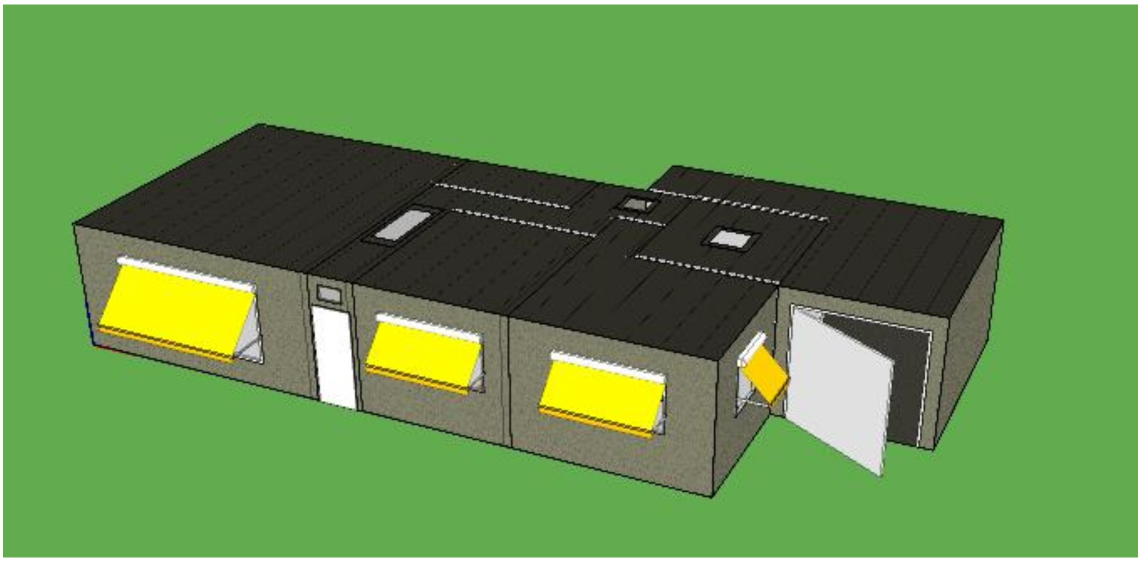
KTH Industrial Engineering
and Management

Design and analysis of a nZEB with IDA ICE.

Hector Parra Molina



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Approved Date	Examiner Joachim Claesson	Supervisor Joachim Claesson
	Commissioner	Contact person

Abstract

Recently, the environmental policy makers have realized that the building sector is the largest end-use sector with a significant percentage of the environmental load of human activities. Moreover, according to official sources, it is necessary a reduction in the building sector of 88-91% of greenhouse gas emissions in order to achieve the goals established by the European Roadmap 2050. That is why laws such as the Directive 2010/31/EU are coming up. That directive says that all member states shall ensure that all new buildings are near zero energy buildings (nZEB) by December 31st, 2019. Therefore, the aim of this master thesis is the design of a nZEB in different climate zones around Spain. All near zero energy buildings designed meet the requirements established by the Spanish technical building code (CTE). In regard to the supply system, a facility is developed by means of IDA ICE consisting of a heat pump connected to an outdoor pool and a ground heat exchanger. The operation of the ground heat exchanger will depend on the temperature of the swimming pool. Finally, it is explained if the swimming pool can work as a heat source for each location studied.

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1 SCOPE OF THIS MASTER THESIS.

This project entails all processes to elect and build the best option for a nZEB, analysing all the parameters that are quite determinant for the characterisation of a house with a very low consumption. In this case, it will be designed a nZEB for a typical Spanish family, composed by a father, a mother and one child. The building will be a single house of 97.1 m^2.

In existing highly efficient building concepts, the high level of insulation, efficient windows, high level of airtightness and balanced mechanical ventilation are typically combined with passive and active solar measures and other renewable energy sources.

Therefore, the main goals during the development of this master thesis are the design of the nZEB in different climate zones around Spain, where not only the active and passive measures are implemented but also the building has to accomplish the Spanish legislation requirements, and the development of the supply system by means of IDA ICE. That supply system consists of a heat pump connected to the swimming pool and the ground heat exchanger. The operation of the ground heat exchanger will depend on the swimming pool temperature.

In the end, the final results of the energy balance for each option are exposed, and it is explained if the supply system and the use of the swimming pool as the heat source is possible or not.

2 ENERGY CONTEXT

In Europe, the built environment accounts for more than 40% of the current total primary energy consumption, 36% of the overall CO2 emissions and approximately 44% of the total material used, which means a significant percentage of the total environmental load of human activities and makes the building sector the largest end-use sector in Europe (Brambilla *et al.*, 2016). As a consequence, the assessment of the impact of the building sector is a priority for the achievement of a sustainable society and it is an issue commonly addressed by most environmental policies. The energy upgrade of the building sector produces multiple benefits such as reduced energy consumption, which is consistent with the reduction of air pollution. Additionally, there has been a significant enhancement in the internal comfort conditions of the building, which promotes occupant health and productivity.

In the context of the environmental policy, the Climate-Energy Framework 2020 sets three key goals to cut back a 20% in green gas emissions (compared to 1990 levels), to augment the EU renewables share by 20% and enhance the energy efficiency by 20% (The European Commission, 2010). The principal instrument to reach those goals in the building sector is the Energy Performance of Building Directive (EPBD) that sets the standards for new and renovated buildings across Europe (Attia *et al.*, 2019).

Recent goals have been established by the 2030 Climate & Energy framework. This package fixes the reduction of greenhouse gas emissions at 40% from 1990 levels, the share for renewable energy at 32% and the improvement in energy efficiency at 32.5% (The European Commission, 2018). In the end, the European Roadmap 2050 aims at decreasing the greenhouse gas emissions by at least 80% by 2050 compared to 1990 levels (The European Commission, 2012). As the building sector has been appointed as one of the key sectors for cost-efficient savings, at least 88–91% reduction of greenhouse gas emissions is necessary in the building sector in order to reach that challenging goal (BPIE, 2011). Therefore, the 2050 goal will only be reached if the primary energy use of both the new buildings and the extant building stock is decreased, and the renewable energy sources take more presence in the energy supply systems. However, the 88–91% reduction cannot be guaranteed in the extant building stock, which means that new buildings, which still have to be built by 2050, must compensate with much larger reductions (Szalay and Zöld, 2014).

3 WHAT IS A NEARLY ZERO ENERGY BUILDING BY EUROPEAN UNION?

The *Directive 2010/31/EU* is the referent law for the energy efficiency in buildings, and it establishes that each member state must define a near zero energy building, following a provided general definition:

“Nearly-zero energy building means a building that has a very high energy performance. The near zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby” (The European Parliament, 2010).

The design process entails an integrative approach focusing on (Attia *et al.*, 2019):

- The reduction of energy needs for heating and cooling by optimising the envelope and integrating passive heating and cooling techniques.
- Improvement of energy efficiency of active systems.
- And the incorporation of renewable energy.

Furthermore, it is necessary to differentiate between nearly Zero Energy Building (nZEB) and the Net Zero Energy Building (NZEB), which refers to a building with an energy balance close to zero on an annual basis. In the latter one, the total annual energy used by the building is approximately equal to the renewable energy generated on-site or off-site (Zero Energy Buildings, 2014).

On the other hand, as it is included in the *Directive 2010/31/EU*, the actions to enhance the buildings' energy efficiency must consider the comfort conditions, the weather and the profitability in terms of the cost-effectiveness of envelope elements and the equipment installed at the building.

In many countries, the maximum primary energy (kWh/m^2 year) is assumed the main indicator for the nZEB definition. With the objective of having unified data, comparable among them, the member states have to apply the ISO 52000-1 norm. This norm establishes a common methodology in the European Union and will define the various indicators that nZEB needs to accomplish.

Moreover, the Directive establishes that on the 31st of December 2018, all the new buildings, properties of public authorities, must be near zero energy buildings. It also establishes that on 31st of December 2020, all new buildings must be near zero energy buildings (The European Parliament, 2010).

Projecting the 2020 prices and technologies, benchmarks for the energy performance of NZEB are in the following ranges for the different EU climatic zone (The European Commission, 2016).

	Reference values established by the European Commission		
	Primary energy use (kWh/m2)	Net Primary energy (kWh/m2)	On-site Renewable Energy (kWh/m2)
	Mediterranean Zone		
Offices	80-90	20-30	60
New Single Family	50-65	0-15	50-65
	Oceanic Zone		
Offices	85-100	40-55	45
New Single Family	50-65	15-30	35
	Continental Zone		
Offices	85-100	40-55	45
New Single Family	50-65	15-30	35
	Nordic Zone		
Offices	85-100	55-70	30
New Single Family	65-90	40-65	25

Table 1: Reference values established by the European Commission.

4 WHAT IS A NEARLY ZERO ENERGY BUILDING BY SPANISH LEGISLATION?

In Spain, the legislation related to energy efficiency has suffered great modifications during the past years. But, the first law on energy efficiency was the *Royal Decree 47/2007* and it laid the foundations of all the laws that would come later (efENERGIA, 2019).

The *Directive 2010/31/EU*, related to energy efficiency in buildings, establishes a periodical review, in time intervals not exceeding 5 years, of the requirements for energy efficiency (The European Parliament, 2010). That was why the Spanish government transposed the Directive 2010/31/EU by the *Royal Decree 235/2013.*

The first time the nZEB concept appeared was in The *Royal Decree 235/2013* but there was nothing written about what requirements a building had to meet to be considered nZEB. Therefore, as the Directive 2010/31/EU was partially transposed by the Spanish government, the *Royal Decree 235/2013* was modified by the *Royal Decree 564/2017* and it says: "The requirements that must be fulfilled by the nZEB will be those that at each moment are determined in the technical building code" (BOE, 2017).

The Technical Building Code, CTE in Spanish, is the regulatory framework that regulates the basic quality requirements for the buildings, including their facilities, in order to satisfy the basic requirements of safety and habitability (CTE, 2013). In regard to energy efficiency, there is a Basic Document "DB-HE Energy Saving" that specifies objective parameters and procedures whose compliance ensures the satisfaction of the basic requirements and the exceeding of the minimum quality levels of the basic requirement of energy saving (CTE, 2013). This Basic Document has been modified at the end of 2018 and it establishes the minimum requirements that the nZEB must meet.

During the following paragraph, it is displayed the requirements settled by the Technical Building Code but only the requirements related to the residential sector.

First of all, the Basic Document "DB-HE Energy Saving" is divided into six sections, these sections are explained below.

HE0: Limitation of the energy consumption.

The energy consumption of buildings will be limited according to the climate zone of their location, use of the building and, in the case of existing buildings, the scope of the intervention. Energy consumption will be largely satisfied by the use of energy from renewable sources (CTE, 2018).

- Non-renewable primary energy consumption $C_{ep,nren}$:

	Winter Climate Zone					
	α	A	B	C	D	E
New Buildings and Extensions	20	25	28	32	38	43
Changes of use to residential private and reforms	40	50	55	65	70	80

*Table 2: Limit Value (kWh/m2*year)*

Important note: peninsular climate zones correspond to the combination of a winter climatic severity (α , A, B, C, D or E) together with a summer climatic severity (1, 2, 3, or 4)

- Total primary energy Consumption $C_{ep,Tot}$:

	Winter Climate Zone					
	α	A	B	C	D	E
New Buildings and Extensions	40	50	56	64	76	86
Changes of use to residential private and reforms	55	75	80	90	105	115

*Table 3: Limit Value (kWh/m2*year)*

<u>HE1: Conditions for the control of energy demand.</u>

The buildings will have a thermal envelope with different characteristics, which limit the needs of primary energy to achieve thermal well-being, depending on the climatic zone of its location, the summer and winter regime, the use of the building and, in the case of existing buildings, the scope of the intervention (CTE, 2018).

Conditions of the thermal envelope:

- Transmittance of the thermal envelope:
    - Thermal transmittance (U) of each element:

	Winter Climate Zone					
	α	A	B	C	D	E
Walls and floors in contact with external air (US, UM) Walls, floors and roofs in contact with uninhabitable spaces (UNH) or terrain (UT) Party walls (UMD)	1.35	1.25	1	0.75	0.6	0.55
Roofs in contact with the outside air (UC)	1.2	0.8	0.65	0.5	0.4	0.35
Holes (frame and glass set) (UH)	4	4	3.2	2.7	2.3	1.8

Table 4: Limit Value of thermal transmittance, Ulim (W/m²K)

- Overall coefficient of heat transfer (K):

	Winter Climate Zone					
Compactness V/A (m^3/m^2)	α	A	B	C	D	E
V/A <= 1	0.67	0.6	0.58	0.53	0.48	0.43
V/A >=4	0.86	0.8	0.77	0.72	0.67	0.62

Table 5: Limit Value of Overall Coefficient of Heat Transfer, Klim (W/m^2K)

- Solar control of the envelope:

Sector	Qsol,July
Residential	2

*Table 6: Limit value of Solar Control (kWh/ m^2*month)*

- Air permeability of the thermal envelope:

	Winter Climate Zone					
	α	A	B	C	D	E
Air permeability of holes ($Q_{100,lim}$)	<= 27	<= 27	<= 27	<= 9	<= 9	<= 9

*Table 7: Limit value Q100 (m3/h*m2)*

- Limitation of decompensations:
  - Thermal transmittance (U) of internal walls:

		Winter Climate Zone					
	Type of partitions	α	A	B	C	D	E
Between spaces of the same usage.	Horizontal	1.9	1.8	1.55	1.35	1.2	1
	Vertical	1.4	1.4	1.2	1.2	1.2	1
Between spaces of different usage.	Horizontal and vertical	1.35	1.25	1.1	0.95	0.85	0.7

Table 8: Limit value of U (W/m^2K)

HE2: Conditions of thermal installations.

The thermal installations of the buildings will be appropriate to achieve the thermal well-being of its occupants. This requirement is currently developed in the Regulation on Thermal Installations in Buildings (RITE in Spanish), and its application will be defined in the building project (CTE, 2018).

HE3: Conditions of lighting installations.

The buildings will have lighting facilities adapted to the needs of their users and at the same time energy-efficient by having a control system enabling the switching-on to be adjusted to the actual occupation of the area, as well as a regulation system that optimizes the use of natural light, in areas that meet certain conditions (CTE, 2018).

Nevertheless, this section is not applicable to the residential sector. Therefore the residential buildings do not need to accomplish the requirements appointed in the section HE3.

HE4: Minimum energy contribution by renewable energy to supply the Sanitary Hot Water (SHW).

Buildings will meet your ACS or indoor pool heating needs by largely using energy from renewable sources, cogeneration processes or residual energy sources from the installation of heat recovery outside the building's own thermal installation; either in the building itself or through the connection to an urban network (district heating or cooling) (CTE, 2018).

In this case, it is important to point out that this section is only for the buildings with a SHW demand higher than 100 l/day.

For that kind of buildings, the minimum energy contribution by renewable energy must be at least 50% of the SHW demand.

HE5: Minimum production of electrical energy.

This section applies to buildings with different use to the private residential where electric power generation systems will be incorporated using renewable sources for own use or supply to the network (CTE, 2018).

5 CURRENT SITUATION OF NZEB IN EU.

As it is mentioned before, The European legislation (Energy Performance of Buildings Directive) makes nearly Zero-Energy Buildings (nZEBs) a standard by 2020. The technology is already available and proven; however, the large-scale uptake of nZEB construction and renovation will be a great challenge for all stakeholders and market actors implicated. There is a difficulty in evaluating the success of policies and measures proposed by the policy-makers due to the significant gap in reliable data on current market activities. Thus, *ZEBRA2020* monitors the market uptake of nZEBs across Europe and provides data on how to reach the nZEB standard (ZEBRA2020, 2016).

First of all, the following picture shows in which level of development the nZEB definitions are depending on the European country.

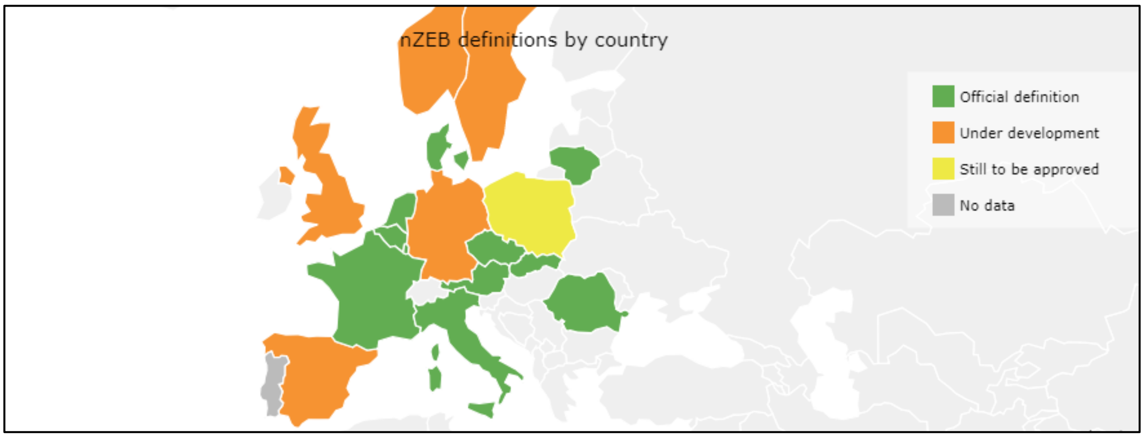


Image 1: nZEB definitions by country by 2014. Source: www.zebra-monitoring.enerdata.eu

The French government has an official definition where it is considered that its nZEB definition matches the present regulation RT2012. For new residential buildings the RT 2012 requires a primary energy consumption lower than 50 kWh/m2/year. For new non-residential buildings, a primary energy consumption lower than 70 kWh/m2/year for buildings without air-conditioning, and 110 kWh/m2/year for buildings with air-conditioning. Then, since the 1st of January 2013, all new constructions are nZEBs in France (ZEBRA2020, 2014).

In regard to Italy, the nZEB has to accomplish the energy requirements defined by the decree D.M 26 of June 2015, which came into effect in October 2015.

Moreover, it is important to highlight that the colour of Spain should be green as well as France, because the Spanish government released the new Basic Document “Energy Saving” where the requirements of nZEB are established and approved in 2018.

Secondly, it is shown the distribution of new constructed dwellings in the year 2014 according to different building standards.

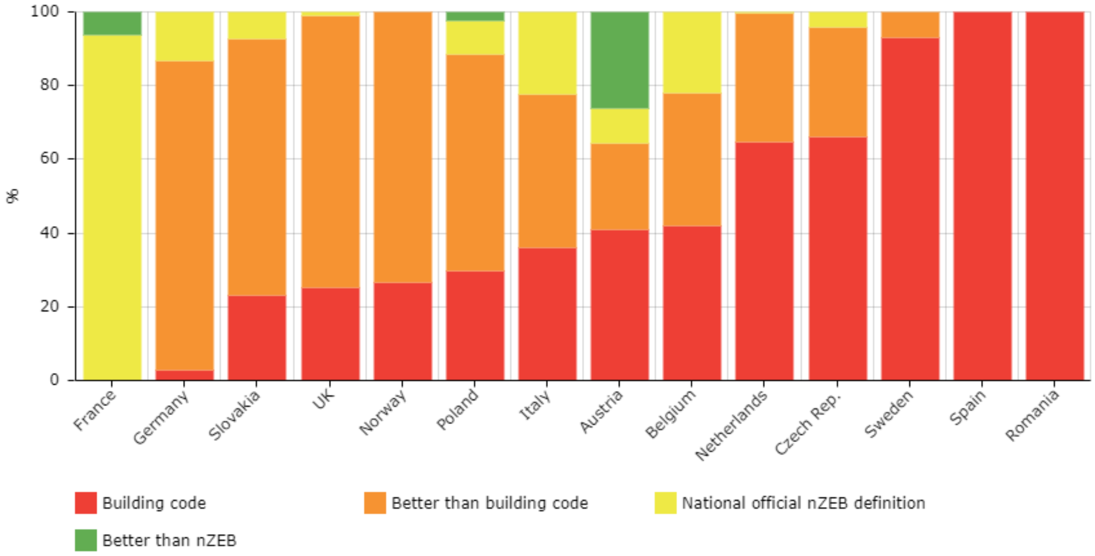


Image 2: Distribution of new dwellings according to different buildings standards by 2014.

Source: www.zebra-monitoring.enerdata.eu

In France, most of the new constructed dwellings are inside the official nZEB definition and the other ones are even better. By contrast, in Spain, all the new constructed buildings meet the building code requirements as there is not an official definition of nZEB in 2014. In Sweden, even though there is no official definition, there is a small share on new dwellings that are better than the building code.

Another interesting indicator is the equivalent major renovation rate, Article 7 of the EPBD states that “Member States shall take the necessary measures to ensure that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements”.

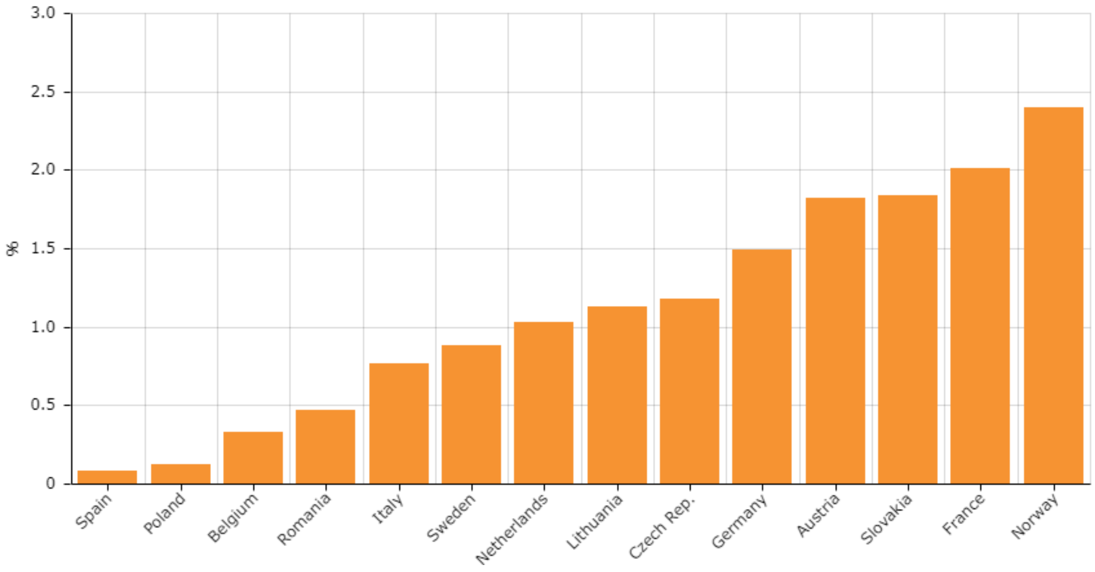


Image 3: Equivalent major renovation rate. Source: www.zebra-monitoring.enerdata.eu

The Image 3 shows the major equivalent indicators stemming from our research. The annual share of the building stock representing an equivalent to major renovation is very low: it is below 0.5% in Spain, Poland or Belgium; around 1% in the Netherlands or Sweden; above 1.5% in others like Germany, France or Austria.

In the end, the indicator of primary energy demand per country is displayed in the following image; this indicator provides an idea of how much is the average of nZEBs in Europe. Moreover, it is shown that the country with the lowest average of primary energy demand is Italy with 15.9 kWh/m2*year followed by Germany with 26.6 kWh/m2*year. Sweden and Spain have a higher average of primary energy demand, 64.4 and 87.6 kWh/m2*year respectively.

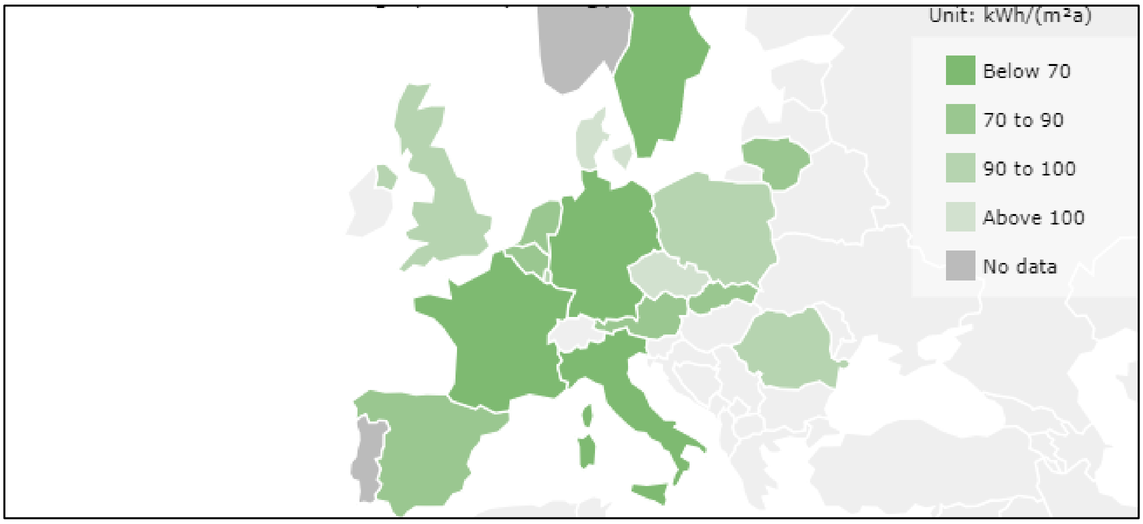


Image 4: Average of primary energy demand per country. Source: www.zebra-monitoring.enerdata.eu

As a conclusion, an overall view of the situation of nZEBs around Europe regarding the Climate Zone is presented.

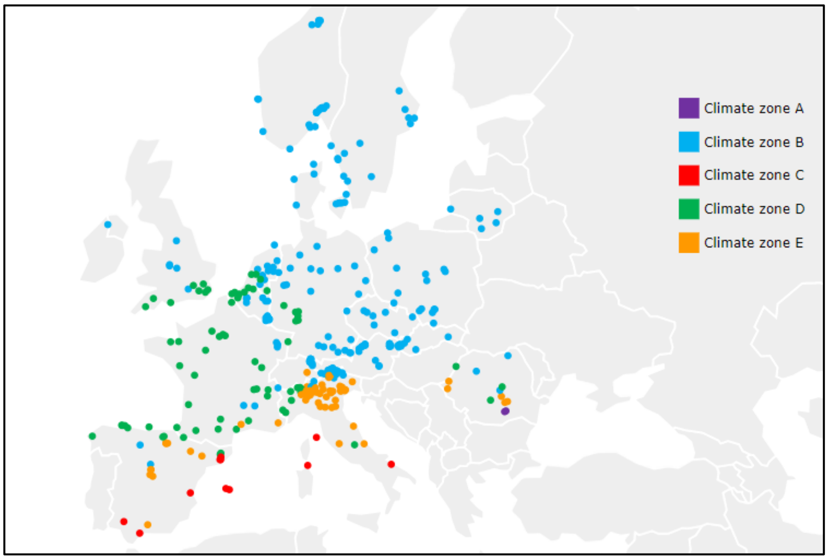
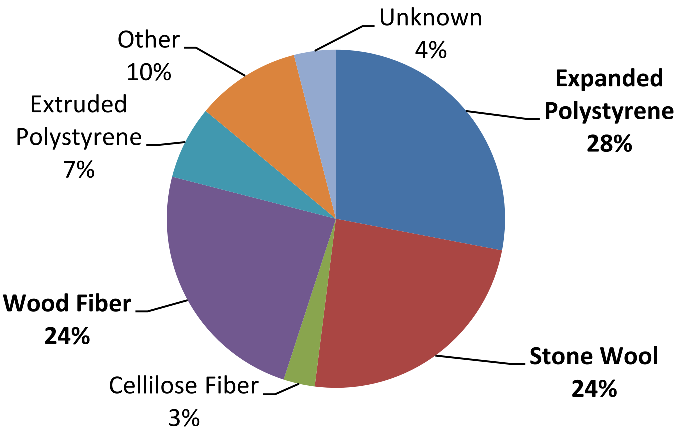


Image 5: Overall view of nZEB in 2014. Source: www.zebra-monitoring.enerdata.eu

6 CURRENT SITUATION OF NZEB IN SPAIN.

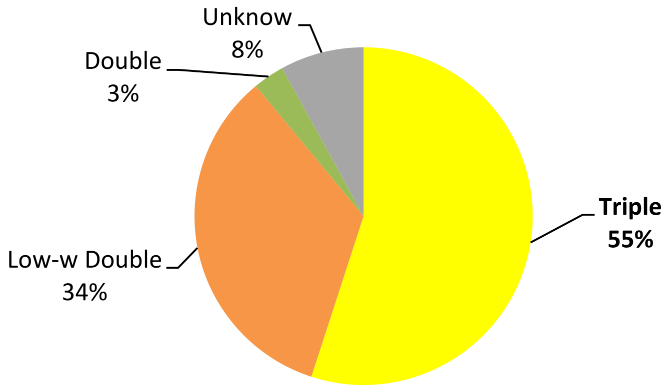
During this section, the most common solutions taken in residential sector for the construction of nZEBs in Spain are going to be explained, and thus it is going to be obtained an overview of current trends.

With regards to the building envelope, expanded polystyrene as insulating material is the most used by Spanish nZEBs, 28% of the share, followed by the stone wool with a 24 % of the share.



Graph 1: Wall insulation materials in Spain. Source: www.zebra-monitoring.enerdata.eu

Another part that belongs to the envelope of the building is the glazing; in this case, the triple glass window is the preferred type of glazing, since it has more than half of the share, as shown in the following graph.



Graph 2: Windows glazing types in Spain. Source: www.zebra-monitoring.enerdata.eu

ZEBRA2020 data tool also provides the average of transmittance depending on the part of the building envelope. Therefore, the corresponding transmittances are presented in the table 9.

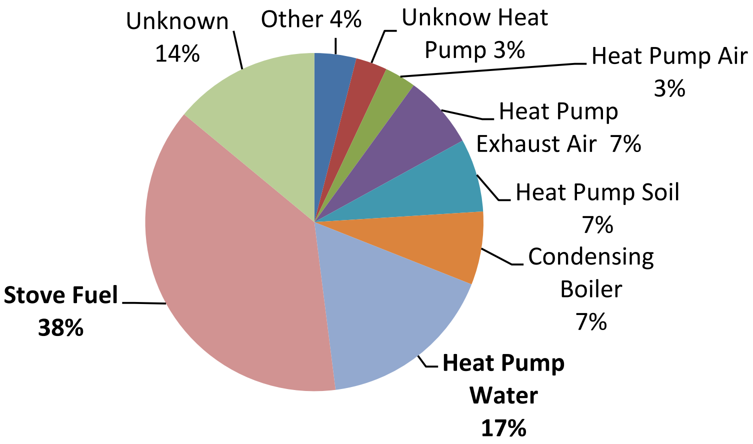
	Wall	Roof	Floor	Window
U (W/m^2*K)	0.18	0.16	0.31	1.2

*Table 9: Average of transmittance U (W/m2*K). Source: www.zebra-monitoring.enerdata.eu*

The previous solutions are considered as passive energy efficiency solutions, but there is another kind of solutions called active energy efficiency solutions.

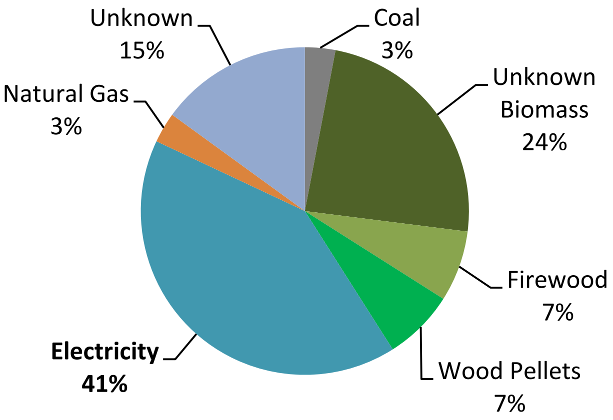
One of the active solutions is the installation of heat recovery in the mechanical ventilation. In Spain, all the nZEBs, which are recollected by the ZEBRA2020 data tool, use the heat recovery with an efficiency average of 83%.

Another active solution is the heating system; in this case, there is more than one solution as it is shown in the next graph. The stove fuel and the heat pump water are the most common solutions among the nZEBs in Spain.



Graph 3: Heating system typologies in Spain. Source: www.zebra-monitoring.enerdata.eu

In the end, the energy carrier with major share is the electricity (41% of the share) followed by the biomass (38% of the share).



Graph 4: Heating system energy carrier. Source: www.zebra-monitoring.enerdata.eu

7 DESIGN OF THE PROTOTYPE BUILDING

During the following section, the layout of the rooms and why that layout has been chosen is going to be explained. The prototype building is the one which is going to be simulated in all the locations, even though there are some changes due to the dimension of the windows and the shading system depending on the location.

7.1 Distribution of the building.

Analysing the weather data of each location, where the building will take place, by means of Climate Consultant (Annex 1). It is chosen that the distribution of the building is based on the utility of each room, locating the most useful rooms at the South-West side of the house and the least useful rooms at the North-East, as the sun radiation is higher in the South-West side of the building than the North-East side.

7.2 Location of the rooms.

- ✓ Living room and Kitchen:

As it was mentioned before, during the summer and winter the sun radiation penetrating in the South-West side of the building is higher than the rest of the building. So that, the living room and the kitchen are located at the West side. Moreover, as the kitchen has its own thermal loads (due to the oven, the toaster, the induction hob, the microwave, etc.), it is located at the North-West of the house. Then, the living room is located at the South-West. Both rooms are an open space and they are distributed as shown in image 6.

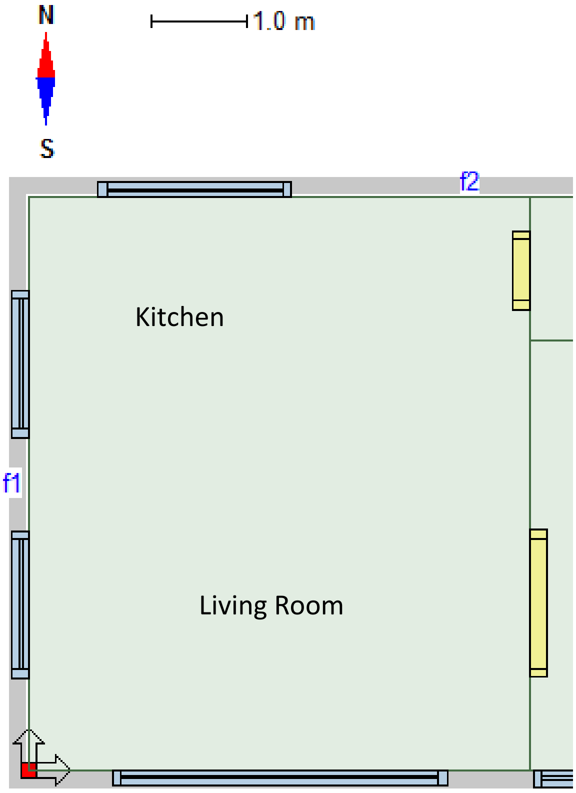


Image 6: Kitchen and Living room layout.

- ✓ Bedrooms:

Regarding the bedrooms, as the house is designed for a standard Spanish family (3 people) there are two kinds of bedrooms: the main and the second one. Furthermore, bedrooms are spaces where the people spend quite time, that is why they are situated at the South-East side of the building.

- ✓ Bathroom, Corridor and Laundry room:

On the other hand, the remaining rooms are the least used parts of the house, such as the bathroom, the corridor and the laundry room. Thus, they are located in the coldest place of the house, that is, at the North. Moreover, the laundry room is at the side further north as it has its own thermal loads.

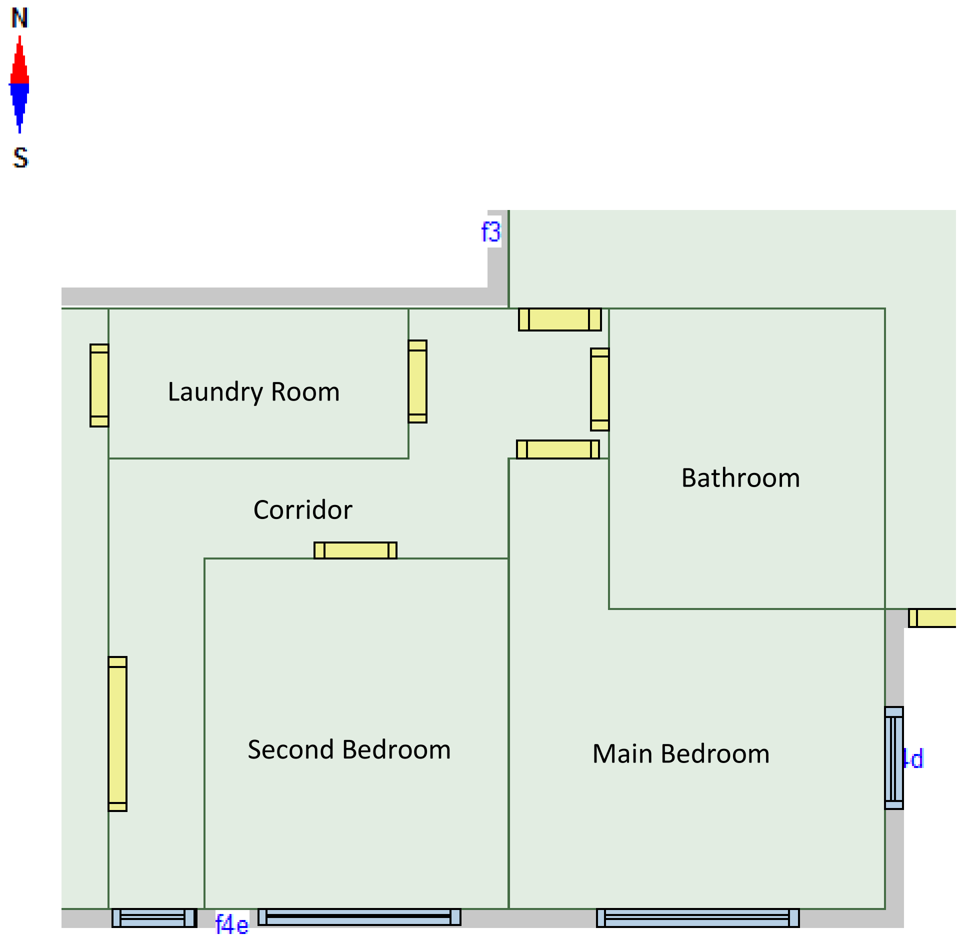


Image 7: Main bedroom, second room, laundry room, bathroom and corridor layout.

✓ Garage:

It is located at the North-East because it is the place where the sun radiation is lower. The garage prevents the drop of the temperature inside the house, providing an extra insulation and keeping indoor temperatures more uniform.

The area of the garage is available for parking a car and for the installation of all the necessary machines used to the air conditioning of the building.

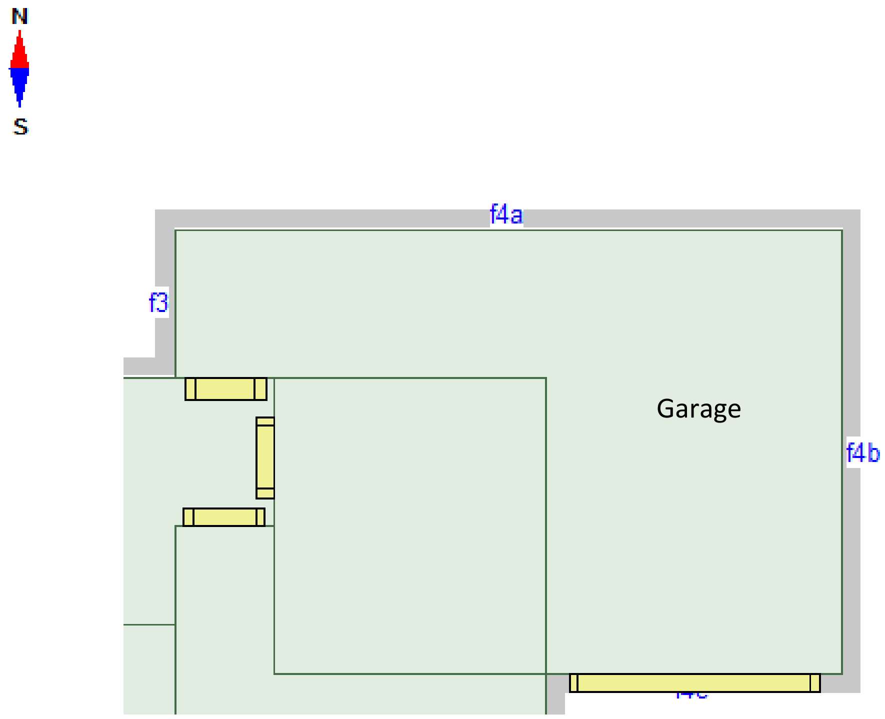


Image 8: Garage layout.

7.3 Schedule of Lighting and Occupancy.

Due to the lack of proper data in this field, the choices of the schedules have been made by the knowledge of the author, and, they are exposed in Annex 5.

7.4 Electrical Appliances in each room.

In regard to the electrical appliances, it is defined different characteristic appliances depending on each room instead of establishing a value of W/m^2 (except the garage that has a 7.5 W/m^2 due to the machines as the heat pump, inverter, motor of the door and so on). Moreover, as it is known, the electrical appliances can emit some heat to the environment. Therefore, for each device, it is established a share of emitted heat that is deposited in the corresponding zone(ASHRAE, 2001). On the other hand, the power consumption of each appliance is obtained by means of different papers (ASHRAE, 2001; Standards, 2014; ICE, 2016; Energuide, 2017).

- ✓ Living room and Kitchen.

The electrical appliances, which are set in the living room and kitchen area as internal gains, are exposed in the following table. Moreover, the schedule of each electrical appliance is shown in Annex 6:

ELECTRICAL APPLIANCE	Units	Power (W)	Utilization factor	Energy carrier
COFFE BREWER	1	1100	0.33	Electricity
DISH WASHER MACHINE	1	1050	0.13	Electricity
REFRIGERATOR AND FREEZER	1	200	0.40	Electricity
INDUCTION HOB	1	2500	0.40	Electricity
ELECTRIC OVEN	1	1500	0.30	Electricity
TOASTER	1	950	0.35	Electricity
MICROWAVE	1	1000	0.2	Electricity
TV 42"	1	300	0.1	Electricity
SMARTPHONE CHARGER	4	5	0.2	Electricity

Table 10: Characteristic of the electrical appliances in the Living room and the kitchen.

- ✓ Laundry room.

The electrical appliances, which are installed in the laundry room as internal gains, are:

ELECTRICAL APPLIANCES	Units	Power (W)	Utilization factor	Energy carrier
WASHING MACHINE	1	1020	0.15	Electricity
DRYER	1	2260	0.15	Electricity
ELECTRIC IRON	1	2000	0.20	Electricity
VACUUM CLEANER	1	2000	0.00	Electricity

Table 11: Characteristic of the electrical appliances in the Laundry room.

- ✓ Bathroom.

ELECTRICAL APPLIANCES	Units	Power (W)	Utilization factor	Energy carrier
BLOW DRYER	1	2000	0.50	Electricity

Table 12: Characteristic of the electrical appliances in theBathroom.

7.5 Composition of structural components.

In this section, the different materials that are used to build the main structural components are exposed. It is considered as the main components: the internal and external walls, the floor and foundation, the ceiling and finally the glazing.

- Walls.

First of all, the walls, which are used in this building, do not have the same number of layer or the same composition. It depends on where the wall will be located inside the envelope of the building or in which room. So that, the walls are classified into 4 types:

- ➢ External Wall.

This kind of wall is used to the whole envelope of the residential building. It is an Exterior Insulation Finish System (EIFS) that uses natural linen fibers as an insulator. It has been chosen the Linen fiber because it is an eco-friendly material and the supplier is a Spanish company. That means that the cost could be reduced due to the buildings will be built in Spain. Moreover, according to the Spanish Building Legislation (CTE), the load-bearing walls have to accomplish at least a minimum thickness of 140 mm for perforated brick walls (Construmática, 2018).

Description of the Structural Component	U-Value	
Exterior Insulation Finish System. Insulator: Linen Fiber Ecological	0.2707	W/(m2*K)
Layers (From the floor to the wall inside)		
Plaster Low Hardness	0.015	m
Perforated Brick nZEB	0.24	m
Polyurethane foam	0.002	m
Linen Fiber	0.1	m
Plaster Low Hardness	0.015	m
Thickness	0.372	m

Table 13: External Wall, EISF.

- ➢ Internal Type A Wall.

It is used to the internal walls that divide the garage area from the corridor and the bathroom. It is an EIFS wall and a bit less thickness than the Type B due to the fact that it has to delimit the air conditioned zones from the non-air-conditioned zone (the garage).

Description of the Structural Component	U-Value	
Exterior Insulation Finish System. Insulator: Linen Fiber Ecological	0.3099	
	W/(m2*K)	
Layers (From the floor to the wall inside)		
Plaster Low Hardness	0.015	m
Hollow brick nZEB	0.07	m
Polyurethane foam	0.002	m
Linen Fiber	0.1	m
Plaster Low Hardness	0.015	m
Thickness	0.202	m

Table 14: Internal Wall Type A, EIFS.

- Internal Type B Wall.

It has been used for most internal walls that take part of the building. Furthermore, it is enough thickness to be a load-bearing wall if it was necessary.

Description of the Structural Component	U-Value	
Internal wall Type B nZEB Insulator: Linen Fiber Ecological	0.5344	
	W/(m2*K)	
Layers (From the floor to the wall inside)		
Plaster Low Hardness	0.015	m
Hollow brick nZEB	0.07	m
Linen Fiber	0.05	m
Plaster Low Hardness	0.015	m
Thickness	0.15	m

Table 15: Internal Wall Type B.

- Floor.

The floor is one of the most important parts in this building as it is a radiant floor. It means that the floor will provide the heating and cooling demand. Therefore, it has been designed in a particular way in order to take advantage of the heat transmission.

Description of the Structural Component	U-Value	
Radiant floor. The foundation has been taken into account, Concrete 150 mm	0.2967	
	W/(m2*K)	
Layers (From the floor to the wall inside)		
Oak Parquet	0.02	m
Mortar heating floor	0.065	m
Sand and Gravel	0.05	m
Linen Fiber	0.1	m
Lightweight Concrete	0.2	m
Concrete	0.15	m
Thickness	0.585	m

Table 16: Radian floor.

- Ceiling.

According to the Spanish Building Regulation (CTE), there are various kinds of ceilings that accomplish the CTE requirements. So, it has been chosen the Solution C.1 (CTE, 2010).

Description of the Structural Component	U-Value	
Solution C.1 from CTE	0.3104	
	W/(m2*K)	
Layers (From the floor to the wall inside)		
Bituminous	0.02	m
Mortar with light aggregates	0.05	m
Linen Fiber	0.1	m
Polyurethane foam	0.002	m
Concrete with light aggregates	0.07	m
Concrete	0.15	m
Thickness	0.392	m

Table 17: Ceiling, Solution C.1.

- Glazing.

Regarding the glazing, it has been done a market analysis about different glazing suppliers. In the end, the selected brand has been Pilkington as it has good quality materials and is a well-known company. The model is the Suncool 70/40 with a glass configuration "Optitherm™ S3 #5". Moreover, it is a triple glass in order to have as low U-value as possible. Otherwise, the technology used is the solar control as it is the best one to install in high irradiation areas (Pilkington, 2019).

Description		
Pilkington SunCool 70/40 Optitherm S3 #5 3-Glass		
Shading Coefficients		
g, Solar Heat Gain Coef.	Glazing U-Value	
0.38	0.7	W/(m2*K)
T, Solar Transmittance	Internal Emissivity	
0.33	0.837	0-1
Tvis, Visible Transmittance	External Emissivity	
0.64	0.837	0-1

Table 18: Pilkington SunCool 70/40.

To sum up, all the exposed components accomplish with the U-values that are established by the CTE and are explained in section called "What is a nearly zero energy building by Spanish legislation?".

7.6 Supply System.

Throughout this section, the steps taken to develop the final supply system are displayed. As mentioned earlier, the ultimate target is a supply system that uses the pool as a heat source, although a ground heat exchanger will be used when the pool is not available.

Therefore, the natural behavior of the swimming pool during the whole year takes a great importance due to the fact that the pool is going to be set as the heat source of the heat pump. For that reason, the energy balance of the swimming pool has to be evaluated.

7.6.1 Energy Balance of the Outdoor Swimming Pool.

First of all, it has done the energy balance without taking into account the energy ejected or absorbed by the heat pump, ergo, in this first step, it is developed the energy balance of a swimming pool that is affected by the natural effects.

