Erasmus+ Project ID: 2023-1-ES01-KA220-HED-000156652

Spanish Case Study

Part I: Spanish Case Study approach and analysis of the building initial situation

1. Case Study Approach

Spanish case study consists of analysing the energy demand and consumption, as well as proposing alternatives that improve its efficiency, of an existing single-family house, type terraced house, located in the municipality of Ceutí, Spain.

2. Description of the single-family house

2.1. Introduction

The terraced single-family house consists of a basement, first floor and second floor. The roof of the house is a flat roof. This building was built in 2023.

The basement has a space of 60 m^2 for vehicle parking and a storage room of 12 m^2.

The first floor has an interior usable area of 56 m^2, not including stairs. The spaces on the first floor are a bedroom, a living room, the kitchen and a bathroom. On the outside of the first floor, the house has a terrace of 13 m2 where the main door of the house is.

On the second floor it has an interior usable area of 54.6 m^2, not including the staircase. This floor consists of 3 bedrooms, and a bathroom. On the outside of this floor, one of the bedrooms has a balcony of 3 m^2 useful.

The width of the façade of this terraced house is 7.71 m and the depth is 11.64 m. On the main façade of the house has a fenced plot of 36 m2 where the ramp is located to go down to the basement with the vehicle.

Figure 1: Terraced houses in Spain

This detached house is located in the municipality of Ceutí, province of Murcia (Spain)

The location data of this building are the following:

Location data		
City	Ceutí	
Altitude	94.000	m
Latitude	38.1	degrees
Longitude	-1.3	degrees
Time zone	0.0	
SCOP climatic conditions	Warm climate	

Figure 2: Location of the house

The main façade of the house faces west.

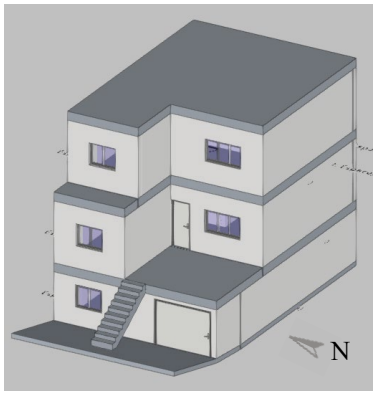


Figure 3: Orientation of the house

2.2. House Plans

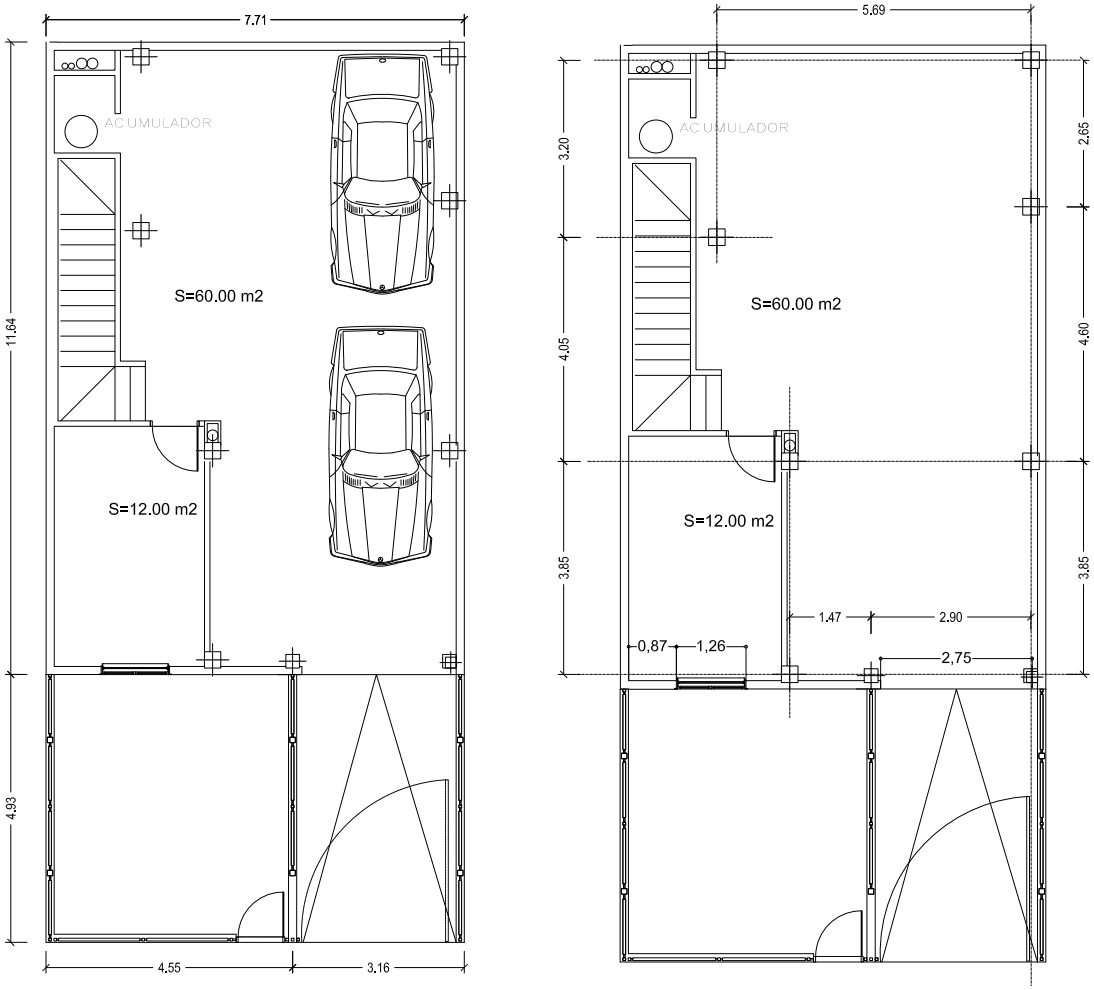


Figure 4: Basement Floor Plans

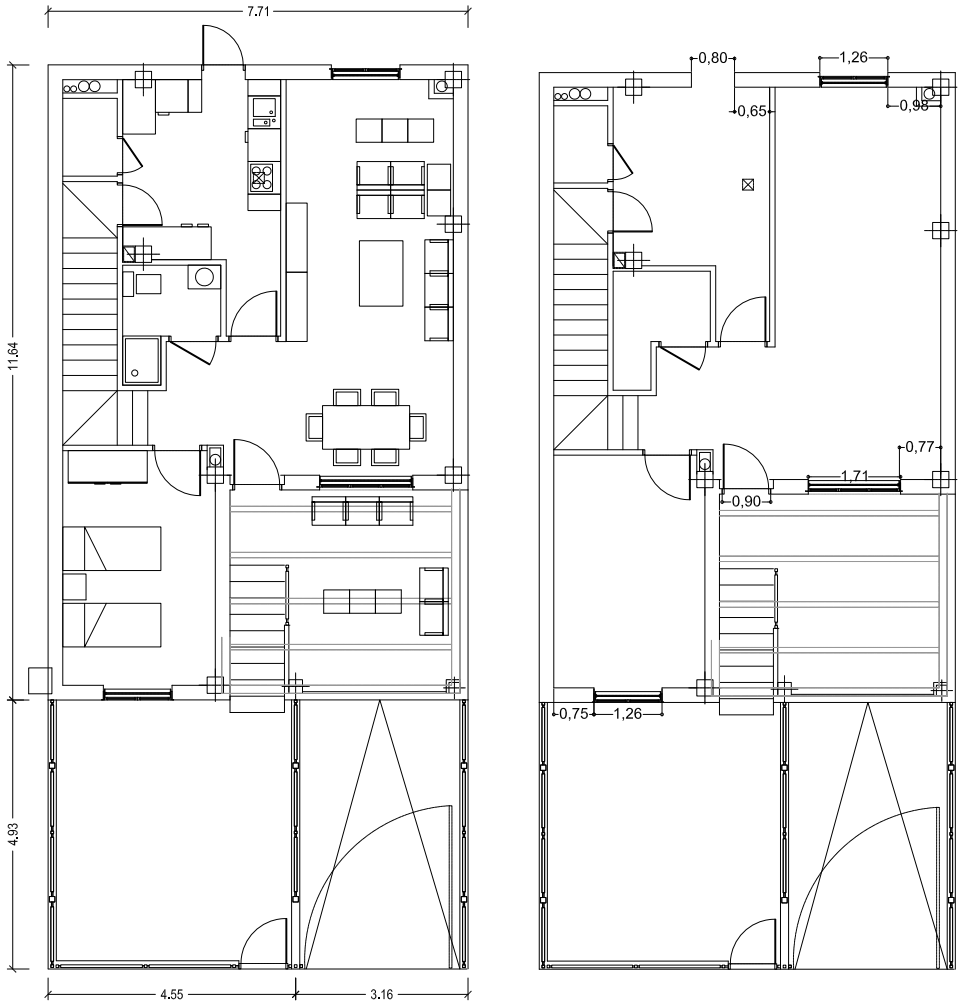


Figure 5: Ground Floor Plans

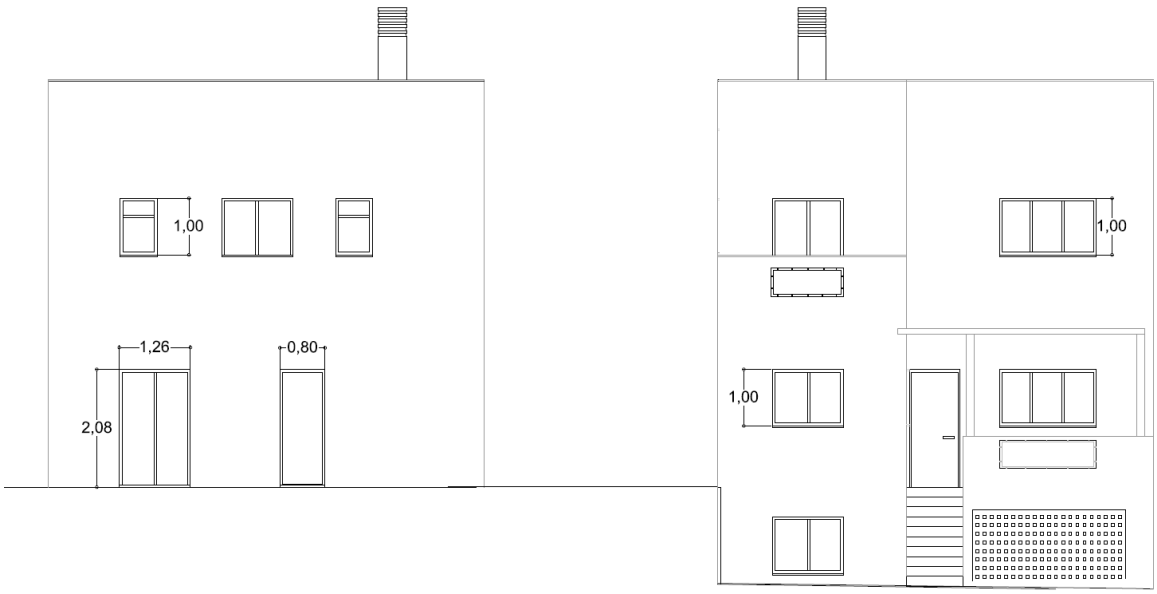


Figure 6: Rear and front elevations.

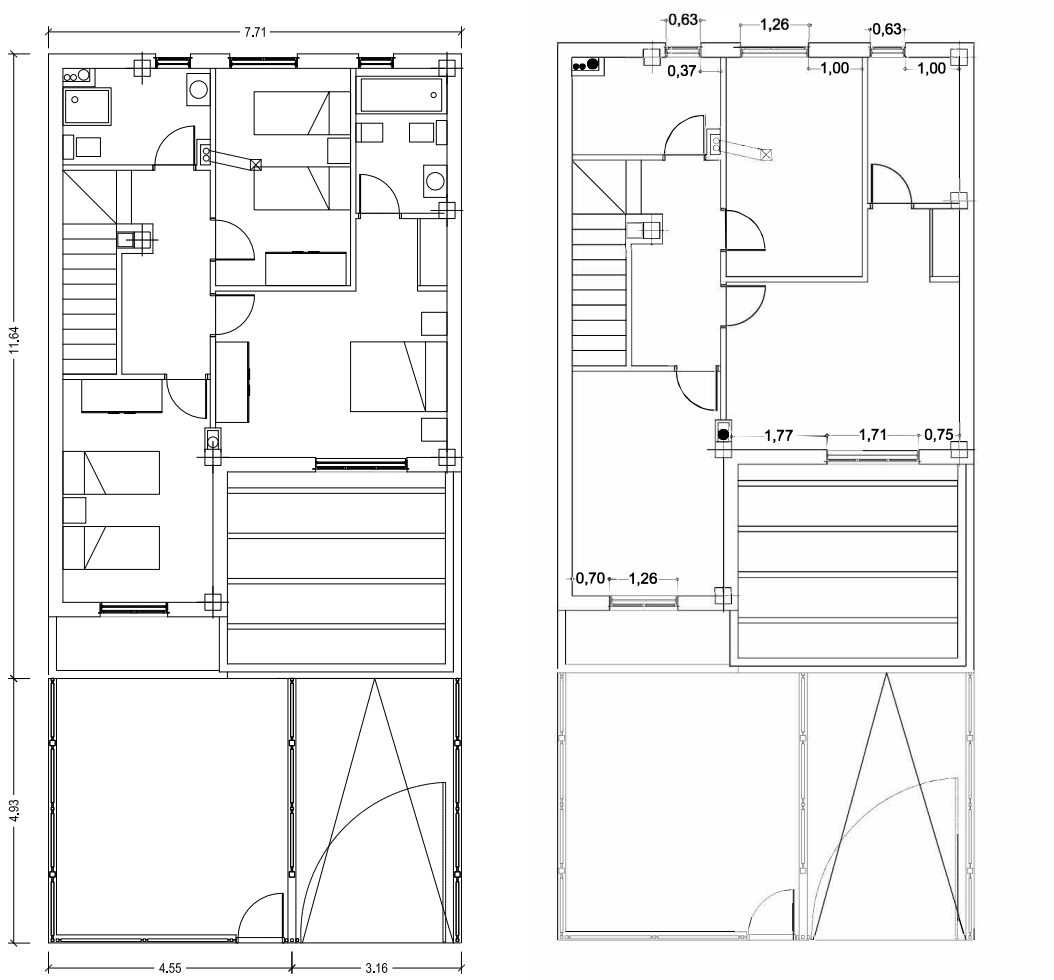


Figure 7: First Floor Plans

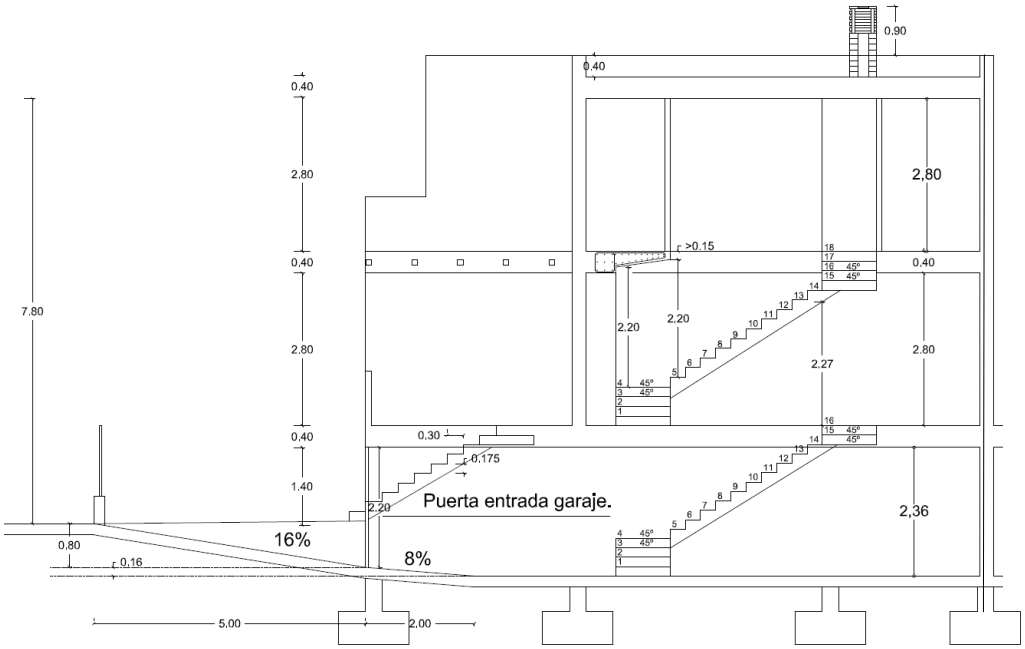


Figure 8: Building section.

