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Spanish Case Study

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 m² for vehicle parking and a storage room of 12 m².

The first floor has an interior usable area of 56 m², 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 m², 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 m² 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

2.2. House Plans

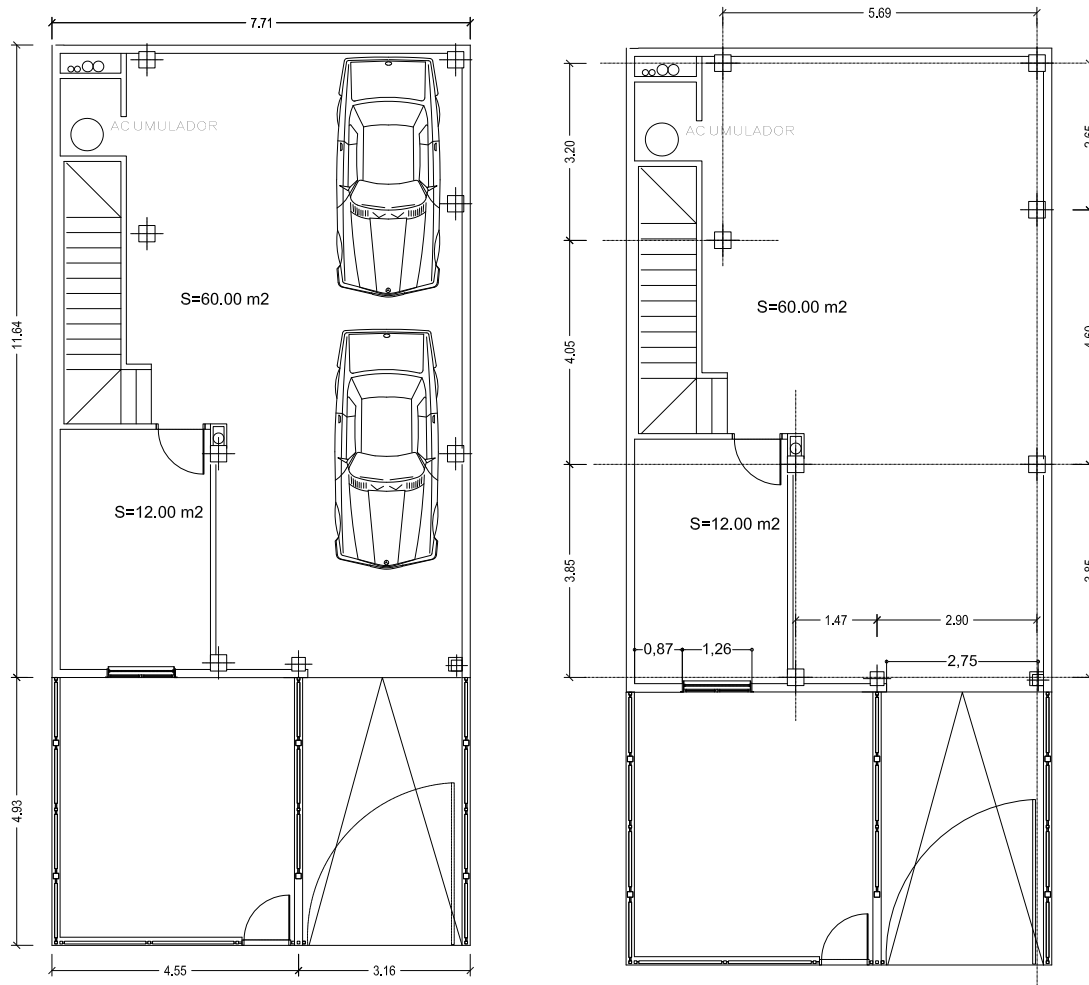


Figure 2: Basement Floor Plans

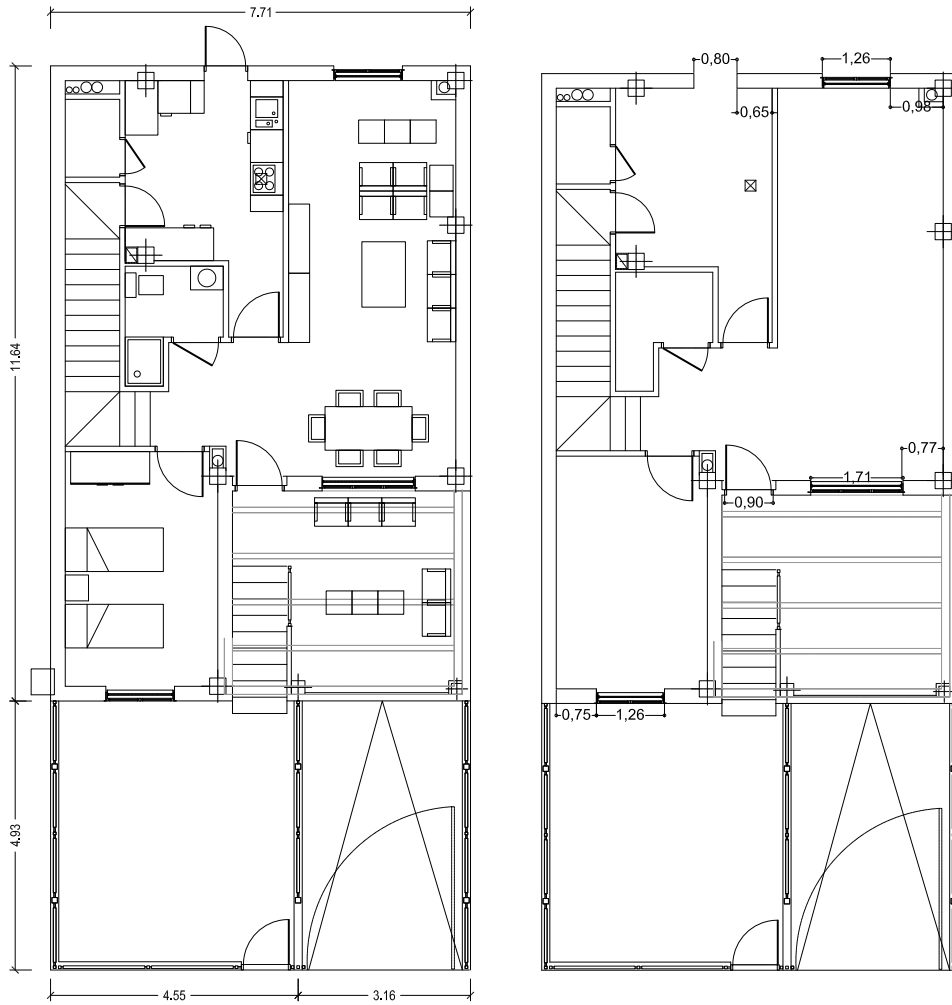


Figure 3: First Floor Plans



Figure 5: Rear and front elevations.

