

Energy demand

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Energy demand

1.- ENERGY DEMAND CALCULATION SUMMARY.

The table below summarises the results obtained for the calculation of the heating and cooling energy demand of each occupied zone, as well as the total energy demand of the building.

Habitable zones	S_u (m ²)	D_{heat}		D_{cool}	
		(kWh/year)	(kWh/m ² ·year)	(kWh/year)	(kWh/m ² ·year)
Offices - South	189.33	462.75	2.44	9809.41	51.81
Offices - North	143.72	720.49	5.01	7748.66	53.91
Cafeteria	50.51	81.11	1.61	1984.31	39.28
Unconditioned	57.53	-	-	-	-
	441.10	1264.36	2.87	19542.38	44.30

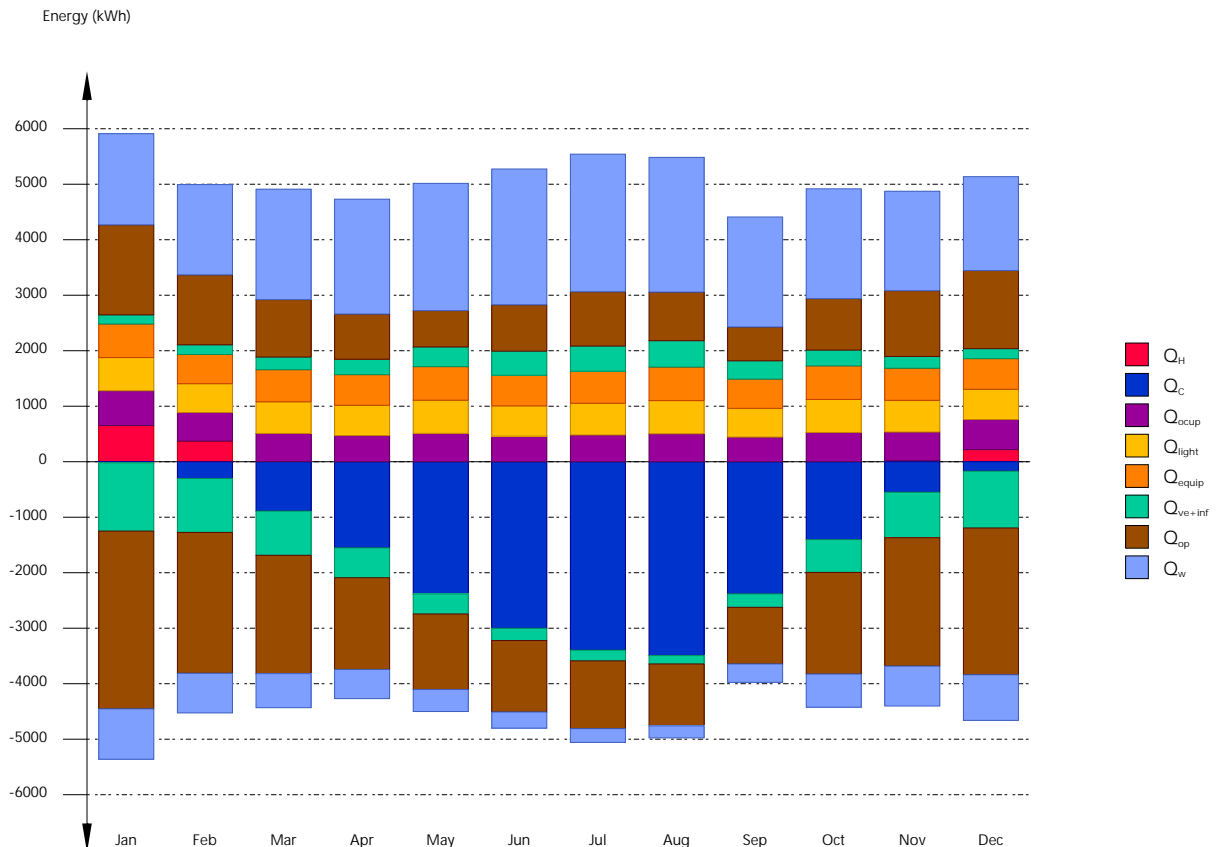
where:

- S_u : Useful surface area of the habitable zone, m².
- D_{heat} : Calculated value of the heating energy demand, kWh/m²·year.
- D_{cool} : Calculated value of the cooling energy demand, kWh/m²·year.

