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Sun coupled innovative Heat pumps

D6.1 – Report on baseline and boundary conditions of SunHorizon demo sites, including monitoring aspects

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Participants: RINA-C, CEA, SE, BH, ITAE, CARTIF, AJSCV, GRE, BDR, VEO, RTU, EMVS

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Executive summary

The current D6.1 report[1] about T6.1 activities is aiming to gather relevant information from the 8 demo sites visit and available historical data to feed appropriate inputs in TRNSYS modelling task 2.4 and detailed engineering of the demo sites in following Task6.2.

SunHorizon participants are elaborating technology packages to be deployed during "WP6 Demonstration" in the 8 demo sites across Europe, to meet the requirements related to the different climatic conditions and different building typologies. The organisation of the partners according to their roles in every demo site demonstration work referred as T6.1.x has been regularly updated since the beginning of the project.

For each of the 8 demo sites managed in SunHorizon, the T6.1 work focuses on the analysis by simulation/support partners of the data collected by every demo responsible during T2.1. The main objectives are:

- to extract and to summarize the relevant information for the building and energy system modelling in T2.4 (moderate level of detail for overall energy assessment), relying on the KPI definition in parallel in T2.3 (D2.4 report),
- to help the technology manufacturing partners to understand the boundary conditions of existing heating/cooling system for the partial or full scope of the Technology Package (TP) new system to be deployed in the building,
- to highlight any specific technical, economical, regulatory requirement that the TPs have to face

The D6.1 report illustrates the main activities followed by each T6.1.x demo group during this task T6.1 until delivery of the current D6.1 report at M18. In parallel to WP4 work related to on-site TP Monitoring, a sketch of the monitoring to be installed along the TPs at M24 was issued by the 8 groups during T6.1.x time since it has to be performed during the general preliminary definition phase of the project. This preliminary monitoring plan will be refined further with Schneider Electric as monitoring solutions suppliers during the next T6.2 detailed engineering phase lead by RINA.

The 8 demo specific sections of D6.1 report contain: a general description of the demo case, local weather characteristics, building geometry, building use and occupants, existing heating and cooling systems, specific requirements for the coming TP integration in the building, preliminary monitoring plan.

The crosswork performed in task T6.1 and T2.4 allowed to draw such energy baseline for the 8 SunHorizon demo cases. It was required to design and size the components of TP1-4, including the control, prior the detailed engineering in the T6.2 next phase of the demonstration. The conclusion shows an overview of the key aspects of the 8 demo cases from T2.4 building energy baseline simulation work. It emphasizes that the demo case groups working in parallel had to consider very different integration constraints (single family to multi-apartment buildings or type of building's use like swimming pool, sport center, civic center, or variations in envelope's renovation level, or variations in availability of the monitoring data details). Some demo cases show already good energy efficiency performance level for the envelope (range 32-250 kWh/m² in space heating) or the primary energy consumed by the existing heating / cooling system (range 100-495 kWh/m² as whole non-renewable primary energy demand) or both while others shows poor ones. The report highlights also different system boundaries when including the specific electricity consumption of the whole building for the evaluation of the TP2 and TP4 with PV electricity production or only the electricity consumed by the DHW / heating / cooling system for the evaluation of the TP1 and TP3 with renewable solar thermal production.

[1] DTS/LV/2020/050

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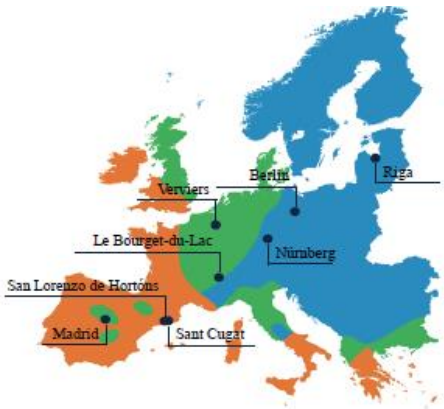
1 Introduction

The technology packages are elaborated by the SunHorizon participants to be deployed during "WP6 Demonstration" in the 8 demo sites across Europe as summarized in the Figure 1. The organisation of the partners according to their roles in every demo site demonstration work has been regularly updated since the beginning of the project and status is summarized in Table 1.



N°	Location	Resp.	Technology Packages Solar, HP, TES, MON, UI
1	Bayreuth (Germany)	BH	TP1: TVP, BH, RATIO, SE, CW
2	Nurnberg (Germany)	BH	TP2: DS, BH, RATIO, SE, CW
3	Saint Cugat (Spain), AJSCV	VEO	TP3: TVP, FAHR, RATIO, SE, CW
4	Madrid (Spain), EMVS	VEO	TP4: DS, BDR, RATIO, SE, CW
5	San Lorenzo de Hortons (Spain)	BDR	TP4: BDR,BDR,BDR, SE, CW
6	Verviers Sport Centre (Belgium)	GRE	TP1: TVP, BH, RATIO, SE, CW
7	Verviers Swimming Pool (Belgium)	GRE	TP2: DS, BH, RATIO, SE, CW
8	Riga (Latvia)	RTU	2x TP2: DS, BH, RATIO, SE, CW

Figure 1: overview of the 8 SunHorizon demonstration cases

For each of the 8 demo sites managed in Sunhorizon, the T6.1 work focuses on the analysis by simulation/support partners of the data collected by every demo responsible during T2.1. The main objectives are:

- to extract and to summarize the relevant information for the building and energy system modelling in T2.4 (moderate level of detail for overall energy assessment), relying on the KPI definition in parallel in T2.3 (D2.3 report),
- to help the technology manufacturing partners to understand the boundary conditions of existing heating/cooling system for the partial or full scope of the Technology Package (TP) new system to be deployed in the building,
- to highlight specific technical, economical, regulatory requirements that the TPs have to face

Figure 2 illustrates the main activities followed by each T6.1.x demo group during this task T6.1 until delivery of the current D6.1 report at M18. In parallel to WP4 work related to on-site TP Monitoring, a sketch of the monitoring to be installed along the TPs at M24 was issued by the 8 groups during T6.1.x time, since it has to be performed during the general preliminary definition phase of the project. This preliminary monitoring plan will be refined further with Schneider Electric as monitoring solutions suppliers during the next T6.2 detailed engineering phase lead by RINA-C.

The following 2-9 sections are summarizing these energy baseline contents for the 8 demo cases following similar perspectives: general description of the demo case, local weather characteristics, building geometry, building use and occupants, existing heating and cooling systems, specific requirements for the coming TP integration in the building, preliminary monitoring plan.

Table 1: distribution of the generic roles among the partners in relation with each specific demo case

	demo 1	demo 2	demo 3	demo 4	demo 5	demo 6	demo 7	demo 8
Participants location	Berlin	Nurnberg	Sant Cugat	Madrid	San Lorenço	Verviers Sport Center	Verviers Swimming pool	2 separate houses: Sunisi (8a) – Imanta(8b)
Resp in Sunhorizon	**BH: Steven Paupe**	**BH: Steven Paupe**	**VEO : Silvia Jane**	**VEO : Silvia Jane**	**BDR: Elise Betchold, Pierre Koenig**	**GRE Thibault VANDERHAUWART**	**GRE Thibault VANDERHAUWART**	**RTU Zane Broka, Jevgenijs Kozadajevs**
Owner :	**-**	-	AJSCV: Victor Martinez, Pau Asens	EMVS Diego Romera, Daniel Morcillo	-	Verviers Municipality – Yvon Hardouin	Verviers Municipality - Yvon Hardouin	-
Local technical team	BH : Norbert DISCHINGER	BH : Norbert DISCHINGER	-	-	-	Verviers Municipality – Yvon Hardouin	Verviers Municipality – Yvon Hardouin	-
General support analysis, simulation, control	CEA, David Chèze	CEA Joël Wyttenbach	CNR ITAE Andrea Frazzica, Guiseppe Dino / CARTIF Andrea Gabaldon / IES G. Tardioli	CARTIF Manuel Andres Chicote, Andrea Gabaldon	CEA Antoine Leconte	CARTIF Manuel Andres Chicote , Andrea Gabaldon	CARTIF Manuel Andres Chicote, Andrea Gabaldon	RINA Silvia Vela (8a Imanta)/ (8b Sunisi)/ Carlo Maccio, Matteo Porta (simulation 8a-b)
Superv support methodology, KPIs	RINA Alessandra Cuneo	RINA Alessandra Cuneo	RINA Alessandra Cuneo	RINA Alessandra Cuneo	RINA Alessandra Cuneo	RINA Alessandra Cuneo	RINA Alessandra Cuneo	RINA Alessandra Cuneo
SOL supply/integration	TVP Marco Scarpellino, Guglielmo Cioni	DS Laetitia Brottier, Jean-Marie Drap	TVP Marco Scarpellino, Guglielmo Cioni	DS Laetitia Brottier, Jean-Marie Drap	BDR Elise Betchold, Pierre Koenig	TVP Marco Scarpellino, Guglielmo Cioni	DS Laetitia Brottier, Jean-Marie Drap	DS Laetitia Brottier, Jean-Marie Drap
HP supply/integration	BH : Guillaume Aniès	BH : Guillaume Aniès	FAHR Bashir Kanawati	BDR Pierre Koenig	BDR Elise Betchold, Pierre Koenig	BH : Guillaume Aniès	BH : Guillaume Aniès	BH : Guillaume Aniès
TES supply/integration	RATIO Julian Krucks/ Thomas Lechner	RATIO Julian Krucks/ Thomas Lechner	RATIO Julian Krucks/ Thomas Lechner	RATIO Julian Krucks/ Thomas Lechner	RATIO Julian Krucks/ Thomas Lechner	RATIO Julian Krucks/ Thomas Lechner	RATIO Julian Krucks/ Thomas Lechner	RATIO Julian Krucks/ Thomas Lechner
MON supply/integration	SE Luiza Bentivoglio, Francesco Martinelli	SE Luiza Bentivoglio, Francesco Martinelli	SE Luiza Bentivoglio, Francesco Martinelli	SE Luiza Bentivoglio, Francesco Martinelli	SE Luiza Bentivoglio, Francesco Martinelli	SE Luiza Bentivoglio, Francesco Martinelli	SE Luiza Bentivoglio, Francesco Martinelli	SE Luiza Bentivoglio, Francesco Martinelli
UI supply/integration	CW Dan-Eric Archer, Vivian Esquivias	CW Dan-Eric Archer, Vivian Esquivias	CW Dan-Eric Archer, Vivian Esquivias	CW Dan-Eric Archer, Vivian Esquivias	CW Dan-Eric Archer, Vivian Esquivias	CW Dan-Eric Archer, Vivian Esquivias	CW Dan-Eric Archer, Vivian Esquivias	CW Dan-Eric Archer, Vivian Esquivias

			2019											2020			
T6.1.x	**demo resp.**	**Baseline and Site boundary conditions**	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
		SunHorizon timeline	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		Energetic system requirements																
	sim/supp	Collected data analysis and summary																
	demo resp.	Missing information management																
	demo resp.	Building, users, specific requirements to TPs																
	demo resp.	preliminary monitoring plan																
		Report writing																
	task leader CEA	draft ToC with sections resp.																
	demo resp.	inputs collection and overall management														D6.1.x		
	task leader CEA	inputs merge and general sections writing															D6.1	

Figure 2: T6.1 main subtasks and timeline

2 Berlin demo site #1

The #1 Berlin demo site is actually a house located Deviertweg 14, in Berlin (12207), in Germany. It's an old building from the beginning of the XX century renovated in 2006 as illustrated by Figure 3 and Figure 4. The building is composed of three floors (284m²), split into 2 apartments occupied by 4 and 3 people typically. In the basement, two separate gas boilers provide space heating and DHW for the two separate apartments. The existing 4 m² solar thermal panels installed on the roof are supporting the DHW supply for the upper apartment only.

Figure 3: north façade view from the main street (left) – south façade view from garden in the backyard

Figure 4:view of the south facing roof with existing solar thermal panels

2.1 Local weather characteristics

The closest weather station from the demo site (red bullet close to Lichterfeld) are Berlin-Dahlem and Berlin-Tempelhof as yellow-highlighted in the Figure 5.

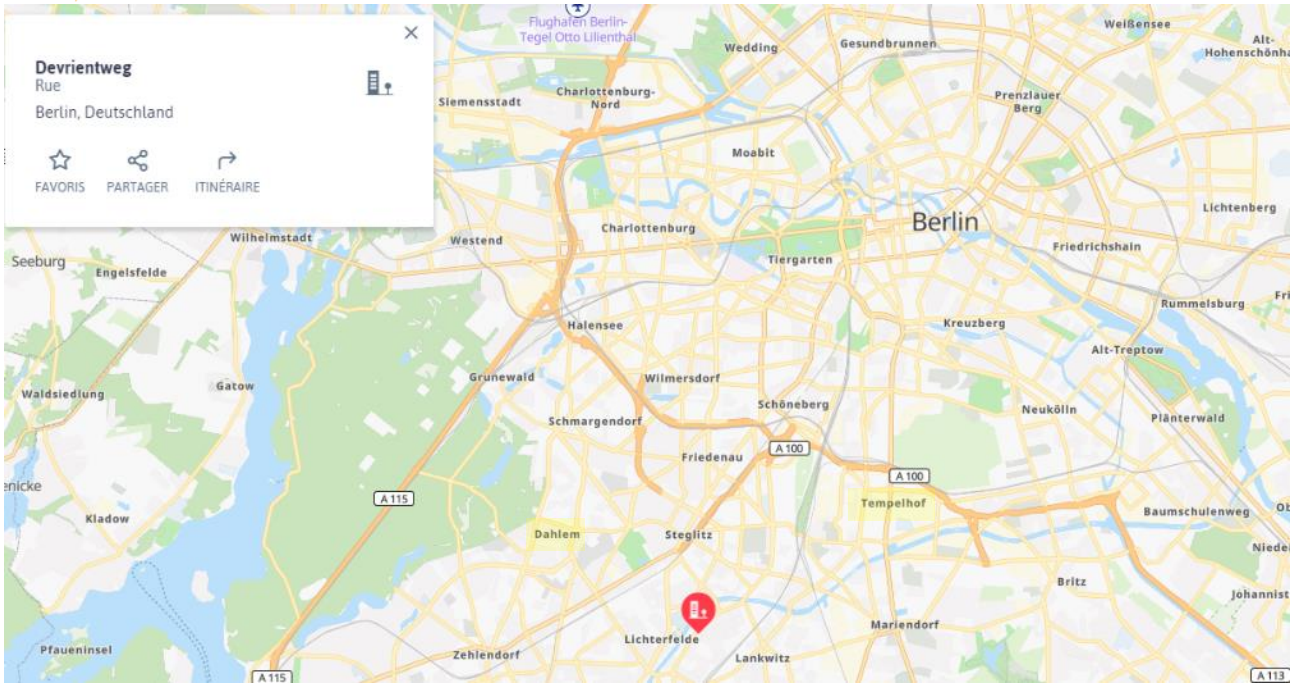


Figure 5 : closest weather stations to the Berlin demo site

On the website https://www.infoclimat.fr/climatologie/annee/2015/berlin-dahlem/valeurs/10381.html, we found historical monthly datasets until 2015 for Berlin Dalhem close weather station and give an outlook and qualitative representation of the variations over the past three decades in Figure 6 and Figure 7. For the TRNSYS simulation we need higher time resolution datasets and the closest standard meteonorm (typical weather synthetic data, not simple average of the historical data) weather station found is Berlin Tempelhof, nearly as close as Dahlem from the demo case place.

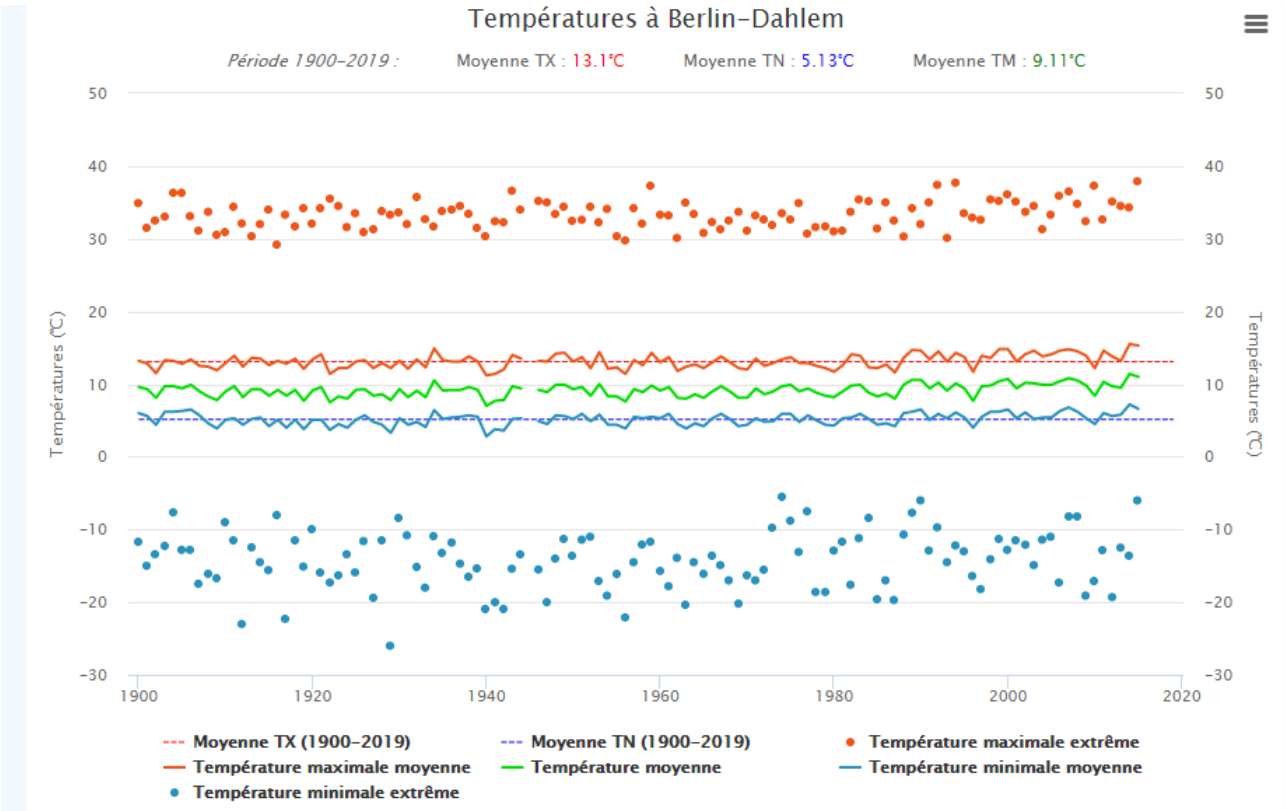


Figure 6: overview of Berlin-Dahlem temperature

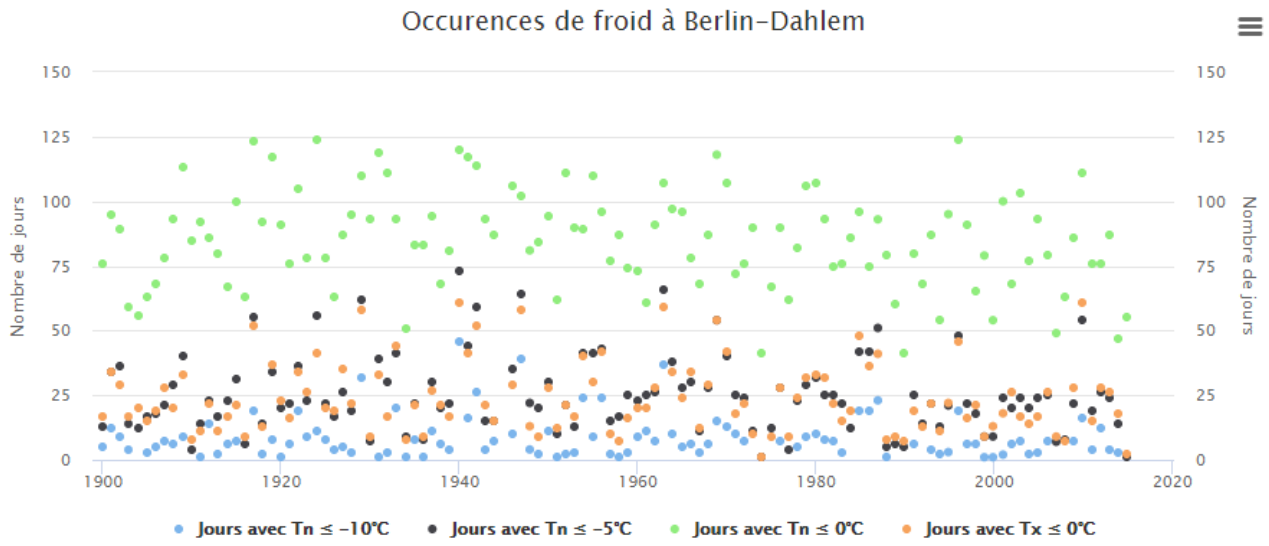


Figure 7: overview of Berlin-Dahlem cold days statistics

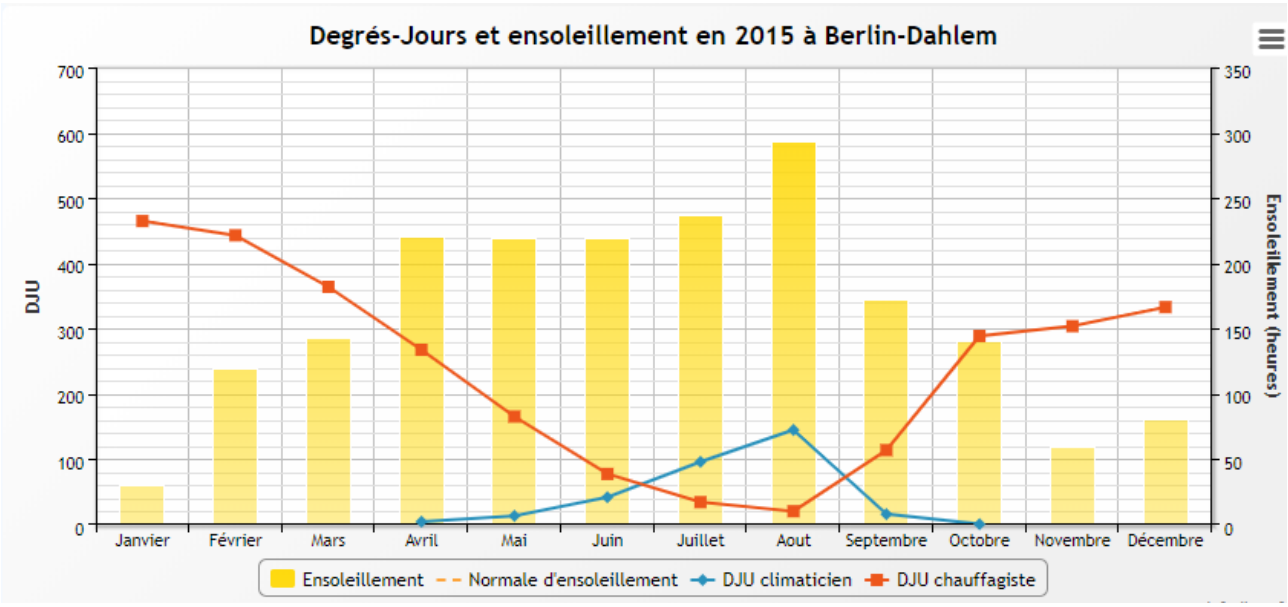


Figure 8: overview of Berlin-Dahlem heat demand and solar radiation resource

Figure 9 shows the Tempelhol standard Meteonorm dataset compared with the Dahlem monthly dataset of 2013. The view on the right compares the average, minimum and maximum outdoor air temperatures for both datasets and reveals acceptable agreement for each variable. The left view compares the sun hours measured in Dahlem 2013 dataset with the calculated value from Meteonorm Tempelhof station. Sun hours are accounted when the beam radiation on horizontal plane rises above 120 W/m². The deviation is significant during summer while acceptable during the heating season. Therefore, we conclude that the Meteonorm Tempelhof weather data is representing relevant weather conditions for the design of the new heating system. Additionally, this weather file is suitable to combine with building model in order to estimate the space heating load, the gas consumption with the existing heating system and to compare with the annual manual energy consumption records performed by the owner over the 2006-2018 period reported in 2.2. The figure is also indicating the total solar radiation falling on 1m² horizontal area; total amount reaches 1MWh/m².

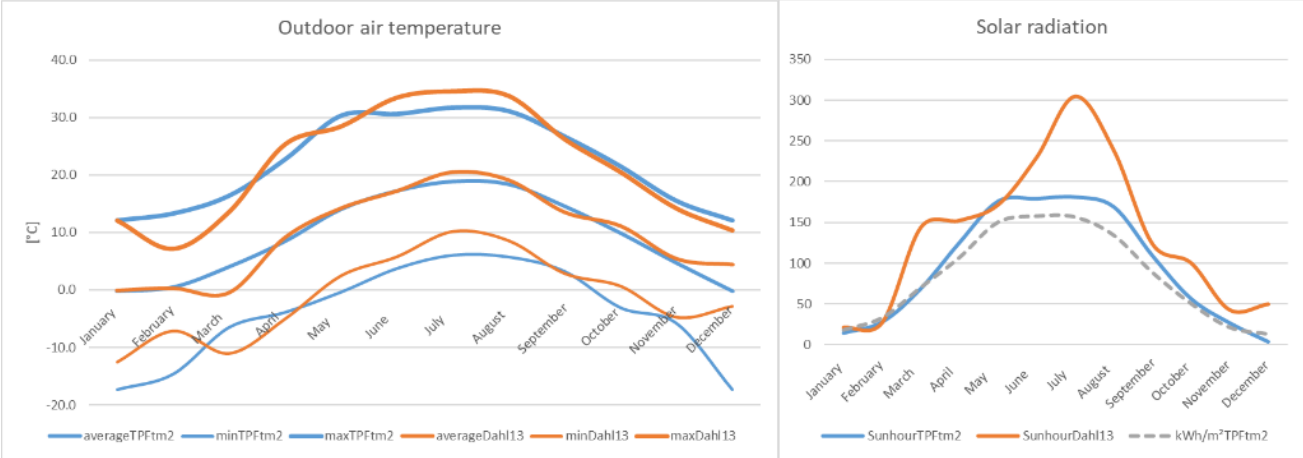


Figure 9: Comparison of two weather datasets for Berlin demo case

2.2 Building geometry and use

2.2.1 Summary of the demo site survey

As reported in D2.1, the survey performed in February 2019 allows to get drawings from the building renovation in 2006. From these drawings, overall geometry was sketched first as in Figure 10. The information was used to design a more detailed 3D model in T2.4 which main assumptions and results are also reported in 2.2.2. The demo site visit also provided manual annual meters records by the building's owner related to the gas, electricity and fresh water consumption reported below.

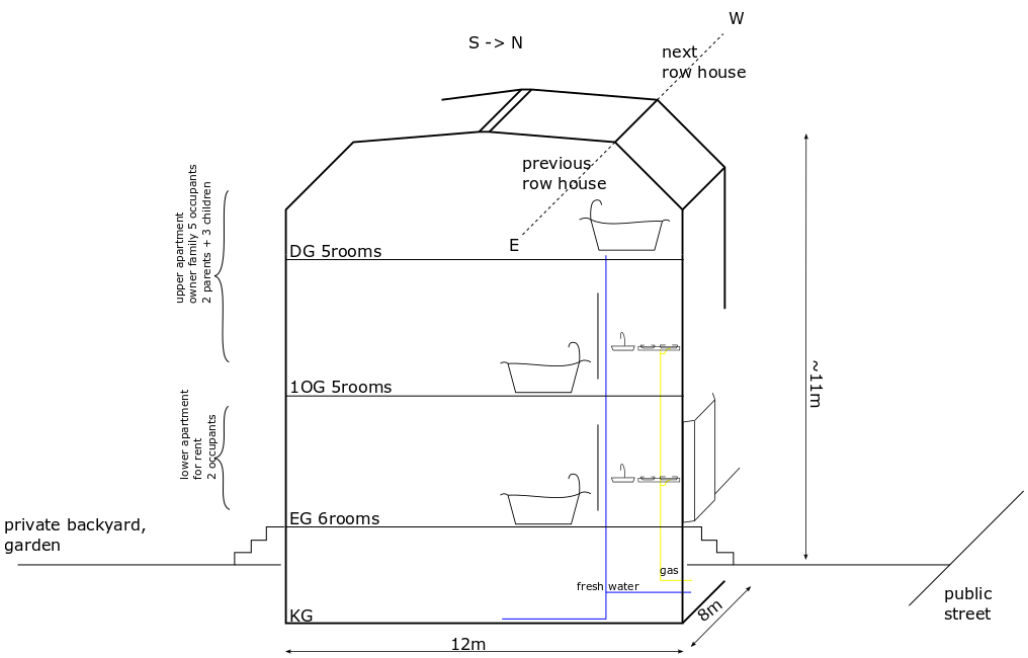


Figure 10 Overview of the #1 Berlin demo building dimensions

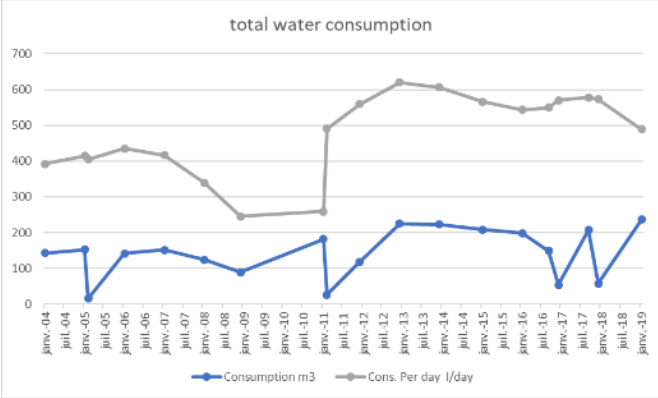


Figure 11 : annual fresh water consumption of the whole building

From Figure 11 derives the total cold water consumption about 500L/day. DHW consumption assumption for the design is commonly selected in the range 35-50L/day at 45°C. Considering two families, 7 people, are living in the two apartments of the building, this means DHW consumption in the range 250-350L/day. From Figure 12 derives that typical total gas consumption of the whole building is about 32MWh/year. From Figure 13, the typical electricity consumed by the whole buidling is about 4MWh.