It is assumed that the water in the swimming pool is ideally mixed so that the first law of thermodynamics can be expressed as follows (Auer, 1996):

$$\frac{\delta E}{\delta t} = \sum(Q_{Gain} - Q_{Loss}) \quad \text{A1.1}$$

It is also assumed that a liquid is incompressible and its thermal conductivity and density are constants. Then, equation A1.1 can be expressed as:

$$\rho_w * C_{pw} * V_{pool} * \frac{\delta T}{\delta t} = \sum(Q_{Gain} - Q_{Loss}) \quad A1.2$$

Where

ρ_w	Density of the water (1000 kg/m^3)
C_{pw}	Specific heat of the water (4186 J/(Kg*K))
V_{pool}	Volume of the Pool (m^3)

Moreover, a swimming pool loses heat to the environment by convection, evaporation, radiation, and conduction to the ground. The heat loss due to conduction is normally quite low in both in-ground and aboveground pools and can be neglected for making easier the model , it has only a minor influence on the overall energy assessment (<1 %) (J.T. Czarnecki, 1978). Finally, it is assumed that there is a continuous amount of water in the pool as the evaporation mass is replaced by the make-up water from the network.

$$\rho_w * C_{pw} * V_{pool} * \frac{\delta T}{\delta t} = \dot{Q}_{Sun} + \dot{Q}_{Make-up\ water} - \dot{Q}_{eva} - \dot{Q}_{Rad} - \dot{Q}_{conv} \quad A1.3$$

Where

$\dot{Q}_{Sun}$	Heat flow rate by Short-wave Radiation (W)
$\dot{Q}_{Make-up\ water}$	Heat flow rate by water supply (W)
$\dot{Q}_{eva}$	Heat flow rate by Evaporation (W)
$\dot{Q}_{Rad}$	Heat flow rate by long-wave Radiation (W)
$\dot{Q}_{conv}$	Heat flow rate by Convection (W)

The following picture displays the schematic view of all heat flow rates:

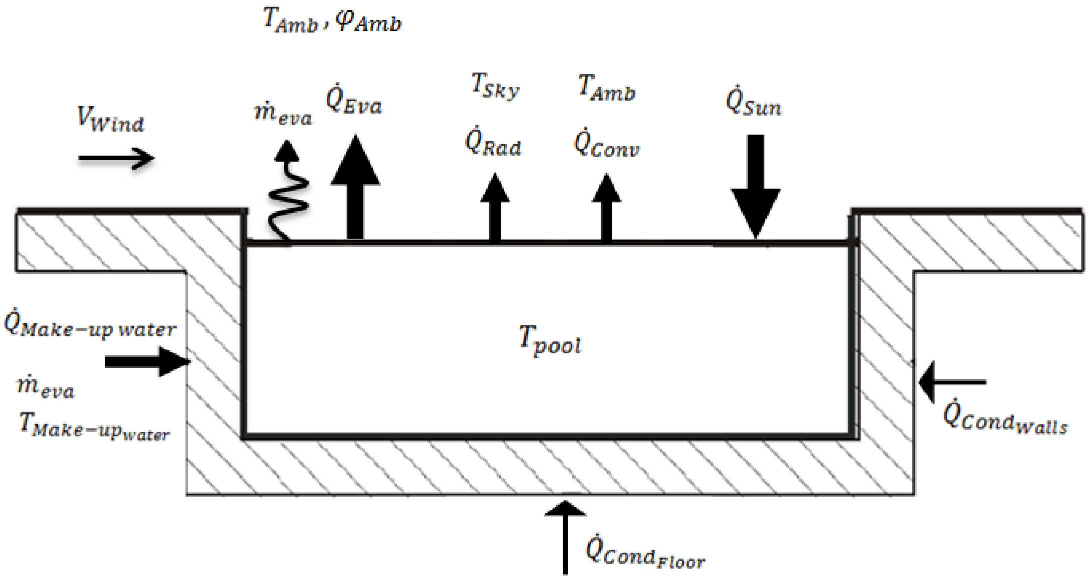


Image 9: Energy Balance of the Outside Swimming Pool.

During the following sections, the different heat flows are explained and the equations which are used to calculate the corresponding heat flows.

Evaporative losses.

For outdoor pools, the equations that describe the evaporative losses are semi-empirical equations. These equations include the difference in vapor pressure between water surface and ambient air as a driving force, and the evaporative heat transfer coefficient as an empirical function of the wind speed (Ruiz and Martı, 2010). Furthermore, evaporative losses normally account for more than 60% of the total energy losses (Kubler, 1994).

$$\dot{Q}_{eva} = \dot{m}_{Eva} * LH_{Eva} = A_p * h_{eva} * \left(P_{v,sat}\left(T_{pool}\right) - P_o(T_{Amb})\right) * 100 \quad (W) \quad A1.4$$

Where

$\dot{m}_{Eva}$	Rate of evaporation (Kg/s)
LH_{Eva}	Latent heat of water, evaporation (2257*10e3 J/Kg)
A_p	Pool surface area (m^2)
$P_{v,sat}(T_{pool})$	Saturated water-vapor pressure at pool water temperature (Pa)
$P_o(T_{Amb})$	Partial water vapor pressure in air, non-saturated state (Pa)
$h_{eva} = a + b * v_{wind}^{n}$	Evaporation heat transfer coefficient (W/ (m^2*Pa))

On the one hand, regarding the evaporation heat transfer coefficient, in this case, it is followed the ASHRAE Handbooks (1991) indications where the parameters a, b and n are defined.

$$h_{eva} = 0.089 + 0.0782 * v_{wind}^{1} \quad A1.5$$

On the other hand, the previous pressures are obtained by the next equations.

Saturated water-vapor pressure at pool water temperature:

$$P_{v,sat}\left(T_{pool}\right) = 6.1087 * e^{\left(\frac{17.08085 * T_{POOL}}{234.157 + T_{POOL}}\right)} \quad (HPa) \quad A1.6$$

And for the non-saturated partial water vapor pressure in air:

$$P_{v,amb}\left(T_{Amb,}\varphi_{Amb}\right) \approx \frac{\varphi_{Amb}}{100} * P_{v,sat}(T_{Amb}) = 6.1087 * e^{\left(\frac{17.08085 * T_{Amb}}{234.157 + T_{Amb}}\right)} \quad (HPa) \quad A1.7$$

φ_{Amb}	Humidity of the ambient air (%)

Radiative Losses:

In an outdoor swimming pool appears a radiation heat loss due to infrared radiation exchange with the sky. This loss has been calculated by means of the equation X where it is considered a longwave emissivity of the water of 0.95.

$$\dot{Q}_{Rad} = A_p * \varepsilon_w * \sigma * \left(T_{Pool}^4 - T_{Sky}^4\right)(W) \quad A1.8$$

Where

A_p	Pool surface area (m^2)
ε_w	Emissivity of the water
σ	Constant of Stefan-Boltzmann 5.67*10e^{-8} (W/m^2*K^4)
T_{Pool}	Temperature of the Pool (K)
T_{Sky}	Temperature of the Sky (K)

Convective Losses:

This kind of heat loss depends mainly on the wind speed as the evaporative loss. Now, it is chosen the Australian Standard (1989) on solar heating systems for swimming pools proposes to evaluate the convective heat transfer coefficient.

$$\dot{Q}_{conv} = A_p * h_{conv}\left(T_{pool} - T_{amb}\right)(W) \quad A1.9$$

Where

A_p	Pool surface area (m^2)
$h_{eva} = 3.1 + 4.1 * v_{wind}$	Convective heat transfer coefficient (W/ (m^{2}K))
T_{Pool}	Temperature of the Pool (K)
T_{Amb}	Temperature of the ambient air (K)

Solar Radiation Heat Gain:

The absorption of the solar radiation by the pool is considered as a gain and is calculated by means of the equation A1.10. The solar absorptance is dependent on the pool depth and on the absorptance of the bottom and sidewalls. The value of 0.85 is recommended by ISO TC 180 (1995) for light-colored pools.

$$\dot{Q}_{Sun} = A_p * \alpha * G_{Irrad}\ (W)\quad A1.10$$

Where

A_p	Pool surface area (m^2)
α	Absorptance of the Pool
G_{Irrad}	Global solar irradiance (W/m^2)

Make-up water heat gain:

In order to balance the system, there is a supply of fresh water that replaces the evaporation mass. In this case, this heat flow is considered as a gain but it could be considered as a loss as well.

$$\dot{Q}_{Make-up\ water} = \dot{m}_{eva} * C_{pw} * \left(T_{make-up\ water} - T_{pool}\right)\ (W)\quad A1.11$$

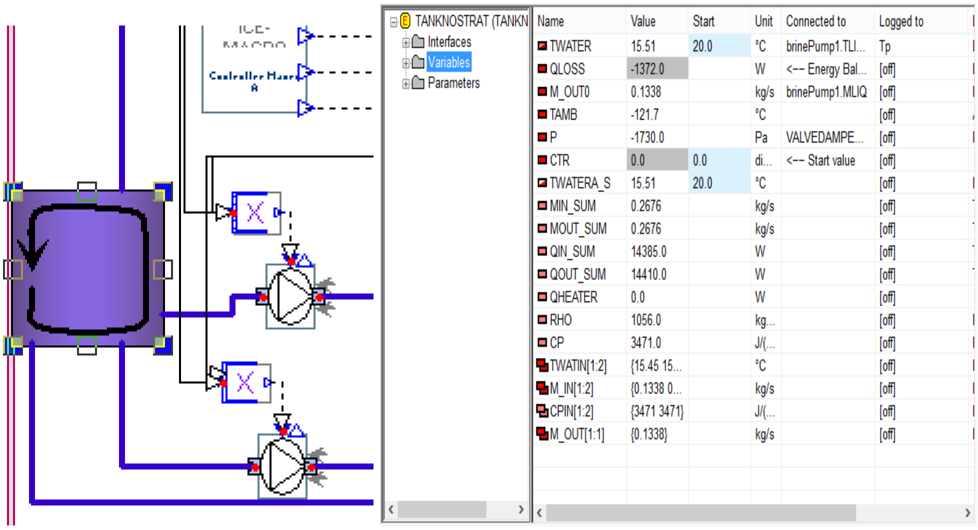
Where

$\dot{m}_{Eva}$	Rate of evaporation (Kg/s)
C_{pw}	Specific heat of the water (4186 J/(Kg*K))
T_{Pool}	Temperature of the Pool (K)
$T_{make-up\ water}$	Temperature of the water network (K)

7.6.2 Introduction of the Swimming Pool in the IDA ICE Software:

The way how the outdoor swimming pool has been introduced is explained during the following section.

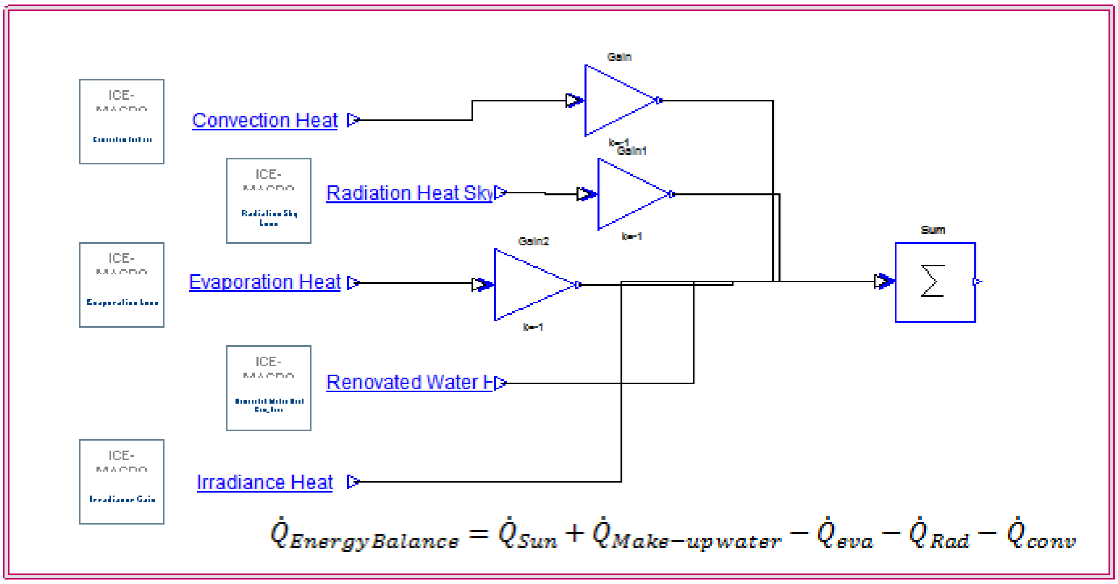
In the first place, a tank without stratification has been set as the swimming pool because the depuration system will mix the water of the swimming pool and the temperature of the swimming pool will be uniform. Moreover, the balance of the outdoor swimming pool is introduced to the tank by means of the Qloss variable.



Name	Value	Start	Unit	Connected to	Logged to
TWATER	15.51	20.0	°C	brinePump1.TLI...	Tp
QLOSS	-1372.0		W	<-- Energy Bal...	[off]
M_OUT0	0.1338		kg/s	brinePump1.MLIQ	[off]
TAMB	-121.7		°C		[off]
P	-1730.0		Pa	VALVEDAMPE...	[off]
CTR	0.0	0.0	di...	<-- Start value	[off]
TWATERA_S	15.51	20.0	°C		[off]
MIN_SUM	0.2676		kg/s		[off]
MOUT_SUM	0.2676		kg/s		[off]
QIN_SUM	14385.0		W		[off]
QOUT_SUM	14410.0		W		[off]
QHEATER	0.0		W		[off]
RHO	1056.0		kg...		[off]
CP	3471.0		J/(...		[off]
TWATIN[1:2]	{15.45 15...		°C		[off]
M_IN[1:2]	{0.1338 0...		kg/s		[off]
CPIN[1:2]	{3471 3471}		J/(...		[off]
M_OUT[1:1]	{0.1338}		kg/s		[off]

Image 10: Screenshot of tank without stratification and the variables of the tank.

Otherwise, it has been used a macro to simulate the energy balance of the outdoor swimming pool. The following image shows the macro that calculates the total heat flow of the outside swimming pool.



$$\dot{Q}_{Energy\,Balance} = \dot{Q}_{Sun} + \dot{Q}_{Make-up\,water} - \dot{Q}_{eva} - \dot{Q}_{Rad} - \dot{Q}_{conv}$$

Image 11: Energy Balance in a Macro from IDA ICE.

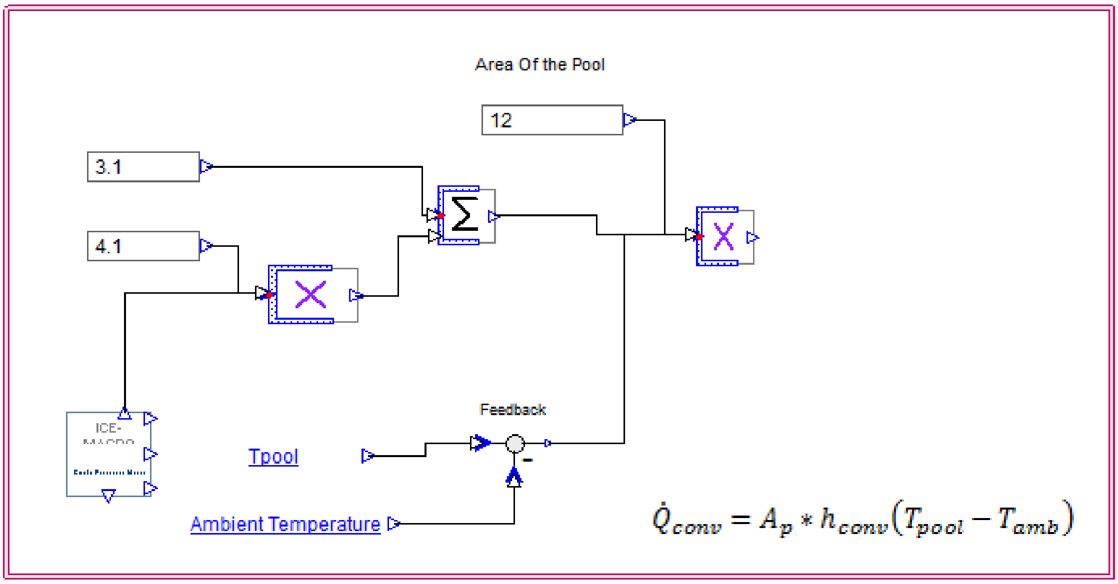


Image 12: Convection Heat Macro from IDA ICE.

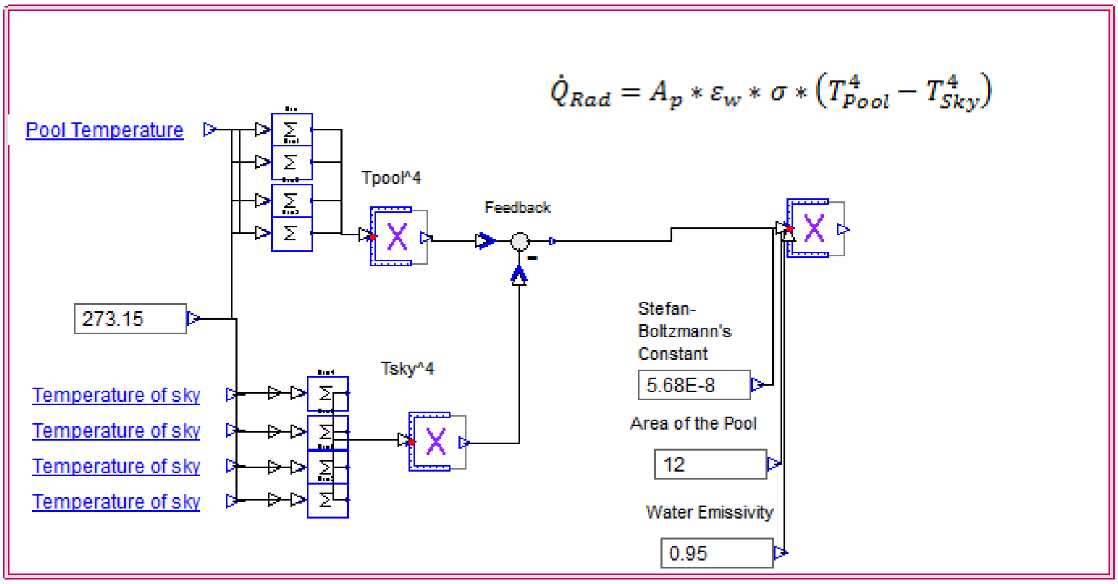
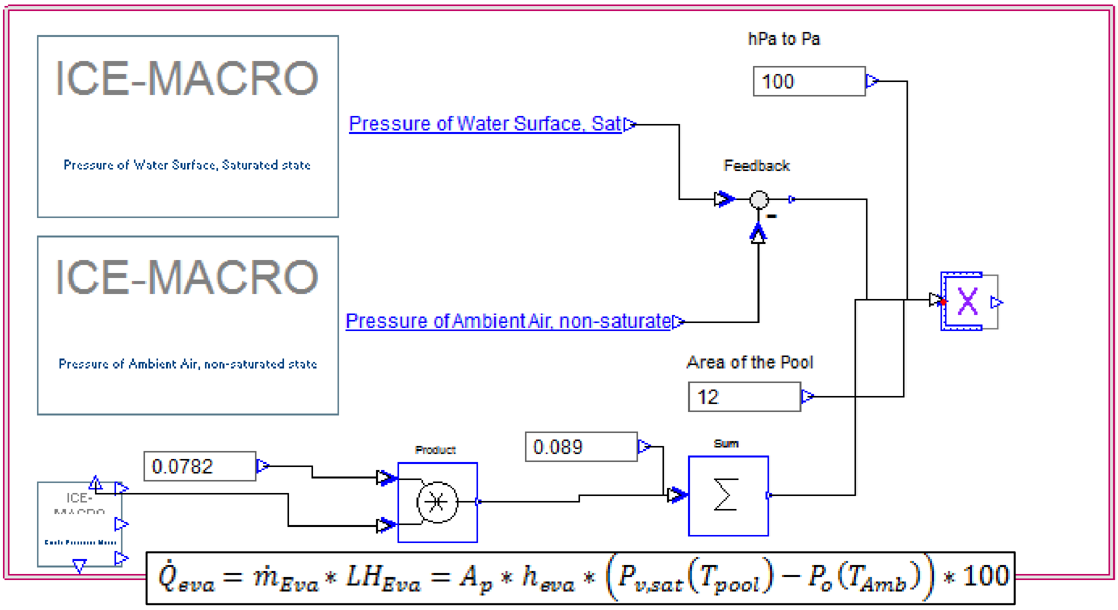
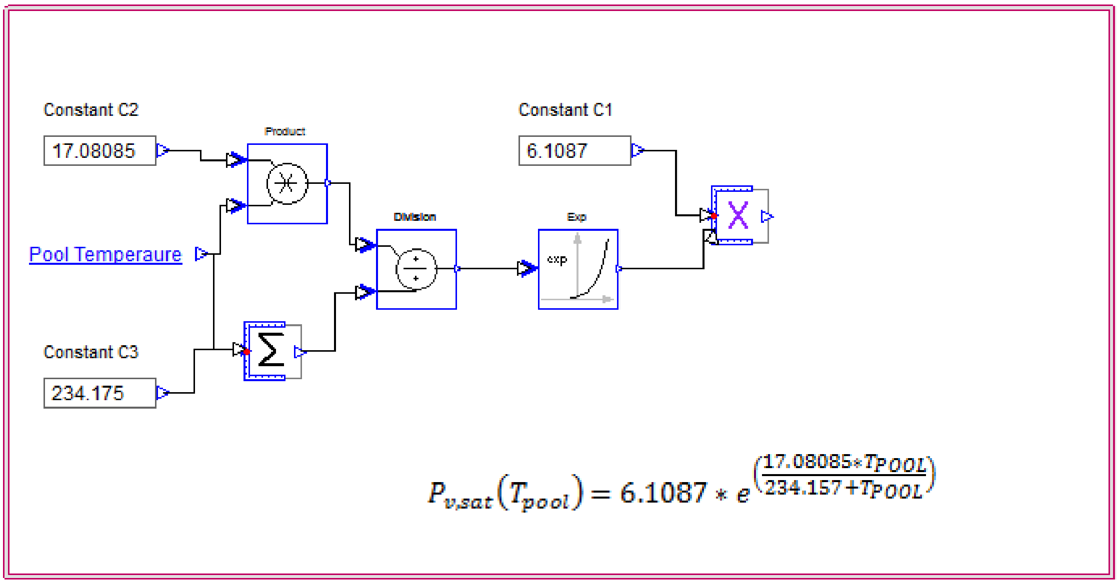


Image 13: Radiation heat Macro from IDA ICE.



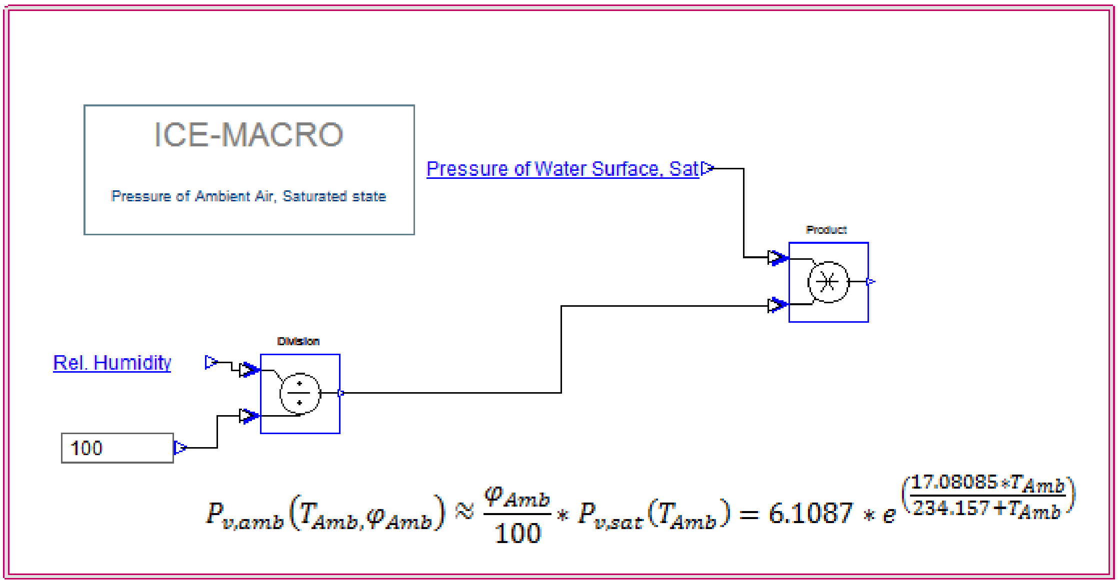
$$\dot{Q}_{eva} = \dot{m}_{Eva} * LH_{Eva} = A_p * h_{eva} * \left(P_{v,sat}\left(T_{pool}\right) - P_o\left(T_{Amb}\right)\right) * 100$$

Image 14: Evaporation heat Macro from IDA ICE.



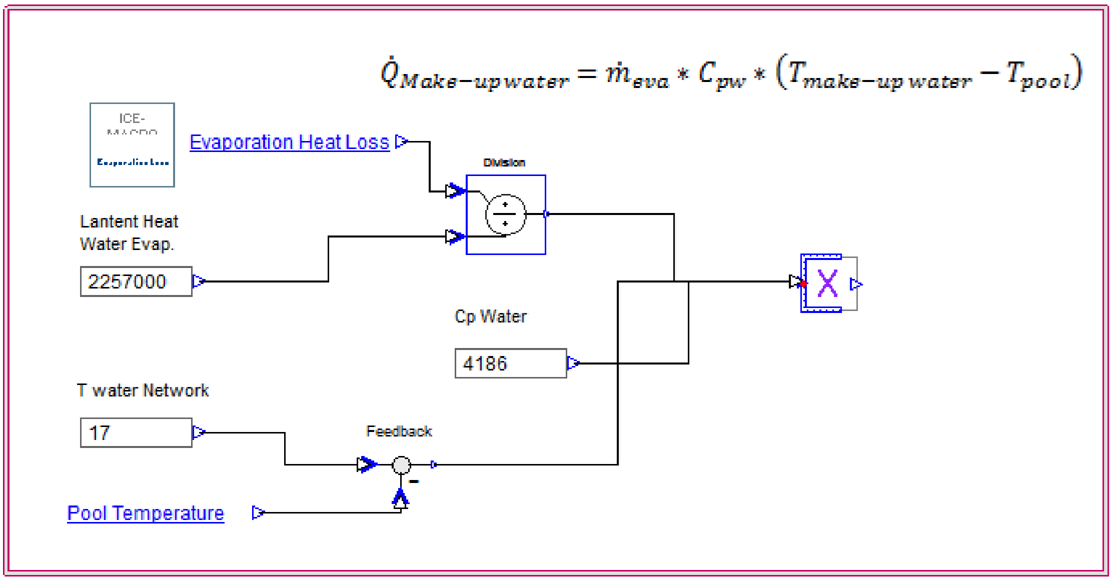
$$P_{v,sat}\left(T_{pool}\right) = 6.1087 * e^{\left(\frac{17.08085 * T_{POOL}}{234.157 + T_{POOL}}\right)}$$

Image 15: Saturated Pressure of Water Surface Macro from IDA ICE.



$$P_{v,amb}(T_{Amb},\varphi_{Amb}) \approx \frac{\varphi_{Amb}}{100} * P_{v,sat}(T_{Amb}) = 6.1087 * e^{\left(\frac{17.08085 * T_{Amb}}{234.157 + T_{Amb}}\right)}$$

Image 16:Non-Saturated Pressure of Water Surface Macro from IDA ICE.



$$\dot{Q}_{Make-up\,water} = \dot{m}_{eva} * C_{pw} * (T_{make-up\,water} - T_{pool})$$

Image 17: Renovated Water heat Macro from IDA ICE.

The temperature of the water network is different for each location. That temperature varies throughout the year but it is set as the average temperature of the year. The next table shows the average temperature of the water network for each location.

Average Temperature of the Network			
Soria	10ºC	Seville	16ºC
Madrid	13ºC	Valencia	15ºC
Sebastian	12ºC	Almeria	16ºC
Barcelona	14ºC	Malaga	16ºC
A Coruña	13ºC	Tenerife	17ºC

Table 19: Average temperature of the water network.

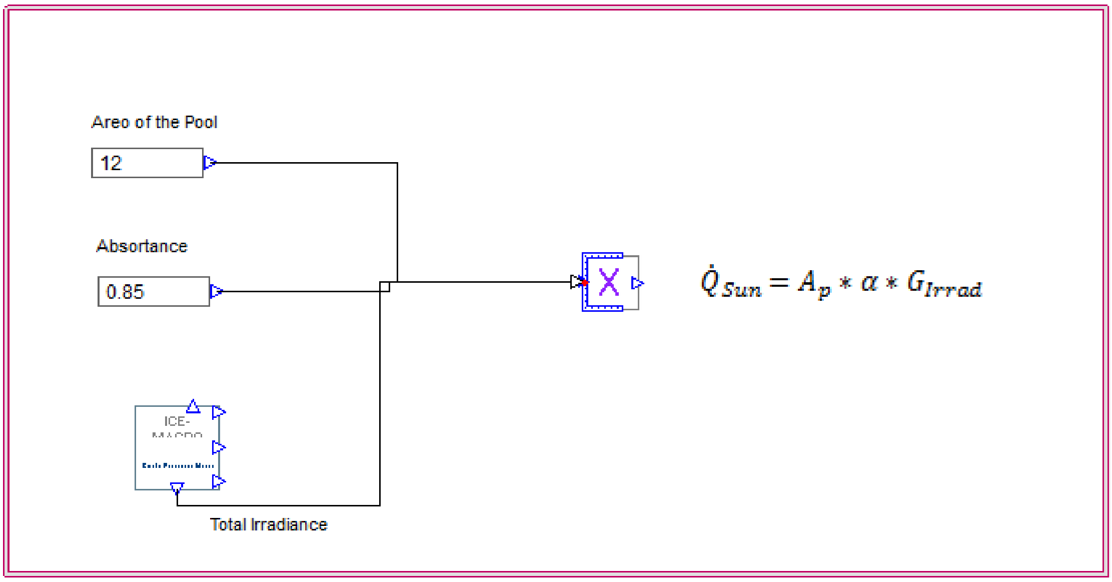


Image 18: Irradiance heat Macro from IDA ICE.

7.6.3 Development of the supply system in IDA ICE.

Firstly, it is set a temperature range for the swimming pool. The upper temperature limit is 30 ºC and the lower temperature limit is 3ºC. When the temperature of the swimming pool is out of the upper or the lower benchmark, the ground heat exchanger turns on.

- **Step 1**: Supply System A. Only the swimming pool as a heat source.

First of all, it is designed a supply system where the heat pump uses the swimming pool as a heat source. In the picture below, the Tank 1 is set as the swimming pool with a volume of 18 m^3, and the variable Qloss is equal to the macro of energy balance (Explained in the section: 7.6.1 Energy balance of the outdoor swimming pool.). Otherwise, the Tank 2 is set a volume of 1.0E-6 in order to reduce its impact on the system.

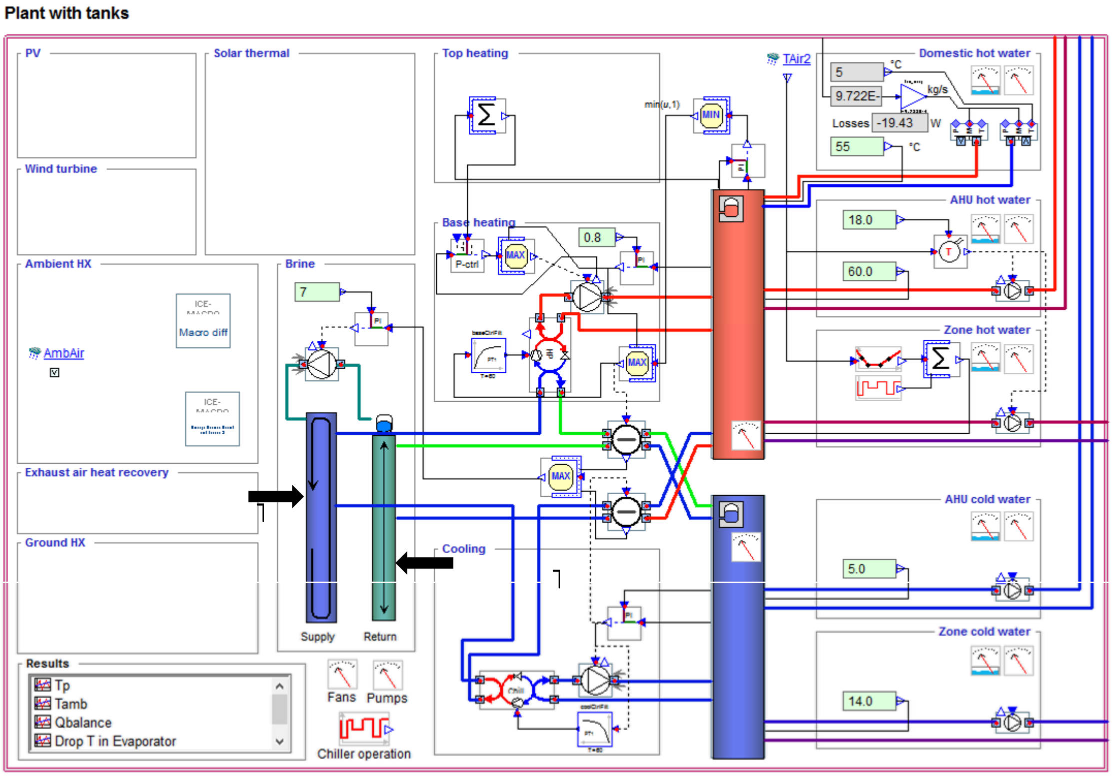


Image 19: Layout of the Supply System from IDA ICE, Step 1.

The previous layout is gotten from the following ESBO Plant, and then it has been modified as it is mentioned before:

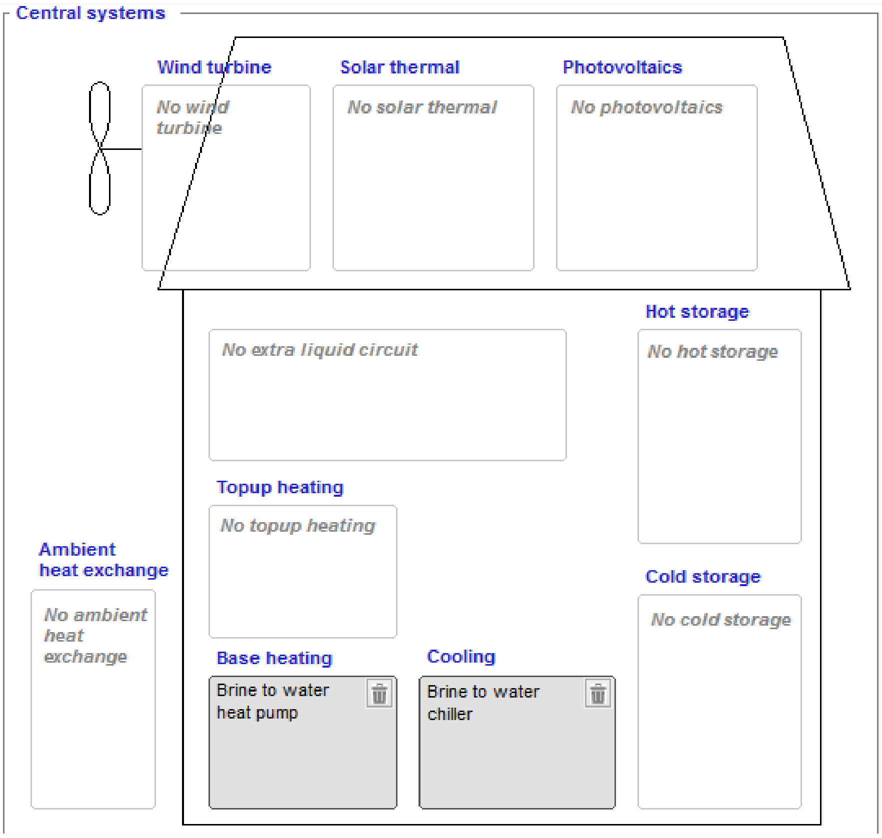
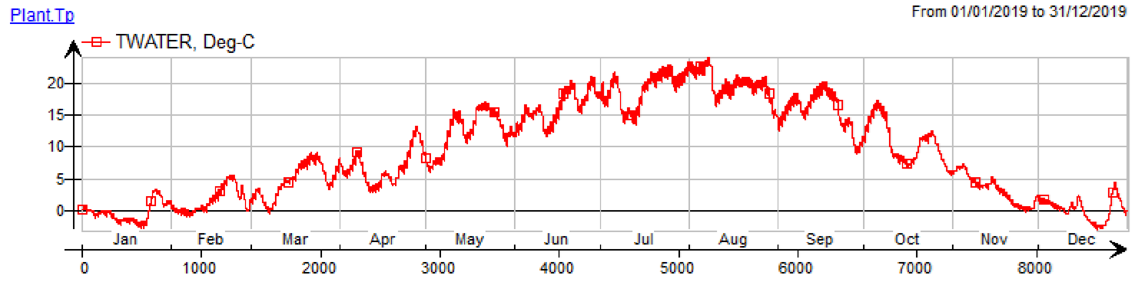


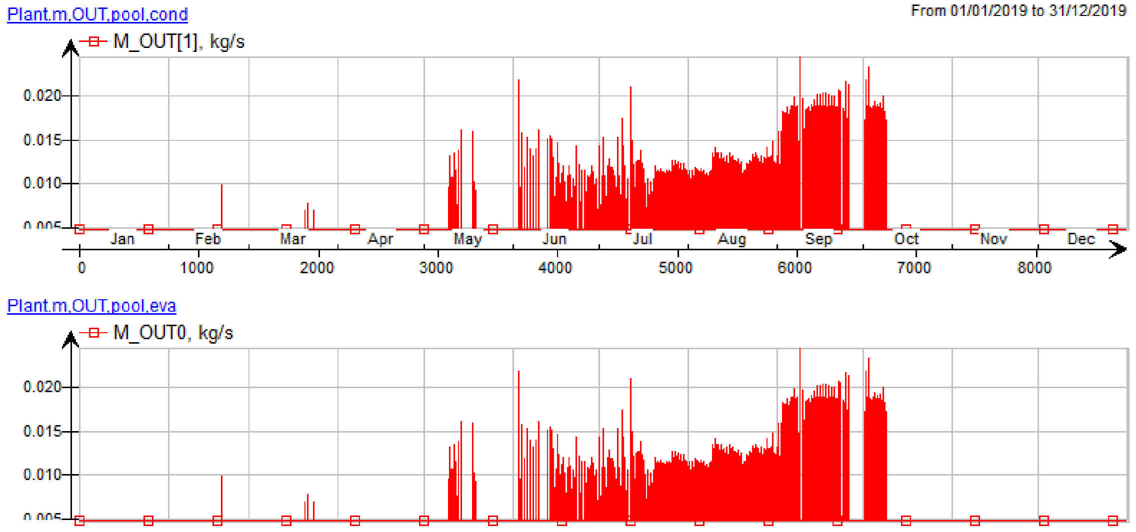
Image 20: ESBO Plant. Screenshot from IDA ICE.

If the simulation is run, it is obtained the following chart for the temperature of the swimming pool.



Graph 5: Swimming Pool Temperature from Step 1.

It is also followed up the mass flow that goes to the evaporator and the mass flow that flows to the condenser (m,OUT,pool,eva and m,OUT,pool,cond respectively). As you can see, both mass flows are equal during the whole year as there is only one pump that is controlled by one controller. It is also created a macro that obtains the drop in the evaporator and condenser.



Graph 6: Mass flow from pool to condenser and to evaporator respectively.

In this case, there are some troubles such as:

- The pool could reach high temperatures because there is no controller that avoids it. (The condenser ejects too much heat)
- The pool could reach low temperatures as the evaporator absorbs too much heat.

- **Step 2**: Supply System B. Swimming pool and ground heat exchanger as heat sources.

To prevent the problems that are mentioned in the previous section, it is designed a new layout for the supply system and a controller. This layout and all important parameters are shown in the next picture.

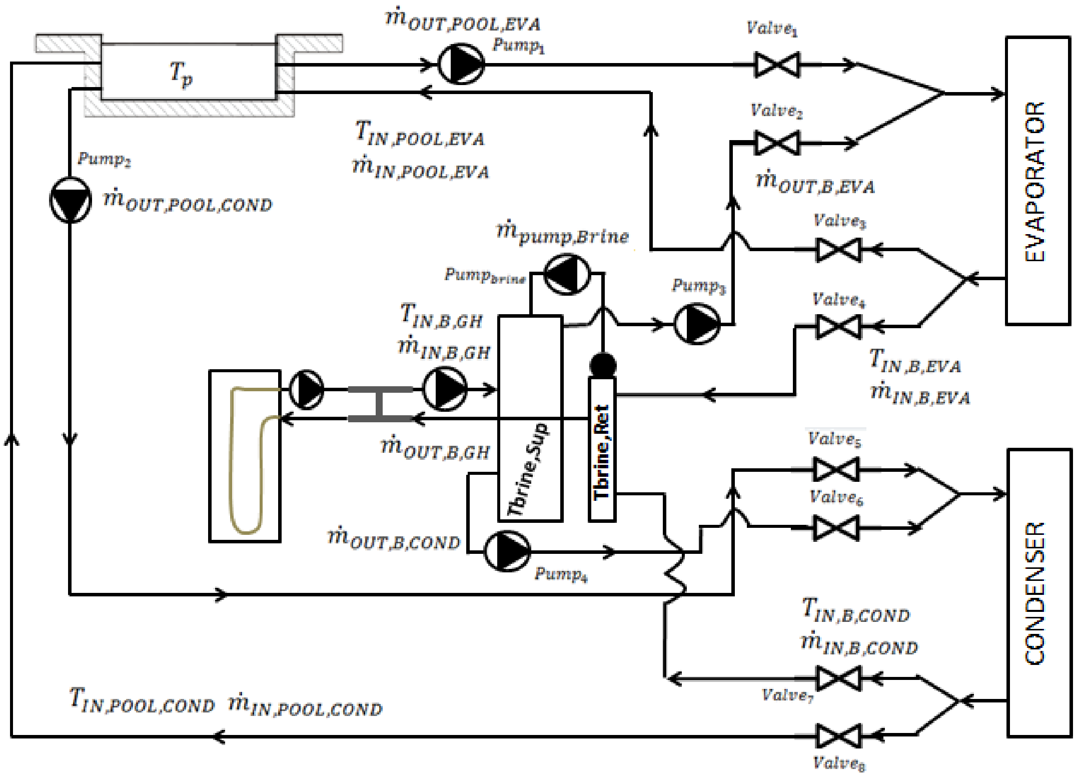
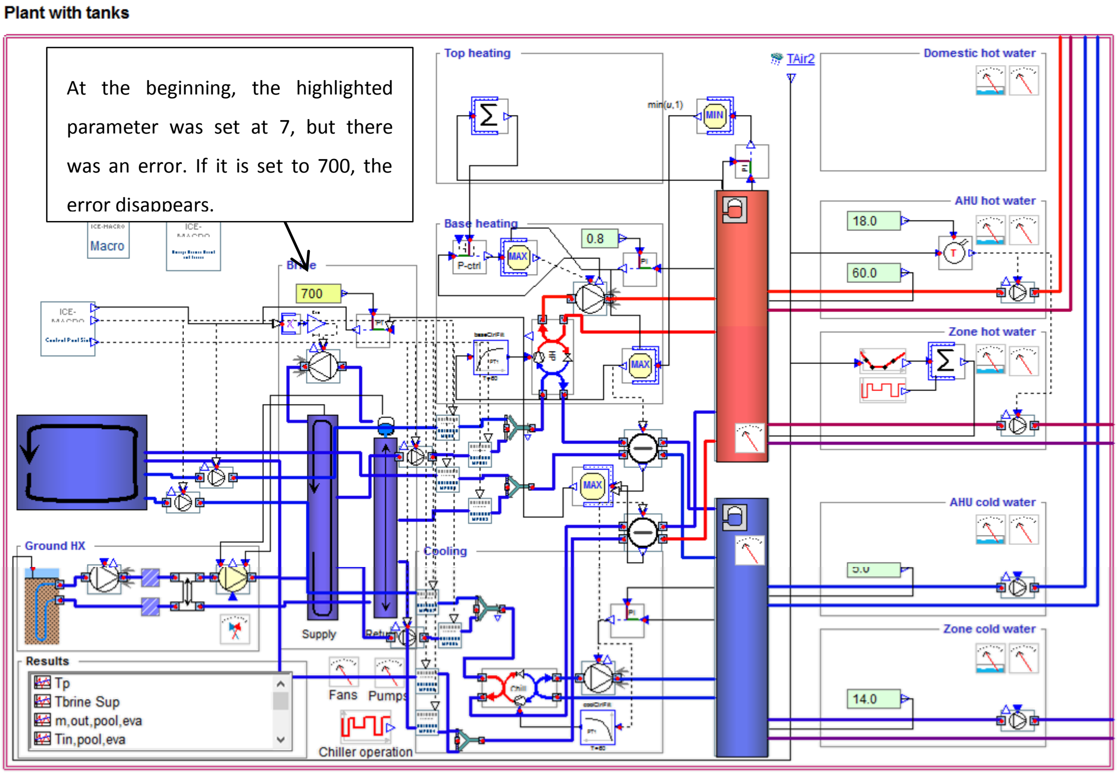


Image 21: Layout of the supply system, Step 2.



At the beginning, the highlighted parameter was set at 7, but there was an error. If it is set to 700, the error disappears.

Image 22: Layout of Supply System from IDA ICE, Step 2.

Changing the set point from 7 to 700 causes the external signal to maintain a constant value throughout the year and, therefore, no error appears during the simulation.

Now, it is explained the controller. The main goal is to avoid the high and low temperatures in the pool due to the condenser and the evaporator (The pool could reach high and low temperatures due to the environmental conditions as well). That is why the controller has to be able to turn on and turn off the corresponding valves and hydraulic pumps.

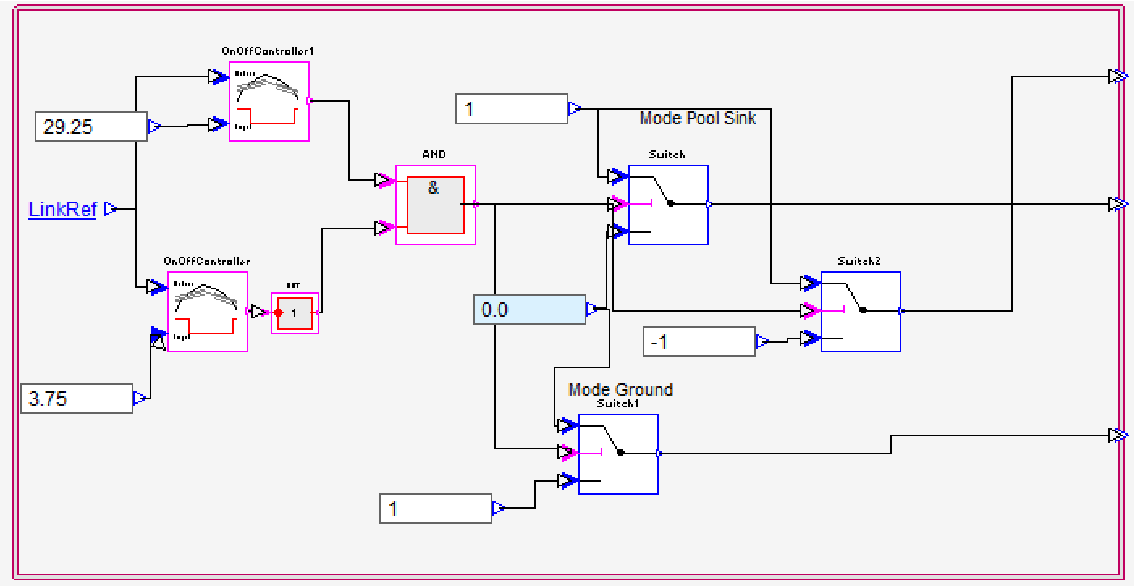
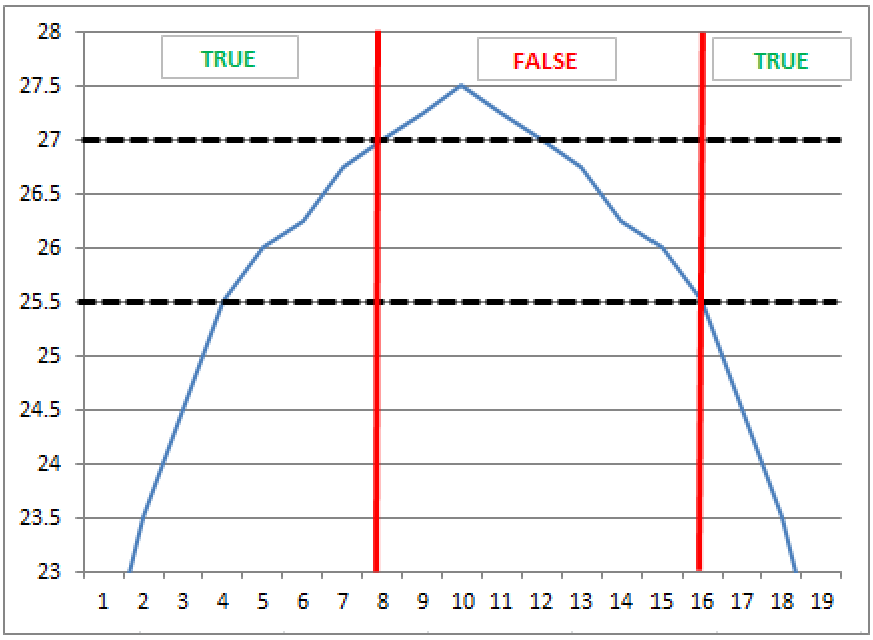
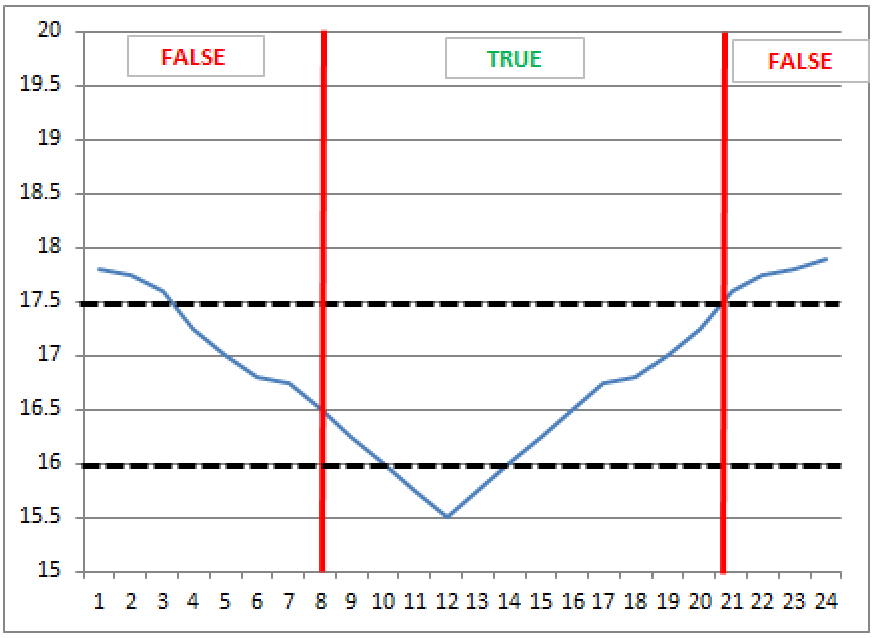


Image 23: Step 2 Macro of the Step 2 Controller.