2.3. Thermal Envelope Materials

The thermal envelope of a building refers to the collective system of elements that separate the conditioned interior spaces from the unconditioned exterior environment. It includes exterior walls, roofs, floors (particularly those in contact with unconditioned areas or the ground), as well as windows and exterior doors.

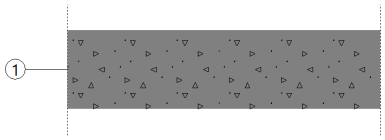
The primary function of the thermal envelope is to regulate the flow of heat, air, and moisture, thereby minimizing heat loss during cold seasons and heat gain during warm seasons. It also reduces air infiltration and exfiltration, contributing significantly to occupant thermal comfort and the overall energy efficiency of the building.

The performance of the thermal envelope is typically evaluated through its thermal resistance (R-value), thermal transmittance (U-value), and airtightness.

A well-designed and properly constructed thermal envelope is essential for achieving high energy performance standards, reducing operational energy costs, and maintaining indoor environmental quality.

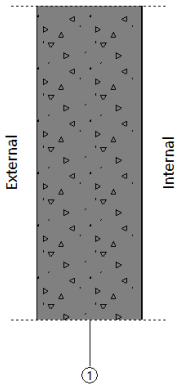
The characteristics of the elements that belong to the thermal envelope of the studied building are described below.

Floors in contact with the ground (screed)



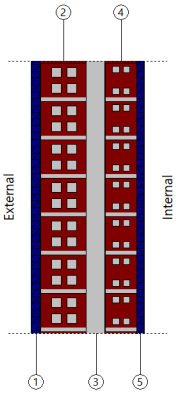
Layers
1 - Concrete. Medium density (density 1800): 15.00 cm Total thickness: 15.00 cm
Thermal description
Thermal resistance: 0.13 (m^2·K)/W

Walls in contact with soil



Layers
1 - Concrete. Medium density (density 2200): 20.00 cm Total thickness: 20.00 cm
Thermal description
Thermal resistance: 0.12 (m^2·K)/W

Façades



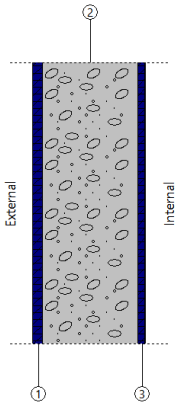
Layers
1 - Cement, sand: 2.00 cm
2 - M01 - 100 mm brick: 10.16 cm
3 - F04 - Wall air space resistance: 4.00 cm
4 - M007 - 70 mm brick: 7.00 cm
5 - Gypsum (density 600): 1.60 cm
Total thickness: 24.76 cm
Thermal description
Heat transfer coefficient (U): 1.61 W/(m²·K)
Thermal capacity: 53714.62 J/m²·K

Façade openings

Windows with aluminum frame and monolithic glass

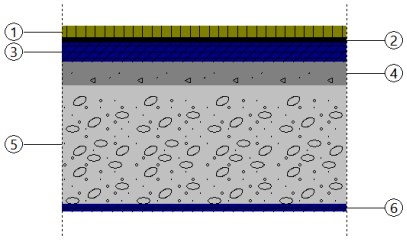
Heat transfer coefficient (U)	5.70	W/(m²·K)
Solar heat gain coefficient	0.70	

Party walls



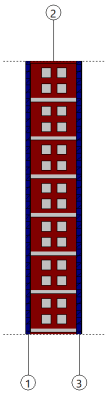
Layers
1 - Cement, sand: 2.00 cm
2 - M03 - 200 mm LW concrete block: 20.32 cm
3 - Gypsum (density 600): 1.50 cm
Total thickness: 23.82 cm
Thermal description
Heat transfer coefficient (U): 1.29 W/(m²·K)
Thermal capacity: 37649.65 J/m²·K

Roofs



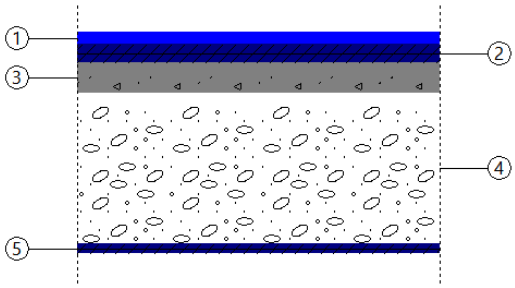
Layers
1 - F18 - Terrazzo: 2.54 cm
2 - Asphalt: 1.00 cm
3 - Cement, sand: 4.00 cm
4 - Concrete. Reinforced (with 2% of steel): 5.00 cm
5 - M04 - 300 mm LW concrete block: 25.00 cm
6 - Gypsum (density 600): 1.50 cm
Total thickness: 39.04 cm
Thermal description
Heat transfer coefficient (cooling): 1.36 W/(m²·K)
Heat transfer coefficient (heating): 1.51 W/(m²·K)
Thermal capacity: 145567.19 J/m²·K

Interior partitions



Layers
1 - Gypsum (density 600): 1.00 cm
2 - M01 - 100 mm brick: 10.16 cm
3 - Gypsum (density 600): 1.00 cm
Total thickness: 12.16 cm
Thermal description
Heat transfer coefficient (U): 2.06 W/(m²·K)
Thermal capacity: 53129.19 J/m²·K

Intermediate slabs



Layers
1 - Ceramic/porcelain: 2.00 cm
2 - Cement, sand: 3.00 cm
3 - Concrete. Medium density (density 2200): 5.00 cm
4 - M03 - 200 mm LW concrete block: 25.00 cm
5 - Gypsum (density 600): 1.50 cm
Total thickness: 36.50 cm
Thermal description
Ceiling slab
Heat transfer coefficient (cooling): 1.00 W/(m²·K)
Heat transfer coefficient (heating): 1.16 W/(m²·K)
Floor slab
Heat transfer coefficient (cooling): 1.16 W/(m²·K)
Heat transfer coefficient (heating): 1.00 W/(m²·K)
Floor slab exposed to open air
Heat transfer coefficient (cooling): 1.25 W/(m²·K)
Heat transfer coefficient (heating): 1.15 W/(m²·K)
Thermal capacity: 141371.08 J/m²·K

2.4. Heating and air conditioning systems

The heating and air conditioning system is a multi-split direct expansion system with the properties shown in the following Figure.

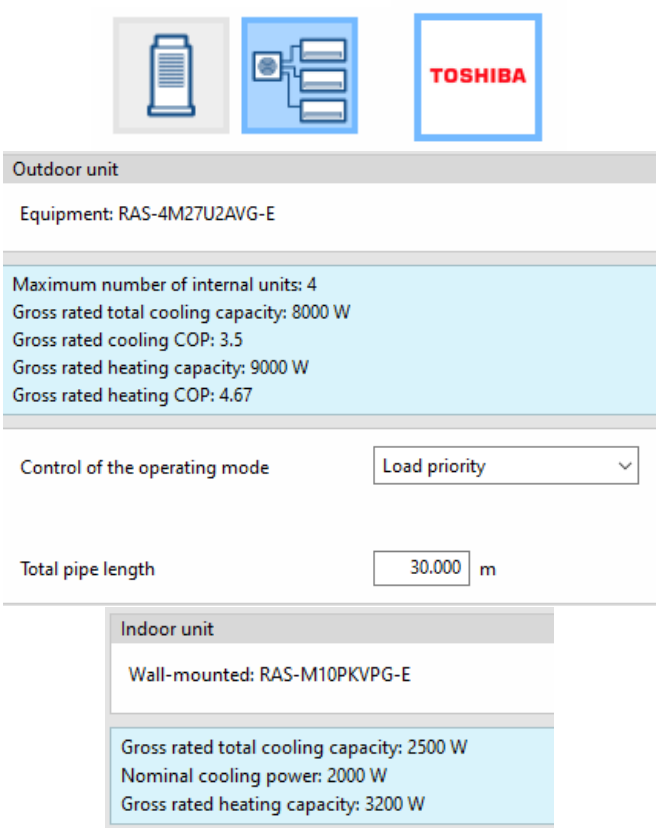


Figure 9: Heating and air conditioning system: multi-split direct expansion system properties.

The System has 4 indoor units

2.5. Domestic hot water system

The domestic hot water system consists of an Electric hot water boiler.

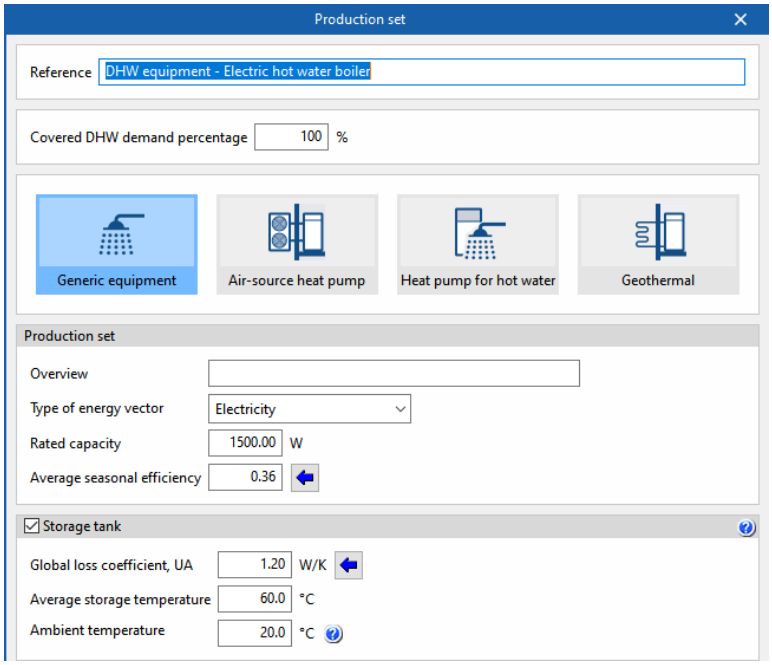


Figure 10: Electric hot water boiler properties.

In this study of the Spanish single-family house, it has been assumed that the temperature of the water for domestic use in the network, before heating it, varies between **10.2 in December** and January and **19.9 °C in August.**

The occupancy considered in the building for the purposes of calculating the need for domestic hot water has been **4 people** in this case study. Domestic hot water needs: **28 litres per person and per day**.

3. Development of the Spanish Case Study

3.1. Building BIM model

A **Building Information Model** (BIM) for energy analysis is a digital representation of a building that integrates both geometric and semantic data, enabling detailed simulations of the building's energy performance. Unlike a standard 3D model, a BIM includes information about materials, thermal properties, occupancy schedules, lighting systems, HVAC equipment, and more.

When used for energy analysis, the BIM serves as a data-rich foundation that can be exported to energy simulation software (EnergyPlus in this case study). This allows energy consultants to evaluate heating and cooling loads, daylighting, thermal comfort, and overall energy consumption.

Key benefits include:

- **Automated data transfer** from design to simulation
- **Improved accuracy** due to consistent and detailed inputs
- **Integrated design workflows** between architects, engineers, and energy analysts

The following figures show several views of the building's geometric BIM model.

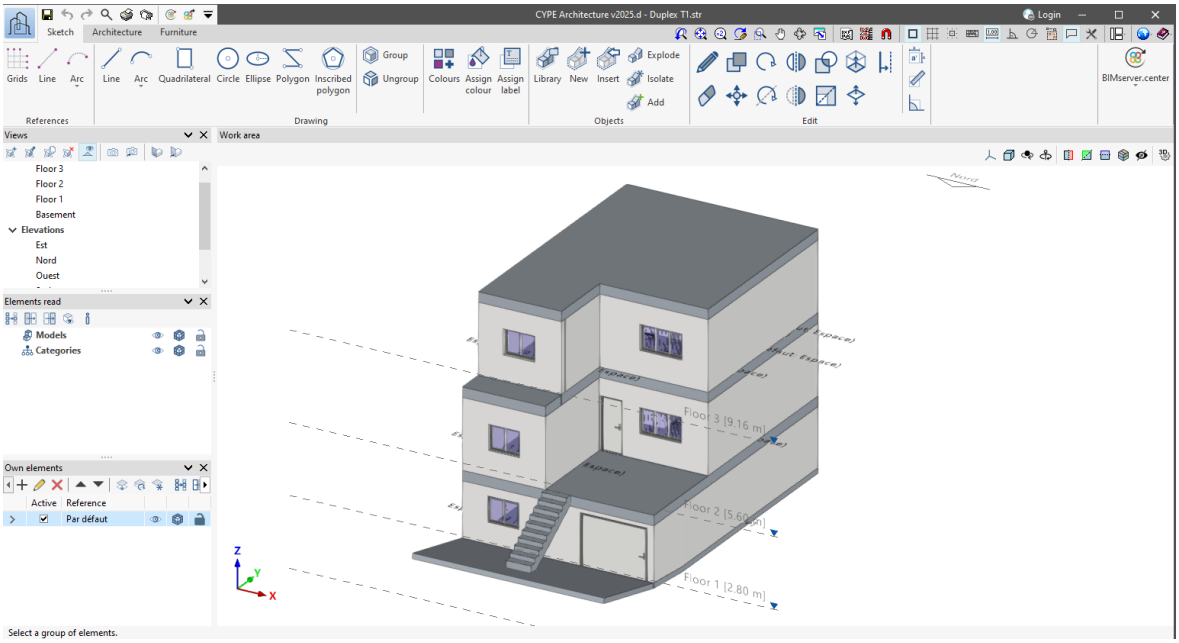


Figure 11 BIM model

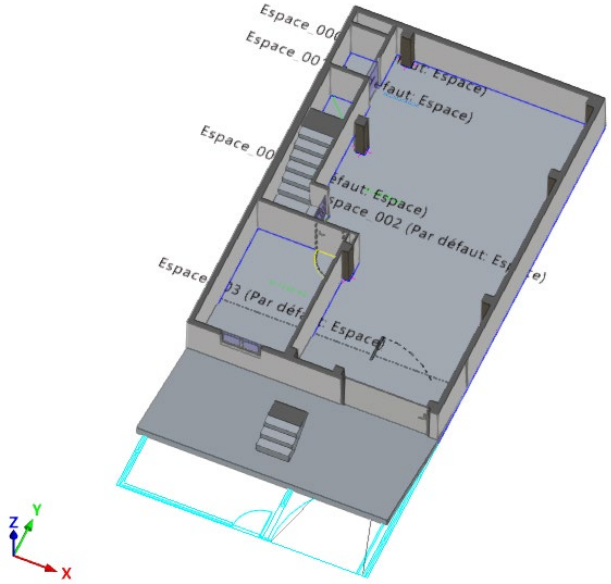


Figure 12 Basement floor in BIM model

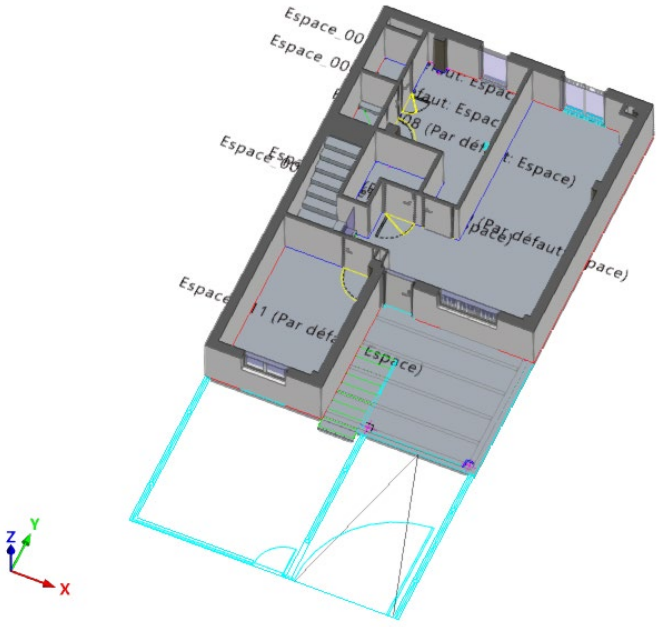


Figure 13 Ground floor in BIM model

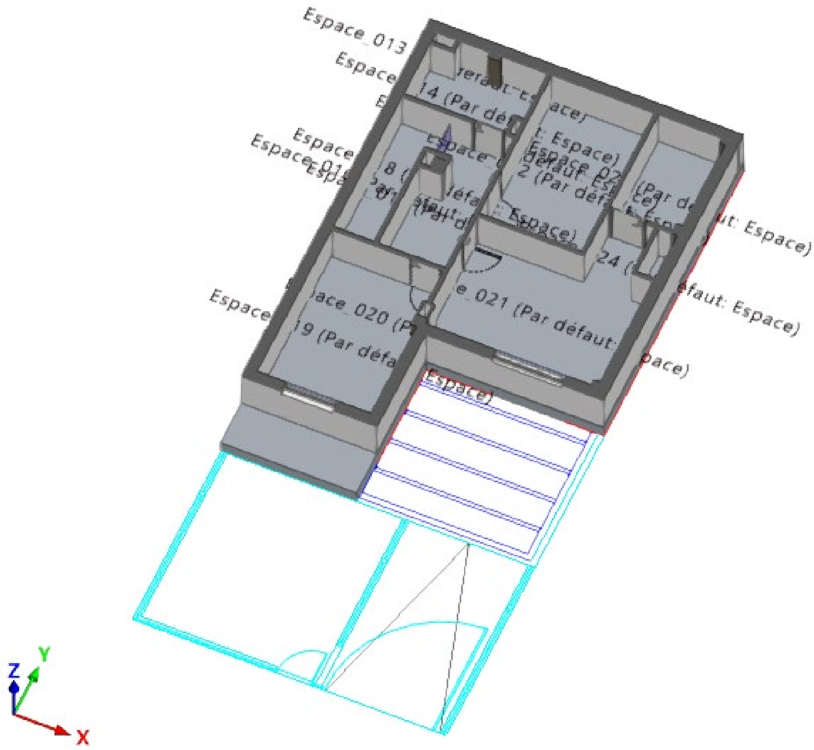


Figure 14 Fist floor in BIM model

3.2. Analytical model of the building.

The **analytical model of the building** is made up of the interior spaces of the building into which the interior volume of the building is divided with its characteristics (volume of space, surfaces that eliminate the space...).