2.- MONTHLY RESULTS.

2.1.- Annual energy balance of the building.

The following bar chart shows the energy balance of the building for each month, taking into account the energy lost or gained due to thermal transmission via opaque and light elements (Q_{op} and Q_w , respectively), the energy interchange due to ventilation and infiltrations (Q_{ve+inf}), the gain in heat due to occupancy (Q_{occup}), lighting (Q_{light}) and internal equipment (Q_{equip}) as well as the necessary heating (Q_H) and cooling (Q_C) inputs.



The following table displays the numerical values of the preceding bar chart, the energy balance of the whole building, as the sum of the energy involved in the energy balance of each thermal zone of the building calculation model.

The sign criteria adopted consists of using positive values for energy contributed to the zone and negative

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values for energy that is extracted.

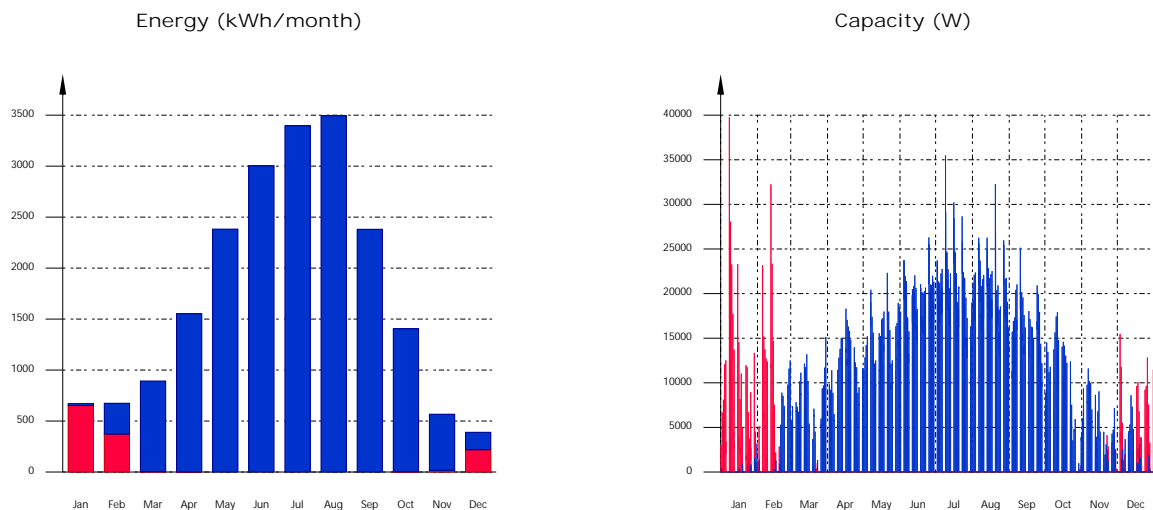
	Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m ² .year)
Annual energy balance of the building.														
Q_{op}	1622.1	1260.6	1035.4	813.4	655.6	836.0	979.2	875.7	609.2	927.7	1185.1	1407.8	-10111.35	-22.92
Q_w	1642.3	1626.4	1989.5	2070.3	2292.4	2446.3	2478.0	2427.5	1981.9	1978.4	1791.7	1691.9	18037.02	40.89
Q_{ve+inf}	165.3	174.7	227.9	278.2	355.0	434.4	453.5	475.3	331.1	284.5	212.8	180.1	-3571.47	-8.10
Q_{equip}	-1231.6	-971.2	-797.3	-539.3	-361.9	-220.2	-192.6	-151.5	-243.3	-591.8	-819.6	-1023.7		
Q_{light}	604.6	525.8	578.3	552.0	604.6	552.0	578.3	604.6	525.8	604.6	578.3	552.0	6861.18	15.55
Q_{occup}	596.9	519.1	571.0	545.0	596.9	545.0	571.0	596.9	519.1	596.9	571.0	545.0	6773.70	15.36
Q_{occup}	627.4	515.6	505.9	471.7	511.3	461.1	481.8	504.1	443.0	523.8	518.2	541.7	6105.64	13.84
Q_H	652.2	371.6	3.2	0.1	--	--	--	--	--	2.0	16.9	218.5	1264.36	2.87
Q_C	-19.3	-302.9	-889.3	-1551.4	-2382.6	-3002.5	-3396.1	-3493.4	-2380.8	-1403.0	-550.0	-171.1	-19542.38	-44.30
Q_{HC}	671.5	674.4	892.5	1551.5	2382.6	3002.5	3396.1	3493.4	2380.8	1404.9	566.8	389.6	20806.74	47.17