In regard to the controller, it is important to set the lower and upper limits of the swimming pool temperature. In the previous case, the upper limit is 30ºC and the lower limit 3ºC as the bandwidth is 1.5ºC. It is chosen an on/off controller to avoid the off and on continuous of the valves and pumps. The following graph shows when the on/off controller sends a true signal or a false one.



Graph 7: Controller.



Graph 8: Controller 1.

It is important to point out that the controller1 is sending the False and True signal in a way contrary to what is needed. That is why, it is set a logical NOT block after the on/off controller1. Therefore:

- AND Block: It sends a true or false signal depending on the Controller blocks.

- Switch: This block is the controller of the valves and pumps for the pool. It sends 1 when the AND block is true and 0 when the AND block is false.(**Pool Heat Mode**)

  Controlled Devices: Pump 1 and Pump 2; Valve 1, Valve 3, Valve 5 and Valve 8.

- Switch1: This block is the controller of the valves and pumps for the ground heat exchanger. It sends 1 when the AND block is false and 0 when the AND block is true. (**Ground Mode**)

  Controlled Devices: Pump 3 and Pump 4; Valve 2, Valve 4, Valve 6 and Valve 7.

- Switch2: This block is the controller of the brine pump. It sends 1 when the AND block is true and -1 when the AND block is false.(**Pump Brine Mode**)
  This one has to be in concordance with Switch2. Then, the signal is changed outside the controller. (It is quite strange because if I make the change inside the controller, IDA ICE crashes…)

  Controlled Devices: Brine Pump.

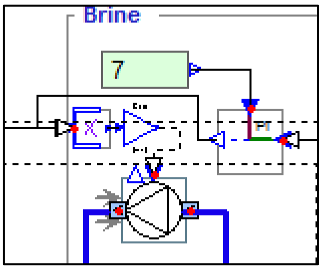


Image 24: Brine Pump from IDA ICE.

Now, it is displayed the main parameters in order to understand if the controller is well designed. But the limit has been changed to appreciate the changes of valves and pumps. Now the upper and lower limits are 27ºC and 16ºC respectively.

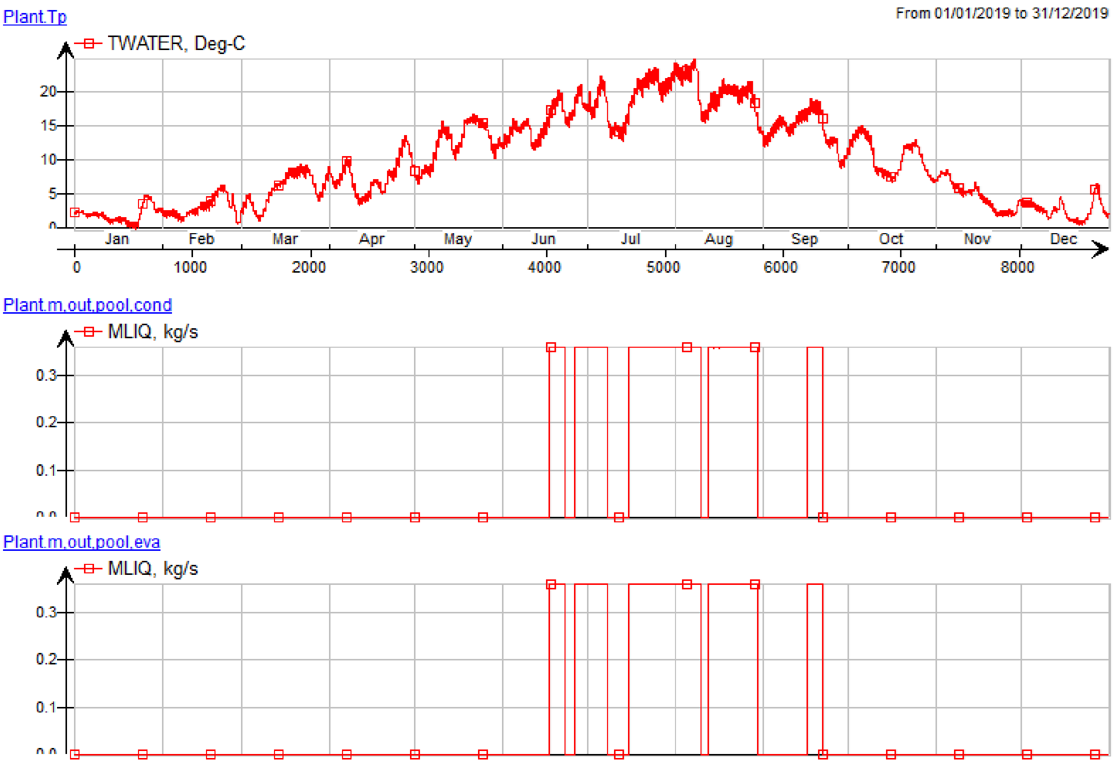


Image 25: Screenshot of different parameters from IDA ICE.

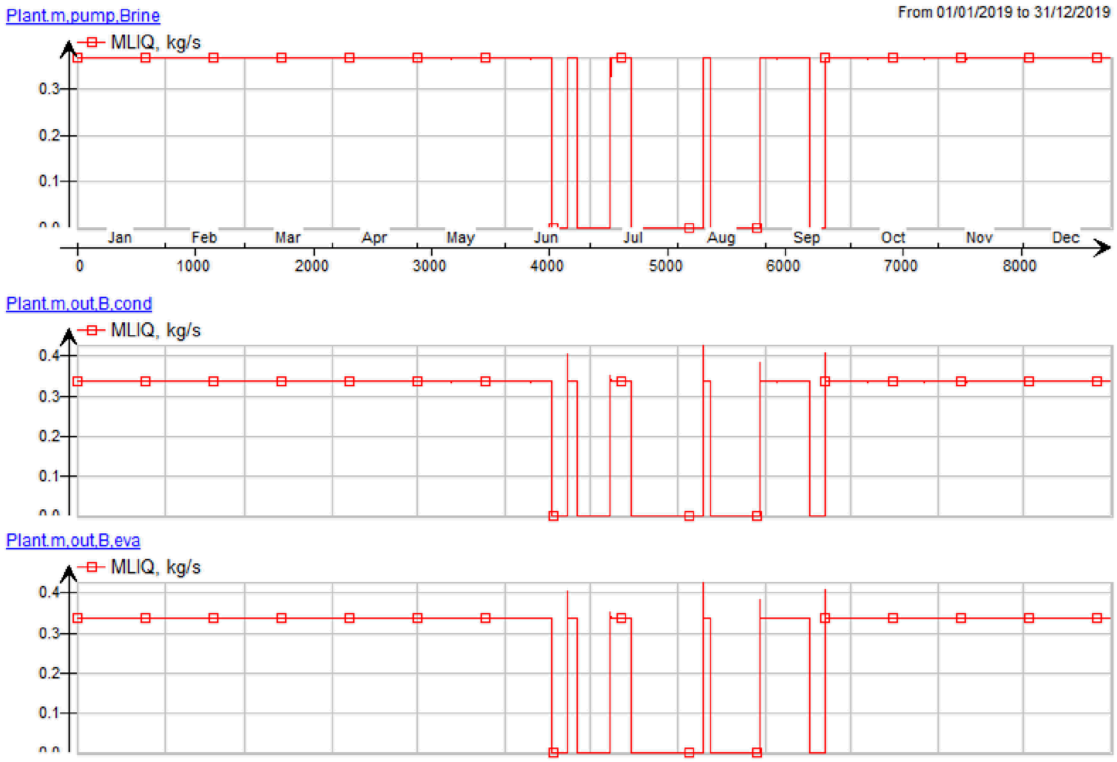
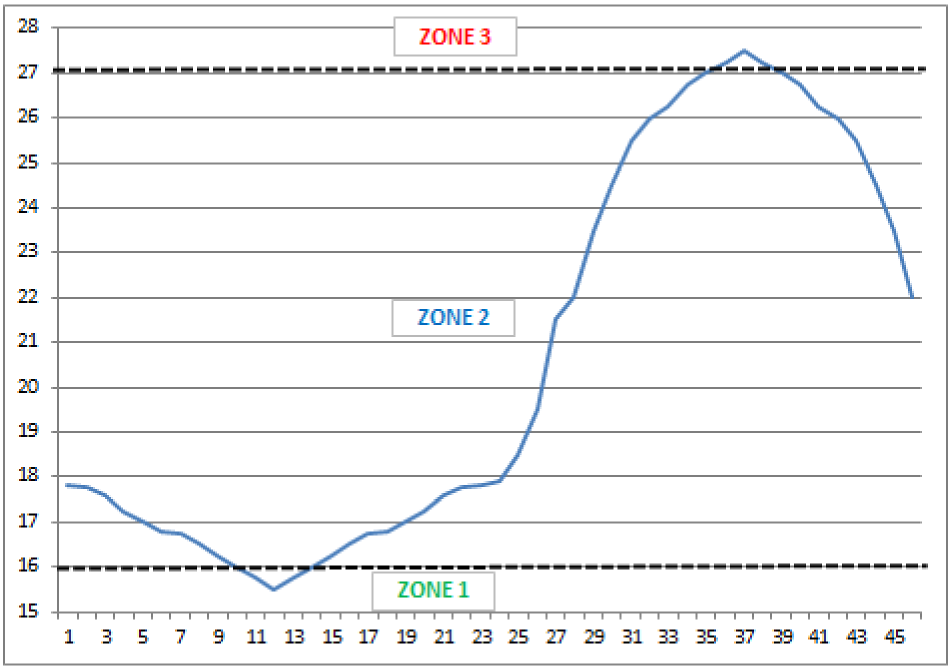


Image 26: Screenshot of different parameters from IDA ICE.

To sum up, the controller is working well but it can be improved as it could be used the pool as a heat source for the condenser meanwhile the evaporator is using the ground heat exchanger or vice versa, depending on the temperature of the swimming pool. It means that if the temperature is below the lower temperature limit, the evaporator should use the ground heat exchanger but the condenser can still use the swimming pool as a heat source.

Maybe it is more understandable with the following picture, it is an example.



Graph 9: Example: Different modes.

As it is shown, there are three different zones;

Zone 1: The evaporator is connected to the ground heat exchanger, and the condenser could be connected to the swimming pool.

Zone2: The evaporator and condenser are connected to the swimming pool, taking into account the controllers.

Zone3: The condenser is connected to the ground heat exchanger and the evaporator could be connected to the swimming pool.

- **<u>Step 3</u>**: <u>Supply System C</u>. Swimming pool and ground heat exchanger as heat sources. Another controller is used.

Now, the layout has change a bit due to the new two controllers and it has been removed the Pump 3 and 4.

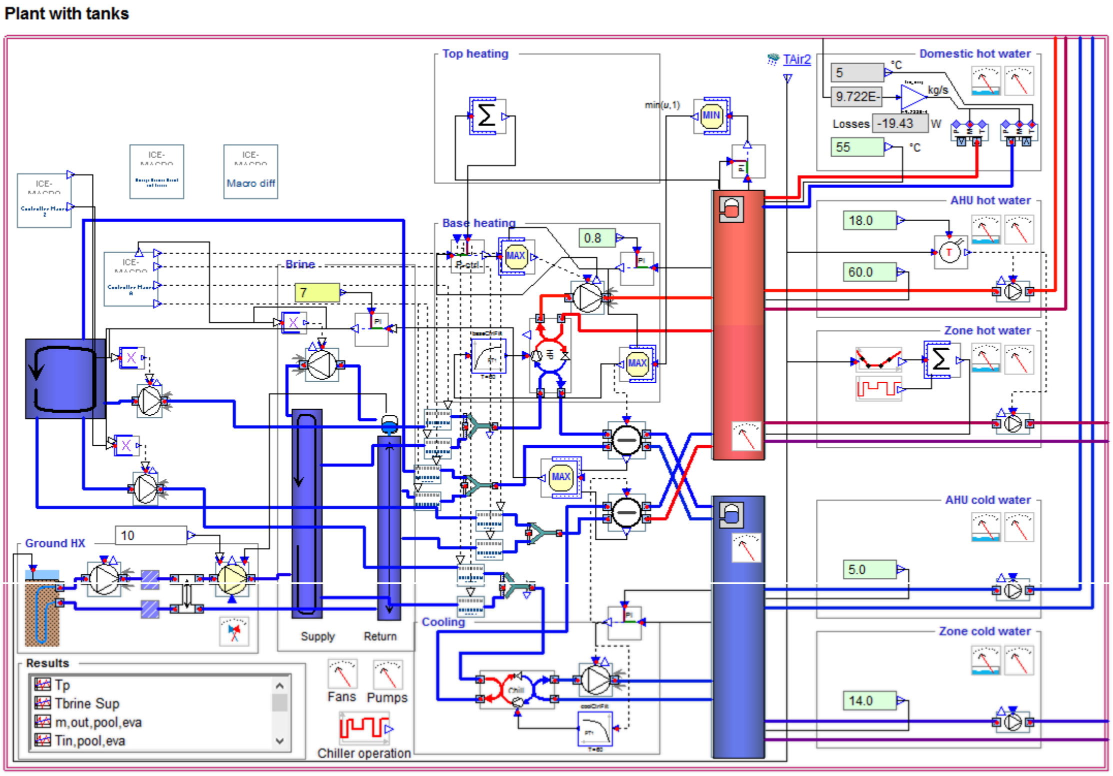


Image 27: Layout of the Supply System from IDA ICE, Step 3.

The controllers are quite different in comparison with the previous one.

Controller A: It only controls valves and the Brine pump.

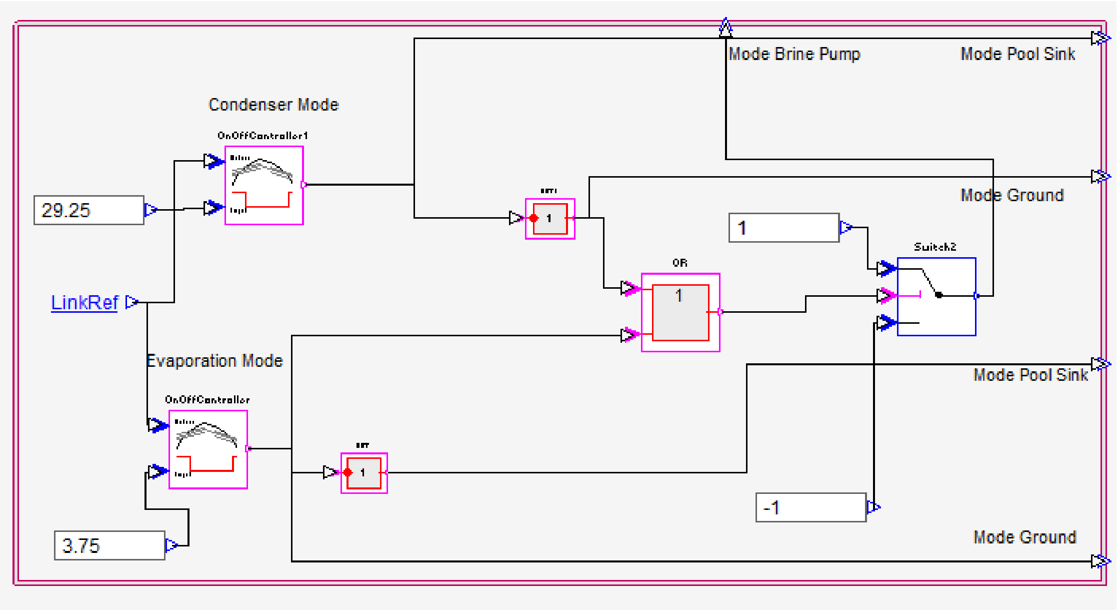


Image 28: Macro of the Controller A.

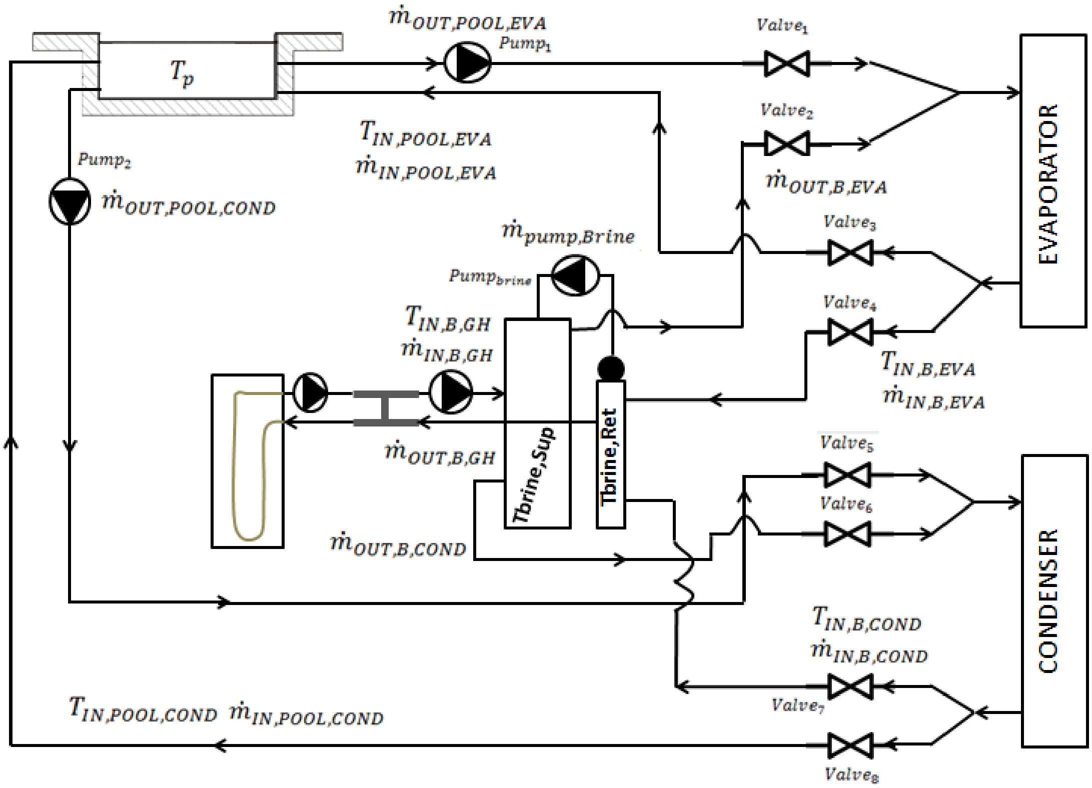


Image 29: Layout of the Supply System, Step 3.

Controller 2: It controls the pump 1 and 2.

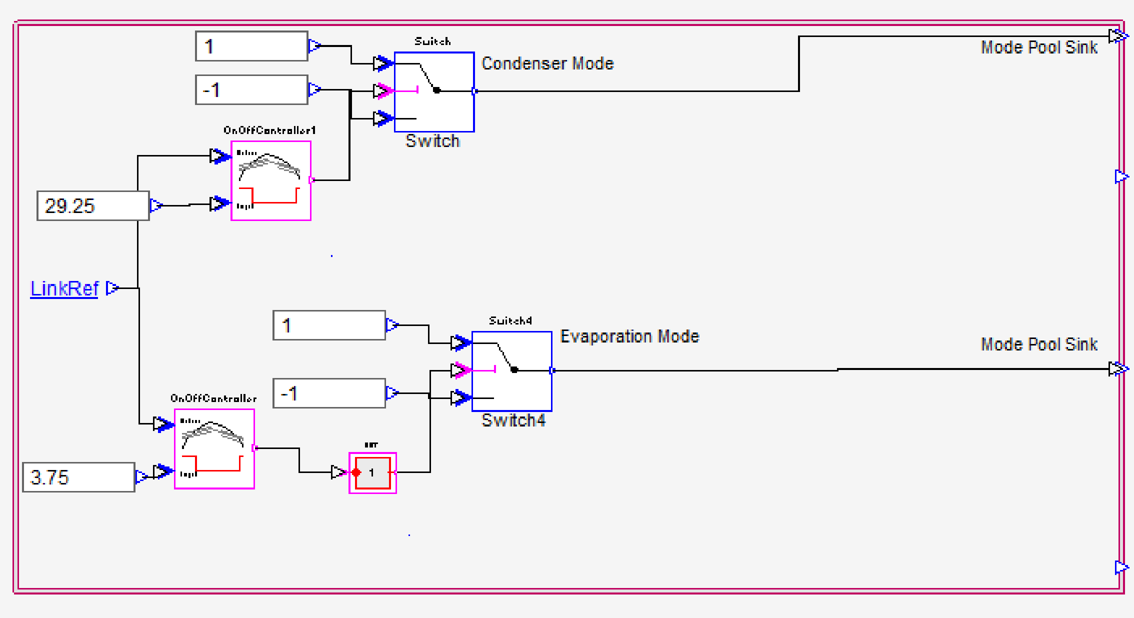


Image 30: Macro of the Controller B.

- Switch: it controls the Pump 2.
- Switch4: Pump 1.

The pool temperature range has been changed in order to analyse all the possible cases. Now the upper and lower limits are 20ºC and 9.25ºC respectively.

If the previous model of IDA ICE is run, the software does not crash.

The results:

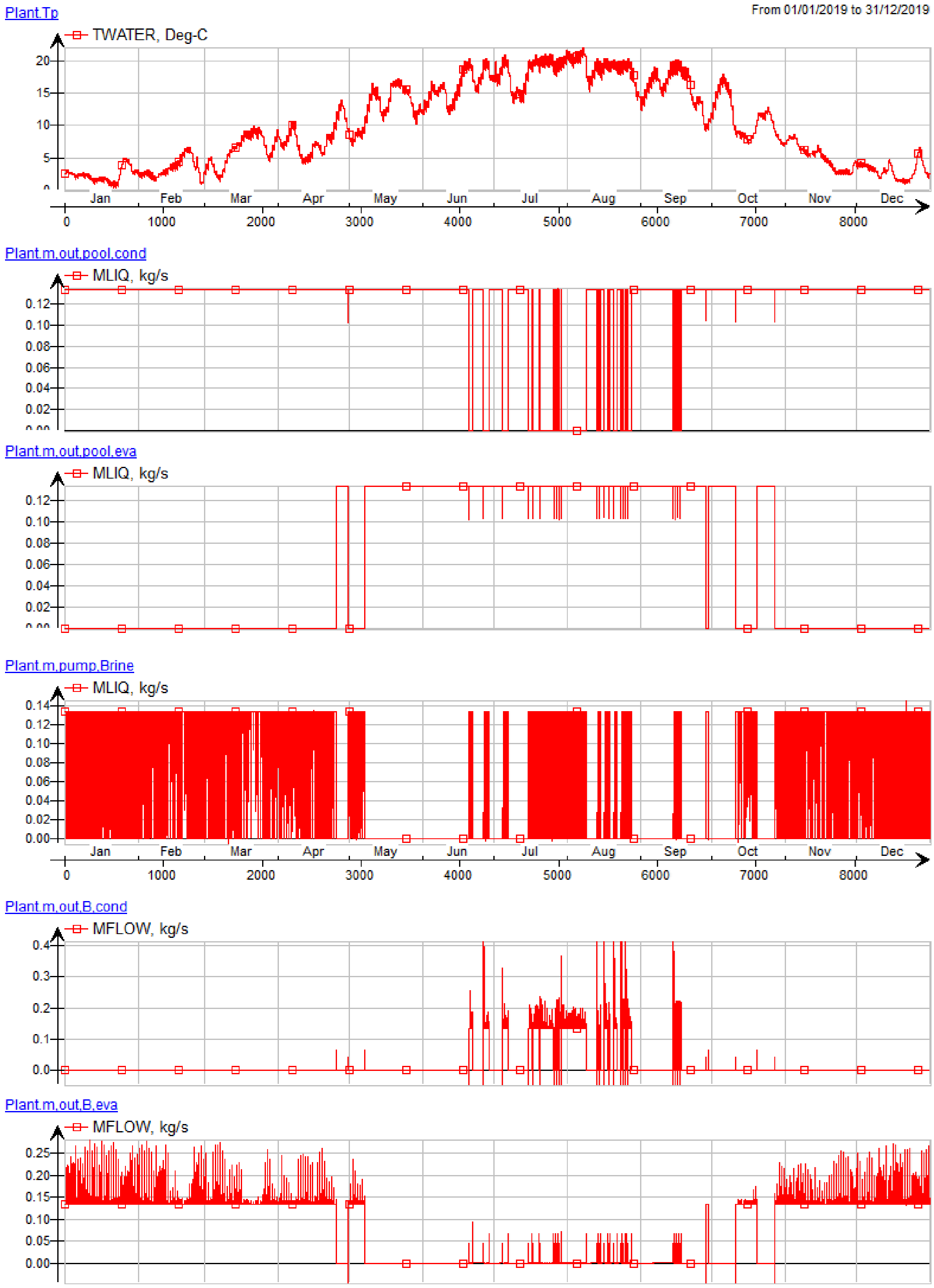


Image 31: Screenshot of various parameters from IDA ICE.

In the end, the controller has been improved and it works properly without any errors during the simulation.Therefore, this supply system will be used during the whole simulations.

Sanitary hot water demand.

It is an easy calculation as the Annex F of the Basic Document "DB-HE Energy Saving" establishes a value of 28 litres/(day*person) at 60ºC for the residential buildings (CTE, 2018).

$$D_{SHW}\left(\frac{l}{day}\right) = Nºpeople * 28\left(\frac{l}{day * person}\right) = 3 * 28 = 84\frac{l}{day} \quad (7.1)$$

Hence, as the sanitary hot water demand is lower than the specified demand in the CTE (100 l/day), the building is exempt from complying with the section “HE4: Minimum energy contribution by renewable energy to supply the Sanitary Hot Water”.

8 PHOTOVOLTAIC SYSTEM.

The building designed has the best characteristics to be supplied by a photovoltaic installation. The climate is optimum because the sun days in Spain are more than 300 as an average, so it is possible to consume almost every day from the energy supplied by the sun.

Orientation and Slope.

The near zero energy building is going to be oriented towards south, so the photovoltaic system will have an azimuth of 0 º.

Regarding the degree of slope, it has been decided to take the optimal slope that provides the maximum amount of energy during all year for each location. For this reason, it has been used the online programme PVGIS that shows the optimal inclination angle depending on the localization of the NZEBuilding. (The European Commission, 2019)

As a result, it has obtained this table where the optimal inclination angle for each location is shown.

Climate Zone	Label	Autonomous community	City	Optimal Angle
E	E4	-	-	-
	E1	Castilla y León	Soria	36
D	D3	C. de Madrid	Madrid	36
	D1	Vasc Country	San Sebastián	36
C	C3	Catalonia	Barcelona	37
	C1	Galicia	A Coruña	36
B	B4	Andalucia	Seville	33
	B3	C. Valenciana	Valencia	36
A	A4	Andalucia	Almería	34
	A3	Andalucia	Málaga	33
α	α3	Canarias Islands	Santa Cruz Tenerife	26
	α1	-	-	-

Table 20: Optimal Angle

Finally, losses due to inclination according to azimuth are obtained by the loss diagram. Image 27 shows losses with a blue circle, they are between 95% and 100% for all the cases.

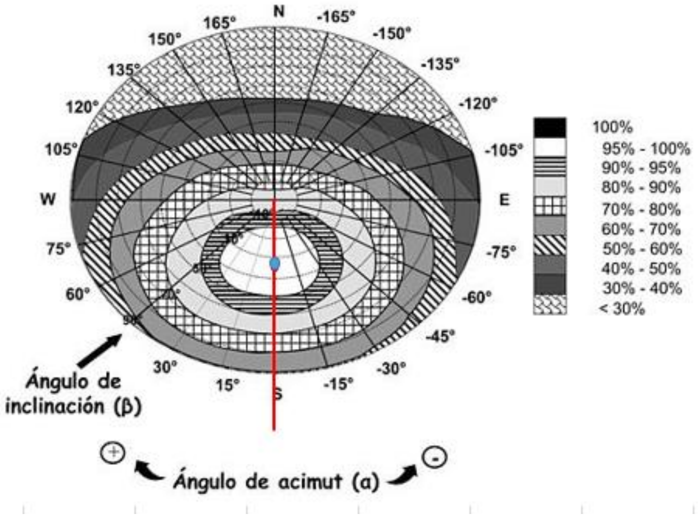


Image 32: Loss Diagram

<u>Shadows and Losses.</u>

Furthermore, it is possible that shadows appear owing to panels themselves. To avoid this type of shades, it is going to be calculated the minimum distance between panels as it is explained in the following paragraph.

<u>Distance between panels.</u>

During this paragraph it is going to be obtained the maximum number of photovoltaic panels that are possible to install on the roof, avoiding the shadow produced between panels.

It is important to prevent from shadows not only because the shadowed part of the panel doesn't produce energy, but also dissipates it. This fact produces an increase of the panel temperature that could damage it.

The next process has been done for the Soria case, but it is the same for the other locations.

In order to obtain the minimum length, it has been chosen the solar path that produces the highest shadows. This frame time is in winter solstice, on 21st of December.

It has used the following equations;

$$d \geq h * k = \frac{h}{\tan(61° - latitude)} \quad (8.1)$$

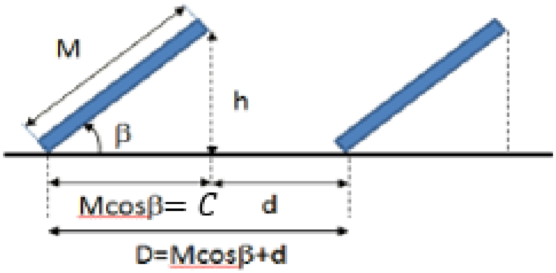


Table 21: Distance to avoid shadows.

The process to follow to obtain the maximum number of panels has two options;

a) It is going to be put panels in landscape, i.e., the longest part of the panel on the floor. In the next table it is shown parameters used in equations.

Length on Floor (T)	1.645	m
Length of Panel (M)	0.99	m
Azimuth (α)	0	º
Azimuth (α)	0	rad
Slope (β)	36	º
Slope (β)	0,6283	rad
Latitude	41,769	º
h	0,5819	m

Table 22:Parameters in landscape.

Using the equation 8.1 and previous parameters, it has been obtained the minimum distance. (dmin).

dmin	1,6681	m
C	0,8009	m
L	2,4690	m

Table 23:Results in landscape.

Now, it is going to be specified which security distances are taken on the roof; these distances are the same for both options. The area, where the photovoltaic system will be installed, is inside the red zones. Furthermore, it is specified the distances of those zones.

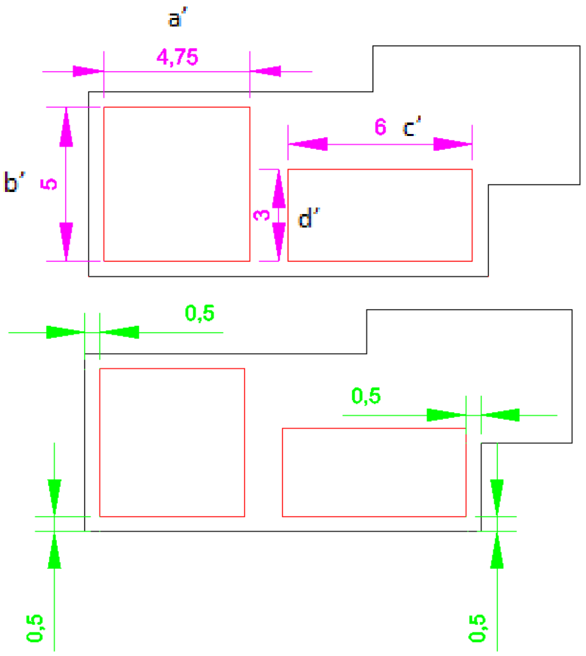


Image 33: Security distance and zones.

In the case a) it has been followed the next equations in order to get the maximum number of panels.

$$Nº\ Panel\ width\ Zone\ 1 \leq \left(\frac{b'}{T}\right) = 2.7 \quad (8.2)$$

$$Nº\ Panel\ width\ Zone\ 2 \leq \left(\frac{d'}{T}\right) = 3.6474 \quad (8.3)$$

The number of panels has to be a whole number, so the number of panels is 2 and 3.

$$Nº\ Panel\ width\ Zone\ 1 = 2$$

$$Nº\ Panel\ width\ Zone\ 2 = 3$$

$$Nº\ Panels\ length\ Zone\ 1 \leq \left(\frac{a' + Dmin}{L}\right) = 2{,}8875 \qquad (8.4)$$

$$Nº\ Panels\ length\ Zone\ 2 \leq \left(\frac{c' + Dmin}{L}\right) = 1.86 \qquad (8.5)$$

$$Nº\ Panels\ length\ Zone\ 1 = 2$$

$$Nº\ Panels\ length\ Zone\ 2 = 1$$

$$Maximum\ Nº\ Panels\ \ in\ Landscape = 2 * 2 + 3 * 1 = 7\ panels.$$

If this distribution was implemented the power would be 1.89 kWp.

b) In the case b) the shortest part of the panel is collocated on the floor, i.e., in vertical way. The same process, which has been followed previously, it is going to carry out now.

Length on Floor (T)	0,99	m
Length of Panel (M)	1,645	m
Azimuth (α)	0	º
Azimuth (α)	0	rad
Slope (β)	36	º
Slope (β)	0,6283	rad
Latitude	41,769	º
h	0,9669	m

Table 24: Parameters in vertical.

Using the equation 8.1 and previous parameters, it has obtained the minimum distance. (dmin).

dmin	2,7717	m
C	1,3308	m
L	4,1025	m

Table 25: Results in vertical.

In case b) it has been followed the next equations in order to get the maximum number of panels.

$$Nº\ Panel\ width\ Zone\ 1 \leq \left(\frac{b'}{T}\right) = 4.7979 \quad (8.6)$$

$$Nº\ Panel\ width\ Zone\ 2 \leq \left(\frac{d'}{T}\right) = \ 6.06 \quad (8.7)$$

The number of panels has to be a whole number, so the number of panels is 4 and 6.

$$Nº\ Panel\ width\ Zone\ 1 = 4$$

$$Nº\ Panel\ width\ Zone\ 2 = 6$$

$$Nº\ Panels\ length\ Zone\ 1 \leq \left(\frac{a' + Dmin}{L}\right) = \ 1.89 \quad (8.8)$$

$$Nº\ Panels\ length\ Zone\ 2 \leq \left(\frac{c' + Dmin}{L}\right) = \ 1.40 \quad (8.9)$$

$$Nº\ Panels\ length\ Zone\ 1 = 1$$

$$Nº\ Panels\ length\ Zone\ 2 = 1$$

$$Maximum\ Nº\ Panels\ \ in\ Landscape = 4 * 1 + 6 * 1 = 10\ panels.$$

If this distribution was implemented the power would be 2.7 kWp.

Finally, it is going to be chosen the case b), because it provides the highest number of photovoltaic panels. The same process has been done for all locations and the results are displayed in table 16.

Climate Zone	Label	City	Nº Vertical	kWp	Nº Landscape	kWp
E	E4	-	-	-	-	-
	E1	Soria	10	2.7	7	1.89
D	D3	Madrid	10	2.7	7	1.89
	D1	San Sebastián	10	2.7	7	1.89
C	C3	Barcelona	10	2.7	7	1.89
	C1	A Coruña	10	2.7	7	1.89
B	B4	Seville	14	3.78	12	3.24
	B3	Valencia	10	2.7	7	1.89
A	A4	Almería	14	3.78	12	3.24
	A3	Málaga	14	3.78	12	3.24
α	α3	Santa Cruz Tenerife	14	3.78	12	3.24
	α1	-	-	-	-	-

Table 26: kWp per location.

9 DESIGN OF THE WINDOWS DIMENSION.

Once the layout of the building and the supply system are designed, the next step is the search of the windows dimensions design that provides the lowest consumption among the options studied. Then, it is going to be followed the next process:

1. There are 11 options where the dimensions of the windows are different (Annex 2) and it is set three different Air Handling Unit controls: Temperature and CO2 control, only CO2 control and only humidity control. The AHUs and the three controls are explained at the end of this section.
2. It is run the 33 simulations for each location (330 simulations).
3. It is selected the option with less demand (the sum of cooling and heating demand). The results are shown in the Annex 3.

It is obvious that the option chosen could not be the best solution because it could be another option with less demand that is not considered on the previous list. Anyway, the option chosen will be considered the best solution in order not to make the number of simulations too many.

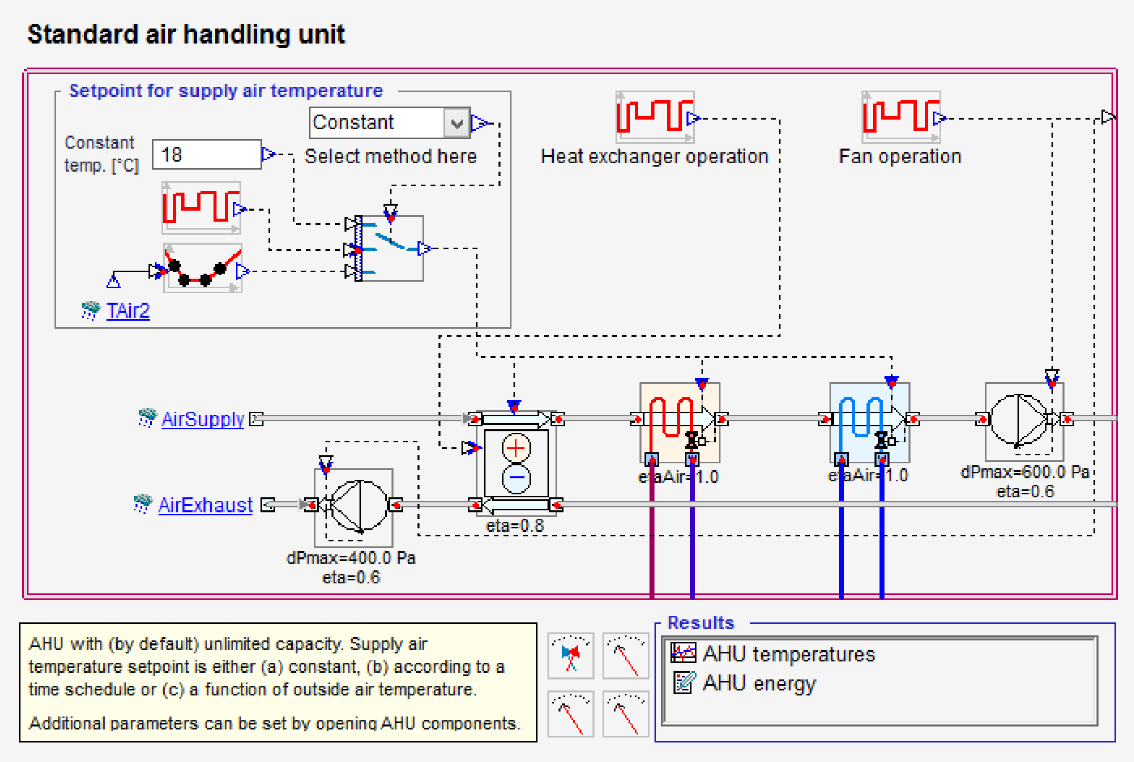
Climate Zone	Label	City	Final Solution	Total Demand (kWh)
E	E4	-	-	-
	E1	Soria	Temp+CO2 Option 5	5423
D	D3	Madrid	Only CO2 Option 9	4958
	D1	San Sebastián	Temp+CO2 Option 5	3664
C	C3	Barcelona	Only CO2 Option 9	4396
	C1	A Coruña	Only CO2 Option 8	2914
B	B4	Seville	Only CO2 Option 9	5352
	B3	Valencia	Only CO2 Option 9	4903
A	A4	Almería	Only CO2 Option 9	4972
	A3	Málaga	Only CO2 Option 9	4543
α	α3	Santa Cruz Tenerife	Only CO2 Option 9	5289
	α1	-	-	-

Table 27: Results of the Window Dimension Design.

It is observed that for warmer zones the best solution is the only CO2 control with an appropriate percentage of discomfort. Otherwise, there are two locations where the temperature and CO2 control is more suitable.

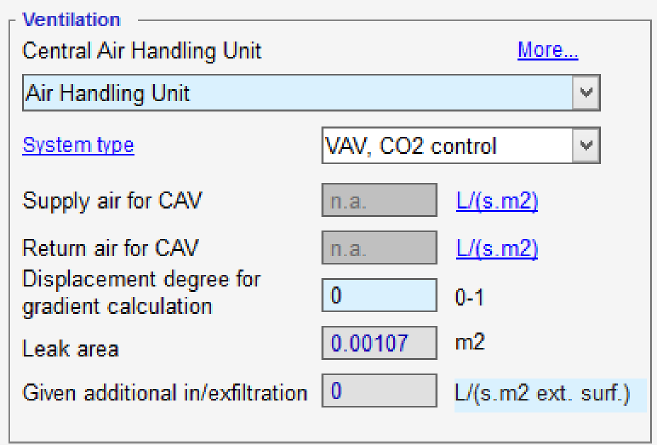
Air handling Units and the controls.

As it is mentioned before, three different controls are set in order to analyse if there is any difference in the final consumption of the nZEB. Otherwise, there are only two air handling units, the Standard Air Handling Unit (for temperature & CO2 control, only CO2 control) and another one for the only humidity control, the return air humidity control (steam).



AHU with (by default) unlimited capacity. Supply air temperature setpoint is either (a) constant, (b) according to a time schedule or (c) a function of outside air temperature.

Additional parameters can be set by opening AHU components.

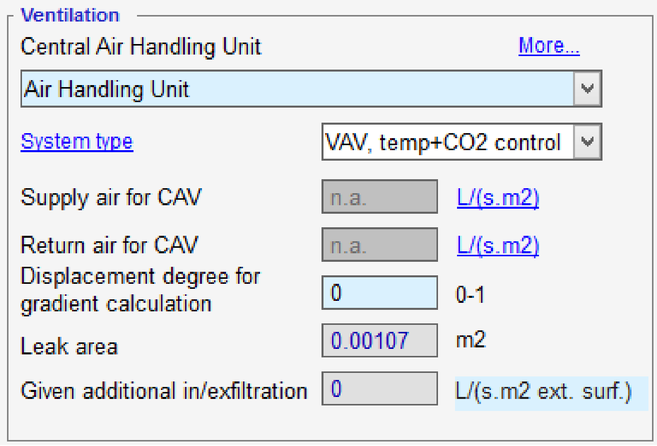


Ventilation

Central Air Handling Unit More...

Air Handling Unit

System type	VAV, CO2 control	
Supply air for CAV	n.a.	L/(s.m2)
Return air for CAV	n.a.	L/(s.m2)
Displacement degree for gradient calculation	0	0-1
Leak area	0.00107	m2
Given additional in/exfiltration	0	L/(s.m2 ext. surf.)

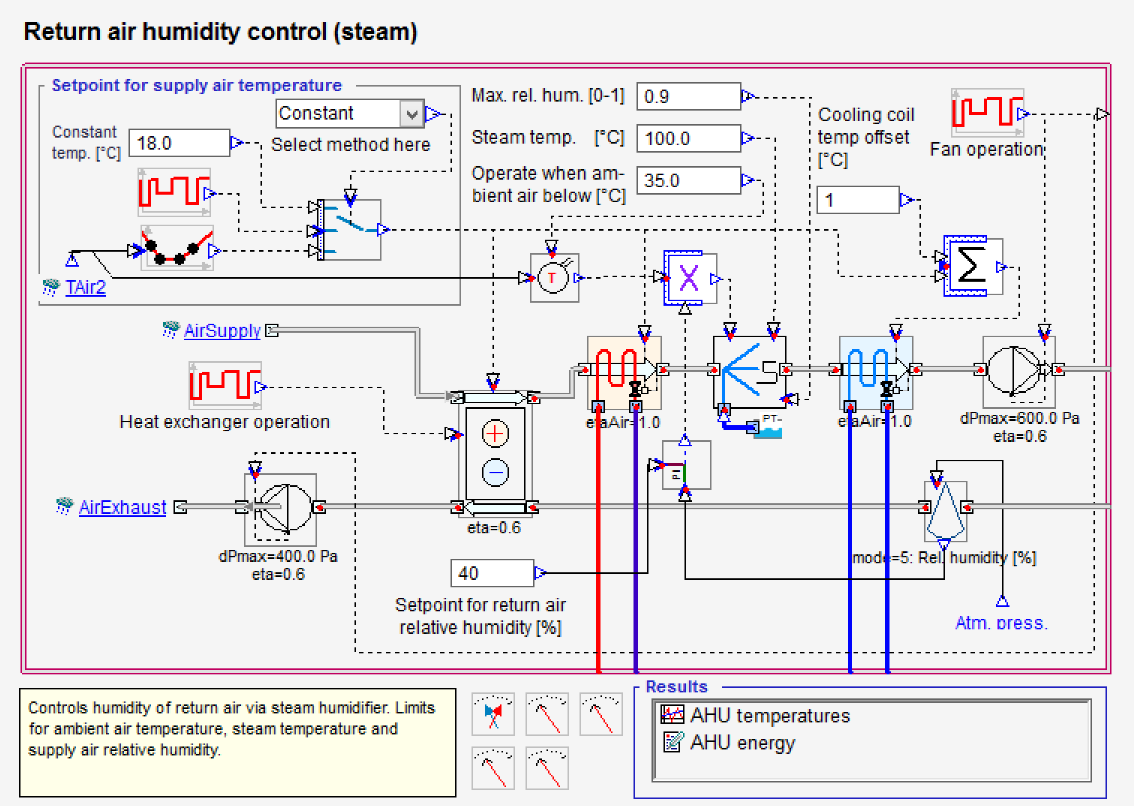


Ventilation

Central Air Handling Unit More...

Air Handling Unit

System type	VAV, temp+CO2 control	
Supply air for CAV	n.a.	L/(s.m2)
Return air for CAV	n.a.	L/(s.m2)
Displacement degree for gradient calculation	0	0-1
Leak area	0.00107	m2
Given additional in/exfiltration	0	L/(s.m2 ext. surf.)



Constant temp. [°C] 18.0

Constant — Select method here

Max. rel. hum. [0-1] 0.9

Steam temp. [°C] 100.0

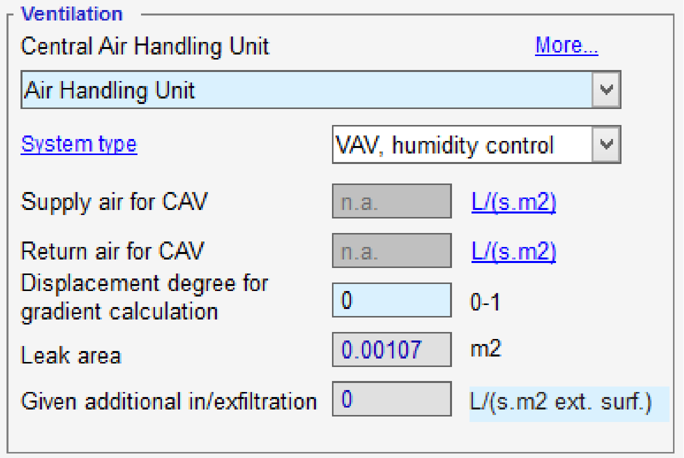
Operate when ambient air below [°C] 35.0

Cooling coil temp offset [°C] 1

Setpoint for return air relative humidity [%] 40

Controls humidity of return air via steam humidifier. Limits for ambient air temperature, steam temperature and supply air relative humidity.

Results:
- AHU temperatures
- AHU energy



Central Air Handling Unit

Air Handling Unit

System type	VAV, humidity control	
Supply air for CAV	n.a.	L/(s.m2)
Return air for CAV	n.a.	L/(s.m2)
Displacement degree for gradient calculation	0	0-1
Leak area	0.00107	m2
Given additional in/exfiltration	0	L/(s.m2 ext. surf.)

10 DESIGN OF THE SHADING SCHEDULE.

Now, the following step is the reduction of the cooling demand by means of a proper shading schedule. It is important to mention that for each location the shading schedule is different and they are shown in the Annex 4. Even thought, if the shading schedule is bad designed, it could appear an increment of the heating demand.

In this case, the process to follow is:

1. Install the shading system in all windows, except the windows that face north.
2. Create a shading schedule for all windows.
3. Run the simulation.
4. Create another shading schedule.
5. Run the simulation and observe if there is a reduction in the demand.
6. Repeat the process from point 4 until you find the shading schedule with the lowest demand.

Following the previous process, it is obtained an option with the lowest consumption for each location and they are displayed in the next table. As it is a trial and error method, the option chosen could not be the best solution because maybe there is another shading schedule that provides a lower consumption.