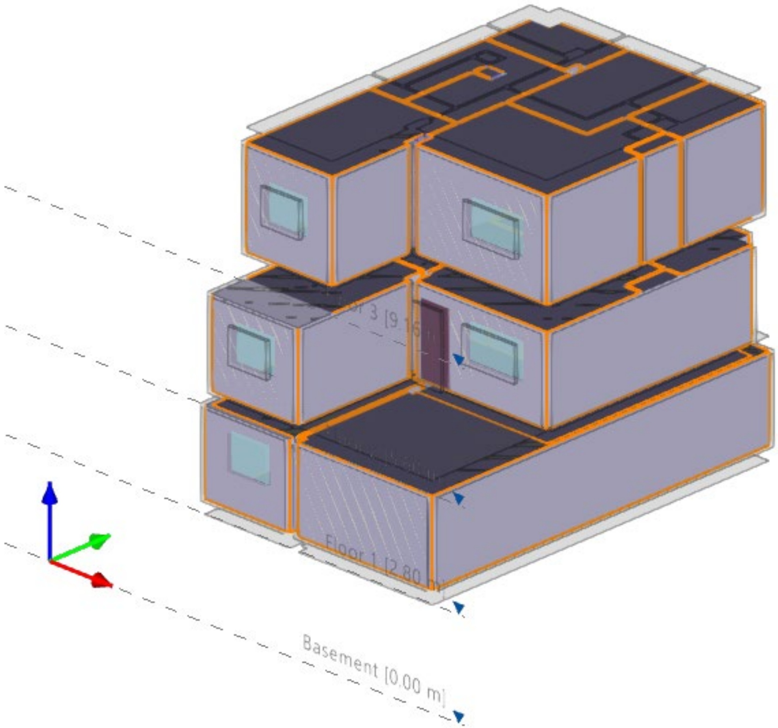
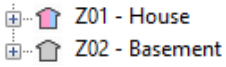


Figure 15 Analytical model of the building.

In this work, the interior spaces of the building have been grouped into 2 different zones.

These zones are:



Zone 1 (House) is the dwelling. It is the conditioned area of the building.

Zone 2 (Basement) is not habitable

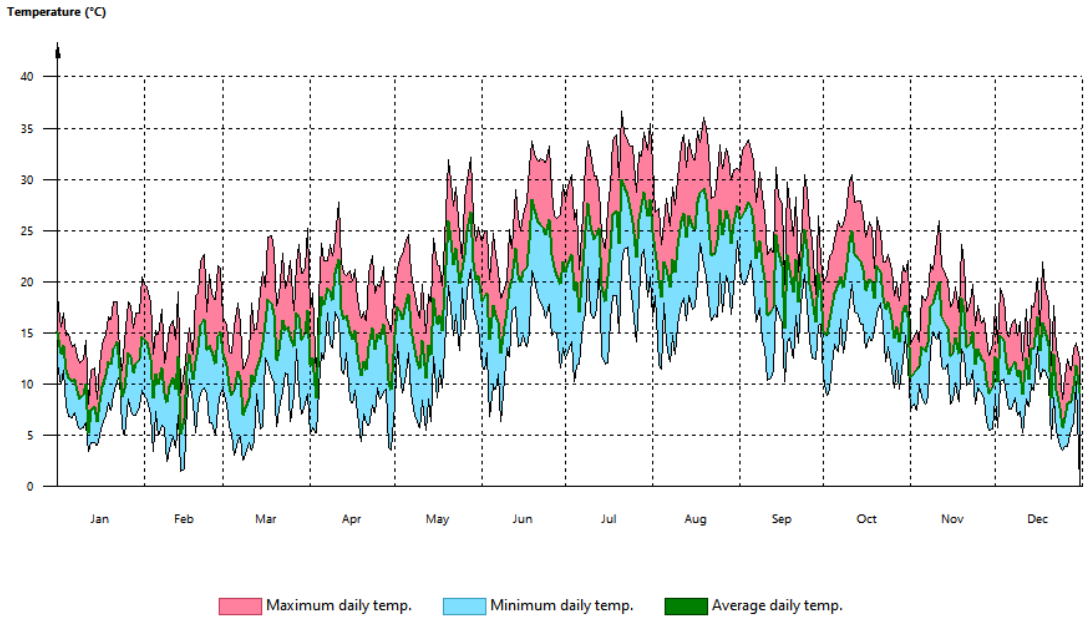
The ventilation of the existing building consists of natural ventilation.

The ventilation needs introduced in the model have been **0.63 interior air renovations per hour** for dwellings, common areas, and kitchens and bathrooms, and 1 renovation per hour for the basement.

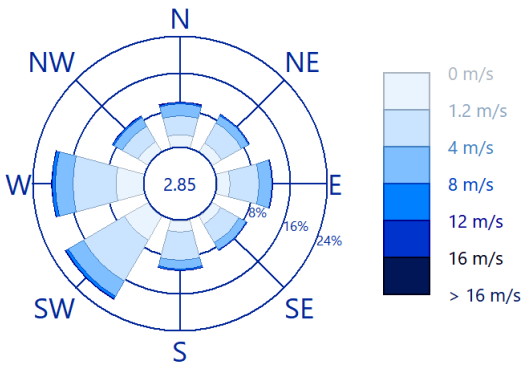
3.3. Climatic zone

The climatic zone in which the house is located is B3 according to the Spanish standard of energy efficiency in the building. B3 corresponds to a climatic zone with a mild winter and a hot summer.

The data of the **outside temperature** considered in this case study in this climatic zone are as follows:

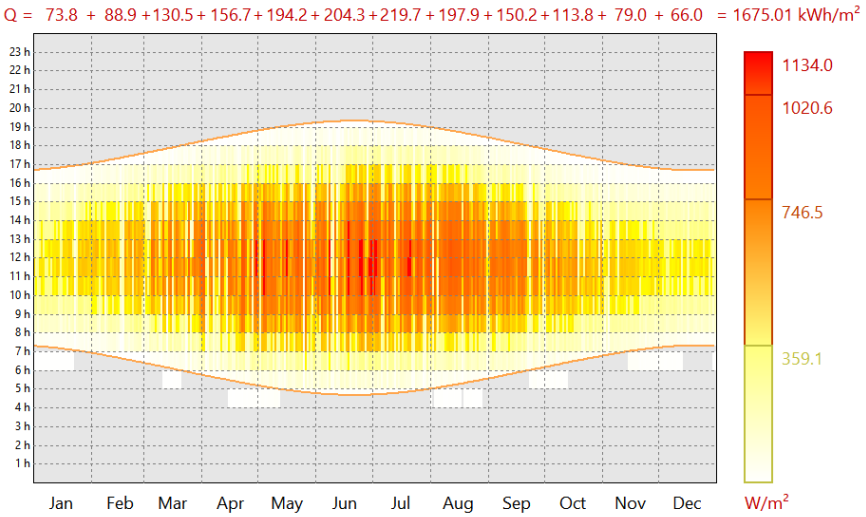


Wind distribution:



Solar irradiation on the site of the house:

The graph below shows the global irradiance on a horizontal surface



3.4. Operational conditions of conditioned spaces for private residential use

For the energy analysis of the building, the operational conditions of the conditioned spaces of the building have been used, which are indicated in the following table.

Table 1: Operational conditions of the conditioned spaces of the building for private residential use

		Schedule (typical week)			
		0:00-6:59	7:00-14:59	15:00-22:59	23:00-23:59
High setpoint temperature (ºC)	January to May	--	--	--	--
	June to September	25	--	25	27
	October to December	--	--	--	--
Low setpoint temperature (ºC)	January to May	17	20	20	17
	June to September	--	--	--	--
	October to December	17	20	20	17

3.5. Building Energy Model

A building energy model is a detailed digital simulation of a building's energy use, created to analyse and predict its energy performance. It includes inputs such as the building's geometry, orientation, construction materials, insulation levels, HVAC systems, lighting, occupancy patterns, and local climate data. The model uses this information to calculate energy consumption for heating, cooling, lighting, ventilation, and plug loads over time.

This model is essential for:

- Evaluating design alternatives
- Estimating energy savings
- Complying with building codes
- Supporting green building certifications (e.g., LEED, BREEAM)
- Performing cost-benefit analysis of energy efficiency measures

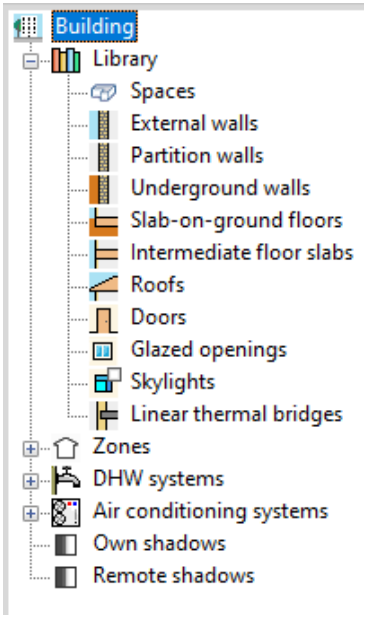


Figure 16: Some components of the Building Energy Model

3.6. Spanish single family house project in BIMServer.center

The BIM model of the building, the analytical model and the energy model of the current situation of the building are shared on the **BIM platform**. BIMServer.center.

This project can be visited using the following link:

https://bimserver.center/es/project/604611?tab=0

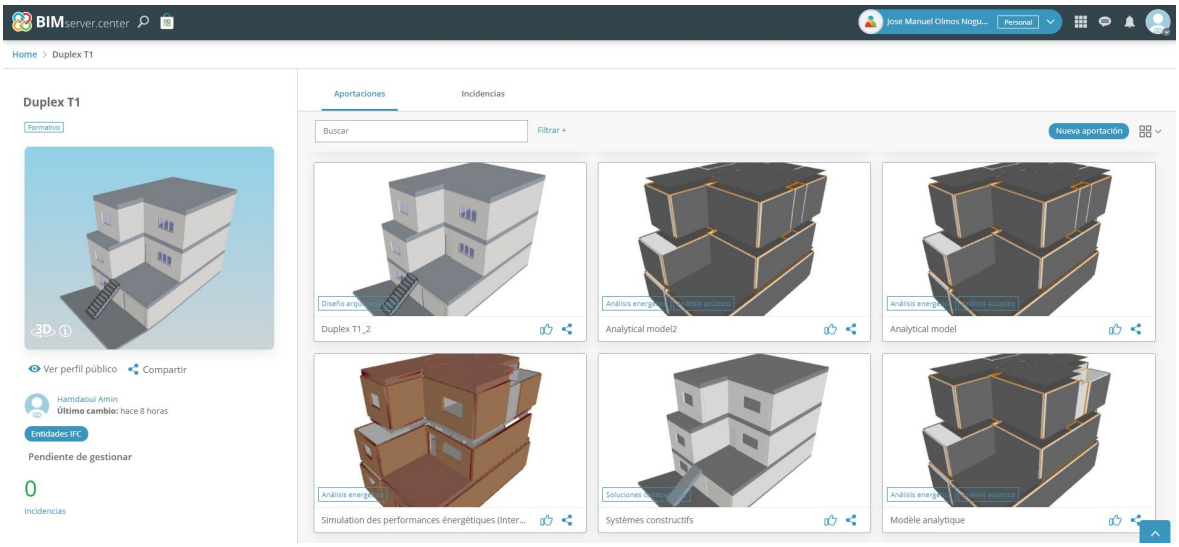
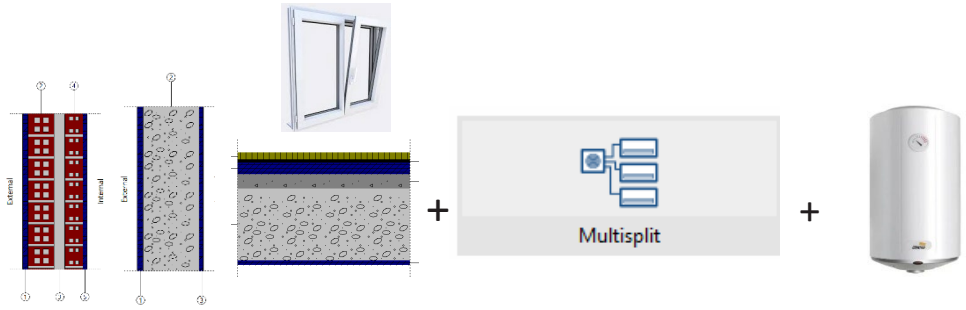


Figure 17: Single family house in BIMServer.center

3.7. Cases analysed. Description

- **Case 1: Initial situation 1: Envelope without isolation + H & AC direct expansion system + DHW with Electric boiler.**

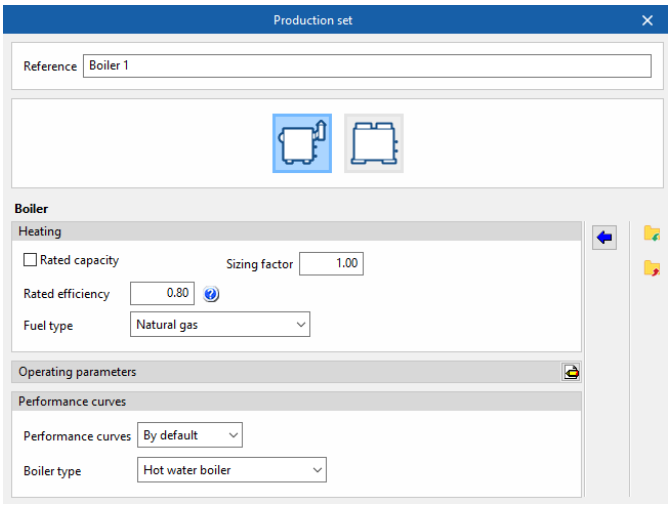


(Façade party wall + roof)
(Single glass windows with aluminum frame. U=5.7 W/(m^2·K))
Envelope without insolation + HVAC direct expansion system + DHW with Electric boiler

- **Case 2: Initial situation 2: Envelope without isolation + Gas Boiler & radiators for heating and DHW + Cooling system multi-split direct expansion system.**

(Façade party wall + roof)
(Single glass windows with aluminum frame. U=5.7 W/m^2·K)

Envelope without insolation + Heating and DHW gas boiler and radiators + AC with direct expansion multisplit system.