where:

- Q_{op} : Energy transfer corresponding to the thermal transmission across opaque elements of the envelope, kWh/m².year.
- Q_w : Energy transfer corresponding to the thermal transmission across light elements of the envelope, kWh/m².year.
- Q_{ve+inf} : Energy transfer corresponding to the thermal transmission due to ventilation, kWh/m².year.
- Q_{equip} : Energy transfer corresponding to the internal heat gain due to internal equipment, kWh/m².year.
- Q_{light} : Energy transfer corresponding to the internal heat gain due to lighting, kWh/m².year.
- Q_{occup} : Energy transfer corresponding to the internal heat gain due to internal occupancy, kWh/m².year.
- Q_H : Heating energy input, kWh/m².year.
- Q_C : Cooling energy input, kWh/m².year.
- Q_{HC} : Heating and cooling energy input, kWh/m².year.

2.2.- Monthly heating and cooling energy demand.

Attending only to the energy demand to be covered by the heating and cooling systems, the energy and instantaneous net power requirements throughout the year are shown below:

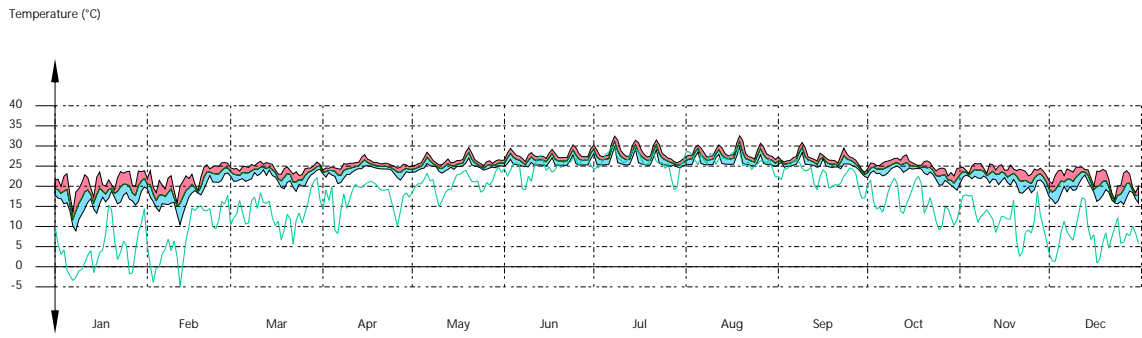


2.3.- Temperature evolution.