Climate Zone	Label	City	Final Solution	Total Demand (kWh)	Reduction (kWh)
E	E4	-	-	-	-
	E1	Soria	Sh8	4956	466
D	D3	Madrid	Sh9	4256	702
	D1	San Sebastian	Sh2	3579	85
C	C3	Barcelona	Sh7	3703	692
	C1	A Coruña	Sh5	2757	157
B	B4	Seville	Sh4	4306	1045
	B3	Valencia	Sh5	4011	892
A	A4	Almeria	Sh7	4026	946
	A3	Malaga	Sh4	3745	798
α	α3	Santa Cruz Tenerife	Sh3	4220	1069
	α1	-	-	-	-

Table 28: Results of the Shading Schedule Design.

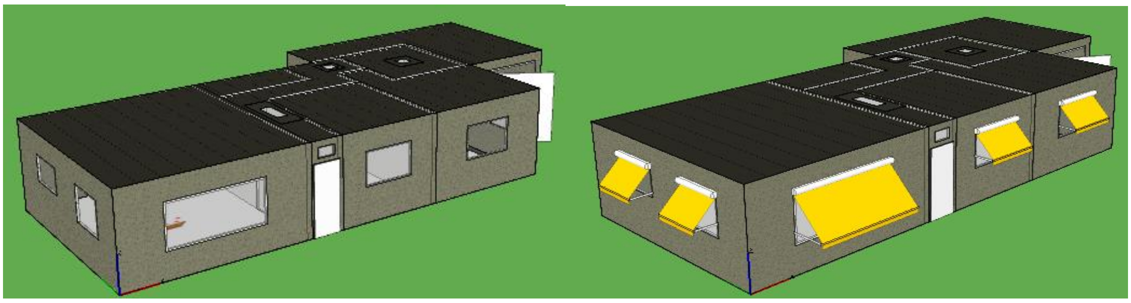
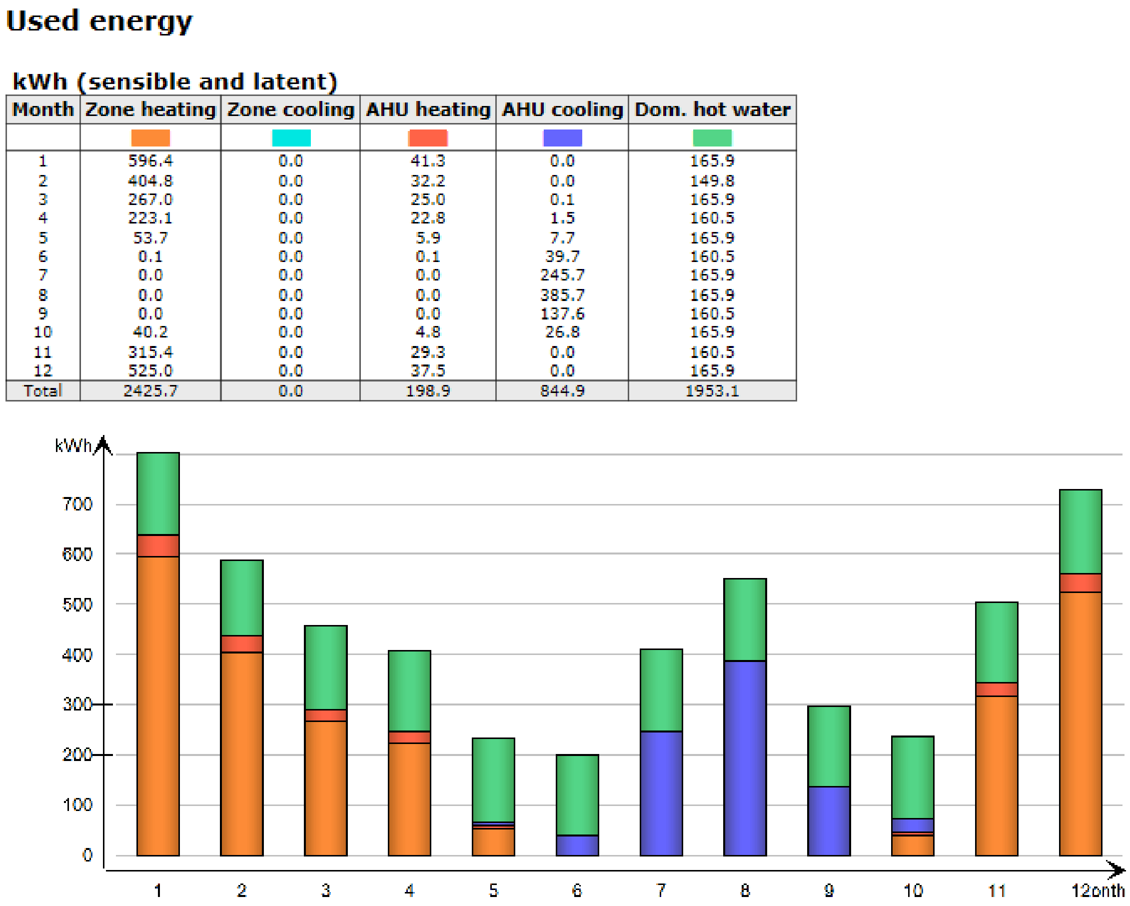


Table 29: Installation of Shading System in Málaga.

<u>How to create a Shading schedule.</u>

The explanation will be easier with an example. Thus, it is used Soria to explain the creation of a shading schedule. So, firstly, the results for the building are obtained without the shading systems installed.



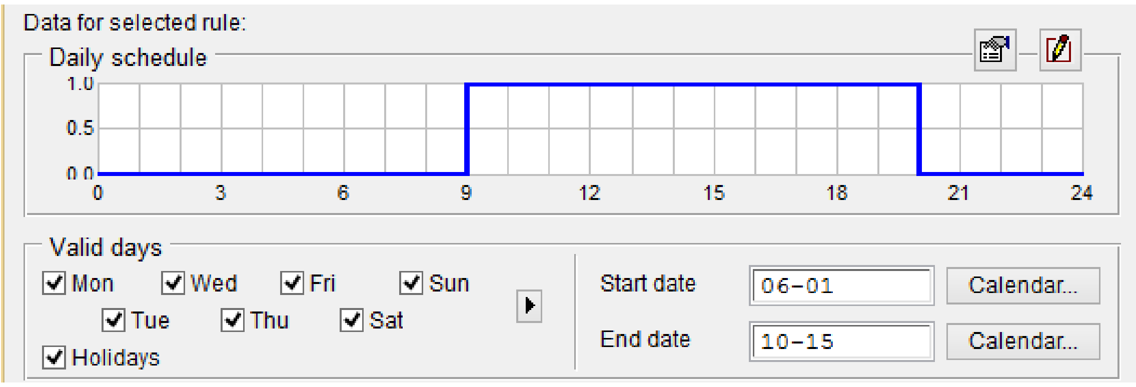
Used energy

kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
	🟧	🟦	🟥	🟦	🟩
1	596.4	0.0	41.3	0.0	165.9
2	404.8	0.0	32.2	0.0	149.8
3	267.0	0.0	25.0	0.1	165.9
4	223.1	0.0	22.8	1.5	160.5
5	53.7	0.0	5.9	7.7	165.9
6	0.1	0.0	0.1	39.7	160.5
7	0.0	0.0	0.0	245.7	165.9
8	0.0	0.0	0.0	385.7	165.9
9	0.0	0.0	0.0	137.6	160.5
10	40.2	0.0	4.8	26.8	165.9
11	315.4	0.0	29.3	0.0	160.5
12	525.0	0.0	37.5	0.0	165.9
Total	2425.7	0.0	198.9	844.9	1953.1

Image 34: Used energy without shading schedule in Soria.

If the previous table and graph are analysed, the conclusions prove that it is possible to reduce the cooling demand from June to September, and even October. Therefore, the first shading schedule is displayed in the next image.



Data for selected rule:

Daily schedule

Valid days

☑ Mon ☑ Wed ☑ Fri ☑ Sun

☑ Tue ☑ Thu ☑ Sat

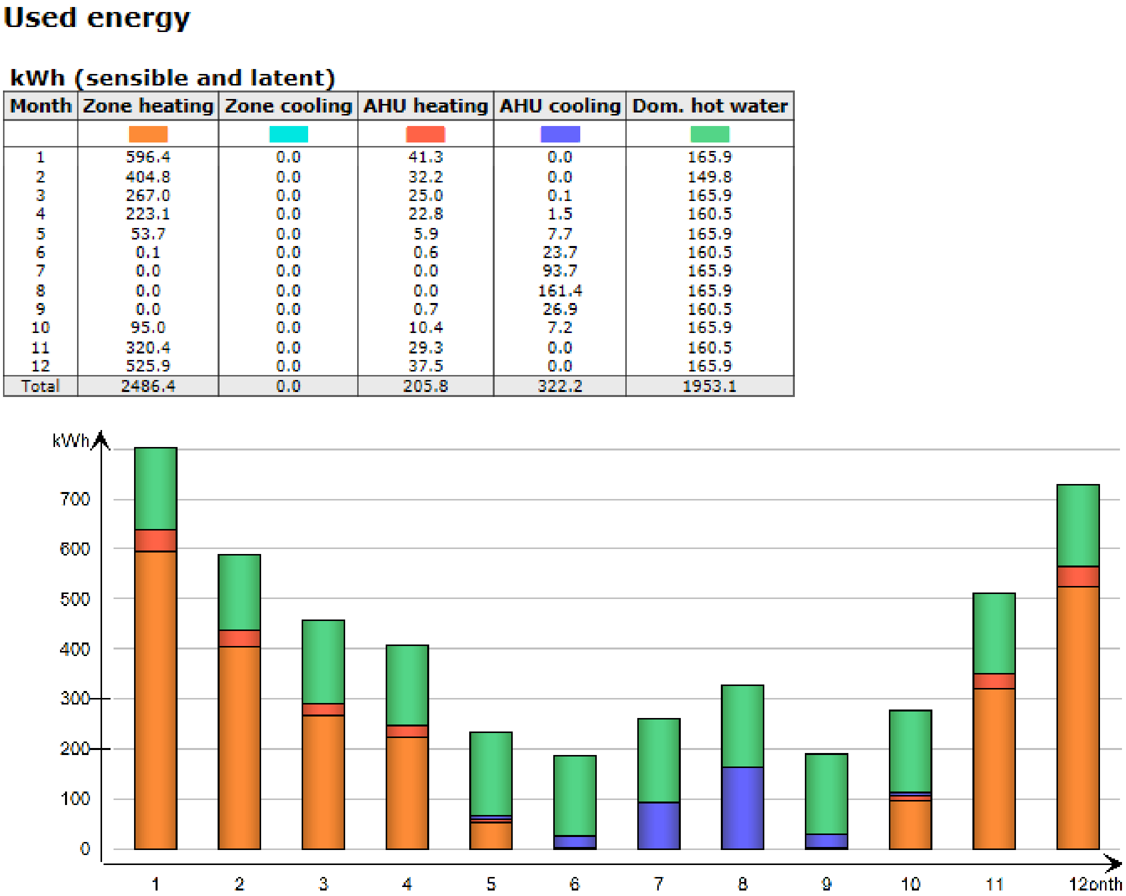
☑ Holidays

Start date 06-01 Calendar...

End date 10-15 Calendar...

Image 35: Shading Schedule 1 in Soria.

Then, the schedule is from June 1st until October 15th, and from 9 am to 8 pm. The simulation is done again and this is the result.



Used energy

kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
	🟧	🟦	🟥	🟦	🟩
1	596.4	0.0	41.3	0.0	165.9
2	404.8	0.0	32.2	0.0	149.8
3	267.0	0.0	25.0	0.1	165.9
4	223.1	0.0	22.8	1.5	160.5
5	53.7	0.0	5.9	7.7	165.9
6	0.1	0.0	0.6	23.7	160.5
7	0.0	0.0	0.0	93.7	165.9
8	0.0	0.0	0.0	161.4	165.9
9	0.0	0.0	0.7	26.9	160.5
10	95.0	0.0	10.4	7.2	165.9
11	320.4	0.0	29.3	0.0	160.5
12	525.9	0.0	37.5	0.0	165.9
Total	2486.4	0.0	205.8	322.2	1953.1

Image 36: Used energy with shading schedule 1 in Soria.

As it is obvious, there is a significant reduction in the cooling demand (from 844.9 kWh to 322.2 kWh), but there is an increment in the heating demand (from 4577.7 to 4645.3). That increment is due to a bad design of the shading schedule, but only in October, because in the rest of the months the shading schedule works well. It is clear if it is observed the following image or compared the previous tables.

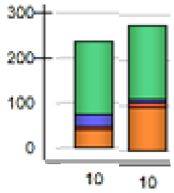
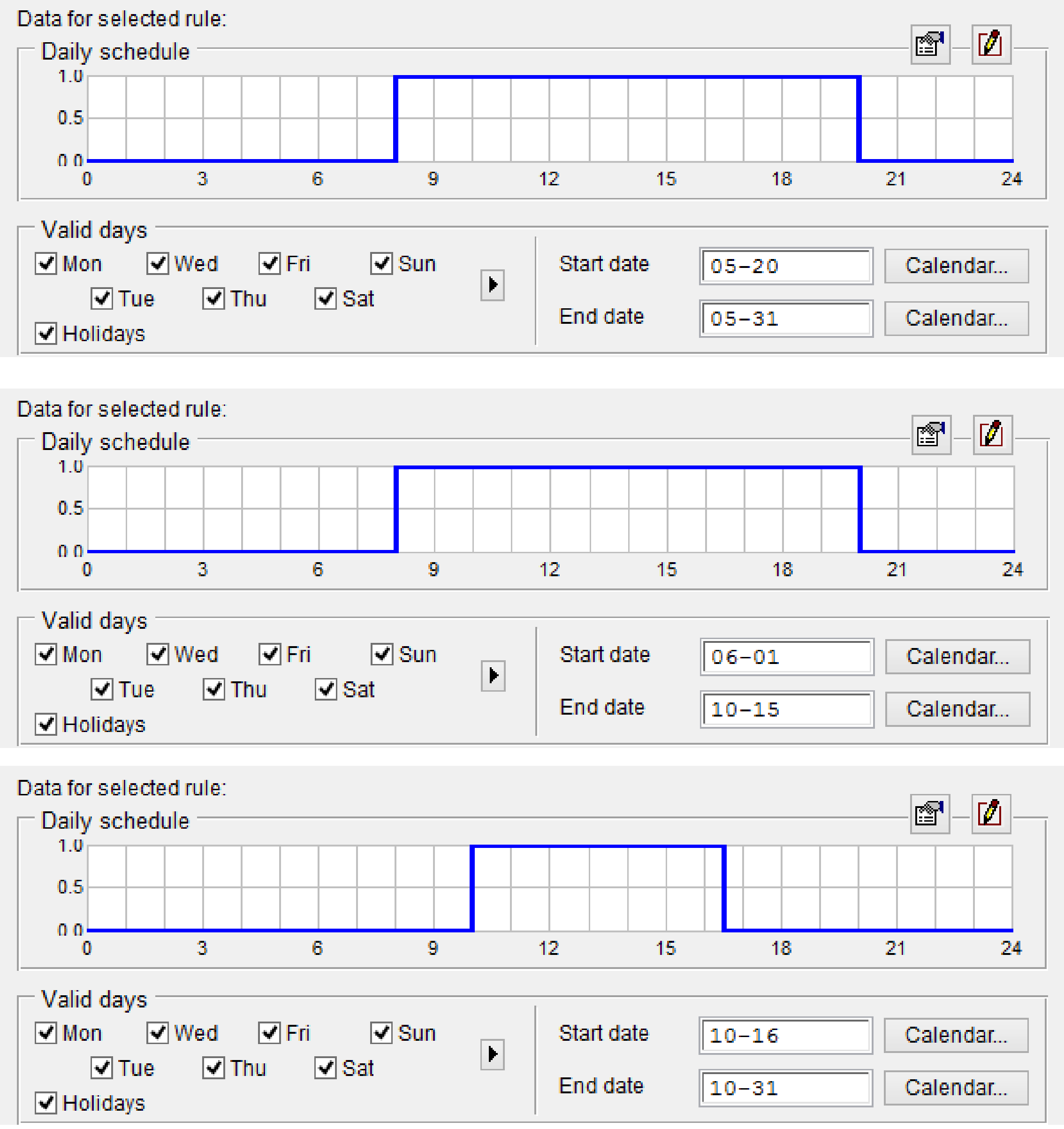


Image 37: Comparison between both October months.

A new shading schedule is needed to decrease the consumption, and as the shading schedule of October is the problem, it is done a new one where it is added a shading schedule for the end of May to decrease the little amount of cooling demand.


Data for selected rule:

Daily schedule

Valid days

☑ Mon ☑ Wed ☑ Fri ☑ Sun
☑ Tue ☑ Thu ☑ Sat
☑ Holidays

Start date: 05–20
End date: 05–31

Data for selected rule:

Daily schedule

Valid days

☑ Mon ☑ Wed ☑ Fri ☑ Sun
☑ Tue ☑ Thu ☑ Sat
☑ Holidays

Start date: 06–01
End date: 10–15

Data for selected rule:

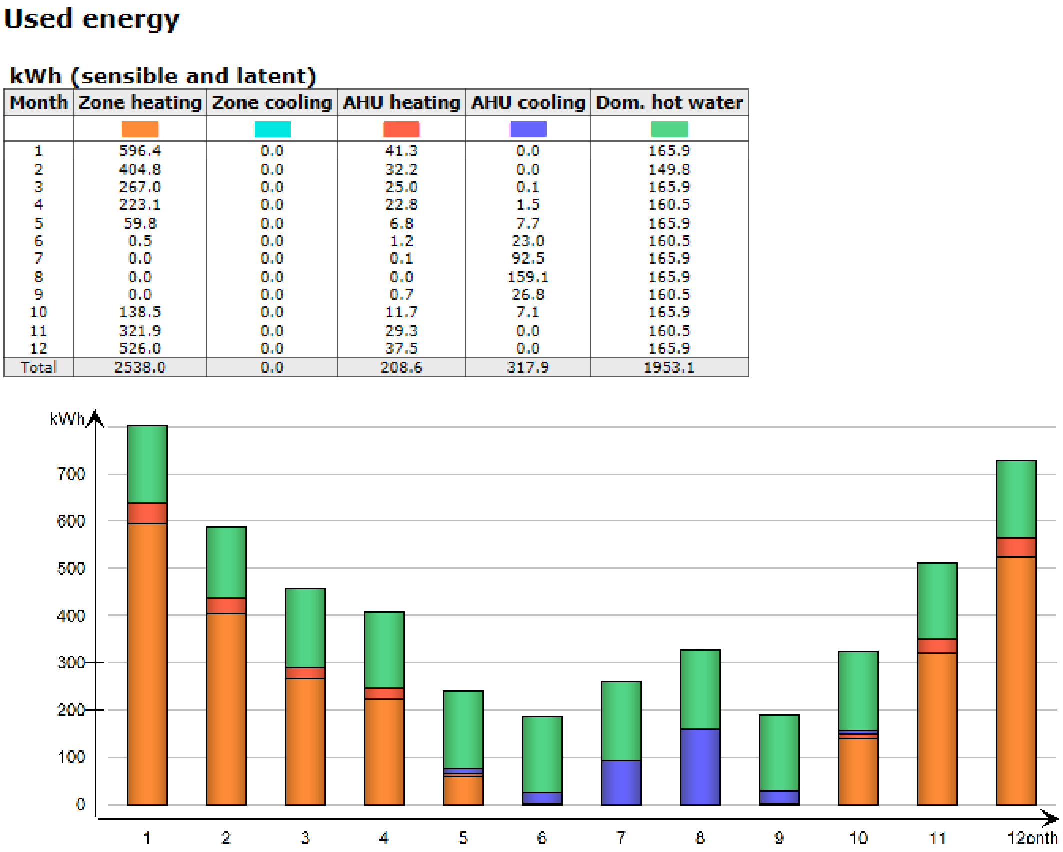
Daily schedule

Valid days

☑ Mon ☑ Wed ☑ Fri ☑ Sun
☑ Tue ☑ Thu ☑ Sat
☑ Holidays

Start date: 10–16
End date: 10–31

Image 38: Shading Schedule 2 in Soria.



Used energy

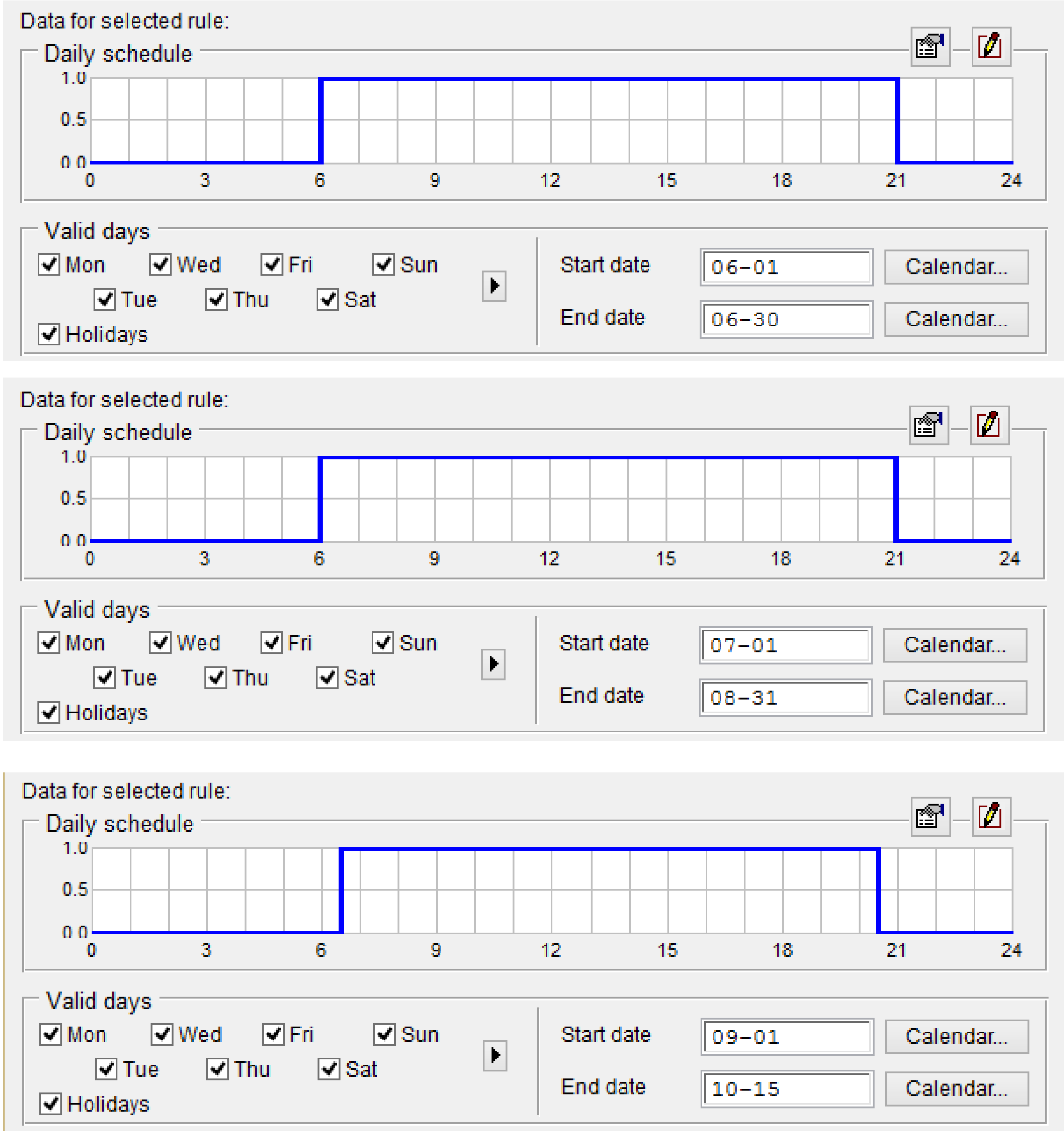
kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
	🟧	🟦	🟥	🟪	🟩
1	596.4	0.0	41.3	0.0	165.9
2	404.8	0.0	32.2	0.0	149.8
3	267.0	0.0	25.0	0.1	165.9
4	223.1	0.0	22.8	1.5	160.5
5	59.8	0.0	6.8	7.7	165.9
6	0.5	0.0	1.2	23.0	160.5
7	0.0	0.0	0.1	92.5	165.9
8	0.0	0.0	0.0	159.1	165.9
9	0.0	0.0	0.7	26.8	160.5
10	138.5	0.0	11.7	7.1	165.9
11	321.9	0.0	29.3	0.0	160.5
12	526.0	0.0	37.5	0.0	165.9
Total	2538.0	0.0	208.6	317.9	1953.1

Image 39: Used Energy with Shading Schedule 2 in Soria.

The previous image shows the results for the second schedule shading. In this case, the shading schedule does not provide a significant reduction in the cooling demand (322.2 kWh to 317.9 kWh)and there is an increment in the heating demand (from 4645.3 kWh to 5233.2 kWh). The increment is produced by the shading schedule in May, so that, for the next schedule, it is important to reduce the working hours or remove the schedule in May. Moreover, the aument of the working hours in the schedule (from June 1st to October 15th) worked as it was expected.

Therefore, following the methodology mentioned before, it is obtained a shading schedule that provides the lowest energy consumption for each location. For Soria, the best shading schedule designed is the Shading Schedule 8, and it is displayed with its results in the next page.



Data for selected rule:

Daily schedule

Valid days

☑ Mon ☑ Wed ☑ Fri ☑ Sun
☑ Tue ☑ Thu ☑ Sat
☑ Holidays

Start date: 06-01
End date: 06-30

Data for selected rule:

Daily schedule

Valid days

☑ Mon ☑ Wed ☑ Fri ☑ Sun
☑ Tue ☑ Thu ☑ Sat
☑ Holidays

Start date: 07-01
End date: 08-31

Data for selected rule:

Daily schedule

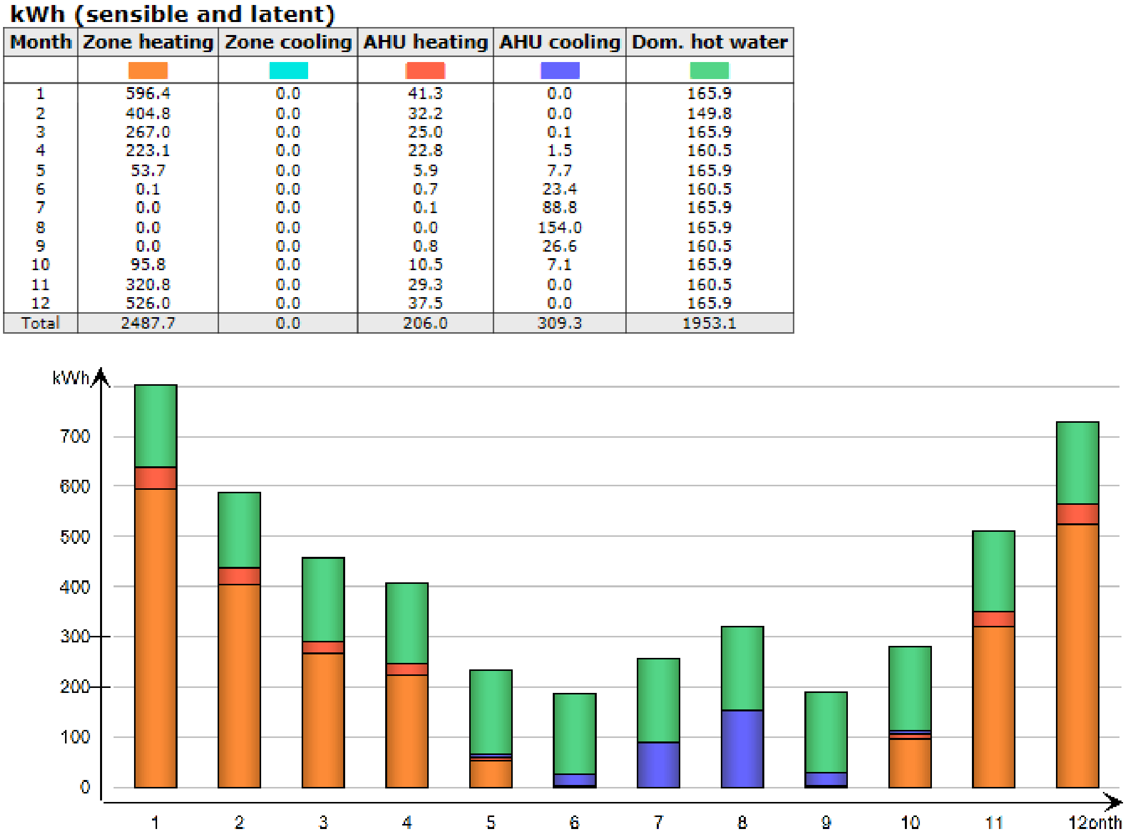
Valid days

☑ Mon ☑ Wed ☑ Fri ☑ Sun
☑ Tue ☑ Thu ☑ Sat
☑ Holidays

Start date: 09-01
End date: 10-15

Image 40: Shading Schedule 3 in Soria.

The first schedule corresponds to May, and the working hours are from 6 am to 9 pm. The second one is for July and August with the same working hours. In the end, the last schedule is used from September 1st to October 15th, and it has less working hours (6:30 am to 8:30 pm).



kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
	🟧	🟦	🟥	🟦	🟩
1	596.4	0.0	41.3	0.0	165.9
2	404.8	0.0	32.2	0.0	149.8
3	267.0	0.0	25.0	0.1	165.9
4	223.1	0.0	22.8	1.5	160.5
5	53.7	0.0	5.9	7.7	165.9
6	0.1	0.0	0.7	23.4	160.5
7	0.0	0.0	0.1	88.8	165.9
8	0.0	0.0	0.0	154.0	165.9
9	0.0	0.0	0.8	26.6	160.5
10	95.8	0.0	10.5	7.1	165.9
11	320.8	0.0	29.3	0.0	160.5
12	526.0	0.0	37.5	0.0	165.9
Total	2487.7	0.0	206.0	309.3	1953.1

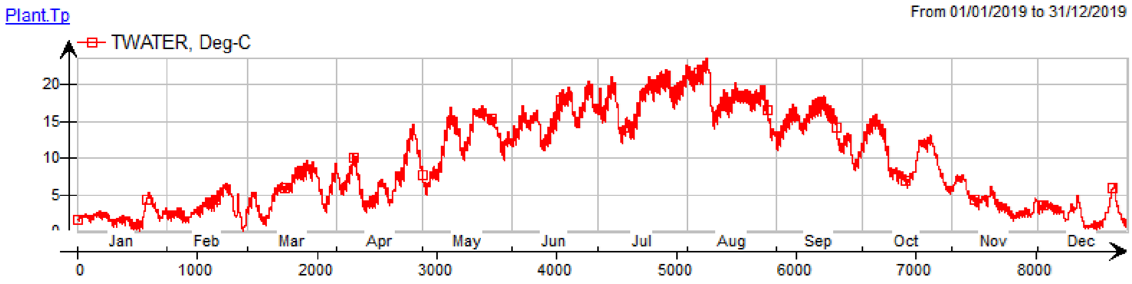
Image 41: Used Energy with schedule shading 3 in Soria.

To sum up, it has been obtained a great amount of energy saved because of the installation of the shading system and the design of a proper shading schedule. In Soria, the reduction is 466.5 kWh.

11 CONCLUSIONS ABOUT THE VIABILITY OF THE SWIMMING POOL.

In this section, it is going to be exposed the final behaviour of the swimming pool depending on the location. It is important to point out that all swimming pools have the same dimension 4*3*1.5 m. Moreover, it is considered that the period for being used the outdoor swimming pool is from June until September. Then, it is going to analyse if the swimming pool as the heat source can be used in that period. The suitable range of temperature is 30 ºC (as the maximum temperature) and 21 ºC (as the minimum temperature) (Delgado, 2016).

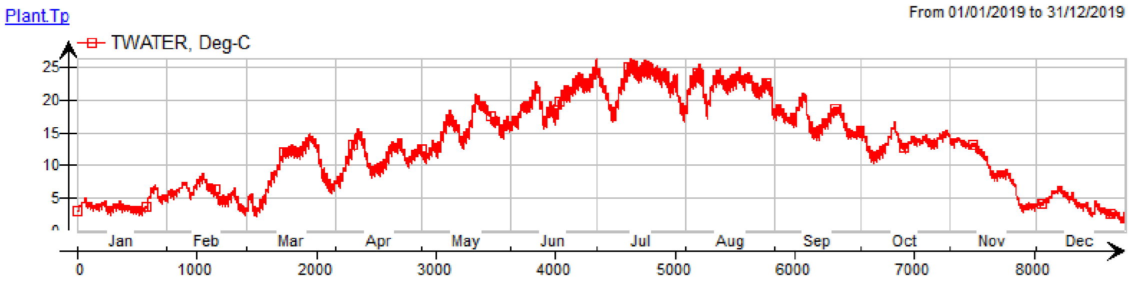
Soria.



Graph 10: Temperature of the Swimming pool during the whole year in Soria.

The first case shows that the swimming pool could only be used 2 weeks at most. So, in this case there is no sense to use the swimming pool as the heat source. Even though, it would be interesting to mention that maybe an outdoor swimming pool in Soria never would reach the specifications established before. Therefore, the swimming pool could be used as a heat source and it would be used by the bravest users.

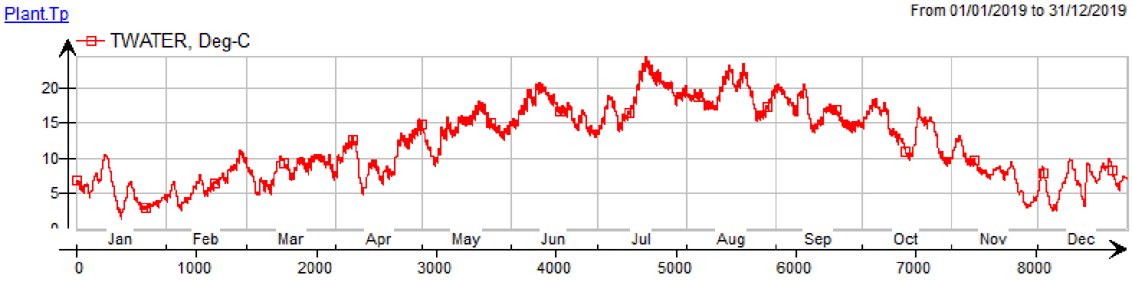
Madrid.



Graph 11: Temperature of the Swimming pool during the whole year in Madrid.

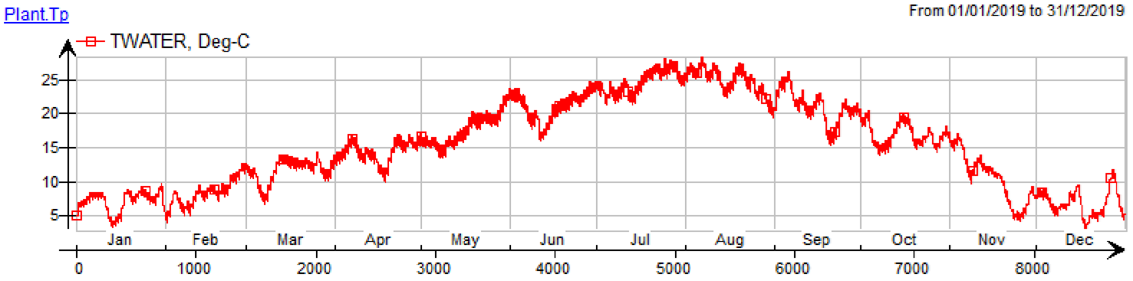
In Madrid, the swimming pool is available from half of June until September. Then, it is considered that the system fits the requirements.

San Sebastián.



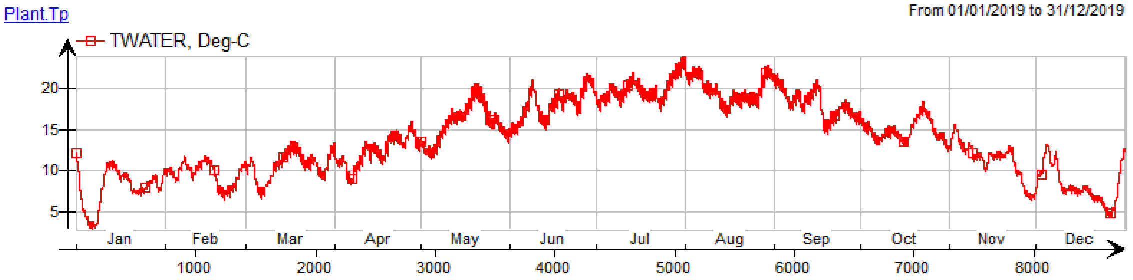
The third case is similar to the first case as there are only two weeks where the swimming pool is available. Therefore, the case is discarded.

Barcelona.



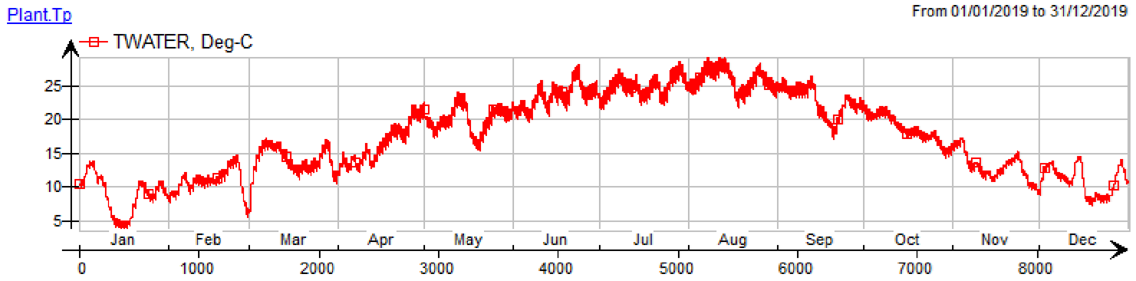
In Barcelona's case, the swimming pool could be used from June to September except for one week in June. So, this case is considered as a good one.

A Coruña.



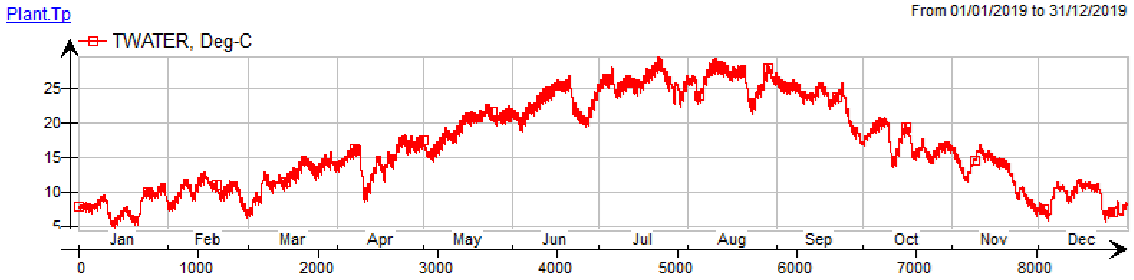
In A Coruña the swimming pool could be used only three or four weeks at most. It is also a discarded option.

Seville.

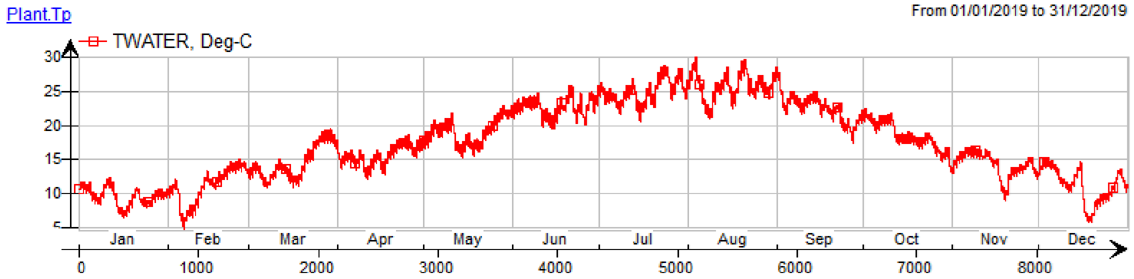


In Seville's case, it is observed that the swimming pool is available all the established period. Thus, the swimming pool could be the heat source of the heat pump.

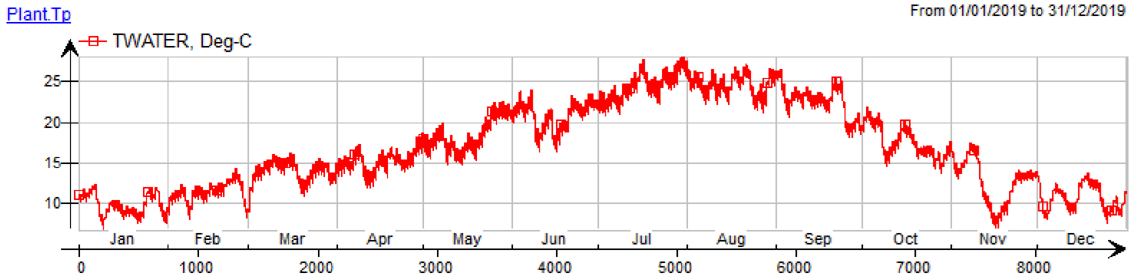
Valencia.



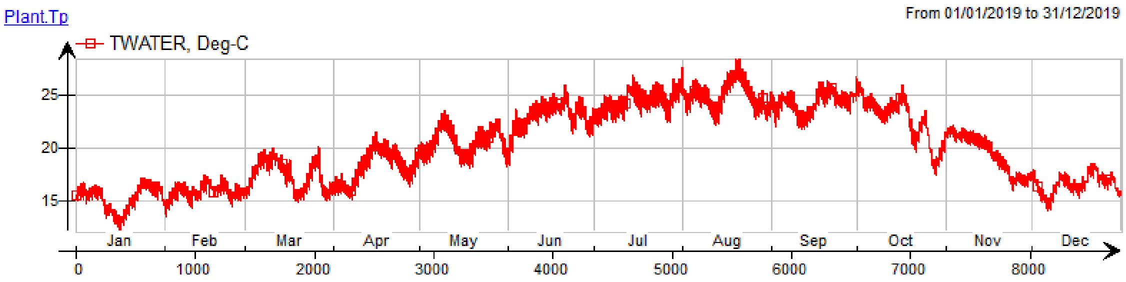
Almería.



Málaga.



Tenerife.



Valencia, Almería, Málaga and Tenerife cases accomplish the requirements for being a heat source of the heat pump studied.

Climate Zone	Label	City	Swimming pool as a heat source	Range of temperatures requirement
E	E4	-	-	-
	E1	Soria	✓	X
D	D3	Madrid	✓	✓
	D1	San Sebastián	✓	X
C	C3	Barcelona	✓	✓
	C1	A Coruña	✓	X
B	B4	Seville	✓	✓
	B3	Valencia	✓	✓
A	A4	Almería	✓	✓
	A3	Málaga	✓	✓
α	α3	Santa Cruz Tenerife	✓	✓
	α1	-	-	-

Table 30: Final Results.

To sum up, the discarded cases are refused because they do not meet the range of temperature for the swimming pool but they work properly as the heat source, because the temperature of the swimming pool does not reach lower temperatures than 0 ºC or very high temperatures.

12 Conclusions about the Building.

Once the conclusions about the swimming pool are exposed, it is time to display the final results related to the construction and consumption of the building.

First of all, the important requirements according to the Spanish Building Legislation (CTE) are the thermal transmittance (U) of each element and the overall coefficient of heat transfer (K). In regard to the thermal transmittance, all the elements of the building fit the limits as it is explained in the section "7. Design of the Prototype Building". On the other hand, as the compactness is 0.78 m3/m2, the limits are established in the second row of the next table for the overall coefficient of heat transfer.

	Winter Climate Zone									
Compactness V/A (m^3/m^2)	α3	A3	A4	B3	B4	C1	C3	D1	D3	E1
V/A <= 1	0.67	0.6		0.58		0.53		0.48		0.43
	Tenerife	Malaga	Almeria	Valencia	Seville	A Coruña	Barcelona	San Sebastian	Madrid	Soria
Overall Coeff. Of heat transfer (W/(m2 K)	0.3135	0.3135	0.3135	0.3135	0.3135	0.3161	0.3135	0.3196	0.3135	0.3196

Table 31: Overall coefficient of heat transfer for each location.

All buildings have an overall coefficient of heat transfer lower than the limit one. Hence, the construction requirements are met for all cases studied.

In the end, two of the most important and valuable indicators are the non-renewable primary energy consumption (Cep,nren) and total primary energy consumption (Cep,Tot). Both indicators are used to evaluate if a building could be considered as a near zero energy building (nZEB).

	Winter Climate Zone									
	α3	A3	A4	B3	B4	C1	C3	D1	D3	E1
Cep,nren Limit	20	25		28		32		38		43
Cep,tot Limit	40	50		56		64		76		86
	Tenerife	Malaga	Almeria	Valencia	Seville	A Coruña	Barcelona	San Sebastian	Madrid	Soria
Cep,nren (kWh/(m2 year)	11.4	10.68	11.94	10.94	11.95	9.95	10.95	13.31	13.27	17.87
Cep,tot (kWh/(m2 year)	19.56	18.21	19.63	19.19	19.90	16.18	18.76	19.51	21.15	25.26

Table 32: Non-renewable and total primary energy consumption for each location.

Therefore, as all the cases meet the limit requirements, it is considered that all buildings are near zero energy buildings. Moreover, as an interesting fact, the building located in A Coruña has the lowest consumption and the building with the highest consumption is located in Soria.

13 RECOMMENDATIONS AND FINAL CONCLUSIONS.

Finally, the most important factor in order to build a near zero energy building is the user behavior because users do not always know the technology that has been installed, and a bad use of it could lead to an increment of the consumption. Therefore, it is quite important to teach the future owners how to manage the nZEB to keep the low consumption. Also, during the construction phase, several critical mistakes may be made. So, in order to avoid them, it is highly recommended visiting the facility as many times as possible, selecting experienced companies and the implementation of quality test such as the blower door and thermography test.

Other factors that could affect the consumption in a bad way are the sensors, monitoring and control systems, as they may not be configured properly. Moreover, it could appear an unexpected lower performance of the used technologies or constructions problems. For these reasons, it is important to keep a continuous monitoring of the whole house and a regular maintenance (thermal systems, energy consumption, and so on).

To sum up, after many simulations with IDA ICE software, it is designed a near zero energy building for each location that has been studied in this master thesis. Moreover, in some cases, the use of the swimming pool as a heat source is feasible.

On the other hand, there is future work such as the study of the daylight factor, the introduction of a heat pump more efficient than the default heat pump provided by IDA ICE, and the benefits and savings for using the swimming pool as a heat source. Furthermore, the non-renewable primary energy consumption for all cases could be reduced if a battery system was installed, as there is sold electricity according to the IDA ICE report which is produced by the photovoltaic panels.

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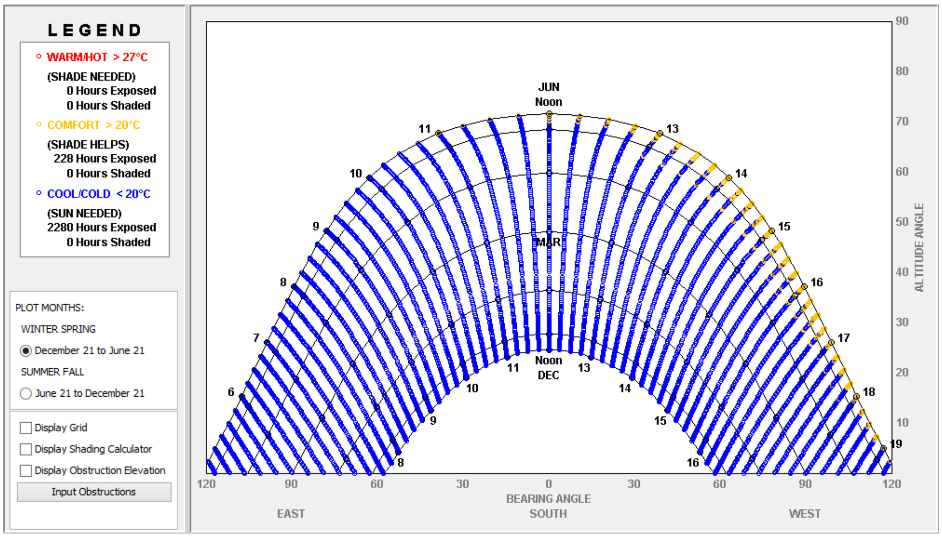
ANNEX 1: CLIMATE CONSULTANT.

In this annex, it is used the software Climate Consultant 3.0 to carry out a study of the climate for the design of the buildings. The design is truly climate responsive and depends first on gaining a detailed accurate understanding of the local climate.

An important parameter of the building is the Human Thermal comfort that can be defined primarily by dry bulb temperature and humidity, although different sources have slightly different definitions. Regarding comfort models, the chosen model has been ASHRAE Standard 55 and Current Handbook of Fundamentals Model.

Therefore, it is analysed the sun shading chart for each location in order to know how to locate the different rooms that exist in a typical residential building.