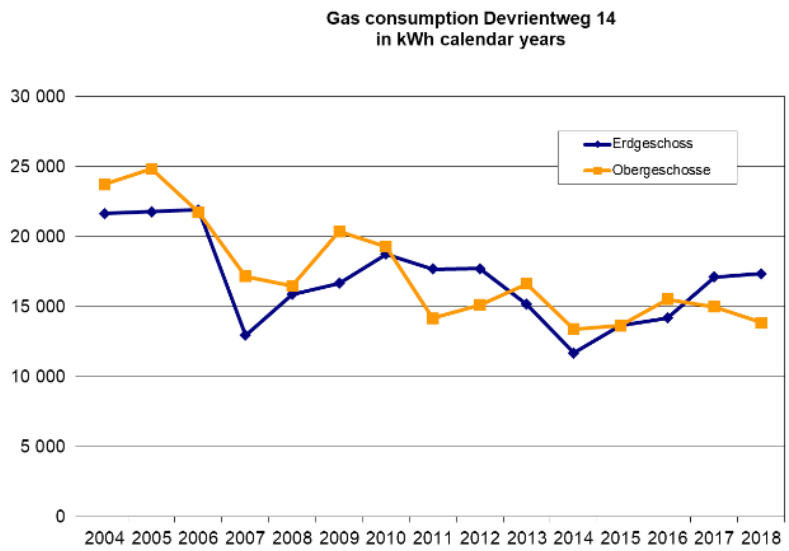


Figure 12: annual gas consumption of the two apartments

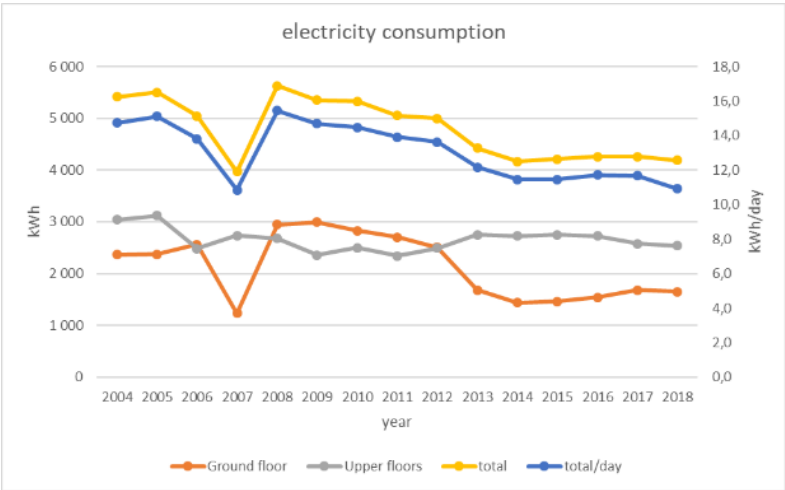


Figure 13: annual electricity consumption of the two apartments

2.2.2 Building model and baseline

From the analysis of data collected during the demo site survey ,Figure 14 shows an overview of this more accurate model of the building's real geometry (like roof or covered balcony details accounted), openings characteristics and walls compositions. It is used to calculate the reference figures for the final design and configurations to be deployed on-site.

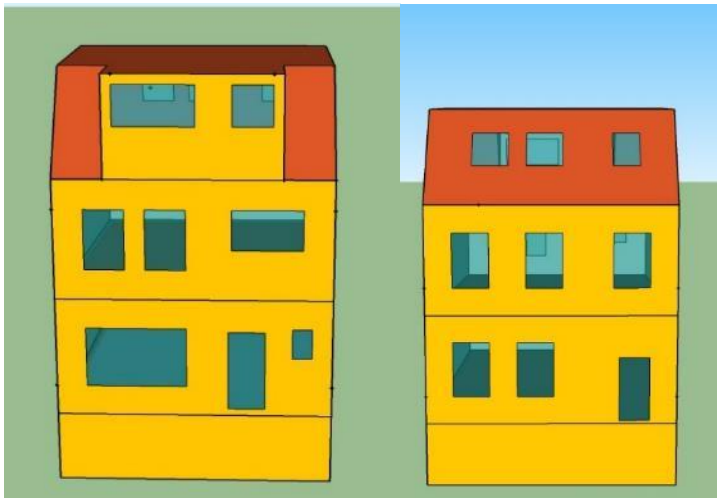


Figure 14: overview of north (left) and south (right) façades

Table 2: building energy demand summary

	QHEAT	max design heating rate
	kWh	W
ground	12511	5244
1st	7561	3895
2nd	4336	2725
tot	**24411**	**11864**

It defines 4 thermal zones as the cellar, the ground floor, the first floor and the second floor (attic). The model accounts ground temperature variations derived from the outdoor air temperature variation. The basement is not heated and half-underground; the East/West lateral walls are adiabatic. The reference total heated area is 284 m². The sunny façade is oriented S+ 30°W (right view in Figure 14).

The infiltration air change rate is adjusted from initial first guess 0.8 to 0.55 Vol/h, consistent with the renovated windows in 2006. Table 2 gives an overview of the heat demand for each zone and the 24.4MWh as annual heating demand. Without any information regarding people occupancy schedule, equipment, monitoring of the actual temperature distribution in the dwellings or consumption estimation of the wood stove in the ground floor apartment, constant internal heat gains are assumed as 60W/pers. and 7W/m² of reference heated area (2400W for the whole building). From Figure 15, we assume about 5660 hours actual heating demand to keep air temperature close to 20°C in the whole building which means about 13.6 MWh of extra heating demand in addition to the radiators space heating loop. Once deduced ~ 4-5 MWh heat gains from electricity, it means about 3 wood steres (4.5 kWh/kg).

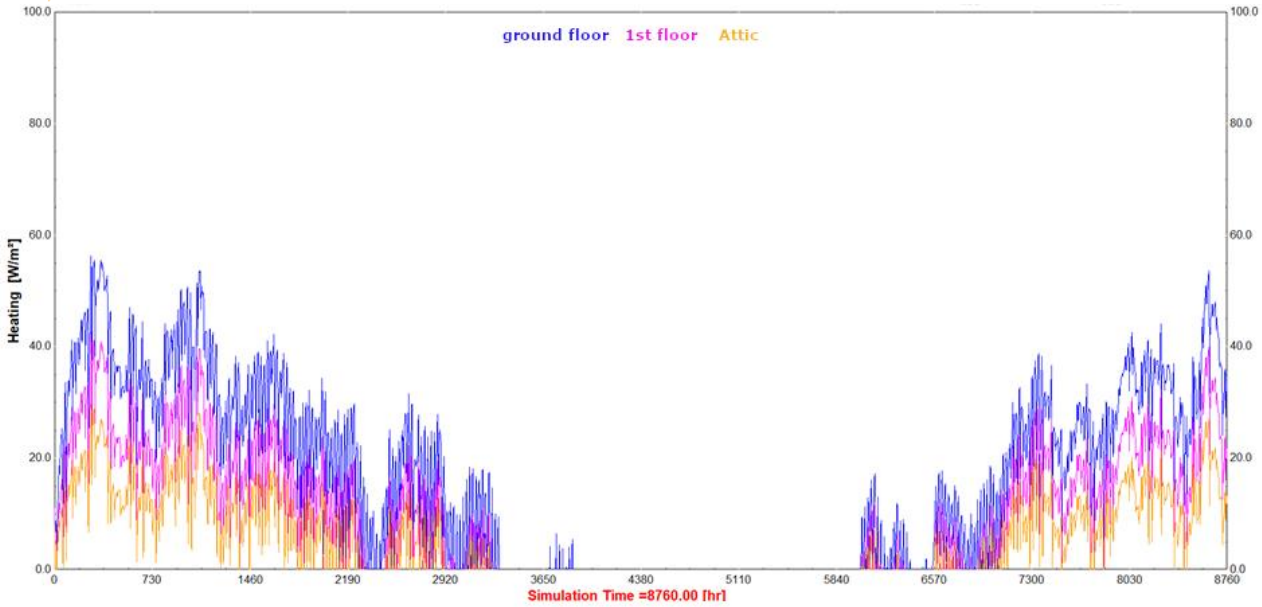


Figure 15: heating demand rate for Berlin adjusted building model

Figure 15 shows max heating rate from the radiator loop is 11.9 kW which is aligned with the BH20 variable capacity up to max 20 kW. At the maximum heating rate, the distribution is 44%, 33% and 23% for the ground, 1st and 2nd floors respectively. Consequently, the asymmetry between the floors leads to nearly the same heat consumption for the upper apartment (1st and 2nd floor) and for the ground floor apartment, uninsulated towards the unheated cellar. Indeed the annual simulation of the building to estimate the heating demand leads also to the temperature distribution represented in Figure 16 and it reveals that the cellar temperature (blue) dropped below 10°C most of the time during heating season while the heated zone remained close to 20°C set point.

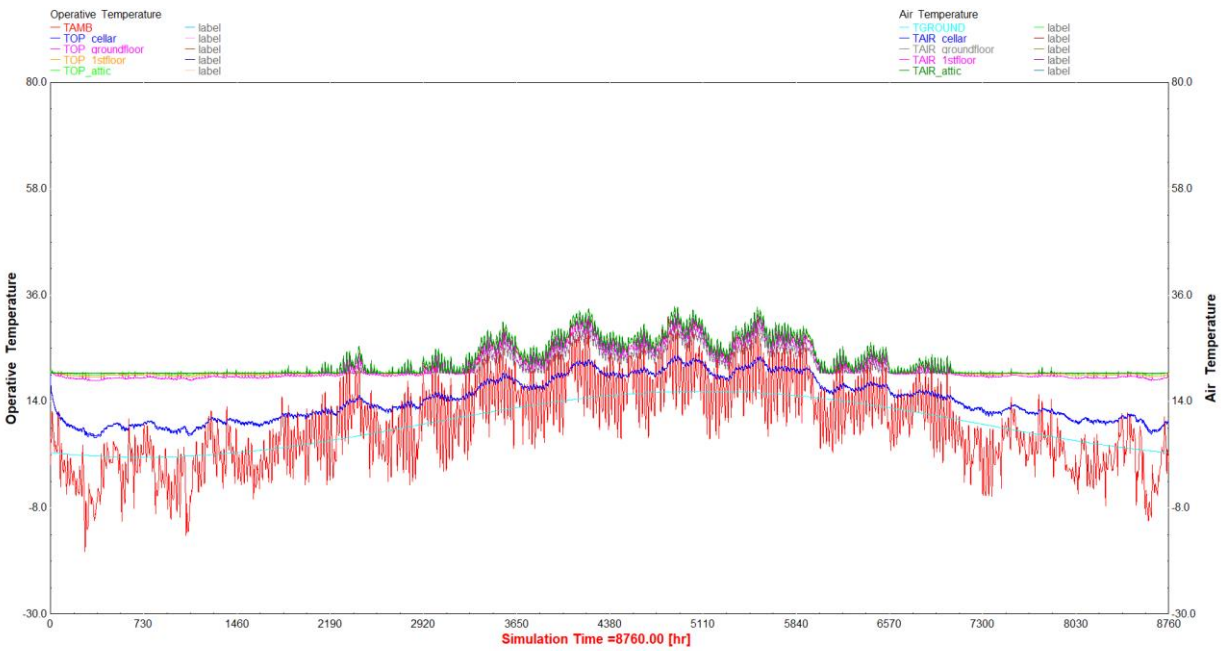


Figure 16 : temperature variations along the typical year for the 4 zones according to ambient and ground temperatures

2.3 Heating/cooling system with heat, cold and DHW distribution

From the energy demand perspective, special events in the building's life leaned from the survey:

- Solar thermal flat panels 2x2m² installed during summer 2006 (also the Brötje condensing gas boiler in upper apartment)
- End of building renovation in 2007
- Wood burning stove installed in 2013 (in lower floor)
- New tenant in the ground floor apartment in 2013, 2 months with no tenant
- More wood burned in January 2014 compared to previous and future years where it is used essentially for entertainment.

The heating curve from the survey is approximately 60°C flow temperature when -12°C outdoor temperature. Visitors also noticed thermostatic valves on every radiator to adapt to local users requirements (set position 3 on the valves). We supposed ~20°C requirements all the time for the rooms, for both lower and upper apartments.

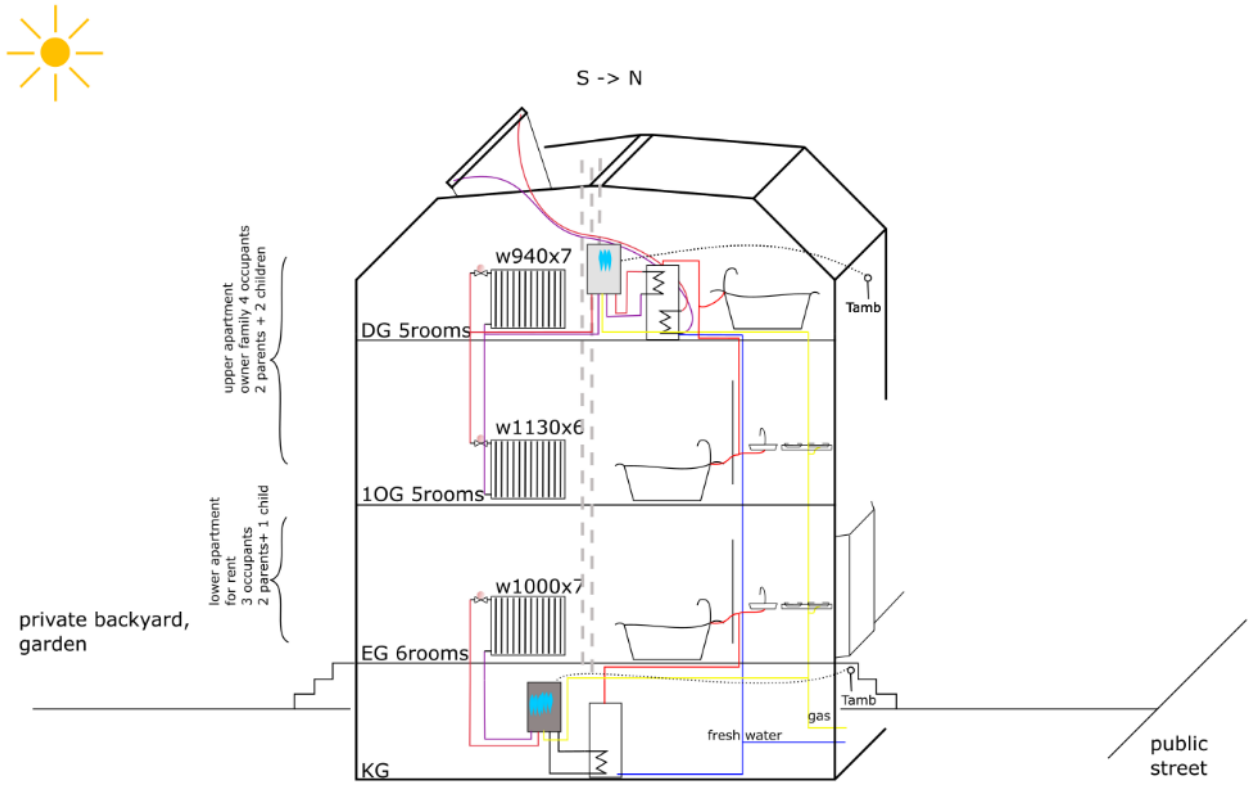


Figure 17: Overview of the existing heating system integrated in the building

From the 2.2.1, it is assumed a DHW consumption of 300L/day 45°C for 7 people in average along the year. A statistical DHW profiles generator[2] was used to generate a consistent annual subhourly DHW profile to run the simulations in T2.4. It leads to an estimated 4.4 MWh heat demand for DHW.

[2] Jordan, Ulrike, Klaus Vajen, and Universität Kassel. 2005. 'DHWcalc: PROGRAM TO GENERATE DOMESTIC HOT WATER PROFILES WITH STATISTICAL MEANS FOR USER DEFINED CONDITIONS'. In Proc. ISES Solar World Congress, 6. Orlando (US). http://www.solar.uni-kassel.de/sat_publikationen_pdf/2005%20ISES-SWC%20Jordan%20und%20Vajen%20Program%20to%20Generate%20Domestic%20Hot%20Water%20Profiles%20with%20Statistical%20Means%20for%20User%20Defined%20Conditions.pdf.

Assuming a reference gas condensing boiler annual efficiency[3] of 85% and 50% DHW load annual coverage by the solar DHW installation leads to (24.5+0.5*4.4 31.4)/0.85= 31.4 MWh gas consumption, aligned with 32 MWh, as average annual gas consumption in 2015-2018 period from Figure 12.

2.4 Specific requirements for the new heating/cooling system

In addition to the pure energy demand of the existing #1BERLIN building and its occupants which was summarized in the previous section, the new TP1 shall meet a few extra requirements regarding the location of the components in the building, the regulatory and economic frameworks where the components TVP solar panels, BOOSTHEAT gas burner and CO_2 heat pump, RATIOTHERM will be integrated:

- up to 14m² TVP LT solar collectors could be integrated on metallic frame foreseen on the south facing roof in replacement of 4m² existing ones. The chimneys outlets through the roof to be considered carefully when fastening the support to the roof. TVP LT solar panels are expected to outperform the former ones and to comply with the ISO9806.
- Admissible mechanical load (static and dynamic) on the roof up to 7 TVP solar panels (2m² each) : specific study ordered by Boostheat to evaluate if roof re-enforcement to be done on such historical building from early XXth century.
- Boostheat outdoor fan coil could be installed on the ground, aside the street, about 15 meters from the BH unit in the basement. The installation should also comply with the regulation regarding the noise emission, same as air source heat pump requirements from EN14511.
- in the technical room in the basement where is foreseen to install the RATIOTHERM tank(s) and indoor unit of Boostheat: free floor area ~ 15 m² available but limited height: 2 m
- The DHW use temperature is assumed at 45°C, while no DHW recycling loop request from the owner
- The expected room air temperature for user's comfort is 20°C.
- Separate energy (DHW, space heating, electricity) monitoring for ground floor and upper floors occupants to derive building's general costs breakdown
- The upgrade of heating system in private context for #1 BERLIN demo case doesn't require to apply for administrative permit neither for solar thermal collector integration on the roof nor for the gas heat pump. The maximum gas capacity of the Boostheat is 20kW lower than the existing 40kW gas burners installed therefore no change request to address to the local natural gas supplier. Since existing solar collectors already integrated on the roof and the new ones will be integrated following the same principles, there's no extra constraint to consider regarding neighbourhood rules apart from the mechanical support of the roof structure
- The performance tests performed on the TVP solar collectors, Boostheat thermal compression heat pump and Ratiotherm thermal storage and hydraulic package show higher rates than existing solar collectors

In the SunHorizon project, Major KPIs like PESnren, GHGsav and Cf fuel/energy costs are relying on following local constraints listed in Table 3, assumed conversion factors both for baseline and TP1 in BERLIN demo case calculations.

Table 3: conversion factors to consider in #1 BERLIN demo case

	PEFnren	PEFren	fGHG	Cf/Ef
Energy carrier:	-	-	gCO_2/kWh	€/kWh
Solar thermal	0	1	0	-
Environment Air	0	1	0	-
Gas	1,1	0	220	0.0608
Electricity	2,3	0,2	420	0.3

[3] Chèze, David, George Benett, Yu Li, Jean-Laurent Hyppolite, Carlo Macciò, Matteo Porta, Nicolas Lamaison, Federica Fuligni, Patrick James, and Andoni Anero. 2017. 'Heating and Cooling Technology Assessment Report'. THERMOSS task 3.1 Deliverable D3.1. THERMOSS project. https://thermoss.eu/download/deliverables/?wpdmdl=1215&ind=1536331629332.

2.5 Preliminary monitoring plan

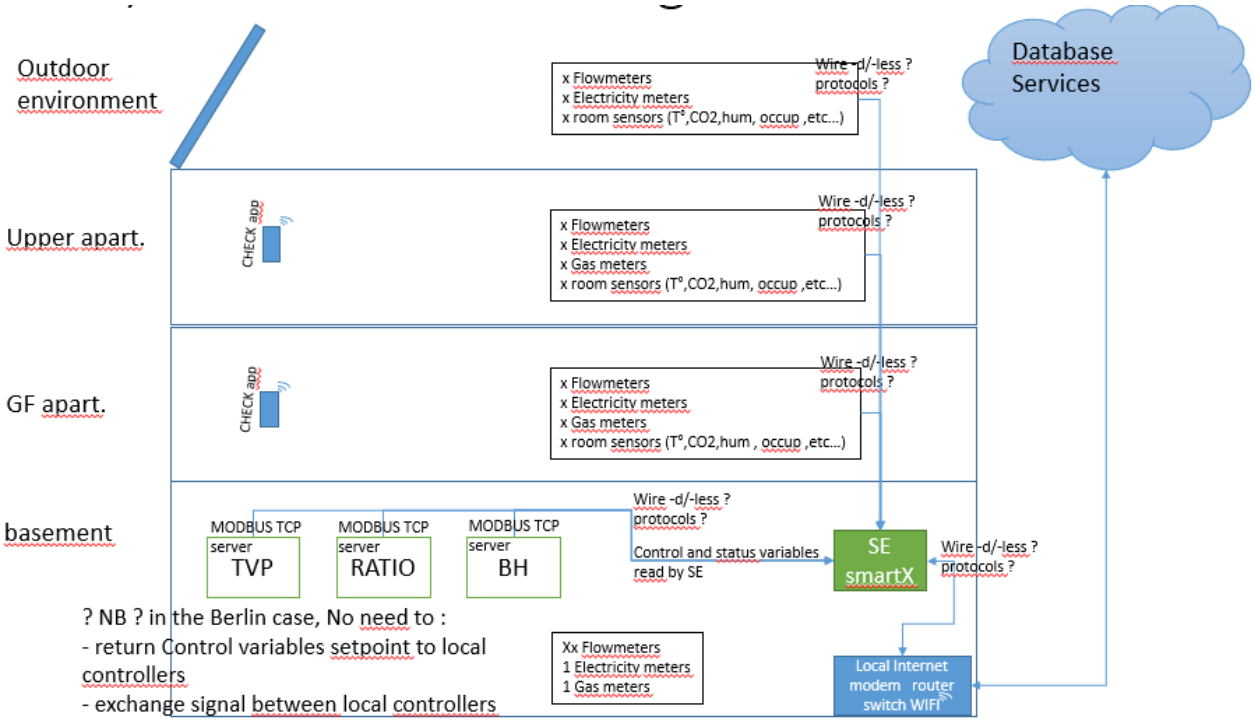


Figure 18: preliminary communication architecture for monitoring in Berlin case

During the pre-design period from M1 to M18 of the tasks T2.4 (preliminary TP1 design, integration in Berlin demo site and simulation) and T6.1 (energy baseline representation), the partners involved in the Berlin demo site discussed to establish the list of sensors that will be relevant to monitor the SunHorizon technology TP1 to be specifically implemented in the demo site. #1Berlin case-specific discussions with Schneider in parallel lead to draft the requirements and principles of communication between the heating technology controllers and Schneider monitoring gateway with the cloud services developed in WP4 and WP5 of SunHorizon. As illustrated in Figure 18, this communication will essentially rely on MODBUS TCP for the Berlin case. Figure 19 shows the specific sensors to monitor TP1 in Berlin and highlights the requirement to be able to manage separately the energy consumption metering (heat and electricity) for the two apartments. Based on these preliminary monitoring plans, the comprehensive monitoring architecture with all sensors and communication devices will be further developed by Schneider during the next M18-24 period (T6.2) through iterative process with the #1-Berlin case other technology providers (TVP, RATIO, CW) and Boostheat in particular as demo site responsible.

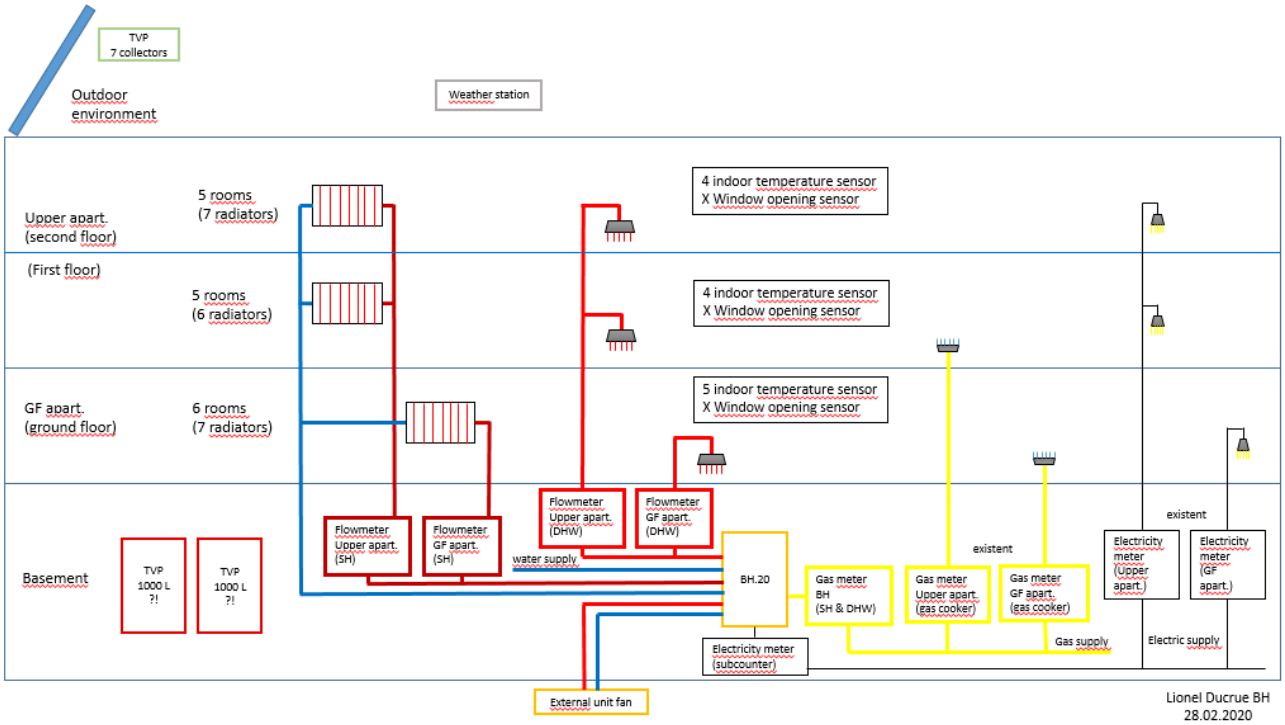


Figure 19: preliminary monitoring plan of the TP1 implemented in Berlin case

3 Nurnberg demo site #2

3.1 General description

The Nürnberg demosite is a four-family apartment building, one apartment per floor. There are 12 inhabitants in 2018-2019, all year round. It was built in 1906, it is not insulated, its heated surface is 330 m².

Space heating systems and domestic hot water systems are not centralized and there is no cooling system in the whole building.

Heating systems, from ground floor to top floor:

- Apt. #1: Wood + coal stove + 3.000l aquarium at 24°C electrically heated 24/7
- Apt. #2: Combined gas boiler, 18kW, efficiency 84%, Viessmann Vitopend 200W Kombi, installed in 1992 in the basement. There is no storage water tank
- Apt. #3: Combined gas boiler, 18kW, efficiency 84%, Wolf CGU 18, installed in 2006 in the apartment, extremely narrow site. There is a storage water tank
- Apt. #4: Coal backup stove

Domestic hot water production systems, from ground floor to top floor:

- Apt. #1: Electric
- Apt. #2: Combined gas boiler
- Apt. #3: Combined gas boiler
- Apt. #4: Electric

The demosite responsible is Boostheat.

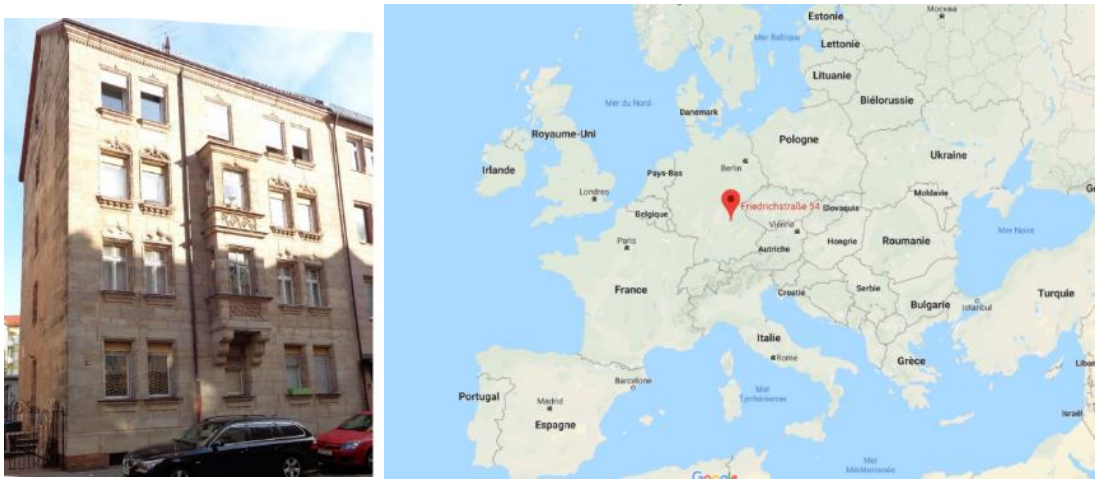


Figure 20 – Nürnberg demosite building

3.2 Local weather characteristics

The simulation uses Meteonorm weather file in Nürnberg. This weather station is located at the airport, GPS coordinates are 49.50° north, 11.08° east, elevation is 312 m above sea level. The distance to the demo location is very small: only 4 km.