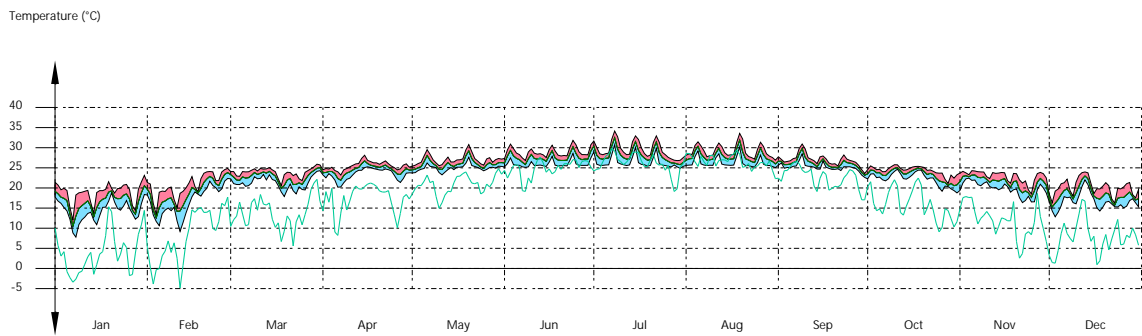
The evolution of the internal operative temperature of the modelled zones of the building is shown in the following graphs, which display the evolution of the minimum, maximum and average temperatures of each day in each zone:

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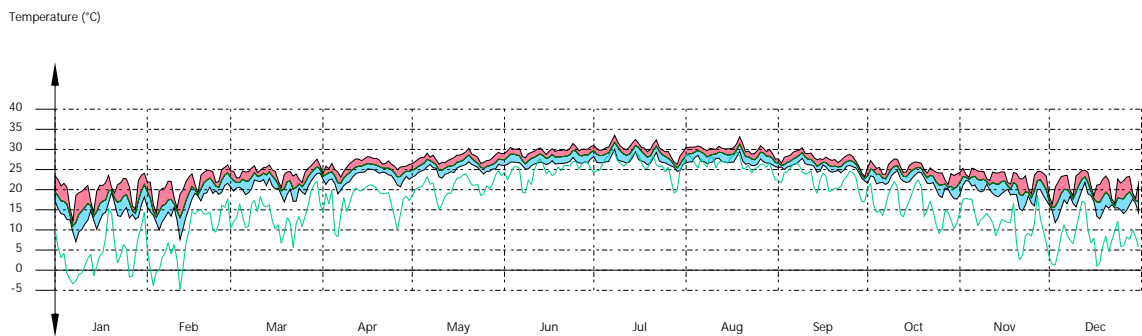
Offices - South