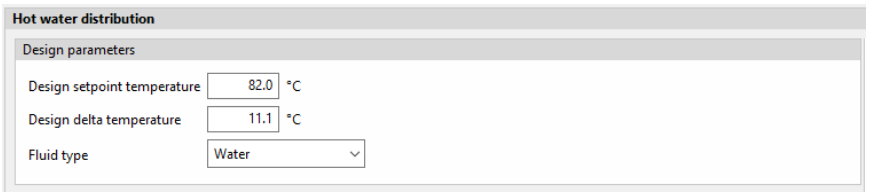
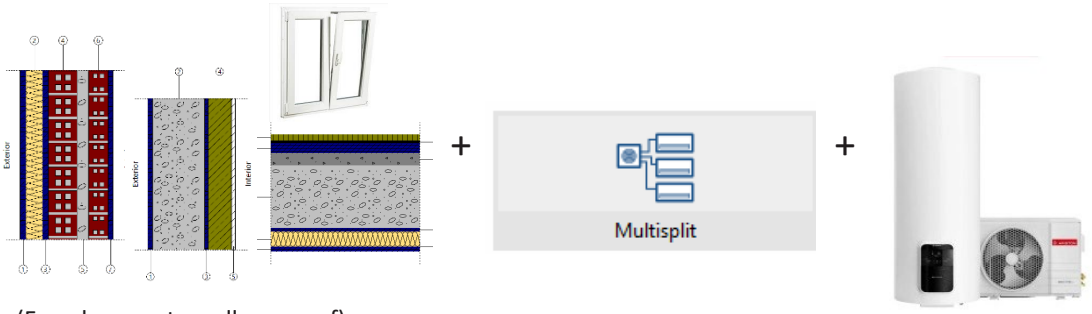


Figure 18: Heating and DHW gas boiler features

- **Case 3: Improvement 1 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas + H & AC direct expansion multisplit System + DHW heat pump.**



(Façade party wall roof)
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

Improved envelope 6 cm Insolation layer + H & AC direct expansion multisplit System + DHW heat pump.

Features of the DHW heat pump:

- Rated Power 1500 W
- SCOP: 3.57 in accordance with EN-16147
- Accumulation capacity: 200 liters.

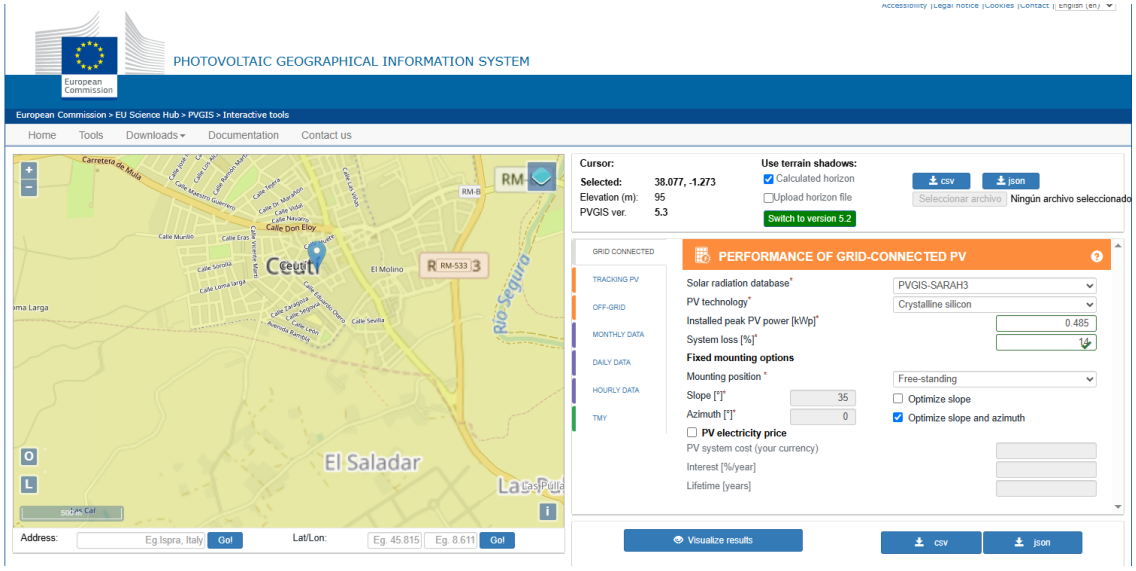
-

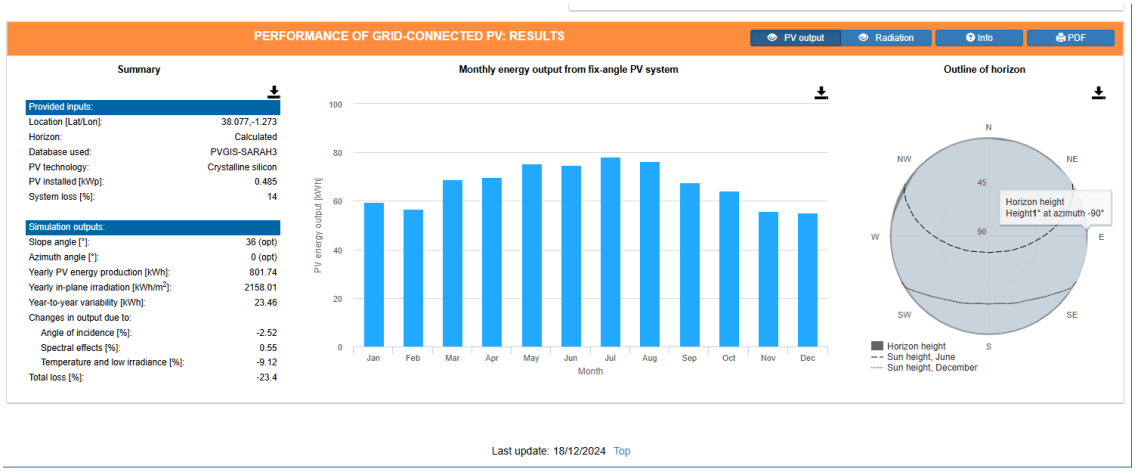
- **Case 4: Improvement 2 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas +H & AC direct expansion multi-split System + DHW heat pump + Photovoltaic panels.**

Case 3+  12 m2 of photovoltaic panels of (161.6 W/m2)

Characteristics of Photovoltaic Panels:

The power of the module is 485W, efficiency – 22.4%.
Size of the panel (module): 3 m^2.
Orientation (azimuth angle) : 0^o
Slope angle: 35^o
Number of panels used: 4



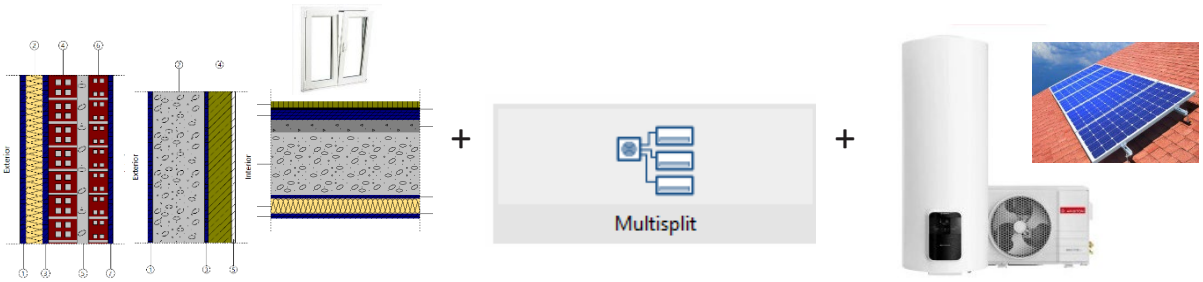


Energy production of the photovoltaic system by month in Ceutí (Spain):

	Energy production per panel	Number of panels	Energy production
	kwh		kwh
January	59,6	4	238,4
February	56,8	4	227,2

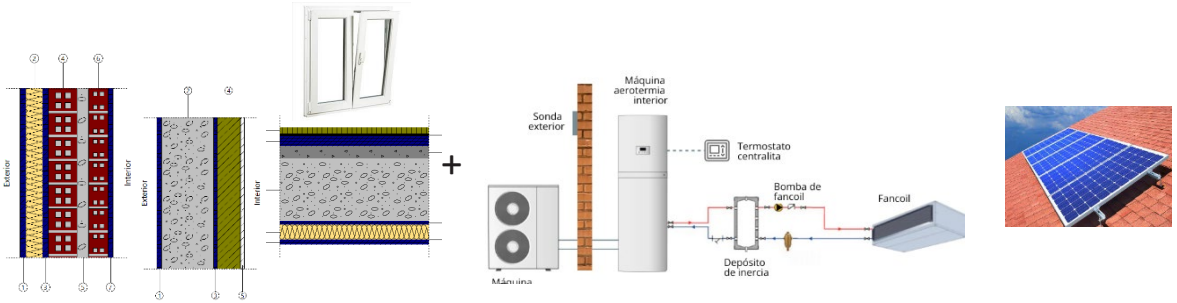
	Energy production per panel	Number of panels	Energy production
	kwh		kwh
march	68,7	4	274,8
April	69,7	4	278,8
may	75,4	4	301,6
June	74,9	4	299,6
July	78,1	4	312,4
August	76,3	4	305,2
September	67,5	4	270
October	64	4	256
November	55,8	4	223,2
December	55	4	220
Total	**801,8**		**3207,2**

- **Case 5: Improvement 3 of the Initial situation case 1. Improved envelope 10 cm Insolation + PVC Double glazed windows with argon gas + H & AC direct expansion multisplit System + DHW heat pump + Photovoltaic panels. (Case 4 but with 10 cm of insulation layer in the enveloped) .**



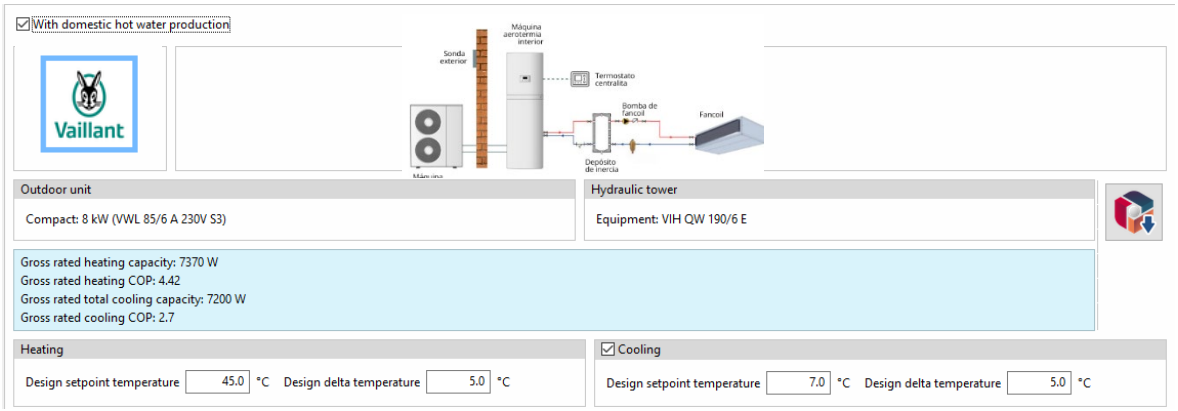
(Façade party wall roof)
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)
(Case 4 but with 10 cm of insulation layer in the enveloped) .

- **Case 6 : Improvement 4 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas + H & AC and DHW Aerothermal with fan coil + Photovoltaic panels**

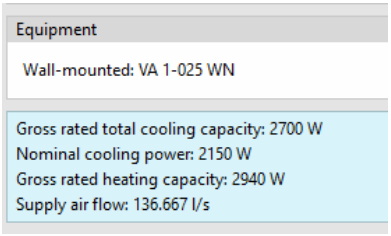


(Façade party wall roof) Aerothermal system with fan coils
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

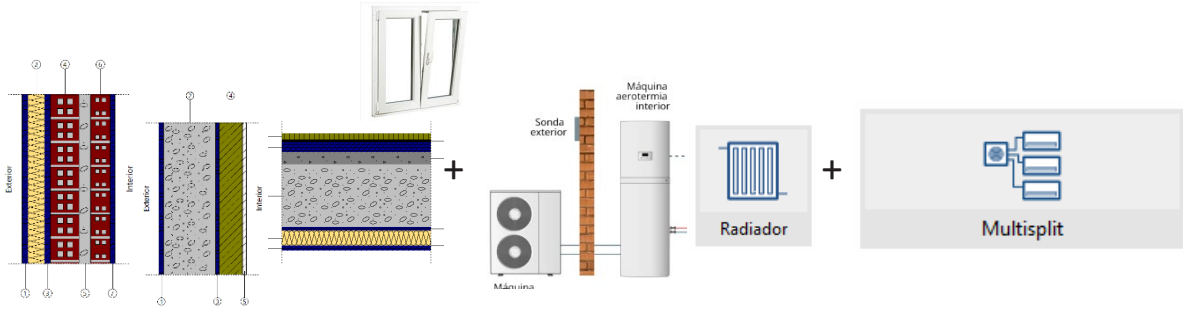
Characteristics of Aerothermal system with fan coils for heating and cooling.



Fan coil unit:



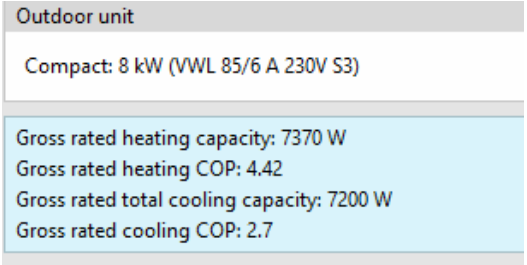
- **Case 7 : Improvement 1 of the Initial situation case 2. Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + Cooling with direct expansion multi-split system.**

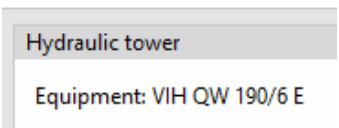


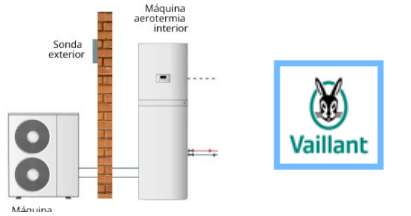
(Façade party wall roof) + Aerothermal heating system with radiators + AC direct expansion system.

(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

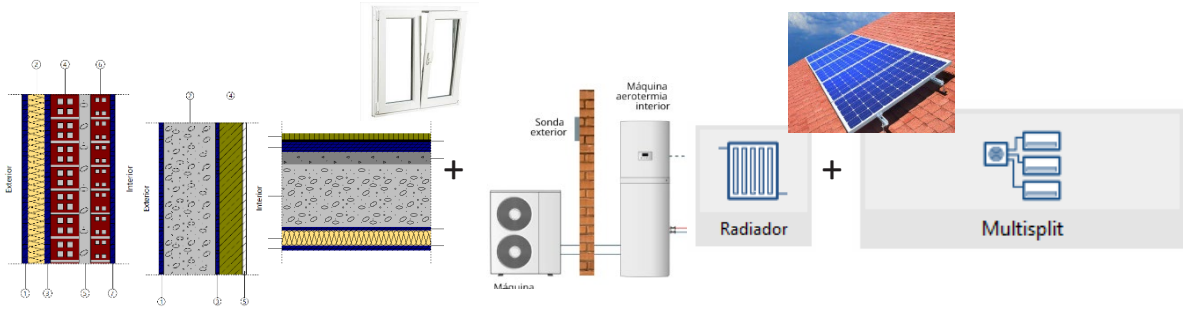
Characteristics of the Aerothermal system for heating and DHW:







- **Case 8 : Improvement 2 of the Initial situation case 2. Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + Cooling with direct expansion multi-split system + Photovoltaic panels.**



(Façade party wall roof) + Aerothermal heating system with radiators + Cooling multisplit direct expansion system.
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

Table 2: Summary of the cases studied. Initial situations and improvements

Initial situation of the house	House with impovement
Case 1: Initial situation 1: Envelope without isolation + H & AC direct expansion system + DHW with Electric boiler.	**Case 3:** Improvement 1 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas + H & AC direct expansion multi-split System + DHW heat pump
	Case 4: Improvement 2 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas +H & AC direct expansion multi-split System + DHW heat pump + Photovoltaic panels. (case 3+ PV panels)
	Case 5: Improvement 3 of the Initial situation case 1. Improved envelope 10 cm Insolation + PVC Double glazed windows with argon gas + H & AC direct expansion multi-split System + DHW heat pump + Photovoltaic panels. (Case 4 but with 10 cm of insulation layer in the enveloped)
	Case 6: Improvement 4 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas + H & AC and DHW Aerothermal with fan coil + Photovoltaic panels
Case 2: Initial situation 2: Envelope without isolation + Heating and DHW Sys: Gas Boiler & radiators + Cooling system: multisplit direct expansion system	**Case 7:** Improvement 1 of the Initial situation case 2. Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + Cooling with direct expansion multi-split system.
	Case 8: Improvement 2 of the Initial situation case 2. Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + Cooling with direct expansion multi-split system + Photovoltaic panels. (Case 7 + PV Panels)

3.8. Case Results. Energy Consumption and Energy rating of the existing building.

In this section and in the following one, the annual consumption of final energy, primary energy and non-renewable primary energy corresponding to the different technical services of the building are shown for the 2 initial situation of the building and for the 5 alternatives to improve its energy performance. The consumption of heating and cooling services includes the electricity consumption of the auxiliary equipment of the air conditioning systems.