E1 Soria:



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
0 Hours Exposed
0 Hours Shaded

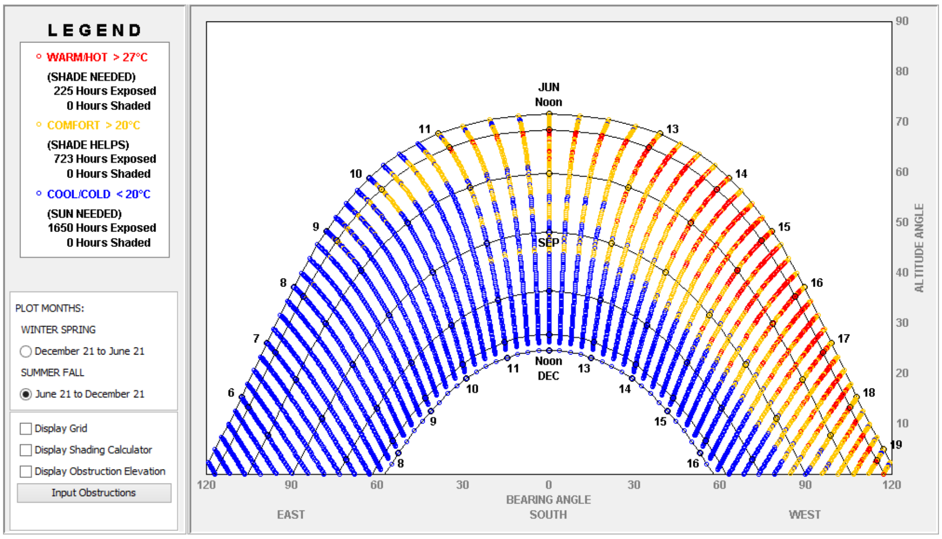
○ COMFORT > 20°C
(SHADE HELPS)
228 Hours Exposed
0 Hours Shaded

○ COOL/COLD < 20°C
(SUN NEEDED)
2280 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 12: Winter-Spring Sun Shading chart, Soria E1.



LEGEND

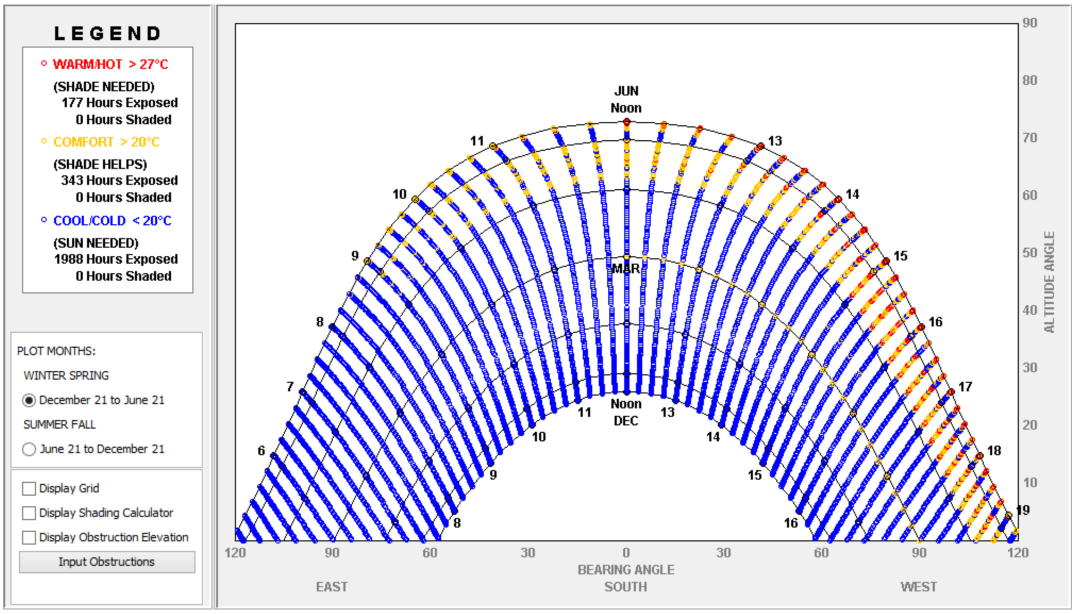
- WARM/HOT > 27°C
  (SHADE NEEDED)
  225 Hours Exposed
  0 Hours Shaded
- COMFORT > 20°C
  (SHADE HELPS)
  723 Hours Exposed
  0 Hours Shaded
- COOL/COLD < 20°C
  (SUN NEEDED)
  1650 Hours Exposed
  0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 13: Summer-Fall Sun Shading chart, Soria E1.

D3 Madrid:



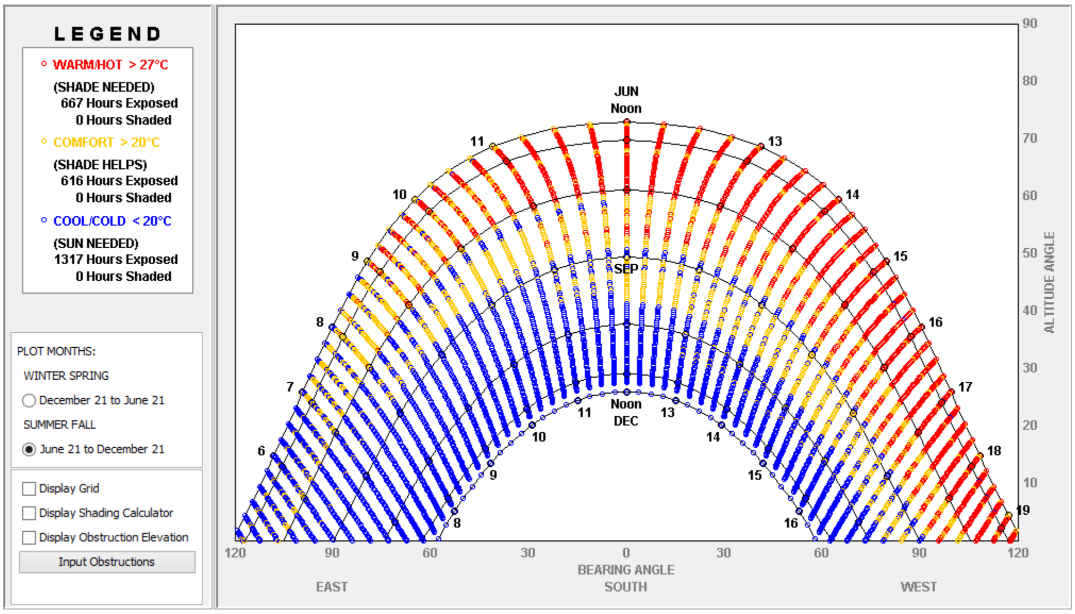
LEGEND

- WARM/HOT > 27°C
  (SHADE NEEDED)
  177 Hours Exposed
  0 Hours Shaded
- COMFORT > 20°C
  (SHADE HELPS)
  343 Hours Exposed
  0 Hours Shaded
- COOL/COLD < 20°C
  (SUN NEEDED)
  1988 Hours Exposed
  0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 14: Winter-Spring Sun Shading chart, Madrid D3.


LEGEND

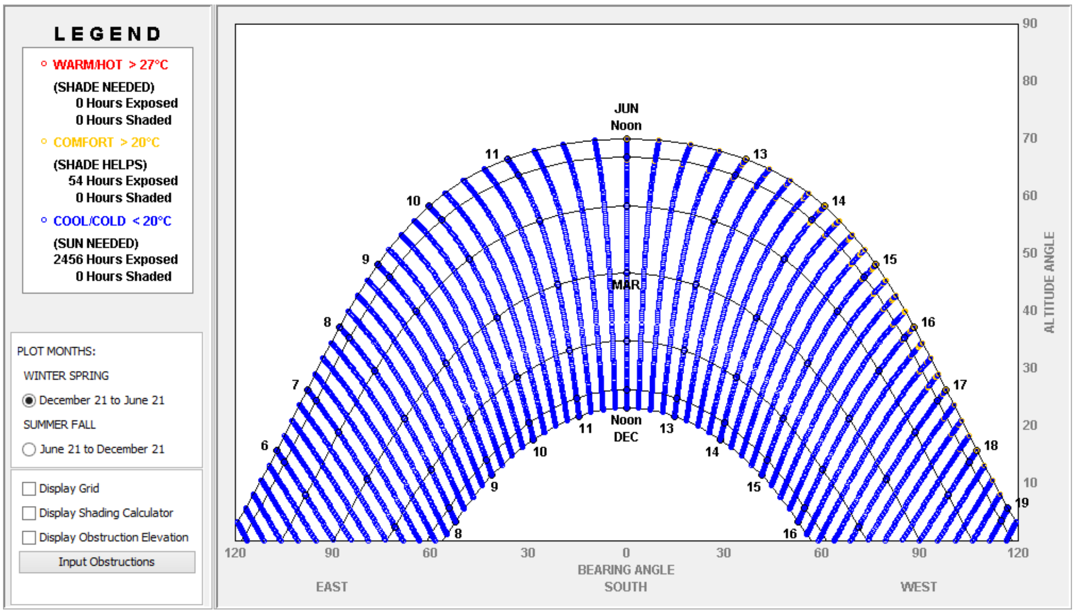
- WARM/HOT > 27°C
  (SHADE NEEDED)
  667 Hours Exposed
  0 Hours Shaded
- COMFORT > 20°C
  (SHADE HELPS)
  616 Hours Exposed
  0 Hours Shaded
- COOL/COLD < 20°C
  (SUN NEEDED)
  1317 Hours Exposed
  0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 15: Summer-Fall Sun Shading chart, Madrid D3.

D1 San Sebastián

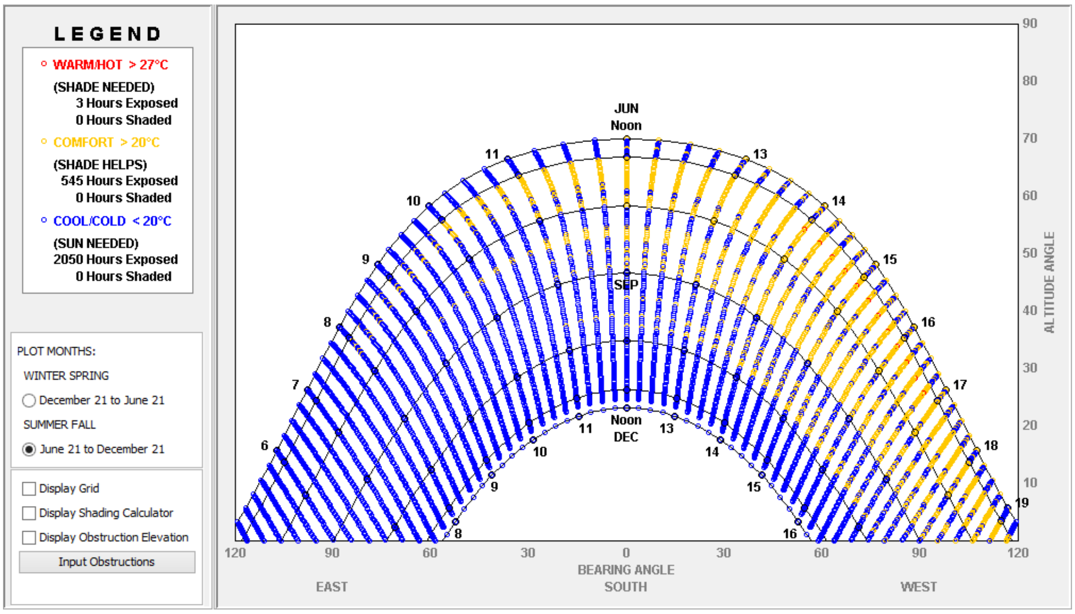

LEGEND

- WARM/HOT > 27°C
  (SHADE NEEDED)
  0 Hours Exposed
  0 Hours Shaded
- COMFORT > 20°C
  (SHADE HELPS)
  54 Hours Exposed
  0 Hours Shaded
- COOL/COLD < 20°C
  (SUN NEEDED)
  2456 Hours Exposed
  0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 16: Winter-Spring Sun Shading chart, San Sebastián D1.



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
3 Hours Exposed
0 Hours Shaded

○ COMFORT > 20°C
(SHADE HELPS)
545 Hours Exposed
0 Hours Shaded

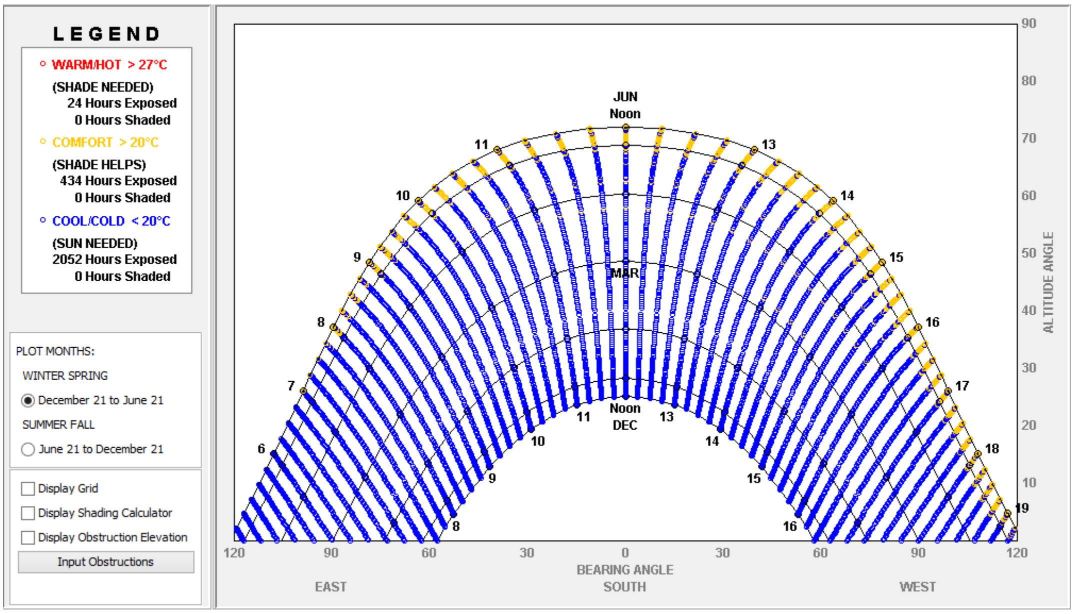
○ COOL/COLD < 20°C
(SUN NEEDED)
2050 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 17: Summer-Fall Sun Shading chart, San Sebastián D1.

C3 Barcelona:



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
24 Hours Exposed
0 Hours Shaded

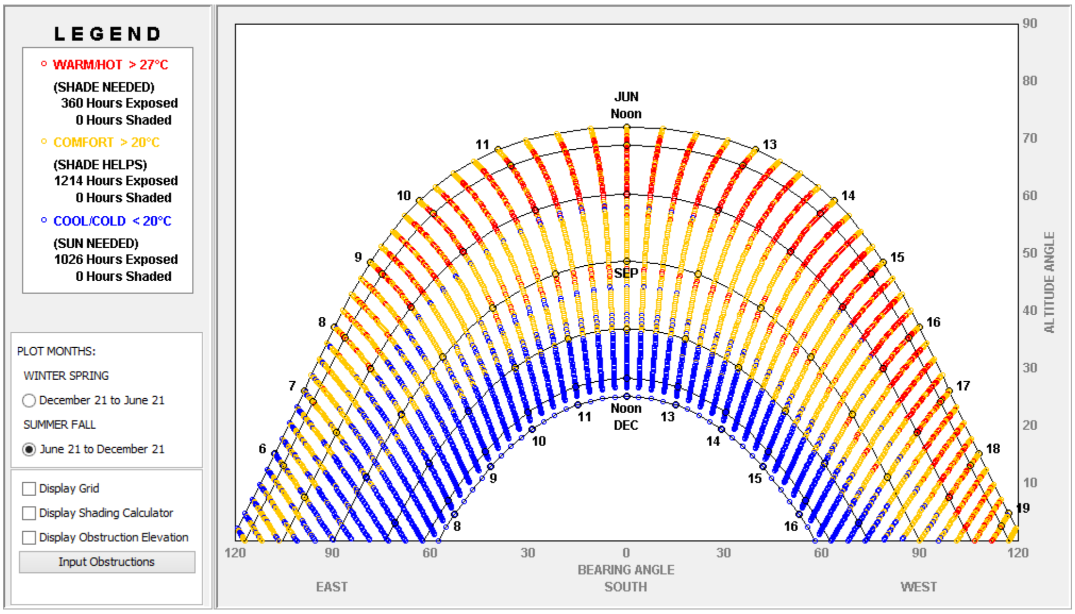
○ COMFORT > 20°C
(SHADE HELPS)
434 Hours Exposed
0 Hours Shaded

○ COOL/COLD < 20°C
(SUN NEEDED)
2052 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 18: Winter-Spring Sun Shading chart, Barcelona C3.



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
360 Hours Exposed
0 Hours Shaded

○ COMFORT > 20°C
(SHADE HELPS)
1214 Hours Exposed
0 Hours Shaded

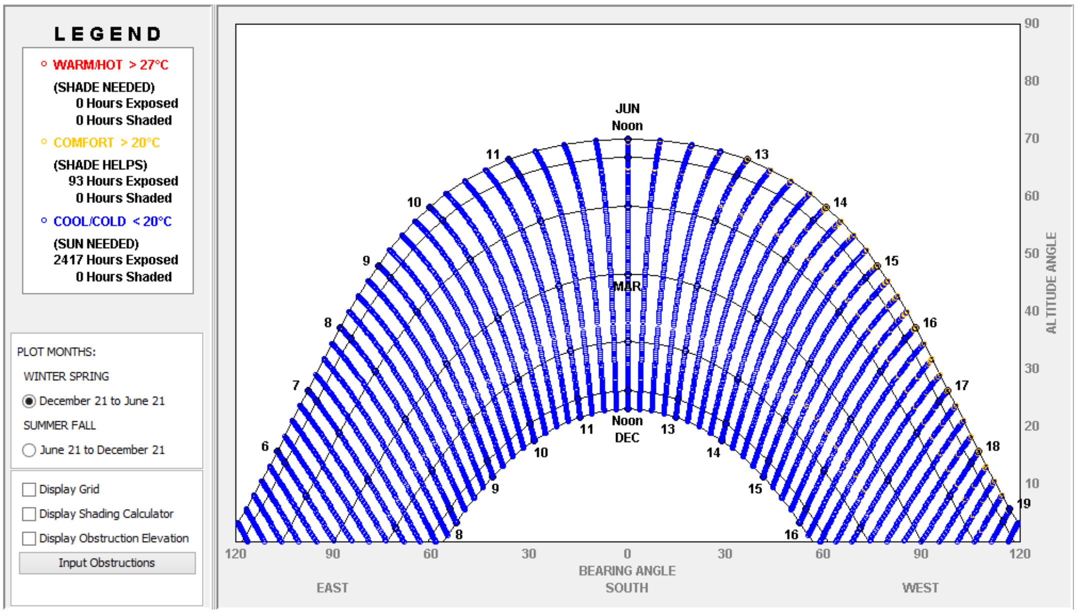
○ COOL/COLD < 20°C
(SUN NEEDED)
1026 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 19: Summer-Fall Sun Shading chart, Barcelona C3.

C1 A Coruña



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
0 Hours Exposed
0 Hours Shaded

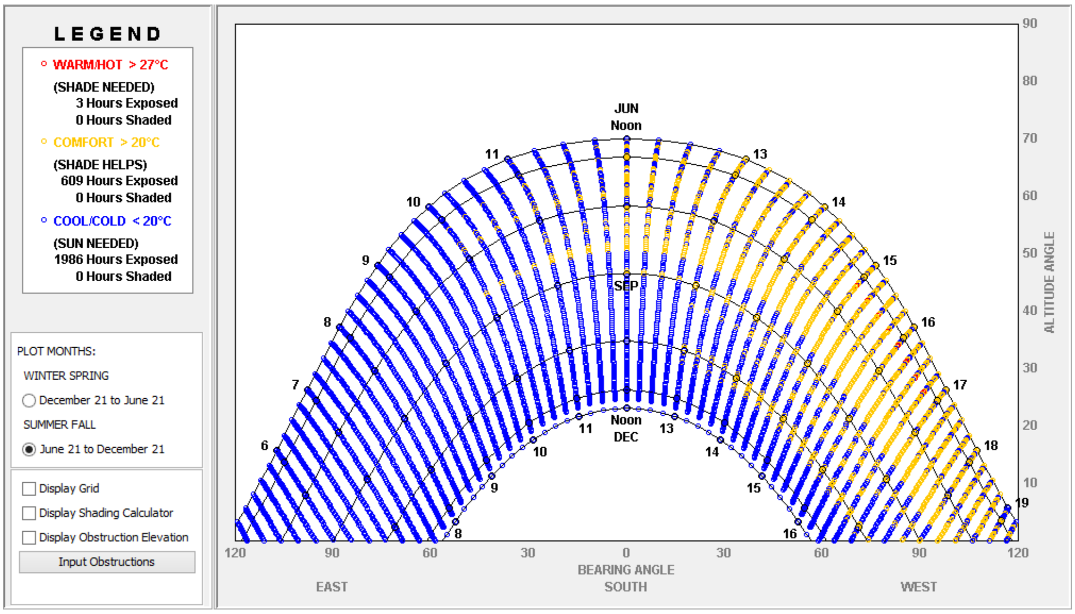
○ COMFORT > 20°C
(SHADE HELPS)
93 Hours Exposed
0 Hours Shaded

○ COOL/COLD < 20°C
(SUN NEEDED)
2417 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 20: Winter-Spring Sun Shading chart, A Coruña C1.


LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
3 Hours Exposed
0 Hours Shaded

○ COMFORT > 20°C
(SHADE HELPS)
609 Hours Exposed
0 Hours Shaded

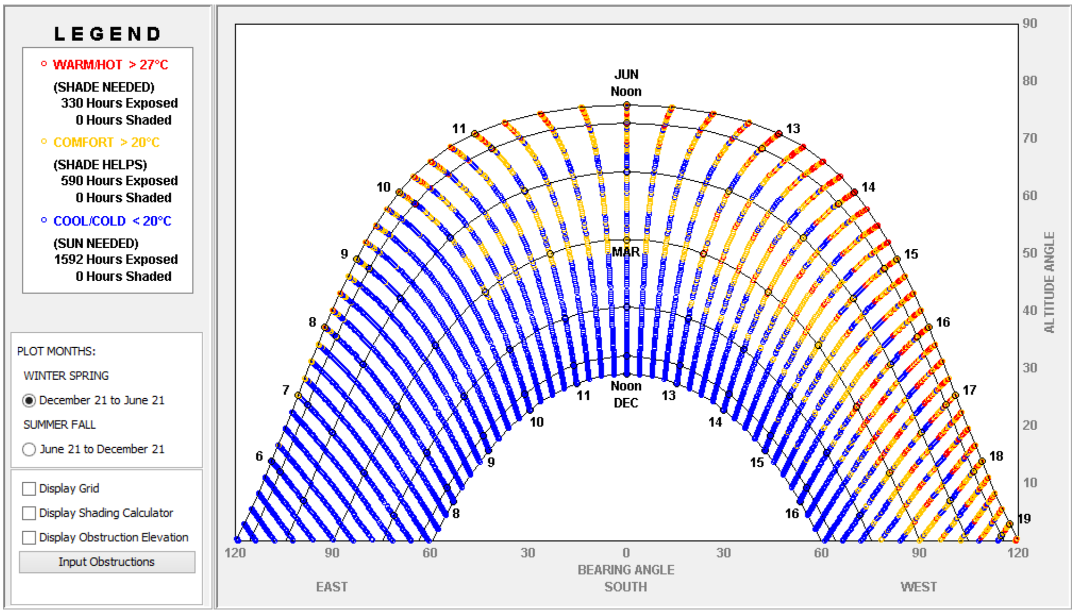
○ COOL/COLD < 20°C
(SUN NEEDED)
1986 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 21: Summer-Fall Sun Shading chart, A Coruña C1.

B4 Seville


LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
330 Hours Exposed
0 Hours Shaded

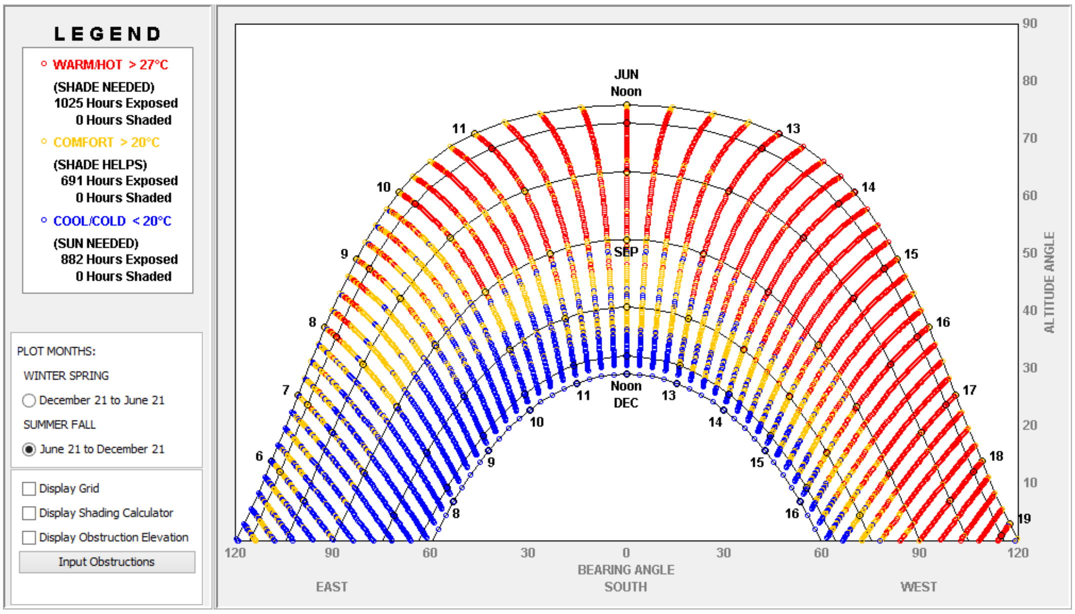
○ COMFORT > 20°C
(SHADE HELPS)
590 Hours Exposed
0 Hours Shaded

○ COOL/COLD < 20°C
(SUN NEEDED)
1592 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 22: Winter-Spring Sun Shading chart, Seville B4.



LEGEND

WARM/HOT > 27°C
(SHADE NEEDED)
1025 Hours Exposed
0 Hours Shaded

COMFORT > 20°C
(SHADE HELPS)
691 Hours Exposed
0 Hours Shaded

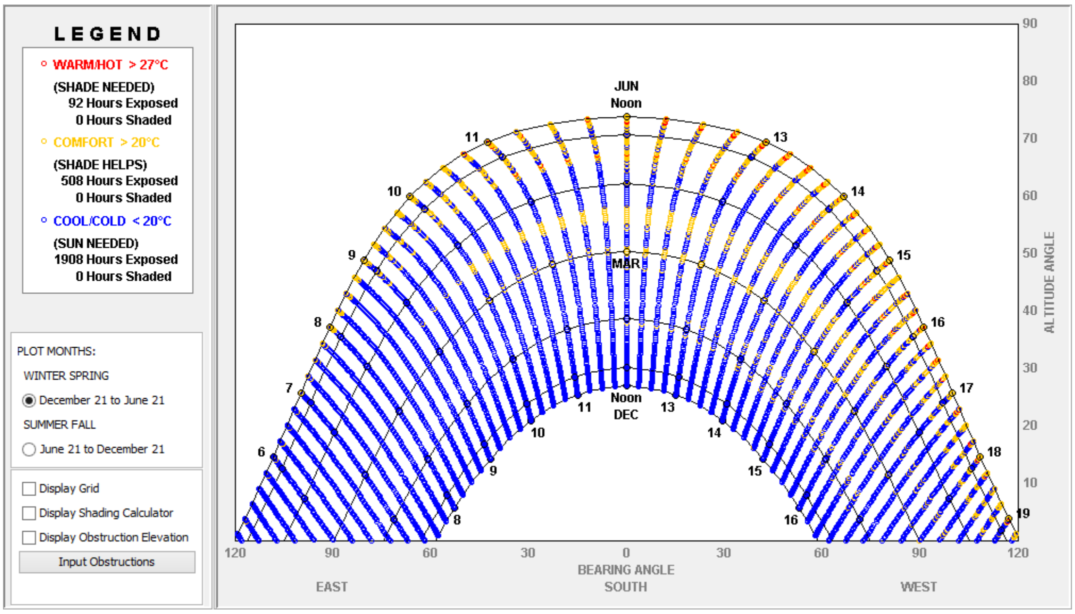
COOL/COLD < 20°C
(SUN NEEDED)
882 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 23: Summer-Fall Sun Shading chart, Seville B4.

B3 Valencia



LEGEND

WARM/HOT > 27°C
(SHADE NEEDED)
92 Hours Exposed
0 Hours Shaded

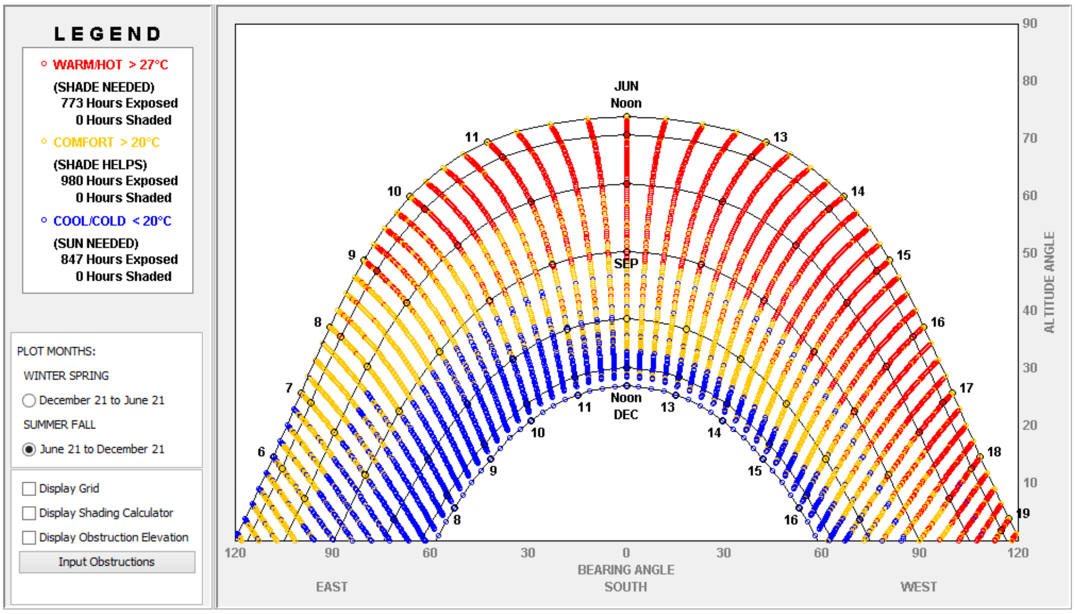
COMFORT > 20°C
(SHADE HELPS)
508 Hours Exposed
0 Hours Shaded

COOL/COLD < 20°C
(SUN NEEDED)
1908 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 24: Winter-Spring Sun Shading chart, Valencia B3.



LEGEND

- WARM/HOT > 27°C
  (SHADE NEEDED)
  773 Hours Exposed
  0 Hours Shaded
- COMFORT > 20°C
  (SHADE HELPS)
  980 Hours Exposed
  0 Hours Shaded
- COOL/COLD < 20°C
  (SUN NEEDED)
  847 Hours Exposed
  0 Hours Shaded

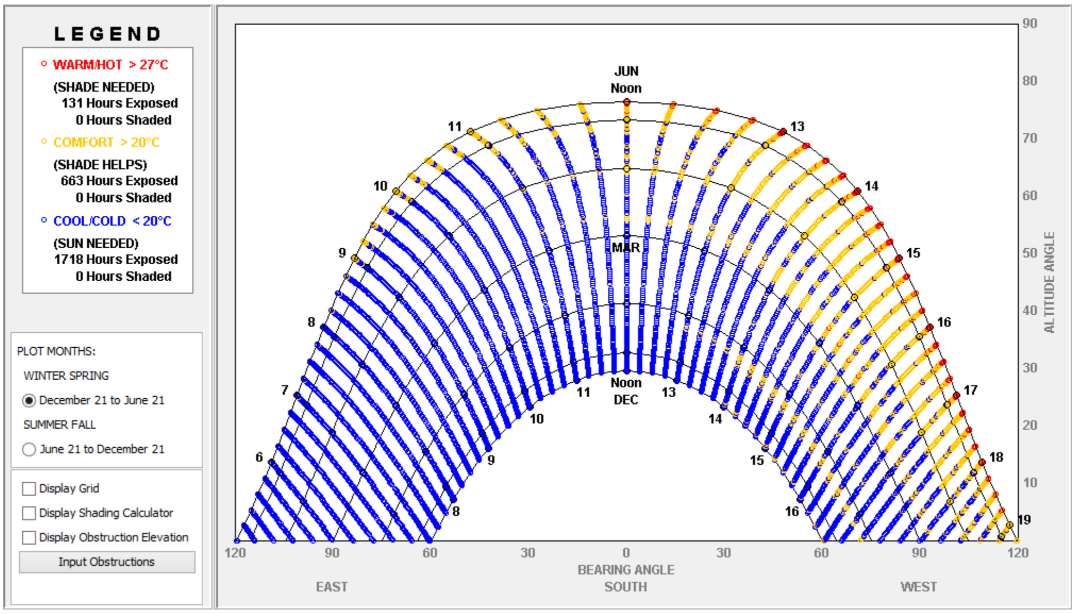
PLOT MONTHS:

WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 25: Summer-Fall Sun Shading chart, Valencia B3.

A4 Almería



LEGEND

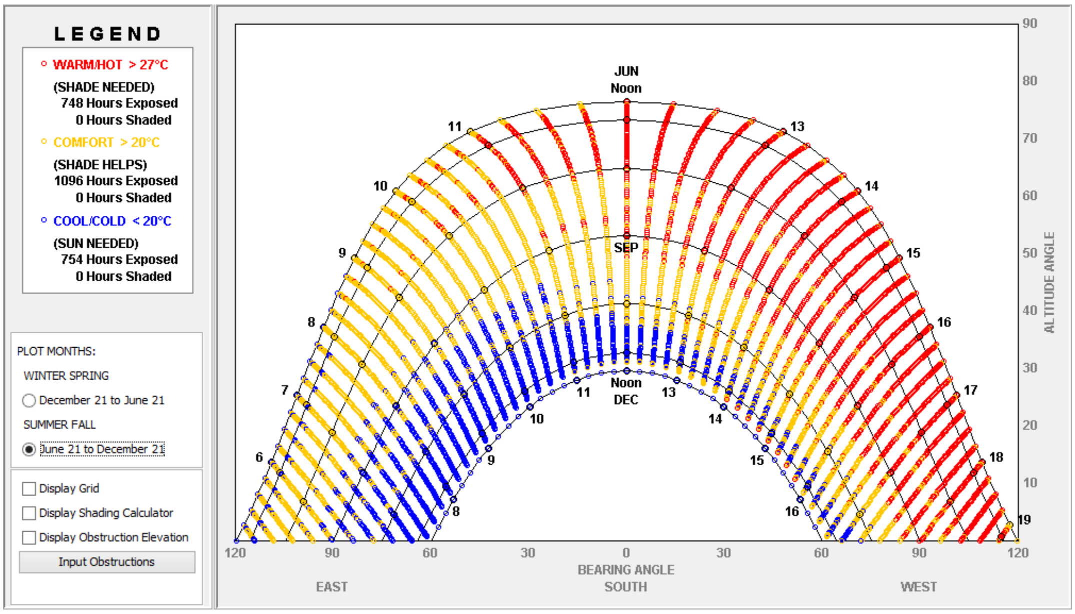
- WARM/HOT > 27°C
  (SHADE NEEDED)
  131 Hours Exposed
  0 Hours Shaded
- COMFORT > 20°C
  (SHADE HELPS)
  663 Hours Exposed
  0 Hours Shaded
- COOL/COLD < 20°C
  (SUN NEEDED)
  1718 Hours Exposed
  0 Hours Shaded

PLOT MONTHS:

WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 26: Winter-Spring Sun Shading chart, Almería A4.



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
748 Hours Exposed
0 Hours Shaded

○ COMFORT > 20°C
(SHADE HELPS)
1096 Hours Exposed
0 Hours Shaded

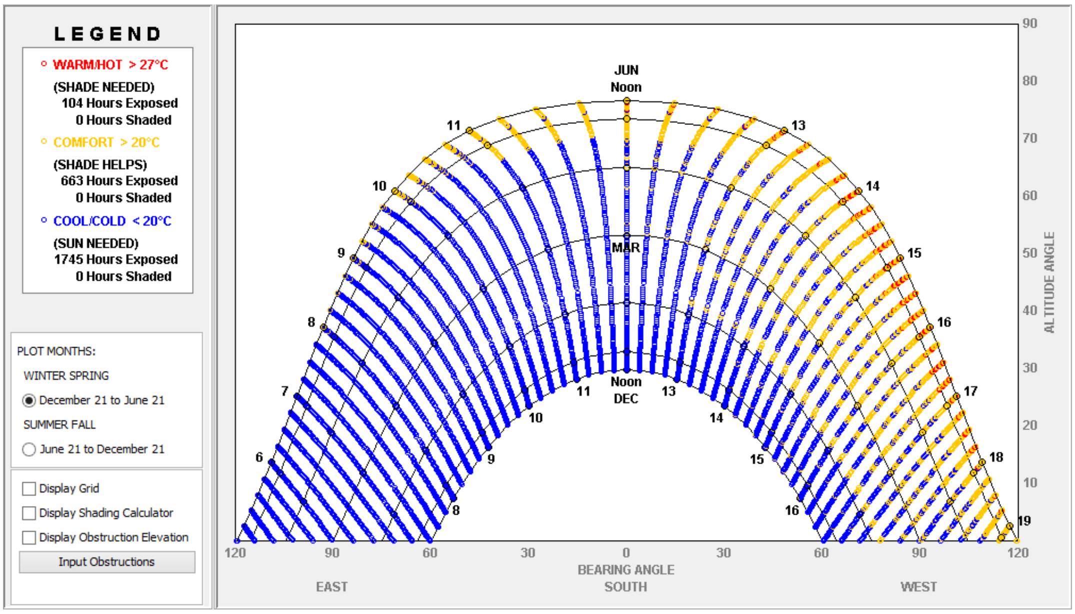
○ COOL/COLD < 20°C
(SUN NEEDED)
754 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 27: Summer-Fall Sun Shading chart, Almería A4.

A3 Málaga



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
104 Hours Exposed
0 Hours Shaded

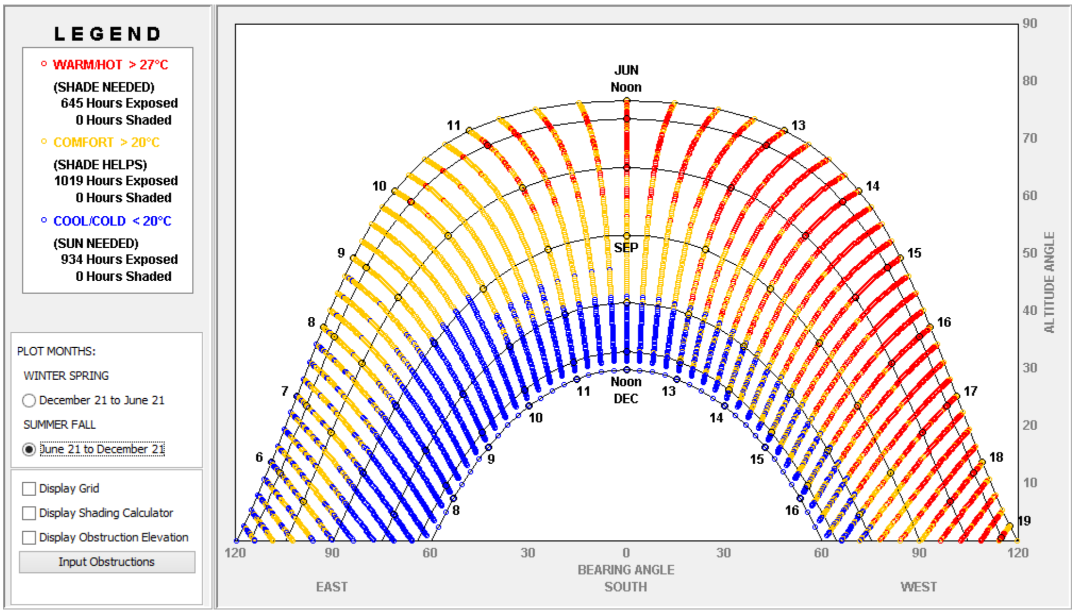
○ COMFORT > 20°C
(SHADE HELPS)
663 Hours Exposed
0 Hours Shaded

○ COOL/COLD < 20°C
(SUN NEEDED)
1745 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 28: Winter-Spring Sun Shading chart, Málaga A3.


LEGEND

WARM/HOT > 27°C
(SHADE NEEDED)
645 Hours Exposed
0 Hours Shaded

COMFORT > 20°C
(SHADE HELPS)
1019 Hours Exposed
0 Hours Shaded

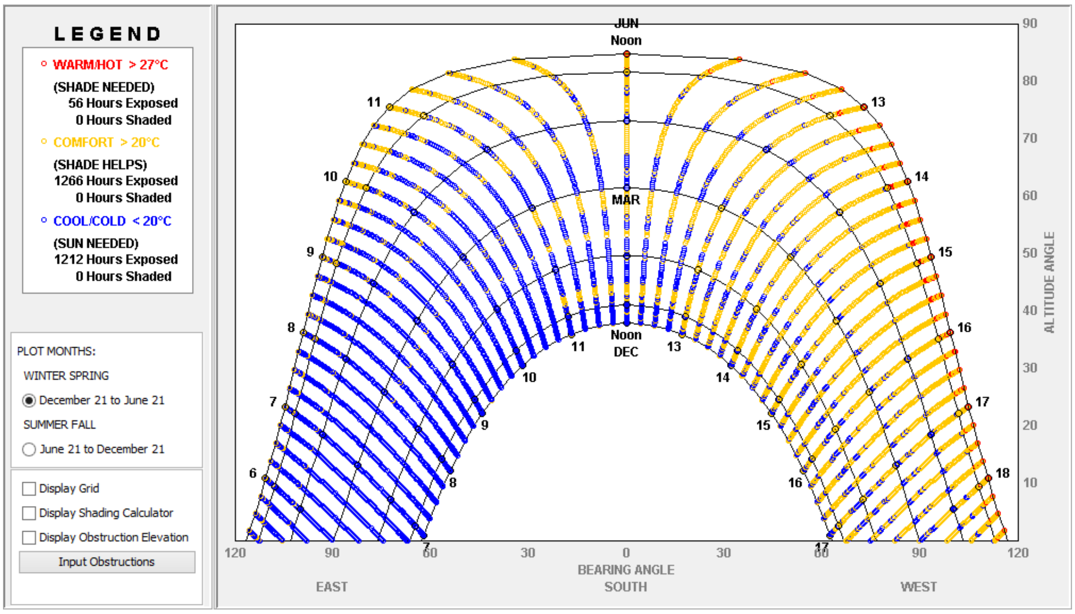
COOL/COLD < 20°C
(SUN NEEDED)
934 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 29: Summer-Fall Sun Shading chart, Málaga A3.

α3 Tenerife


LEGEND

WARM/HOT > 27°C
(SHADE NEEDED)
56 Hours Exposed
0 Hours Shaded

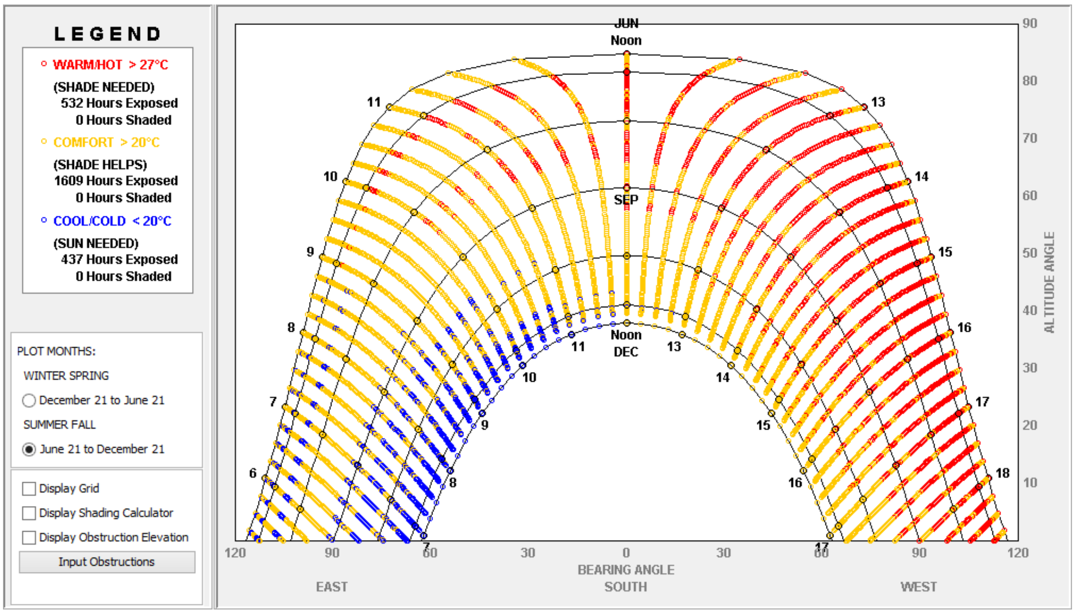
COMFORT > 20°C
(SHADE HELPS)
1266 Hours Exposed
0 Hours Shaded

COOL/COLD < 20°C
(SUN NEEDED)
1212 Hours Exposed
0 Hours Shaded

PLOT MONTHS:
WINTER SPRING
● December 21 to June 21
SUMMER FALL
○ June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 30: Winter-Spring Sun Shading chart, Tenerife α3.



LEGEND

○ WARM/HOT > 27°C
(SHADE NEEDED)
532 Hours Exposed
0 Hours Shaded

○ COMFORT > 20°C
(SHADE HELPS)
1609 Hours Exposed
0 Hours Shaded

○ COOL/COLD < 20°C
(SUN NEEDED)
437 Hours Exposed
0 Hours Shaded

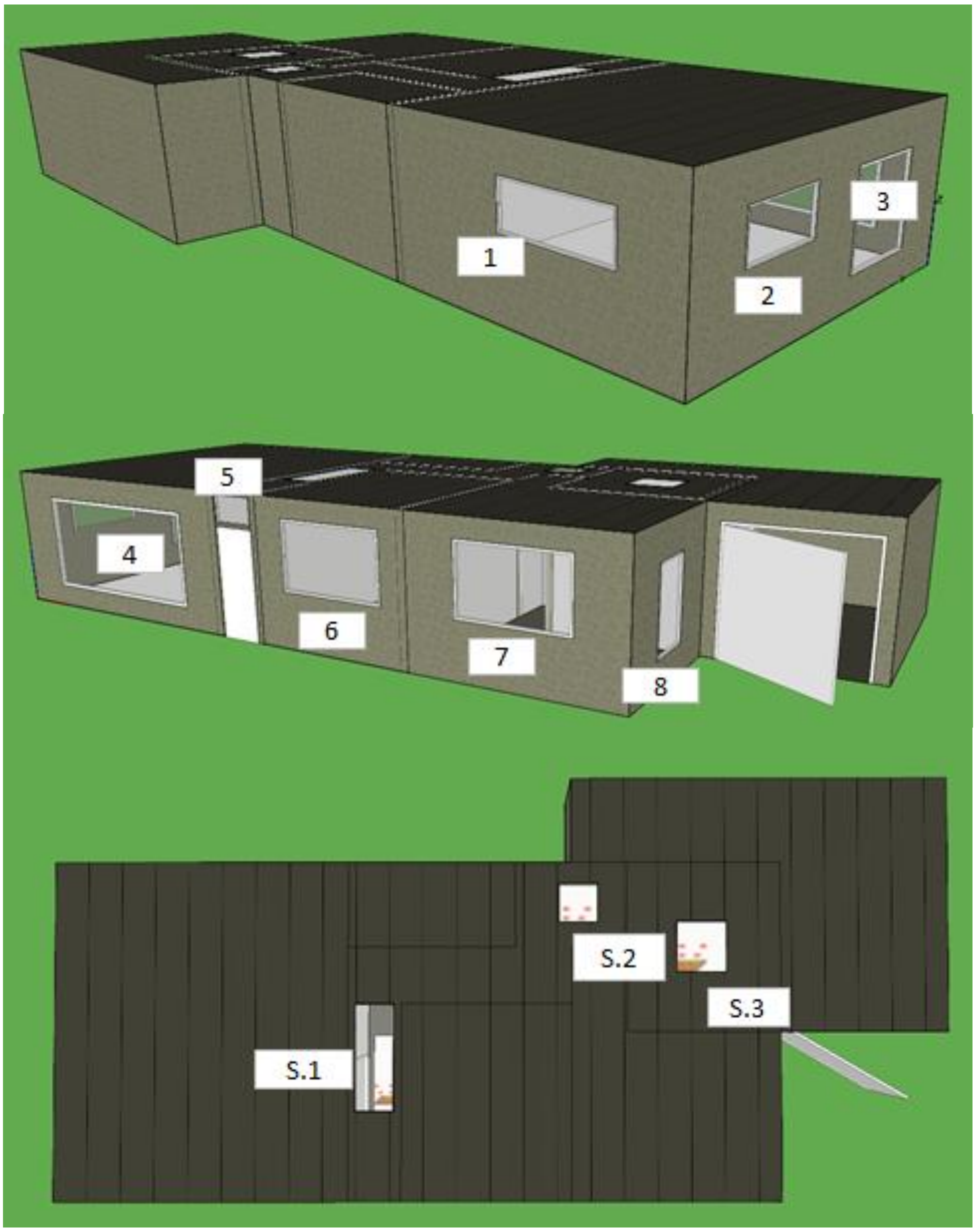
PLOT MONTHS:
WINTER SPRING
○ December 21 to June 21
SUMMER FALL
● June 21 to December 21

☐ Display Grid
☐ Display Shading Calculator
☐ Display Obstruction Elevation

Graph 31: Summer-Fall Sun Shading chart, Tenerife α3.

As a conclusion, if all the charts are analyzed, there is a common factor. This factor is that the west side needs more shading that the east side. It means that the temperature in west side will be higher than the east. Therefore, the most useful rooms are located at the South-West side of the house and the least useful rooms at the North-East.

Annex 2: Options of Windows Dimensions.