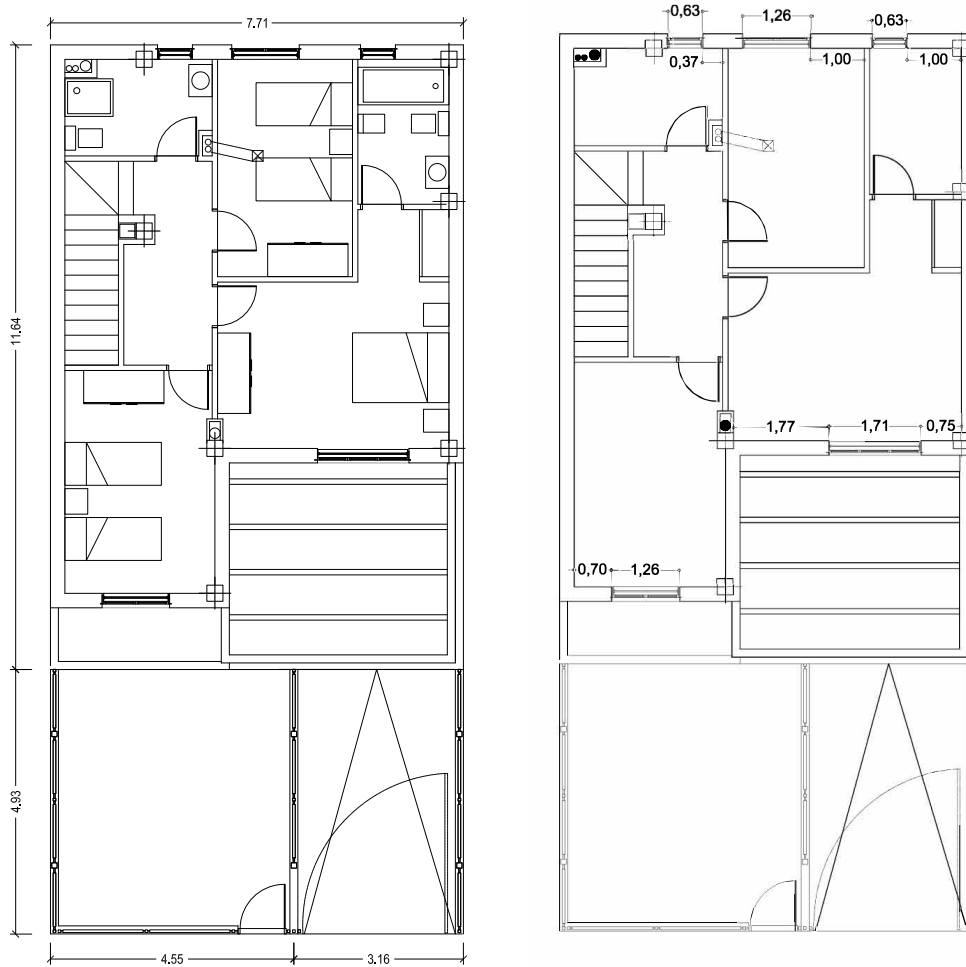


Figure 4: Second Floor Plans

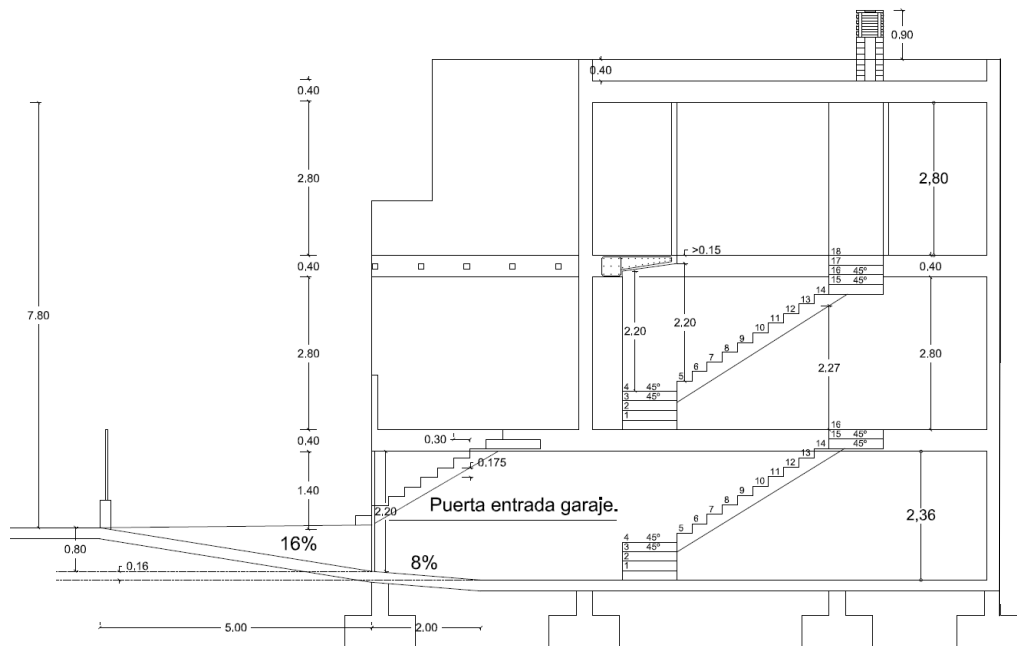


Figure 5: Building section.

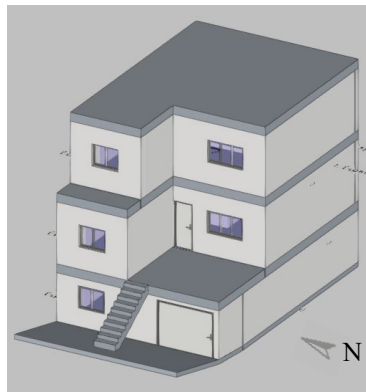
2.3. Location

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	Ceuti
Altitude	94,000 m
Latitude	38,1 degrees
Longitude	-1,3 degrees
Time zone	0,0
SCOP climatic conditions	Warm climate

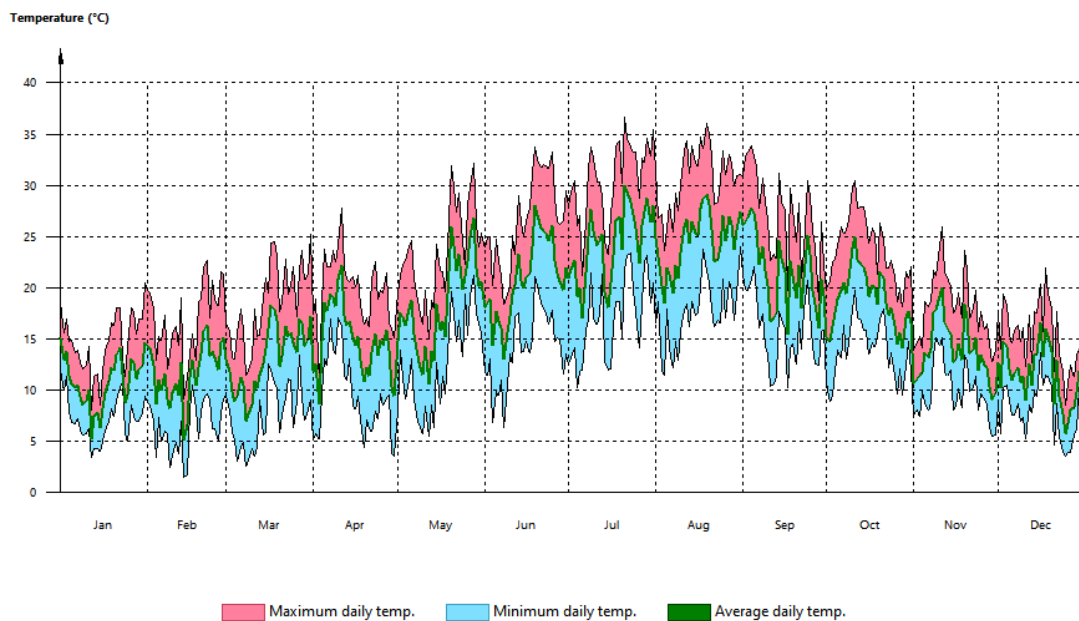
The main façade of the house faces west.



2.4. Climatic zone

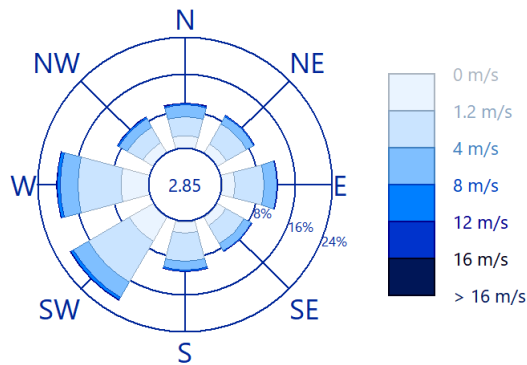
The climatic zone in which the house is located is B3 according to the Spanish standard of energy efficiency in the building.