Meteonorm weather file: DE-Nuernberg-107630.tm2

Figure 21 – Weather station in Nürnberg

3.2.1.1 Weather Database comparison with temperature records over 40 years

Meteonorm standard year temperatures are compared to historical temperatures over 40 years, using data from the infoclima.fr website.

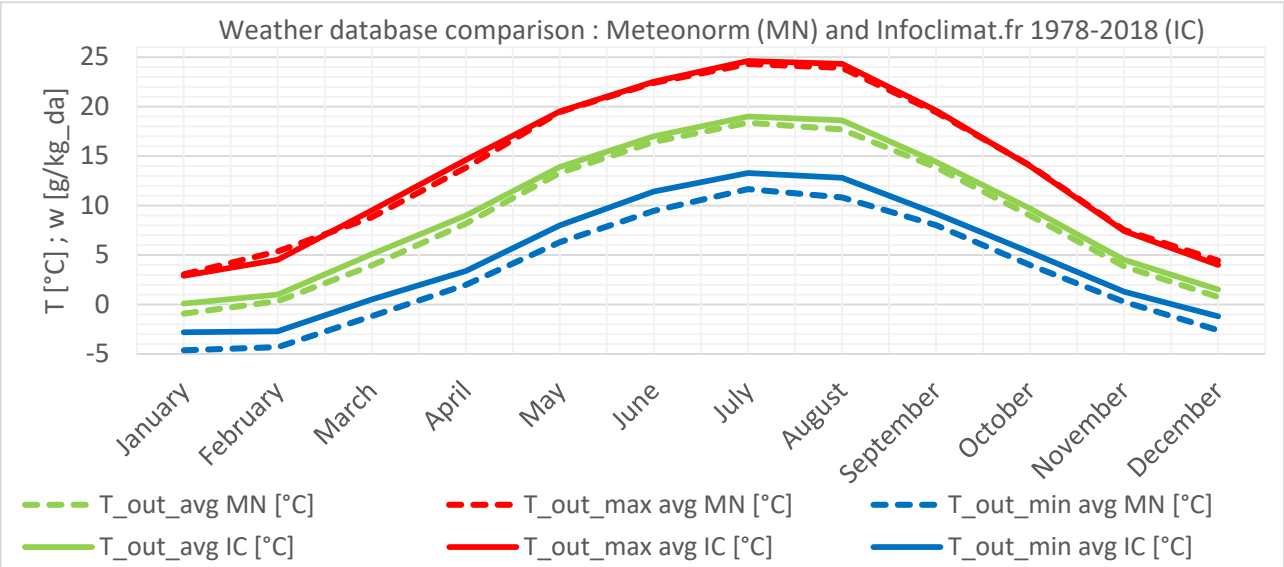


Figure 22 – Ambient temperature (T_out) comparison between Meteonorm and historical measurements over 40 years in Nürnberg

Meteonorm's yearly temperature average is 0.75°C colder than 40 years measurement average given by infoclimat.fr. This difference requires a closer analysis of historical weather values.

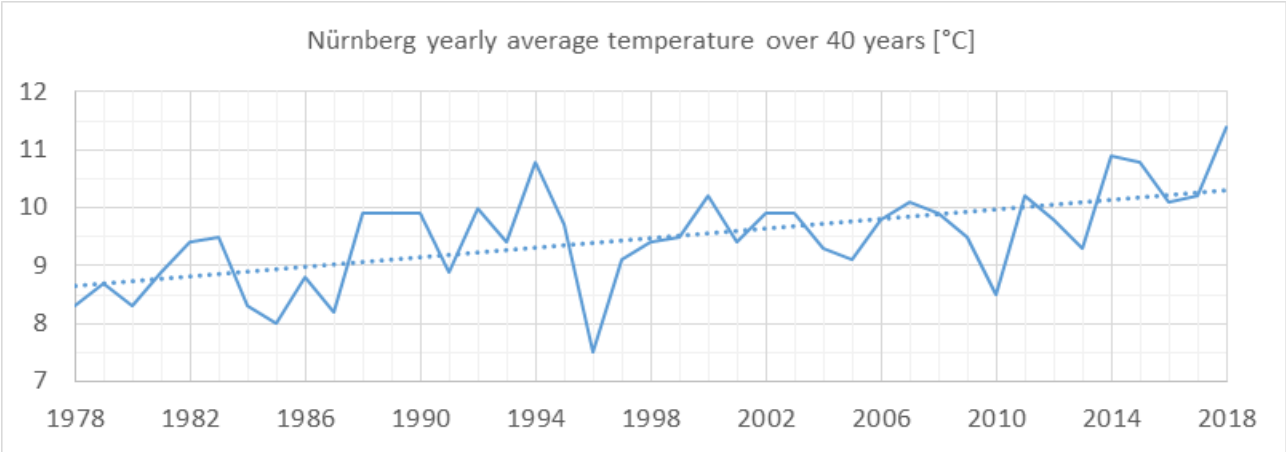


Figure 23 – Yearly average temperature in Nürnberg over last 40 years [Source: infoclimat.fr]

Figure 4 shows historical yearly average temperature in Nürnberg over last 40 years [Source: infoclimat.fr]. It highlights a rising trend at an average rate of 0.0416°C/year over the last 40 years. Looking at the trend line, Meteonorm average temperature corresponds approximately to year 1980. Since climatic conditions tend to warm up constantly, averages over older measurements may not be applicable in the future years. Therefore, we decide to define a temperature correction.

3.2.1.2 Increasing Meteonorm temperature for baseline and retrofitted cases

We chose to modify Meteonorm ambient temperature so that it corresponds approximately to the trend line in year 2010. This means a yearly average temperature of 9.97°C, which is also the average over the 2005-2018 period. Since Meteonorm average temperature is 8.73°C, this requires to set the temperature increase at **+1.24°C**. Absolute humidity remains unchanged, as there is no clear model to modify it.

Sunhorizon project in Nürnberg concerns only heating systems, which is why the temperature correction has to be validated using only heating season months. Indeed, if summer months alone were responsible of the climate warming, the above correction would not be realistic for the heating season. Therefore, a comparison between Meteonorm and historical temperatures was performed without warmer months (June July and August). Meteonorm average is then only 5.81°C. Increasing this value with the difference calculated above, we get 7.05°C, which corresponds approximately to trend line in 2011, as shown on Figure 24.

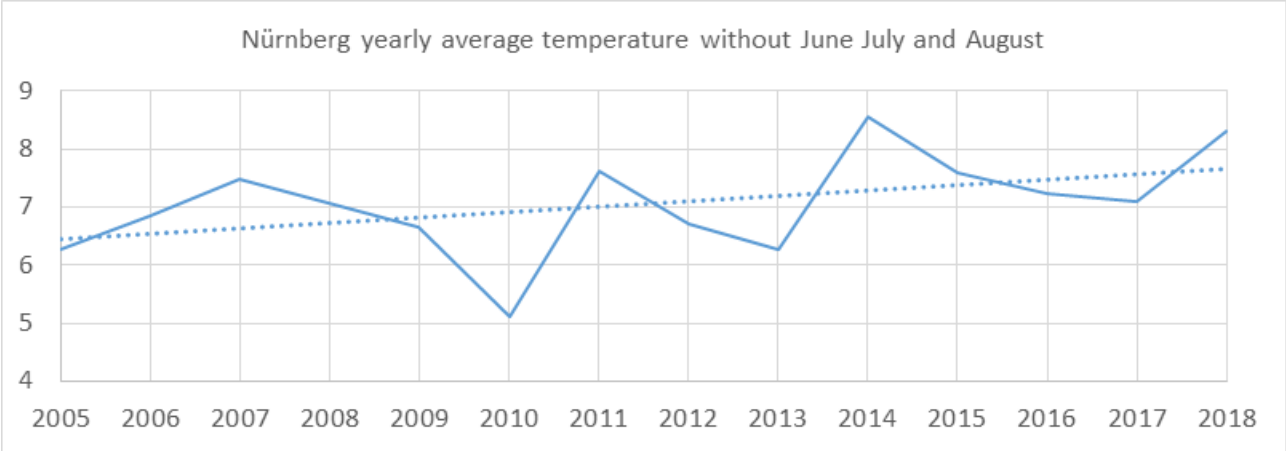


Figure 24 – Yearly average temperature in Nürnberg without June July and August [Source: infoclimat.fr]

Figure 6 presents Meteonorm's main outputs, with the temperature correction.

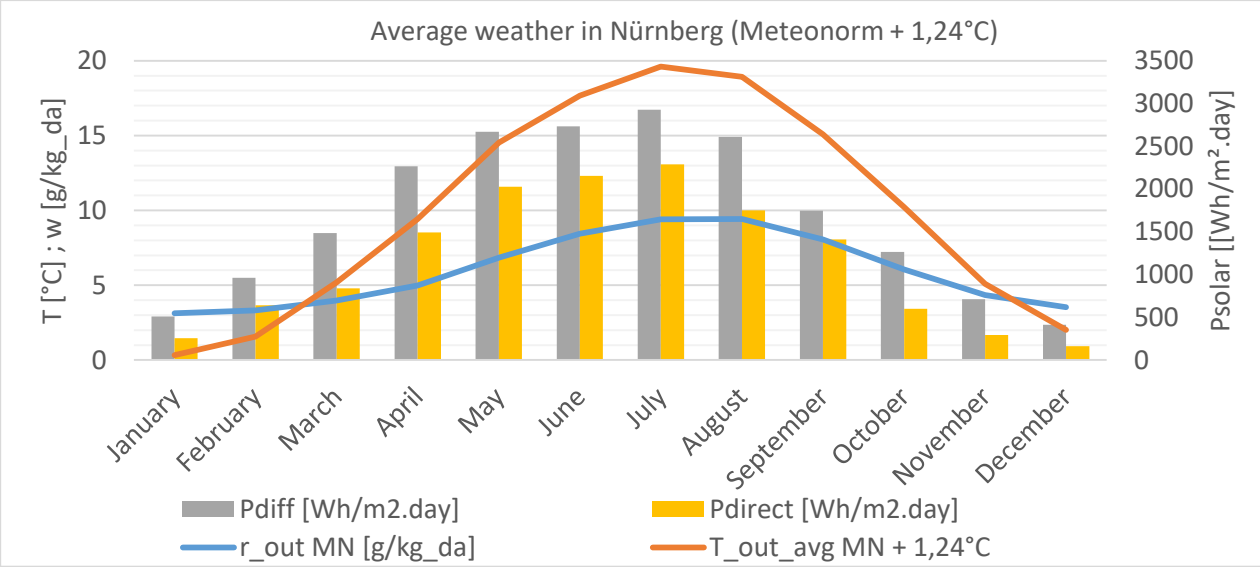


Figure 25 – Meteonorm weather and solar data in Nürnberg

3.2.1.3 Increasing Meteonorm temperature for building model assessment (year 2018)

The building model validation is performed through a measure/simulation energy consumption comparison. Since gas consumption measurements are available only for year 2018, simulation has to use a weather file as close as possible to the actual 2018 weather, knowing that this specific year is known to be the warmest ever measured. A quick analysis shows that year 2018 temperature average is 2.644°C higher than Meteonorm weather file in Nürnberg (Figure 26).

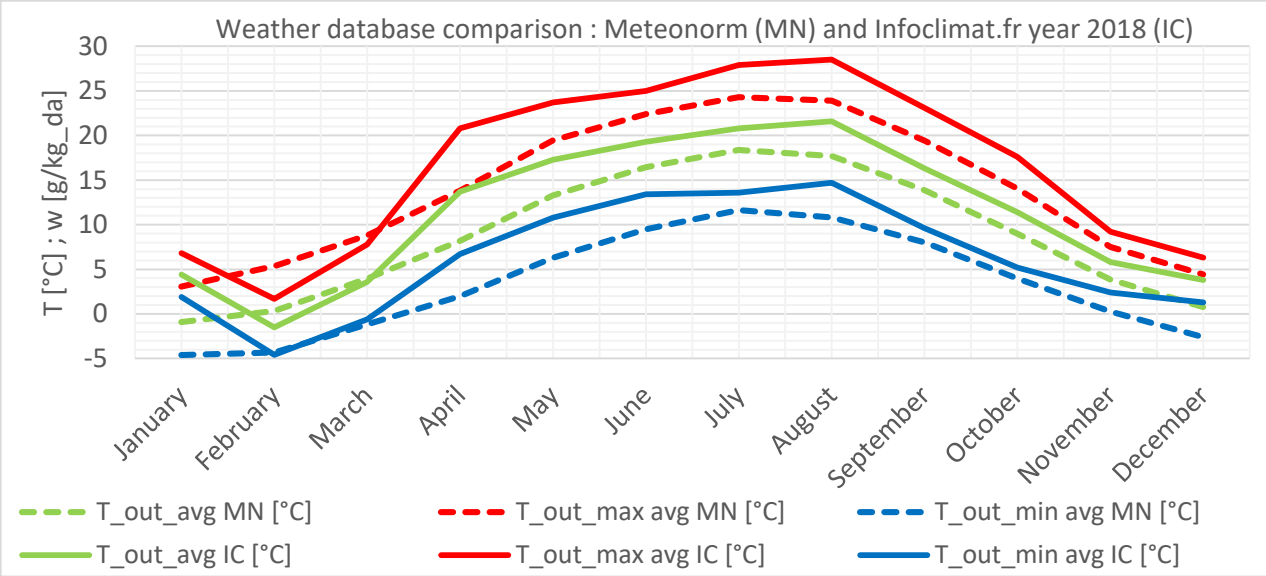


Figure 26 – Weather comparison in Nürnberg: Meteonorm database and actual year 2018

Although the temperature difference is not constant over the year, the model uses a constant +2.644°C correction from Meteonorm outside temperature, only to check that building model consumption is similar to actual energy measurements. Then, the baseline energy consumption prior retrofit is calculated with the 1.24°C corrected Meteonorm file, which represents a broader average of Nürnberg weather.

3.3 Building geometry and use

3.3.1 Building's general description

ID card:

- Year of construction: 1906
- Type: 4 family apartment houses
- Not monument protected
- Not insulated
- Location: Friedrichstr. 54, 90408 Nürnberg
- Closest existing weather station: Nürnberg https://www.wetterdienst.de/Deutschlandwetter/Potsdam/Aktuell/103810
- Heated surface: 330 m², 4 floors
- Inhabitants: 12, living there all year long
- Comfort air temperature: 20°C by default
- Occupancy schedule: not known
- Comfort water temperature: 70°C/60°C for apt. #2 and #3

3.3.2 Building Photos, drawings, general dimensions

The Nürnberg Friedrichstrasse building was modelled using Sketchup 3D drawing software and the TRNsys 3D plugin.

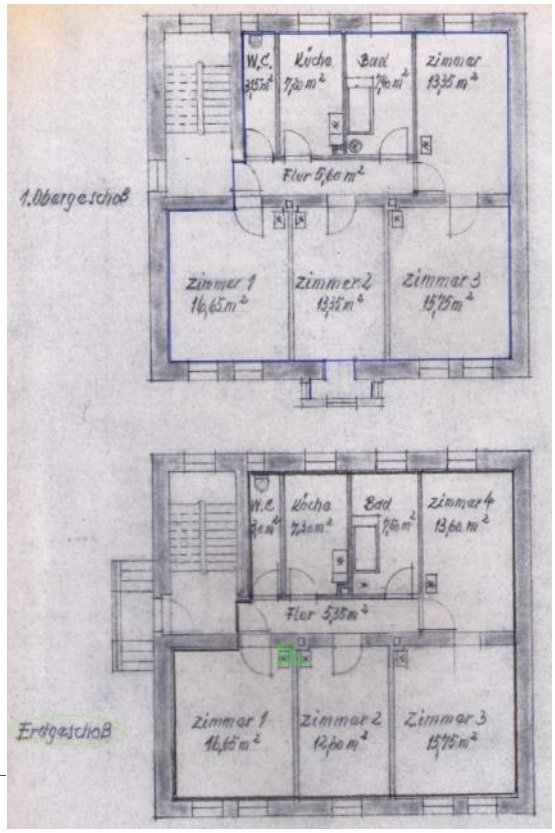


Figure 27 – Photo and existing drawings of the Nürnberg building

The size of the building is calculated using the drawings and the room surface information. Global size is then double checked with Google map information.

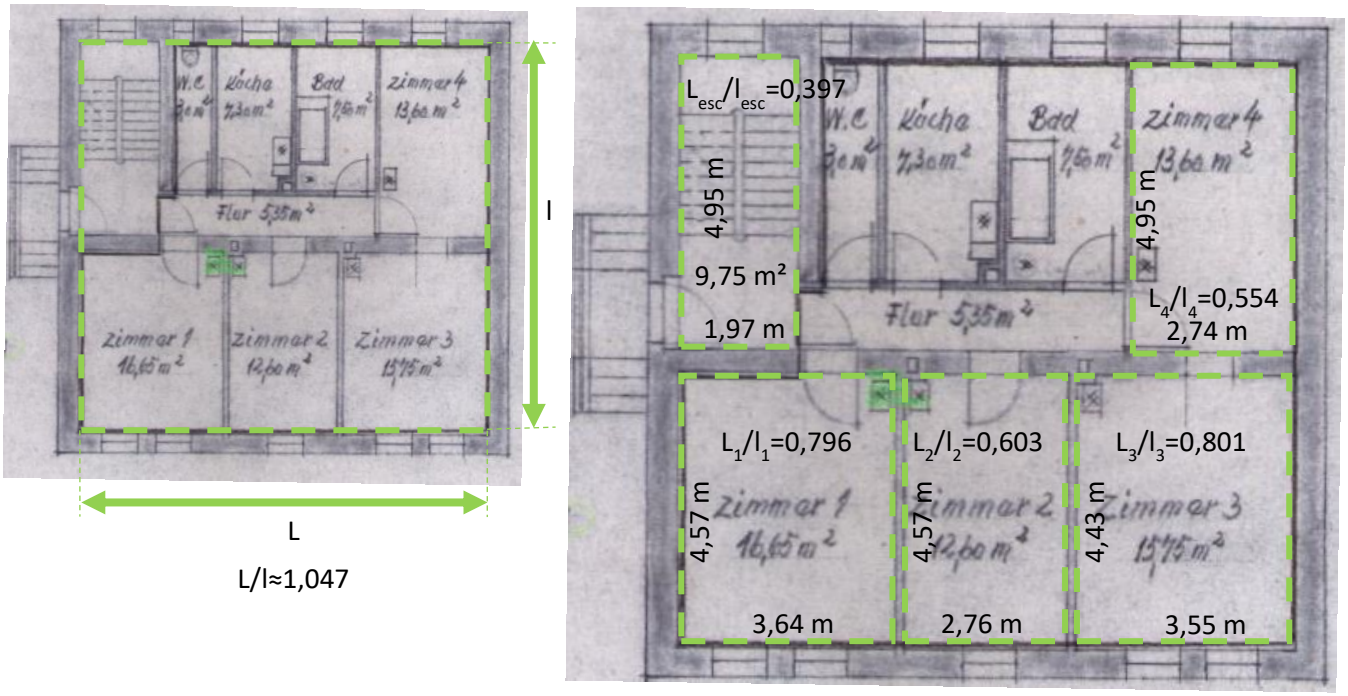


Figure 28 - Calculation of building's actual size

For each room, a graphic estimation sets the ratio length/width. Combining these ratios with known surfaces provides length and width of each room.

Doing this for rooms 1 to 4 allows calculating the full heated zone dimensions. The result is a length ("L" on Figure 28) of 10.36 m and a width ("l" on Figure 28) of 9.9 m.

Double check with Google map:

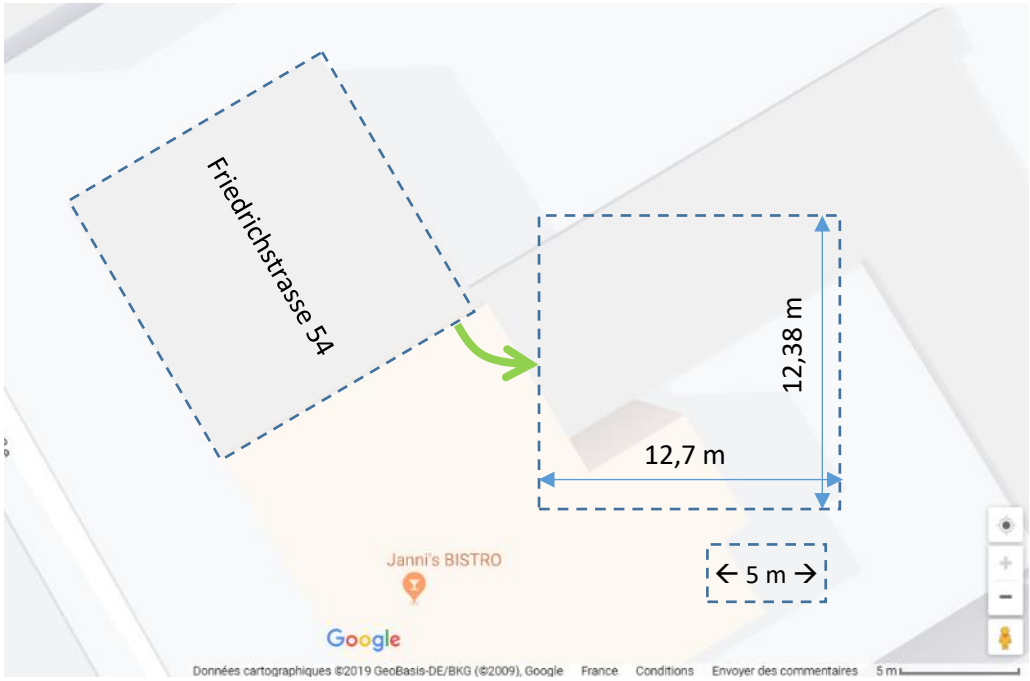


Figure 29 – dimension double check with Google map

When taking into account overhanging roof edge and wall thickness, the 12.38 m dimension is lowered by 2 times 0.5 m and 2 times 0.48, we have therefore a building inner width of 10.4 m when calculated from city map, to be compared with

9,9 m when calculated with drawings. These two methods provide quite close results, which confirms the calculated dimensions. The thermal model uses values obtained with the drawing calculation method.

3.3.3 Building modelling

The deliverable D2.5 details the building model. Here is a quick sum up:

- External walls: They are made of brick (12 cm)+ air gap (4 cm) + limestone (32 cm). These double walls are 48cm thick. There is no insulation.
- Internal walls: mortar (1 cm) + brick (10 cm) + mortar (1 cm). See Figure 32 § 3.3.7
- Windows: Window ratio is 0,2, average window length is 1,6 m and average window height is 0,9 m. There are two layers of windows with a large od style 5 cm spacing
- Roof: Terra cotta (tiles) (15 mm) + Heavy wood (10 mm) + Plastic film (1 mm) + Heavy wood (35 mm). It is a wooden framework, 6 cm total thickness. It is not insulated. Roof's window ratio is 0.01. Slope is around 40°. See Figure 33 § 3.3.8
- Slabs: Concrete (5 cm) + heavy wood (15 cm) + light wood cladding (2 cm). The slab between basement and apartment 1 is different: brick + sand (25 cm). See § 3.3.10.
- Ground floor: The ground floor is made of 25 cm of brick and sand. It is not insulated
- Ventilation: Ventilation air change rate is natural; there is no air heat recovery nor mechanical ventilation. Natural, infiltration rate is 0.8 ACH, except in the attic: 1.5 ACH
- Shutters: Windows are equipped with old style shutters, not modeled
- Solar shadings: Solar shadings are described on Figure 13 (§ 3.3.1)
- Thermal zones: 4 heated zones, 1 per floor. Detail on Figure 37 (§ 3.3.6)
- HVAC: No HVAC modeled for baseline simulation prior retrofit. For model/measurement comparison in 2018, thermostats for apt #1 to # 4 are set to 20°C, 20°C, 18°C, 17°C. For baseline calculation, all thermostats are set to 20°C.
- Internal gains: 7 adults + 5 children. 50W/p at night, 100 W/p during the day. An occupancy scenario is setup. See 3.4.5
- DHW drawoff profile: 40L/p/day from 10 to 45°C, for 11.5 inhabitants (one person present only half of the time). Yearly consumption is 167900 L.
- Specific electricity: Yearly consumption is 16041 kWh for the whole building. The distribution is as follows (apt. #1 to apt. #4): 4000 ; 5162 ; 1465 ; 5414 kWh

3.3.4 Main schematics (baseline situation)

Figure 30 depicts the existing system inside Nürnberg building

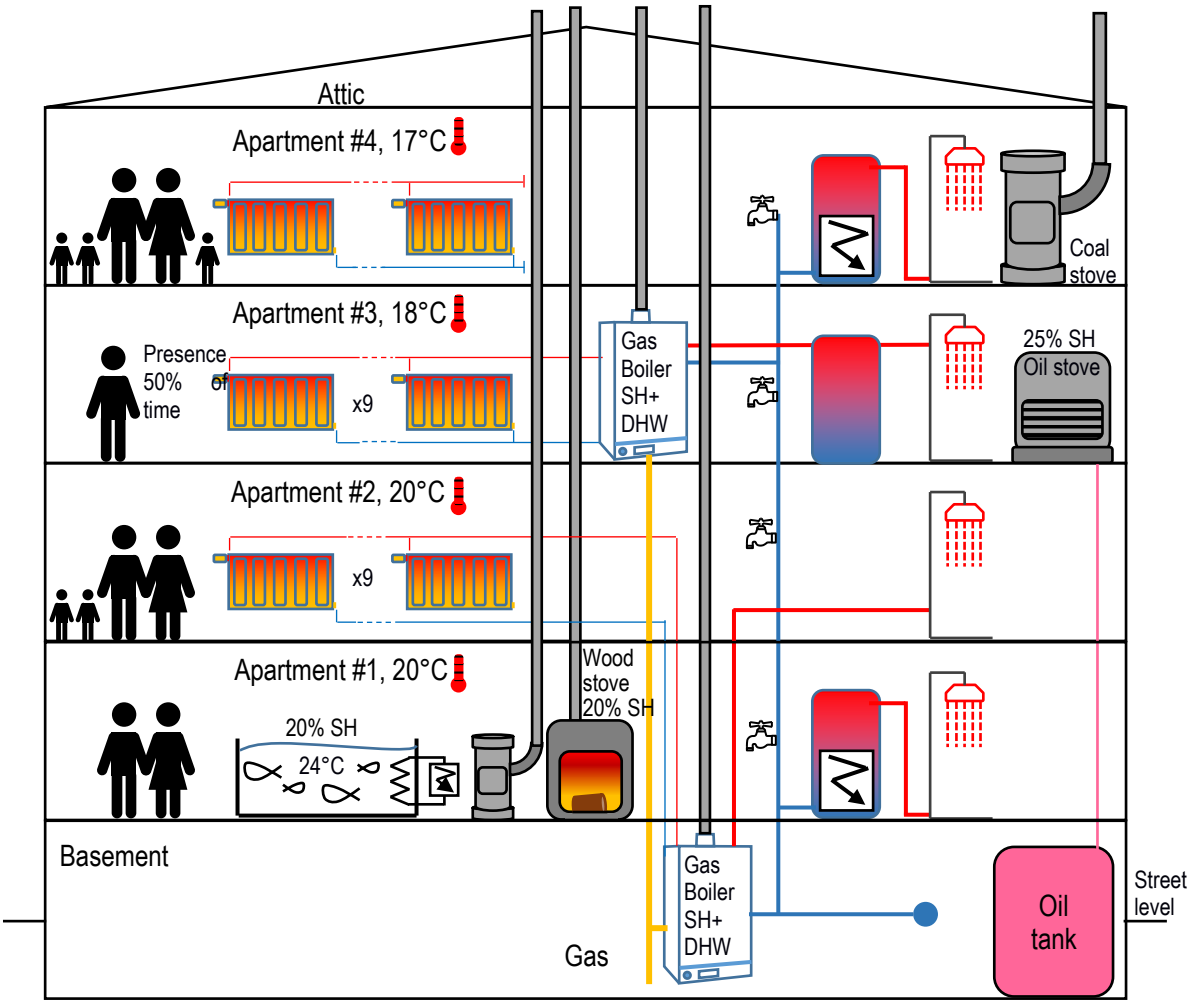


Figure 30 – Existing heating and domestic hot water systems

3.3.5 Shadings

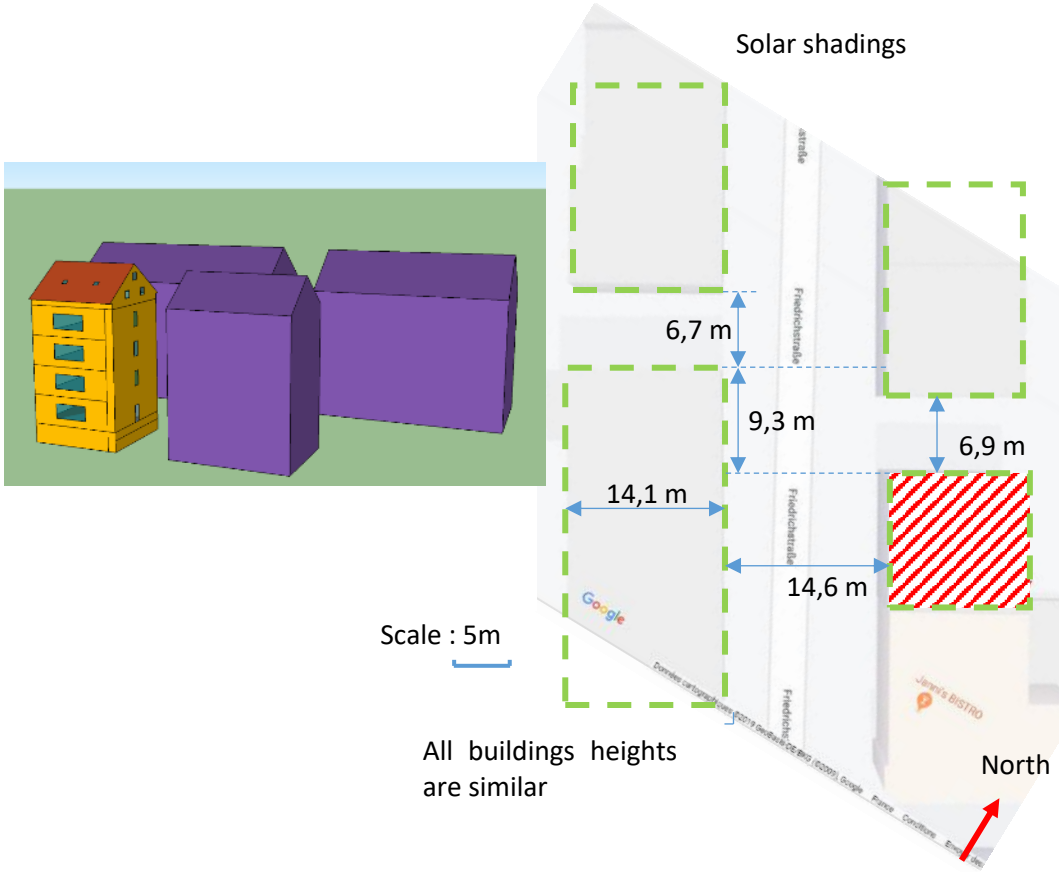


Figure 31 – Solar masks from closest buildings

3.3.6 Thermal zones

There are 4 thermal zones representing the 4 dwellings on top of each other. In addition, there are 3 unheated thermal zones, representing the stairway, the basement and the attic. For numerical reasons, the basement is divided in two heated zone and the actual geometry of the stairway was modified.