In addition, the energy rating of the cases studied (2 initial situations and the 5 improvement alternatives) is also shown. This rating has been calculated following Spanish standards considering climate zone: B3

In order to clarify concepts, some definitions are introduced here:

Total primary energy consumption.

Total Primary Energy Consumption in the context of a building energy efficiency analysis refers to the total amount of energy from all sources (like electricity, gas, oil, or renewables) that is required to operate the building, including the energy used to produce and deliver that energy.

More specifically:

- **"Primary energy"** means the energy in its original, raw form—before it is converted into electricity or heat. For example, coal, natural gas, crude oil, or sunlight.
- This includes energy **used on-site** (like gas for heating) and **converted energy** (like electricity), but it also accounts for the **losses that occur during generation, transmission, and distribution**.

So, Total Primary Energy Consumption tells you how much raw energy is ultimately needed to run the building, giving a full picture of its environmental impact.

Primary energy consumption of non-renewable origin.

Primary energy consumption of non-renewable origin refers to the **total amount of non-renewable primary energy** used to operate a building, including:

- **Fossil fuels**: coal, natural gas, and oil
- **Nuclear energy**
- **Any other non-renewable energy sources**

This measurement includes:

- Energy **directly used on-site**, like natural gas for heating
- Energy **used indirectly**, such as electricity generated from coal or gas (including losses from generation and transmission)

Energy consumption at the point of consumption (final energy).

Energy consumption at the point of consumption, also known as **final energy consumption**, refers to the **amount of energy actually used by the building** for its various functions, such as:

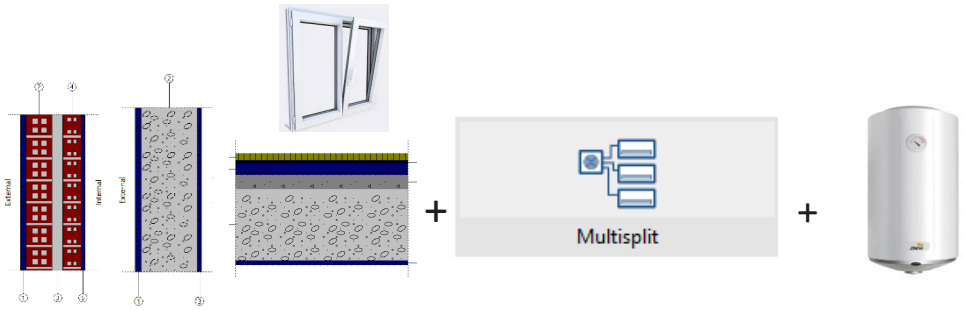
- **Heating**
- **Cooling**
- **Lighting**
- **Hot water**
- **Appliances and equipment**

This is the **energy delivered to the building** and **measured at the meter**, such as electricity bills or gas usage. It **does not include energy losses** that occurred during production, conversion, or transmission (which are included in *primary energy*).

In summary:

- **Final energy** = Energy used **inside the building**, as seen by the user.
- **Primary energy** = Final energy **plus upstream losses** (e.g. power plant efficiency, grid transmission losses).

- **Case 1: Initial situation 1: Envelope without isolation + H & AC direct expansion system + DHW with Electric boiler.**



(Façade party wall + roof)
(Single glass windows with aluminum frame. U=5.7 W/(m²·K))
Envelope without insolation + HVAC direct expansion system + DHW with Electric boiler

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	6509.13	55.93	8858.99	76.12	3356.51	28.84
Cooling	473.72	4.07	1121.75	9.64	925.65	7.95
DHW	7469.42	64.18	17687.61	151.99	14595.27	125.42
	14452.27	124.19	27668.47	237.75	18877.44	162.21
Requirements of the Spanish standard kWh/m²·year				<80.00 **NO!**	kWh/m²·year	<55.00 **NO!**

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
BUILDING (S_u = 116.38 m²)															
Energy demand	**Heating**	**1529.5**	**1108.3**	**909.5**	**486.1**	**253.7**	**--**	**--**	**--**	**--**	**48.1**	**640.7**	**1378.7**	**6354.6**	**54.6**
	Cooling	**--**	**--**	**--**	**--**	**--**	**180.7**	**488.1**	**539.1**	**211.4**	**--**	**--**	**--**	**1419.3**	**12.2**
	DHW	**244.3**	**220.7**	**240.1**	**227.6**	**226.8**	**211.2**	**209.8**	**205.6**	**207.2**	**223.1**	**228.2**	**244.3**	**2689.0**	**23.1**
	TOTAL	**1773.8**	**1329.0**	**1149.5**	**713.7**	**480.5**	**392.0**	**697.9**	**744.8**	**418.5**	**271.3**	**869.0**	**1623.0**	**10462.9**	**89.9**
Electricity	**Heating**	409.5	298.8	246.5	132.8	69.1	0.8	2.0	2.2	0.9	13.2	172.1	369.9	1717.8	14.8
	Cooling	3.1	2.3	1.8	1.0	0.5	59.8	157.9	174.4	68.9	0.1	1.2	2.8	473.7	4.1
	DHW	678.6	613.0	666.9	632.3	629.9	586.8	582.9	571.2	575.5	619.9	634.0	678.6	7469.4	64.2
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment	**Heating**	1155.6	835.4	684.4	365.0	189.9	--	--	--	--	36.0	483.1	1042.0	4791.4	41.2
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$C_{ef,total}$	**2246.8**	**1749.4**	**1599.6**	**1131.0**	**889.4**	**647.3**	**742.7**	**747.8**	**645.3**	**669.1**	**1290.4**	**2093.3**	**14452.3**	**124.2**

where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Case1. Initial situation 1.

Climatic zone (eq.)	B3	Use	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G 27,48 D	HEATING		DHW	
	Heating emissions [kgCO₂/m²·year]	A	DHW emissions [kgCO₂/m²·year]	C
	4.89		21.25	
	COOLING		LIGHTING	
Global emissions[kgCO₂/m²·year][1]	Cooling emissions [kgCO₂/m²·year]	A	Lighting emissions [kgCO₂/m²·year]	-
	1.35		-	

2.

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	kgCO₂/m²·year	kgCO₂·year
CO2 emissions from electricity consumption	27.48	3197.76
CO2 emissions from other fuels	0.00	0.00

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G 162,21 E	HEATING		DHW	
	Primary energy heating [kWh/m²·year]	A	DHW Primary energy [kWh/m²·year]	E
	28.84		125.42	
	COOLING		LIGHTING	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	A	Primary energy lighting [kWh/m²·year]	-
	7.95		-	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G 54,60 E	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G 12,20 B
Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

6.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **Case 2: Initial situation 2: Envelope without isolation + Gas Boiler & radiators for heating and DHW + Cooling system multi-split direct expansion system.**

(Façade party wall + roof)
(Single glass windows with aluminum frame. U=5.7 W/m²·K)

Envelope without insolation + Heating and DHW gas boiler and radiators + AC with direct expansion multisplit system.

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	7986.61	68.63	9631.15	82.76	9524.55	81.84
Cooling	529.43	4.55	1253.60	10.77	1034.46	8.89
DHW	2835.66	24.37	3388.63	29.12	3374.43	29.00
	11351.69	97.54	14273.38	122.65	13933.44	119.73
Requirements of the Spanish standard kWh/m²·year				<80.00 **NO!**	kWh/m²·year	<55.00 **NO!**

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
EDIFICIO (S_u = 116.38 m²)															
Energy demand	**Heating**	**1529.0**	**1107.9**	**909.1**	**485.9**	**253.6**	**--**	**--**	**--**	**--**	**48.1**	**640.5**	**1378.3**	**6352.3**	**54.6**
	Cooling	**--**	**--**	**--**	**--**	**--**	**180.7**	**488.1**	**539.1**	**211.4**	**--**	**--**	**--**	**1419.3**	**12.2**
	DHW	**208.6**	**188.4**	**204.4**	**193.1**	**191.0**	**176.7**	**174.1**	**169.9**	**172.6**	**187.4**	**193.7**	**208.6**	**2268.5**	**19.5**
	TOTAL	**1737.6**	**1296.3**	**1113.5**	**678.9**	**444.6**	**357.4**	**662.2**	**709.0**	**384.0**	**235.5**	**834.1**	**1586.9**	**10040.1**	**86.3**
Electricity	**Heating**	14.1	11.6	10.4	6.7	3.9	1.3	3.4	3.8	1.5	1.2	8.6	13.4	80.0	0.7
	Cooling	11.9	9.7	8.9	5.8	3.5	60.6	161.1	177.4	70.3	1.2	7.5	11.5	529.4	4.5
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Natural Gas	**Heating**	1899.5	1372.9	1126.1	600.0	312.9	--	--	--	--	58.6	791.3	1711.3	7872.5	67.6
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	260.7	235.5	255.4	241.3	238.8	220.9	217.6	212.4	215.8	234.3	242.1	260.7	2835.6	24.4
Environment	**Heating**	7.5	6.4	4.8	3.1	1.4	--	--	--	--	0.1	4.1	6.9	34.1	0.3
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$C_{ef,total}$	**2193.7**	**1636.1**	**1405.7**	**856.9**	**560.5**	**282.8**	**382.1**	**393.6**	**287.6**	**295.4**	**1053.5**	**2003.8**	**11351.7**	**97.5**

where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Case2. Initial situation 2.

Climatic zone (eq.)	B3	Use	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G **24,92 D**	**HEATING**		**DHW**	
	Heating emissions [kgCO₂/m²·year]	**A**	DHW emissions [kgCO₂/m²·year]	**C**
	17.28		**6.14**	
	COOLING		**LIGHTING**	
Global emissions[kgCO₂/m²·year][1]	Cooling emissions [kgCO₂/m²·year]	**A**	Lighting emissions [kgCO₂/m²·year]	**-**
2.	**1.51**		**-**	

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	kgCO₂/m²·year	kgCO₂·year
CO2 emissions from electricity consumption	1.73	201.71
CO2 emissions from other fuels	23.19	2698.47

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G **119,73 D**	**HEATING**		**DHW**	
	Primary energy heating [kWh/m²·year]	**A**	DHW Primary energy [kWh/m²·year]	**E**
	81.84		**29**	
	COOLING		**LIGHTING**	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	**A**	Primary energy lighting [kWh/m²·year]	**-**
	8.89		**-**	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G **54,58 E**	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G **12,20 B**
6. Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

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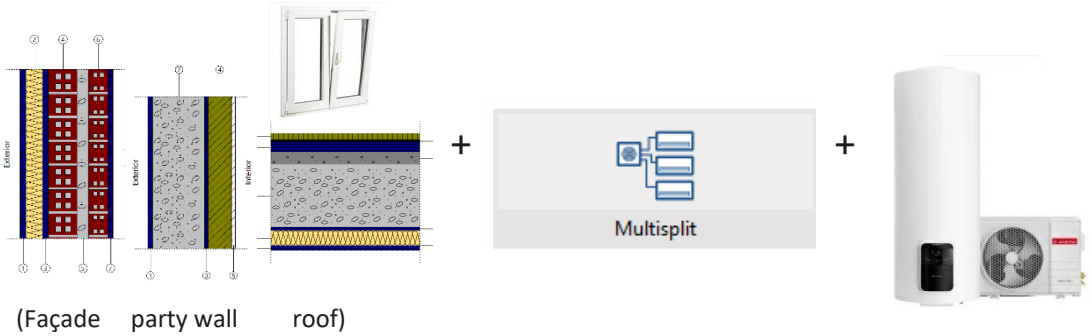
Spanish Case Study

Part II: Analysis of improvement measures

3.9. Case Results II. Energy Consumption and Energy rating of the alternatives to improve the building.

- **Case 3: Improvement 1 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas + H & AC direct expansion multi-split System + DHW heat pump.**



(Façade party wall roof)

(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	1092.34	9.39	1513.58	13.01	601.66	5.17
Cooling	380.28	3.27	900.52	7.74	743.06	6.38
DHW	2268.50	19.49	3137.72	26.96	1241.61	10.67
	3741.11	32.15	5551.83	47.71	2586.34	22.22
Requirements of the Spanish standard kWh/m²·year				<80.00 **OK!**	kWh/m²·year	<55.00 **OK!**

where:

S_u: *Living area included in the thermal envelope, m².*

EF: *Final energy consumed by the technical service at the point of consumption.*

EP_{tot}: *Total primary energy consumption.*

EP_{nren}: *Primary energy consumption of non-renewable origin.*

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
BUILDING (S_u = 116.38 m²)															
Energy demand	**Heating**	**338.9**	**226.1**	**173.1**	**21.0**	**12.1**	--	--	--	--	--	**23.8**	**270.0**	**1065.0**	**9.2**
	Cooling	--	--	--	--	--	**136.2**	**361.3**	**445.3**	**204.9**	--	--	--	**1147.7**	**9.9**
	DHW	**208.6**	**188.4**	**204.4**	**193.1**	**191.0**	**176.7**	**174.1**	**169.9**	**172.6**	**187.4**	**193.7**	**208.6**	**2268.5**	**19.5**
	TOTAL	**547.5**	**414.5**	**377.4**	**214.1**	**203.2**	**312.9**	**535.4**	**615.2**	**377.5**	**187.4**	**217.4**	**478.6**	**4481.1**	**38.5**
Electricity	**Heating**	96.1	64.3	49.4	6.2	3.5	0.6	1.6	1.9	0.9	--	6.8	76.7	307.9	2.6
	Cooling	0.7	0.5	0.4	0.0	0.0	45.0	119.5	145.8	67.9	--	0.0	0.6	380.3	3.3
	DHW	58.4	52.8	57.2	54.1	53.5	49.5	48.8	47.6	48.4	52.5	54.3	58.4	635.4	5.5
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment	**Heating**	249.9	166.6	127.2	15.3	8.9	--	--	--	--	--	17.5	199.0	784.4	6.7
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	

	Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	(kWh/m²·año)
DHW	150.2	135.6	147.1	139.0	137.5	127.2	125.3	122.3	124.3	134.9	139.4	150.2	1633.1	14.0
$C_{ef,total}$	**555.3**	**419.8**	**381.4**	**214.6**	**203.5**	**222.3**	**295.1**	**317.6**	**241.4**	**187.4**	**218.0**	**484.8**	**3741.1**	**32.1**

where:

S_u: *Living area included in the thermal envelope, m².*

$C_{ef,total}$: *Energy consumption at the point of consumption (final energy), kWh/m²·year.*

Energy rating of the building: Case 3. Improvement 1 of case 1.