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





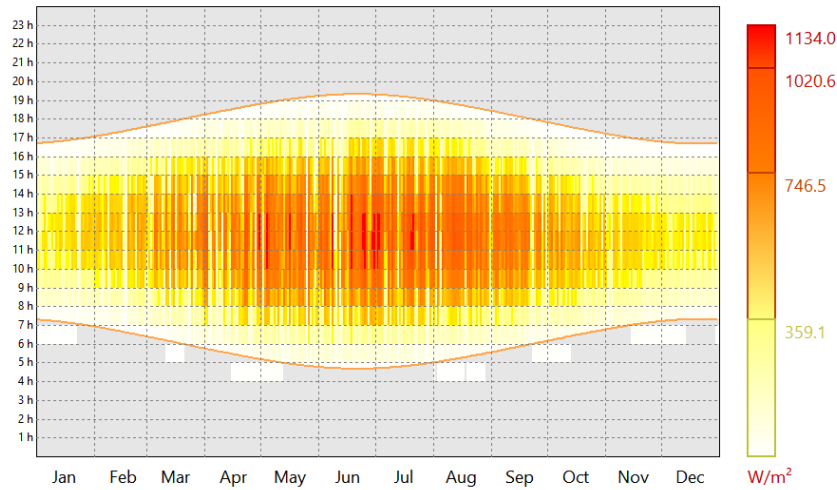
Wind distribution:



Solar irradiation on the site of the house:

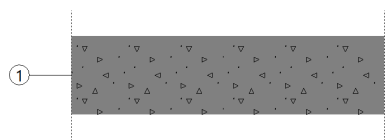
The graph below shows the global irradiance on a horizontal surface

$$Q = 73.8 + 88.9 + 130.5 + 156.7 + 194.2 + 204.3 + 219.7 + 197.9 + 150.2 + 113.8 + 79.0 + 66.0 = 1675.01 \text{ kWh/m}^2$$



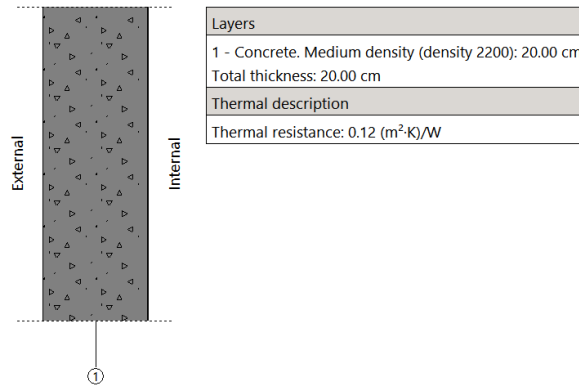
2.5. Thermal Envelope Materials

Floors in contact with the ground (screed)

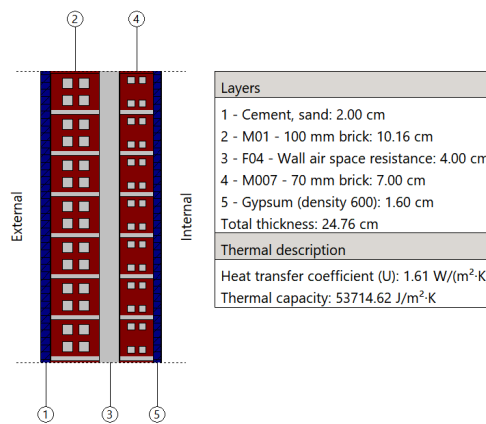


Layers
1 - Concrete. Medium density (density 1800): 15.00 cm Total thickness: 15.00 cm
Thermal description
Thermal resistance: 0.13 (m ² ·K)/W

Walls in contact with soil



Façades

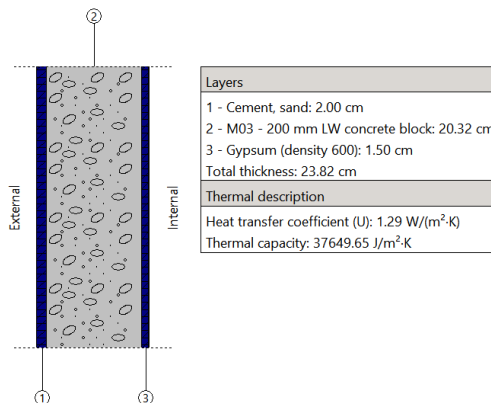


Façade openings

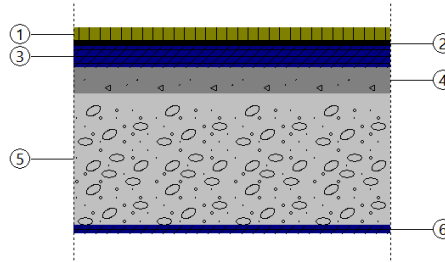
Windows with aluminum frame and monolithic glass

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

Party walls



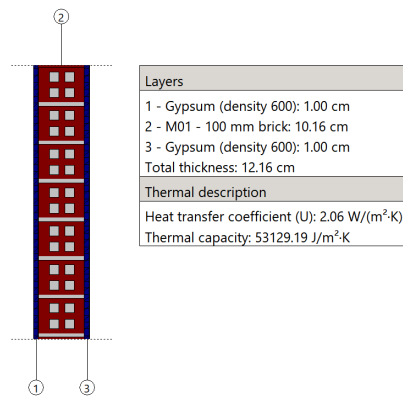
Roofs



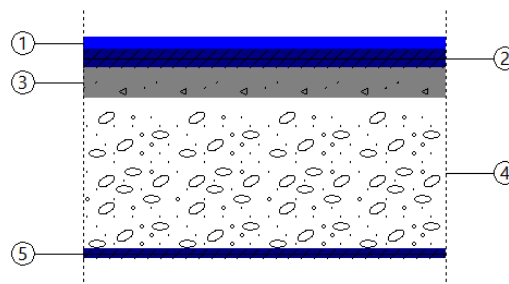
Layers
1 - F18 - Terrazzo: 2.54 cm
2 - Asphalt: 1.00 cm
3 - Cement, sand: 4.00 cm
4 - Concrete. Reinforced (with 2% of steel): 5.00 cm
5 - M04 - 300 mm LW concrete block: 25.00 cm
6 - Gypsum (density 600): 1.50 cm
Total thickness: 39.04 cm
Thermal description
Heat transfer coefficient (cooling): 1.36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

2.6. Interior partitions and Intermediate slabs.

Interior partitions



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/(m ² ·K)
Heat transfer coefficient (heating): 1.16 W/(m ² ·K)
Floor slab
Heat transfer coefficient (cooling): 1.16 W/(m ² ·K)
Heat transfer coefficient (heating): 1.00 W/(m ² ·K)
Floor slab exposed to open air
Heat transfer coefficient (cooling): 1.25 W/(m ² ·K)
Heat transfer coefficient (heating): 1.15 W/(m ² ·K)
Thermal capacity: 141371.08 J/m ² ·K

2.7. 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.

Outdoor unit

Equipment: RAS-4M27U2AVG-E

Maximum number of internal units: 4
 Gross rated total cooling capacity: 8000 W
 Gross rated cooling COP: 3.5
 Gross rated heating capacity: 9000 W
 Gross rated heating COP: 4.67

Control of the operating mode Load priority

Total pipe length 30.000 m

The system includes 4 indoor units as the following:

Indoor unit

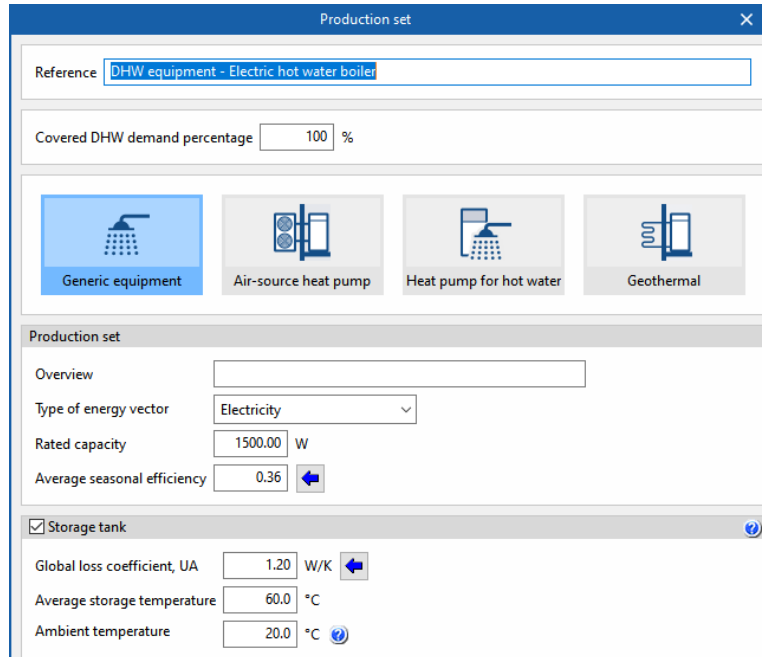
Cassette: RAS-M10U2MUVG-E

Gross rated total cooling capacity: 2500 W
 Nominal cooling power: 2000 W
 Gross rated heating capacity: 3200 W

Operational conditions: Minimum temperature inside the house is 20 degrees and maximum 25 degrees.