3.3.7 External wall composition

External walls are made of brick and limestone, double, 48cm thick. With building's year of construction (1906), we define the external wall as follows for thermal simulation:

(from inside to outside): • 12 cm brick • 4 cm air gap • 32 cm limestone wall	Thermal settings: U-value = 1.669 m/m².K Solar absorptance: Front = 0.5 ; Back = 0.5 Longwave emission coefficient: Front = 0.9 ; Back = 0.9 Convective heat transfer coefficient: Front = 11 ; Back = 64

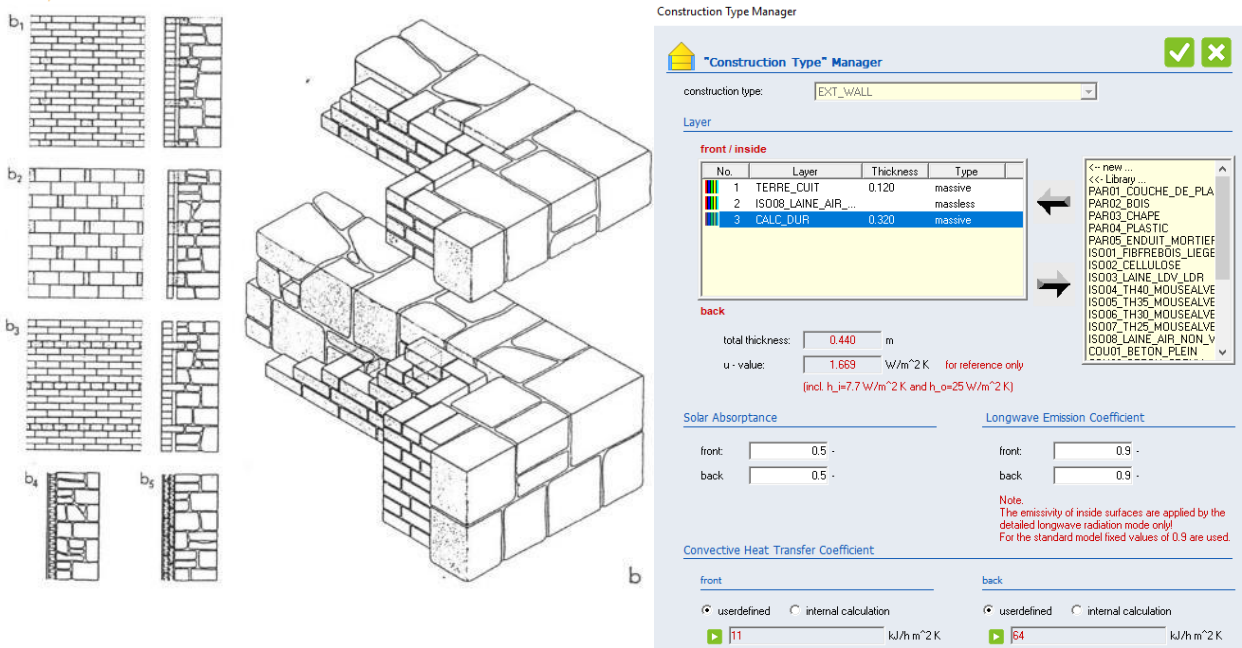


Figure 32 – External wall composition, with TRNsys settings

3.3.8 Roof

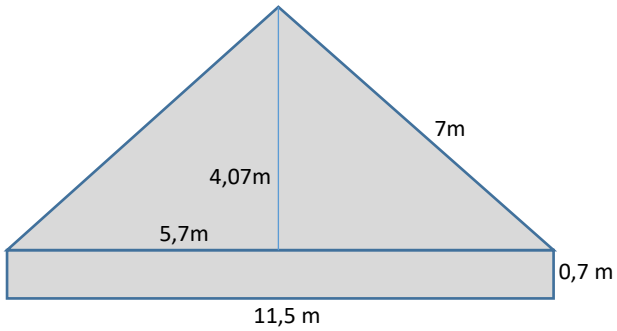


Figure 33 – Roof dimensions

There is no drawing available concerning the roof. Its dimensions are calculated from approximate measurements performed on site: Slope around 40°, length around 10.8 m. Overall dimensions of the building are also used to help defining roof's dimensions as follows:

- Parapet's height is 0.7 m
- Parapet's length is 11.5 m
- Roof's triangle height is 4.07 m
- Roof slope's length is 7 m

Roof's composition is guessed from available pictures:

- Terra cotta (tiles), thickness 15 mm
- Heavy wood, thickness 10 mm
- Plastic film, thickness 1 mm
- Heavy wood, thickness 35 mm
- Total thickness 61 mm

Thermal settings: U-value = 2.595 m/m².K

Solar absorptance: Front = 0.1 ; Back = 0.5

Longwave emission coefficient: Front = 0.9 ; Back = 0.9

Convective heat transfer coefficient: Front = 11 ; Back = 64

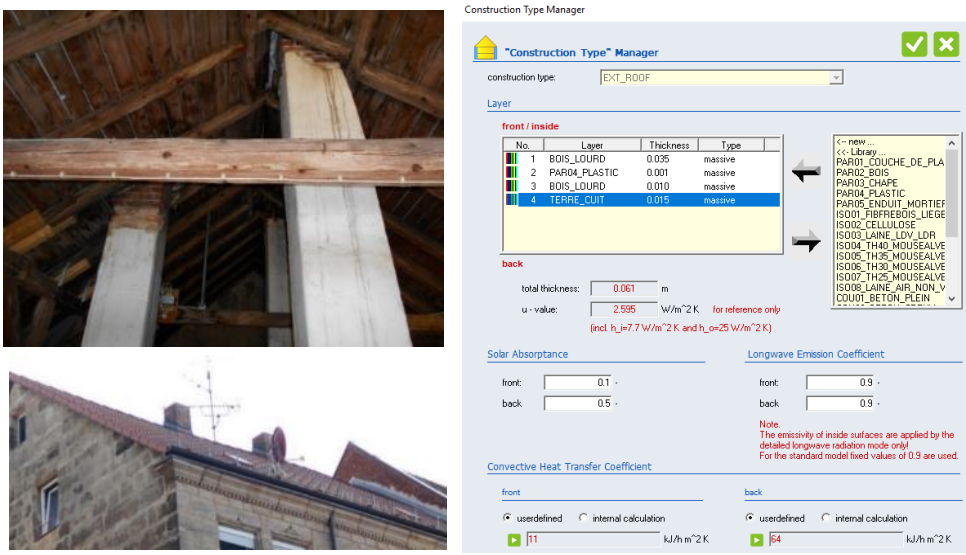


Figure 34 – Roof composition, TRNsys settings

3.3.9 Windows

The window ratio is 0.2 on vertical surfaces. Average window length and height are 1.6 m and 0.9 m. The transmission coefficient is not known, window type is “two layers, old large space type 5 cm”

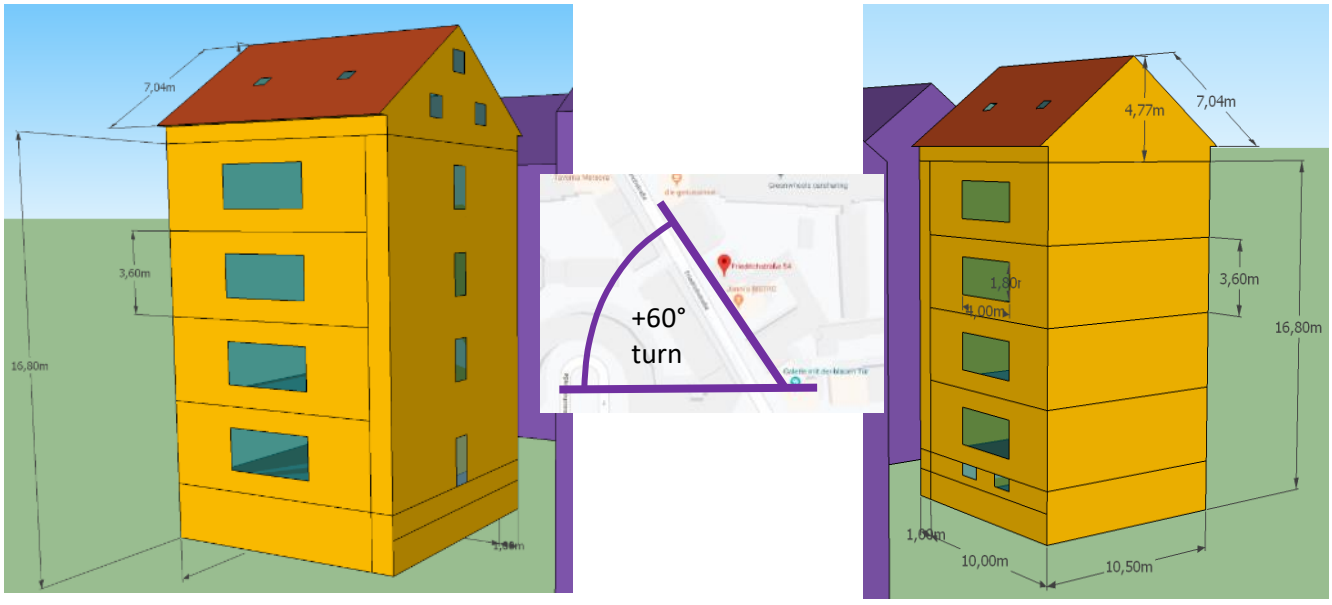


Figure 35 – Final model geometry

Figure 36 – Window distribution on stairway façade, front and rear façades

Windows on front and rear façades are modelled as a single surface equivalent window per façade. Stairway façade windows are modelled according to their actual positions.

3.3.10 Slabs between floors

The slabs composition between heated floors is not known. CEA's proposal is as follows:

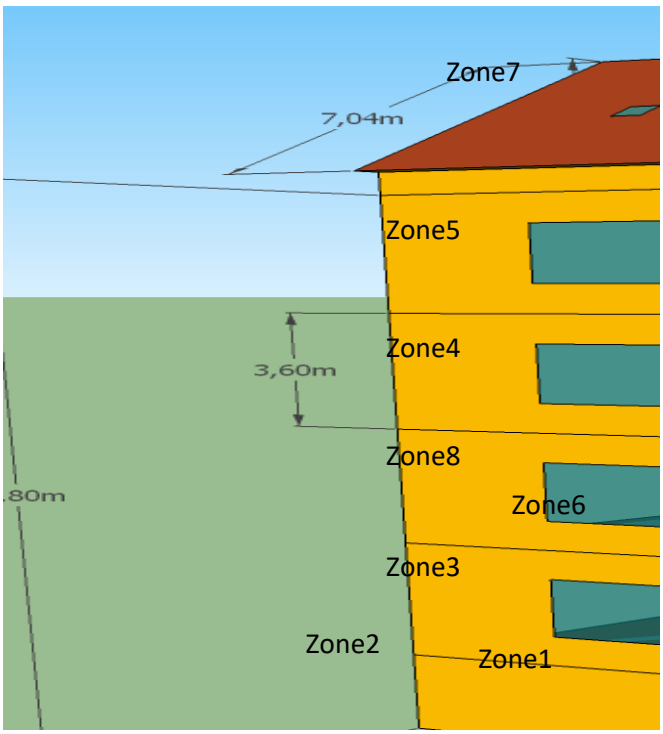
- 5 cm concrete slab
- 15 cm heavy wood
- 2 cm light wood cladding as surface rendering on ceiling

The lower slab between basement and apartment 1 is defined as follows:

- Brick, sand, 25cm

Sand thermal characteristics:

- Capacity: 0,83 kJ/kgK (source: https://www.engineeringtoolbox.com/specific-heat-capacity-d_391.html)
- Density: 1500 kg/m^3 (source: https://theconstructor.org/building/properties-of-building-materials-construction/14891/)
- Thermal conductivity: 1 W/mK or 3,6 kJ/(h.m.K) (source: https://link.springer.com/article/10.1007%2Fs00231-007-0357-1 or https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)



- Zone1: basement1
- Zone2: basement2
- Zone3: flat1
- Zone4: flat3
- Zone5: flat4
- Zone6: staircase
- Zone7: attic
- Zone8: flat2

Figure 37 – Thermal zones of the Nürnberg building in the numerical model

3.4 Heating/cooling system with heat, cold and DHW distribution

3.4.1 Initial heating equipment

Space heating systems and domestic hot water systems are not centralized. Here is the description for each zone from ground floor to top floor:

- Apt. #1: Wood + coal stove + 3.000l aquarium at 24°C electrically heated 24/7
- Apt. #2: Combined gas boiler, 18kW, efficiency 84%, Viessmann Vitopend 200W Kombi, installed in 1992 in the basement. There is no storage water tank
- Apt. #3: Combined gas boiler, 18kW, efficiency 84%, Wolf CGU 18, installed in 2006 in the apartment, extremely narrow site. There is a storage water tank
- Apt. #4: Coal backup stove

Figure 38 - Existing heating systems

There is no cooling system in the whole building

3.4.2 Domestic hot water systems and profiles

There is a shower, a bathtub and a kitchen sink in each apartment.

Domestic hot water production per zone:

- Apt. #1: assumed to be electric
- Apt. #2: Combined gas boiler
- Apt. #3: Combined gas boiler
- Apt. #4: assumed to be electric

A DHW profile is generated for 2 reasons:

1. For determining the portion of energy dedicated to domestic hot water production, so that space heating energy can be calculated from global energy measurements. This is used to check if the simulated energy consumption using the numerical TRNsys building model complies with measured values.
2. In the system simulation, the DHW profile is used to perform the hot water draw offs

The DHW profile is generated using the DHW-calc tool. Parameters are set for a 40L/person/day DHW consumption. It is translated in energy assuming a temperature rise from 10°C to 45°C. The daily flow settings is calculated for 11.5 inhabitants. Indeed, a person is present only half of the time in apt #3

DHW-calc settings are shown on Table 4.

According to DHW-calc results, the yearly domestic hot water consumption is 167900 L for the full building. With the 10°C to 45°C assumption, this corresponds to 6823 kWh. The maximum energy demand per hour is 25.3 kWh.

Table 4 DHW profile settings in DHWcalc tool

LOGFILE DHWxNurnbergx12px40Lpj\DHWxNurnbergx12px40Lpj_log.txt for a multi-family house with 4 households Total duration: 365 days Start day : 1. day of the year Mean daily draw-off vol.: 460 l/day No. of categories: 4 Time step duration: 6 min Daylight saving time: applied FLOW RATE SETTINGS Categories: 1 2 3 4 Mean flow Rate: 10 60 1400 400 l/h Duration of draw-off: 6 6 6 6 min portion: 14 36 10 40 % sigma: 20 20 20 20 l/h min. flow rate: 6 l/h max. flow rate: 4800 l/h	PROBABILITY FUNCTION SETTINGS Step function probability distribution for weekdays + weekend-days Mean DHW-volume tapped during 6 time periods: weekdays time period ratio of daily DHW-volume 22:00-06:30 2 % 06:30-07:30 50 % 07:30-12:00 6 % 12:00-13:00 16 % 13:00-18:00 6 % 18:00-22:00 20 % weekend-days time period ratio of daily DHW-volume 23:00-07:00 3 % 07:00-09:00 14 % 09:00-15:00 20 % 15:00-17:00 20 % 17:00-20:00 38 % 20:00-23:00 5 %	Ratio of the mean daily draw-off volume tapped on weekend-days/on weekdays: 120 % Seasonal Variations: Sine amplitude: 10 % Day of sine maximum: 45 Holiday Periods: Period: 1.7. - 1.9. Nr. of holidays: 14 Relative consumption: 0

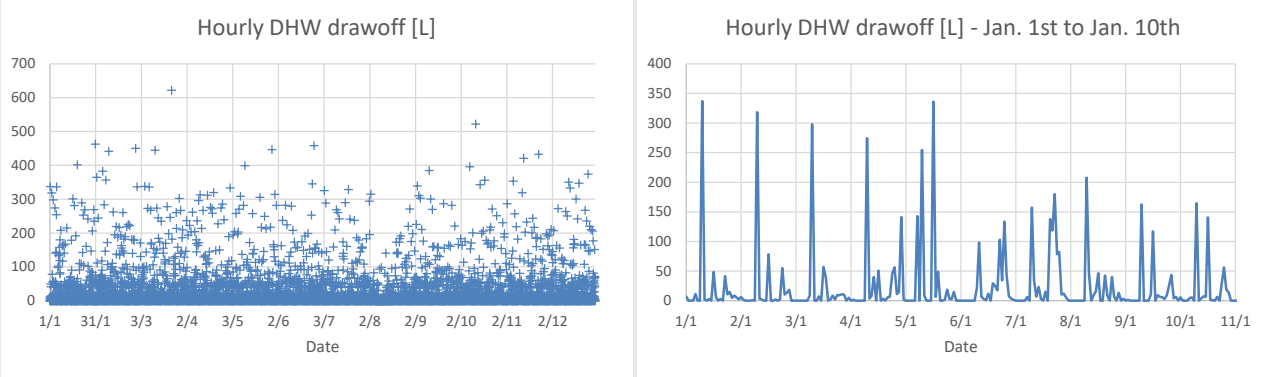


Figure 39 – DHW profile settings in DHW-calc tool

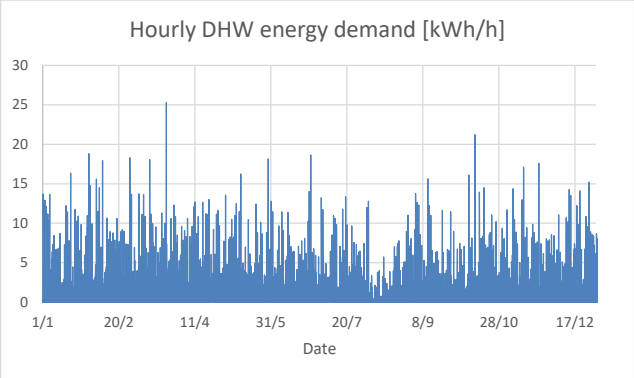


Figure 40 – Hourly DHW energy demand

3.4.3 Emitters (Radiators)

- Apt. #1: 0 (will be installed for the project)
- Apt. #2: 9 units, type 22, installed in 1990, with thermostatic valve
- Apt. #3: 9 units, type 22, installed in 1990, with thermostatic valve
- Apt. #4: 9 units, (installed in 2018, but the heat source is still missing)

The radiator models are not connected for baseline energy consumption definition.

Figure 41 - Radiators, type 22

3.4.4 Specific electricity consumption

Known equipment in the existing building:

- Plate cookers
  - Apt. #1: Electric
  - Apt. #2: Gas
  - Apt. #3: Gas
  - Apt. #4: Electric
- All apartments: refrigerator, lights (energy saving bulbs and LEDs)
- Apartment #1: Massive heated aquarium. It is considered as an additional electric heater.

As this is not enough information for determining realistic electrical consumption, a profile tool is used to calculate the specific electricity consumption in each apartment throughout the year at a 1h time step.

This consumption is used for two things:

1. For determining the portion of electricity dedicated to specific use, so that space heating energy and/or domestic hot water production energy can be calculated from global energy measurements. This participates in the input data required to define the baseline situation before retrofit.
2. In the retrofitted system, specific electricity consumption is one of the major energy use. An hourly profile feeds the building and participates in the space heating process as a lot of equipment finally transform electricity into heat. These hourly profiles also allows to calculate a real time photovoltaic self-consumption rate

The electricity consumption profile is calculated using the CREST v2.2.1 tool developed by Loughborough University, Leicestershire LE11 3TU, UK. CEA added a VBA macro that allows to run the simulation for each day of the year. Results are aggregated through daily and hourly totals for each zone and through hourly detail for the whole building.

Each dwelling is described in the CREST tool as described in Table 5.

Table 5 – Dwelling description in the CREST specific electricity tool, today's situation

Dwelling index	Number of residents	Building index*	Primary heating system index*	PV system index	Solar thermal collector index	Cooling system index
1	2	3	3	0 (no PV)	0 (no ST)	1 (no cooling)
2	4	3	3	0	0	1
3	1	3	3	0	0	1
4	5	3	3	0	0	1

*with:

Building index	Building description
1	Detached

Primary heating system index	Type of heating unit
1	Boiler (regular)

2	Improved detached
3	Semi-detached
4	Improved semi-detached
5	Terraced
6	Improved terrace
7	Cement block apartment
8	Small brick-built house

2	Boiler (combi)
3	Boiler (system)
4	No Heating or Cooling
5	Electric Water Heater

Table 6 - Simulation inputs in the CREST specific electricity tool

Specify the date:	CEA's VBA macro runs the simulation tool 365 times
2. Specify if this is a weekday (wd) or weekend (we):	CEA's macro specifies "wd" or" we" for each day of the year
3. Specify the location for solar: (this function of the tool is not used)	Latitude (°):49,4628482 Longitude (°):11,0805719 Local standard time meridian (°):15
4. Specify the location for temperature: (this function of the tool is not used)	England (Germany not available)
5. Specify country and year for appliance ownership	UK (Germany not available), 2019, urban area
6. Country uses daylight saving time (summer time)?	Yes
7. Specify the number of dwellings to simulate in this run:	4
8. Stochastically assign dwelling parameters?	No, parameters are set manually in the "Dwellings" worksheet (see Table 5)
9. Include high-resolution dynamic output?	Yes
10. Include daily demand totals for each dwelling?	Yes
11. Overwrite existing data?	Yes
12. PV included as an option?	No
13. Run or stop the model by clicking the buttons to the right:	By using CEA's VBA macro, runs start automatically for simulating a full year profile

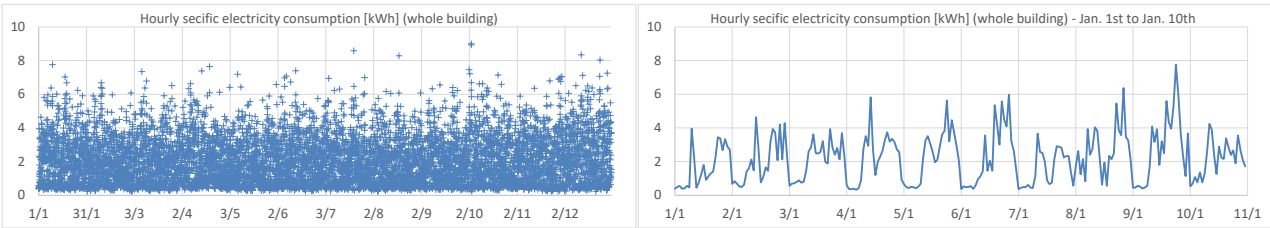


Figure 42 – Specific electricity profile – hourly consumption for the full Nürnberg building

The yearly specific electricity consumption is given on Table 7, for each apartment and for the full building.

Table 7 - Yearly specific energy consumption

	Appt. 1 [kWh]	Appt. 2 [kWh]	Appt. 3 [kWh]	Appt. 4 [kWh]
Per apartment	3999,8	5162,4	1464,8	5414,0
Whole building	16041			

3.4.5 Inhabitants and Internal gains

Inhabitants distribution, from street level to top floor:

- Apt. #1: 91 m², 2 inhabitants (adults)
- Apt. #2: 81.5 m², 3 inhabitants (2 adults + 1 child)
- Apt. #3: 81.5 m², 4 inhabitants (2 adults + 2 children)
- Apt. #4: 76 m², 2 inhabitants (adults)

Each heated zone air volume is set to 378 m^3

For each of the 12 inhabitants, the internal gains are calculated as follows:

- 50W/person at night
- 100W/person during daytime
- For apartment #3, the gain is reduced in order to take into account the 50% time presence.
- Then, the gains below are multiplied by the daily presence profile (Figure 43). Gains:
    - apt 1 value: 200W (2p)
    - apt 2 value: 400W (4p)
    - apt 3 value: 50W (1p; 50% presence)
    - apt 4 value: 500W (5p)

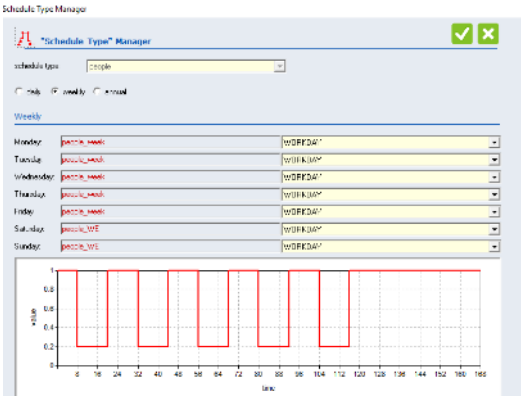


Figure 43 – Occupancy scenario in the Nürnberg building

3.4.6 Measured energy consumptions

Gas consumption (approximately over year 2018)

	Gas meters	η_gas boiler	Thermal energy
	kWh	%	kWh
Apt. #1	-	-	-
Apt. #2	14200	84%	11928
Apt. #3	15600	84%	13104
Apt. #4	-	-	-

Electricity consumption

From	to	E_elec	Climate factor
		kWh	
01/05/2003	30/04/2004	45010	1,07
01/05/2004	30/04/2005	43196	1
01/05/2005	30/04/2006	33352	0,96

Cold water consumption average over the 2016-2018 period is 240 m^3/year. This is in line with the assumption of 167.9 m^3 for hot water only.

3.4.7 Method for missing energy measurement compensation

The energy consumption measurements are not fully available for the existing building prior retrofit. In addition, the comfort level in each apartment is not equivalent. Therefore, we need to have a specific method so that initial energy situation can be assessed in a realistic way. This baseline has to be suited to a comparison with retrofitted situation.

This method is described by the flowchart presented on Figure 44.