Climatic zone (eq.)	B3	**Use**	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G 3,77 A	**HEATING**		**DHW**	
	Heating emissions [$kgCO_2/m^2$·year]	**A**	DHW emissions [$kgCO_2/m^2$·year]	**C**
	0.88		**1.81**	
	COOLING		**LIGHTING**	
Global emissions[$kgCO_2/m^2$·year][1]	Cooling emissions [$kgCO_2/m^2$·year]	**A**	Lighting emissions [$kgCO_2/m^2$·year]	**-**
2.	**1.08**		**-**	

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	$kgCO_2/m^2$·year	**$kgCO_2$·year**
CO2 emissions from electricity consumption	3.76	438.13
CO2 emissions from other fuels	0.00	0.00

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G 22,22 A	**HEATING**		**DHW**	
	Primary energy heating [kWh/m²·year]	**A**	DHW Primary energy [kWh/m²·year]	**E**
	5.17		**10.67**	
	COOLING		**LIGHTING**	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	**A**	Primary energy lighting [kWh/m²·year]	**-**
	6.39		**-**	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

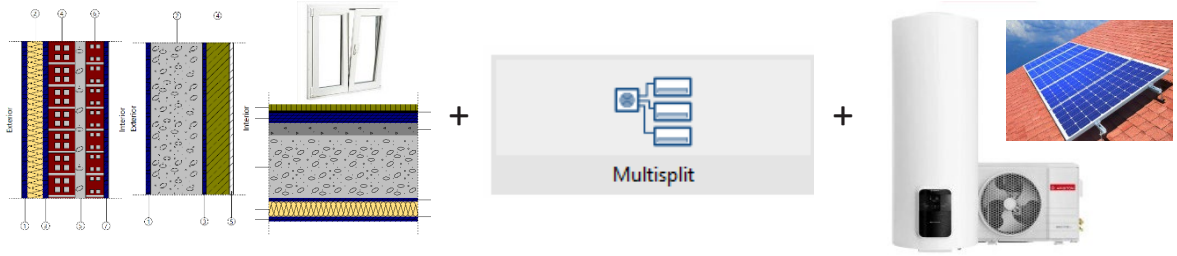
The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G 9,15 A	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G 9,86 A
6. Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **Case 4: Improvement 2 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas +H & AC direct expansion multi-split System + DHW heat pump + Photovoltaic panels. (Case 3+ Photovoltaic panels)**



(Façade party wall roof)
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	1092.34	9.39	1092.30	9.39	--	--
Cooling	380.28	3.27	380.32	3.27	--	--
DHW	2268.50	19.49	2268.51	19.49	--	--
	3741.11	32.15	3741.13	32.15	--	--
Requirements of the Spanish standard kWh/m²·year				<80.00 **OK!**	kWh/m²·year	<55.00 **OK!**

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
BUILDING (S_u = 116.38 m²)															
Energy demand	**Heating**	**338.9**	**226.1**	**173.1**	**21.0**	**12.1**	**--**	**--**	**--**	**--**	**--**	**23.8**	**270.0**	**1065.0**	**9.2**
	Cooling	**--**	**--**	**--**	**--**	**--**	**136.2**	**361.3**	**445.3**	**204.9**	**--**	**--**	**--**	**1147.7**	**9.9**
	DHW	**208.6**	**188.4**	**204.4**	**193.1**	**191.0**	**176.7**	**174.1**	**169.9**	**172.6**	**187.4**	**193.7**	**208.6**	**2268.5**	**19.5**
	TOTAL	**547.5**	**414.5**	**377.4**	**214.1**	**203.2**	**312.9**	**535.4**	**615.2**	**377.5**	**187.4**	**217.4**	**478.6**	**4481.1**	**38.5**
Electricity	**Heating**	96.1	64.3	49.4	6.2	3.5	0.6	1.6	1.9	0.9	--	6.8	76.7	307.9	2.6
	Cooling	0.7	0.5	0.4	0.0	0.0	45.0	119.5	145.8	67.9	--	0.0	0.6	380.3	3.3
	DHW	58.4	52.8	57.2	54.1	53.5	49.5	48.8	47.6	48.4	52.5	54.3	58.4	635.4	5.5
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment	**Heating**	249.9	166.6	127.2	15.3	8.9	--	--	--	--	--	17.5	199.0	784.4	6.7
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	150.2	135.6	147.1	139.0	137.5	127.2	125.3	122.3	124.3	134.9	139.4	150.2	1633.1	14.0
	$C_{ef,total}$	**555.3**	**419.8**	**381.4**	**214.6**	**203.5**	**222.3**	**295.1**	**317.6**	**241.4**	**187.4**	**218.0**	**484.8**	**3741.1**	**32.1**

where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Case 4. Improvement 2 of case 1.

Climatic zone (eq.)	B3	**Use**	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G 0,00 A	**HEATING**		**DHW**	
	Heating emissions [kgCO₂/m²·year]	**A**	DHW emissions [kgCO₂/m²·year]	**C**
	0		**0**	
	COOLING		**LIGHTING**	
Global emissions[kgCO₂/m²·year][1]	Cooling emissions [kgCO₂/m²·year]	**A**	Lighting emissions [kgCO₂/m²·year]	**-**
	0		**-**	

2.

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	kgCO₂/m²·year	**kgCO₂·year**
CO2 emissions from electricity consumption	0.00	0.00
CO2 emissions from other fuels	0.00	0.00

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G 0,00 A	**HEATING**		**DHW**	
	Primary energy heating [kWh/m²·year]	**A**	DHW Primary energy [kWh/m²·year]	**E**
	0		**0**	
	COOLING		**LIGHTING**	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	**A**	Primary energy lighting [kWh/m²·year]	**-**
	0		**-**	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

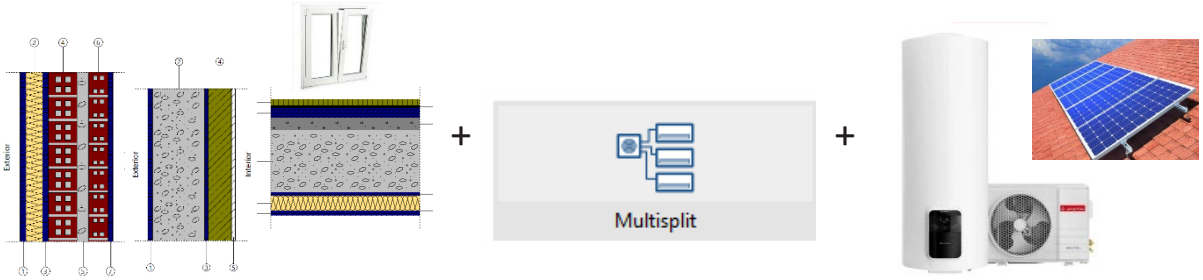
5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G 9,15 A	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G 9,86 A
Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

6.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **Case 5: Improvement 3 of the Initial situation case 1. Improved envelope 10 cm Insolation + PVC Double glazed windows with argon gas + H & AC direct expansion multisplit System + DHW heat pump + Photovoltaic panels. (Case 4 but with 10 cm of insulation layer in the enveloped) .**



(Façade party wall roof)
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)
(Case 4 but with 10 cm of insulation layer in the enveloped) .

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	748.17	6.43	748.18	6.43	--	--
Cooling	365.77	3.14	365.77	3.14	--	--
DHW	2268.50	19.49	2268.51	19.49	--	--
	3382.44	29.06	3382.46	29.07	--	--
Requirements of the Spanish standard kWh/m²·year				<80.00 **OK!**	kWh/m²·year	<55.00 **OK!**

where:

S_u: *Living area included in the thermal envelope, m².*
EF: *Final energy consumed by the technical service at the point of consumption.*
EP_{tot}: *Total primary energy consumption.*
EP_{nren}: *Primary energy consumption of non-renewable origin.*

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
BUILDING (S_u = 116.38 m²)															
Energy demand	**Heating**	**245.4**	**162.3**	**123.8**	**6.4**	**3.5**	**--**	**--**	**--**	**--**	**--**	**4.8**	**181.4**	**727.7**	**6.3**
	Cooling	**--**	**--**	**--**	**--**	**--**	**130.5**	**343.7**	**427.4**	**202.6**	**--**	**--**	**--**	**1104.3**	**9.5**
	DHW	**208.6**	**188.4**	**204.4**	**193.1**	**191.0**	**176.7**	**174.1**	**169.9**	**172.6**	**187.4**	**193.7**	**208.6**	**2268.5**	**19.5**
	TOTAL	**454.0**	**350.7**	**328.2**	**199.5**	**194.5**	**307.2**	**517.9**	**597.3**	**375.2**	**187.4**	**198.5**	**390.0**	**4100.5**	**35.2**
Electricity	**Heating**	70.1	46.4	35.7	1.9	1.0	0.6	1.5	1.8	0.9	--	1.4	51.9	213.4	1.8
	Cooling	0.5	0.3	0.3	0.0	0.0	42.7	114.2	140.2	67.1	--	0.0	0.4	365.8	3.1
	DHW	78.4	70.8	76.8	72.6	71.8	66.4	65.5	63.9	64.9	70.5	72.8	78.4	852.8	7.3
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment	**Heating**	180.6	119.4	90.8	4.6	2.6	--	--	--	--	--	3.5	133.4	534.8	4.6
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	130.2	117.6	127.5	120.5	119.2	110.3	108.7	106.0	107.7	117.0	120.9	130.2	1415.7 12.2	
	$C_{ef,total}$	**459.8**	**354.6**	**331.0**	**199.6**	**194.6**	**219.9**	**289.9**	**311.9**	**240.7**	**187.4**	**198.6**	**394.3**	**3382.4**	**29.1**

where:

S_u: *Living area included in the thermal envelope, m².*
$C_{ef,total}$: *Energy consumption at the point of consumption (final energy), kWh/m²·year.*

Energy rating of the building: Case 5. Improvement 3 of case 1.

Climatic zone (eq.)	B3	**Use**	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR		PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G 0,00 A		**HEATING**		**DHW**	
		Heating emissions [kgCO₂/m²·year]	**A**	DHW emissions [kgCO₂/m²·year]	**C**
		0		**0**	
		COOLING		**LIGHTING**	
Global emissions[kgCO₂/m²·year][1]		Cooling emissions [kgCO₂/m²·year]	**A**	Lighting emissions [kgCO₂/m²·year]	**-**
		0		**-**	

2.

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	kgCO₂/m²·year	**kgCO₂·year**
CO2 emissions from electricity consumption	0.00	0.00
CO2 emissions from other fuels	0.00	0.00

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR		PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G 0,00 A		**HEATING**		**DHW**	
		Primary energy heating [kWh/m²·year]	**A**	DHW Primary energy [kWh/m²·year]	**E**
		0		**0**	
		COOLING		**LIGHTING**	
Global consumption of non-renewable primary energy[kWh/m²·year][1]		Primary energy cooling [kWh/m²·year]	**A**	Primary energy lighting [kWh/m²·year]	**-**
		0		**-**	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

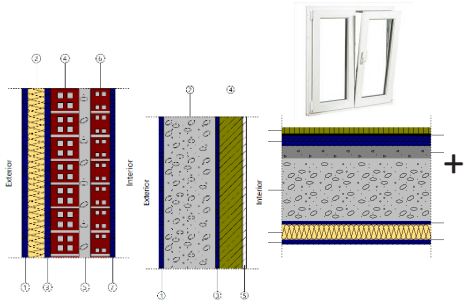
The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

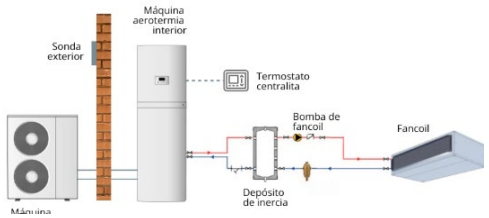
5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G 6,25 A	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G 9,49 A
6. Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **Case 6: Improvement 4 of the Initial situation case 1. Improved envelope 6 cm Insolation + PVC Double glazed windows with argon gas + H & AC and DHW Aerothermal with fan coils + Photovoltaic panels**





(Façade party wall roof) Aerothermal system with fan coils
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	1065.16	9.15	1065.19	9.15	--	--
Cooling	258.28	2.22	258.24	2.22	--	--
DHW	2268.52	19.49	2268.51	19.49	--	--
	3591.95	30.87	3591.94	30.86	--	--
Requirements of the Spanish standard kWh/m²·year				<80.00 **OK!**	kWh/m²·year	<55.00 **OK!**

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
BUILDING (S_u = 116.38 m²)															
Energy demand	**Heating**	**338.9**	**226.1**	**173.1**	**21.0**	**12.1**	**--**	**--**	**--**	**--**	**--**	**23.8**	**270.0**	**1065.1**	**9.2**
	Cooling	**--**	**--**	**--**	**--**	**--**	**136.2**	**361.3**	**445.3**	**204.9**	**--**	**--**	**--**	**1147.6**	**9.9**
	DHW	**208.6**	**188.4**	**204.4**	**193.1**	**191.0**	**176.7**	**174.1**	**169.9**	**172.6**	**187.4**	**193.7**	**208.6**	**2268.5**	**19.5**
	TOTAL	**547.5**	**414.5**	**377.5**	**214.1**	**203.2**	**312.9**	**535.4**	**615.2**	**377.5**	**187.4**	**217.5**	**478.6**	**4481.2**	**38.5**
Electricity	**Heating**	86.2	57.0	43.8	5.4	2.9	0.4	1.1	1.3	0.6	--	6.0	68.1	272.8	2.3
	Cooling	0.7	0.5	0.4	0.1	0.0	26.5	83.0	97.4	49.0	--	0.1	0.6	258.3	2.2
	DHW	47.3	42.7	46.3	43.8	43.3	40.1	39.5	38.5	39.1	42.5	43.9	47.3	514.4	4.4
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment	**Heating**	251.7	168.4	128.7	15.6	9.2	--	--	--	--	--	17.7	201.1	792.3	6.8
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	161.3	145.7	158.0	149.3	147.7	136.6	134.6	131.4	133.5	144.9	149.8	161.3	1754.1	
	$C_{ef,total}$	**547.2**	**414.3**	**377.2**	**214.1**	**203.2**	**203.6**	**258.2**	**268.6**	**222.2**	**187.4**	**217.5**	**478.4**	**3592.0**	**30.9**

where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Case 6. Improvement 4 of case 1.

Climatic zone (eq.)	B3	**Use**	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR		PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G 0,00 A		**HEATING**		**DHW**	
		Heating emissions [kgCO₂/m²·year]	**A**	DHW emissions [kgCO₂/m²·year]	**C**
		0		**0**	
		COOLING		**LIGHTING**	
Global emissions[kgCO₂/m²·year][1]		Cooling emissions [kgCO₂/m²·year]	**A**	Lighting emissions [kgCO₂/m²·year]	**-**
		0		**-**	

2.

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	kgCO₂/m²·year	**kgCO₂·year**
CO2 emissions from electricity consumption	0.00	0.00
CO2 emissions from other fuels	0.00	0.00

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR		PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G 0,00 A		**HEATING**		**DHW**	
		Primary energy heating [kWh/m²·year]	**A**	DHW Primary energy [kWh/m²·year]	**E**
		0		**0**	
		COOLING		**LIGHTING**	
Global consumption of non-renewable primary energy[kWh/m²·year][1]		Primary energy cooling [kWh/m²·year]	**A**	Primary energy lighting [kWh/m²·year]	**-**
		0		**-**	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

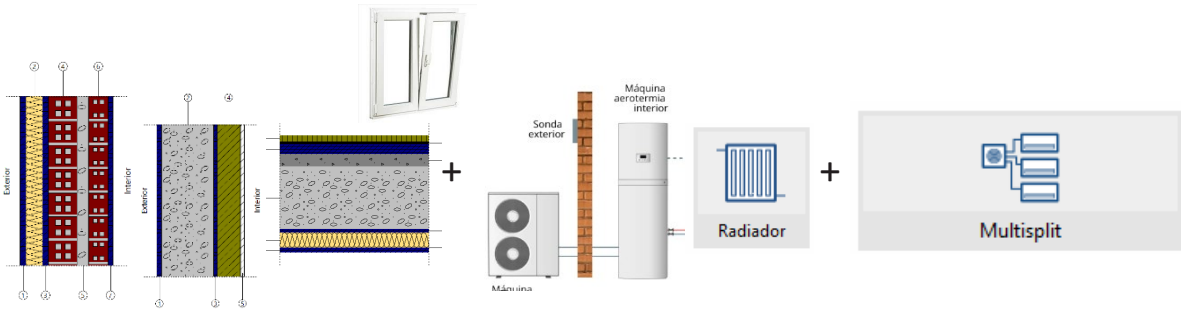
5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G 9,15 A	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G 9,86 A
Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

6.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **Case 7: Improvement 1 of the Initial situation case 2. Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + Cooling with direct expansion multi-split system.**



(Façade party wall roof) + Aerothermal heating system with radiators + AC direct expansion system.
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	1074.53	9.23	1428.16	12.27	505.19	4.34
Cooling	308.59	2.65	730.72	6.28	602.94	5.18
DHW	2268.52	19.49	2969.10	25.51	1000.60	8.60
	3651.64	31.38	5127.98	44.06	2108.73	18.12
Requirements of the Spanish standard kWh/m²·year				<80.00 **OK!**	kWh/m²·year	<55.00 **OK!**

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
BUILDING (S_u = 116.38 m²)															
Energy demand	**Heating**	**339.0**	**226.2**	**173.1**	**21.2**	**12.2**	**--**	**--**	**--**	**--**	**--**	**24.0**	**270.1**	**1065.8**	**9.2**
	Cooling	**--**	**--**	**--**	**--**	**--**	**136.5**	**361.7**	**445.6**	**205.1**	**--**	**--**	**--**	**1148.8**	**9.9**
	DHW	**208.6**	**188.4**	**204.4**	**193.1**	**191.0**	**176.7**	**174.1**	**169.9**	**172.6**	**187.4**	**193.7**	**208.6**	**2268.5**	**19.5**
	TOTAL	**547.6**	**414.6**	**377.5**	**214.3**	**203.2**	**313.2**	**535.8**	**615.5**	**377.7**	**187.4**	**217.7**	**478.7**	**4483.2**	**38.5**
Electricity	**Heating**	79.9	52.9	40.5	5.0	2.8	1.0	2.7	3.2	1.6	--	5.6	63.2	258.5	2.2
	Cooling	0.0	0.0	0.0	0.0	--	36.7	97.3	119.0	55.6	--	0.0	0.0	308.6	2.7
	DHW	47.1	42.5	46.1	43.6	43.1	39.9	39.3	38.4	39.0	42.3	43.7	47.1	512.1	4.4
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment	**Heating**	259.2	173.3	132.6	16.2	9.4	--	--	--	--	--	18.3	206.9	816.0	7.0
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	161.5	145.9	158.2	149.5	147.9	136.8	134.8	131.6	133.7	145.1	150.0	161.5	1756.4 15.1	
	$C_{ef,total}$	**547.7**	**414.7**	**377.6**	**214.3**	**203.2**	**214.4**	**274.0**	**292.1**	**229.8**	**187.4**	**217.7**	**478.7**	**3651.6**	**31.4**

where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Case 7. Improvement 1 of case 2.