2.8. Domestic hot water system

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

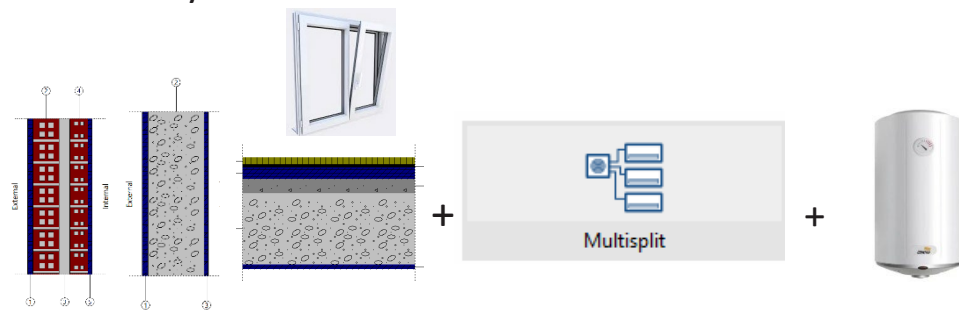


The screenshot shows the 'Production set' configuration window. At the top, the reference is 'DHW equipment - Electric hot water boiler'. The 'Covered DHW demand percentage' is set to 100%. Below this are four equipment options: 'Generic equipment' (selected), 'Air-source heat pump', 'Heat pump for hot water', and 'Geothermal'. The 'Production set' section includes an 'Overview' field, 'Type of energy vector' set to 'Electricity', 'Rated capacity' of 1500.00 W, and 'Average seasonal efficiency' of 0.36. The 'Storage tank' section is checked and includes 'Global loss coefficient, UA' of 1.20 W/K, 'Average storage temperature' of 60.0 °C, and 'Ambient temperature' of 20.0 °C.

3. Development of the Spanish single-family house Case Study

3.1. Cases analysed. Description

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



(Façade party wall + roof)
(Single glass windows with aluminum frame)

Envelope without insulation + HVAC direct expansion system + DHW with Electric boiler

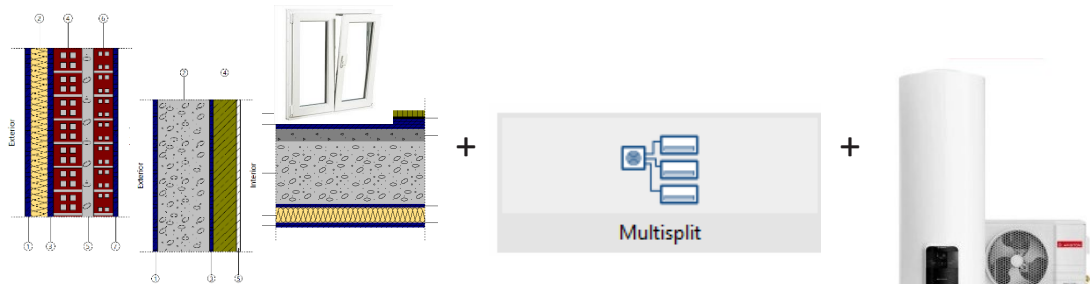
- **Case 2: Initial situation: Envelope without isolation + Gas Boiler & radiators + Air conditioning direct expansion system.**



(Façade party wall + roof)
(Single glass windows with aluminum frame)

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

- **Case 3: Improved envelope 6 cm Insulation + H & AC direct expansion multisplit System + DHW heat pump.**



(Façade party wall roof)
(PVC Double glazed windows)

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

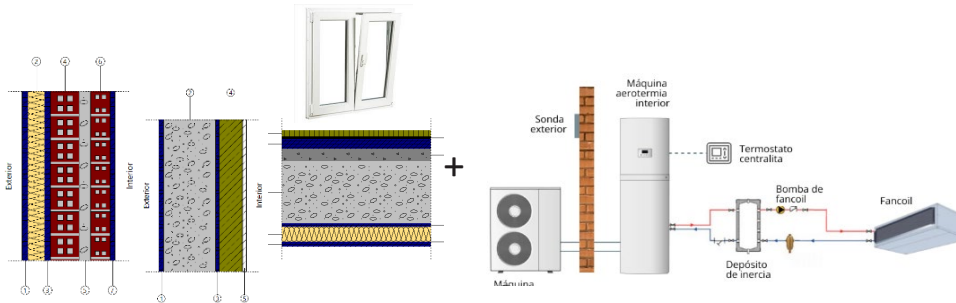
- **Case 4 : Improved envelope 6 cm Insulation + H & AC direct expansion msplit System + DHW heat pump + Photovoltaic panels.**



Case 3+

20 m² of photovoltaic panels of (200 w/m²) (System: 20 KWh/day)

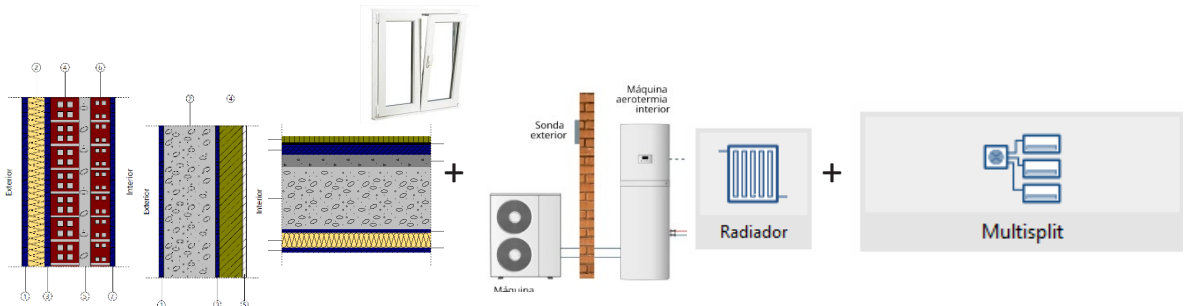
- **Case 5 : Improved envelope 6 cm Insolation + H & AC and DHW Aerothermal with fan coil**



(Façade party wall roof)
(PVC Double glazed windows)

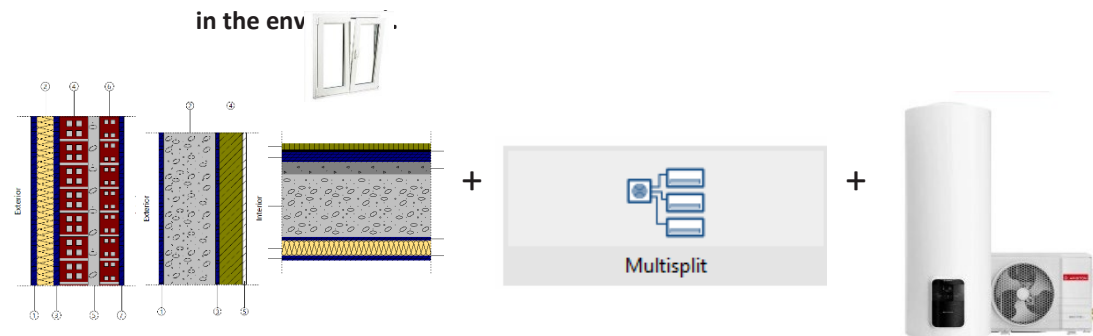
Aerothermal system with fan coils

- **Case 6 : Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + AC with direct expansion multisplit system.**



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

- **Case 7: Improved envelope 10 cm Insolation + H & AC direct expansion multisplit System + DHW heat pump. (Case 3 by with 10 cm of insulation layer in the env**

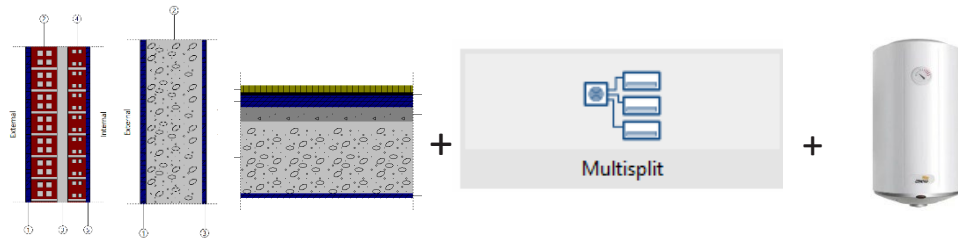


(Façade party wall roof)
(PVC Double glazed windows)

Improved envelope 10 cm Insolation layer + H & AC direct expansion multisplit System + DHW heat pump.