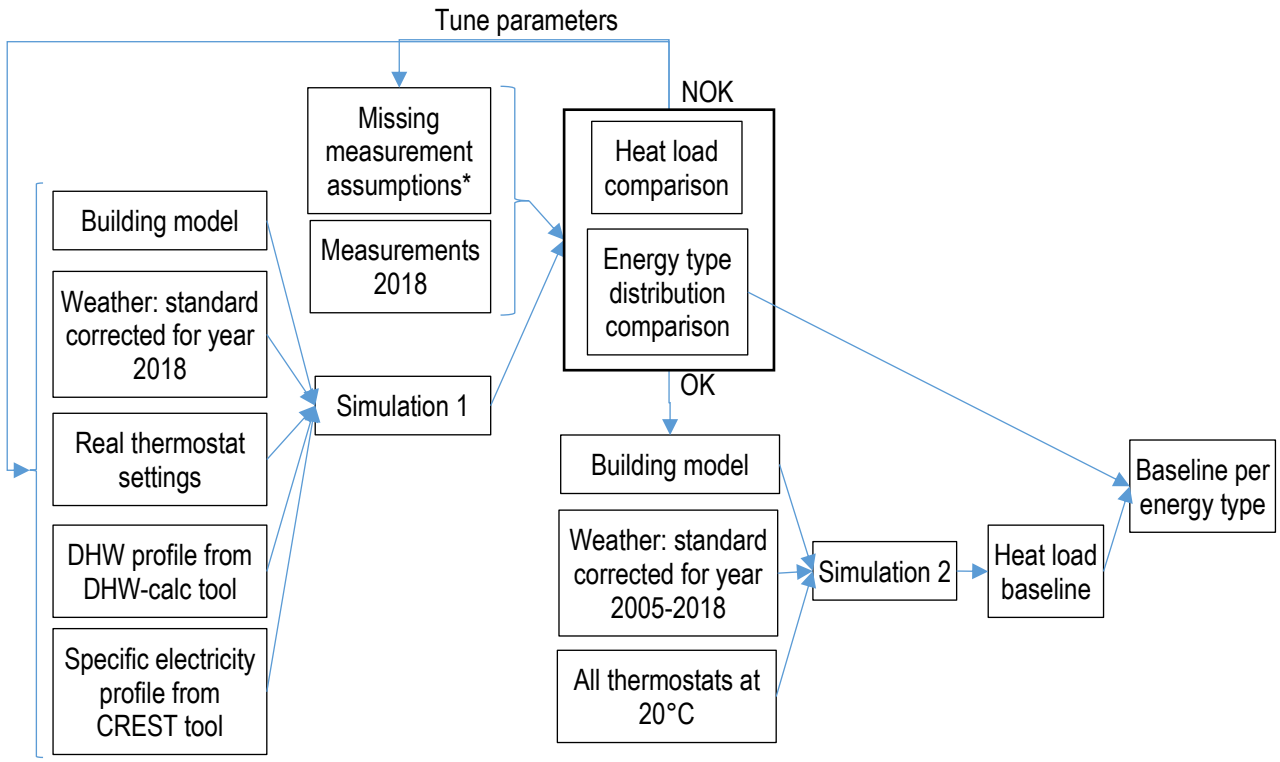


Figure 44 – Baseline definition method - Flowchart

*Assumptions for compensating missing measurements:

- Space heating consumption distribution aver the 4 apartments is given by the simulation. It is used as a convergence criteria when setting other parameters.
- Energy dedicated to DHW production is calculated with the DHW-calc tool
- Specific electricity needs are calculated with the CREST tool
- The remaining electricity (measurements are greater than CREST estimation) is affected to heating purpose in apt. #1 and apt. #2.
- For apartment #1, Boostheat's assumption is that space heating load distribution is 20% wood, 20% electric (big aquarium at 24°C) and 60% coal.
- For apartment #4, coal consumption cannot be very high because of the small size of the stove, in addition to the fact that coal must be carried manually up to the 4th floor.
- For apartment #3, Boostheat's assumption is that oil consumption is quite low

The distribution per energy type is based on 2018 measurements with additions from assumptions and simulation in a comparable weather. It is detailed on Table 8

*Table 8 – Detailed baseline energy consumption (**2018 weather**)*

Function	Energy	Apt. 1 [kWh]	Apt. 2 [kWh]	Apt. 3 [kWh]	Apt. 4 [kWh]
Space heating	Electricity	4658	6100		7400
	Gas		9555	12807	
	Oil			2800	
	Coal	13974			4500
	Wood	4658			
	Total	23290	15655	15607	11900
DHW	Electricity	1187			2967
	Gas		2373	297	
Specific	Electricity	4000	5162	1465	5414

With this set of parameters, measured and simulated distribution match quite successfully: Convergence (simulation minus measurement) is 0.1% on space heating, -5.3% on electricity, 0% on heat distribution per zone.

3.4.8 Baseline results

The #2NURNBERG energy related baseline is estimated as follows by Sunhorizon KPIs (**2005-2018 weather** and following conversion coefficients in section 3.5):

Table 9 - Initial yearly consumptions prior retrofit (baseline)

	Consumption	PE_{nren}	Pe_{ren}	PE_{tot}	GHG	Cost
	kWh	**kWh**	kWh	kWh	**tCO2_eq**	€
Oil	3891	4281	0	4281	1,241	165,51
Wood	5104	1021	5104	6125	0,041	395,06
Gas	30701	33772	0	33772	7,430	1866,65
Coal	22360	24596	0	24596	8,485	1257,71
Electricity	43420	99866	8684	108550	41,944	13025,99
Total		163535			59,141	**16710,93**

The baseline assessment is then as follows:

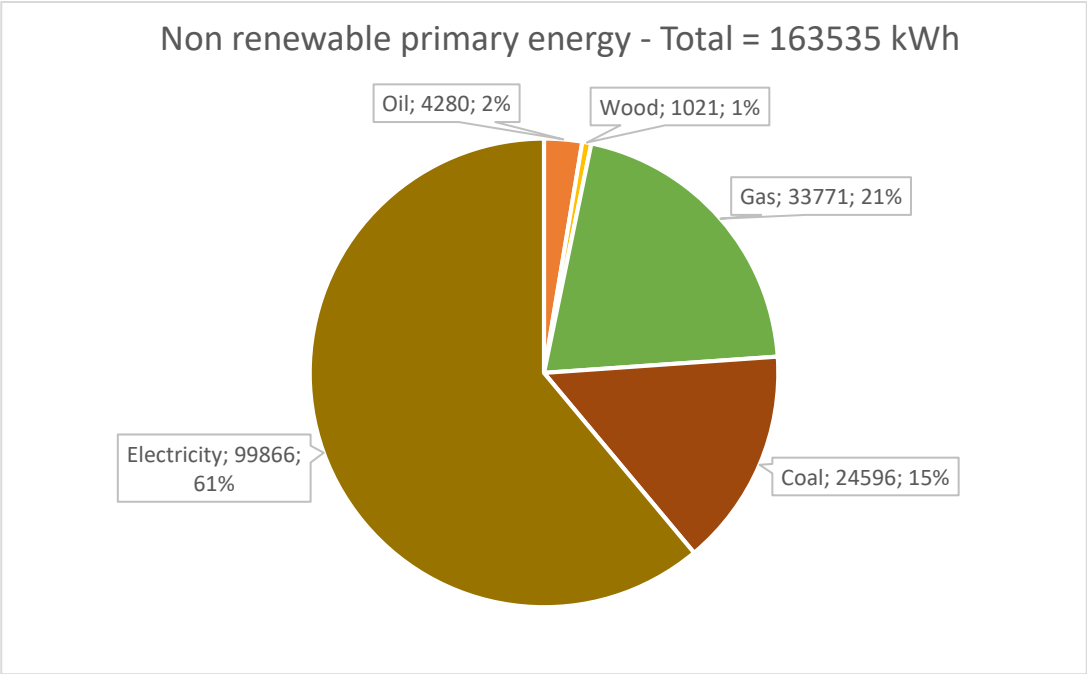


Figure 45 – Non-renewable primary energy consumption per fuel – Baseline situation

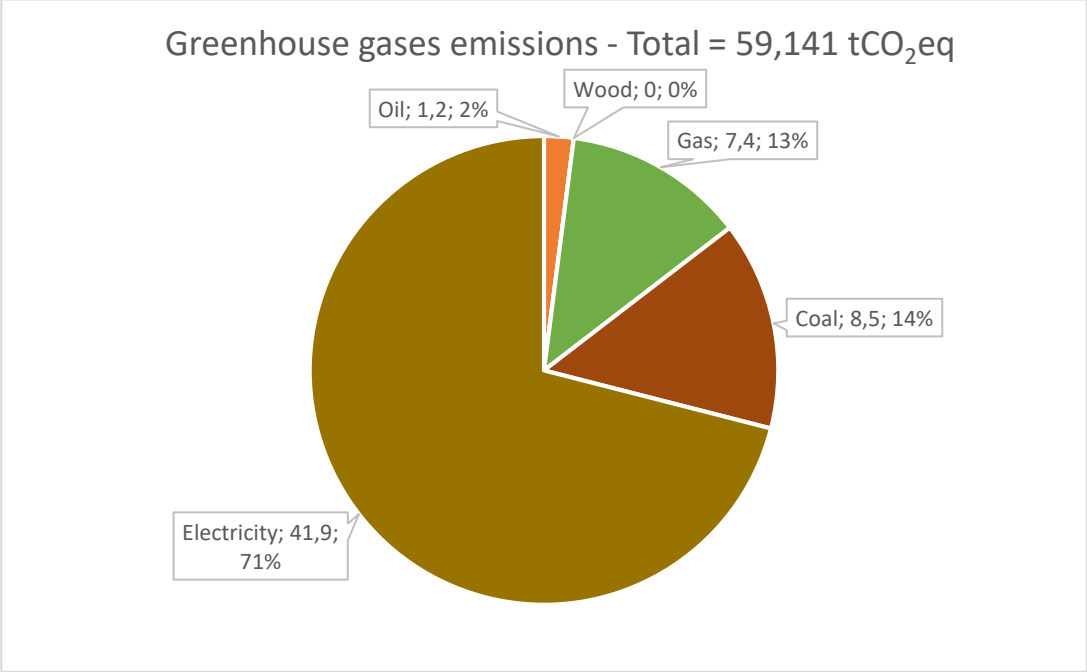


Figure 46 – Greenhouse gases emissions by fuel – Baseline situation

3.5 Specific requirements for the new heating/cooling system

In addition to the pure energy demand of the existing #2NURNBERG building and its occupants which was summarized in the previous section, the new TP2 shall meet a few extra requirements regarding the location of the components in the building, the regulatory and economic frameworks where the components DUALSUN PVT solar panels, BOOSTHEAT gas burner and CO_2 heat pump, RATIOTHERM will be integrated:

- up to 75 m² DUALSUN PVT solar collectors could be integrated on tilted south facing roof (cover: tiles). Solar panels roof integration is expected to comply with the ISO9806.
- Admissible mechanical load (static and wind/snow dynamic) on the roof up to 47 solar panels (1.6m² each): specific study ordered by Boostheat to evaluate if roof re-enforcement to be done on such historical building from early XXth century.
- Chimneys: there are 4 independent chimney ways. Two are used by the existing gas boilers, 2 are free to find pipes' paths. Wood stove chimney is separate.
- Boostheat outdoor unit installation is foreseen either in the attic or in the courtyard on the backside of the building.
- Installation of Boostheat indoor unit, RATIOTHERM tanks and hydraulics is foreseen in the technical room in the basement considering its limited geometry (height 2,0-2,15 m), tiny entrance through 1m wide access and turning 180°+90° as shown in Figure 47 .
- The DHW use temperature is assumed at 45°C and a recycling loop will be required because of centralized DHW preparation in the basement.
- The expected room air temperature for user's comfort with the new TP2 installed is 20°C for every 4 apartments.
- Separate energy (DHW, space heating, electricity) monitoring for every apartment to derive building's general costs breakdown.
- Compared to the heating systems already in place, none national/regional regulatory constraint was identified through the discussions at demo group level in the actual upgrade/renovation context of the heating system to restrict the deployment either of the DUALSUN solar PVT panels on the roof or the gas fired thermal compression BoostHeat heat pump.

In the SunHorizon project, Major KPIs like PESnren, GHGsav and Cf fuel/energy costs are relying on following local constraints listed in Table 10, assumed conversion factors both for baseline and TP2 in NURNBERG demo case calculations. Unclear situation for the feed-in electricity tariff after 2020 in Germany prevent to predict reasonable fixed sale price less than 5 c€/kWh sale.

Table 10 – Conversion factors for primary energy, greenhouse gases and energy costs

	PEFnren	PEFren	fGHG	Cf or Ef
	-	-	gCO2/kWh	€/kWh
Oil	1,1	0	290	0,0425317
Wood	0,2	1	40	0,0774026
Gas	1,1	0	220	0,0608
Coal	1,1	0	345	0,0562493
Electricity	2,3	0,2	420	0.3

Figure 47 – Nürnberg building's basement tiny entrance

3.6 Preliminary monitoring plan

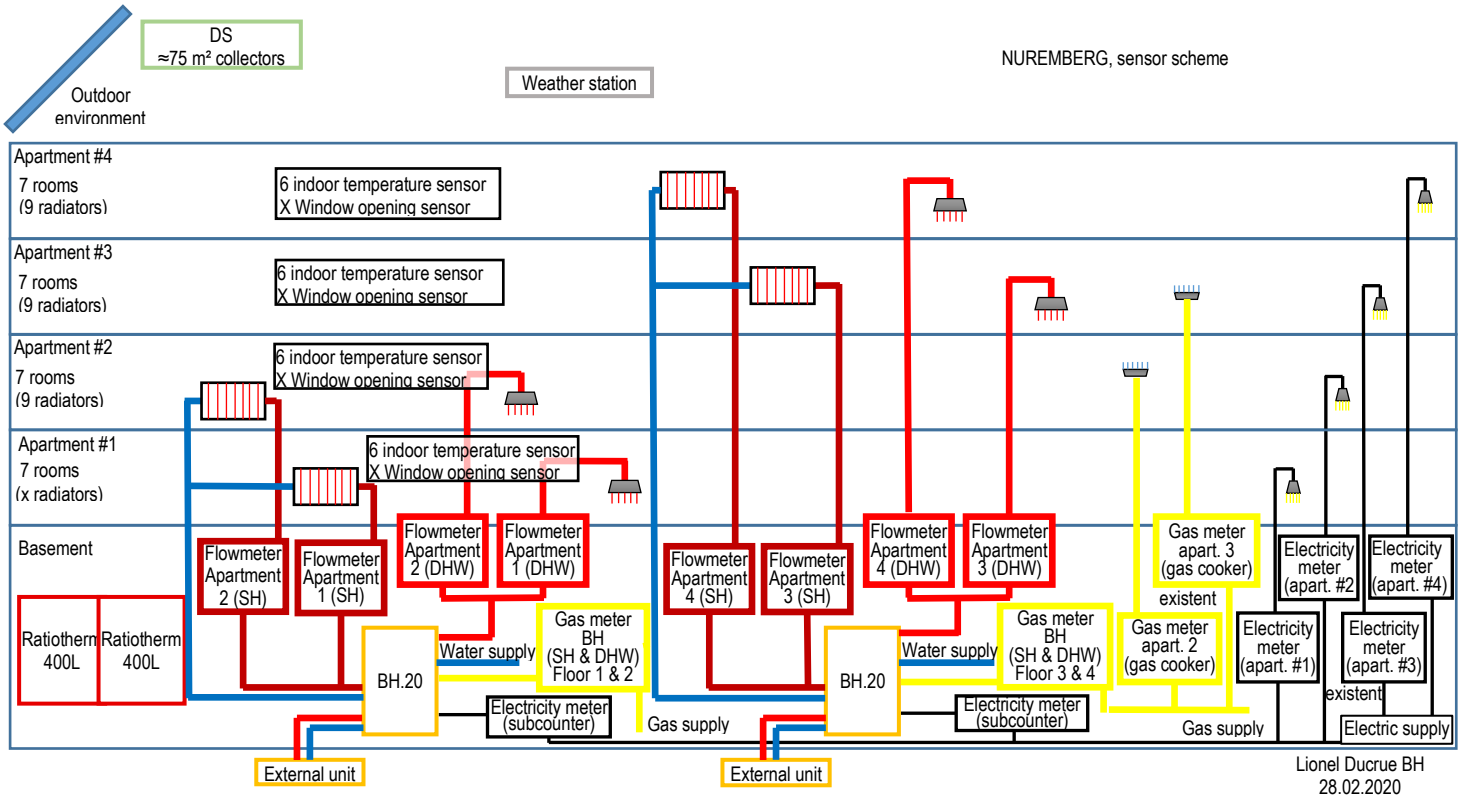


Figure 48 – Preliminary monitoring plan

4 Sant Cugat demo site #3

4.1 General description

The Sant Cugat demo site building (Mira-sol Civic Center) is a municipal facility (tertiary building) that has different spaces to develop all kinds of cultural activities.

Mira-sol Civic Center offers: a wide program of courses and workshops; public cession of spaces; service to support entities and collectives of the neighbourhood; revitalization of popular and traditional culture; child service activities; a stable cultural program with small-format shows.

It is located in Mira-sol neighbourhood of Sant Cugat del Vallès, a town close to Barcelona (Figure 49).

Figure 49: location of the Sant Cugat demo site

Figure 50: aerial view of the Sant Cugat demo site

Type of building: Tertiary Civic Center. This building was built in two phases:

- the first one was built in October 1996
- the second one was built in February 2006 and it represents the demo building in which the SunHorizon solution will be validated.

The part of the demo site building affected by the project is the second stage building (second phase; built in 2006), it is located on the south part of the building (Figure 50).

The heating and cooling demands are covered by an independent HVAC installation for each area. The conditioned area consists in 12 rooms and 1 corridor.

Currently, the heating and cooling installation (second stage building) is formed by the following equipment:

- Reversible air to water heat pump: 93.6 kW (nominal cooling capacity) – 96.3 (nominal heating capacity)
- Air handling unit: 110 kW (cooling capacity) – 67.78 (heating capacity)

There is no DHW demand, so the entire consumption is due to the space heating and cooling.

4.2 Local weather characteristics

The pilot is located in Sant Cugat del Vallès, a town close to Barcelona where, being a Mediterranean region, high levels of solar irradiation and temperatures are expected.

In Sant Cugat del Vallès, the summers are short, warm, humid, dry, and mostly clear and the winters are long, cold, and partly cloudy. Over the course of the year, the temperature typically varies from 3°C to 28°C and is rarely below -1°C or above 32°C.

- **Temperature**

The warm season lasts for 2.8 months, from June 18 to September 13, with an average daily high temperature above 26°C. The hottest day of the year is August 4, with an average high of 28°C and low of 19°C.

The cool season lasts for 3.9 months, from November 18 to March 16, with an average daily high temperature below 15°C. The coldest day of the year is January 8, with an average low of 3°C and high of 13°C.

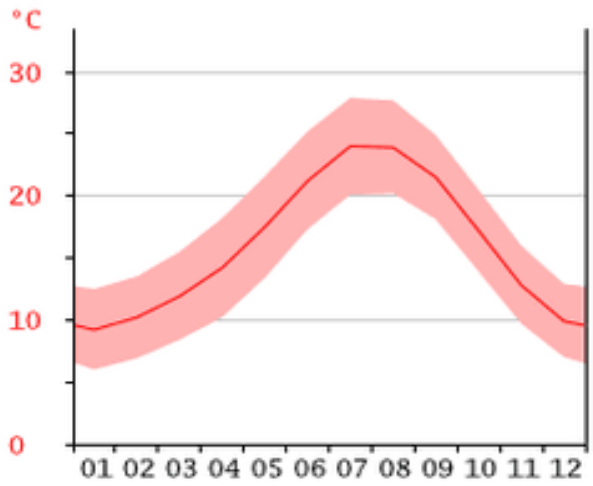


Figure 51: Weather analysis for Sant Cugat del Valles: Average temperature diagram

- **Wind**

The average wind speed per hour in Sant Cugat has slight seasonal variations over the course of the year.

The windiest part of the year lasts 7.0 months, from October 2 to May 2, with average wind speeds above 11.9 kilometers per hour. The windiest day of the year on April 5, with an average wind speed of 13.1 kilometers per hour.

The calmest time of the year lasts 5.0 months, from May 2 to October 2. The calmest day of the year is August 17, with an average wind speed of 10.8 kilometers per hour.

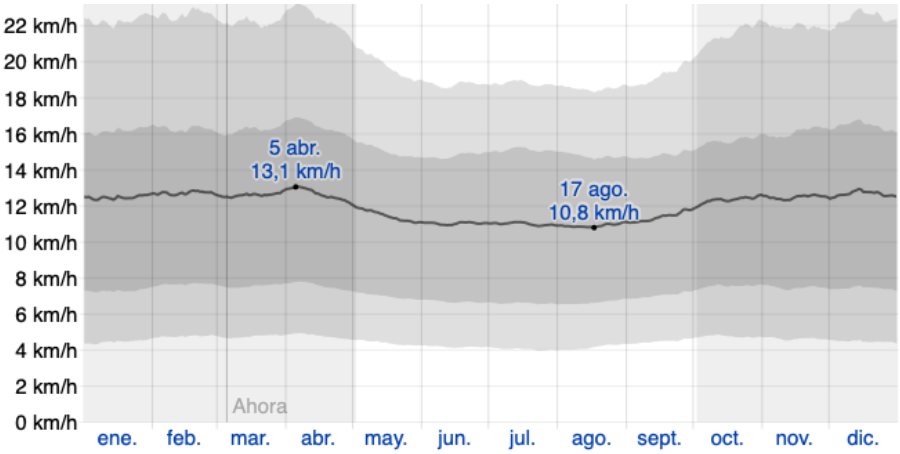


Figure 52: The average wind speed per hour (dark grey line), with the percentile bands 25º to 75º and 10º to 90º

The average predominant wind direction in Sant Cugat varies during the year.

The wind most often comes from the south for 6.1 months, from April 11 to October 13, with a maximum percentage of 52% on August 8. The wind most often comes from the west for 5.9 months, from October 13 to April 11, with a maximum percentage of 47% on January 1.

- **Precipitation**

A wet day is one with at least 0.04 inches of liquid or liquid-equivalent precipitation. The chance of wet days in Sant Cugat del Vallès varies throughout the year.

The wetter season lasts 9.5 months, from August 23 to June 7, with a greater than 15% chance of a given day being a wet day. The chance of a wet day peaks at 22% on October 3.

The drier season lasts 2.5 months, from June 7 to August 23. The smallest chance of a wet day is 8% on July 13.

Among wet days, we distinguish between those that experience rain alone, snow alone, or a mixture of the two. Based on this categorization, the most common form of precipitation throughout the year is rain alone, with a peak probability of 22% on October 3.

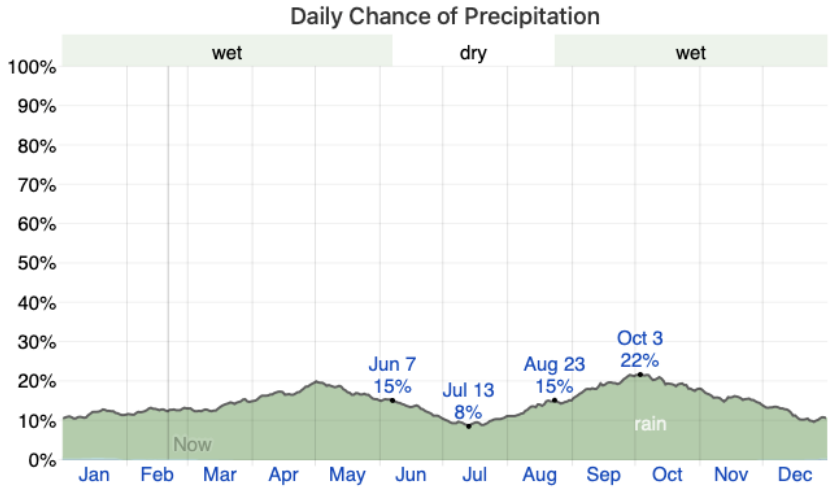


Figure 53: The percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed (both rain and snow fell in the same day).

- **Solar Energy**

This section discusses the total daily incident shortwave solar energy reaching the surface of the ground over a wide area, taking full account of seasonal variations in the length of the day, the elevation of the Sun above the horizon, and absorption by clouds and other atmospheric constituents. Shortwave radiation includes visible light and ultraviolet radiation.

The average daily incident shortwave solar energy experiences extreme seasonal variation over the course of the year.

The brighter period of the year lasts for 3.2 months, from May 7 to August 15, with an average daily incident shortwave energy per square meter above 6.5 kWh. The brightest day of the year is July 5, with an average of 7.6 kWh.

The darker period of the year lasts for 3.5 months, from October 25 to February 12, with an average daily incident shortwave energy per square meter below 3.1 kWh. The darkest day of the year is December 17, with an average of 2.0 kWh.

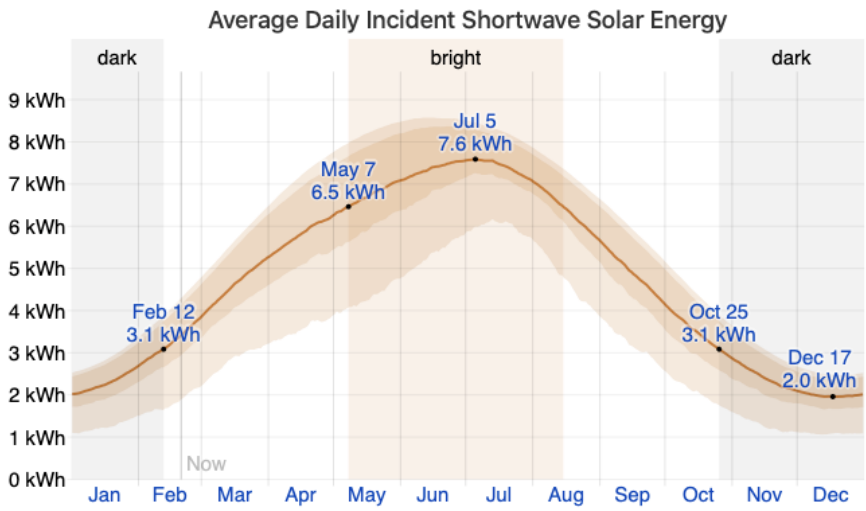


Figure 54: The average daily shortwave solar energy reaching the ground per square meter (orange line), with 25th to 75th and 10th to 90th percentile bands.

4.3 Building geometry and use

The demo site building is divided in two structural areas, of approximately 1,000 m² each, as it was constructed in two stages. While the roof constructed in the first stage is leaning, the roof of the second stage is flat and represents a potential place where installing solar collectors.

Figure 55: Demosite bulding 3D view from the South

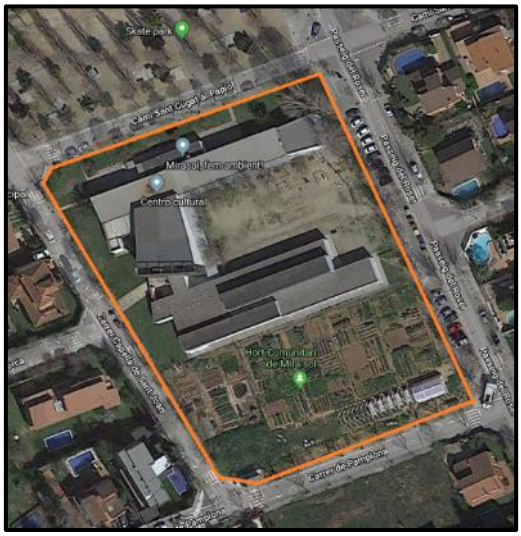


Figure 56: Demosite building top view

The extension of the civic center is placed in the southern part of the plot, closing with a third volume the open patio of the existing building. In this way, the floor of the building goes from an "L" shape to a "U" shape, defining two very different courtyards. The first enclosure, of a different nature, and the second more open, of a more playful and dynamic nature, which, if necessary, can also be closed.

The extension becomes a new facade to the south, which seeks to take advantage of this good orientation to improve the interior-exterior of the building, enhancing the cultural and leisure activities of the center.

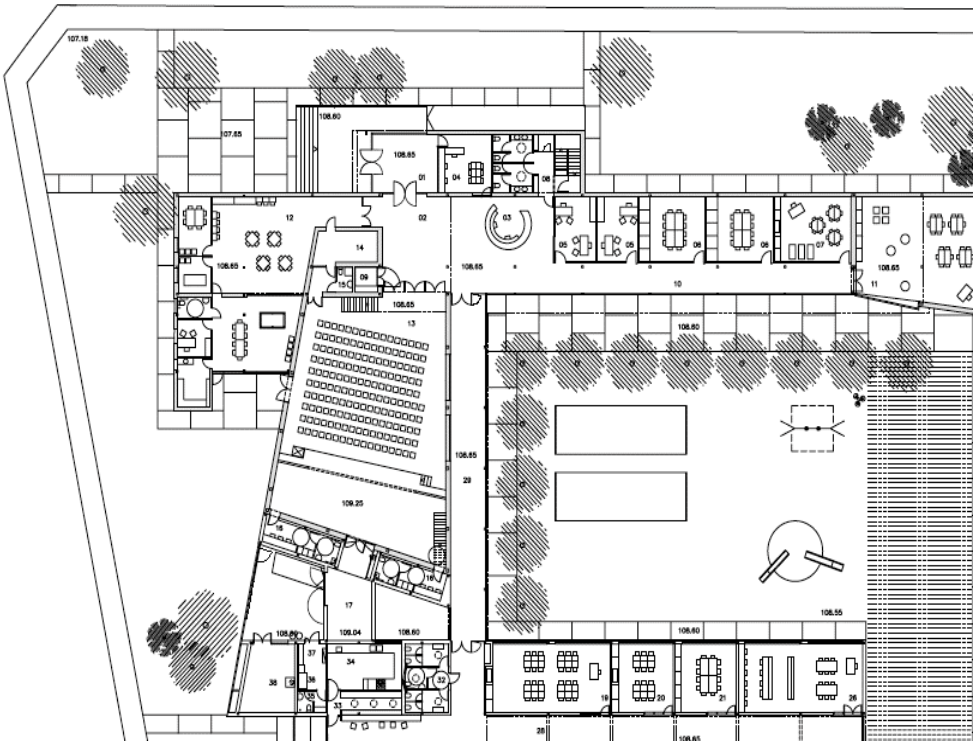


Figure 57: Distribution of the diferents areas at Sant Cugat civic center

The demo site area involves only one section of the entire building, as represented in Figure 58, the most recent one built in 2006. The building structures have the following properties:

Table 11: Construction type description for Sant Cugat

Construction Type	Name	Area m²	U-Value (W/M².K)	G-Value
External Wall	SC_External_wall	412.57	0.25	-
Roof	SC_Roof	96.85	0.33	-
Exposed Floor	SC_Exposed_floor	853.85	0.22	-
Door	2013 Door	26.34	2.17	-
Internal Ceiling/Floor	SC_Internal_ Ceiling/Floor	378.73	3.4	-
Internal Partition	SC_Internal_Partitions	497.77	1.08	-
External Window	SC_External_Window	284.62	1.9	0.41

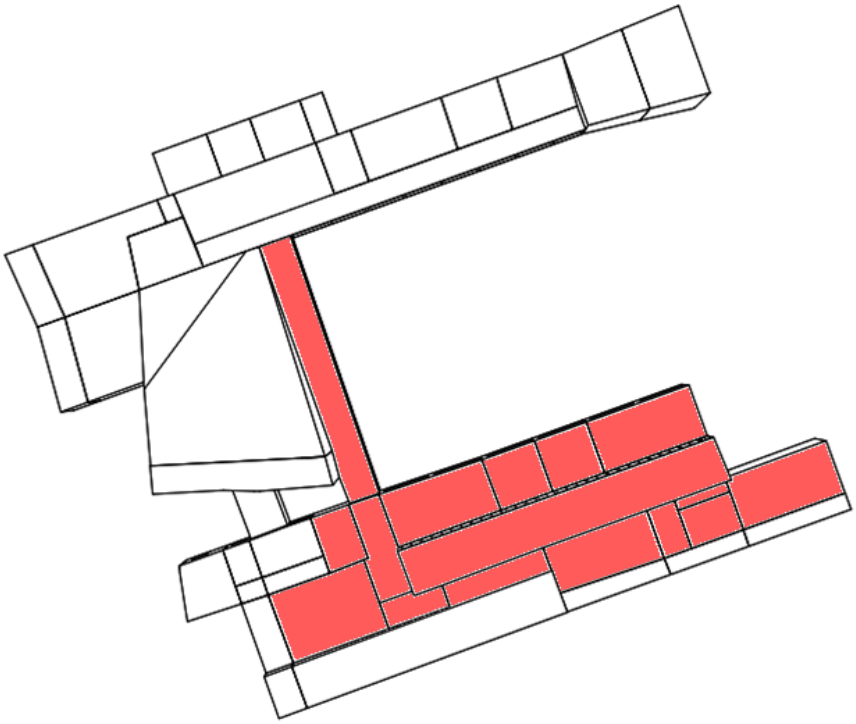


Figure 58: Part of the building considered as conditioned spaces during the energy model creation

The red portion of the building is the one served by the existing heating and cooling system. The total floor area for the portion of the building served by the heating and cooling system is of about 816 m^2. The total floor area in the model for the part of the building considered is of about 806 m^2 indicating a quite accurate reproduction of the geometry and conditioned spaces of the building, the evaluated total net volume for space conditioning is of about 3400 m^3. IESVE underlined the presence of slight mismatch between measures definition in the energy model and measures indicated and considered for the evaluation of heating and cooling load in the executive project provided by the demo-site owner. Those small differences are due to small variations of the geometry during the process of model creation due to the way inner volumes voids and plenum are considered in the energy model and approximated to the actual surface. A 3D model was built in IESVE environment (Figure 59)

Figure 59: comparisons between actual geometry of the building and its digital representation

The use of actual schedules of operation of the building is reported below. These schedules of operation have been gathered directly from a survey of the building. It should be noted that those schedules are not the operative schedules of the building. A data analysis procedure has been carried out on the BMS data from Veolia in iSCAN to identify the actual schedules of operation of the AHU and therefore create profiles of operation to be used in VE.