Offices - North

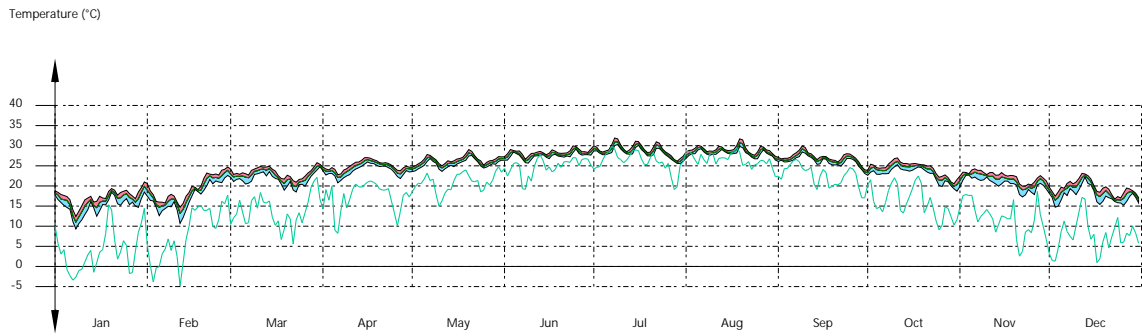


Cafeteria

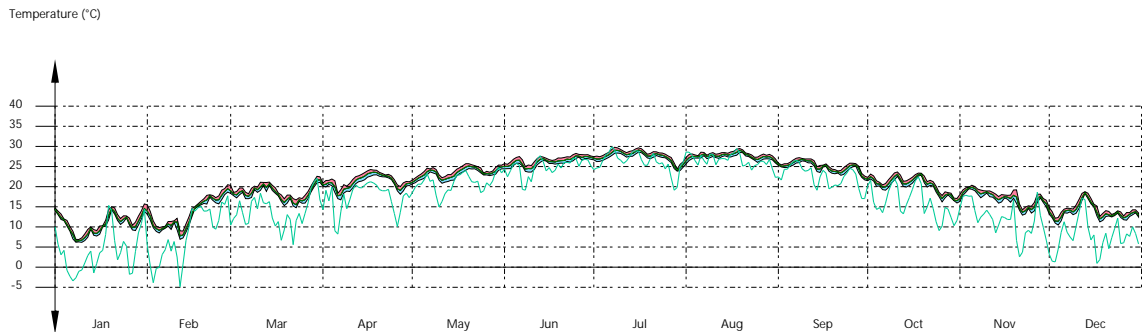


Unconditioned

Energy demand



Unoccupied



2.4.- Numerical results of the energy balance per zone and per month.

The following table shows the results of the total heat transferred by transmission and ventilation, the total internal heat, and the energy required for heating and cooling for each calculation zone of the building.

The sign criteria adopted consists of using positive values for energy contributed to the zone and negative values for energy that is extracted.

	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/m ² .year)
Offices - South ($A_v = 189.33 \text{ m}^2$; $V = 643.14 \text{ m}^3$)														
Q_{op}	573.3	449.9	359.9	282.1	231.4	352.2	446.2	403.9	237.9	334.5	424.0	513.1	-6474.41	-34.20
	-1826.9	-1401.1	-1100.5	-759.0	-528.0	-428.8	-408.0	-380.8	-430.2	-980.6	-1297.0	-1542.0		
Q_w	1141.3	1048.5	1090.2	965.7	944.8	969.4	995.1	1036.7	967.7	1180.3	1175.7	1175.3	10276.18	54.28
	-355.5	-277.9	-233.6	-193.6	-140.6	-98.5	-83.1	-73.2	-121.5	-230.5	-280.8	-325.5		
Q_{ve+inf}	86.5	92.3	122.0	141.1	175.2	192.6	203.2	211.5	161.0	149.0	114.0	95.6	-409.78	-2.16
	-376.2	-310.9	-236.3	-156.4	-98.7	-61.1	-49.8	-36.5	-69.1	-180.8	-247.5	-330.3		
Q_{equip}	319.0	277.4	305.1	291.3	319.0	291.3	305.1	319.0	277.4	319.0	305.1	291.3	3620.17	19.12
Q_{light}	306.6	266.6	293.2	279.9	306.6	279.9	293.2	306.6	266.6	306.6	293.2	279.9	3478.90	18.37
Q_{occup}	187.6	156.5	154.8	145.3	158.4	144.0	150.6	157.5	137.5	161.3	156.2	161.9	1871.54	9.88
Q_H	249.9	142.7	0.7	--	--	--	--	--	--	0.4	2.2	66.9	462.75	2.44
Q_C	-14.2	-197.8	-504.0	-758.1	-1108.2	-1404.8	-1610.1	-1688.3	-1202.6	-795.5	-393.0	-132.9	-9809.41	-51.81
Q_{HC}	264.1	340.5	504.7	758.1	1108.2	1404.8	1610.1	1688.3	1202.6	796.0	395.1	199.8	10272.16	54.25
Offices - North ($A_v = 143.72 \text{ m}^2$; $V = 485.51 \text{ m}^3$)														
Q_{op}	558.8	447.9	377.1	312.7	271.1	378.7	439.1	392.9	254.7	341.0	421.8	495.0	-2562.56	-17.83
	-1026.4	-832.1	-717.6	-581.5	-494.4	-485.1	-448.0	-368.2	-295.7	-527.8	-701.4	-775.0		