3.2. Cases Results. Energy Consumption

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



(Façade party wall + roof)

Envelope without insulation + HVAC direct expansion system + DHW with Electric boiler

Energy consumption of the building's technical services

BUILDING ($S_u = 116.38 \text{ m}^2$)

Technical Services	FE		PF _{tot}		PF _{ren}	
	(kWh/year)	(kWh/m ² ·year)	(kWh/year)	(kWh/m ² ·year)	(kWh/year)	(kWh/m ² ·year)
Calefacción	6189.27	53.18	8429.57	72.43	3199.87	27.50
Refrigeración	469.02	4.03	1110.69	9.54	916.46	7.88
ACS	7469.42	64.18	17687.61	151.99	14595.27	125.42
	14127.71	121.40	27227.75	233.96	18711.60	160.79

where:

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

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

PF_{tot}: Total Primary Power Consumption.

PF_{ren}: Primary energy consumption of non-renewable origin.

Annual Energy Demand of the building

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
		(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh/year)	(kWh/m ² ·year)
Energy demand	Heating	1464.7	1055.4	862.9	455.1	237.1	--	--	--	--	41.5	604.3	1320.7	6041.7	51.9
	Cooling	--	--	--	--	--	179.6	481.8	535.0	210.2	--	--	--	1406.6	12.1
	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	1709.0	1276.1	1102.9	682.7	463.9	390.8	691.6	740.6	417.4	264.6	832.6	1565.0	10137.3	87.1
Electricity	Heating	393.3	285.4	234.5	124.6	64.6	0.8	2.0	2.2	0.9	11.4	162.7	355.2	1637.6	14.1
	Cooling	2.9	2.1	1.8	0.9	0.5	59.4	155.8	173.2	68.5	0.1	1.2	2.6	469.0	4.0
	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	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Environment	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Heating	1105.8	795.0	648.8	341.3	177.3	--	--	--	--	31.0	455.4	997.0	4551.7	39.1
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	C_{ef,total}	2180.7	1695.5	1551.9	1099.1	872.2	647.0	740.7	746.6	644.9	662.3	1253.3	2033.5	14127.7	121.4

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.

- **Case 2: Initial situation: Envelope without isolation + Gas Boiler & radiators + Air conditioning direct expansion system.**



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

Energy consumption of the building's technical services

BUILDING ($S_u = 116.38 \text{ m}^2$)

Technical Services	FE		PF _{tot}		PF _{ren}	
	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)
Heating	7594.03	65.25	9155.17	78.67	9054.85	77.81
Cooling	420.35	3.61	995.36	8.55	821.38	7.06
DHW	2835.66	24.37	3388.63	29.12	3374.43	29.00
	10850.03	93.23	13539.05	116.34	13250.55	113.86

where:

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

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

PF_{tot}: Total Primary Power Consumption.

PF_{ren}: Primary energy consumption of non-renewable origin.

Annual Energy Demand of the building

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
		(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh/year)	(kWh/m ² -year)
Energy demand	Heating	1464.7	1055.4	862.9	455.1	237.1	--	--	--	--	41.5	604.3	1320.7	6041.7	51.9
	Cooling	--	--	--	--	--	179.6	481.8	535.0	210.2	--	--	--	1406.6	12.1
	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	1673.3	1243.8	1067.2	648.2	428.1	356.2	655.9	704.9	382.8	228.9	798.0	1529.3	9716.8	83.5
Electricity	Heating	13.7	11.2	9.9	6.4	3.7	0.8	2.2	2.5	1.0	1.0	8.2	13.1	73.7	0.6
	Cooling	11.5	9.3	8.5	5.5	3.4	47.5	122.5	135.9	54.5	1.0	7.1	11.0	417.7	3.6
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Ventilation	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Humidity control	--	--	--	--	--	0.9	1.7	--	--	--	--	--	2.6	0.0
	Lighting	1819.6	1308.0	1068.8	561.9	292.5	--	--	--	--	50.7	746.8	1639.7	7488.0	64.3
Environment	Heating	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
	Cooling	7.3	6.0	4.6	2.9	1.2	--	--	--	--	0.0	3.6	6.7	32.3	0.3
	DHW	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	C_{ef,total}	2112.7	1570.0	1347.3	818.0	539.6	269.2	343.3	352.5	271.3	287.1	1007.8	1931.2	10850.0	93.2

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.

- **Case 3: Improved envelope 6 cm Insolation + H & AC direct expansion msplit System + DHW heat pump.**



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

Energy consumption of the building's technical services

BUILDING ($S_u = 116.38 \text{ m}^2$)

Technical Services	FE		PF _{tot}		PF _{ren}	
	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)
Heating	1005.22	8.64	1393.83	11.98	555.11	4.77
Cooling	377.11	3.24	893.07	7.67	736.89	6.33
DHW	2268.50	19.49	3435.18	29.52	1666.39	14.32
	3650.82	31.37	5721.97	49.17	2958.39	25.42

where:

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

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

PF_{tot}: Total Primary Power Consumption.

PF_{ren}: Primary energy consumption of non-renewable origin.

Annual Energy Demand of the building

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
		(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh/year)	(kWh/m ² -year)
Energy demand	Heating	317.0	208.3	161.1	15.2	9.4	--	--	--	--	--	17.8	250.8	979.5	8.4
	Cooling	--	--	--	--	--	135.8	357.1	442.0	203.8	--	--	--	1138.7	9.8
	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	525.6	396.7	365.5	208.2	200.4	312.5	531.3	611.9	376.4	187.4	211.5	459.4	4386.7	37.7
Electricity	Heating	90.1	59.3	46.1	4.5	2.7	0.6	1.6	1.8	0.9	--	5.1	71.4	284.1	2.4
	Cooling	0.7	0.4	0.3	0.0	0.0	44.7	118.1	144.7	67.5	--	0.0	0.5	377.1	3.2
	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	233.6	153.4	118.4	11.0	6.9	--	--	--	--	--	13.1	184.8	721.1	6.2
	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}	532.9	401.5	369.2	208.6	200.7	222.0	293.8	316.5	241.1	187.4	211.9	465.3	3650.9	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.



- **Case 4 : Improved envelope 6 cm Insolation + H & AC direct expansion msplit System + DHW heat pump + Photovoltaic panels.**



Case 3+

 30 m² of photovoltaic panels of (200 w/m²) (System: 30 kWh/day)

Energy consumption of the building's technical services

BUILDING ($S_u = 116.38 \text{ m}^2$)

Technical Services	FE		PF _{tot}		PF _{ren}	
	(kWh/year)	(kWh/m ² ·year)	(kWh/year)	(kWh/m ² ·year)	(kWh/year)	(kWh/m ² ·year)
Heating	1005.22	8.64	1005.25	8.64	--	--
Cooling	377.11	3.24	377.06	3.24	--	--
DHW	2268.50	19.49	2268.51	19.49	--	--
	3650.82	31.37	3650.83	31.37	--	--

where:

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

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

 PF_{tot}: Total Primary Power Consumption.

 PF_{ren}: Primary energy consumption of non-renewable origin.