Schedules have been modified considering the actual data from the building derived from a survey. The following schedules have been used in an updated version of the energy model:

- 8-14h; 16-22h (from Monday to Friday)
- 10-13:30h; 16-20h (Saturday)
- 16-22h (Sunday)

Those schedules have been identified as the most frequent for the operation of the building although there is not distinction between summer and winter periods. As regard the heating and cooling operation period, they have been set as suggested by the Sant Cugat municipality:

- Heating: from 1st January to 1st April and from 1st November to 31st December
- Cooling: from 1st June to 1st October

Table 12 provides a description of the expected occupancy in the building during different times of operations. An additional analysis was carried out on the data from the BMS operated by Veolia in the building. In particular, return temperatures of the AHU during the year 2019 were considered for the evaluation of both operational schedules of the building and an estimation of the temperature set-points of the rooms in the building. This underlined some differences between the data extracted from the survey and D6.1 and the actual operation of the building. It is evident that for weekdays during the heating season (November 2019) the AHU operates from 5.30 am to 8.30 pm. For weekends it operates from 5.30 am to 6 pm for Saturdays and from 10 am to 8pm for Sundays (from December 2019). Return temperature during weekends after 6 pm follow a descendent trend with slight slope. This may indicate that the building is still occupied although the heating system is not operated. The survey indicates that an average of 40-70 people may be still present in the building for that time of the day. AHU operation may be changed to maximize comfort of the people in the building during this time of operation. The return air temperature suggests a set-point is 21˚C for the heating season.

From the analysis of the data, the following schedules of operation have been used for the building.

- 5.30-20h (from Monday to Friday)
- 5.30-18h (Saturday)
- 10-20h (Sunday)

It should be noted that operational data during summer time and cooling season is not available from the BMS of the building for this reason the same schedules as in winter time have been used.

Table 12: occupancy schedule from building survey

	Hall / Events Room	Exhibition Room	Dance and movement 1	Music Classroom 1	Music Classroom 2	Warehouse training room	Dance and movement 2	Civic centre direction Office	Local entities Room	Workshop Room	Main corridor	Hall	Connecting corridor	Bathrooms
8-14h (from Monday to Friday)	20	5	5	2	2	0 (20 people in 2020-2021)	10	2	4	8	2	1	1	1
16-22h (from Monday to Friday)	60	10	10	2	2	0 (10 people in 2020-2021)	10	2	4	8	2	1	1	1
10-13:30h (Saturday)	20	5	5	2	2	0	10	1	4	8	2	1	1	1
16-20h (Saturday	40	10	10	0	0	0	5	0	2	4	1	1	1	1
16-21h (Sunday)	30	5	5	0	0	0	0	0	0	0	0	0	0	0

Regarding the program of the existing building, the theatre and the senior citizens' area will keep the same scheme of operation but instead will change the use of the area where all the workshops are currently located.

Therefore, the current concierge will be eliminated and transformed into a multifunctional office (04-image above). The same toilets (08) will be maintained. The current workshops will have the following functions: offices for Social Services and SOM (05), support rooms for organizations (06), children's playground (07) and the current multifunctional room will host the library (11).

The multifunctional room will be intervened to improve and enhance its operation. New locker rooms (16) with direct access to the theatre 'scenario, showers and toilets, a new store (17) with sufficient height for the scenario and direct access to the street through the service yard will be constructed. Alternative routes will be built for improve accessibility and removal of architectural barriers on the theatre.

The areas of the building where the SunHorizon system is to be installed include the following areas:

	Description	Num	Surface (m^2)	Total surface (m^2)
MULTIFUNCIONAL ROOM EXTENSION				
16	Dressing room	2	12,30	24,60
17	Store	1	32,45	32,45
18	Room	1	1,05	1,05
TRAINING AND LEARNING CHILDREN AND ADULTS				
19	Expression classroom 2	1	64,40	64,40
20	Civic center direction office	1	32,20	32,20
21	Local entities and collectives' room	1	32,20	32,20
22	Expression classroom	1	64,40	64,40
23	Music classroom	1	15,45	15,45
24	Music classroom	1	23,10	23,10
25	Youth area	1	64,00	64,00
COMMUNE AREAS				
26	Big workshop	1	64,25	64,25
27	Exhibition hall	1	64,00	64,00
28	Multi-use space	1	149,45	149,45
29	Exhibition corridor	1	106,80	106,80
30	Meeting area		9,70	9,70
BAR-LIVE PERFORMANCE				
31	Events room /Assembly hall	1	105,60	105,60
32	Toilets	1	23,55	23,55
33	Warehouse	1	16,60	16,60
34	Warehouse	1	29,85	29,85
35	Dressing room	1	4,60	4,60
36	Cold store	1	2,15	2,15
37	Pantry	1	4,40	4,40
38	Installations	1	25,10	25,10
Total useful area building extension				**959,90**
Total useful area porch extension				**169,10**

- **Working hours and occupancy**

Occupancy has been estimated based on the surface of each area, considering the square meters per person typical for the type of activity that takes place in it.

The occupancy in each zone are described in the following table:

Area	Activity	Num . pers.	m² per pers.	Cs (w)	Cl (w)	Working hours
Ground floor	-	-	-	-	-	-
Expression classroom 2	Classrooms	25	2,6	90	95	6-18h
Civic center direction office	Office	12	2,7	90	95	6-18h
Local entities and collectives' room	Office	12	2,6	90	95	6-18h
Big workshop	Workshops in educational centers	25	2,6	60	40	6-18h
Exhibition hall	Exhibitions	15	4,3	90	95	6-18h
Expression classroom	Classrooms	25	2,5	90	95	6-18h
Music classroom 1	Classrooms	10	1,6	60	40	6-18h

Area	Activity	Num . pers.	m² per pers.	Cs (w)	Cl (w)	Working hours
Music classroom 2	Classrooms	10	2,3	60	40	6-18h
Youth area	Workshops in educational centers	26	2,5	90	95	6-18h
Exhibition corridor	Exhibitions	30	5,2	90	95	6-18h
Events room /Assembly hall	Assembly halls, conference rooms.	60	2,2	60	40	6-18h
Theatre zone	-	-	-	-	-	-
Theatre	Auditoriums, assembly halls, theatres, cinema, conference rooms, television studios	175	1,7	60	40	6-18h
Theatre toilet 1	Typical occupancy	1	11,9	142	283	6-18h
Theatre toilet 2	Typical occupancy	2	6,8	142	283	6-18h

Cs: Sensitive heat in w contributed by person at ambient temperature (25°C).

Cl: Latent heat in w contributed by person at ambient temperature (25°C).

- **Ventilation**

Ventilation air flow is obtained based on the use of the room, its surface and the number of occupants, using Table 2 of the standard UNE 100011.

The ventilation levels assigned to each zone are showing in the following table:

	OUTDOOR AIR FLOW					
Area	Per person (l/s)	Per m² (l/s)	Per room/others (l/s)	Chosen value (m³/h)	Renov. (1/h)	Working hours
Ground floor	-	-	-	-	-	-
Expression classroom 2	10,0	3,0	-	720,0	3,7	6-18h
Civic center direction office	10,0	3,0	-	345,0	3,6	6-18h
Local entities and collectives room	8,0	-	-	345,0	3,6	6-18h
Big workshop	8,0	-	-	720,0	3,7	6-18h
Exhibition hall	8,0	4,0	-	432,0	2,3	6-18h
Expression classroom	8,0	-	-	720,0	3,8	6-18h
Music classroom 1	8,0	-	-	288,0	6,0	6-18h
Music classroom 2	8,0	-	-	288,0	4,2	6-18h
Youth area	10,0	3,0	-	750,0	3,8	6-18h
Exhibition corridor	8,0	4,0	-	900,0	1,1	6-18h
Assembly hall/Events room	12,0	12,0	-	1.728,0	4,3	6-18h
Theatre zone	-	-	-	-	-	-
Theatre	12,0	-	-	5.760,0	3,9	6-18h

	OUTDOOR AIR FLOW					
Area	**Per person (l/s)**	**Per m² (l/s)**	**Per room/others (l/s)**	**Chosen value (m³/h)**	**Renov. (1/h)**	**Working hours**
Theatre toilet 1	10,0	2,5	-	107,1	3,0	6-18h
Theatre toilet 2	10,0	2,5	-	123,3	3,0	6-18h

Evolution of the percentage of operation throughout the day for each hour:

Reference								Percentage of gains for each solar hour															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Working hours 6-18h																							
0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0

- **Primary closure**

Considering that the rainfall in the area is less than 600 mm, the roofs can be flat. The option has been taken to solve the cover by a cover formed by a galvanized profiled sheet, e: 0.8mm, height 40mm on which the NTIG system is placed, which consists of 40mm Roofmate insulation, Rhenofol cg PVC waterproof sheet, 40mm Roofmate insulation and Feltemper 150 P geotextile, finishing with 60mm round edge gravel and 40Kg / m² border.

The two roofs that rise above the rest of the building, forming the porch and the skylight of the multifunctional room, will be solved with a lightweight cover system consisting of galvanized sheet metal sandwich panels, e: 60mm, Aspersa type, geotextile and coating with glued zinc trays type VM Zinc.

The roof linking the extension building to the existing building will use this second type of roof described above.

Both decks are supported by their corresponding horizontal and vertical padding boards and veneers and include the relevant overhangs on the facade.

The façade closures will basically be GRC (Glass Reinforced Concrete) panels, and gero closures with basalt stone cladding and the facade sandwich panels covered with RAL 9007 mini-wave sheet. The annexed installations to the multifunctional room will have closures of mini-wave sheet metal stamped and in its storage wall of gero and monolayer.

Concrete panels and fiberglass shavings are 10cm thick. They incorporate 8cm of polystyrene insulation and are fastened to the bearing structure by stainless-steel fasteners. They can be grooved or smooth. The panel-to-panel tolerances will be a maximum of 2cm, the sealing will be done using bottoms with foam round and special mastic for prefabricated facades. All of them will be painted white on the basis of silicate paint preparation. The panels must be approved and have the DIT (*Document d'Idoneïtat Tècnica*).

The facades with basalt stone will be formed by gero wall of e: 14cm, plastered of type I, e: 4cm, type I basil 60x40cm.

The facades with mini-wave sheet are made up of sandwich panel for façade with polyurethane insulation, Rockacier solderable type e: 40mm, mini-wave sheet PL-18-76, e: 0.8mm, painted RAL9007 and fixed with omega 30mm galvanized steel profiles.

The central skylight will have a facade formed by Mecano type curtain wall and will incorporate PVC drainpipes.

The facades of the installation consist of a plate with mini-wave PL-18-76, e: 0.8mm, stamped, painted galvanized steel and lacquered color RAL9007, which is fixed to the metal structure by steel profiling based on omegas or zetas.

Inside and coating the metal structure will be simple 15mm waterproof plasterboard on a support structure, embedded in the pillars, which will incorporate high density rock wool.

- **External closures**

The facade of the building will have three types of finishes: The majority, with a GRC type prefabricated panel with a smooth finish, white painted on a silicate paint preparation base, and two layers of anti-graffiti paint.

Occasionally, gero closures with a type I basalt stone, 60x40cm and the painted and lacquered sheet metal RAL9007.

Finally, the installation is also finished with RAL9007 painted and lacquered mini-wave sheet and the warehouse walls are monolayer, white.

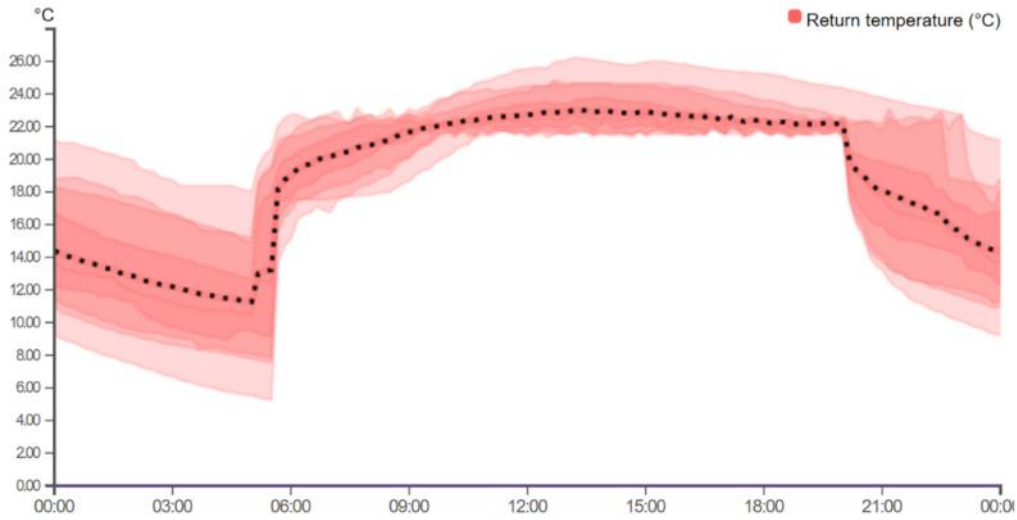


Figure 60: AHU Return air temperatures overlay during weekdays of November 2019

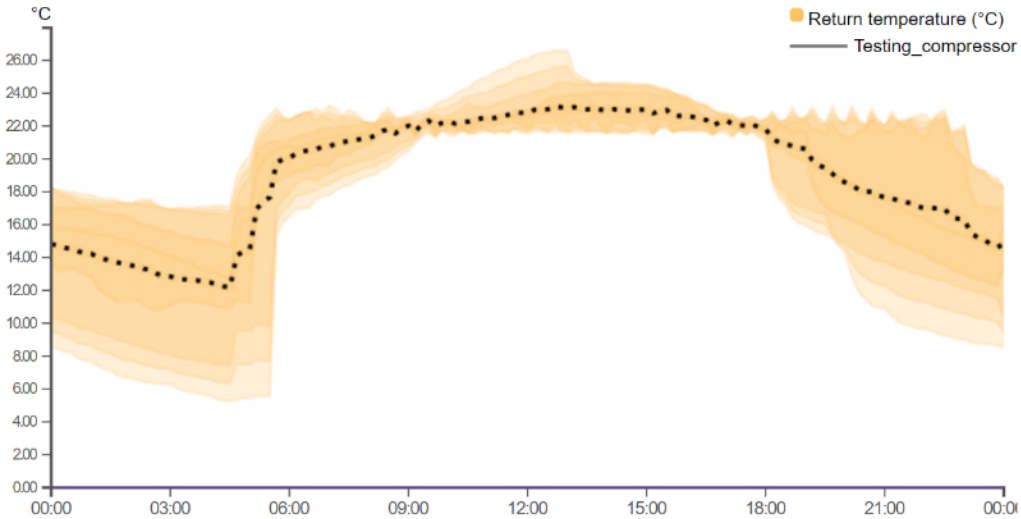


Figure 61: AHU Return air temperatures overlay during weekend (Saturday) of November 2019

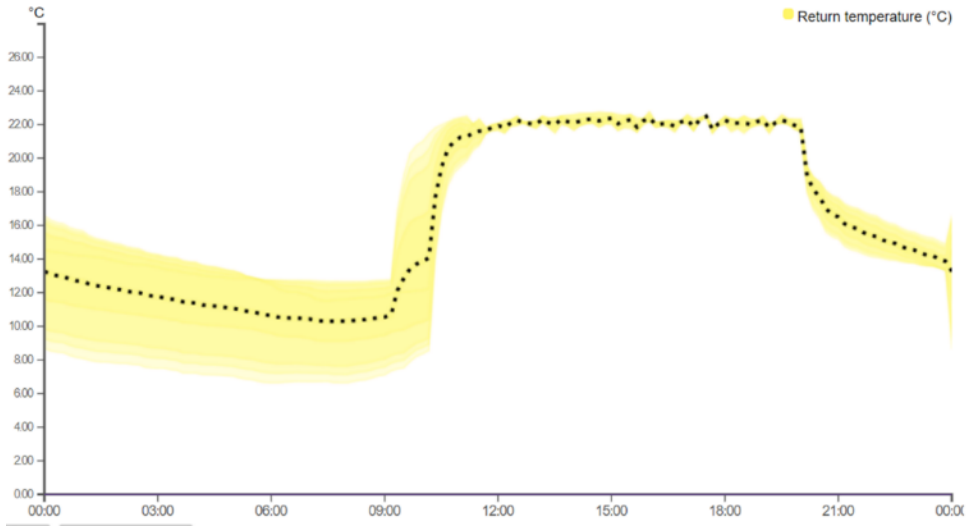


Figure 62: AHU Return air temperatures overlay during weekend (Sunday) of December 2019

- **Thermal zones in Sant Cugat demo site (Mira-sol Civic Center).**

According to the following figure, the different thermal zones are described below:

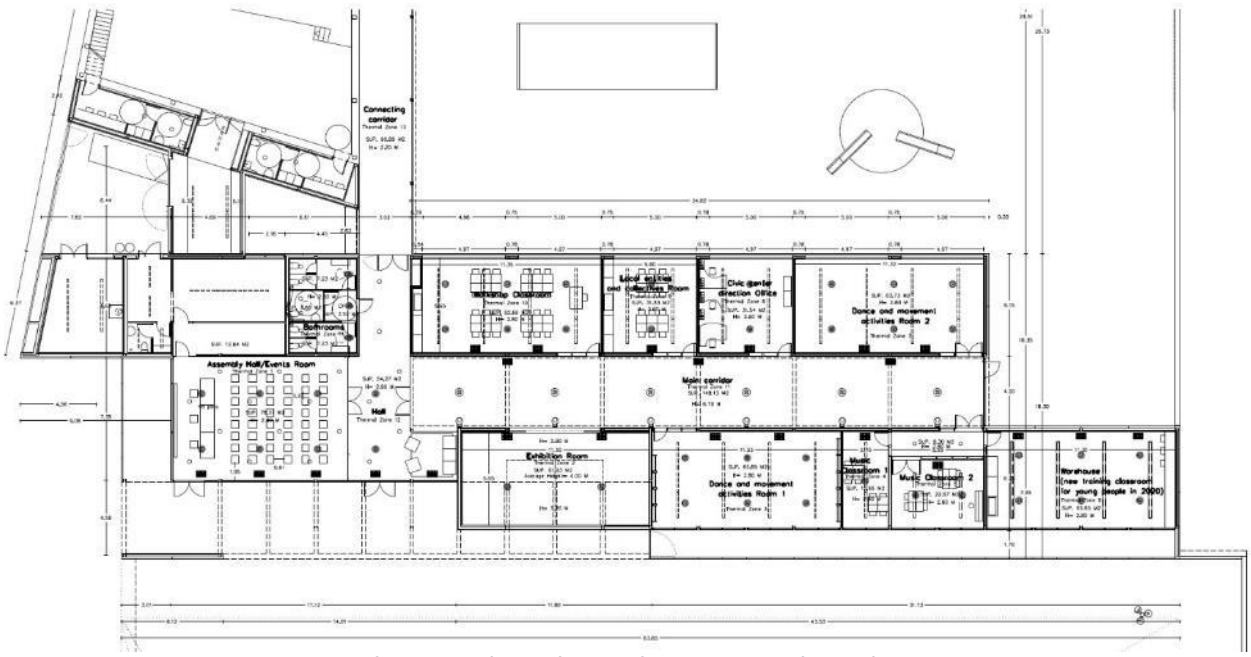


Figure 63: Thermal zones in Sant Cugat demo site

<u>Thermal zone 1 (Assembly Hall / Events Room):</u>

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 20 people
  - 16-22h (from Monday to Friday): 60 people
  - 10-13:30h (Saturday): 20 people
  - 16-20h (Saturday): 40 people

- 16-21h (Sunday): 30 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 219.44 m3

- external wall types and characteristics
  Material: windows of double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Area: 50.62 m2

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 7
  Area: 50.62 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 2 (Exhibition Hall):

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 5 people
  - 16-22h (from Monday to Friday): 10 people
  - 10-13:30h (Saturday): 5 people
  - 16-20h (Saturday): 10 people
  - 16-21h (Sunday): 5 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 247.72 m3

- external wall types and characteristics
  Material: (cavity wall): Plasterboard partition + Internal insulation + cavity + hollow brick wall + natural stone cladding
  Thickness: 0.3 m
  U value: 0.45 W/m2-k
  Position of insulation: indoor
  Area: 40.85 m2

- windows types and characteristics, number, area

Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
G value: 3.1 W/m2-k
Number: 12
Area: 16.41 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 3 (Expression Room 1):

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 5 people
  - 16-22h (from Monday to Friday): 10 people
  - 10-13:30h (Saturday): 5 people
  - 16-20h (Saturday): 10 people
  - 16-21h (Sunday): 5 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 184.38 m3

- external wall types and characteristics
  Material: windows of double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Area: 31.72 m2

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 4
  Area: 31.72 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 4 (Music Classroom 1)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 2 people
  - 16-22h (from Monday to Friday): 2 people
  - 10-13:30h (Saturday): 2 people
  - 16-20h (Saturday): 0 people
  - 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 43.85 m3

- external wall types and characteristics
  Material: windows of double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Area: 7.53 m2

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 1
  Area: 7.53 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 5 (Music Classroom 2)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 2 people
  - 16-22h (from Monday to Friday): 2 people
  - 10-13:30h (Saturday): 2 people
  - 16-20h (Saturday): 0 people
  - 16-21h (Sunday): 0 people

- Comfort air temperature schedule requirements:
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 63.48 m3

- external wall types and characteristics
  Material: windows of double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Area: 15.48 m2

- windows types and characteristics, number, area

  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"

G value: 3.1 W/m2-k
Number: 2
Area: 15.48 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 6 (Current Warehouse. New training classroom for Young people in 2020)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 0 people (20 people in 2020-2021)
  - 16-22h (from Monday to Friday): 0 people (10 people in 2020-2021)
  - 10-13:30h (Saturday): 0 people
  - 16-20h (Saturday): 0 people
  - 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 183.82 m3

- external wall types and characteristics
  Material: Grass Reinforced Concrete
  Thickness: 0.3 m
  U value: 0.24 W/m2-k
  Position of insulation: indoor
  Area: 47.88 m2

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 4 + 1
  Area: 31.58 m2 + 3.96 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 7 (Expression Room 2)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 10 people
  - 16-22h (from Monday to Friday): 10 people
  - 10-13:30h (Saturday): 10 people

- 16-20h (Saturday): 5 people
- 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 178.44 m3

- external wall types and characteristics
  Material: Glass Reinforced Concrete
  Thickness: 0.3 m
  U value: 0.24 W/m2-k
  Position of insulation: indoor

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 2
  Area: 13.42 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 8 (Civic center direction Office)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 2 people
  - 16-22h (from Monday to Friday): 2 people
  - 10-13:30h (Saturday): 1 people
  - 16-20h (Saturday): 0 people
  - 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 88.31 m3

- external wall types and characteristics
  Material: Glass Reinforced Concrete
  Thickness: 0.3 m
  U value: 0.24 W/m2-k
  Position of insulation: indoor

- windows types and characteristics, number, area

Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
G value: 3.1 W/m2-k
Number: 1
Area: 6.71 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 9 (Local entities and collectives Room)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 4 people
  - 16-22h (from Monday to Friday): 4 people
  - 10-13:30h (Saturday): 4 people
  - 16-20h (Saturday): 2 people
  - 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 88.28 m3

- external wall types and characteristics
  Material: Glass Reinforced Concrete
  Thickness: 0.3 m
  U value: 0.24 W/m2-k
  Position of insulation: indoor

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 1
  Area: 6.71 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 10 (Workshop Room)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 8 people
  - 16-22h (from Monday to Friday): 8people
  - 10-13:30h (Saturday): 8 people

- 16-20h (Saturday): 4 people
- 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 175.45 m3

- external wall types and characteristics
  Material: Glass Reinforced Concrete
  Thickness: 0.3 m
  U value: 0.24 W/m2-k
  Position of insulation: indoor

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 2
  Area: 13.42 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 11 (Exhibition corridor)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 2 people
  - 16-22h (from Monday to Friday): 2 people
  - 10-13:30h (Saturday): 2 people
  - 16-20h (Saturday): 1 people
  - 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 991.47 m3

- external wall types and characteristics
  Material: windows of double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k

- windows types and characteristics, number, area
  Skylights:
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"

G value: 3.1 W/m2-k
Number: 72
Area: 207 m2
Windows:
Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
G value: 3.1 W/m2-k
Number: 2
Area: 9.02 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 12 (Hall)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 1 people
  - 16-22h (from Monday to Friday): 1 people
  - 10-13:30h (Saturday): 1 people
  - 16-20h (Saturday): 1 people
  - 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 151.96 m3

- external wall types and characteristics
  Material: windows of double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 3
  Area: 18.40 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 13 (Connecting corridor)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 1 people
  - 16-22h (from Monday to Friday): 1 people

- 10-13:30h (Saturday): 1 people
- 16-20h (Saturday): 1 people
- 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 199.96 m3

- external wall types and characteristics
  Material: windows of double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 6
  Area: 63.07 m2

- ventilation type and characteristics
  Mechanical ventilation.
  System in place (AHU: Air handling Unit):

Thermal zone 14 (Bathrooms)

- Occupancy: 8-14h; 16-24h (from Monday to Friday). 10-13:30h; 16-20h (Saturday). 16-21h (Sunday).
- Occupancy pattern:
  - 8-14h (from Monday to Friday): 1 people
  - 16-22h (from Monday to Friday): 1 people
  - 10-13:30h (Saturday):1 people
  - 16-20h (Saturday): 1 people
  - 16-21h (Sunday): 0 people

- comfort air and water temperatures schedule requirements,
  Normative comfort air temperature requirement in winter: 21ºC
  Real comfort air temperature in building: 22-23ºC, because some activities need higher comfort air temperature.
  Normative comfort air temperature requirement in summer: 26ºC
  Real comfort air temperature in building: 24-25ºC, because some activities need lower comfort air temperature.