First Solution			Second Solution		
Nº Window	mm	mm	Nº Window	mm	mm
1	2000	750	1	1500	750
2	1500	750	2	1500	750
3	1500	1500	3	1500	1000
4	3500	1750	4	3000	1500
5	800	500	5	800	500
6	2000	1250	6	2000	1000
7	2000	1250	7	2000	1000
8	1000	1500	8	1000	1000
Nº Skylight	m2		Nº Skylight	m2	
S.1	1.32		S.1	1.32	
S.2	0.48		S.2	0.48	
S.3	0.79		S.3	0.79	

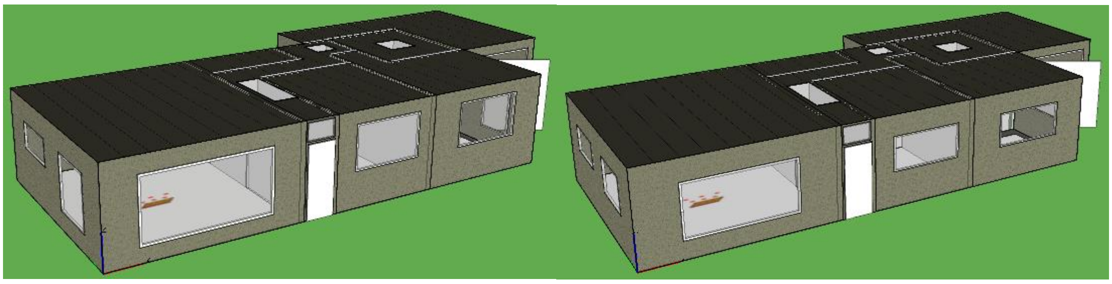


Image 42: First and Second Solution.

Third Solution			Fourth Solution		
Nº Window	mm	mm	Nº Window	mm	mm
1	1500	750	1	0	0
2	1500	750	2	1500	750
3	1500	1000	3	1500	1000
4	3000	1250	4	3000	1500
5	500	300	5	500	300
6	2000	1000	6	2000	1000
7	2000	1000	7	2000	1000
8	1000	1000	8	1000	1000
Nº Skylight	m2		Nº Skylight	m2	
S.1	1.32		S.1	1.32	
S.2	0.48		S.2	0.48	
S.3	0.79		S.3	0.79	

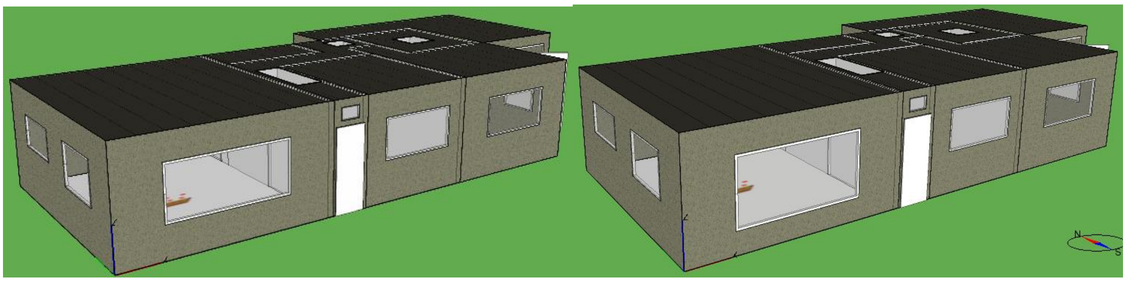


Image 43: Third and Fourth Solution.

Fifth Solution			Sixth Solution		
Nº Window	mm	mm	Nº Window	mm	mm
1	0	0	1	0	0
2	1500	750	2	1500	750
3	1500	1000	3	1500	1000
4	3000	1500	4	3000	1500
5	500	300	5	500	300
6	2000	1000	6	2000	1000
7	2000	1000	7	2000	1000
8	1000	1000	8	1000	1000
Nº Skylight	m2		Nº Skylight	m2	
S.1	0.75		S.1	0.4	
S.2	0.24		S.2	0.15	
S.3	0.4		S.3	0.15	

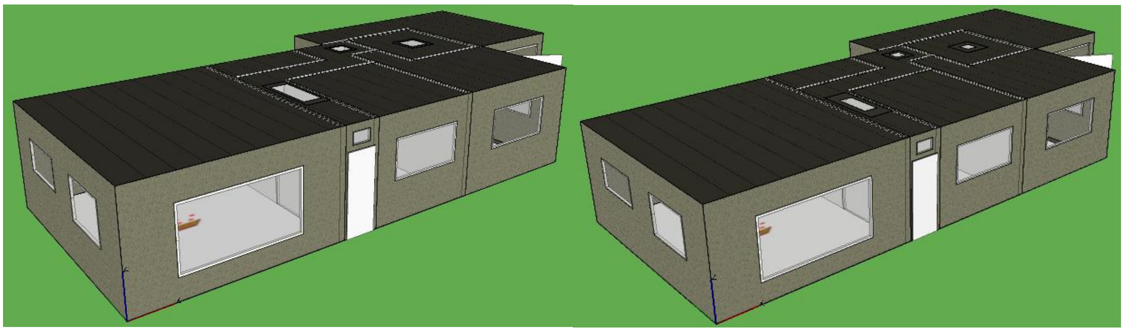


Image 44: Fifth and Sixth Solution.

Seventh Solution			Eighth Solution		
Nº Window	mm	mm	Nº Window	mm	mm
1	0	0	1	0	0
2	1500	750	2	1250	750
3	1500	1000	3	1250	1000
4	3000	1250	4	3000	1250
5	500	300	5	500	300
6	2000	1000	6	2000	1000
7	2000	1000	7	2000	1000
8	1000	1000	8	1000	750
Nº Skylight	m2		Nº Skylight	m2	
S.1	0.4		S.1	0.4	
S.2	0.15		S.2	0.15	
S.3	0.15		S.3	0.15	

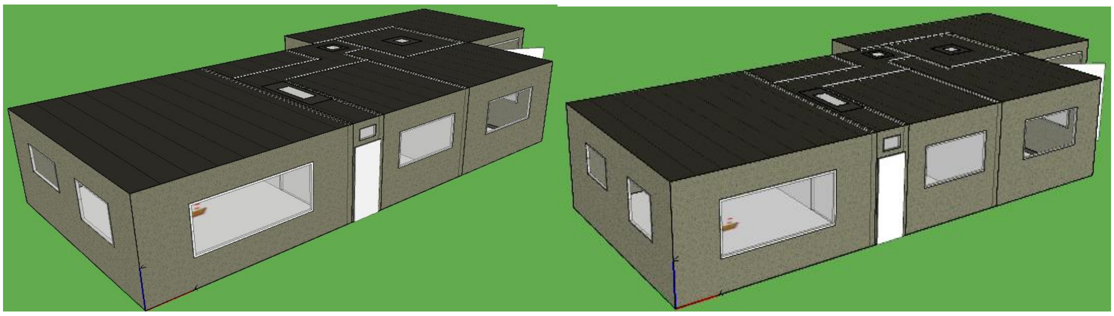


Image 45: Seventh and Eighth Solution.

ninth Solution			Tenth Solution			Eleventh Solution		
Nº Window	mm	mm	Nº Window	mm	mm	Nº Window	mm	mm
1	0	0	1	2000	200	1	2000	200
2	1250	750	2	1750	750	2	2250	750
3	1250	1000	3	1750	1500	3	1750	1500
4	2750	1250	4	3500	1750	4	3500	1750
5	500	250	5	800	500	5	800	500
6	1500	1000	6	2250	1250	6	2250	1250
7	1500	1000	7	2250	1250	7	2250	1250
8	1000	750	8	1000	1500	8	1000	1500
Nº Skylight	m2		Nº Skylight	m2		Nº Skylight	m2	
S.1	0.3		S.1	1.32		S.1	0.65	
S.2	0.15		S.2	0.48		S.2	0.24	
S.3	0.15		S.3	0.79		S.3	0.4	

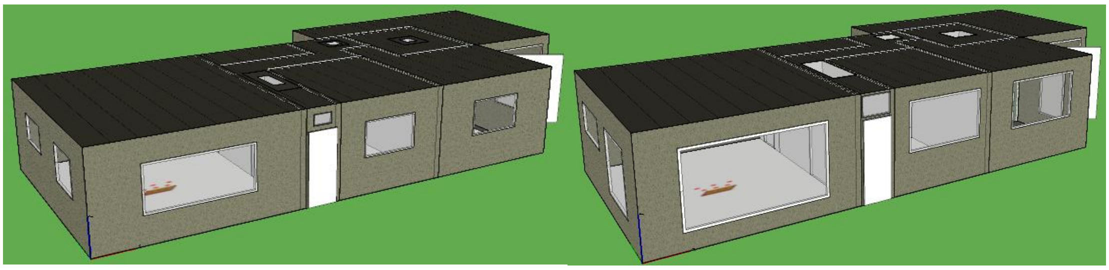


Image 46: Ninth and Tenth Solution.

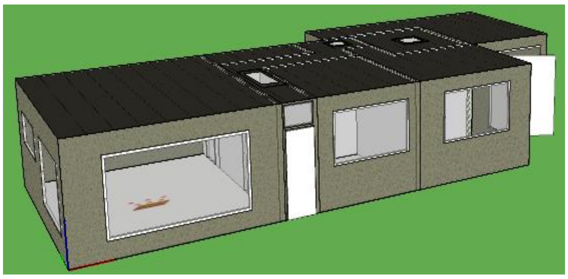


Image 47: Eleventh Solution.

ANNEX 3: RESULTS OF THE THREE AIR HANDLING UNITS.

The results obtained by means of IDA ICE have been introduced in Excel and they are displayed during the following tables. The minimum demand has been pointed out in blue for each air handling unit and location.

Results of Soria.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	1250	kWh		5530.4		1	0	14
	Heating	4280.4	kWh						
S2.0	Cooling	1019.9	kWh	230.1	5558.4	-28	1	0	15
	Heating	4538.5	kWh	-258.1					
S3.0	Cooling	954.5	kWh	295.5	5594.7	-64.3	1	0	15
	Heating	4640.2	kWh	-359.8					
S4.0	Cooling	1006.5	kWh	243.5	5493.5	36.9	1	0	15
	Heating	4487	kWh	-206.6					
S5.0	Cooling	844.9	kWh	405.1	5422.6	107.8	0	0	15
	Heating	4577.7	kWh	-297.3					
S6.0	Cooling	695.4	kWh	554.6	5471.9	58.5	0	0	15
	Heating	4776.5	kWh	-496.1					
S7.0	Cooling	642.4	kWh	607.6	5498	32.4	0	0	16
	Heating	4855.6	kWh	-575.2					
S8.0	Cooling	591.8	kWh	658.2	5476.9	53.5	0	0	16
	Heating	4885.1	kWh	-604.7					
S9.0	Cooling	487.4	kWh	762.6	5538.2	-7.8	0	0	17
	Heating	5050.8	kWh	-770.4					
S10.0	Cooling	1292.4	kWh	-42.4	5471.7	58.7	2	1	14
	Heating	4179.3	kWh	101.1					
S11.0	Cooling	1141.3	kWh	108.7	5441.6	88.8	1	1	14
	Heating	4300.3	kWh	-19.9					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	1588.6	kWh		5891.6		5	1	14
	Heating	4303	kWh						
S2.0	Cooling	1213.8	kWh	374.8	5772.8	118.8	3	0	15
	Heating	4559	kWh	-256					
S3.0	Cooling	1122.2	kWh	466.4	5783.5	108.1	3	0	15
	Heating	4661.3	kWh	-358.3					
S4.0	Cooling	1212.5	kWh	376.1	5731.7	159.9	3	0	15
	Heating	4519.2	kWh	-216.2					
S5.0	Cooling	1031.7	kWh	556.9	5629.8	261.8	0	0	15
	Heating	4598.1	kWh	-295.1					
S6.0	Cooling	829.9	kWh	758.7	5627	264.6	0	0	16
	Heating	4797.1	kWh	-494.1					
S7.0	Cooling	759.5	kWh	829.1	5636.1	255.5	0	0	16
	Heating	4876.6	kWh	-573.6					
S8.0	Cooling	695.8	kWh	892.8	5599.4	292.2	0	0	16
	Heating	4903.6	kWh	-600.6					
S9.0	Cooling	575	kWh	1013.6	5644.4	247.2	0	0	17
	Heating	5069.4	kWh	-766.4					
S10.0	Cooling	1685.5	kWh	-96.9	5890	1.6	5	1	14
	Heating	4204.5	kWh	98.5					
S11.0	Cooling	1520.4	kWh	68.2	5846.3	45.3	0	0	15
	Heating	4325.9	kWh	-22.9					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	1582.1	kWh		1		4	1	13	S1.0
Heating	4689.2	kWh							
Cooling	1202.2	kWh	379.9	6141.2	130.1	4	1	14	S2.0
Heating	4939	kWh	-249.8						
Cooling	1110.1	kWh	472	6155.1	116.2	3	0	14	S3.0
Heating	5045	kWh	-355.8						
Cooling	1200	kWh	382.1	6120.2	151.1	3	0	14	S4.0
Heating	4920.2	kWh	-231						
Cooling	1018.5	kWh	563.6	6009.7	261.6	0	0	15	S5.0
Heating	4991.2	kWh	-302						
Cooling	820.4	kWh	761.7	6026.8	244.5	0	0	15	S6.0
Heating	5206.4	kWh	-517.2						
Cooling	752.2	kWh	829.9	6041.2	230.1	0	0	15	S7.0
Heating	5289	kWh	-599.8						
Cooling	692.1	kWh	890	6012.1	259.2	0	0	16	S8.0
Heating	5320	kWh	-630.8						
Cooling	575.5	kWh	1006.6	6067.9	203.4	0	0	16	S9.0
Heating	5492.4	kWh	-803.2						
Cooling	1682.5	kWh	-100.4	6251.8	19.5	4	1	13	S10.0
Heating	4569.3	kWh	119.9						
Cooling	1512.8	kWh	69.3	6215.9	55.4	0	0	14	S11.0
Heating	4703.1	kWh	-13.9						

Results of Madrid.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	3346.1	kWh		5874.1		4	1	10
	Heating	2528	kWh						
S2.0	Cooling	2944.7	kWh	401.4	5673.2	200.9	4	0	11
	Heating	2728.5	kWh	-200.5					
S3.0	Cooling	2844.4	kWh	501.7	5665.7	208.4	3	0	11
	Heating	2821.3	kWh	-293.3					
S4.0	Cooling	2910.5	kWh	435.6	5613.4	260.7	3	0	11
	Heating	2702.9	kWh	-174.9					
S5.0	Cooling	2650.8	kWh	695.3	5408.9	465.2	0	0	11
	Heating	2758.1	kWh	-230.1					
S6.0	Cooling	2357.2	kWh	988.9	5239.1	635	0	0	12
	Heating	2881.9	kWh	-353.9					
S7.0	Cooling	2273.5	kWh	1072.6	5229.5	644.6	0	0	12
	Heating	2956	kWh	-428					
S8.0	Cooling	2180.9	kWh	1165.2	5157.6	716.5	0	0	12
	Heating	2976.7	kWh	-448.7					
S9.0	Cooling	1979	kWh	1367.1	5106.4	767.7	0	0	13
	Heating	3127.4	kWh	-599.4					
S10.0	Cooling	3427.6	kWh	-81.5	5895.6	-21.5	4	1	10
	Heating	2468	kWh	60					
S11.0	Cooling	3185.7	kWh	160.4	5717	157.1	3	1	10
	Heating	2531.3	kWh	-3.3					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	3403.7	kWh		5944.5		13	2	11
	Heating	2540.8	kWh						
S2.0	Cooling	2792.2	kWh	611.5	5527.7	416.8	13	2	11
	Heating	2735.5	kWh	-194.7					
S3.0	Cooling	2659	kWh	744.7	5486.3	458.2	12	2	11
	Heating	2827.3	kWh	-286.5					
S4.0	Cooling	2763.1	kWh	640.6	5481.4	463.1	11	1	11
	Heating	2718.3	kWh	-177.5					
S5.0	Cooling	2529.6	kWh	874.1	5297.6	646.9	10	1	12
	Heating	2768	kWh	-227.2					
S6.0	Cooling	2213.3	kWh	1190.4	5104.5	840	8	0	12
	Heating	2891.2	kWh	-350.4					
S7.0	Cooling	2112.6	kWh	1291.1	5076.1	868.4	7	0	12
	Heating	2963.5	kWh	-422.7					
S8.0	Cooling	2016.1	kWh	1387.6	5000.9	943.6	7	0	12
	Heating	2984.8	kWh	-444					
S9.0	Cooling	1822.4	kWh	1581.3	4957.9	986.6	6	0	13
	Heating	3135.5	kWh	-594.7					
S10.0	Cooling	3560.8	kWh	-157.1	6043	-98.5	13	3	10
	Heating	2482.2	kWh	58.6					
S11.0	Cooling	3329.6	kWh	74.1	5876.7	67.8	11	1	11
	Heating	2547.1	kWh	-6.3					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	3398.8	kWh		2		13	2	10	S1.0
Heating	2768	kWh							
Cooling	2792.6	kWh	606.2	5771	395.8	12	2	11	S2.0
Heating	2978.4	kWh	-210.4						
Cooling	2668	kWh	730.8	5742.7	424.1	11	1	11	S3.0
Heating	3074.7	kWh	-306.7						
Cooling	2765.6	kWh	633.2	5739.2	427.6	11	1	11	S4.0
Heating	2973.6	kWh	-205.6						
Cooling	2527	kWh	871.8	5543.6	623.2	1	0	11	S5.0
Heating	3016.6	kWh	-248.6						
Cooling	2229.1	kWh	1169.7	5378.3	788.5	0	0	12	S6.0
Heating	3149.2	kWh	-381.2						
Cooling	2138.8	kWh	1260	5365.6	801.2	0	0	12	S7.0
Heating	3226.8	kWh	-458.8						
Cooling	2045.6	kWh	1353.2	5295.5	871.3	0	0	12	S8.0
Heating	3249.9	kWh	-481.9						
Cooling	1870.6	kWh	1528.2	5282.8	884	0	0	13	S9.0
Heating	3412.2	kWh	-644.2						
Cooling	3558.7	kWh	-159.9	6265.5	-98.7	13	2	10	S10.0
Heating	2706.8	kWh	61.2						
Cooling	3323.4	kWh	75.4	6102.8	64	1	0	10	S11.0
Heating	2779.4	kWh	-11.4						

<u>Results of San Sebastián.</u>

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	487.8	kWh		3720.8		0	0	12
	Heating	3233	kWh						
S2.0	Cooling	340.9	kWh	146.9	3710.3	10.5	0	0	13
	Heating	3369.4	kWh	-136.4					
S3.0	Cooling	309.6	kWh	178.2	3735.7	-14.9	0	0	13
	Heating	3426.1	kWh	-193.1					
S4.0	Cooling	337.8	kWh	150	3670.5	50.3	0	0	13
	Heating	3332.7	kWh	-99.7					
S5.0	Cooling	292	kWh	195.8	3664.2	56.6	0	0	13
	Heating	3372.2	kWh	-139.2					
S6.0	Cooling	237.3	kWh	250.5	3764.4	-43.6	0	0	14
	Heating	3527.1	kWh	-294.1					
S7.0	Cooling	223.1	kWh	264.7	3795.8	-75	0	0	14
	Heating	3572.7	kWh	-339.7					
S8.0	Cooling	215.1	kWh	272.7	3803.4	-82.6	0	0	14
	Heating	3588.3	kWh	-355.3					
S9.0	Cooling	207	kWh	280.8	3891.5	-170.7	0	0	14
	Heating	3684.5	kWh	-451.5					
S10.0	Cooling	518.6	kWh	-30.8	3699.8	21	0	0	12
	Heating	3181.2	kWh	51.8					
S11.0	Cooling	453.3	kWh	34.5	3714	6.8	0	0	13
	Heating	3260.7	kWh	-27.7					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	612.2	kWh		3849.2		0	0	12
	Heating	3237	kWh						
S2.0	Cooling	421.9	kWh	190.3	3792.3	56.9	0	0	13
	Heating	3370.4	kWh	-133.4					
S3.0	Cooling	382.8	kWh	229.4	3810.1	39.1	0	0	13
	Heating	3427.3	kWh	-190.3					
S4.0	Cooling	444.8	kWh	167.4	3789.9	59.3	0	0	13
	Heating	3345.1	kWh	-108.1					
S5.0	Cooling	383	kWh	229.2	3759.5	89.7	0	0	13
	Heating	3376.5	kWh	-139.5					
S6.0	Cooling	288	kWh	324.2	3818.1	31.1	0	0	14
	Heating	3530.1	kWh	-293.1					
S7.0	Cooling	266.3	kWh	345.9	3841.2	8	0	0	14
	Heating	3574.9	kWh	-337.9					
S8.0	Cooling	250.6	kWh	361.6	3841.4	7.8	0	0	14
	Heating	3590.8	kWh	-353.8					
S9.0	Cooling	235.6	kWh	376.6	3922.1	-72.9	0	0	15
	Heating	3686.5	kWh	-449.5					
S10.0	Cooling	665.9	kWh	-53.7	3851.6	-2.4	0	0	12
	Heating	3185.7	kWh	51.3					
S11.0	Cooling	606.7	kWh	5.5	3873	-23.8	0	0	13
	Heating	3266.3	kWh	-29.3					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	804.5	kWh		0					S1.0
Heating	3680.4	kWh							
Cooling	801.4	kWh	3.1	4651.5	-166.6	0	0	15	S2.0
Heating	3850.1	kWh	-169.7						
Cooling	801.2	kWh	3.3	4721.7	-236.8	0	0	15	S3.0
Heating	3920.5	kWh	-240.1						
Cooling	847.7	kWh	-43.2	4693.6	-208.7	0	0	15	S4.0
Heating	3845.9	kWh	-165.5						
Cooling	799.8	kWh	4.7	4671.7	-186.8	0	0	15	S5.0
Heating	3871.9	kWh	-191.5						
Cooling	797.8	kWh	6.7	4863.1	-378.2	0	0	16	S6.0
Heating	4065.3	kWh	-384.9						
Cooling	797	kWh	7.5	4918.7	-433.8	0	0	16	S7.0
Heating	4121.7	kWh	-441.3						
Cooling	795.4	kWh	9.1	4942	-457.1	0	0	16	S8.0
Heating	4146.6	kWh	-466.2						
Cooling	790.7	kWh	13.8	5056.7	-571.8	0	0	17	S9.0
Heating	4266	kWh	-585.6						
Cooling	808.9	kWh	-4.4	4415.1	69.8	0	0	14	S10.0
Heating	3606.2	kWh	74.2						
Cooling	453.3	kWh	351.2	3714	770.9	0	0	13	S11.0
Heating	3260.7	kWh	419.7						

Results of Barcelona.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	4716.9	kWh		6775.8		0	0	9
	Heating	2058.9	kWh						
S2.0	Cooling	4080.6	kWh	636.3	6223	552.8	0	0	10
	Heating	2142.4	kWh	-83.5					
S3.0	Cooling	3911.2	kWh	805.7	6105.2	670.6	0	0	9
	Heating	2194	kWh	-135.1					
S4.0	Cooling	4003.5	kWh	713.4	6128	647.8	0	0	10
	Heating	2124.5	kWh	-65.6					
S5.0	Cooling	3663.8	kWh	1053.1	5832.2	943.6	0	0	10
	Heating	2168.4	kWh	-109.5					
S6.0	Cooling	3239.1	kWh	1477.8	5472.1	1303.7	0	0	10
	Heating	2233	kWh	-174.1					
S7.0	Cooling	3099.3	kWh	1617.6	5372.7	1403.1	0	0	10
	Heating	2273.4	kWh	-214.5					
S8.0	Cooling	2965.2	kWh	1751.7	5250	1525.8	0	0	11
	Heating	2284.8	kWh	-225.9					
S9.0	Cooling	2652.1	kWh	2064.8	5028.6	1747.2	0	0	8
	Heating	2376.5	kWh	-317.6					
S10.0	Cooling	4834.4	kWh	-117.5	6874.4	-98.6	0	0	9
	Heating	2040	kWh	18.9					
S11.0	Cooling	4494.3	kWh	222.6	6563.1	212.7	0	0	9
	Heating	2068.8	kWh	-9.9					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	3565.4	kWh		5627.5		12	2	9
	Heating	2062.1	kWh						
S2.0	Cooling	2975.9	kWh	589.5	5120.1	507.4	11	1	9
	Heating	2144.2	kWh	-82.1					
S3.0	Cooling	2835.7	kWh	729.7	5032	595.5	10	1	10
	Heating	2196.3	kWh	-134.2					
S4.0	Cooling	2943.3	kWh	622.1	5075.8	551.7	5	1	9
	Heating	2132.5	kWh	-70.4					
S5.0	Cooling	2737.2	kWh	828.2	4909.8	717.7	6	0	10
	Heating	2172.6	kWh	-110.5					
S6.0	Cooling	2411.9	kWh	1153.5	4648.1	979.4	4	0	10
	Heating	2236.2	kWh	-174.1					
S7.0	Cooling	2308.3	kWh	1257.1	4585.4	1042.1	4	0	10
	Heating	2277.1	kWh	-215					
S8.0	Cooling	2221.7	kWh	1343.7	4509.6	1117.9	4	0	10
	Heating	2287.9	kWh	-225.8					
S9.0	Cooling	2016.3	kWh	1549.1	4395.8	1231.7	4	0	11
	Heating	2379.5	kWh	-317.4					
S10.0	Cooling	3717.3	kWh	-151.9	5760.2	-132.7	12	2	9
	Heating	2042.9	kWh	19.2					
S11.0	Cooling	3479.1	kWh	86.3	5551.9	75.6	7	0	9
	Heating	2072.8	kWh	-10.7					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	5062.8	kWh		2		0	0	8	S1.0
Heating	2244.7	kWh							
Cooling	4702.5	kWh	360.3	7072.8	234.7	0	0	9	S2.0
Heating	2370.3	kWh	-125.6						
Cooling	4643.5	kWh	419.3	7086.9	220.6	0	0	10	S3.0
Heating	2443.4	kWh	-198.7						
Cooling	4717.1	kWh	345.7	7089.9	217.6	0	0	10	S4.0
Heating	2372.8	kWh	-128.1						
Cooling	4656.6	kWh	406.2	7067.5	240	0	0	10	S5.0
Heating	2410.9	kWh	-166.2						
Cooling	4583.3	kWh	479.5	7089.1	218.4	0	0	11	S6.0
Heating	2505.8	kWh	-261.1						
Cooling	4558.4	kWh	504.4	7122.2	185.3	0	0	11	S7.0
Heating	2563.8	kWh	-319.1						
Cooling	4550.8	kWh	512	7134.6	172.9	0	0	11	S8.0
Heating	2583.8	kWh	-339.1						
Cooling	4526	kWh	536.8	7238.4	69.1	0	0	12	S9.0
Heating	2712.4	kWh	-467.7						
Cooling	5179.8	kWh	-117	7384.1	-76.6	0	0	8	S10.0
Heating	2204.3	kWh	40.4						
Cooling	5100	kWh	-37.2	7347	-39.5	0	0	9	S11.0
Heating	2247	kWh	-2.3						

Results of A Coruña.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	854.9	kWh		3120		0	0	10
	Heating	2265.1	kWh						
S2.0	Cooling	648.1	kWh	206.8	3026.4	93.6	0	0	10
	Heating	2378.3	kWh	-113.2					
S3.0	Cooling	597.9	kWh	257	3029.4	90.6	0	0	11
	Heating	2431.5	kWh	-166.4					
S4.0	Cooling	642.5	kWh	212.4	2998.5	121.5	0	0	11
	Heating	2356	kWh	-90.9					
S5.0	Cooling	537.5	kWh	317.4	2926.4	193.6	0	0	11
	Heating	2388.9	kWh	-123.8					
S6.0	Cooling	433	kWh	421.9	2926.5	193.5	0	0	11
	Heating	2493.5	kWh	-228.4					
S7.0	Cooling	395.1	kWh	459.8	2931.9	188.1	0	0	12
	Heating	2536.8	kWh	-271.7					
S8.0	Cooling	363.4	kWh	491.5	2914	206	0	0	12
	Heating	2550.6	kWh	-285.5					
S9.0	Cooling	296.5	kWh	558.4	2939.5	180.5	0	0	12
	Heating	2643	kWh	-377.9					
S10.0	Cooling	890.2	kWh	-35.3	3119.1	0.9	0	0	10
	Heating	2228.9	kWh	36.2					
S11.0	Cooling	792.1	kWh	62.8	3066.8	53.2	0	0	10
	Heating	2274.7	kWh	-9.6					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	1364	kWh		3632.2		0	0	10
	Heating	2268.2	kWh						
S2.0	Cooling	971.2	kWh	392.8	3351.7	280.5	0	0	11
	Heating	2380.5	kWh	-112.3					
S3.0	Cooling	882.2	kWh	481.8	3315.3	316.9	0	0	11
	Heating	2433.1	kWh	-164.9					
S4.0	Cooling	967.5	kWh	396.5	3334.4	297.8	0	0	11
	Heating	2366.9	kWh	-98.7					
S5.0	Cooling	840.8	kWh	523.2	3232.9	399.3	0	0	11
	Heating	2392.1	kWh	-123.9					
S6.0	Cooling	624.7	kWh	739.3	3122	510.2	0	0	12
	Heating	2497.3	kWh	-229.1					
S7.0	Cooling	561.9	kWh	802.1	3101.1	531.1	0	0	12
	Heating	2539.2	kWh	-271					
S8.0	Cooling	511.1	kWh	852.9	3064.4	567.8	0	0	12
	Heating	2553.3	kWh	-285.1					
S9.0	Cooling	415.4	kWh	948.6	3061.1	571.1	0	0	12
	Heating	2645.7	kWh	-377.5					
S10.0	Cooling	1467.9	kWh	-103.9	3700.4	-68.2	0	0	10
	Heating	2232.5	kWh	35.7					
S11.0	Cooling	1323.2	kWh	40.8	3602	30.2	0	0	10
	Heating	2278.8	kWh	-10.6					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	742.4	kWh		0					S1.0
Heating	2602.6	kWh							
Cooling	676.5	kWh	65.9	3435	-90	0	0	12	S2.0
Heating	2758.5	kWh	-155.9						
Cooling	672	kWh	70.4	3499.8	-154.8	0	0	12	S3.0
Heating	2827.8	kWh	-225.2						
Cooling	723.4	kWh	19	3481.9	-136.9	0	0	12	S4.0
Heating	2758.5	kWh	-155.9						
Cooling	692.2	kWh	50.2	3474.9	-129.9	0	0	13	S5.0
Heating	2782.7	kWh	-180.1						
Cooling	705.5	kWh	36.9	3633.4	-288.4	0	0	13	S6.0
Heating	2927.9	kWh	-325.3						
Cooling	711	kWh	31.4	3694.9	-349.9	0	0	14	S7.0
Heating	2983.9	kWh	-381.3						
Cooling	717.5	kWh	24.9	3724.5	-379.5	0	0	14	S8.0
Heating	3007	kWh	-404.4						
Cooling	728.1	kWh	14.3	3858.2	-513.2	0	0	14	S9.0
Heating	3130.1	kWh	-527.5						
Cooling	785.6	kWh	-43.2	3329.9	15.1	0	0	10	S10.0
Heating	2544.3	kWh	58.3						
Cooling	800	kWh	-57.6	3407.6	-62.6	0	0	11	S11.0
Heating	2607.6	kWh	-5						

Results of Seville.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	6971.7	kWh		8941.2		6	1	7
	Heating	1969.5	kWh						
S2.0	Cooling	6205.8	kWh	765.9	8191.7	749.5	6	1	7
	Heating	1985.9	kWh	-16.4					
S3.0	Cooling	6013.5	kWh	958.2	8015.9	925.3	5	1	7
	Heating	2002.4	kWh	-32.9					
S4.0	Cooling	6124.3	kWh	847.4	8103	838.2	5	1	7
	Heating	1978.7	kWh	-9.2					
S5.0	Cooling	5685.2	kWh	1286.5	7684.5	1256.7	0	0	8
	Heating	1999.3	kWh	-29.8					
S6.0	Cooling	5132.9	kWh	1838.8	7152	1789.2	0	0	8
	Heating	2019.1	kWh	-49.6					
S7.0	Cooling	4976.8	kWh	1994.9	7009.8	1931.4	0	0	8
	Heating	2033	kWh	-63.5					
S8.0	Cooling	4795.3	kWh	2176.4	6832.2	2109	0	0	8
	Heating	2036.9	kWh	-67.4					
S9.0	Cooling	4408.4	kWh	2563.3	6480.5	2460.7	0	0	9
	Heating	2072.1	kWh	-102.6					
S10.0	Cooling	7122.3	kWh	-150.6	9088.8	-147.6	6	1	7
	Heating	1966.5	kWh	3					
S11.0	Cooling	6705.4	kWh	266.3	8678.5	262.7	4	2	7
	Heating	1973.1	kWh	-3.6					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	5482.3	kWh		7452.8		23	4	8
	Heating	1970.5	kWh						
S2.0	Cooling	4621.9	kWh	860.4	6609	843.8	21	4	8
	Heating	1987.1	kWh	-16.6					
S3.0	Cooling	4426.7	kWh	1055.6	6429.8	1023	21	3	8
	Heating	2003.1	kWh	-32.6					
S4.0	Cooling	4562	kWh	920.3	6543.8	909	17	2	7
	Heating	1981.8	kWh	-11.3					
S5.0	Cooling	4285.1	kWh	1197.2	6285.8	1167	17	1	8
	Heating	2000.7	kWh	-30.2					
S6.0	Cooling	3835.6	kWh	1646.7	5856.2	1596.6	15	1	8
	Heating	2020.6	kWh	-50.1					
S7.0	Cooling	3694.4	kWh	1787.9	5728.5	1724.3	15	1	8
	Heating	2034.1	kWh	-63.6					
S8.0	Cooling	3562.5	kWh	1919.8	5600.5	1852.3	15	1	8
	Heating	2038	kWh	-67.5					
S9.0	Cooling	3278	kWh	2204.3	5351.6	2101.2	14	1	9
	Heating	2073.6	kWh	-103.1					
S10.0	Cooling	5704.4	kWh	-222.1	7672	-219.2	23	4	8
	Heating	1967.6	kWh	2.9					
S11.0	Cooling	5404.8	kWh	77.5	7379.5	73.3	18	2	7
	Heating	1974.7	kWh	-4.2					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	5763.5	kWh		4		15	3	8	S1.0
Heating	2084.9	kWh							
Cooling	5019.8	kWh	743.7	7148.9	699.5	14	2	8	S2.0
Heating	2129.1	kWh	-44.2						
Cooling	4853	kWh	910.5	7013.6	834.8	13	2	8	S3.0
Heating	2160.6	kWh	-75.7						
Cooling	4979.3	kWh	784.2	7108.7	739.7	13	2	8	S4.0
Heating	2129.4	kWh	-44.5						
Cooling	4779.3	kWh	984.2	6932.8	915.6	1	0	8	S5.0
Heating	2153.5	kWh	-68.6						
Cooling	4430.8	kWh	1332.7	6629.8	1218.6	0	0	8	S6.0
Heating	2199	kWh	-114.1						
Cooling	4308.4	kWh	1455.1	6534.3	1314.1	0	0	8	S7.0
Heating	2225.9	kWh	-141						
Cooling	4198.2	kWh	1565.3	6434.3	1414.1	0	0	8	S8.0
Heating	2236.1	kWh	-151.2						
Cooling	3980.2	kWh	1783.3	6287	1561.4	0	0	9	S9.0
Heating	2306.8	kWh	-221.9						
Cooling	5963.8	kWh	-200.3	8035.5	-187.1	15	2	7	S10.0
Heating	2071.7	kWh	13.2						
Cooling	5736.2	kWh	27.3	7827.8	20.6	1	1	7	S11.0
Heating	2091.6	kWh	-6.7						

Results of Valencia.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	6539.4	kWh		8497.8		5	1	7
	Heating	1958.4	kWh						
S2.0	Cooling	5740.9	kWh	798.5	7709.4	788.4	5	1	7
	Heating	1968.5	kWh	-10.1					
S3.0	Cooling	5539	kWh	1000.4	7517.4	980.4	3	0	7
	Heating	1978.4	kWh	-20					
S4.0	Cooling	5657.9	kWh	881.5	7620	877.8	3	0	7
	Heating	1962.1	kWh	-3.7					
S5.0	Cooling	5212.9	kWh	1326.5	7190	1307.8	0	0	8
	Heating	1977.1	kWh	-18.7					
S6.0	Cooling	4654.1	kWh	1885.3	6645.6	1852.2	0	0	8
	Heating	1991.5	kWh	-33.1					
S7.0	Cooling	4489.3	kWh	2050.1	6490.6	2007.2	0	0	8
	Heating	2001.3	kWh	-42.9					
S8.0	Cooling	4316.4	kWh	2223	6320.9	2176.9	0	0	8
	Heating	2004.5	kWh	-46.1					
S9.0	Cooling	3939.9	kWh	2599.5	5977.5	2520.3	0	0	9
	Heating	2037.6	kWh	-79.2					
S10.0	Cooling	6702.2	kWh	-162.8	8659.2	-161.4	5	1	7
	Heating	1957	kWh	1.4					
S11.0	Cooling	6267	kWh	272.4	8226.7	271.1	3	1	7
	Heating	1959.7	kWh	-1.3					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	5210.3	kWh		7173.3		20	3	8
	Heating	1963	kWh						
S2.0	Cooling	4211.9	kWh	998.4	6182.9	990.4	19	3	8
	Heating	1971	kWh	-8					
S3.0	Cooling	3997.8	kWh	1212.5	5979	1194.3	18	3	8
	Heating	1981.2	kWh	-18.2					
S4.0	Cooling	4156.5	kWh	1053.8	6121.7	1051.6	13	2	7
	Heating	1965.2	kWh	-2.2					
S5.0	Cooling	3893.3	kWh	1317	5874.7	1298.6	14	1	8
	Heating	1981.4	kWh	-18.4					
S6.0	Cooling	3434	kWh	1776.3	5429.5	1743.8	11	1	8
	Heating	1995.5	kWh	-32.5					
S7.0	Cooling	3278.6	kWh	1931.7	5284	1889.3	11	1	8
	Heating	2005.4	kWh	-42.4					
S8.0	Cooling	3152.6	kWh	2057.7	5161.1	2012.2	11	1	8
	Heating	2008.5	kWh	-45.5					
S9.0	Cooling	2862.4	kWh	2347.9	4903.2	2270.1	10	1	9
	Heating	2040.8	kWh	-77.8					
S10.0	Cooling	5469.3	kWh	-259	7431.1	-257.8	19	3	7
	Heating	1961.8	kWh	1.2					
S11.0	Cooling	5172	kWh	38.3	7140.1	33.2	16	1	7
	Heating	1968.1	kWh	-5.1					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	6909.2	kWh		3		7	1	7	S1.0
Heating	2059.9	kWh							
Cooling	5968.5	kWh	940.7	8044.1	925	6	1	7	S2.0
Heating	2075.6	kWh	-15.7						
Cooling	5779.6	kWh	1129.6	7874.4	1094.7	4	1	7	S3.0
Heating	2094.8	kWh	-34.9						
Cooling	5930.1	kWh	979.1	8005.2	963.9	4	1	7	S4.0
Heating	2075.1	kWh	-15.2						
Cooling	5782.8	kWh	1126.4	7878.4	1090.7	0	0	7	S5.0
Heating	2095.6	kWh	-35.7						
Cooling	5469.6	kWh	1439.6	7592.2	1376.9	0	0	8	S6.0
Heating	2122.6	kWh	-62.7						
Cooling	5333.2	kWh	1576	7473	1496.1	0	0	8	S7.0
Heating	2139.8	kWh	-79.9						
Cooling	5247.1	kWh	1662.1	7393.8	1575.3	0	0	8	S8.0
Heating	2146.7	kWh	-86.8						
Cooling	5102.4	kWh	1806.8	7305.8	1663.3	0	0	9	S9.0
Heating	2203.4	kWh	-143.5						
Cooling	7159.2	kWh	-250	9212.3	-243.2	7	1	7	S10.0
Heating	2053.1	kWh	6.8						
Cooling	6982.3	kWh	-73.1	9050.4	-81.3	0	0	7	S11.0
Heating	2068.1	kWh	-8.2						

Results of Almería.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	6690.5	kWh		8643.7		5	1	6
	Heating	1953.2	kWh						
S2.0	Cooling	5740.9	kWh	949.6	7709.4	934.3	5	1	7
	Heating	1968.5	kWh	-15.3					
S3.0	Cooling	5738.3	kWh	952.2	7694.9	948.8	4	0	7
	Heating	1956.6	kWh	-3.4					
S4.0	Cooling	5849.3	kWh	841.2	7802.6	841.1	4	0	7
	Heating	1953.3	kWh	-0.1					
S5.0	Cooling	5400.1	kWh	1290.4	7356.4	1287.3	0	0	7
	Heating	1956.3	kWh	-3.1					
S6.0	Cooling	4841.6	kWh	1848.9	6801.8	1841.9	0	0	7
	Heating	1960.2	kWh	-7					
S7.0	Cooling	4681	kWh	2009.5	6644	1999.7	0	0	7
	Heating	1963	kWh	-9.8					
S8.0	Cooling	4510.5	kWh	2180	6474.3	2169.4	0	0	7
	Heating	1963.8	kWh	-10.6					
S9.0	Cooling	4136.1	kWh	2554.4	6109	2534.7	0	0	8
	Heating	1972.9	kWh	-19.7					
S10.0	Cooling	6843.7	kWh	-153.2	8796.8	-153.1	5	1	6
	Heating	1953.1	kWh	0.1					
S11.0	Cooling	6267	kWh	423.5	8226.7	417	3	1	7
	Heating	1959.7	kWh	-6.5					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	5378.7	kWh		7332.2		20	3	7
	Heating	1953.5	kWh						
S2.0	Cooling	4402.6	kWh	976.1	6357.2	975	19	3	7
	Heating	1954.6	kWh	-1.1					
S3.0	Cooling	4190	kWh	1188.7	6147	1185.2	18	3	7
	Heating	1957	kWh	-3.5					
S4.0	Cooling	4346.9	kWh	1031.8	6300.4	1031.8	14	2	7
	Heating	1953.5	kWh	0					
S5.0	Cooling	4081.5	kWh	1297.2	6038.4	1293.8	15	1	7
	Heating	1956.9	kWh	-3.4					
S6.0	Cooling	3574.9	kWh	1803.8	5535.4	1796.8	12	1	7
	Heating	1960.5	kWh	-7					
S7.0	Cooling	3416.7	kWh	1962	5380.1	1952.1	12	1	7
	Heating	1963.4	kWh	-9.9					
S8.0	Cooling	3289.4	kWh	2089.3	5253.7	2078.5	11	1	7
	Heating	1964.3	kWh	-10.8					
S9.0	Cooling	2998.9	kWh	2379.8	4972.2	2360	11	1	8
	Heating	1973.3	kWh	-19.8					
S10.0	Cooling	5614.4	kWh	-235.7	7567.8	-235.6	20	3	7
	Heating	1953.4	kWh	0.1					
S11.0	Cooling	5288.9	kWh	89.8	7242.9	89.3	16	1	7
	Heating	1954	kWh	-0.5					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	6803.3	kWh		3		7	1	6	S1.0
Heating	1988	kWh							
Cooling	5980	kWh	823.3	7980.6	810.7	6	1	7	S2.0
Heating	2000.6	kWh	-12.6						
Cooling	5839.8	kWh	963.5	7853.6	937.7	5	1	7	S3.0
Heating	2013.8	kWh	-25.8						
Cooling	5955.7	kWh	847.6	7957.2	834.1	5	1	7	S4.0
Heating	2001.5	kWh	-13.5						
Cooling	5777.9	kWh	1025.4	7788.2	1003.1	0	0	7	S5.0
Heating	2010.3	kWh	-22.3						
Cooling	5512.7	kWh	1290.6	7542.6	1248.7	0	0	7	S6.0
Heating	2029.9	kWh	-41.9						
Cooling	5413	kWh	1390.3	7457.1	1334.2	0	0	7	S7.0
Heating	2044.1	kWh	-56.1						
Cooling	5340.9	kWh	1462.4	7390.2	1401.1	0	0	8	S8.0
Heating	2049.3	kWh	-61.3						
Cooling	5217.5	kWh	1585.8	7306.8	1484.5	0	0	8	S9.0
Heating	2089.3	kWh	-101.3						
Cooling	7034.5	kWh	-231.2	9020.5	-229.2	7	1	6	S10.0
Heating	1986	kWh	2						
Cooling	6831.5	kWh	-28.2	8825	-33.7	0	0	6	S11.0
Heating	1993.5	kWh	-5.5						

Results of Málaga.

	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	5613.5	kWh		7568.3		1	0	6
	Heating	1954.8	kWh						
S2.0	Cooling	4893.3	kWh	720.2	6852	716.3	1	0	7
	Heating	1958.7	kWh	-3.9					
S3.0	Cooling	4715.4	kWh	898.1	6677.3	891	0	0	7
	Heating	1961.9	kWh	-7.1					
S4.0	Cooling	4809.9	kWh	803.6	6765.3	803	0	0	7
	Heating	1955.4	kWh	-0.6					
S5.0	Cooling	4415.2	kWh	1198.3	6376.6	1191.7	0	0	7
	Heating	1961.4	kWh	-6.6					
S6.0	Cooling	3910.4	kWh	1703.1	5880.2	1688.1	0	0	7
	Heating	1969.8	kWh	-15					
S7.0	Cooling	3762.3	kWh	1851.2	5737.4	1830.9	0	0	8
	Heating	1975.1	kWh	-20.3					
S8.0	Cooling	3605.4	kWh	2008.1	5582.2	1986.1	0	0	8
	Heating	1976.8	kWh	-22					
S9.0	Cooling	3273.5	kWh	2340	5266.1	2302.2	0	0	8
	Heating	1992.6	kWh	-37.8					
S10.0	Cooling	5747.6	kWh	-134.1	7701.8	-133.5	1	0	6
	Heating	1954.2	kWh	0.6					
S11.0	Cooling	6267	kWh	-653.5	8226.7	-658.4	3	1	7
	Heating	1959.7	kWh	-4.9					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	4578.3	kWh		6533.3		19	3	7
	Heating	1955	kWh						
S2.0	Cooling	3756.8	kWh	821.5	5715.7	817.6	18	3	7
	Heating	1958.9	kWh	-3.9					
S3.0	Cooling	3580.1	kWh	998.2	5542.4	990.9	18	2	7
	Heating	1962.3	kWh	-7.3					
S4.0	Cooling	3705.1	kWh	873.2	5661.2	872.1	9	1	7
	Heating	1956.1	kWh	-1.1					
S5.0	Cooling	3458.3	kWh	1120	5420.3	1113	11	1	7
	Heating	1962	kWh	-7					
S6.0	Cooling	3027.5	kWh	1550.8	4998.1	1535.2	9	1	7
	Heating	1970.6	kWh	-15.6					
S7.0	Cooling	2902	kWh	1676.3	4877.8	1655.5	9	1	8
	Heating	1975.8	kWh	-20.8					
S8.0	Cooling	2788.8	kWh	1789.5	4766.4	1766.9	9	1	8
	Heating	1977.6	kWh	-22.6					
S9.0	Cooling	2549.8	kWh	2028.5	4543.3	1990	9	1	8
	Heating	1993.5	kWh	-38.5					
S10.0	Cooling	4785.4	kWh	-207.1	6739.9	-206.6	19	3	7
	Heating	1954.5	kWh	0.5					
S11.0	Cooling	4477	kWh	101.3	6433	100.3	13	1	7
	Heating	1956	kWh	-1					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	5636.1	kWh		3		5	1	7	S1.0
Heating	2022.1	kWh							
Cooling	4932	kWh	704.1	6979.9	678.3	4	1	7	S2.0
Heating	2047.9	kWh	-25.8						
Cooling	4810	kWh	826.1	6876.8	781.4	3	0	7	S3.0
Heating	2066.8	kWh	-44.7						
Cooling	4906.6	kWh	729.5	6955.1	703.1	3	0	7	S4.0
Heating	2048.5	kWh	-26.4						
Cooling	4742.8	kWh	893.3	6805.7	852.5	0	0	7	S5.0
Heating	2062.9	kWh	-40.8						
Cooling	4473.1	kWh	1163	6569.6	1088.6	0	0	8	S6.0
Heating	2096.5	kWh	-74.4						
Cooling	4395.6	kWh	1240.5	6511.4	1146.8	0	0	8	S7.0
Heating	2115.8	kWh	-93.7						
Cooling	4333.5	kWh	1302.6	6457.2	1201	0	0	8	S8.0
Heating	2123.7	kWh	-101.6						
Cooling	4248.5	kWh	1387.6	6426.4	1231.8	0	0	9	S9.0
Heating	2177.9	kWh	-155.8						
Cooling	5834.8	kWh	-198.7	7850	-191.8	5	1	6	S10.0
Heating	2015.2	kWh	6.9						
Cooling	5634.7	kWh	1.4	7661.8	-3.6	0	0	7	S11.0
Heating	2027.1	kWh	-5						

Results of Tenerife.