Annual Energy Demand of the building

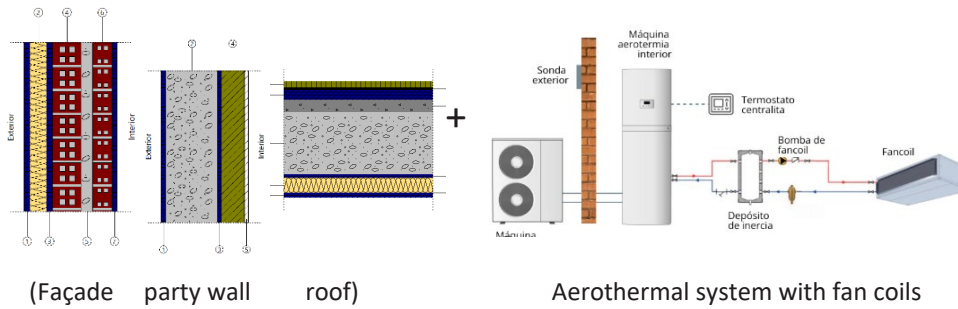
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
		(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh/year)	(kWh/m ² ·year)
Energy demand	Heating	317.0	208.3	161.1	15.2	9.4	--	--	--	--	--	17.8	250.8	979.5	8.4
	Cooling	--	--	--	--	--	135.8	357.1	442.0	203.8	--	--	--	1138.7	9.8
	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	525.6	396.7	365.5	208.2	200.4	312.5	531.3	611.9	376.4	187.4	211.5	459.4	4386.7	37.7
Electricity	Heating	90.1	59.3	46.1	4.5	2.7	0.6	1.6	1.8	0.9	--	5.1	71.4	284.1	2.4
	Cooling	0.7	0.4	0.3	0.0	0.0	44.7	118.1	144.7	67.5	--	0.0	0.5	377.1	3.2
	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	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Environment	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Heating	233.6	153.4	118.4	11.0	6.9	--	--	--	--	--	13.1	184.8	721.1	6.2
	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}	532.9	401.5	369.2	208.6	200.7	222.0	293.8	316.5	241.1	187.4	211.9	465.3	3650.9	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.

- Case 5 : Improved envelope 6 cm Insolation + H & AC and DHW Aerothermal with fan coil



Energy consumption of the building's technical services

BUILDING ($S_u = 116.38 \text{ m}^2$)

Technical Services	FE		PF _{tot}		PF _{nren}	
	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)
Heating	980.03	8.42	1323.66	11.37	490.87	4.22
Cooling	254.91	2.19	603.64	5.19	498.09	4.28
DHW	2268.52	19.49	2972.24	25.54	1005.14	8.64
	3503.45	30.10	4899.54	42.10	1994.10	17.14

where:

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

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

PF_{tot}: Total Primary Power Consumption.

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

Annual Energy Demand of the building

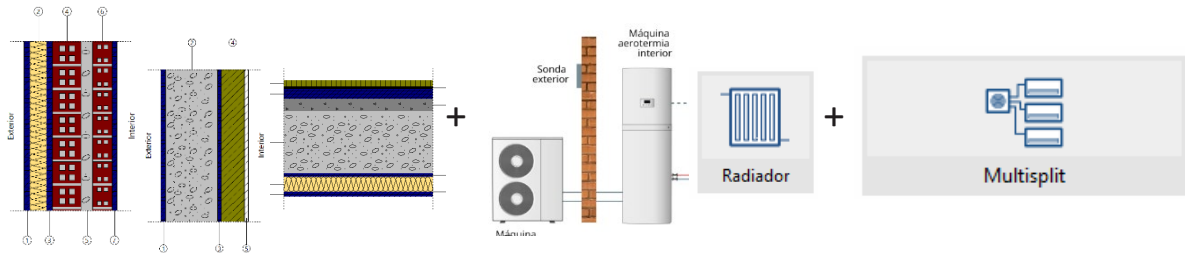
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
		(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh/year)	(kWh/m ² -year)
Energy demand	Heating	317.0	208.3	161.1	15.2	9.4	--	--	--	--	--	17.8	250.8	979.6	8.4
	Cooling	--	--	--	--	--	135.8	357.1	442.0	203.8	--	--	--	1138.7	9.8
	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	525.6	396.7	365.5	208.2	200.4	312.5	531.3	611.9	376.4	187.4	211.5	459.4	4386.8	37.7
Electricity	Heating	80.6	52.5	40.7	3.9	2.3	0.4	1.0	1.3	0.6	--	4.5	63.3	251.2	2.2
	Cooling	0.7	0.5	0.4	0.0	0.0	26.4	81.5	96.3	48.6	--	0.0	0.6	254.9	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	235.4	155.2	119.8	11.2	7.1	--	--	--	--	--	13.2	186.8	728.8	6.3
Environment	Heating	--	--	--	--	--	--	--	--	--	--	--	--	--	
	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	15.1
	C _{ef,total}	525.3	396.6	365.3	208.3	200.4	203.5	256.6	267.5	221.8	187.4	211.5	459.3	3503.5	30.1

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.

- **Case 6 : Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + AC with direct expansion multisplit system.**



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

Energy consumption of the building's technical services

BUILDING ($S_u = 116.38 \text{ m}^2$)

Technical Services	FE		PF _{tot}		PF _{nren}	
	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)	(kWh/year)	(kWh/m ² -year)
Heating	977.86	8.40	1293.05	11.11	450.14	3.87
Cooling	450.76	3.87	1067.40	9.17	880.73	7.57
DHW	2268.52	19.49	2969.10	25.51	1000.60	8.60
	3697.14	31.77	5329.43	45.80	2331.47	20.03

where:

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

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

PF_{tot}: Total Primary Power Consumption.

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

Annual Energy Demand of the building

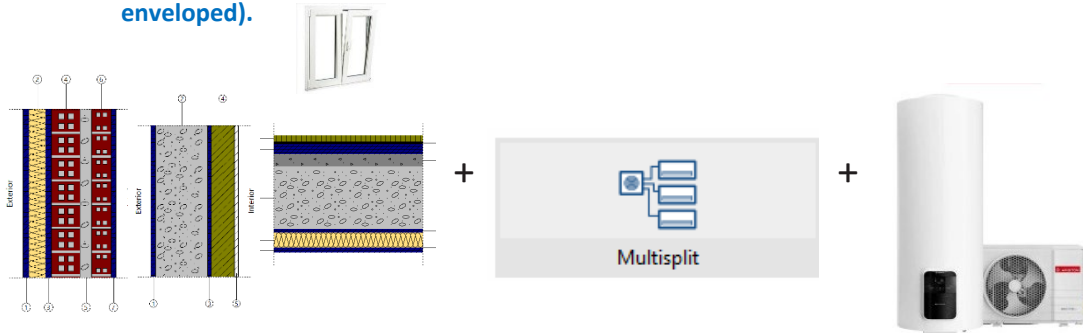
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
		(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh/year)	(kWh/m ² -year)
Energy demand	Heating	317.1	208.3	161.2	15.3	9.5	--	--	--	--	--	18.0	250.9	980.3	8.4
	Cooling	--	--	--	--	--	136.0	357.5	442.3	204.0	--	--	--	1139.9	9.8
	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	525.7	396.7	365.6	208.4	200.5	312.7	531.7	612.2	376.6	187.4	211.7	459.5	4388.7	37.7
Electricity	Heating	74.9	48.7	37.8	3.7	2.1	--	--	--	--	--	4.2	58.8	230.3	2.0
	Cooling	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	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	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Environment	Lighting	--	--	--	--	--	53.9	141.4	175.0	80.5	--	--	--	450.8	3.9
	Heating	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Cooling	241.6	158.8	123.0	11.6	7.3	--	--	--	--	--	13.7	191.5	747.5	6.4
	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,tot}	525.1	396.0	365.2	208.4	200.5	230.5	315.6	344.9	253.1	187.4	211.6	458.9	3697.1	31.8

where:

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

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

- Case 7: Improved envelope 10 cm Insolation + H & AC direct expansion multisplit System + DHW heat pump. (Case 3 by with 10 cm of insulation layer in the enveloped).



Energy consumption of the building's technical services

BUILDING ($S_u = 116.38 \text{ m}^2$)

Technical Services	FE		PF _{tot}		PF _{ren}	
	(kWh/year)	(kWh/m ² ·year)	(kWh/year)	(kWh/m ² ·year)	(kWh/year)	(kWh/m ² ·year)
Heating	670.98	5.77	933.68	8.02	375.20	3.22
Cooling	362.68	3.12	858.85	7.38	708.73	6.09
DHW	2268.50	19.49	3435.18	29.52	1666.39	14.32
	3302.15	28.37	5227.60	44.92	2750.19	23.63

where:

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

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

PF_{tot}: Total Primary Power Consumption.

PF_{ren}: Primary energy consumption of non-renewable origin.