- heated/cooled area, volume 60.54 m3

- external wall types and characteristics
  Material: Glass Reinforced Concrete
  Thickness: 0.3 m
  U value: 0.24 W/m2-k
  Position of insulation: indoor
  Area: 12.18 m2

- windows types and characteristics, number, area
  Glazing type: double glazing (3+3/8/3+3). TECHNAL "TOPAZ GT"
  G value: 3.1 W/m2-k
  Number: 0
  Area: 0 m2

- ventilation type and characteristics
  Mechanical ventilation: exhaust fans (air flow: 100 m3/h)
  System in place (AHU: Air handling Unit):

4.4 Heating/cooling system with heat, cold and DHW distribution

The centre has a 50 m^2 outdoor technical room, where is now installed the heat pump, with enough free surface for installing additional equipment. Additionally, as displayed before, the building has available a large roof where installing solar collectors. See the roof characteristics in the following picture:

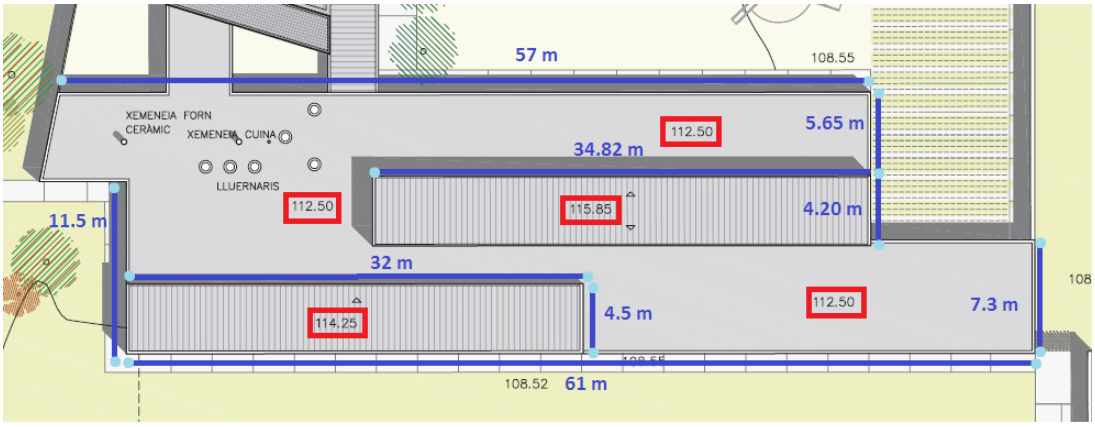


Figure 64: Roof characteristics

Currently, the heating and cooling installation is formed by the following equipment:

Reversible air to water heat pump: 93.6 kW (cooling capacity) – 96.3 (heating capacity) **Air handling unit:** 110 kW (cooling capacity) – 67.78 (heating capacity) **2 x split air conditioner:** 2.1 kW (cooling capacity) – 3 (heating capacity)

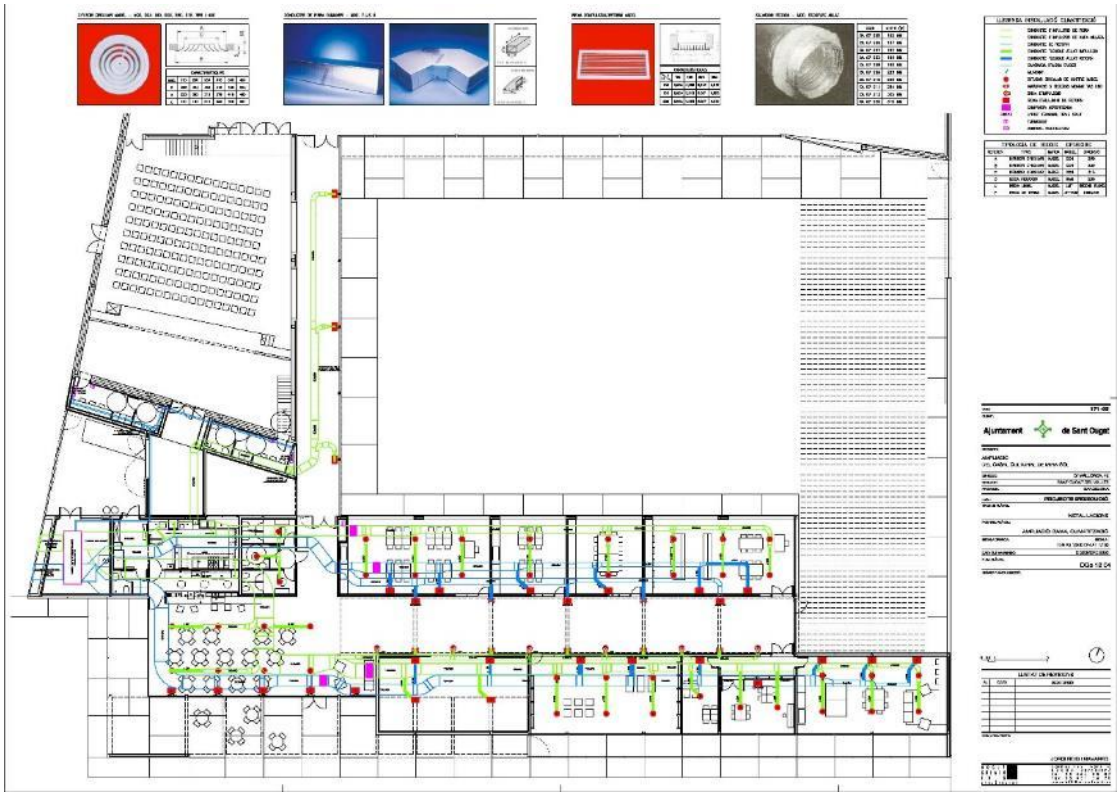


Figure 65: Planimetry of air distribution system

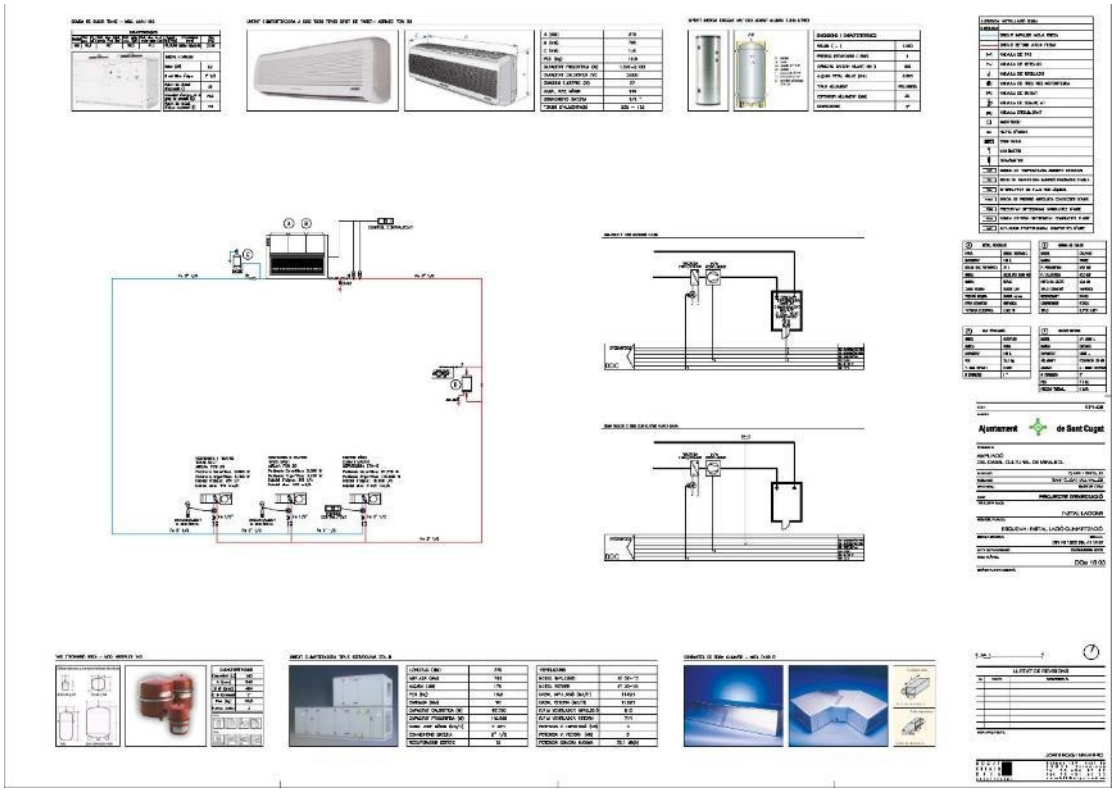


Figure 66: P&ID of the heating and cooling plant

Heat Pump	Service	(heating / DHW / cooling)	heating/cooling
	Fuel type	(text)	Electricity
	Size	(kW)	93,9
	Type / Model	(text)	Climaveneta NECS-N/LN 0412
	Installed in	(year)	2009
	Thermal efficiency	(%)	Electricity
	Backup installed	(yes/no)	no
	Operating mode (on/off, modulating, etc)	(text)	on/off
	Available metered point (temperature, flow rate, frequency, etc)	(yes/no)	no
	Data available online through API or similar	(yes/no)	no
VRV Heating and cooling systems	Service	(heating / DHW / cooling)	heating/cooling
	Fuel type	(text)	Electricity
	Size	(kW)	35
	Type / Model	(text)	1 Hitachi (RAS-12)
	Installed in	(year)	2007
	Energy source	(text)	Electricity
	Backup installed	(yes/no)	NO
	Backup efficiency	(yes/no)	NO
	Operating mode (on/off, modulating, etc)	(text)	modulating
	Available metered point (temperature, flow rate, frequency, etc)	(yes/no)	no
	Data available online through API or similar	(yes/no)	no

Table 13: Heating and cooling system characteristics

- **Heating and cooling production**

A heat pump with the following characteristics has been installed:

Reversible air-water heat pump, silenced model, for compression with axial fans, with the following characteristics: heating capacity 96.3 kw (outside air temp. 7°C, hot water output at 45°C), cooling capacity 96.3 kw (outside air temp. 35 ºC, cold water outlet 7 ºC) equipped with three compressors. Total unit weight of running unit 2149 kg. dimensions 3200x1100x2436 mm. side suction unit, vertical discharge, weather type. Equipped with a hydraulic module composed of a 410-liter buffer tank, a 25-liter expansion vessel and a double pump for the impulsion.

- **Piping network**

A properly insulated black iron pipe has been used to distribute the water intended for supplying the air conditioning pairs. There are a single distribution circuit to power the 3 terminal units. The hydraulic group mounted inside the heat pump will circulate the water throughout the circuit.

Long horizontal sections should have a slope of 0.5% in the fluid direction, to avoid air bags, and automatic air purifiers will be installed at the high points of the installation.

- **Conducts network**

For the distribution of air, rectangular ducts of rigid glass wool plate have been used for insulation (mw) agglomerated with thermosetting resins (<= 0.033 w / mk) r 25 mm thick and > = 0, 75 m2k / w thermal resistance, with aluminium foil, glass mesh and kraft paper. This conduit has been installed in the ceiling and used for the general distribution of the entire building.

For connection to the plenum of the grates and diffusers, a composite flexible tube with thermal insulation, with an inner double-layer aluminium tube and an inner steel spiral, fiberglass insulation of 25 mm thick and 16 kg / m3 density and reinforced aluminium vapor barrier have been used.

The air distribution in the new connecting corridor between the two buildings has been designed with a galvanized steel sheet rectangular duct, 1 mm thick, mounted underground and insulated with thermal insulation of ducts with elastomeric foam with a thermal conductivity at 0°C of 0.035 w/m°C, 6 mm thick and mounted externally. The insulation will not allow condensations inside the duct and insulates cold and heat losses.

The duct network is subdivided into three differentiated zones by flow regulators (flow and air pressure), to install in rectangular duct of sizes according to duct. They are made of natural finished aluminum and gears in polyamide with a fin of 120 mm parallel to the larger dimension, the shaft will be powered by a microprocessor actuator for gates, 24 VAC feeder and par 10 nm. 2-point control signal and stroke time 120 s, degree of protection IP54. The main area is the bar and corridor area, it always works, then there are two zones that can work independently of each other.

- **Grates and Diffusers**

For the impulsion and return of the air, four types of elements will be used, these are:

- To drive the air in the classrooms and the bar area, circular cone-shaped diffusers with a union joint with the ceiling will be used to guarantee tightness. They will be mounted with plenum for circular connection, the diameter of the diffuser will vary depending on the space to be heated. The mounting will be done on the false ceiling. They will be of the Madel model DCN.
- Long-range spherical diffusers, orientable in all directions, will be used to drive air into the central hallway of the new building. Made of aluminium, these will be from the Madel model KAM-W 250.
- To drive the air from the drive of the connecting corridor between the existing building and the new building, linear aluminium grilles with fixed fins, made of aluminium, will be used. They will be suitable for mounting on technical floors and other applications in areas of traffic and people. These will be from the Madel model LMT-SHD 1000x275.
- Aluminium grilles with fixed fins parallel 1000x100 mm, fixed to the ceiling or wall, with mounting frame and plenum will be installed for the return of the air. They will be of the Madel brand LMT-15 1000x100.

The connecting corridor between the existing building and the new building will not have a return being constantly over pressured.

- **Isolation**

All pipes installed in unheated premises, heat sinks and in outdoor areas will be isolated. The insulation used will be of the type of thermal insulation of elastomeric foam 19 mm thick, with a thermal conductivity at 0°C of 0.035 w/ m°C.

For the galvanized steel sheet rectangular duct insulation, elastomeric foam duct insulation with a thermal conductivity at 0°C of 0.035 w/ m °C, 6 mm thick and mounted externally, will be used. The insulation will not allow condensation inside the duct and will insulate it from cold and heat losses.

- **Fan Coils and Air Conditioners**

Two types of machines will be used to heat the center, these are:

Horizontal fan-coils will be used to wall-mounted, with the maximum refrigerating power of 2100 W and the maximum heat power of 4800 W for the dressing room of the theatre area. Maximum air flow of 440 m³ / h. maximum sound level 51 dba. Dimensions 270x795x178 mm. They will include TLW model liquid crystal viewfinder infrared remote control. These will be of the brand Aermec ref. FCW.

For the building's air conditioning, a horizontal soundproofing system will be installed, with free-cooling and static heat recovery, consisting of a impulsion fan and a return fan of the AT 20-15 model, for an air flow of 11.021 m³ / h and 200 Pa, and a sound power between 79.1 and 76.7 dba respectively. Each of them will have a frequency inverter for a maximum of 4 kw. The water battery will be of the type 16t-1050-7f (for cold) and 16t-1050-7f (for heat), installation in two tubes. It will also have eurovent EU-3 filter for an air flow of 11.021 m³ / h. For the correct renovation of the building's air, a system with three 1000 * 500 mm free-cooling gates for outdoor air, return and extraction will be installed. The dimensions of the air conditioner are 3980 * 1330 * 2360 mm, formed by a special aluminium profile structure and injected aluminium bonding squares, 45 mm thick sandwich panels, made of 1.2 mm lacquered galvanized sheet. thick, fiberglass 60 kg / m2 density for insulation. The air conditioner will be of the Servoclima model CTA-8.

The air conditioning in the building will be located in the technical room, next to the kitchen.

- **Electricity consumption for 2019**

Table 14: electricity consumption monthly profile in 2019

	Electricity consumption [kWh]
December 2018	26.557
January 2019	31.865
February 2019	23.485
March 2019	18.133
April 2019	13402
May 2019	8.937
June 2019	16.293
July 2019	20.687
August 2019	5.897
September 2019	12.799
October 2019	10.182
November 2019	19.870
2019 TOTAL	**208.107**

4.5 Specific requirements for the new heating/cooling system

The specific requirements for the new heating and cooling system are:

- Admissible mechanical load (static and dynamic) on the roof for TVP panels and the dry cooler of the FAHR unit
- Regulatory compliance of the following laws:
  - Low Voltage Electrotechnical Regulation (REBT), according to RD 842/2002 of 02/08/2002, and specifically the Complementary Technical Instructions.
  - Royal Decree 1027/2007, of July 20, which approves the Regulation of Thermal Installations in Buildings (RITE).
  - Complementary Technical Instructions called ITE. (Ministerial Order of July 31, 1998).
  - Others: Municipal ordinances, Fire Prevention Ordinance, UNE rules of mandatory compliance, and Ordinance on safety and hygiene at work.

4.6 Preliminary monitoring plan

4.6.1 Pre-monitoring plan of the existing building and heating/cooling system

Since Sant Cugat building has been selected as one of the SunHorizon demo sites for the hybrid controller deployment (to be developed in WP5), a pre-monitoring strategy has been developed for this building in order to collect the data required for refining the energy baseline. It will involve installation of a set of sensors defined within WP4 for monitoring of indoor and outdoor conditions, occupancy, heat demand and electricity consumption. The list of sensors selected for pre-monitoring is listed in **Error! Reference source not found.**.

Figure 67 shown the position of sensors in Sant Cugat demo site in the different rooms, and Figure 68 the communication protocol with these indoor sensors installed within the building.

Table 15 List of sensors and monitoring technology

		Number of floors	Technology Package		
DEMO SITE 3 - Location: SANT CUGAT, civic centre		1	TVP+FAHR		
#	**Data to be monitored**	**Technology or place where the installation/interface is required**	**SE Comments / Solution**	**Number of components**	
1	Brightness / motion	INDOOR - ROOMS	brightness+motion sensor	1 / room	10 rooms (9 classes, 1 for events, 1
2	Windows status	INDOOR - ROOMS	Window contact	1 / window	to be installed on the 10 big
3	Occupant presence	INDOOR - ROOMS	already included in 1	already included in 1	
4	CO2	INDOOR - ROOMS	CO2 sensor (measuring T and RH, wired component)	1 / room	10 rooms or one in the corridor only (in the worst case if not possible to bring cables around or we do not have budget)
5	Humidity	INDOOR - ROOMS	T and RH sensor	1 / room only f not	9 rooms (only if not installing the
6	Air Temperature	INDOOR - ROOMS	already included in 4 or 5	already included in 4 or 5	
7	Ext: T, RH, Global Radiation, Cloud Coverage, Wind	OUTDOOR	KNX Weather station	1	roof or on the wall exposed to South
8	Thermal Energy production of H/C	EXISTING H/C SYSTEM INLET OUTLE	Clamp Thermal energy meter on the existing HP	1	Between inlet and outlet of the HP before the collector - the same is commuting during summer for the cooling
9	Electric Energy consumption for H/C	EXISTING H/C SYSTEM MAIN SWITC	Modbus RTU Electric meter on the HP power supply	1	three-phase
10	Temperature	RT TANK	To establish the communication with the master controller RT Storage Tank controller (Modbus? Master or slave? Is the only point of connection with TP?)		
11	Electric Energy consumption (I,V,kWhel) - Total	ELECTRIC CABINET	Modbus RTU Electric meter on the main of the floor	1	
12	Electric Energy consumption (I,V,kWhel) - Detailed from systems and appliances	ELECTRIC CABINET	Power Tag Electric meter on the main switches of interest (they work with SE circuit breakers	?	
13	Electric Energy Consumption (I,V,kWhel) - TVP	TVP COMPONENTS SWITCHES	Modbus RTU Electric meters on the main	1	
14	TVP Thermal Energy production	TVP	Is the energy production already measured and	-	-
15	Operating Status, alarms	TVP	To establish the communication with the TVP controller	-	-
16	Inlet-Outlet Pressure	TVP	Is the pressure already measured and itegrated in TVP controller?	-	-
17	Hot water circuit: inlet and outlet temperature	Measured in Technology Package	To establish the communication with the master		
18	Hot water circuit: inlet and outlet pressure	No need			
19	Hot water circuit: flow rate	Measured in Technology Package	To establish the communication with the master		
20	Chilled water circuit: inlet and outlet temperature	Measured in Technology Package	To establish the communication with the master		
21	Chilled water circuit: inlet and outlet pressure	No need			
22	Chilled water circuit: flow rate	Measured in Technology Package	To establish the communication with the master		
23	Re-cooling circuit: inlet and outlet temperature	Measured in Technology Package	To establish the communication with the master		
24	Re-cooling circuit: inlet and outlet pressure	No need			
25	Re-cooling circuit: flow rate	Measured in Technology Package	To establish the communication with the master		
26	Total electric consumption	HP ELECTRIC CABINET	3-phase electricity meter		
27	Pumps electric consumption	HP ELECTRIC CABINET	single phase electricity meter		
28	Compressor electric consumption	HP ELECTRIC CABINET	3-phase electricity meter		
29	Re-cooler electric consumption	HP ELECTRIC CABINET	3-phase electricity meter		

Additional Equipment
Gateway bidirezionale EnOcean
Repeater Enocean
SpaceLYnk
Case
Router VPN
AS-P + PS
Power Supply components

Figure 67: Position of sensors in Sant Cugat demo site

Figure 68 Wireless communication(Zigbee) with the indoor sensors to the main room controller. The later one communicates via BACNET with the EcoXtructure platform

4.6.2 Preliminary monitoring plan for SunHorizon performance

The following schematics summarizes the preliminary monitoring architecture of Sant Cugat, the number of sensors and variables to be monitored. Figure 69 shows the sensors defined within WP4 to monitor SunHorizon system's performance. All will be integrated within the monitoring architecture, showed in Figure 70.

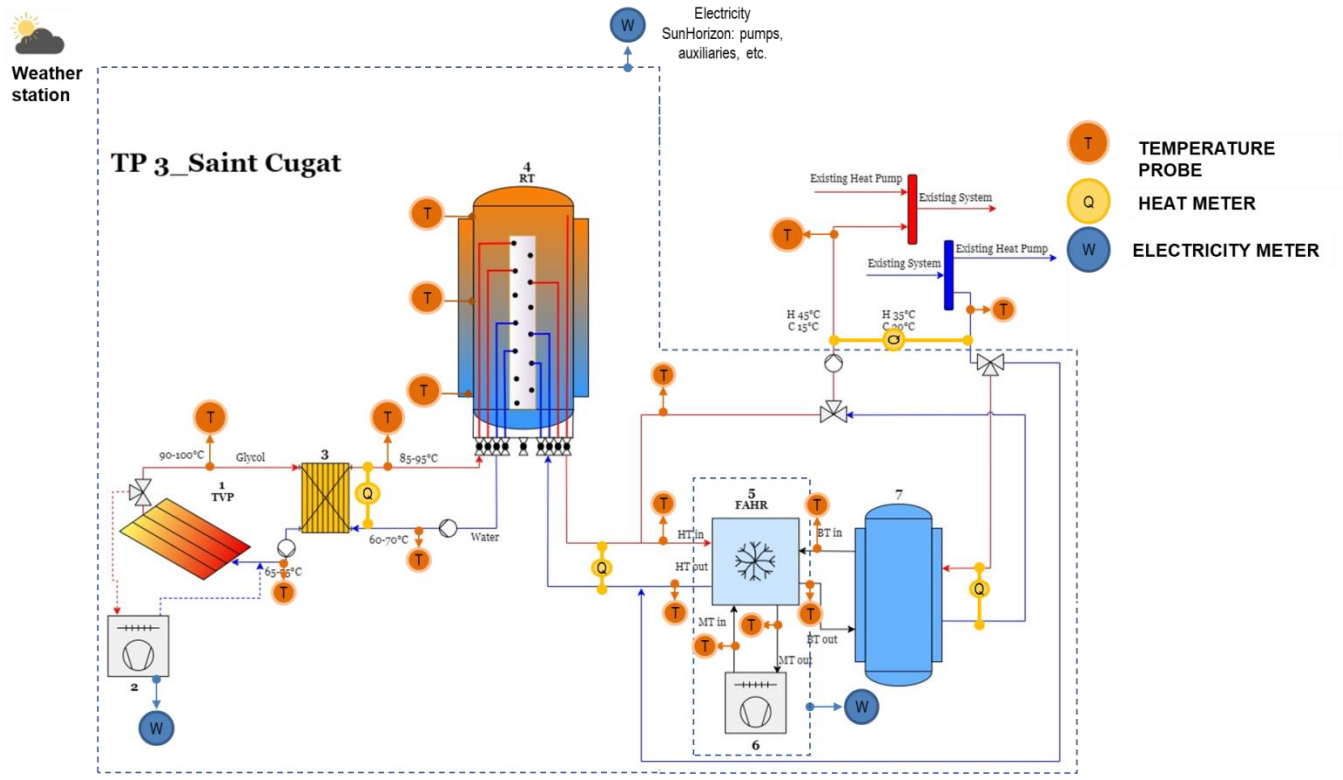


Figure 69: monitoring of SunHorizon system

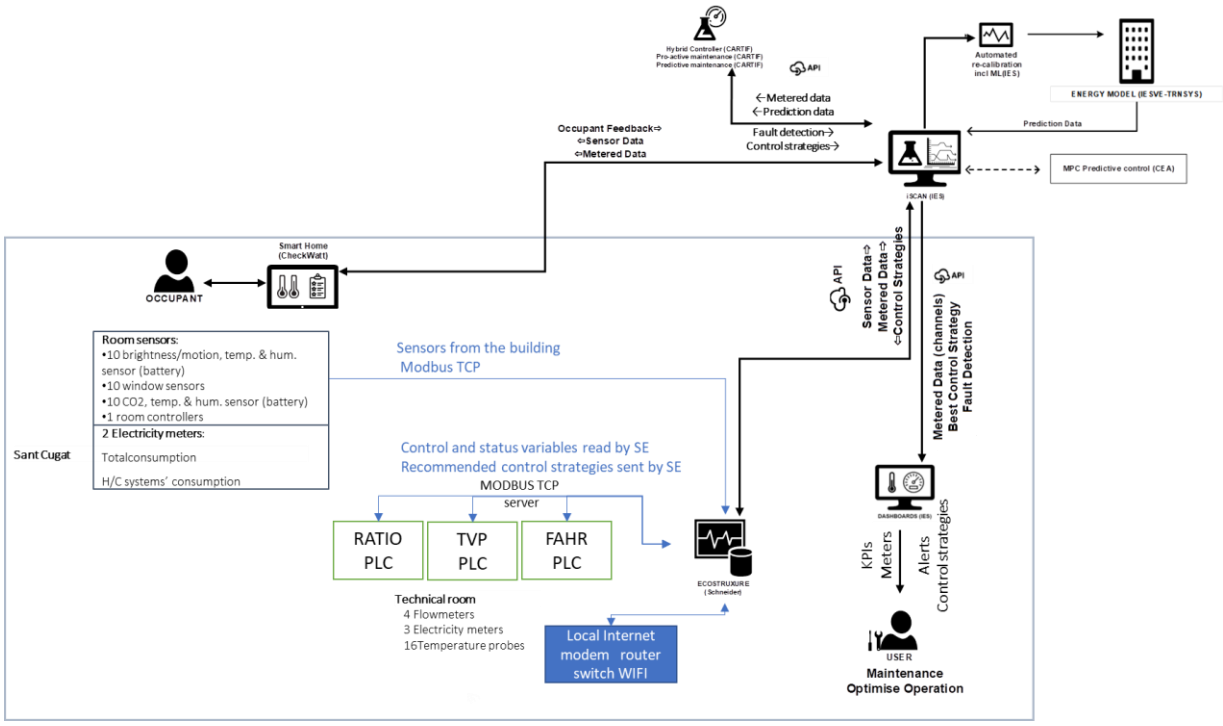


Figure 70: monitoring and WP4 architecture

5 Madrid demo site #4

5.1 General description

Demo site 4 is located in central Madrid, and it is composed by nine social housing apartments. Users are people with low incomes and possibly suffering of energy poverty. Thus, the baseline period to consider is one where most of the time energy demands were not met before SH deployment. The following subsections summarize the available data to describe the existing status of demo case during typically one year before the deployment of the TPs.

5.1.1 Location

The demo-site is placed in Madrid, the capital of Spain. Specifically, the building is located in "Calle lost res Peces Nº9 Madrid (Spain)" (See Figure 72) closed to important spots of the city as Retiro Park, Atocha train Station or Sol Square. This building is a social housing apartment block with 9 dwellings owned by the ***Empresa Municipal de la Vivienda y Suelo de Madrid*** (EMVS), a public entity belonging to the municipality. EMVS provides an affordable housing for the allocation of people with low incomes.

Figure 71 - Map of Madrid with demo location

Figure 72 – Picture from Google Maps of Calle de los Tres Peces, Nº 9 Madrid (Spain).

The following subsections summarize the available data to describe the existing status of demo case during typically one year before the deployment of the TPs.

5.2 Local weather characteristics

Madrid climate is classified as Mediterranean according to Köppen climate classification, with moderately cold winters, and hot summers, with high solar irradiation. Metereonorm files with weather data for Madrid can be found in TRNSYS. The weather files use the TMY2 format, which can be read by Type89 and Type109. Also Energy Plus provides weather data files for TRNSYS, such as the weather stations for Retiro and Getafe. The closest one is Barajas. Both sources, take information from Barajas Airport weather station located in coordinates: {N 40° 27'} {W 3° 32'} {GMT +1.0 Hours} with an elevation of 582m above sea level. Barajas weather file is taken into account for the analyses.

With an annual average temperature of 13.7, Madrid's weather is characterized by hot and dry warm summers and cold winters with frequent frosts and occasional snowfalls. Because of climate change, extreme events such as heat waves and heat island effect can also happen, with excessively hot temperatures in summer (greater than 36.5ºC)[4].

[4] https://www.madrid.es/UnidadesDescentralizadas/Sostenibilidad/EspeInf/EnergiayCC/04CambioClimatico/4cEstuClimaUrb/Ficheros/EstuClimaUrbaMadWeb2016.pdf

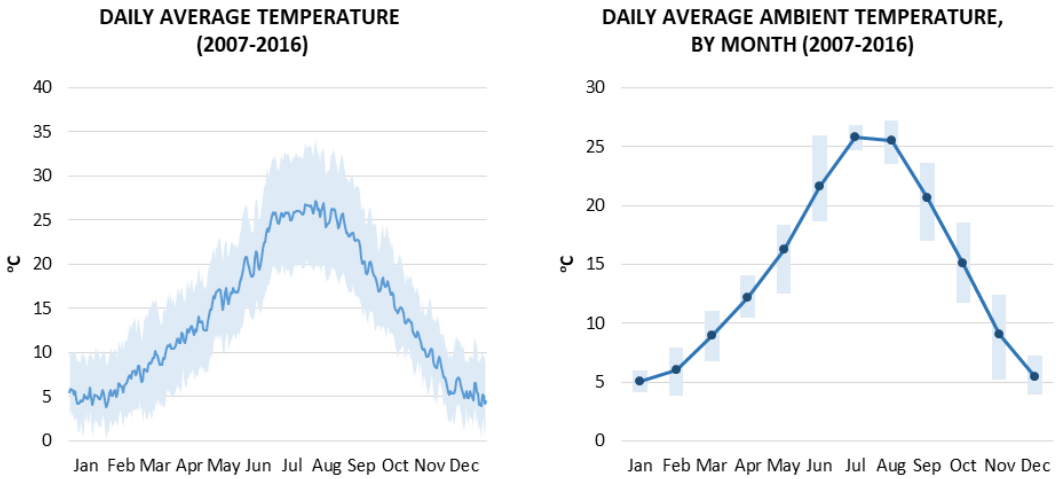


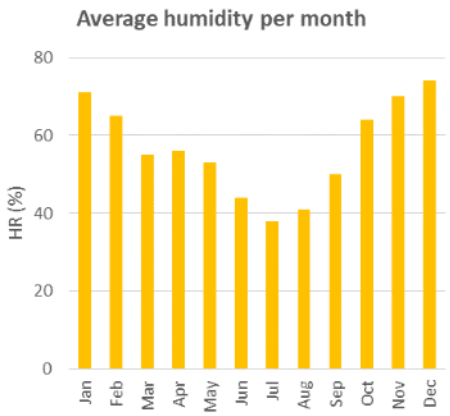
Figure 73 : Weather analysis for Madrid: Average temperature for the years 2007-2016 (Left-side). Monthly average ambient temperature (right-side)

In fact, Madrid is characterized for demanding both: heating and cooling. Heating and cooling degree days for setpoint temperatures of 20ºC and 25ºC, respectively, is shown in Table 16. Average relative humidity is 57%, ranging from 38% in July to 74% in December.