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	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)
Q_w	278.3	358.5	606.4	791.3	991.0	1092.3	1096.4	1014.8	718.1	519.4	369.6	287.1	5372.34	37.38
	-383.0	-302.0	-264.4	-231.5	-178.2	-132.8	-114.7	-98.4	-145.4	-254.3	-303.6	-342.6		
Q_{ve+inf}	75.4	75.4	96.2	108.7	132.7	143.2	151.0	158.1	121.9	115.1	92.1	81.7	-375.12	-2.61
	-274.3	-236.3	-195.1	-138.7	-96.7	-65.2	-54.0	-38.8	-61.5	-140.9	-185.2	-240.0		
Q_{equip}	285.6	248.4	273.2	260.8	285.6	260.8	273.2	285.6	248.4	285.6	273.2	260.8	3241.01	22.55
Q_{light}	232.7	202.4	222.6	212.5	232.7	212.5	222.6	232.7	202.4	232.7	222.6	212.5	2640.82	18.37
Q_{occup}	116.5	94.8	92.0	85.6	93.2	84.6	88.5	92.6	81.0	95.6	95.9	102.7	1123.00	7.81
Q_H	363.4	206.5	1.2	--	--	--	--	--	--	0.7	11.4	137.3	720.49	5.01
Q_C	--	-70.8	-292.6	-628.1	-1024.4	-1292.2	-1453.0	-1461.2	-942.8	-462.7	-100.2	-20.5	-7748.66	-53.91
Q_{HC}	363.4	277.3	293.8	628.1	1024.4	1292.2	1453.0	1461.2	942.8	463.4	111.5	157.8	8469.15	58.93

Cafeteria ($A_t = 50.51 \text{ m}^2$; $V = 171.90 \text{ m}^3$)

Q_{op}	217.5	158.4	118.8	90.5	67.4	51.3	44.8	39.1	53.3	106.5	146.8	179.6	-1635.33	-32.37
	-289.2	-239.7	-239.5	-241.3	-263.3	-262.7	-252.8	-237.5	-194.4	-215.2	-228.9	-244.9		
Q_w	76.8	95.9	167.9	219.3	277.5	307.4	306.9	283.0	197.9	140.7	103.2	78.3	1345.30	26.63
	-127.6	-99.9	-86.0	-74.8	-58.4	-44.5	-38.3	-34.1	-48.0	-82.8	-99.8	-115.3		
Q_{ve+inf}	--	1.3	2.9	15.0	28.6	58.3	62.8	66.4	33.4	12.6	0.9	0.2	-933.13	-18.47
	-238.7	-172.8	-137.9	-85.2	-56.7	-29.1	-26.2	-21.8	-32.1	-92.7	-144.5	-177.8		
Q_{equip}	--	--	--	--	--	--	--	--	--	--	--	--	0.00	0.00
Q_{light}	35.6	30.9	34.0	32.5	35.6	32.5	34.0	35.6	30.9	35.6	34.0	32.5	403.42	7.99
Q_{occup}	323.2	264.3	259.2	240.8	259.7	232.5	242.8	254.0	224.6	267.0	266.0	277.1	3111.10	61.59
Q_H	38.9	22.4	1.3	0.1	--	--	--	--	--	0.9	3.3	14.3	81.11	1.61
Q_C	-5.0	-34.3	-92.8	-165.2	-250.0	-305.5	-333.1	-343.8	-235.5	-144.7	-56.8	-17.7	-1984.31	-39.28
Q_{HC}	43.9	56.6	94.0	165.3	250.0	305.5	333.1	343.8	235.5	145.6	60.2	32.0	2065.42	40.89

Unconditioned ($A_t = 57.53 \text{ m}^2$; $V = 246.23 \text{ m}^3$)

Q_{op}	165.6	125.3	104.8	64.9	39.6	19.8	16.1	13.3	23.9	76.3	112.6	125.3	-122.56	-2.13
	-57.1	-63.4	-71.5	-65.5	-67.7	-99.5	-100.9	-118.8	-95.4	-105.2	-84.3	-80.9		
Q_w	146.0	123.5	125.0	94.0	79.1	77.2	79.7	93.0	98.2	138.0	143.2	151.3	1043.20	18.13
	-42.4	-33.7	-29.5	-25.5	-19.1	-14.1	-12.3	-10.6	-16.2	-29.1	-33.9	-38.6		
Q_{ve+inf}	0.0	0.3	0.9	3.6	6.9	23.7	21.2	25.0	7.1	2.2	0.4	0.0	-1167.80	-20.30
	-234.0	-170.2	-150.3	-91.4	-59.7	-25.9	-24.6	-23.4	-37.5	-104.4	-159.3	-178.6		
Q_{equip}	--	--	--	--	--	--	--	--	--	--	--	--	0.00	0.00
Q_{light}	22.1	19.2	21.1	20.2	22.1	20.2	21.1	22.1	19.2	22.1	21.1	20.2	250.56	4.36
Q_{occup}	--	--	--	--	--	--	--	--	--	--	--	--	0.00	0.00