Annual Energy Demand of the building

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
		(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh/year)	(kWh/m ² ·year)
Energy demand	Heating	223.7	145.4	112.0	3.9	2.1	--	--	--	--	--	2.7	162.2	652.0	5.6
	Cooling	--	--	--	--	--	130.3	339.6	424.1	201.6	--	--	--	1095.6	9.4
	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	432.3	333.8	316.4	197.0	193.2	307.0	513.8	594.0	374.2	187.4	196.3	370.8	4016.2	34.5
Electricity	Heating	64.1	41.7	32.3	1.2	0.6	0.6	1.5	1.8	0.9	--	0.8	46.5	192.0	1.6
	Cooling	0.5	0.3	0.2	0.0	0.0	42.5	112.9	139.1	66.8	--	0.0	0.3	362.7	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	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Environment	Lighting	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Heating	164.5	106.9	82.1	2.8	1.5	--	--	--	--	--	1.9	119.2	479.0	4.1
	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}	437.6	337.3	319.0	197.1	193.2	219.8	288.5	310.8	240.3	187.4	196.4	374.7	3302.2	28.4

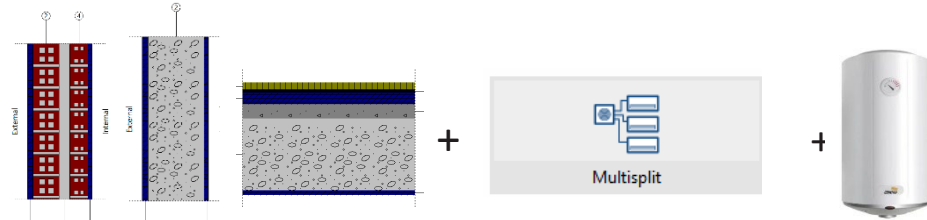
where:

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.

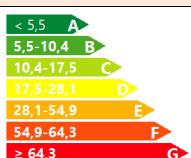
3.3. Cases Results. Energy rating.

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



1. ENERGY RATING OF THE BUILDING IN EMISSIONS

4.

GLOBAL INDICATOR	PARTIAL INDICATORS		
 27,24 D	HEATING		DHW
	Heating emissions [kgCO ₂ /m ² ·year]	A	DHW emissions [kgCO ₂ /m ² ·year]
Global emissions[kgCO ₂ /m ² ·year] ¹	4.66		21.25
5.	COOLING		LIGHTING
	Cooling emissions [kgCO ₂ /m ² ·year]	A	Lighting emissions [kgCO ₂ /m ² ·year]
	1.33		-

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

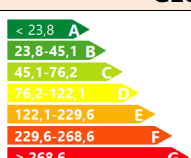
	kgCO ₂ /m ² ·year	kgCO ₂ ·year
CO2 emissions from electricity consumption	27.24	3169.67
CO2 emissions from other fuels	0.00	0.00

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

6.

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.

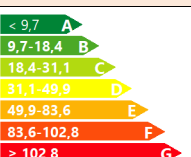
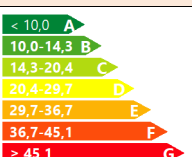
7.

GLOBAL INDICATOR	PARTIAL INDICATORS		
 160,79 E	HEATING		DHW
	Primary energy heating [kWh/m ² ·year]	A	DHW Primary energy [kWh/m ² ·year]
Global consumption of non-renewable primary energy[kWh/m ² ·year] ¹	27.5		125.42
9.	COOLING		LIGHTING
	Primary energy cooling [kWh/m ² ·year]	A	Primary energy lighting [kWh/m ² ·year]
	7.88		-

3. 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.

8.

HEATING DEMAND	COOLING DEMAND
 51,91 E	 12,09 B
g. Heating demand[kWh/m ² ·year]	Cooling demand[kWh/m ² ·year]

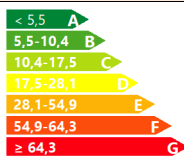
1 The global indicator is the result of the sum of the partial indicators plus the value of the indicator for auxiliary consumption, if any (only tertiary buildings, ventilation, pumping, etc...). Self-consumed electricity is only deducted from the global indicator, not from the partial values.

- **Case 2: Initial situation: Envelope without isolation + Gas Boiler & radiators + Air conditioning direct expansion system.**



1. ENERGY RATING OF THE BUILDING IN EMISSIONS

10.

GLOBAL INDICATOR	PARTIAL INDICATORS	
 Global emissions [kgCO ₂ /m ² ·year] ¹	HEATING	
	Heating emissions [kgCO ₂ /m ² ·year]	A
	16.42	
	COOLING	
		DHW
	DHW emissions [kgCO ₂ /m ² ·year]	C
	6.14	
	LIGHTING	
	Cooling emissions [kgCO ₂ /m ² ·year]	A
	1.2	
		Lighting emissions [kgCO ₂ /m ² ·year]
		-

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

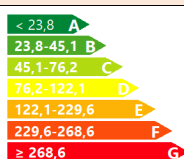
	kgCO ₂ /m ² ·year	kgCO ₂ ·year
CO ₂ emissions from electricity consumption	1.41	163.55
CO ₂ emissions from other fuels	22.35	2601.55

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

12.

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.

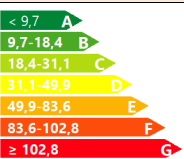
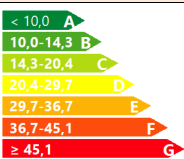
13.

GLOBAL INDICATOR	PARTIAL INDICATORS	
 Global consumption of non-renewable primary energy [kWh/m ² ·year] ¹	HEATING	
	Primary energy heating [kWh/m ² ·year]	A
	77.81	
	COOLING	
		DHW
	DHW Primary energy [kWh/m ² ·year]	E
	29	
	LIGHTING	
	Primary energy cooling [kWh/m ² ·year]	A
	7.06	
		Primary energy lighting [kWh/m ² ·year]
		-

3. PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

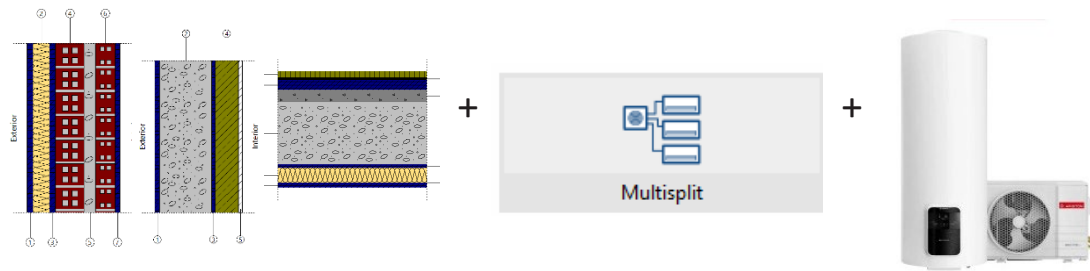
The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

14.

HEATING DEMAND	COOLING DEMAND		
 Heating demand [kWh/m ² ·year]	 Cooling demand [kWh/m ² ·year]		
		51.91 E	12.09 B

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



1. ENERGY RATING OF THE BUILDING IN EMISSIONS

16.

GLOBAL INDICATOR	PARTIAL INDICATORS	
	HEATING	DHW
	Heating emissions [kgCO ₂ /m ² ·year] 0.81	DHW emissions [kgCO ₂ /m ² ·year] 2.43
Global emissions[kgCO ₂ /m ² ·year] ¹	COOLING	LIGHTING
	Cooling emissions [kgCO ₂ /m ² ·year] 1.07	Lighting emissions [kgCO ₂ /m ² ·year] -

17.

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	4.31	501.15
CO2 emissions from other fuels	0.00	0.00

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

18.

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.

19.

GLOBAL INDICATOR	PARTIAL INDICATORS	
	HEATING	DHW
	Primary energy heating [kWh/m ² ·year] 4.77	DHW Primary energy [kWh/m ² ·year] 14.32
Global consumption of non-renewable primary energy[kWh/m ² ·year] ¹	COOLING	LIGHTING
	Primary energy cooling [kWh/m ² ·year] 6.33	Primary energy lighting [kWh/m ² ·year] -

3. 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.

20.

HEATING DEMAND	COOLING DEMAND

21.

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: Improved envelope 6 cm Insolation + H & AC direct expansion multisplit System + DHW heat pump + Photovoltaic panels.**

Case 3+



20 m² of photovoltaic panels of (200 w/m²) (System: 20 kWh/day)

22.