Climatic zone (eq.)	B3	Use	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G 3,07 A	HEATING		DHW	
	Heating emissions [kgCO₂/m²·year]	A	DHW emissions [kgCO₂/m²·year]	C
	0.74		1.46	
	COOLING		LIGHTING	
Global emissions[kgCO₂/m²·year][1]	Cooling emissions [kgCO₂/m²·year]	A	Lighting emissions [kgCO₂/m²·year]	-
	0.88		-	

2.

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	kgCO₂/m²·year	kgCO₂·year
CO2 emissions from electricity consumption	3.07	357.21
CO2 emissions from other fuels	0.00	0.00

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G 18,12 A	HEATING		DHW	
	Primary energy heating [kWh/m²·year]	A	DHW Primary energy [kWh/m²·year]	E
	4.34		8.6	
	COOLING		LIGHTING	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	A	Primary energy lighting [kWh/m²·year]	-
	5.18		-	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

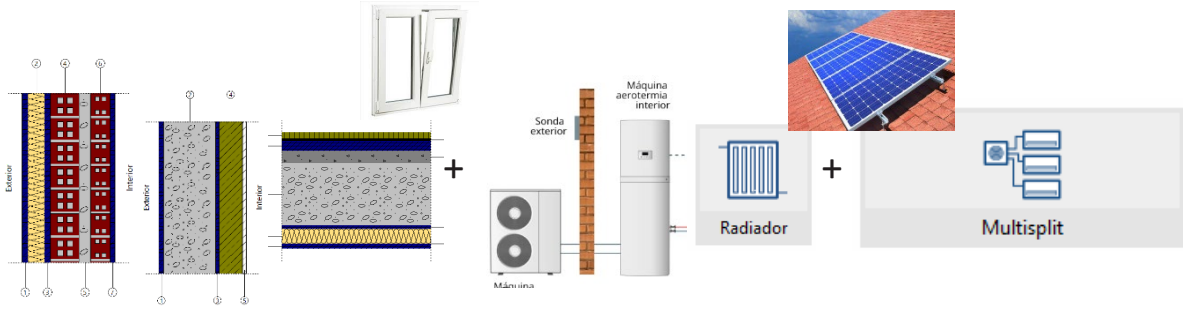
5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G 9,16 A	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G 9,87 A
Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

6.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **Case 8 : Improvement 2 of the Initial situation case 2. Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + Cooling with direct expansion multi-split system + Photovoltaic panels.**



(Façade party wall roof) + Aerothermal heating system with radiators + Cooling multisplit direct expansion system.
(PVC Double glazed windows with argon gas. U= 1.7 W/m²·K)
(Case 7+ PV panels)

Energy consumption of the building's technical services

BUILDING (S_u = 116.38 m²)

Technical Services	EF		EP_{tot}		EP_{nren}	
	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)	(kWh/year)	(kWh/m²·year)
Heating	1074.53	9.23	1074.50	9.23	--	--
Cooling	308.59	2.65	308.63	2.65	--	--
DHW	2268.52	19.49	2268.51	19.49	--	--
	3651.64	31.38	3651.64	31.38	--	--
Requirements of the Spanish standard kWh/m²·year				<80.00 **OK!**	kWh/m²·year	<55.00 **OK!**

where:

S_u: Living area included in the thermal envelope, m².
EF: Final energy consumed by the technical service at the point of consumption.
EP_{tot}: Total primary energy consumption.
EP_{nren}: Primary energy consumption of non-renewable origin.

Final energy consumption of the building. Monthly results.

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m²·año)
BUILDING (S_u = 116.38 m²)															
Energy demand	**Heating**	**339.0**	**226.2**	**173.1**	**21.2**	**12.2**	**--**	**--**	**--**	**--**	**--**	**24.0**	**270.1**	**1065.8**	**9.2**
	Cooling	**--**	**--**	**--**	**--**	**--**	**136.5**	**361.7**	**445.6**	**205.1**	**--**	**--**	**--**	**1148.8**	**9.9**
	DHW	**208.6**	**188.4**	**204.4**	**193.1**	**191.0**	**176.7**	**174.1**	**169.9**	**172.6**	**187.4**	**193.7**	**208.6**	**2268.5**	**19.5**
	TOTAL	**547.6**	**414.6**	**377.5**	**214.3**	**203.2**	**313.2**	**535.8**	**615.5**	**377.7**	**187.4**	**217.7**	**478.7**	**4483.2**	**38.5**
Electricity	**Heating**	79.9	52.9	40.5	5.0	2.8	1.0	2.7	3.2	1.6	--	5.6	63.2	258.5	2.2
	Cooling	0.0	0.0	0.0	0.0	--	36.7	97.3	119.0	55.6	--	0.0	0.0	308.6	2.7
	DHW	47.1	42.5	46.1	43.6	43.1	39.9	39.3	38.4	39.0	42.3	43.7	47.1	512.1	4.4
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Humidity control	--	--	--	--	--	--	--	--	--	--	--	--	--	
	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	
Environment	**Heating**	259.2	173.3	132.6	16.2	9.4	--	--	--	--	--	18.3	206.9	816.0	7.0
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	
	DHW	161.5	145.9	158.2	149.5	147.9	136.8	134.8	131.6	133.7	145.1	150.0	161.5	1756.4	15.1
	$C_{ef,total}$	**547.7**	**414.7**	**377.6**	**214.3**	**203.2**	**214.4**	**274.0**	**292.1**	**229.8**	**187.4**	**217.7**	**478.7**	**3651.6**	**31.4**

where:

S_u: Living area included in the thermal envelope, m².
$C_{ef,total}$: Energy consumption at the point of consumption (final energy), kWh/m²·year.

Energy rating of the building: Case 8. Improvement 2 of case 2.

Climatic zone (eq.)	B3	Use	Private residential

ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 5,5 A 5,5-10,4 B 10,4-17,5 C 17,5-28,1 D 28,1-54,9 E 54,9-64,3 F ≥ 64,3 G 0,00 A	HEATING		DHW	
	Heating emissions [kgCO₂/m²·year]	A	DHW emissions [kgCO₂/m²·year]	C
	0		0	
	COOLING		LIGHTING	
Global emissions[kgCO₂/m²·year][1]	Cooling emissions [kgCO₂/m²·year]	A	Lighting emissions [kgCO₂/m²·year]	-
	0		-	

2.

The overall rating of the building is expressed in terms of carbon dioxide released into the atmosphere as a result of its energy consumption.

	kgCO₂/m²·year	kgCO₂·year
CO2 emissions from electricity consumption	0.00	0.00
CO2 emissions from other fuels	0.00	0.00

ENERGY RATING OF THE BUILDING IN NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

3.

Non-renewable primary energy refers to the energy consumed by the building from non-renewable sources that has not undergone any conversion or transformation process.

4.

GLOBAL INDICATOR	PARTIAL INDICATORS			
< 23,8 A 23,8-45,1 B 45,1-76,2 C 76,2-122,1 D 122,1-229,6 E 229,6-268,6 F ≥ 268,6 G 0,00 A	HEATING		DHW	
	Primary energy heating [kWh/m²·year]	A	DHW Primary energy [kWh/m²·year]	E
	0		0	
	COOLING		LIGHTING	
Global consumption of non-renewable primary energy[kWh/m²·year][1]	Primary energy cooling [kWh/m²·year]	A	Primary energy lighting [kWh/m²·year]	-
	0		-	

PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

5.

HEATING DEMAND	COOLING DEMAND
< 9,7 A 9,7-18,4 B 18,4-31,1 C 31,1-49,9 D 49,9-83,6 E 83,6-102,8 F ≥ 102,8 G 9,16 A	< 10,0 A 10,0-14,3 B 14,3-20,4 C 20,4-29,7 D 29,7-36,7 E 36,7-45,1 F ≥ 45,1 G 9,87 A
Heating demand[kWh/m²·year]	Cooling demand[kWh/m²·year]

6.

1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

3.10. Analysis of Results. Emissions, Energy Consumption and Energy rating of the cases

Comparison of results

Final energy consumption (kWh/m2·year). Part I

Technical Services	Case 1 Initial situation 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+Imp 3	Case 5 Imp 6+Imp 2+ Imp 3	Case 6 Imp 1+ Imp 3+ Imp 4
Heating	55.93	9.39	9.39	6.43	9.15
Cooling	4.07	3.27	3.27	3.14	2.22
DHW	64.18	19.49	19.49	19.49	19.49
	124.19	32.15	32.15	29.06	30.87

Legend

BIS - Building initial situation

Imp 1- Improvement 1: Improved thermal envelope (6 cm isolation layer) + double glassed windows

Imp 2- Improvement 2: DHW heat pump

Imp 3- Improvement 3: Photovoltaic panels

Imp 4 - Improvement 4: Aerothermal Heating and Cooling system with Fancoils

Imp 5 - Improvement 5: Aerothermal heating and DHW system (for radiators)

Imp 6 - Improvement 6: Improved thermal envelope with 10 cm of isolation layer + double glassed windows

Final energy consumption (kWh/m2·year). Part II

Technical Services	Case 2 Initial situation 2	Case 7 Imp 1+Imp 5	Case 8 Imp 1+Imp 3+Imp 5
Heating	68.63	9.23	9.23
Cooling	4.55	2.65	2.65
DHW	24.37	19.49	19.49
	97.54	31.38	31.38

Total primary energy consumption (kWh/m2·year) Part I

Technical Services	Case 1 Initial situation 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+Imp 3	Case 5 Imp 6+Imp 2+ Imp 3	Case 6 Imp 1+ Imp 3+ Imp 4
Heating	76.12	13.01	9.39	6.43	9.15
Cooling	9.64	7.74	3.27	3.14	2.22
DHW	151.99	26.96	19.49	19.49	19.49
	237.75	47.71	32.15	29.07	30.86

Legend

BIS - Building initial situation

Imp 1- Improvement 1: Improved thermal envelope (6 cm isolation layer) + double glassed windows

Imp 2- Improvement 2: DHW heat pump

Imp 3- Improvement 3: Photovoltaic panels

Imp 4 - Improvement 4: Aerothermal Heating and Cooling system with Fancoils

Imp 5 - Improvement 5: Aerothermal heating and DHW system (for radiators)

Imp 6 - Improvement 6: Improved thermal envelope with 10 cm of isolation layer + double glassed windows

Total primary energy consumption (kWh/m2·year) Part II

Technical Services	Case 2 Initial situation 2	Case 7 Imp 1+Imp 5	Case 8 Imp 1+Imp 3+Imp 5
Heating	82.76	12.27	9.23
Cooling	10.77	6.28	2.65
DHW	29.12	25.51	19.49
	122.65	44.06	31.38

Primary energy consumption of non-renewable origin (kWh/m2·year) Part I

Technical Services	Case 1 Initial situation 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+Imp 3	Case 5 Imp 6+Imp 2+ Imp 3	Case 6 Imp 1+ Imp 3+ Imp 4
Heating	28.84	5.17	0.00	0.00	0.00
Cooling	7.95	6.38	0.00	0.00	0.00
DHW	125.42	10.67	0.00	0.00	0.00
	162.21	22.22	0.00	0.00	0.00
Energy rating	**E**	**A**	**A**	**A**	**A**

Legend

BIS - Building initial situation

Imp 1- Improvement 1: Improved thermal envelope (6 cm isolation layer) + double glassed windows

Imp 2- Improvement 2: DHW heat pump

Imp 3- Improvement 3: Photovoltaic panels

Imp 4 - Improvement 4: Aerothermal Heating and Cooling system with Fancoils

Imp 5 - Improvement 5: Aerothermal heating and DHW system (for radiators)

Imp 6 - Improvement 6: Improved thermal envelope with 10 cm of isolation layer + double glassed windows

Primary energy consumption of non-renewable origin (kWh/m2·year) Part II

Technical Services	Case 2 Initial situation 2	Case 7 Imp 1+Imp 5	Case 8 Imp 1+Imp 3+Imp 5
Heating	81.84	4.34	0.00
Cooling	8.89	5.18	0.00
DHW	29.00	8.60	0.00
	119.73	18.12	0.00
Energy rating	**D**	**A**	**A**

Building Emissions (kgCO2/m2·year) Part I

Technical Services	Case 1 Initial situation 1	Case 3 Imp 1+Imp 2	Case 4 Imp 1+Imp 2+Imp 3	Case 5 Imp 6+Imp 2+ Imp 3	Case 6 Imp 1+ Imp 3+ Imp 4
CO2 from electricity	27.48	3.76	0.00	0.00	0.00
CO2 from other fuels	0.00	0.00	0.00	0.00	0.00
	27.48	3.76	0.00	0.00	0.00
Energy rating	**D**	**A**	**A**	**A**	**A**

Legend

BIS - Building initial situation

Imp 1- Improvement 1: Improved thermal envelope (6 cm isolation layer) + double glassed windows

Imp 2- Improvement 2: DHW heat pump

Imp 3- Improvement 3: Photovoltaic panels

Imp 4 - Improvement 4: Aerothermal Heating and Cooling system with Fancoils

Imp 5 - Improvement 5: Aerothermal heating and DHW system (for radiators)

Imp 6 - Improvement 6: Improved thermal envelope with 10 cm of isolation layer + double glassed windows

Building Emissions (kgCO2/m2·year) Part II

Technical Services	Case 2 Initial situation 2	Case 7 Imp 1+Imp 5	Case 8 Imp 1+Imp 3+Imp 5
CO2 from electricity	1.73	3.07	0.00
CO2 from other fuels	23.19	0.00	0.00
	24.92	3.07	0.00
Energy rating	**D**	**A**	**A**

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Spanish Case Study

Part III: Cost-benefit study of energy efficiency measures

3.11. Budget of the improvement alternatives

Improvement 1: Improved thermal envelope (6 cm mineral wool) + double glassed windows

- Description of the price of the **6 cm insulation system of the building facades for the exterior**:

Item	Cost (€ / m²)
Rock wool insulation (6 cm)	€20
Adhesive, anchors, mesh, profiles	€18
Plaster finish (multi-layer)	€12
Labor (installation)	€25
Scaffolding & safety (Single family house)	€9
Waste management and final cleaning	€2
Total Estimated Cost (Installed)	**86 €/ m²**

- Budget – **Interior Insulation on Party Walls, Roof or ground floor slab with Drywall System**

No.	Item	Description	Unit	Max. Price €/m²
1	Surface Preparation	Cleaning and preparing the existing wall or roof surface	m²	4,00
2	Rock Wool Insulation (6 cm)	Supply and installation of 60 mm rock wool panels between metal studs	m²	10,00
3	Metal Stud Framing	Installation of galvanized steel studs and tracks	m²	8,00
4	Drywall Cladding (Plasterboard)	Installation of 12.5 mm standard gypsum board over frame	m²	9,00
5	Joint Finishing and Surface Prep	Taping, joint compound, sanding	m²	5,00
6	Labor (if not included above)	General skilled labor for installation tasks	m²	12,00
7	Waste Disposal and Site Cleaning	Removal of debris and final worksite cleanup	m²	2,00
			Total (€/m²)	**50,00**

- Description of the **new windows** to be installed in the building.
  - Glazing: Double glazing (2 panes)
  - Coating: Low-emissivity (Low-E) on at least one pane
  - Gas fill: Argon gas between panes (for thermal insulation)
  - Frame: uPVC with thermal break

- Installation: Retrofit in existing wall opening (including sealing, trim, disposal of old window)

Improvement 1 budget:

Improvement 1: Thermal envelop isolation (6 cm mineral wool) and new windows

Unit	Description	n.	measurement	price €	amount €
m2	6 cm mineral wool isolation layer in facades with plaster finish installed	1	93,88	86,00 €	8.073,68 €
m2	6 cm mineral wool isolation layer in party wall, roof and slabs (interior drywall system)	1	161,49	50,00 €	8.074,50 €
m2	Low emissive double-glazed PVC windows with argon gas (U= 1.7 W/m²·K)	1	11,32	270,00 €	3.056,40 €
ud	Replacing an exterior door in a duplex in Ceutí (Spain), with a thermal transmittance (U-value) of 1.7 W/m²·K, including removal of the old door and full installation.	1	1	1.200,00 €	1.200,00 €
				Total	**20.404,58 €**