Unoccupied ($A_t = 18.54 \text{ m}^2$; $V = 98.83 \text{ m}^3$)

Q_{op}	106.9	79.1	74.7	63.2	46.0	33.9	33.1	26.5	39.3	69.3	79.8	94.8	683.51	36.88
	-1.9	-2.7	-3.0	-5.4	-6.9	-11.5	-10.6	-10.0	-4.6	-2.8	-2.5	-1.1		
Q_{ve+inf}	3.4	5.3	5.9	9.8	11.6	16.6	15.3	14.2	7.7	5.5	5.4	2.7	-685.64	-36.99
	-108.3	-81.1	-77.6	-67.7	-50.2	-38.9	-38.0	-30.9	-43.2	-72.9	-83.2	-97.0		
Q_{equip}	--	--	--	--	--	--	--	--	--	--	--	--	0.00	0.00
Q_{light}	--	--	--	--	--	--	--	--	--	--	--	--	0.00	0.00
Q_{occup}	--	--	--	--	--	--	--	--	--	--	--	--	0.00	0.00

where:

- A_t : Net surface area of the thermal zone, m².
- V : Internal net volume of the thermal zone, m³.
- Q_{op} : Energy transfer corresponding to the thermal transmission across opaque elements of the envelope, kWh/m²·year.
- Q_w : Energy transfer corresponding to the thermal transmission across light elements of the envelope, kWh/m²·year.
- Q_{ve+inf} : Energy transfer corresponding to the thermal transmission due to ventilation, kWh/m²·year.
- Q_{equip} : Energy transfer corresponding to the internal heat gain due to internal equipment, kWh/m²·year.
- Q_{light} : Energy transfer corresponding to the internal heat gain due to lighting, kWh/m²·year.
- Q_{occup} : Energy transfer corresponding to the internal heat gain due to internal occupancy, kWh/m²·year.
- Q_H : Heating energy input, kWh/m²·year.
- Q_C : Cooling energy input, kWh/m²·year.
- Q_{HC} : Heating and cooling energy input, kWh/m²·year.

Energy demand

3.- DESIGN MODEL OF THE BUILDING.

3.1.- Space groups.

Shown below are the characteristics of the spaces of each calculation zone of the building.

	S (m ²)	V (m ³)	h (%)	ren _h (1/h)	SO _{occup,s} (kWh/year)	SO _{occup,l} (kWh/year)	SO _{equip,s} (kWh/year)	SO _{equip,l} (kWh/year)	SO _{light} (kWh/year)	T ^s heat. Average (°C)	T ^s cool. Average (°C)
Offices - South (Occupied zone)											
Hall	57.59	197.43	70.00	0.58	829.8	553.2	649.4	--	1058.3	20.0	24.0
Office 1	13.92	47.38	70.00	0.45	113.4	75.6	313.9	--	255.8	20.0	24.0
Meeting room	33.14	112.79	70.00	0.45	269.9	179.9	747.4	--	609.0	20.0	24.0
Office 3	16.75	57.02	70.00	0.45	136.4	91.0	377.8	--	307.8	20.0	24.0
Meeting room 2	33.14	110.85	70.00	0.46	269.9	179.9	747.4	--	609.0	20.0	24.0
Office 7	16.75	57.02	70.00	0.45	136.4	91.0	377.8	--	307.8	20.0	24.0
Office 10	18.02	60.66	70.00	0.45	146.8	97.8	406.4	--	331.1	20.0	24.0
	189.33	643.14	70.00	0.47/0.24 [*]	1902.6	1268.4	3620.2	--	3478.9	20.0	24.0