1. ENERGY RATING OF THE BUILDING IN EMISSIONS

GLOBAL INDICATOR	PARTIAL INDICATORS		
	HEATING		
	Heating emissions [kgCO ₂ /m ² ·year]	A	DHW emissions [kgCO ₂ /m ² ·year]
	0		0
	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]
	0		-

23.

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	0.00	0.00
CO2 emissions from other fuels	0.00	0.00

24.

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

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.

25.

GLOBAL INDICATOR	PARTIAL INDICATORS		
	HEATING		
	Primary energy heating [kWh/m ² ·year]	A	DHW Primary energy [kWh/m ² ·year]
	0		0
	COOLING		LIGHTING
Global consumption of non-renewable primary energy[kWh/m ² ·year] ¹	Primary energy cooling [kWh/m ² ·year]	A	Primary energy lighting [kWh/m ² ·year]
	0		-

3. PARTIAL RATING OF HEATING AND COOLING ENERGY DEMAND

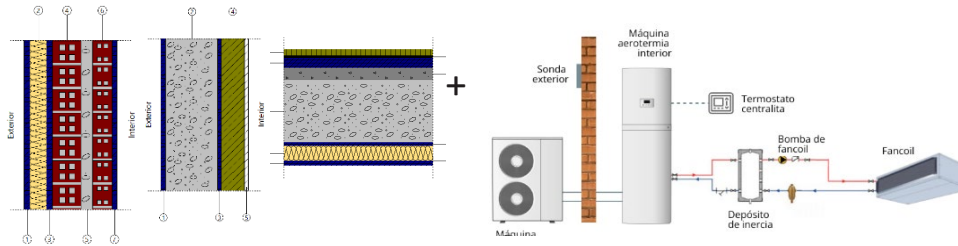
The energy demand for heating and cooling is the energy needed to maintain the building's internal comfort conditions.

26.

HEATING DEMAND	COOLING DEMAND
27. Heating demand[kWh/m ² ·year]	Cooling demand[kWh/m ² ·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 5: Improved envelope 6 cm Insolation + H & AC and DHW Aerothermal with fan coil



1. ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS	
	HEATING	DHW
	Heating emissions [kgCO ₂ /m ² ·year] 0.71	DHW emissions [kgCO ₂ /m ² ·year] 1.46
Global emissions[kgCO ₂ /m ² ·year] ¹	COOLING	LIGHTING
	Cooling emissions [kgCO ₂ /m ² ·year] 0.73	Lighting emissions [kgCO ₂ /m ² ·year] -

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.

	kgCO ₂ /m ² ·year	kgCO ₂ ·year
CO2 emissions from electricity consumption	2.90	337.9
CO2 emissions from other fuels	0.00	0.00

2. 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	
	HEATING	DHW
	Primary energy heating [kWh/m ² ·year] 4.22	DHW Primary energy [kWh/m ² ·year] 8.64
Global consumption of non-renewable primary energy[kWh/m ² ·year] ¹	COOLING	LIGHTING
	Primary energy cooling [kWh/m ² ·year] 4.28	Primary energy lighting [kWh/m ² ·year] -

3. 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.

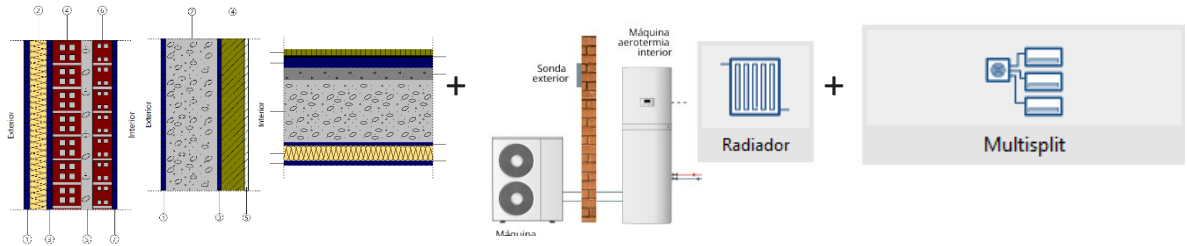
5.

HEATING DEMAND	COOLING DEMAND
Heating demand[kWh/m ² ·year] 8.42	Cooling demand[kWh/m ² ·year] 9.78

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 6 : Improved envelope 6 cm Insolation + Aerothermal with radiators for Heating and DHW + AC with direct expansion multisplit system.**



1. ENERGY RATING OF THE BUILDING IN EMISSIONS

1.

GLOBAL INDICATOR	PARTIAL INDICATORS	
	HEATING	DHW
	Heating emissions [kgCO ₂ /m ² ·year] 0.66	DHW emissions [kgCO ₂ /m ² ·year] 1.46
Global emissions[kgCO ₂ /m ² ·year] ¹	COOLING	LIGHTING
	Cooling emissions [kgCO ₂ /m ² ·year] 1.28	Lighting emissions [kgCO ₂ /m ² ·year] -

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.

	kgCO ₂ /m ² ·year	kgCO ₂ ·year
CO2 emissions from electricity consumption	3.39	394.94
CO2 emissions from other fuels	0.00	0.00

2. 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	
	HEATING	DHW
	Primary energy heating [kWh/m ² ·year] 3.87	DHW Primary energy [kWh/m ² ·year] 8.6
Global consumption of non-renewable primary energy[kWh/m ² ·year] ¹	COOLING	LIGHTING
	Primary energy cooling [kWh/m ² ·year] 7.57	Primary energy lighting [kWh/m ² ·year] -

3. 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.

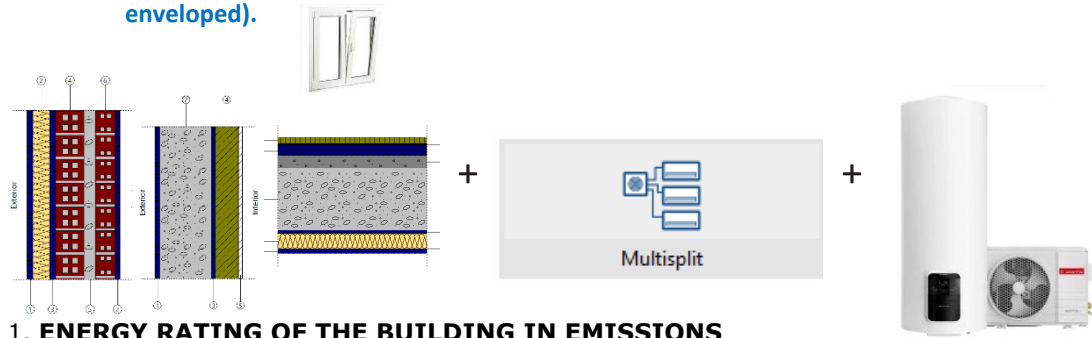
5.

HEATING DEMAND	COOLING DEMAND

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: Improved envelope 10 cm Insolation + H & AC direct expansion multisplit System + DHW heat pump. (Case 3 by with 10 cm of insulation layer in the enveloped).



1. ENERGY RATING OF THE BUILDING IN EMISSIONS

GLOBAL INDICATOR	PARTIAL INDICATORS	
 Global emissions [kgCO ₂ /m ² ·year] ¹	HEATING	
	Heating emissions [kgCO ₂ /m ² ·year] 0.55	DHW DHW emissions [kgCO ₂ /m ² ·year] 2.43
Global emissions [kgCO ₂ /m ² ·year] ¹	COOLING	
	Cooling emissions [kgCO ₂ /m ² ·year] 1.03	LIGHTING Lighting emissions [kgCO ₂ /m ² ·year] -

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	4.00	465.88
CO2 emissions from other fuels	0.00	0.00

2. 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	
 Global consumption of non-renewable primary energy [kWh/m ² ·year] ¹	HEATING	
	Primary energy heating [kWh/m ² ·year] 3.22	DHW DHW Primary energy [kWh/m ² ·year] 14.32
Global consumption of non-renewable primary energy [kWh/m ² ·year] ¹	COOLING	
	Primary energy cooling [kWh/m ² ·year] 6.09	LIGHTING Primary energy lighting [kWh/m ² ·year] -

3. 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
 Heating demand [kWh/m ² ·year] 5.60 A	 Cooling demand [kWh/m ² ·year] 9.41 A

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.