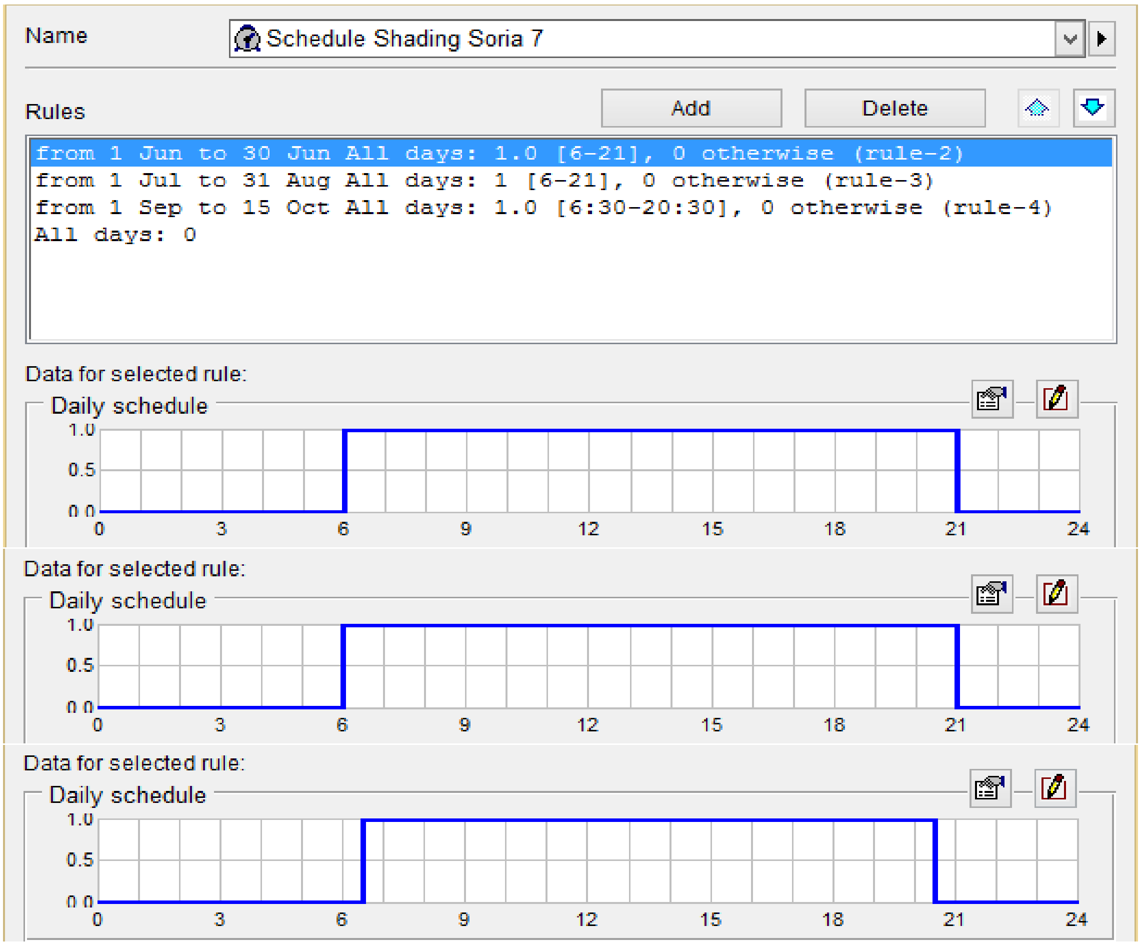
	Air Handling Unit: Temp+CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	6823.1	kWh		8776.2		2	0	6
	Heating	1953.1	kWh						
S2.0	Cooling	5892.5	kWh	930.6	7845.6	930.6	1	0	6
	Heating	1953.1	kWh	0					
S3.0	Cooling	5738.3	kWh	1084.8	7694.9	1081.3	4	0	7
	Heating	1956.6	kWh	-3.5					
S4.0	Cooling	5778.4	kWh	1044.7	7731.5	1044.7	1	0	6
	Heating	1953.1	kWh	0					
S5.0	Cooling	5299.9	kWh	1523.2	7253	1523.2	0	0	6
	Heating	1953.1	kWh	0					
S6.0	Cooling	4645.8	kWh	2177.3	6598.9	2177.3	0	0	6
	Heating	1953.1	kWh	0					
S7.0	Cooling	4454.7	kWh	2368.4	6407.8	2368.4	0	0	6
	Heating	1953.1	kWh	0					
S8.0	Cooling	4260	kWh	2563.1	6213.1	2563.1	0	0	6
	Heating	1953.1	kWh	0					
S9.0	Cooling	3844.6	kWh	2978.5	5797.7	2978.5	0	0	6
	Heating	1953.1	kWh	0					
S10.0	Cooling	6984.8	kWh	-161.7	8937.9	-161.7	2	0	6
	Heating	1953.1	kWh	0					
S11.0	Cooling	6478.9	kWh	344.2	8432	344.2	0	0	6
	Heating	1953.1	kWh	0					

	Air Handling Unit: Only CO2, Radiant Floor								
							27	27	
	Demand			Diff			% worst	% Average	% PDD
S1.0	Cooling	5915.6	kWh		7868.7		23	3	6
	Heating	1953.1	kWh						
S2.0	Cooling	5041.3	kWh	874.3	6994.4	874.3	22	3	6
	Heating	1953.1	kWh	0					
S3.0	Cooling	4806	kWh	1109.6	6759.1	1109.6	21	2	6
	Heating	1953.1	kWh	0					
S4.0	Cooling	4959.2	kWh	956.4	6912.3	956.4	9	1	6
	Heating	1953.1	kWh	0					
S5.0	Cooling	4645.3	kWh	1270.3	6598.4	1270.3	12	1	6
	Heating	1953.1	kWh	0					
S6.0	Cooling	4041	kWh	1874.6	5994.1	1874.6	10	1	6
	Heating	1953.1	kWh	0					
S7.0	Cooling	3859.6	kWh	2056	5812.7	2056	10	1	6
	Heating	1953.1	kWh	0					
S8.0	Cooling	3702	kWh	2213.6	5655.1	2213.6	10	1	6
	Heating	1953.1	kWh	0					
S9.0	Cooling	3336.2	kWh	2579.4	5289.3	2579.4	9	1	6
	Heating	1953.1	kWh	0					
S10.0	Cooling	6108.2	kWh	-192.6	8061.3	-192.6	23	3	6
	Heating	1953.1	kWh	0					
S11.0	Cooling	5699	kWh	216.6	7652.1	216.6	15	1	6
	Heating	1953.1	kWh	0					

Air Handling Unit: Only Humidity, Radiant Floor									
						27	27		
Demand			Diff			% worst	% Average	% PDD	
Cooling	7049.7	kWh		3		5	1	6	S1.0
Heating	1953.1	kWh							
Cooling	6299.4	kWh	750.3	8252.5	750.3	5	1	5	S2.0
Heating	1953.1	kWh	0						
Cooling	6128.7	kWh	921	8081.8	921	3	0	5	S3.0
Heating	1953.1	kWh	0						
Cooling	6250	kWh	799.7	8203.1	799.7	4	0	5	S4.0
Heating	1953.1	kWh	0						
Cooling	6106.9	kWh	942.8	8060	942.8	0	0	5	S5.0
Heating	1953.1	kWh	0						
Cooling	5752.9	kWh	1296.8	7706	1296.8	0	0	5	S6.0
Heating	1953.1	kWh	0						
Cooling	5645.8	kWh	1403.9	7598.9	1403.9	0	0	6	S7.0
Heating	1953.1	kWh	0						
Cooling	5568.9	kWh	1480.8	7522	1480.8	0	0	6	S8.0
Heating	1953.1	kWh	0						
Cooling	5540.2	kWh	1509.5	7493.3	1509.5	0	0	6	S9.0
Heating	1953.1	kWh	0						
Cooling	7251.5	kWh	-201.8	9204.6	-201.8	5	1	5	S10.0
Heating	1953.1	kWh	0						
Cooling	7022	kWh	27.7	8975.1	27.7	0	0	5	S11.0
Heating	1953.1	kWh	0						

ANNEX 4: SHADING SCHEDULE IN EACH LOCATION.

Best option for Soria.



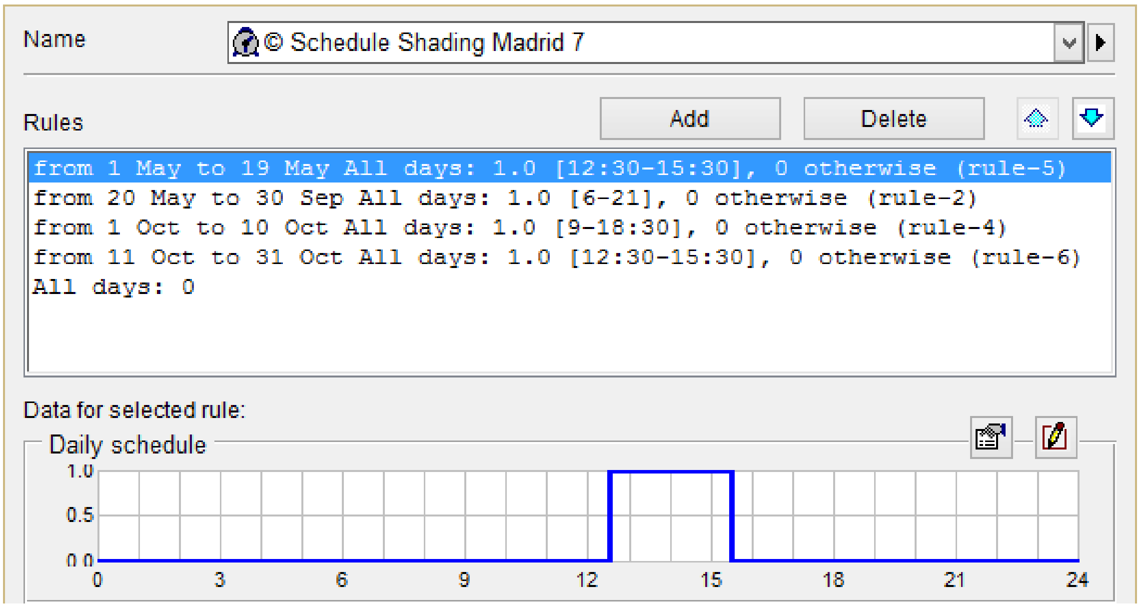
Name: Schedule Shading Soria 7

Rules

```
from 1 Jun to 30 Jun All days: 1.0 [6-21], 0 otherwise (rule-2)
from 1 Jul to 31 Aug All days: 1 [6-21], 0 otherwise (rule-3)
from 1 Sep to 15 Oct All days: 1.0 [6:30-20:30], 0 otherwise (rule-4)
All days: 0
```

Image 48: Best Option for Soria. Screenshot from IDA ICE.

Best option for Madrid.



Name: © Schedule Shading Madrid 7

Rules

```
from 1 May to 19 May All days: 1.0 [12:30-15:30], 0 otherwise (rule-5)
from 20 May to 30 Sep All days: 1.0 [6-21], 0 otherwise (rule-2)
from 1 Oct to 10 Oct All days: 1.0 [9-18:30], 0 otherwise (rule-4)
from 11 Oct to 31 Oct All days: 1.0 [12:30-15:30], 0 otherwise (rule-6)
All days: 0
```

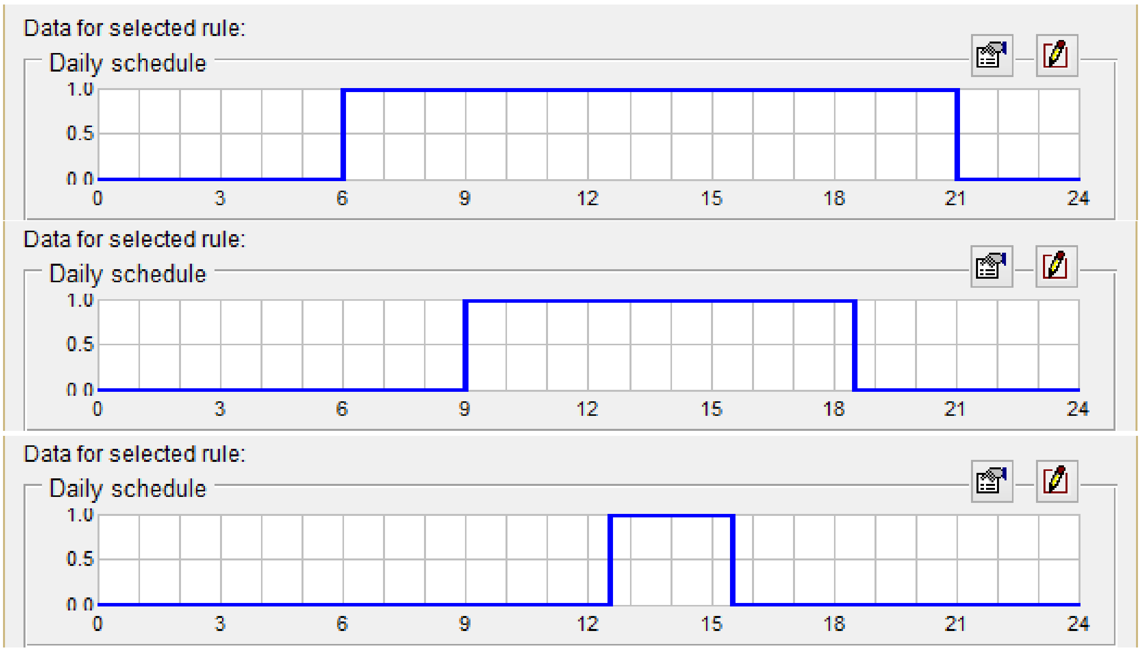
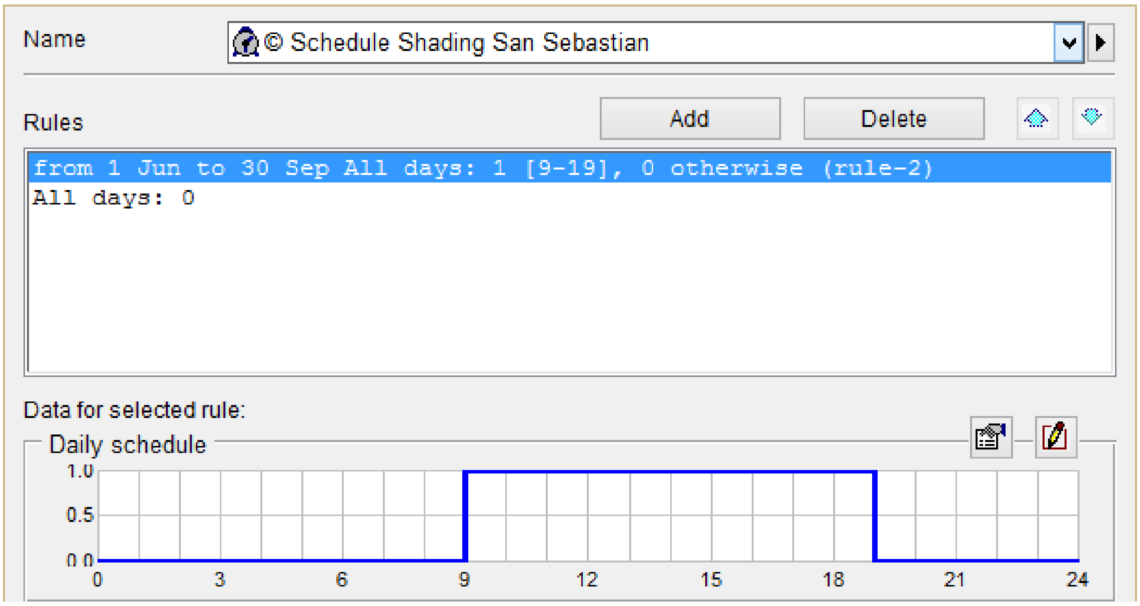


Image 49: Best option for Madrid. Screenshot from IDA ICE.

Best option for San Sebastian.

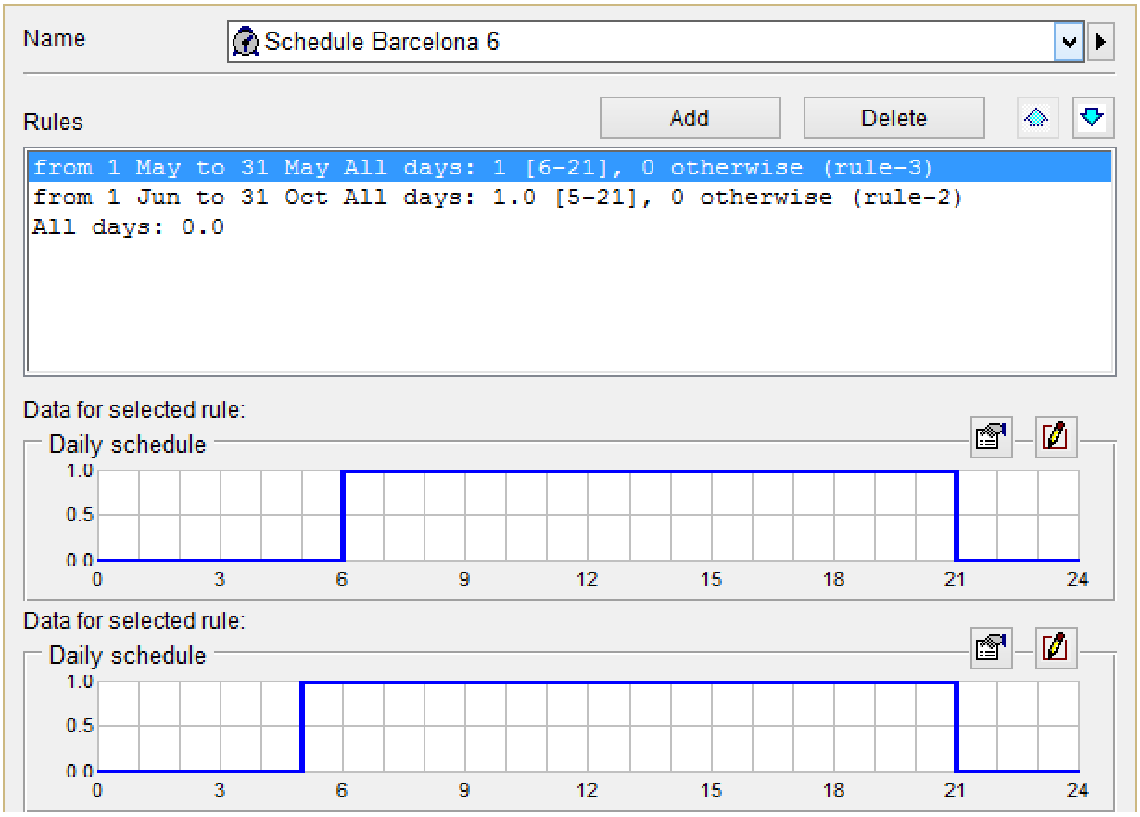

Name: © Schedule Shading San Sebastian

Rules

```
from 1 Jun to 30 Sep All days: 1 [9-19], 0 otherwise (rule-2)
All days: 0
```

Image 50: Best option for San Sebastián. Screenshot from IDA ICE.

Best option for Barcelona.

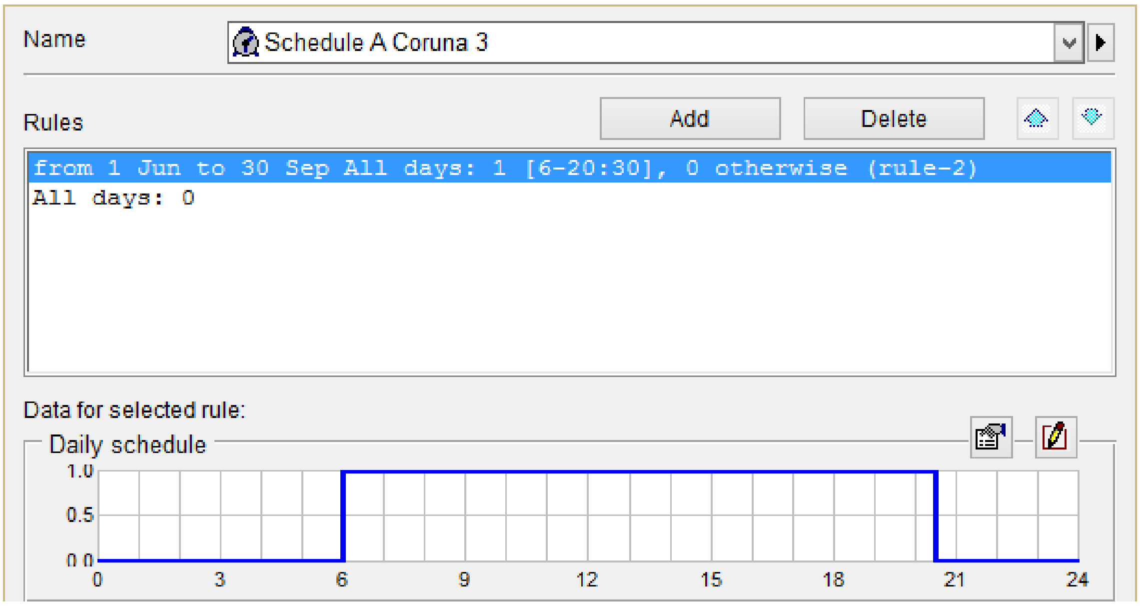


Schedule Barcelona 6

```
from 1 May to 31 May All days: 1 [6-21], 0 otherwise (rule-3)
from 1 Jun to 31 Oct All days: 1.0 [5-21], 0 otherwise (rule-2)
All days: 0.0
```

Image 51: Best option for Barcelona. Screenshot from IDA ICE.

Best option for A Coruña.

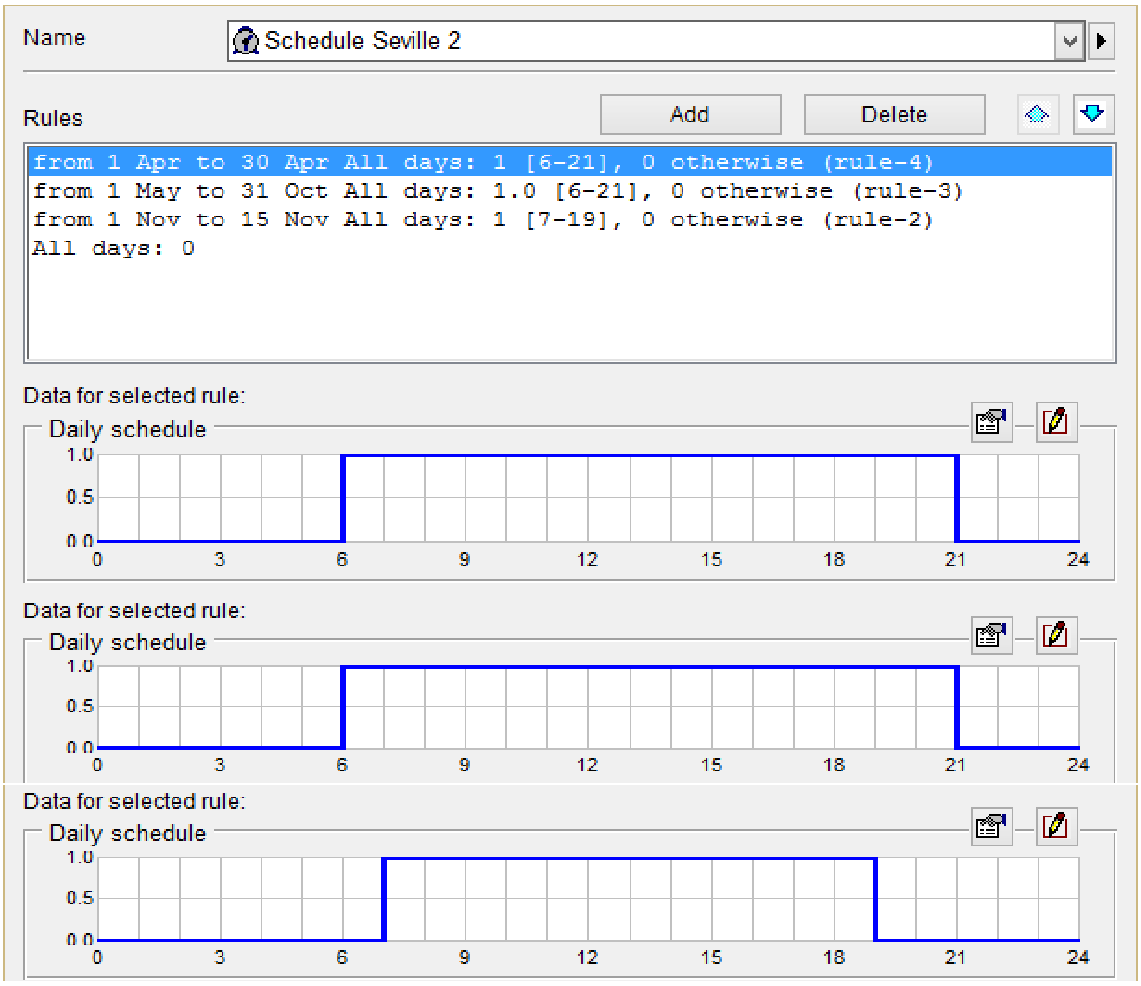


Schedule A Coruna 3

```
from 1 Jun to 30 Sep All days: 1 [6-20:30], 0 otherwise (rule-2)
All days: 0
```

Image 52:Best option for A Coruña. Screenshot from IDA ICE.

Best option for Seville.



Name: Schedule Seville 2

Rules

from 1 Apr to 30 Apr All days: 1 [6-21], 0 otherwise (rule-4)
from 1 May to 31 Oct All days: 1.0 [6-21], 0 otherwise (rule-3)
from 1 Nov to 15 Nov All days: 1 [7-19], 0 otherwise (rule-2)
All days: 0

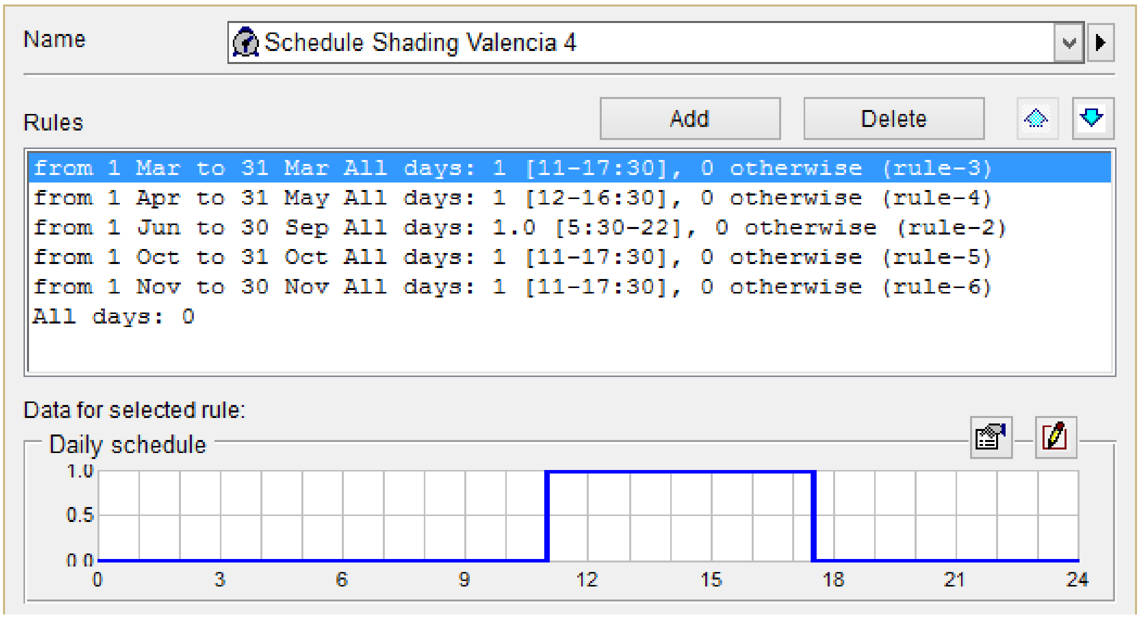
Data for selected rule:

Data for selected rule:

Data for selected rule:

Image 53: Best option for Sevilla . Screenshot from IDA ICE.

Best option for Valencia.



Name: Schedule Shading Valencia 4

Rules

from 1 Mar to 31 Mar All days: 1 [11-17:30], 0 otherwise (rule-3)
from 1 Apr to 31 May All days: 1 [12-16:30], 0 otherwise (rule-4)
from 1 Jun to 30 Sep All days: 1.0 [5:30-22], 0 otherwise (rule-2)
from 1 Oct to 31 Oct All days: 1 [11-17:30], 0 otherwise (rule-5)
from 1 Nov to 30 Nov All days: 1 [11-17:30], 0 otherwise (rule-6)
All days: 0

Data for selected rule:

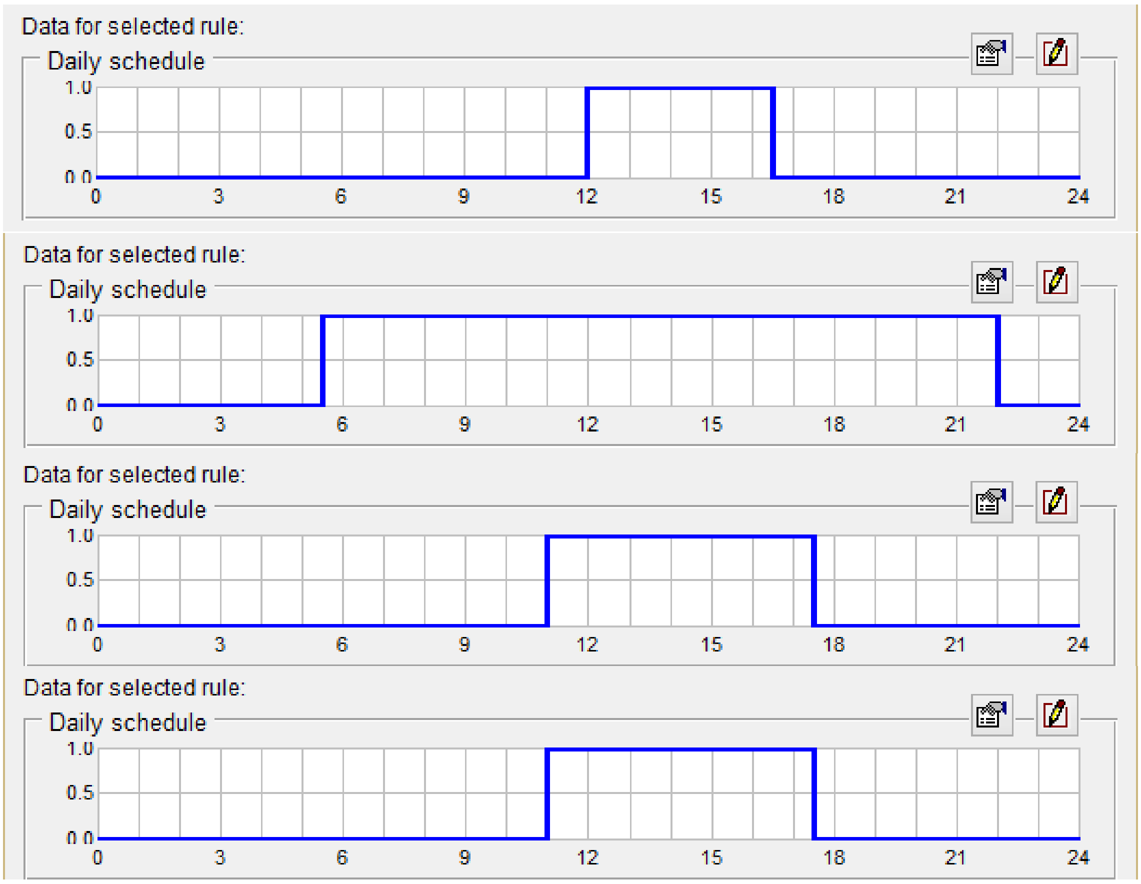
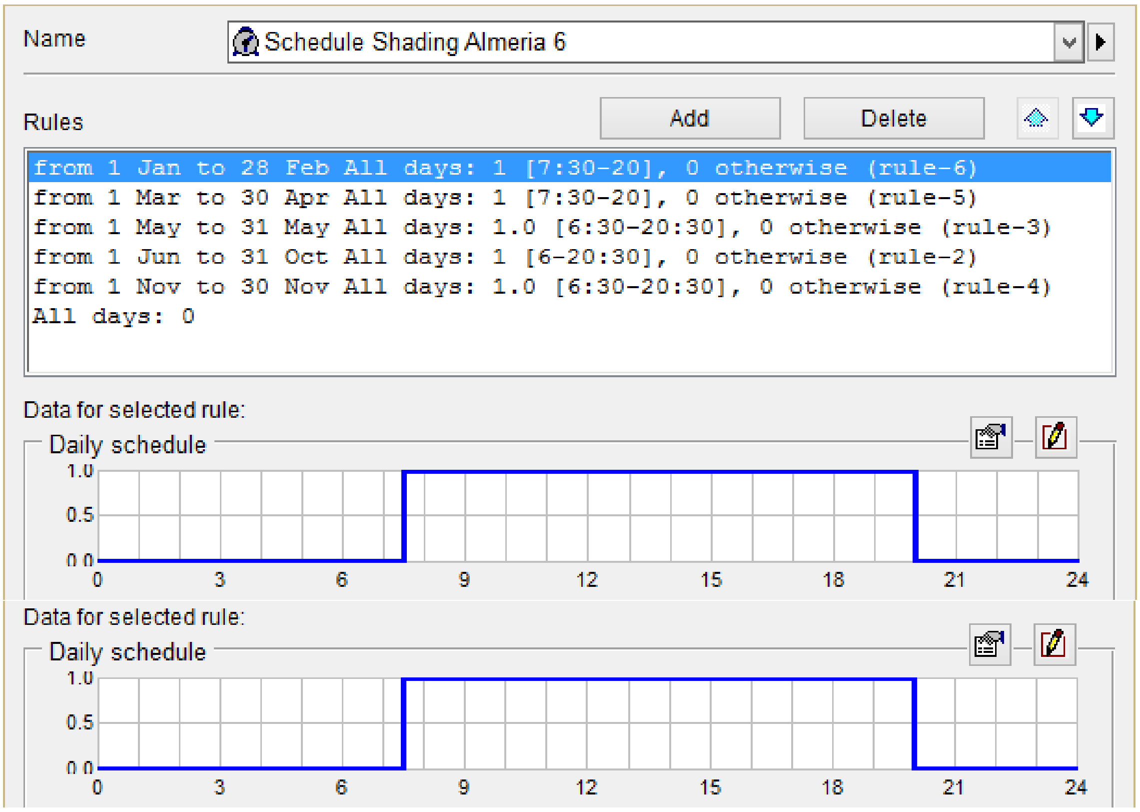


Image 54: Best option for Valencia. Screenshot from IDA ICE.

<u>Best option for Almería.</u>



Name: Schedule Shading Almeria 6

Rules

```
from 1 Jan to 28 Feb All days: 1 [7:30-20], 0 otherwise (rule-6)
from 1 Mar to 30 Apr All days: 1 [7:30-20], 0 otherwise (rule-5)
from 1 May to 31 May All days: 1.0 [6:30-20:30], 0 otherwise (rule-3)
from 1 Jun to 31 Oct All days: 1 [6-20:30], 0 otherwise (rule-2)
from 1 Nov to 30 Nov All days: 1.0 [6:30-20:30], 0 otherwise (rule-4)
All days: 0
```

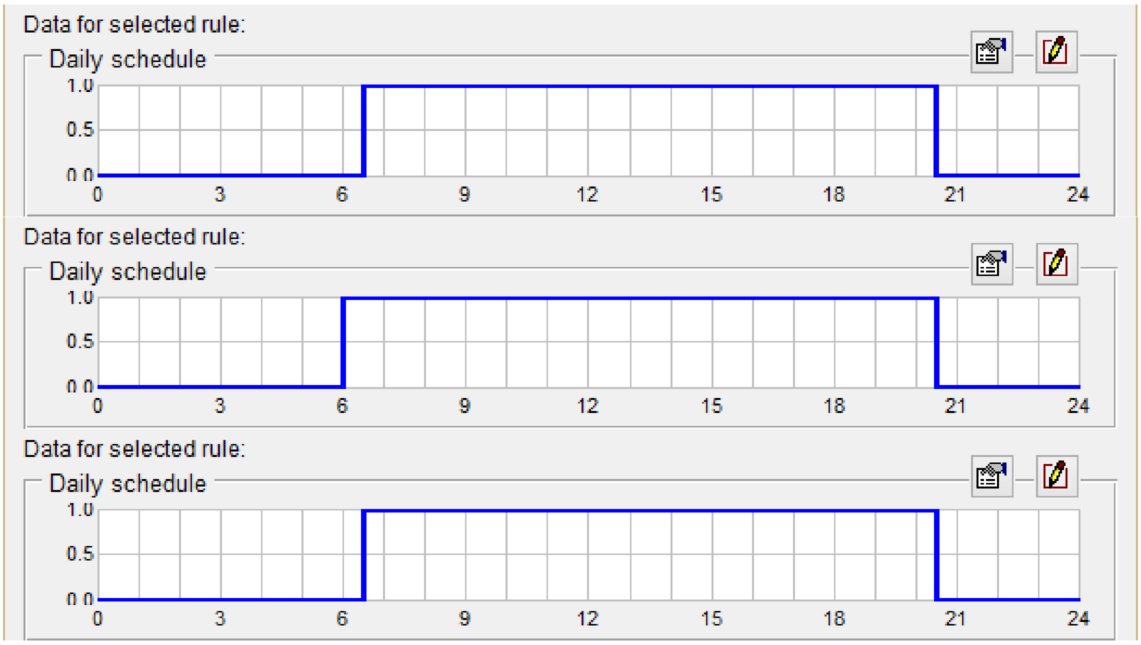
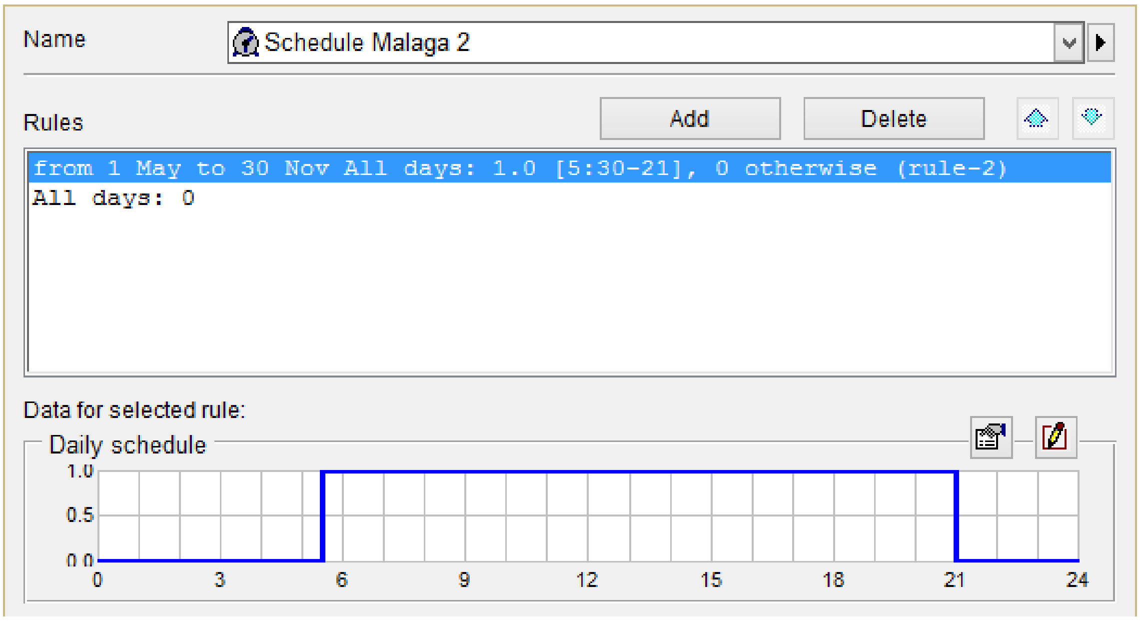


Image 55: Best option for Almería. Screenshot from IDA ICE.

<u>Best option for Málaga.</u>



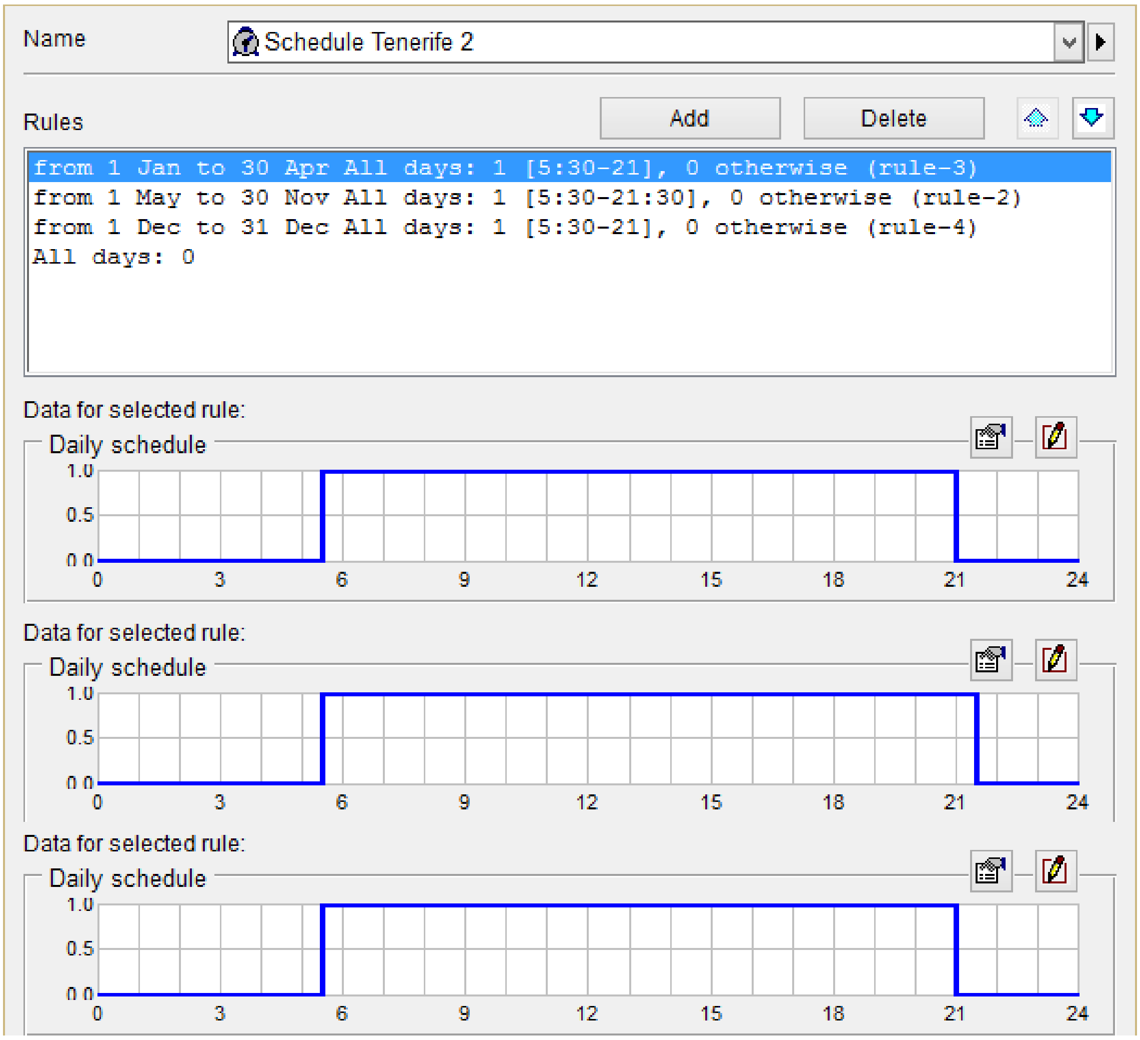
Name: Schedule Malaga 2

Rules

```
from 1 May to 30 Nov All days: 1.0 [5:30-21], 0 otherwise (rule-2)
All days: 0
```

Image 56: Best option for Málaga. Screenshot from IDA ICE.

Best option for Tenerife.



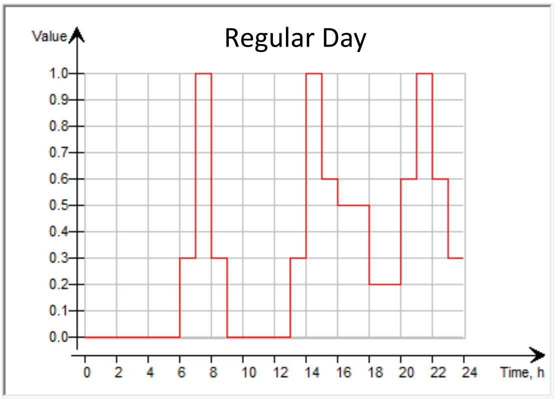
Schedule Tenerife 2

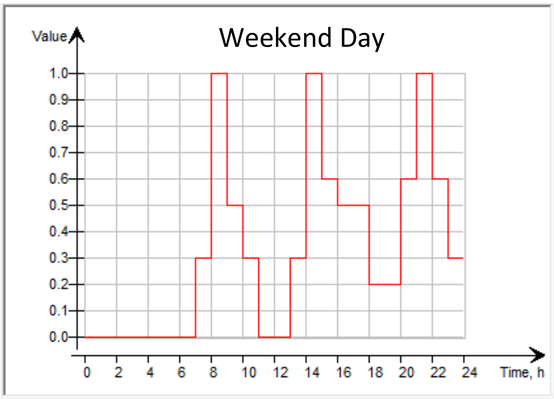
```
from 1 Jan to 30 Apr All days: 1 [5:30-21], 0 otherwise (rule-3)
from 1 May to 30 Nov All days: 1 [5:30-21:30], 0 otherwise (rule-2)
from 1 Dec to 31 Dec All days: 1 [5:30-21], 0 otherwise (rule-4)
All days: 0
```

Image 57: Best option for Tenerife. Screenshot from IDA ICE.

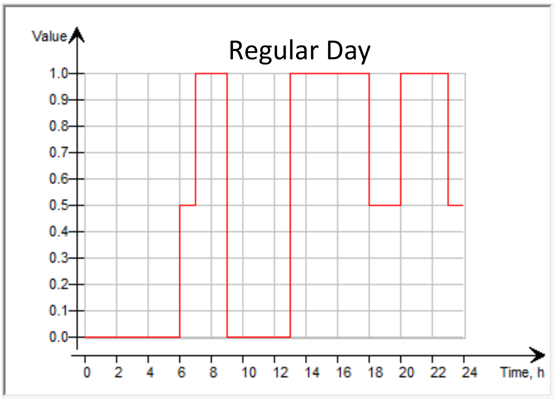
ANNEX 5: SCHEDULE OF LIGHTING AND OCCUPANCY FOR EACH ROOM.

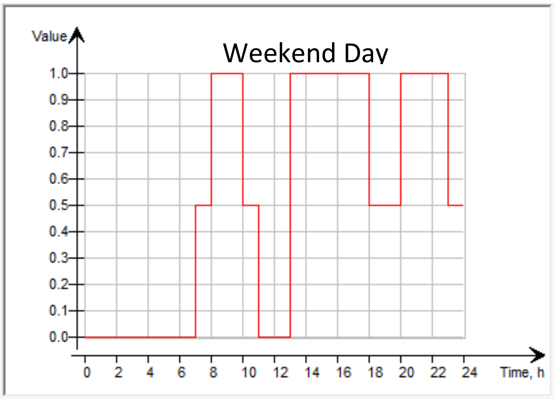
- ✓ Living room and kitchen schedules.
  - ➢ Occupancy:



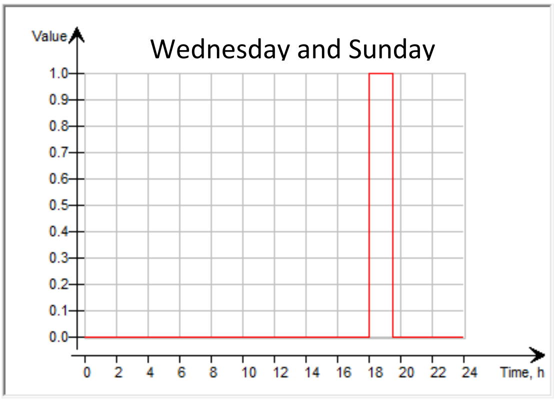


  - ➢ Lighting:

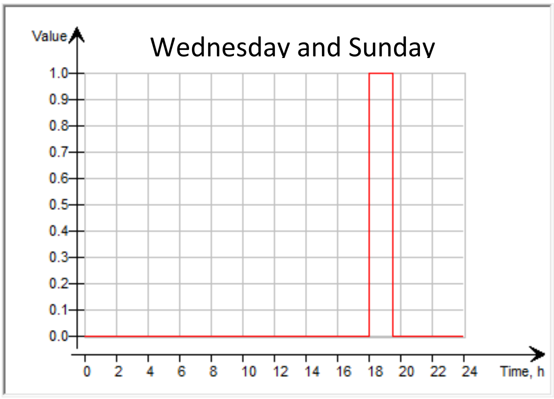




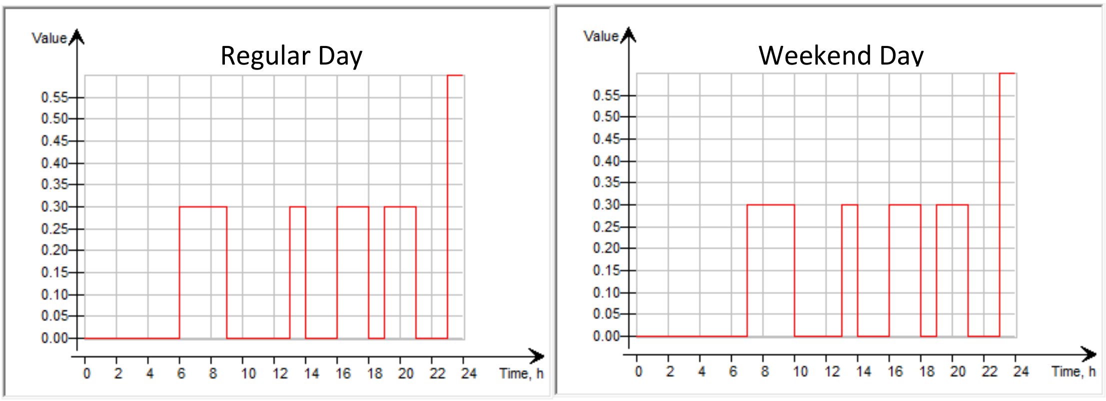
- ✓ Laundry Room schedules.
  - ➢ Occupancy: Rest of the days the value is set to 0 during all the day.



