, so it is proposed to improve the kitchen's air extraction system. They also comment that the spaces are large and high, which takes time to heat. When students get cold, they go to the kitchen because it is a smaller space and easier to heat. Users indicate that they feel fine without refrigeration during the summer. The office on the upper floor has no windows and only one person works there, so it is proposed to install a window.

IV. Conclusions

The study summarizes the energy-environmental analysis of three buildings in Argentina, located in regions with contrasting climatic conditions. This work was carried out within the framework of the Euroclima+ project in response to the current global situation regarding the excessive consumption of finite resources and an increasing number of greenhouse gas emissions. Various challenges arose during the audits. Initial information gathering was particularly difficult, except in a few cases. This required additional work for the auditors, who in some cases had to use fieldwork time to take measurements that would allow for the preparation of plans. Many municipalities were unable to obtain the buildings'

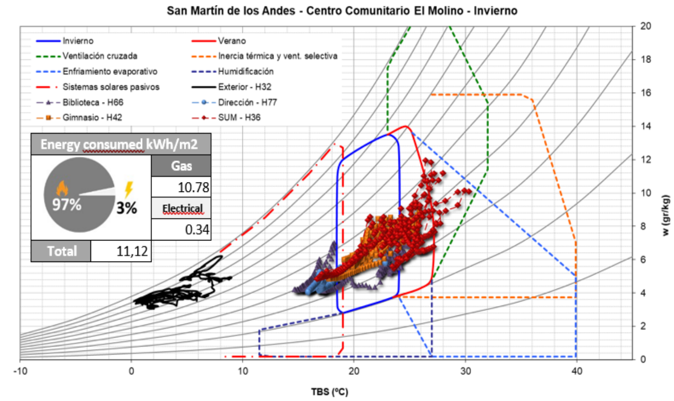


Fig. 18. Psychrometric diagram and energy consumption. Winter measurement. (Source: Authors)

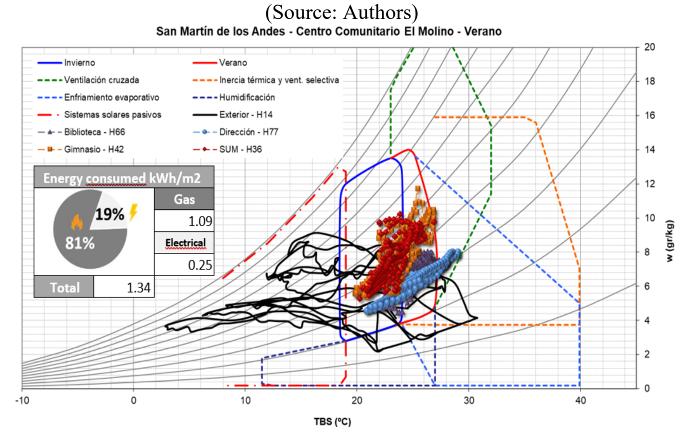


Fig. 19. Psychrometric diagram and energy consumption. Summer measurement. (Source: Authors)

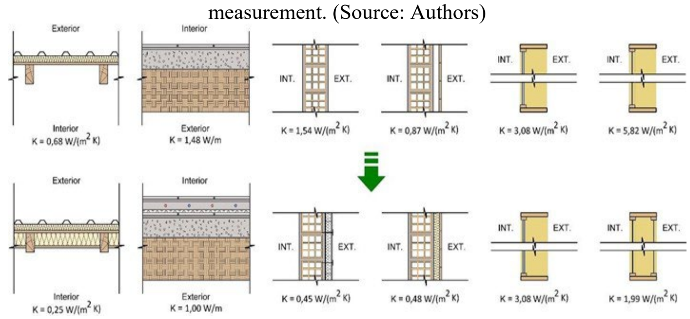


Fig. 20. Constructive systems improvements (Source: Authors).

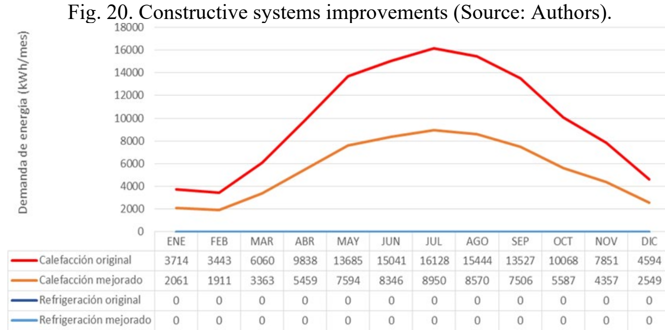


Fig. 21. Heating and cooling energy demand for the original and improved conditions. (Source: Authors)

TABLE I
ANNUAL ENERGY DEMAND. (SOURCE: AUTHORS)

Energy demand	Heating (kWh/year)	Refrigeration (kWh/year)	Total (kWh/year)	Total (kWh/m^2 year)
Original	119394.26	0.00	119394.26	269.77
Improved	66251.72	0.00	66251.72	149.70
Demand reduction	44.51 (%)	0.00 (%)	44.51 (%)	

historical energy consumption, so some indicators could not be calculated. Despite this, results were obtained and improvements proposed to reduce the buildings' energy consumption.

The buildings were found to lack adequate hygrothermal comfort despite their significant energy consumption. Of the three cases analyzed, the psychrometric diagrams show that the San Antonio de Areco school has the worst hygrothermal performance, despite being in a temperate climate. San Martín de los Andes has the best-insulated roofs and walls. It also has the highest energy consumption per square meter of construction.

With improved insulation in the building envelope, energy demand has been reduced by at least 40%. It should be noted that the program used to calculate energy demand does not consider the thermal inertia of the elements, which is an important resource for achieving comfort.

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