Improvement 2: Replacement of Electric Water Heater with DHW Heat Pump (1.5 kW, 200 L)

No.	Item	Description	Unit	Price (€)
1	Supply of DHW Heat Pump Unit	Air-source heat pump for domestic hot water, 1.5 kW, 200 L tank (COP ~3.0)	unit	2.050,00 €
2	Removal of Existing Electric Heater	Safe disconnection and disposal of the old electric water heater	unit	80,00 €
3	Installation of Heat Pump	Plumbing, mounting, electrical connection, and integration	unit	500,00 €
4	Accessories and Installation Materials	Pipes, fittings, valves, insulation, brackets, fasteners	unit	150,00 €
5	Electrical Circuit Adaptation	Circuit breaker upgrade and safety adaptation (if needed)	unit	100,00 €
6	System Start-Up and Testing	Commissioning, functional testing, user instructions	unit	70,00 €
			Total	**2.950,00 €**

Improvement 3: 4-Panel PV Installation (1.94 kWp, Flat Roof, Ceutí)

Technical Specifications of the Photovoltaic panel system:

Location: Ceutí (Spain)
Building: Single family house
System Specifications:

- Number of Panels of glass silicon: 4 (3 m2 each panel)
- Panel Capacity: 480 W each
- Total Capacity: 1.94 kWp

No.	Item	Description	Unit	Unit Price (€)	Quantity	Subtotal (€)
1	Photovoltaic Panels (485 Wp)	High-efficiency monocrystalline panels with glass-silicon encapsulation	panel	280	4	1.120,00 €
2	Mounting Structure (Flat Roof)	Aluminum support structure (ballasted or fixed)	panel	75	4	300,00 €
3	Inverter (2–3 kW)	Grid-tied inverter sized for 2 kWp system, with basic monitoring	unit	700	1	700,00 €
4	Electrical Installation	Wiring (DC/AC), protections, combiner box, generation meter	system	500	1	500,00 €
5	Labor and Commissioning	Assembly, cabling, inverter setup, startup testing	system	600	1	600,00 €
6	Legalization and Admin (optional)	Documentation, grid connection, CIE, BOE, etc.	service	300	1	300,00 €
					Total	**3.520,00 €**

Improvement 4: Vaillant Aerothermal System (Heating + Cooling + DHW with Fan Coils)

Technical Summary:

- **System capacity:**
  - Heating: 7.37 kW (COP 4.42)
  - Cooling: 7.2 kW (EER ~2.7)
  - DHW: 200 L tank with integrated coil (uniSTOR)
- **Hot water** generated directly from aerothermal system
- **Savings** vs. traditional electric heater: up to 65%
- **Space requirement:** DHW tank + buffer in utility room or laundry area

Budget:

No.	Item	Description	Unit	Unit Price (€)	Quan,	Subtotal (€)
1	Vaillant aroTHERM Plus Outdoor Unit	Air-to-water heat pump, 7.37 kW heating / 7.2 kW cooling (COP 4.42), monobloc	unit	3.740,00 €	1	3.740,00 €
2	Vaillant uniSTOR DHW Tank (200 L)	Hot water storage tank with coil for aerothermal systems	unit	1.375,00 €	1	1.375,00 €
3	Fan Coil Units (Vaillant or compatible)	Hydronic fan coils, ultra-quiet, thermostat-controlled	unit	638,00 €	4	2.552,00 €
4	Hydraulic Circuit + DHW Integration	Piping, valves, circulation pump, for heating, cooling, and hot water	system	935,00 €	1	935,00 €
5	Electrical Panel Adaptation	Safety switches, control wiring, DHW-compatible configuration	unit	440,00 €	1	440,00 €
6	Removal of Old AC & Water Heater	Uninstalling multisplit AC + electric water heater, with legal disposal	service	220,00 €	1	220,00 €
7	Installation & Commissioning	Full system installation, hydraulic setup, tests, filling, configuration	system	1.320,00 €	1	1.320,00 €
8	Thermostats / Zoning Controls	Wired or wireless thermostats or digital interfaces	unit	110,00 €	4	440,00 €
					Total	**11.022,00 €**

- Improvement 5: Aerothermal heating and DHW system (for radiators)

Technical characteristics:

- Application: Heating + DHW only
- Radiators and distribution piping not included
- Ideal for homes upgrading from gas or electric systems
- Outdoor unit: Monobloc (no refrigerant handling on-site)
- High efficiency COP > 4 — up to 70% energy savings vs. gas

No.	Item	Description	Unit	Unit Price (€)	Qty	Subtotal (€)
1	Vaillant aroTHERM Plus	Outdoor monobloc unit, 7.37 kW heating (COP 4.42)	unit	3.400,00 €	1	3.400,00 €
2	Vaillant uniTOWER 200 L	Indoor hydraulic tower (hydraulic module + 200 L DHW tank + 3-way valve, pump, sensors)	unit	2.750,00 €	1	2.750,00 €
3	Electrical Panel & Protections	Electrical board adaptation and control wiring	unit	400,00 €	1	400,00 €
4	Removal of Gas Boiler	Safe disconnection and disposal	unit	180,00 €	1	180,00 €
5	Removal of Electric Water Heater	Safe disconnection and disposal	unit	120,00 €	1	120,00 €
6	Installation & Commissioning	Hydraulic and electrical connections, system start-up, testing	unit	950,00 €	1	950,00 €
					Total	**7.800,00 €**

Improvement 6: Improved thermal envelope with 10 cm of isolation layer + double glassed windows

Improvement 6: Thermal envelop isolation (10 cm mineral wool) and new windows

Unit	Description	n.	measurement	price €	amount €
m2	10 cm mineral wool isolation layer in facades with plaster finish installed	1	93,88	114,00 €	10.702,32 €
m2	10 cm mineral wool isolation layer in party wall, roof and slabs (interior drywall system)	1	161.49	66,400 €	10.722,94 €
m2	Low emissive double-glazed PVC windows with argon gas (U= 1.7 W/m²·K)	1	11,32	270,00 €	3.056,40 €
ud	Replacing an exterior door in a duplex in Ceutí (Spain), with a thermal transmittance (U-value) of 1.7 W/m²·K, including removal of the old door and full installation.	1	1	1.200,00 €	1.200,00 €
				Total	**25.681,66 €**

3.12. Cost-benefit study of energy efficiency measures

A cost-benefit analysis (CBA) in the context of building energy renovation is a structured evaluation used to determine whether the investment in upgrading a building's energy performance is economically justified. It compares all expected costs of the renovation against the financial and non-financial benefits it will generate over the building's lifecycle.

In this case study, the *CypeTherm Impromevent plus* software has been used to perform this analysis.
In this study, two methods have been used to carry out this analysis:

- Simple Payback Period (SPP)
- Net Present Value (NPV)

Method 1: The **Simple Payback Period** is one of the most straightforward methods for evaluating the financial return of an investment in energy efficiency, such as the energy renovation of a building.

The Simple Payback Period (SPP) is the amount of time (typically expressed in years) it takes for the cumulative energy cost savings generated by an investment to equal the initial cost of that investment.

$$\text{SPP} = \frac{\text{Initial Investment Cost}}{\text{Annual Energy Savings}}$$

Method 2: The **Net Present Value** method is one of the most widely used and robust financial tools for evaluating the profitability of an investment over time. In the context of building energy renovation, NPV helps determine whether the long-term energy savings and other benefits outweigh the initial costs of the retrofit.

NPV is the sum of all future cash flows (such as energy savings, maintenance savings, or subsidies), discounted back to their present value, minus the initial investment cost.

It accounts for the time value of money, recognizing that money received (or saved) in the future is worth less than money today.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} - I$$

Where:

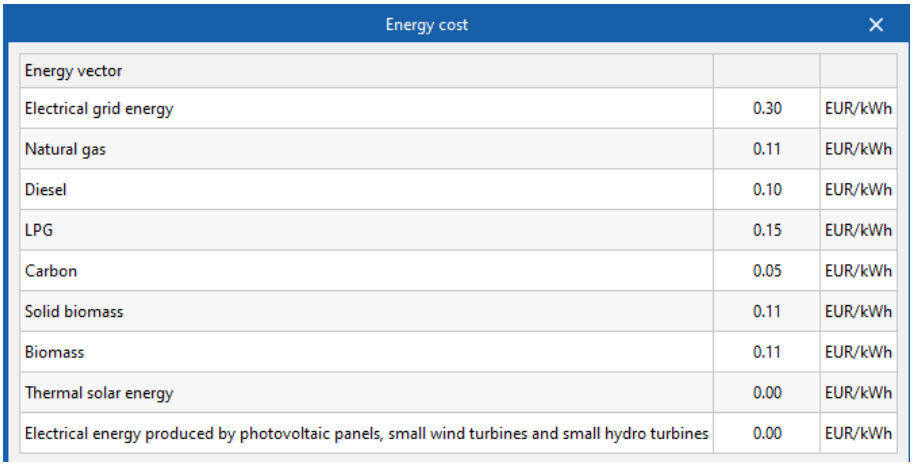
- B_t = Benefits (e.g., energy savings) in year *t*
- C_t = Operating or maintenance costs in year *t*
- r = Discount rate (interest rate or cost of capital)
- t = Year (1 to *n*)
- *I* = Initial investment cost
- n = Analysis period (in years)

If NPV > 0 → The investment is profitable

If NPV = 0 → The investment breaks even

If NPV < 0 → The investment is not financially viable

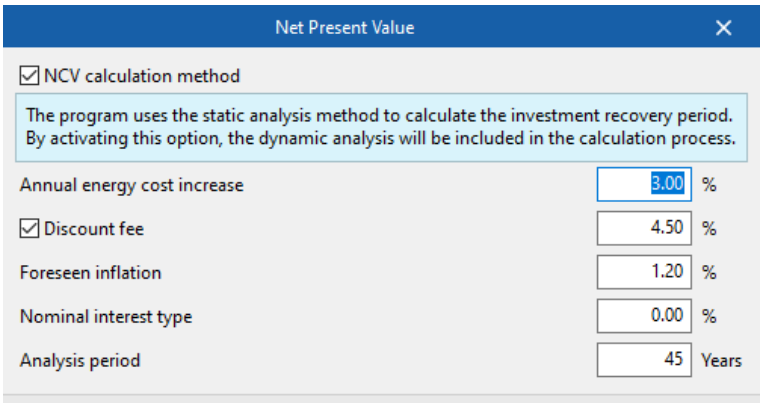
Energy cost considered:



Energy cost

Energy vector		
Electrical grid energy	0.30	EUR/kWh
Natural gas	0.11	EUR/kWh
Diesel	0.10	EUR/kWh
LPG	0.15	EUR/kWh
Carbon	0.05	EUR/kWh
Solid biomass	0.11	EUR/kWh
Biomass	0.11	EUR/kWh
Thermal solar energy	0.00	EUR/kWh
Electrical energy produced by photovoltaic panels, small wind turbines and small hydro turbines	0.00	EUR/kWh

Parameters for the Net present value method:



Summary of the results of the Cost-Benefit study of energy efficiency measures:

	Net cost of the investment (EUR)	Annual energy cost (EUR)	Annual net savings (EUR)	Payback (year)	NCV (year)	Annual consumption of non-renewable primary energy (kWh/m²)	Emissions (kg CO2/m²)
Initial situation 1 (Case 1)	0.00	1642.32	0.00	0.00	0.00	162.20	27.48
Case 3: 6 cm Isolation and DHW Heat pump	23354.58	225.15	1417.17	16.48	18.09	22.23	3.77
Case 4: 6 cm isolation +DHW heat pump + PV Panels	26874.58	0.00	1642.32	16.36	17.96	0.00	0.00
Case 5: 10 cm isolation + DHW heat pump + PV panels	32151.66	0.00	1642.32	19.58	21.62	0.00	0.00
Case 6: 6 cm Insolation + H & AC and DHW Aerothermal with fan coil + PV panels	34946.58	0.00	1642.32	21.28	23.55	0.00	0.00

	Net cost of the investment (EUR)	Annual energy cost (EUR)	Annual net savings (EUR)	Payback (year)	NCV (year)	Annual consumption of non-renewable primary energy (kWh/m²)	Emissions (kg CO2/m²)
Initial situation 2 (Case 2)	0.00	1067.51	0.00	0.00	0.00	119.73	24.93
Case 7: 6 cm Isolation + Aerothermal with radiators for HS and DHW	28204.58	183.40	884.10	31.90	42.35	18.12	3.08
Case 8: 6 cm insolation Aerothermal for HS and DHW and PV panels	31724.58	0.00	1067.51	29.72	38.47	0.00	0.00

In the tables above, the NCV column answers the following question: How many years will it take to recover the investment, considering the time value of money?

	Net investment cost				Annual net savings				Investment recovery period (year)
	Cost (EUR)	Grants (EUR)	Resultant net cost (EUR)	Difference (EUR)	Energy cost (EUR/year)	Energy savings (EUR/year)	Maintenance (EUR/year)	Net savings (EUR/year)	
Initial situation 1 (Case 1)	0.00	0.00	0.00	0.00	1642.32	0.00	0.00	0.00	0.00
Case 3: 6 cm Isolation and DHW Heat pump	23354.58	0.00	23354.58	23354.58	225.15	1417.17	0.00	1417.17	16.48
Case 4: 6 cm isolation +DHW heat pump + PV Panels	26874.58	0.00	26874.58	26874.58	0.00	1642.32	0.00	1642.32	16.36
Case 5: 10 cm isolation + DHW heat pump + PV panels	32151.66	0.00	32151.66	32151.66	0.00	1642.32	0.00	1642.32	19.58
Case 6: 6 cm Insolation + H & AC and DHW Aerothermal with fan coil + PV panels	34946.58	0.00	34946.58	34946.58	0.00	1642.32	0.00	1642.32	21.28

	Net investment cost				Annual net savings				Investment recovery period (year)
	Cost (EUR)	Grants (EUR)	Resultant net cost (EUR)	Difference (EUR)	Energy cost (EUR/year)	Energy savings (EUR/year)	Maintenance (EUR/year)	Net savings (EUR/year)	
Initial situation 2. (Case 2)	0.00	0.00	0.00	0.00	1067.51	0.00	0.00	0.00	0.00
Case 7: 6 cm Isolation + Aerothermal with radiators for HS and DHW	28204.58	0.00	28204.58	28204.58	183.40	884.10	0.00	884.10	31.90
Case 8: 6 cm insolation Aerothermal for HS and DHW and PV panels	31724.58	0.00	31724.58	31724.58	0.00	1067.51	0.00	1067.51	29.72

4. Conclusions

The following conclusions can be drawn from this study:

- **Comprehensive Building Assessment Completed**. The case study thoroughly evaluated the current energy performance of a single family detached house in Ceutí (Spain), using BIM technologies, identifying major inefficiencies in envelope insulation, window performance, DHW systems, and heating system. The building was characterized by high energy consumption and poor thermal comfort, especially during the heating season.
- **Energy Efficiency Measures Identified and Modeled.** A wide range of energy renovation measures were proposed and simulated, including:
  - External wall insulation and roof insulation.
  - Replacement of windows.

- Domestic hot water system modernization (by mean of heat pump system)
- Heating and cooling system modernization (by means of aerothermal systems)
- Integration of rooftop photovoltaic (PV) panels

- **Substantial Energy and CO_2 Savings Potential.** The analysis showed that implementing a combination of passive and active measures could reduce non-renewable primary energy consumption by 100% and CO_2 emissions also by 100%.
- **Cost-Benefit Results Vary by Measure.** The financial assessment revealed that:
  - Deep renovation strategies (isolation, window replacement) require higher investment but offer long-term returns.
  - Heating, cooling and DHW system modernization greatly reduce energy consumption and gas emissions.
  - PV panels contribute significantly to decarbonization goals.
  - If all the measures considered in the study are implemented, the payback period is considerably reduced (18 years) since energy savings are achieved.
- **Combination of Measures Yields Best Results.** The most balanced and sustainable outcome is achieved by combining passive improvements (insulation, airtightness) with active systems (modern DHW heat pump system and PV panels). This synergy maximizes energy savings keeping indoor comfort, and enhances the building's overall value.
- **Technical and Economic Feasibility Confirmed.** Despite initial investment barriers, the study confirms that energy renovation is technically viable and economically beneficial for the single family house. Using metrics such as NPV and SPP, all measures show acceptable economic performance, especially if they are implemented at the same time.
- **Supports National and EU Renovation Goals.** The case aligns with the EU's Green Deal and Renovation Wave strategy, contributing to targets for carbon neutrality, energy efficiency, and healthier indoor environments in public and residential buildings.