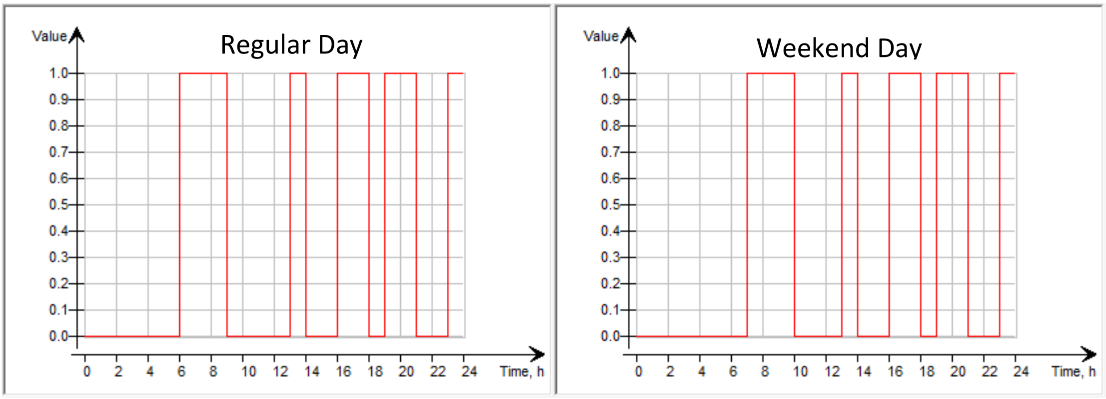
- Lighting: Rest of the days the value is set to 0 during all the day.



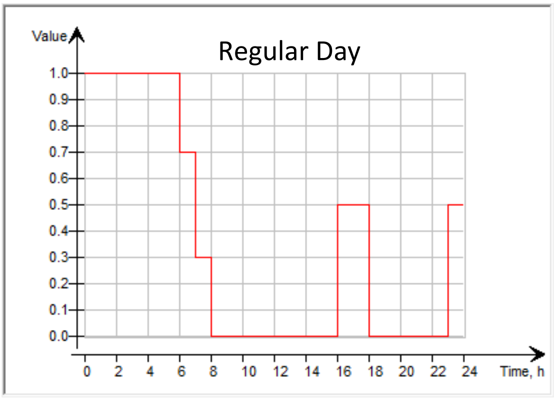
- ✓ Corridor schedules.
  - Occupancy:

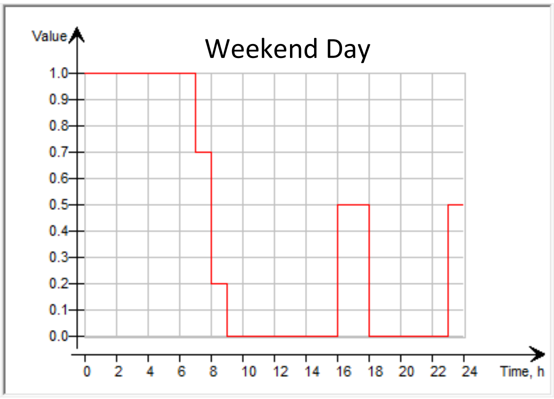


  - Lighting:

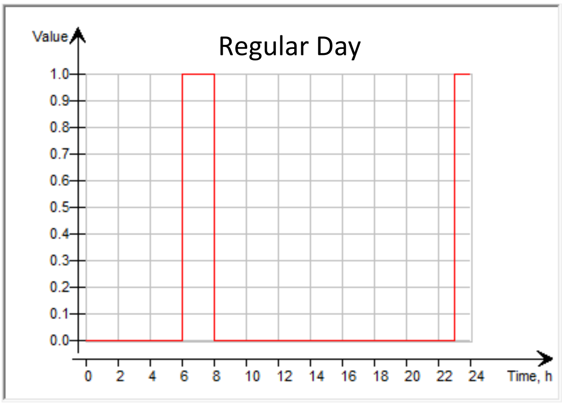


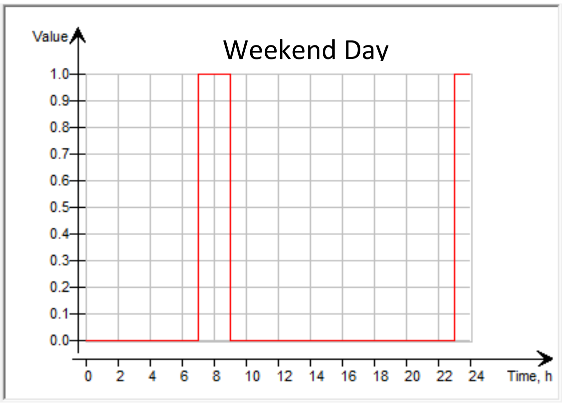
- ✓ Main Bedroom schedules.
  - ➢ Occupancy:



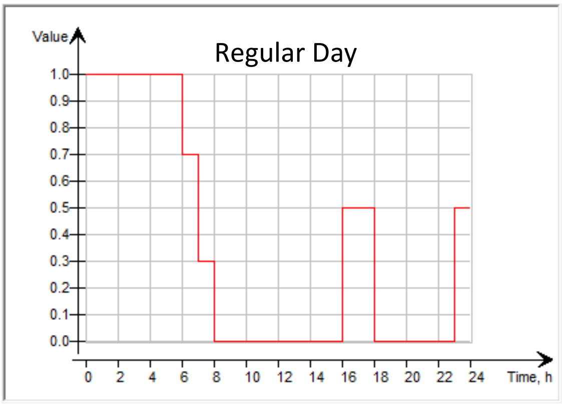


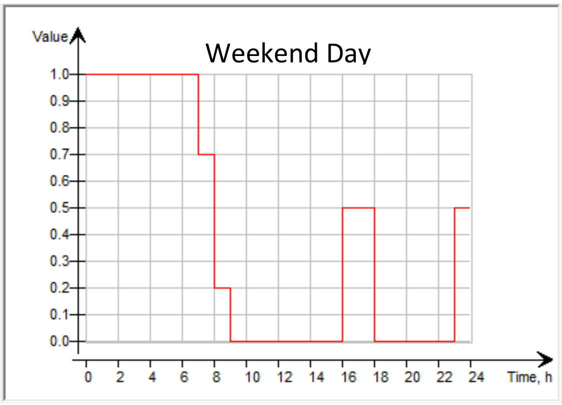
  - ➢ Lighting:



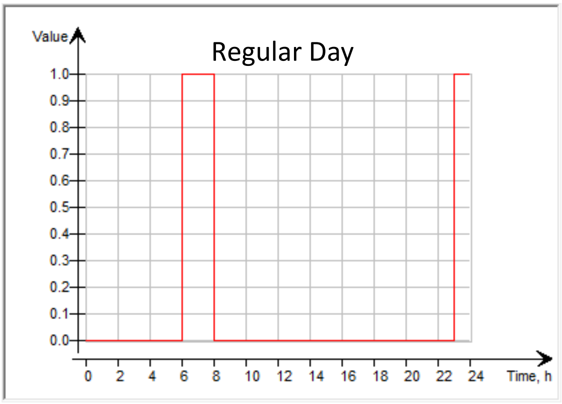


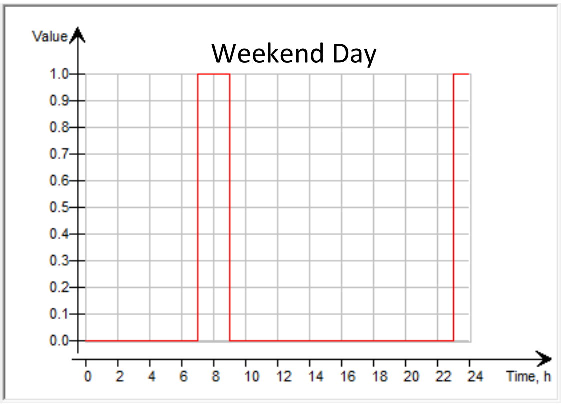
- ✓ Second Bedroom schedules.
  - ➢ Occupancy:





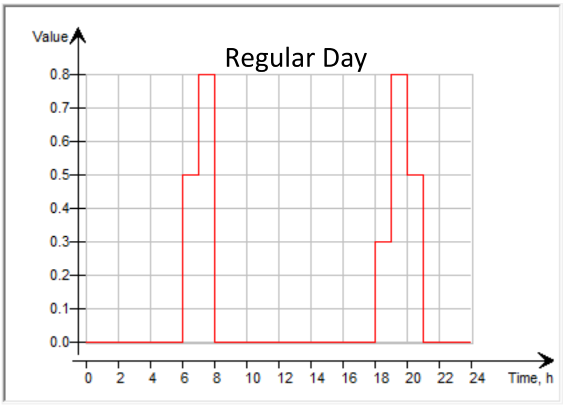
- Lighting:

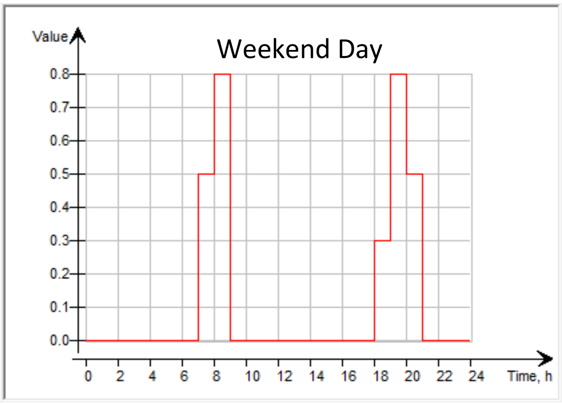




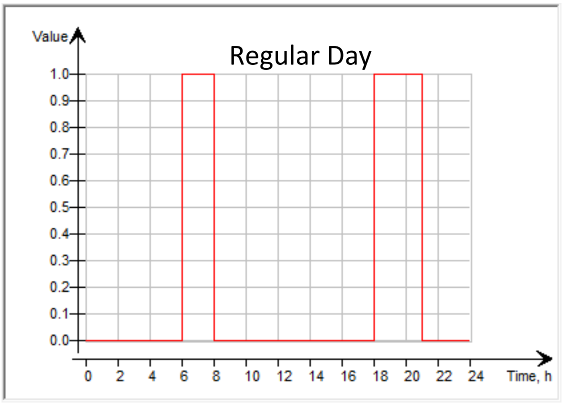
✓ Bathroom schedules.

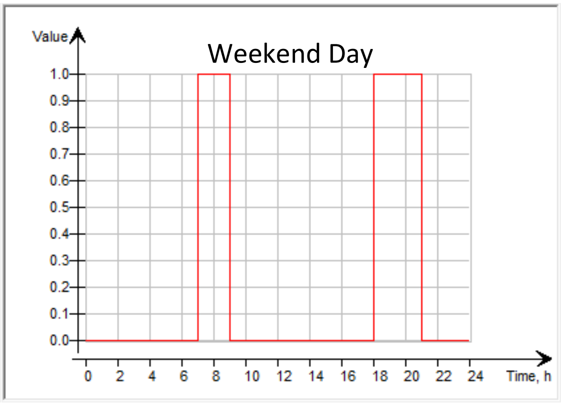
- Occupancy:



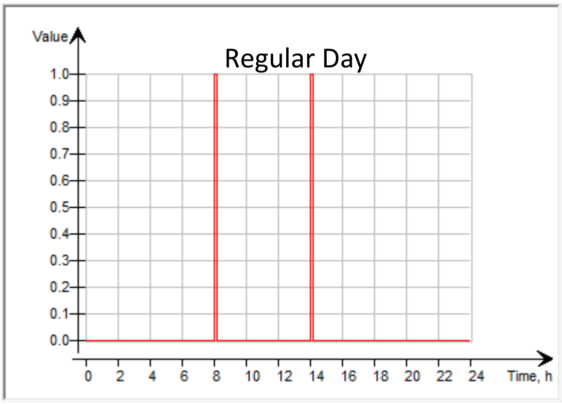


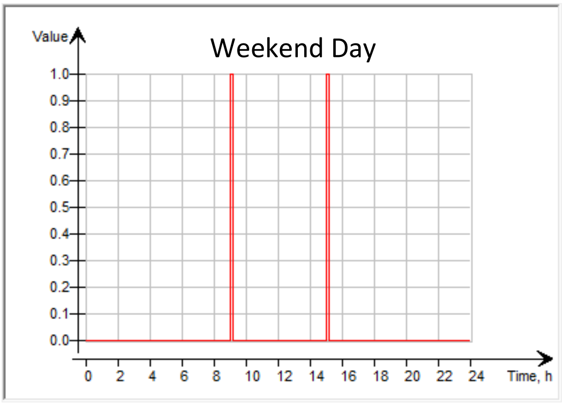
- Lighting:



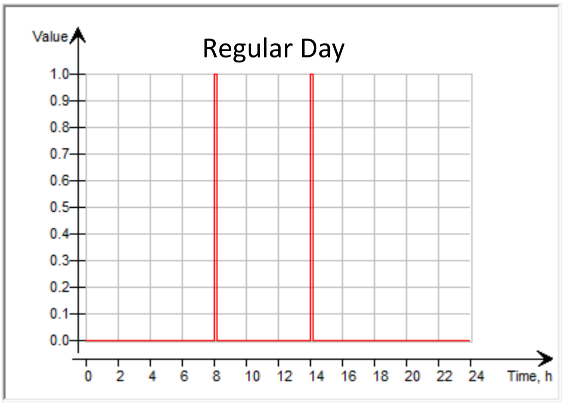


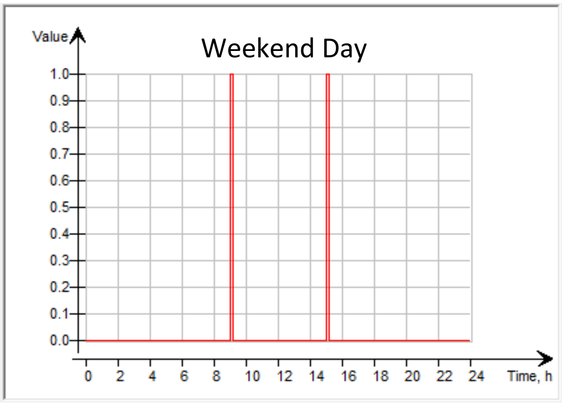
- ✓ Garage schedules.
  - ➢ Occupancy:





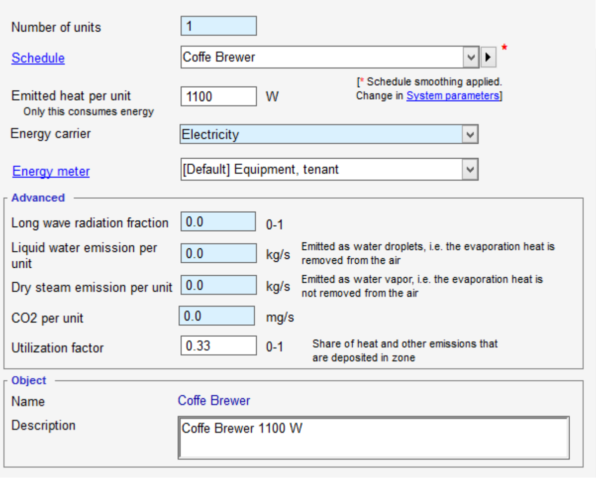
  - ➢ Lighting:





ANNEX 6: SCHEDULES OF ELECTRICAL APPLIANCES.

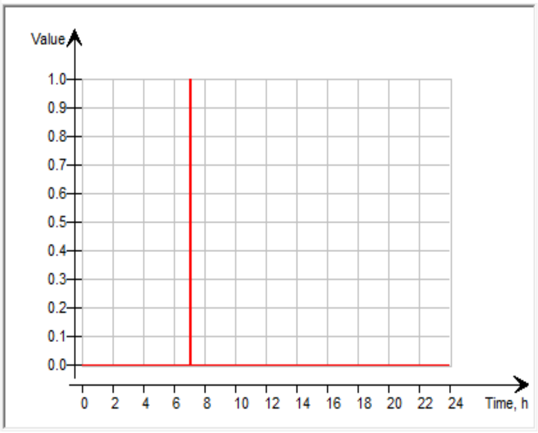
- ✓ Living room and Kitchen.
  - ➢ Coffee Brewer.



Number of units: 1
Schedule: Coffe Brewer *
[* Schedule smoothing applied. Change in System parameters]
Emitted heat per unit (Only this consumes energy): 1100 W
Energy carrier: Electricity
Energy meter: [Default] Equipment, tenant

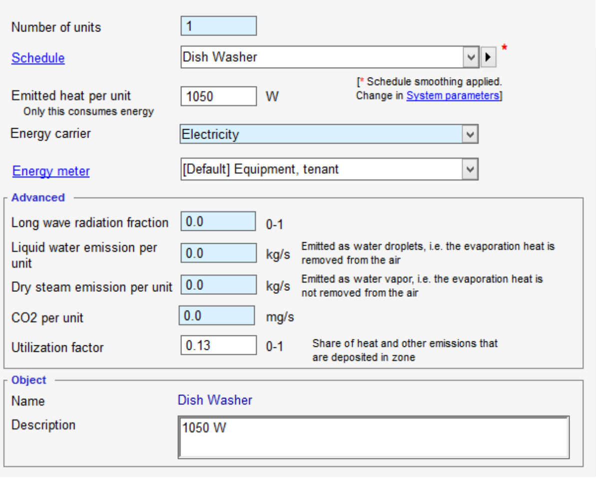
Advanced
Long wave radiation fraction: 0.0 0-1
Liquid water emission per unit: 0.0 kg/s — Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit: 0.0 kg/s — Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit: 0.0 mg/s
Utilization factor: 0.33 0-1 — Share of heat and other emissions that are deposited in zone

Object
Name: Coffe Brewer
Description: Coffe Brewer 1100 W



Graph 32: 5 minutes per day.

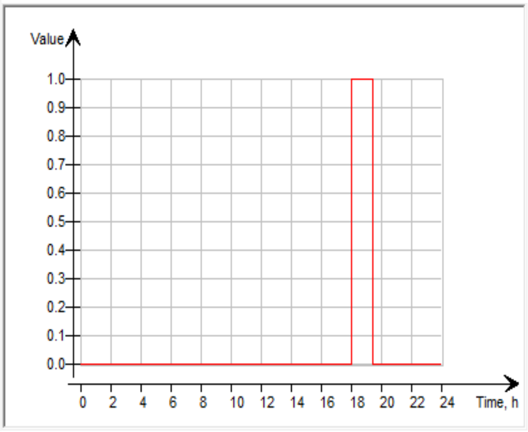
- ➢ Dish Washer Machine.



Number of units: 1
Schedule: Dish Washer *
[* Schedule smoothing applied. Change in System parameters]
Emitted heat per unit (Only this consumes energy): 1050 W
Energy carrier: Electricity
Energy meter: [Default] Equipment, tenant

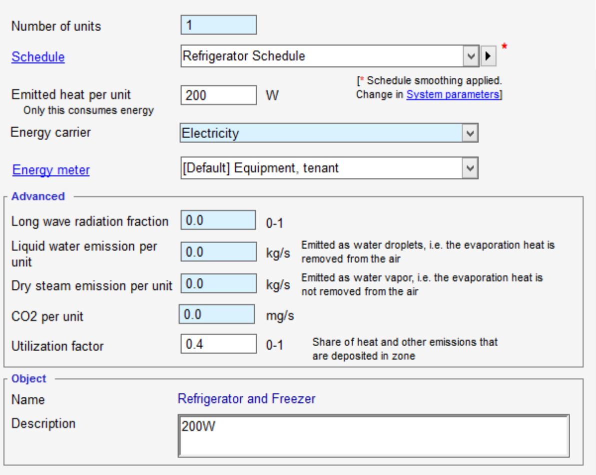
Advanced
Long wave radiation fraction: 0.0 0-1
Liquid water emission per unit: 0.0 kg/s — Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit: 0.0 kg/s — Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit: 0.0 mg/s
Utilization factor: 0.13 0-1 — Share of heat and other emissions that are deposited in zone

Object
Name: Dish Washer
Description: 1050 W



Graph 33: 1h 25 min on Wednesday and Sunday.

- Refrigerator and freezer.



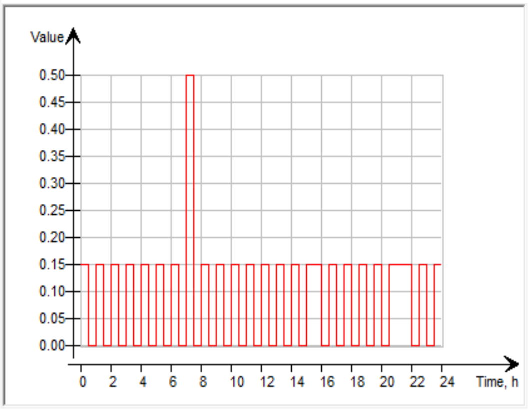
Number of units	1		
Schedule	Refrigerator Schedule		[* Schedule smoothing applied. Change in System parameters]
Emitted heat per unit Only this consumes energy	200	W	
Energy carrier	Electricity		
Energy meter	[Default] Equipment, tenant		

Advanced

Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.4	0-1	Share of heat and other emissions that are deposited in zone

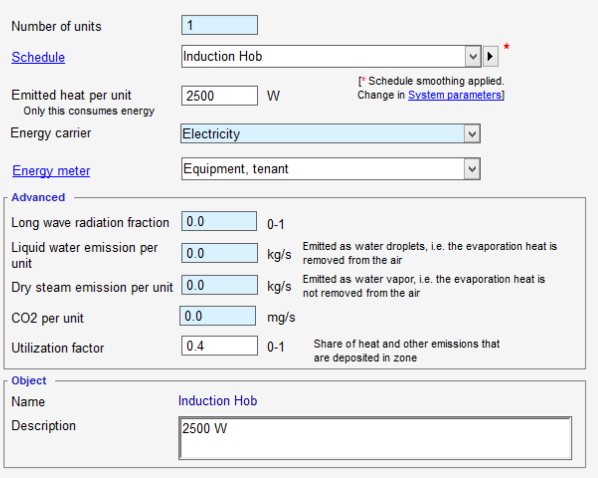
Object

Name	Refrigerator and Freezer
Description	200W



Graph 34: Turn and off of the refrigerator and freezer.

- Induction Hob.



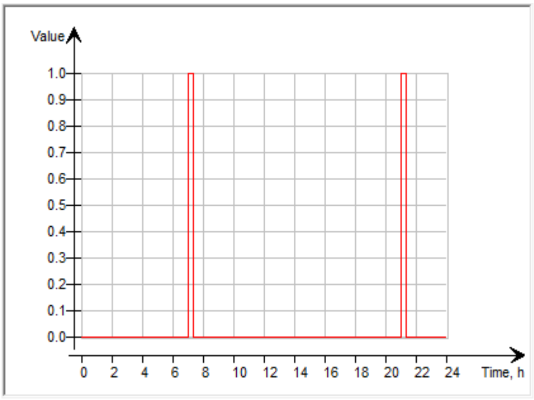
Number of units	1		
Schedule	Induction Hob		[* Schedule smoothing applied. Change in System parameters]
Emitted heat per unit Only this consumes energy	2500	W	
Energy carrier	Electricity		
Energy meter	Equipment, tenant		

Advanced

Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.4	0-1	Share of heat and other emissions that are deposited in zone

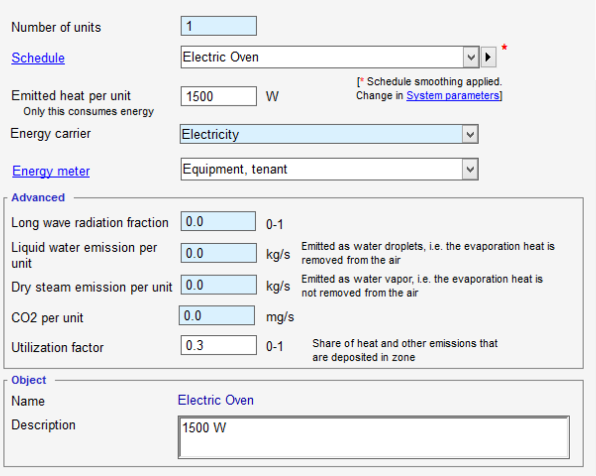
Object

Name	Induction Hob
Description	2500 W



Graph 35: 45 mins per day.

- Electric Oven.



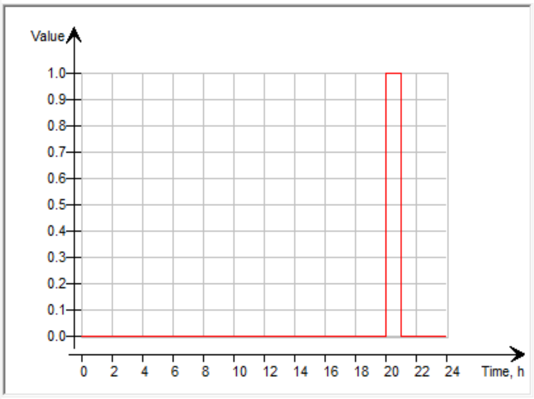
Number of units	1		
Schedule	Electric Oven		[* Schedule smoothing applied. Change in System parameters]
Emitted heat per unit Only this consumes energy	1500	W	
Energy carrier	Electricity		
Energy meter	Equipment, tenant		

Advanced

Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.3	0-1	Share of heat and other emissions that are deposited in zone

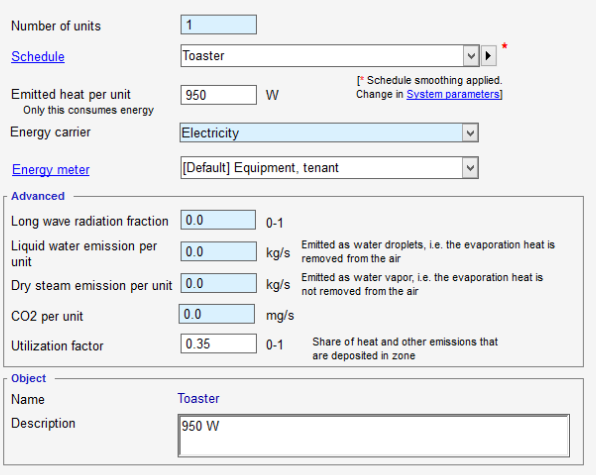
Object

Name	Electric Oven
Description	1500 W



Graph 36: 1h per day.

- Toaster.



Number of units: 1

Schedule: Toaster *

[* Schedule smoothing applied. Change in System parameters]

Emitted heat per unit (Only this consumes energy): 950 W

Energy carrier: Electricity

Energy meter: [Default] Equipment, tenant

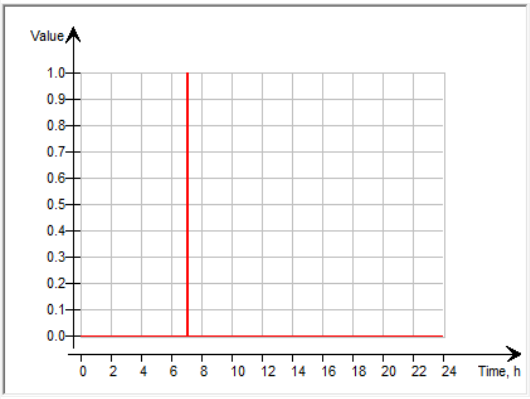
Advanced

Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.35	0-1	Share of heat and other emissions that are deposited in zone

Object

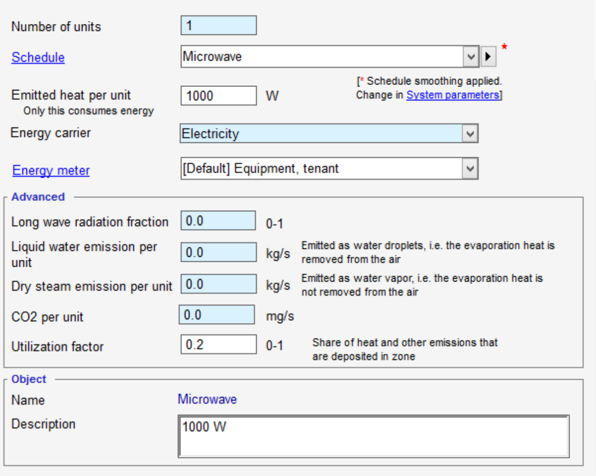
Name: Toaster

Description: 950 W



Graph 37: 6 mins per day.

- Microwave.



Number of units: 1

Schedule: Microwave *

[* Schedule smoothing applied. Change in System parameters]

Emitted heat per unit (Only this consumes energy): 1000 W

Energy carrier: Electricity

Energy meter: [Default] Equipment, tenant

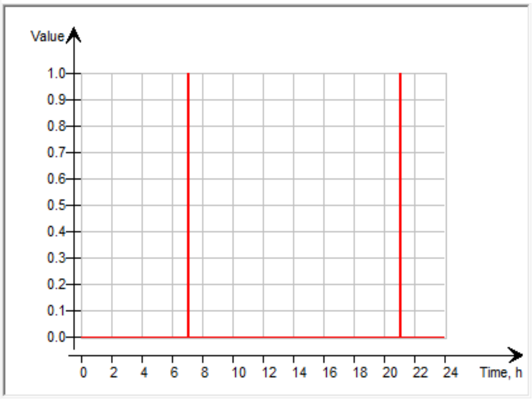
Advanced

Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.2	0-1	Share of heat and other emissions that are deposited in zone

Object

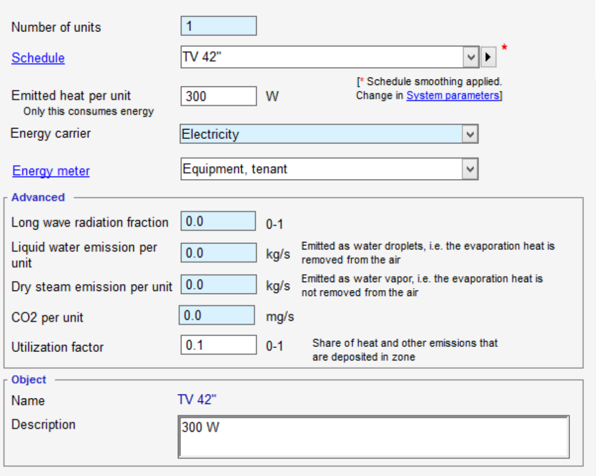
Name: Microwave

Description: 1000 W



Graph 38: 12 mins per day.

- TV 42’’



Number of units: 1

Schedule: TV 42" *

[* Schedule smoothing applied. Change in System parameters]

Emitted heat per unit (Only this consumes energy): 300 W

Energy carrier: Electricity

Energy meter: Equipment, tenant

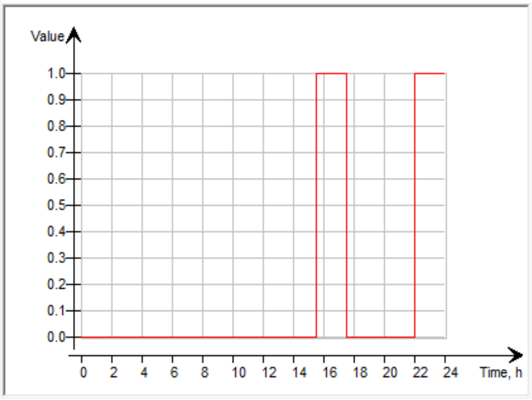
Advanced

Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.1	0-1	Share of heat and other emissions that are deposited in zone

Object

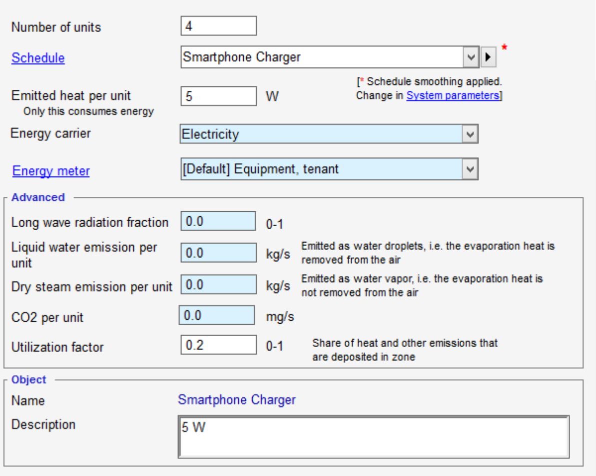
Name: TV 42"

Description: 300 W

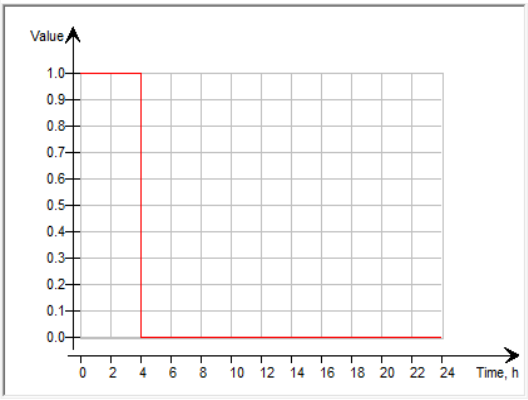


Graph 39: 3h per day.

➢ Smartphone Charger.



Number of units	4		
Schedule	Smartphone Charger *		
			[* Schedule smoothing applied. Change in System parameters]
Emitted heat per unit Only this consumes energy	5	W	
Energy carrier	Electricity		
Energy meter	[Default] Equipment, tenant		
Advanced			
Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.2	0-1	Share of heat and other emissions that are deposited in zone
Object			
Name	Smartphone Charger		
Description	5 W		

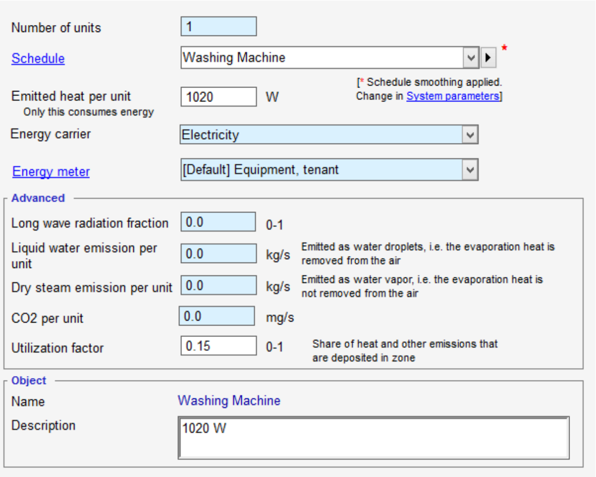


Graph 40: 4h per day.

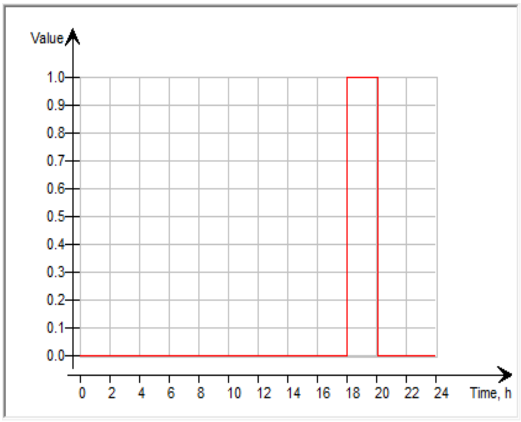
✓ Laundry room.

The electrical appliances, which are installed in the laundry room as internal gains, are:

➢ Washing Machine.

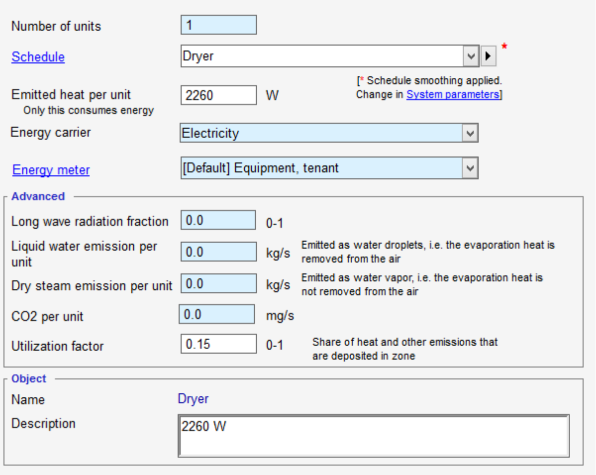


Number of units	1		
Schedule	Washing Machine *		
			[* Schedule smoothing applied. Change in System parameters]
Emitted heat per unit Only this consumes energy	1020	W	
Energy carrier	Electricity		
Energy meter	[Default] Equipment, tenant		
Advanced			
Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.15	0-1	Share of heat and other emissions that are deposited in zone
Object			
Name	Washing Machine		
Description	1020 W		



Graph 41: 2h 6 mins on Wednesday and Sunday.

- Dryer.


Number of units: 1

Schedule: Dryer *

[* Schedule smoothing applied. Change in System parameters]

Emitted heat per unit: 2260 W
Only this consumes energy

Energy carrier: Electricity

Energy meter: [Default] Equipment, tenant

Advanced

Long wave radiation fraction: 0.0 0-1

Liquid water emission per unit: 0.0 kg/s Emitted as water droplets, i.e. the evaporation heat is removed from the air

Dry steam emission per unit: 0.0 kg/s Emitted as water vapor, i.e. the evaporation heat is not removed from the air

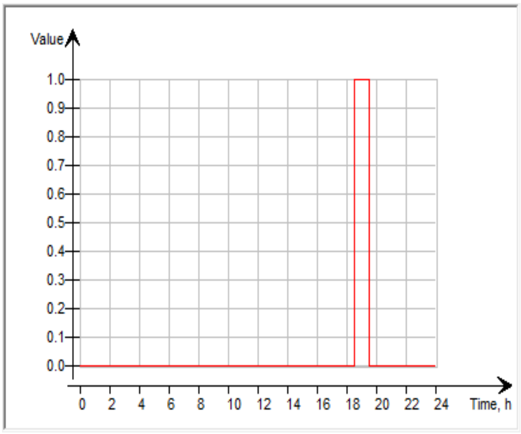
CO2 per unit: 0.0 mg/s

Utilization factor: 0.15 0-1 Share of heat and other emissions that are deposited in zone

Object

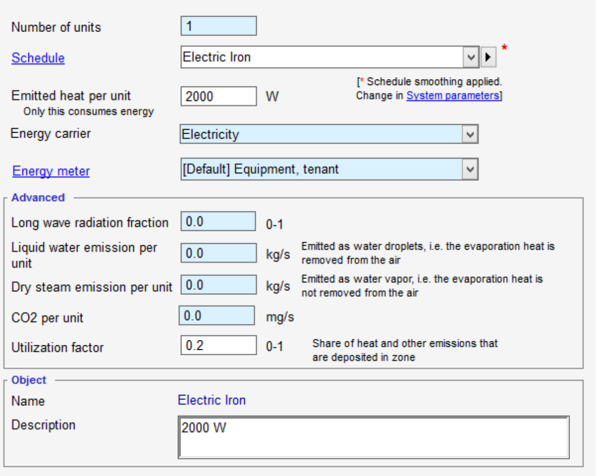
Name: Dryer

Description: 2260 W



Graph 42: 1h on Wednesday and Sunday.

- Electric Iron.


Number of units: 1

Schedule: Electric Iron *

[* Schedule smoothing applied. Change in System parameters]

Emitted heat per unit: 2000 W
Only this consumes energy

Energy carrier: Electricity

Energy meter: [Default] Equipment, tenant

Advanced

Long wave radiation fraction: 0.0 0-1

Liquid water emission per unit: 0.0 kg/s Emitted as water droplets, i.e. the evaporation heat is removed from the air

Dry steam emission per unit: 0.0 kg/s Emitted as water vapor, i.e. the evaporation heat is not removed from the air

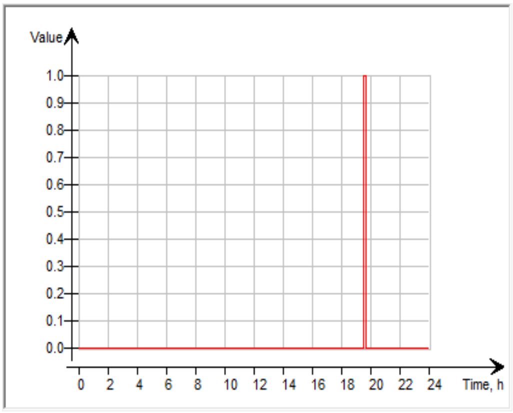
CO2 per unit: 0.0 mg/s

Utilization factor: 0.2 0-1 Share of heat and other emissions that are deposited in zone

Object

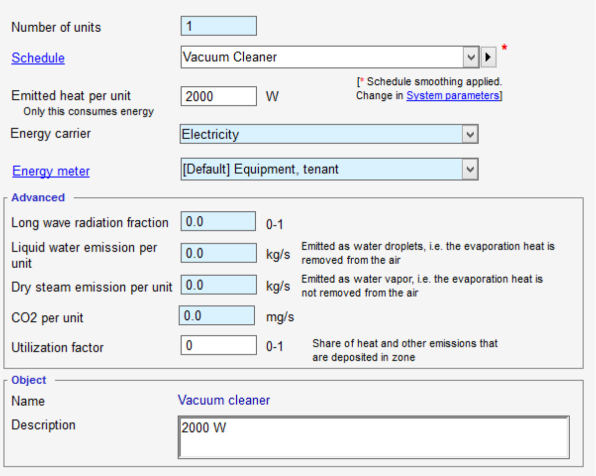
Name: Electric Iron

Description: 2000 W



Graph 43: 12 mins per day on Wednesday and Sunday.

- Vacuum Cleaner.


Number of units: 1

Schedule: Vacuum Cleaner *

[* Schedule smoothing applied. Change in System parameters]

Emitted heat per unit: 2000 W
Only this consumes energy

Energy carrier: Electricity

Energy meter: [Default] Equipment, tenant

Advanced

Long wave radiation fraction: 0.0 0-1

Liquid water emission per unit: 0.0 kg/s Emitted as water droplets, i.e. the evaporation heat is removed from the air

Dry steam emission per unit: 0.0 kg/s Emitted as water vapor, i.e. the evaporation heat is not removed from the air

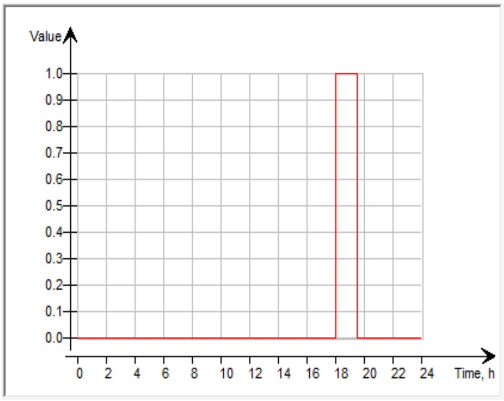
CO2 per unit: 0.0 mg/s

Utilization factor: 0 0-1 Share of heat and other emissions that are deposited in zone

Object

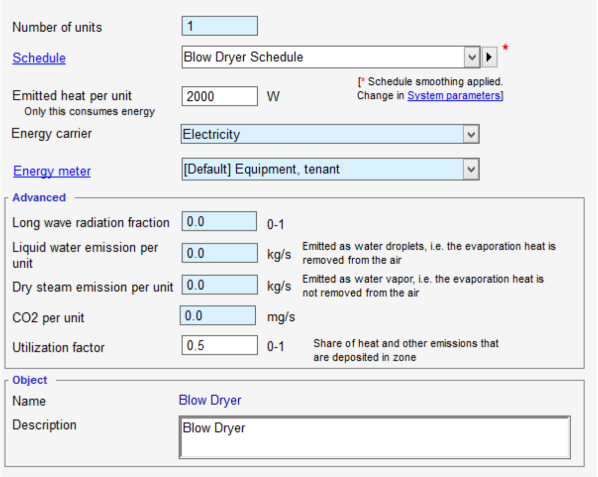
Name: Vacuum cleaner

Description: 2000 W



Graph 44: 1h 30 mins on Saturday.

- ✓ Bathroom.
  - ➢ Blow Dryer.



Number of units: 1

Schedule: Blow Dryer Schedule *

[* Schedule smoothing applied. Change in System parameters]

Emitted heat per unit (Only this consumes energy): 2000 W

Energy carrier: Electricity

Energy meter: [Default] Equipment, tenant

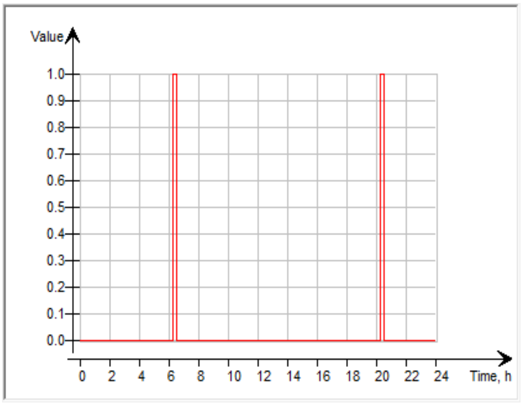
Advanced

Long wave radiation fraction	0.0	0-1	
Liquid water emission per unit	0.0	kg/s	Emitted as water droplets, i.e. the evaporation heat is removed from the air
Dry steam emission per unit	0.0	kg/s	Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit	0.0	mg/s	
Utilization factor	0.5	0-1	Share of heat and other emissions that are deposited in zone

Object

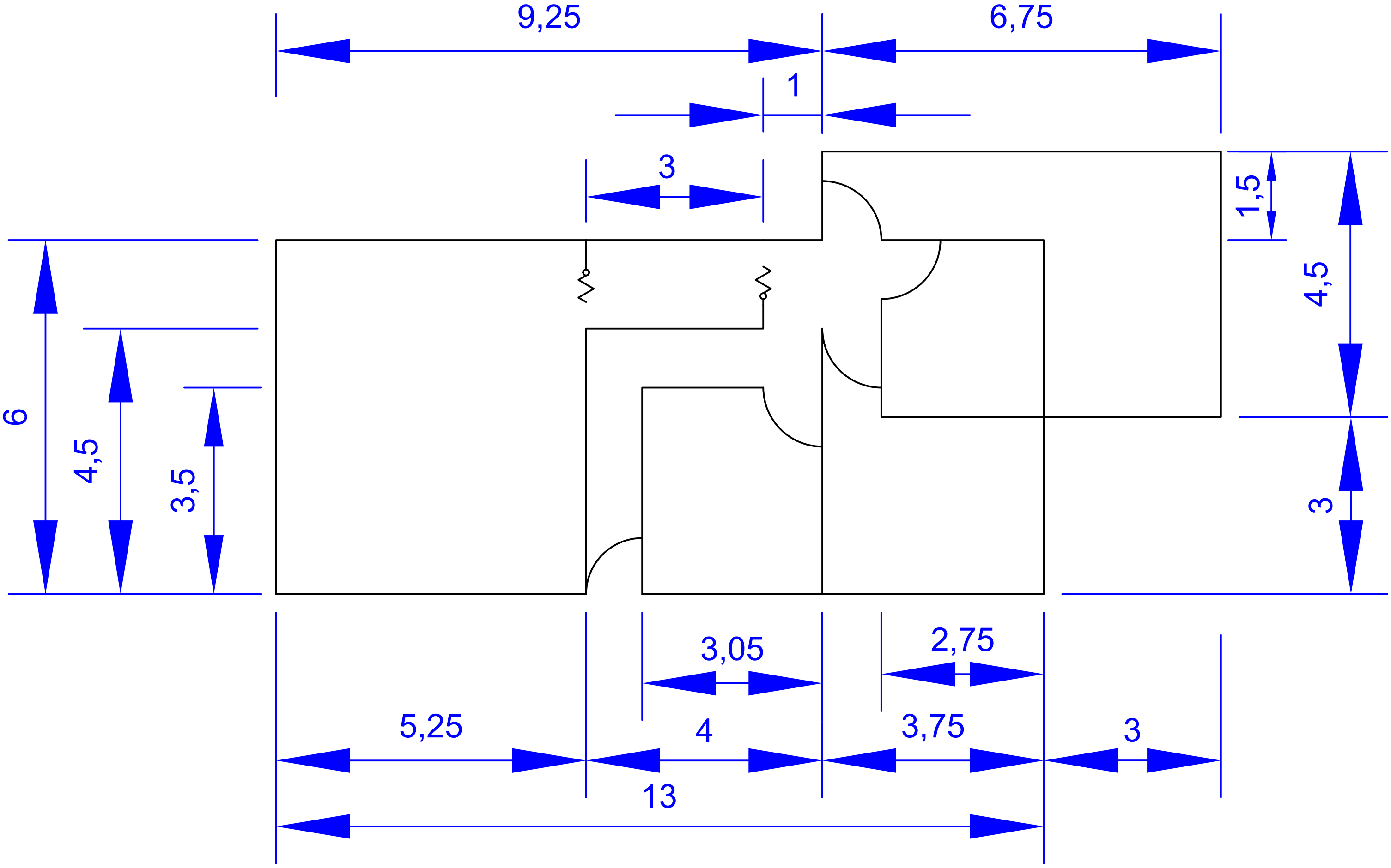
Name: Blow Dryer

Description: Blow Dryer



Graph 45: 30 mins per day.

ANNEX 7: DRAWING OF THE NZEB.


9,25
6,75
1
3
1,5
4,5
6
4,5
3,5
3
3,05
2,75
5,25
4
3,75
3
13