Offices - North (Occupied zone)											
Office 2	31.34	106.67	70.00	0.45	255.2	170.2	706.8	--	575.9	20.0	24.0
Office 4	21.85	74.36	70.00	0.45	178.0	118.6	492.8	--	401.5	20.0	24.0
Office 5	31.34	105.75	70.00	0.45	255.2	170.2	706.8	--	575.9	20.0	24.0
Office 6	21.85	73.87	70.00	0.45	178.0	118.6	492.8	--	401.5	20.0	24.0
Office 8	17.87	59.78	70.00	0.46	145.6	97.0	403.1	--	328.4	20.0	24.0
Office 9	19.46	65.07	70.00	0.46	158.4	105.6	438.7	--	357.5	20.0	24.0
	143.72	485.51	70.00	0.45/0.25 [*]	1170.4	780.2	3241.0	--	2640.8	20.0	24.0

Cafeteria (Occupied zone)											
Dining room	50.51	171.90	70.00	5.40	3796.9	2531.3	--	--	403.4	20.0	24.0
	50.51	171.90	70.00	5.40/1.37 [*]	3796.9	2531.3	--	--	403.4	20.0	24.0

Unconditioned (Occupied zone)											
WC gf	5.34	18.16	--	2.97	--	--	--	--	--	--	--
Corridor	13.16	62.15	--	0.53	--	--	--	--	83.5	--	--
WC 1f	5.34	18.16	--	2.97	--	--	--	--	--	--	--
Corridor 2	13.16	62.15	--	0.53	--	--	--	--	83.5	--	--
WC 2f	5.34	18.16	--	2.97	--	--	--	--	--	--	--
Corridor 3	10.79	52.66	--	0.52	--	--	--	--	83.5	--	--
WC 3f	4.42	14.77	--	3.66	--	--	--	--	--	--	--
	57.53	246.23	--	2.02/0.34 [*]	--	--	--	--	250.6	--	--

Unoccupied (Non-occupied zone)											
Lift	2.35	8.71	--	0.50	--	--	--	--	--	--	--
Risers	1.41	5.21	--	0.50	--	--	--	--	--	--	--
Lift	--	8.71	--	0.50	--	--	--	--	--	--	--
Risers	--	5.21	--	0.50	--	--	--	--	--	--	--
Lift	--	8.71	--	0.50	--	--	--	--	--	--	--
Risers	--	5.21	--	0.50	--	--	--	--	--	--	Free oscillation
Lift	--	7.78	--	0.50	--	--	--	--	--	--	--
Risers	--	4.75	--	0.50	--	--	--	--	--	--	--
Stairs	6.68	22.36	--	0.50	--	--	--	--	--	--	--
Technical room	8.09	22.18	--	1.00	--	--	--	--	--	--	--
	18.54	98.83	--	0.55	--	--	--	--	--	--	--

where:

S: Useful interior surface area of the space, m².

Energy demand

V:	Internal net volume of the space, m ³ .
h:	Thermal efficiency of the heat recovery ventilator, %.
ren _n :	Number of air changes of the space per hour.
*:	Average value of the number of renewals per hour of the air of the residential zone, including the calculated infiltrations.
Q _{occup,s} :	Sum of the sensible internal heat gain due to occupancy of the space throughout the year, kWh/year.
Q _{occup,l} :	Sum of the latent internal heat gain due to occupancy of the space throughout the year, kWh/year.
Q _{equip,s} :	Sum of the sensible internal heat gain due to equipment in the space throughout the year, kWh/year.
Q _{equip,l} :	Sum of the latent internal heat gain due to equipment in the space throughout the year, kWh/year.
Q _{light} :	Sum of the internal heat gain due to lighting of the space throughout the year, kWh/year.
T ^o heat.	Average value of the heating temperature during the operation intervals, °C.
Average:	
T ^o cool.	Average value of the cooling temperature during the operation intervals, °C.
Average:	