Table 16: HDD and CDD for Madrid demosite

Year	HDD	CDD
2013	1673	958
2014	1317	939
2015	1472	1116
2016	1534	1062
2017	1488	1178
2018	1600	992

Figure 74- Monthly average humidity



Wind speed is shown in Figure 75. The typical wind speed is 3m/s.

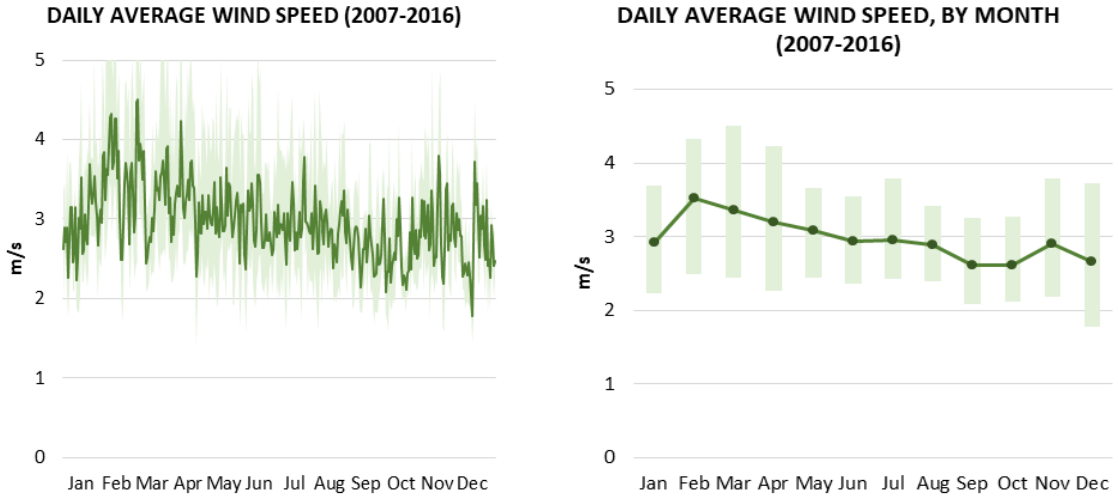


Figure 75: Daily average wind speed for the years 2007 to 2016 and average monthly wind speed (right figure)

Sunshine duration is 2,769 hours per year, days in winter are not as short as in the northern Europe and daylight in summer typically last 14-15 hours. The average global solar irradiance is 1,972 kWh/m²/year, with a PV potential of 1,535 kWh/kWp. In summer the sun elevation is higher and the maximum global solar irradiance is 7 W/m2/day in July, and the lowest (2W/m2/day) is reached in December and January.

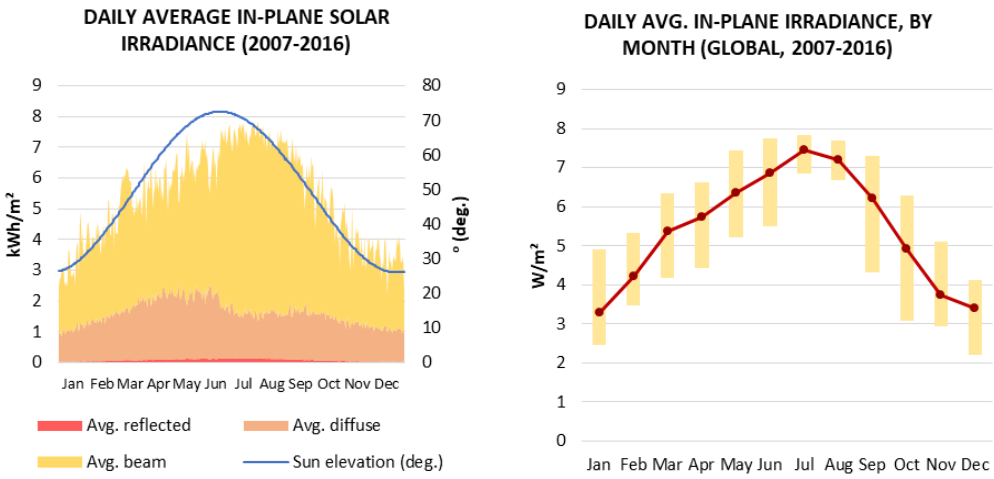


Figure 76 : Weather analysis for Madrid: Average in-plane solar irradiance for the years 2007-2016 (left figure). Monthly global solar irradiance, with minimum and maximum values (Right –figure)

As Figure 77 shows the surrounding buildings do not cause any shadows in the roof, so the losses due to shadows of the Dual Sun panels will be minimized.

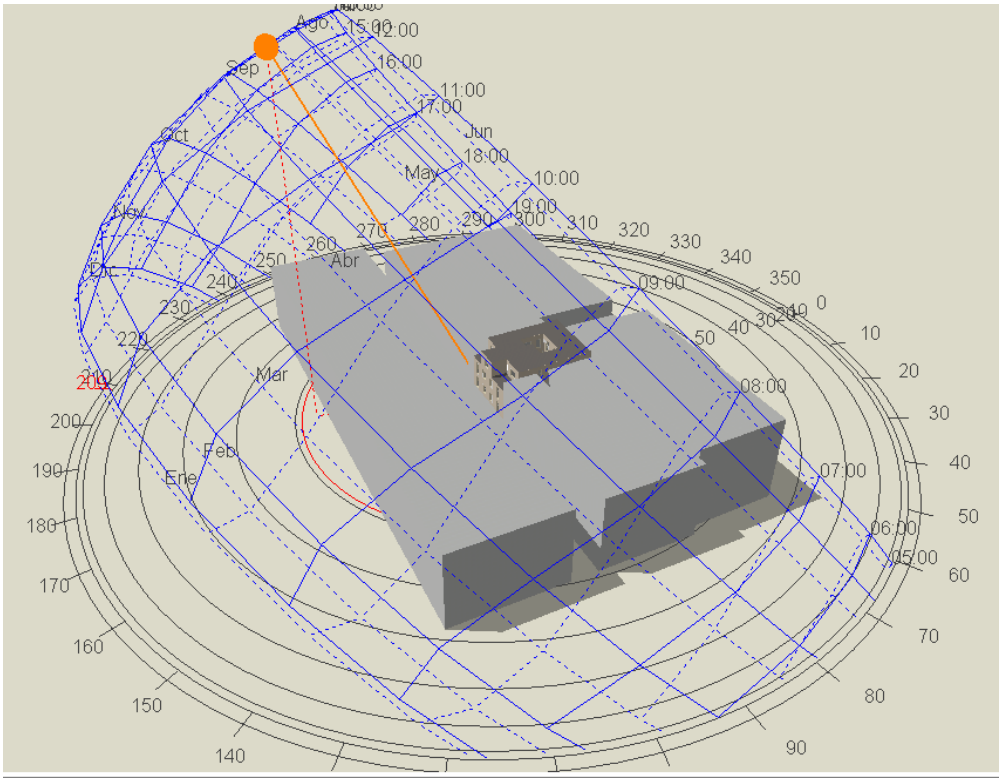


Figure 77: Solar trajectory of Madrid building and surroundings

5.3 Building geometry and use

As reported in D2.1, the survey performed in February 2019 allows to get drawings from the building renovation in 2006. From these drawings, a detailed 3D model was performed in T2.4 (See Figure 79) which main assumptions and results are also reported later.

The building was built in 1948, it was originally a police station and dungeons consisting of just one floor above ground. In the middle of the 20th century, it was refurbished achieving the configuration that currently exists. The distribution of the ground floor was modified and it was built four more floors above it for residential use.

The building belongs entirely to the EMVS and it is being rented to people with social and economic difficulties. Multi-family residential building, rectangular shaped, with south oriented main façade to Tres Peces street. The other three orientations (two sides and the back) consists on dividing walls in contact with other buildings. A central courtyard serves with natural lighting and ventilation to the interior-side rooms of the building. It also accommodates the staircase and the lift hole.

The building has two commercial premises, one interior dwelling and several common rooms on the ground floor, and eight dwellings on the rest of the floors above ground at a rate of two per floor, within four floors.

Figure 78: South building façade (Pictures from demo-site visit)

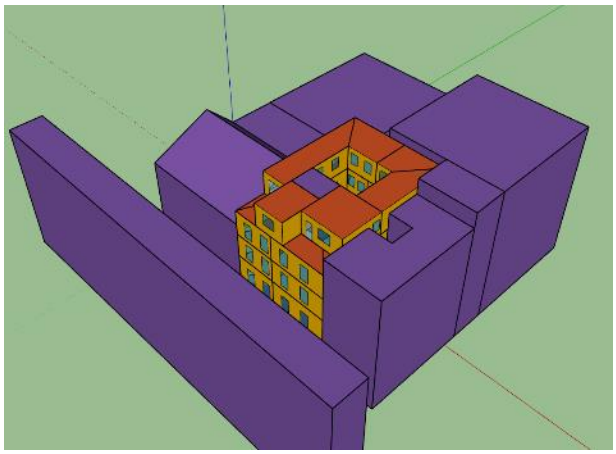


Figure 79: Building TRNSYS 3D model

The building is composed for a ground floor and four floors of housing flats above it. The characteristics of each floor are showed in Table 17. Figure 78 shows the frontal façade of the building, which will be renovated increasing the external insulation. Figure 79 shows the building 3D Model created in Sketch Up and used in TRNSYS (Within T2.4).

Floor	Type	Surface (m²)
Ground floor	Commercial property 1	40.63
	Commercial property 2	39.79
	Dwelling	54.64
	Common areas	86.94
	Total Ground Floor	222.00
First floor	Dwelling 1A	96.39
	Dwelling 1B	108.6
	Common areas	14.30
	Total First Floor	219.29
Second floor	Dwelling 2A	96.39
	Dwelling 2B	108.6
	Common areas	14.30
	Total Second Floor	219.29
Third floor	Dwelling 3A	96.39
	Dwelling 3B	108.6

	Common areas	14.30
	Total Third Floor	219.29
Fourth floor	Dwelling 4A	92.74
	Dwelling 4B	86.94
	Common areas	12.61
	Total Fourth Floor	192.29
Total surface		1072.16

Table 17 – Characteristics of each floor (Madrid's demo site)

An unfavorable ITE (Technical Building Inspection) report was carried out requiring immediate reparation of several technical aspects. For this reason, it is intended to make a refurbishment of structure, envelope, accessibility and energy systems of the building. At the ground floor, the dwelling distribution will be expanded (as shown in Figure 80) and for all, insulation will be improved.

Figure 80: New layout of the ground floor dwelling

The structure of the building is made of solid brick load bearing walls with unidirectional wood slabs in the ground floor and unidirectional metal slabs and pillars in the rest of the floors.

In general, the structure is in good condition and does not present pathologies that may suggest structural problems.

Façade

The façade is made of one sheet solid brick, with plaster covering both in the interior and exterior, and no insulation layer. The general characteristics of the façade are defined in the table below:

Table 18 General Characteristics of the façade

	Thickness (cm)	Description	U Value (W/m2K)
External Wall	45	Solid Brick + Int. & Ext.Plaster. No insulation	0.82
Courtyard Wall	25	Solid Brick + Int. & Ext.Plaster. No insulation	1.27
Windows	0.4	Single Glaze, Wood Frame	4.91

The following figures are from the current state of the building and show that there are many deficiencies in terms of façade insulation, pathologies and conservation needs:

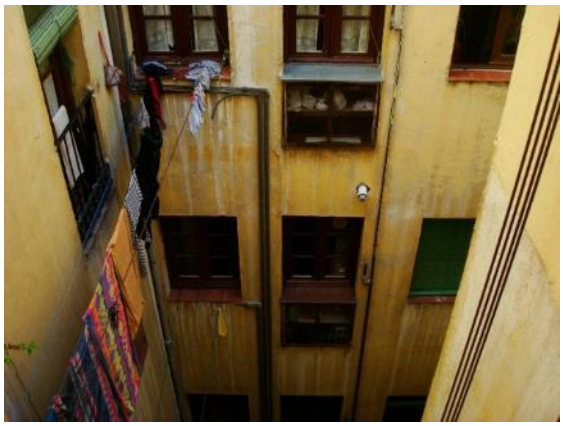


Figure 81: Building façade (left) and courtyard (right)

The main deficiencies found in the façade are:

- Great deterioration of wall covering: generalized dirt with loss of plaster, cracked with possibility of detachment
- Bad thermal properties: no insulation layer, moisture problems inside the apartments
- Leakages in the exterior drainpipes

The next drawings allocate the main deficiencies in the building façade:

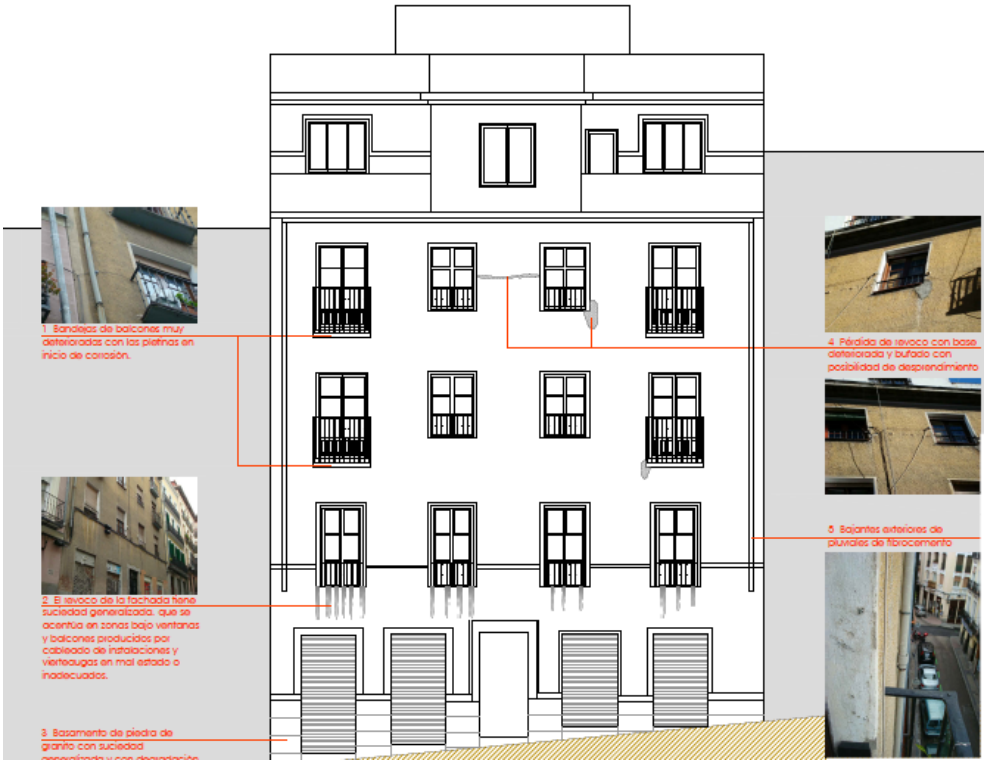


Figure 82: Deficiencies of the main façade

Figure 83: Deficiencies in the other façades

Roof

The roof is flat and is finished in a self-protected asphalt sheet, foreseeably welded on a Catalan tile floor. The parapets surrounding the limits of the roof are made of brick.

The general characteristics of the roof are defined in the table below:

Table 19: General characteristics of the façade

	Thickness (cm)	Description	U Value (W/m2K)
Roof	45	Asphalt sheet, waterproofing layer, ceramic tiles, hollow brick board, slab and plaster. No insulation	0.70

Figure 84: Actual State of the roof

The main deficiencies found in the roof are:

- Bad state of the parapets, roof floor and dividing wall.
- Skylight produces recurrent leaks.
- Deterioration of the access, from stairs to the roof level, with broken elements.

The next drawings allocate the main deficiencies in the building façade:

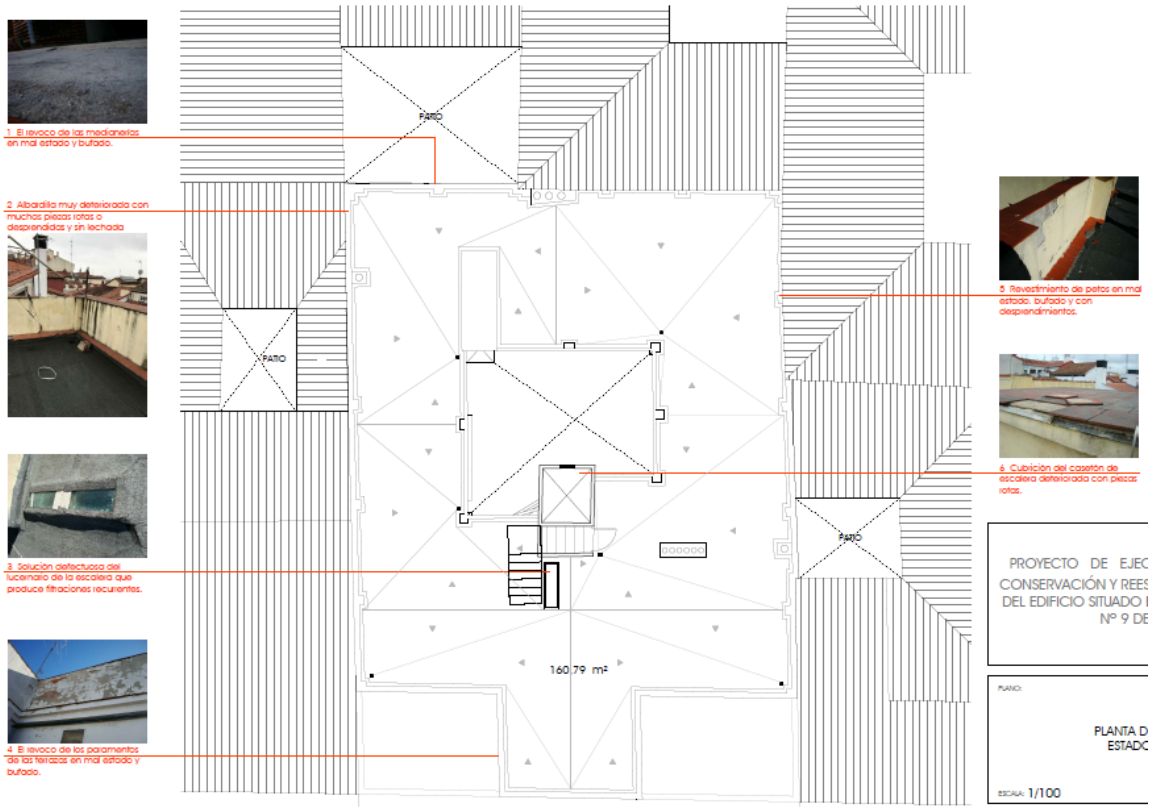


Figure 85: Deficiencies on the roof

The existing and renovated U values are shown in Figure 86. 70% improvement for the walls, windows and roof has been considered.

EXISTING	
Type	**U**
External walls	**1,63 W/m²K**
Internal walls (courtyard)	**2,20 W/m²K**
Roof	**0,95 W/m²K**
Windows	**5,70 W/m²K1**

AFTER RETROFITING	
Type	**U**
Walls	**0,268-0,316 W/m²K *more info in drawings**
Roof	**0,265 W/m²K**
Windows	**1,7 W/m²K1**

Figure 86 : U values: for existing infrastructure and after retrofitting

This project aimed to serve as a replicable model for many other of their buildings along the Madrid city center with similar characteristics. It has not any kind of heritage protection even it belongs to a neighbourhood catalogued as 'historical district.

Building renovation

The building started to be renovated in 2019. The whole renovation will cover both passive and active aspects of the building aiming to achieve better energy performance and improve comfort condition levels.

The retrofitting of the building will consist on:

Main Façade:

- Installation of External Insulation (ETICS). Thickness: 8 cm.
- Substitution of Windows.

- New electric lines and drainpipes distribution through façade

Achieving the following thermal properties:

Table 20: General Characteristics of the façade after renovation

	Thickness (mm)	Description	U Value (W/m2K)
Wall	45 + 8	Solid Brick + Plaster +ETICS	0.262
Windows	4+4-16-6	Double Glaze + Low Emission layer + Solar Control, Aluminium Frame with TBB	1

Roof:

- Renovation of the roof floor and the parapets. Integration of an insulation layer.
- Replacement of the skylight.
- Renovation of the access to the roof.

Achieving the following thermal properties:

Table 21: General Characteristics of the roof after renovation

	Thickness (cm)	Description	U Value (W/m2K)
Roof	52	Asphalt sheet, waterproofing layer, extrude polyestirene (8cm) ceramic tiles, hollow brick board, slab and plaster. No insulation	0.26

Thermal zones

The following pictures show the layout of the dwellings. In each floor (except in the ground floor), there are two dwellings A, on the left side, and B, on the right side. The dwelling is equipped with kitchen, living room, bathroom and two bedrooms.

For the division of the thermal zones in the modelling activities of task 2.4, the dwellings are divided by floor and type of dwelling (A and B). Each dwelling is divided in three convex zones (Except the ground floor that is divided in two convex zones) to be able to use the “detailed beam radiation mode” within the simulation in TRNSYS. For control purposes, an average temperature for the whole building is considered (20±2 for winter and 24±2 for summer).

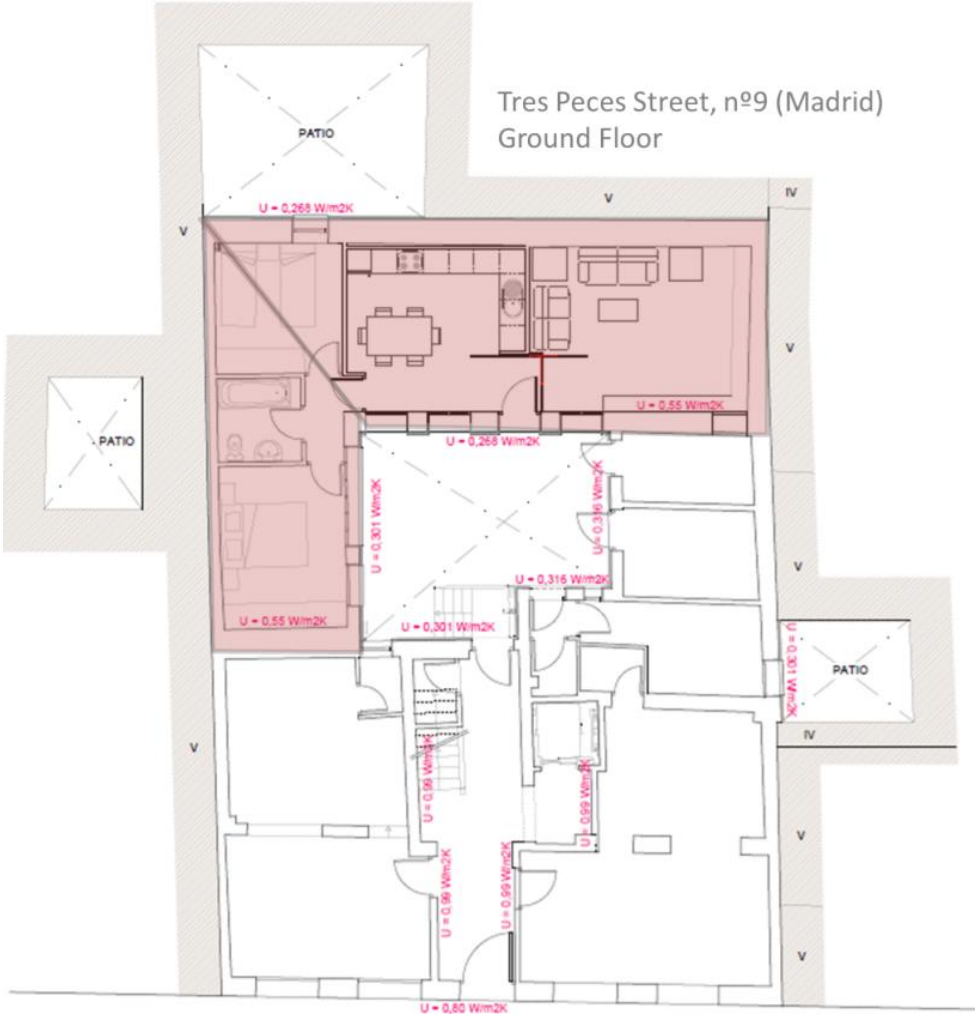


Figure 87 : Ground Floor dwelling (thermal zone code: F0T1-T2)

Figure 88: The left figure shows the distribution of the 1st to 3rd Floor dwellings (thermal zone code: F1-3 T1-T2) and the right figure shows the distribution of the 4th floor.

5.4 Heating/cooling system with heat, cold and DHW distribution

Currently, each apartment has an individual natural gas boiler to satisfy the DHW and space heating demands (Figure 90). On the other hand, some of the apartments have an individual electric chiller to cover the cooling needs. The building owner is going to perform a refurbishment of the building and the energy system. Regarding the later one, a centralised solution to cover the DHW, heating and cooling needs will be installed.

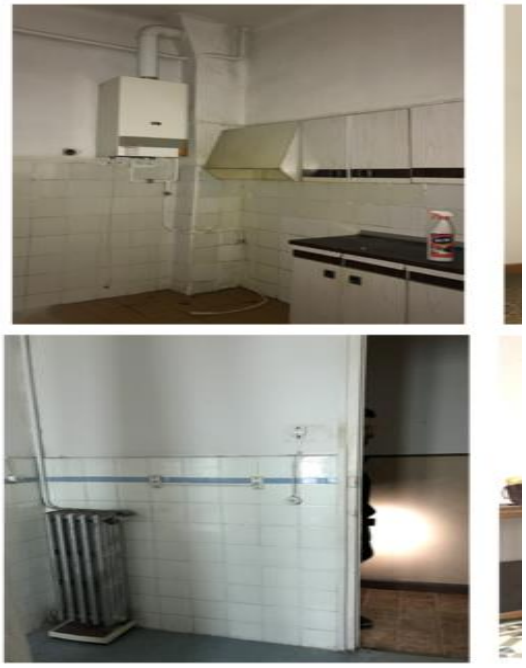


Figure 89 : old radiators and boiler for SH and DHW purposes.

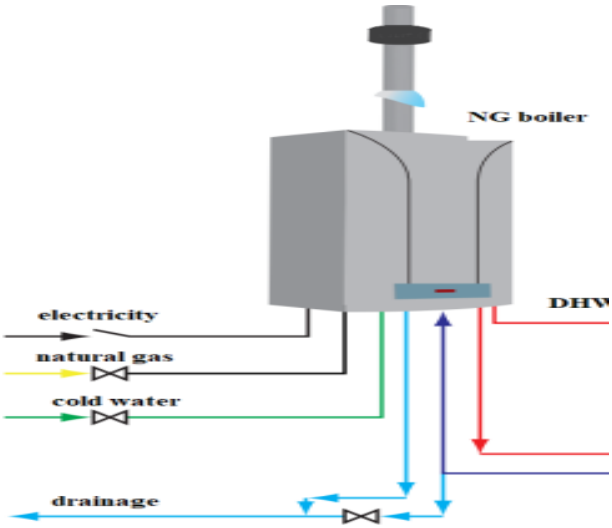


Figure 90 : old existing system (it is going to be removed)

At each dwelling one heat exchanger for DHW preparation (DHW HX) and one fan coil with one coil (for both, heating and cooling) are connected to the distribution system.

All dwellings will have incorporated a de-centralised Mechanical Ventilation Unit with heat recovery, to cover the air quality needs of each dwelling minimizing the energy losses associated to ventilation.

Independent ventilation units will be installed in each dwelling, located in the false ceilings of the kitchens in the right side dwellings, and in the false ceilings of the bathrooms in the left side dwellings. The air is extracted from the bathrooms and kitchens, pass through the heat recovery and it is led to the roof by independent chimneys. On the other side, clean air is taken from the outside, heated up in the heat recovery unit and supplied into the bedrooms and living rooms. The goal would be to integrate this ventilation system within the space heating and cooling system proposed by SunHorizon. This technology definition is still under revision.

In addition, the distribution pipes concerning tap water and gas, and the electric line will be renovated and taking advantage of the new lift installation, they will be slightly moved from its original location. In all cases, they will be installed above the insulation layer of the internal courtyard. There will be two pipes distribution system, one for DHW preparation and one for space heating and space cooling. Tap water coming from the water mains will exchange heat at each apartment DHW HX and it will provide hot water at 45ºC for showers and kitchen. The fan coil water coil setpoints will be set at 45ºC for winter and 16ºC for summer. The SunHorizon system will meet the three demands at the required setpoints.

The fan coils that will be installed will exchange heat with the indoor air (a heat recovery heat exchanger will be installed for ventilation purposes). These units will alternately give, cold or heat, depending on the corresponding season. Ducts

be located in the ceiling and the distribution of the air will be done through galvanized sheet circular ducts internally isolated. The return will be made by plenum (not conducted) from inside the ceiling. The distribution and dimensions of the ducts are indicated in the graphic documentation and will always run through the false ceiling.

Units	Brand	Model	Dimensions	Water flowrate	Heating Battery	Cooling Battery
9	DAIKIN	FWB05BT	239x1389x609	825	6.4 kW	5.22 kW

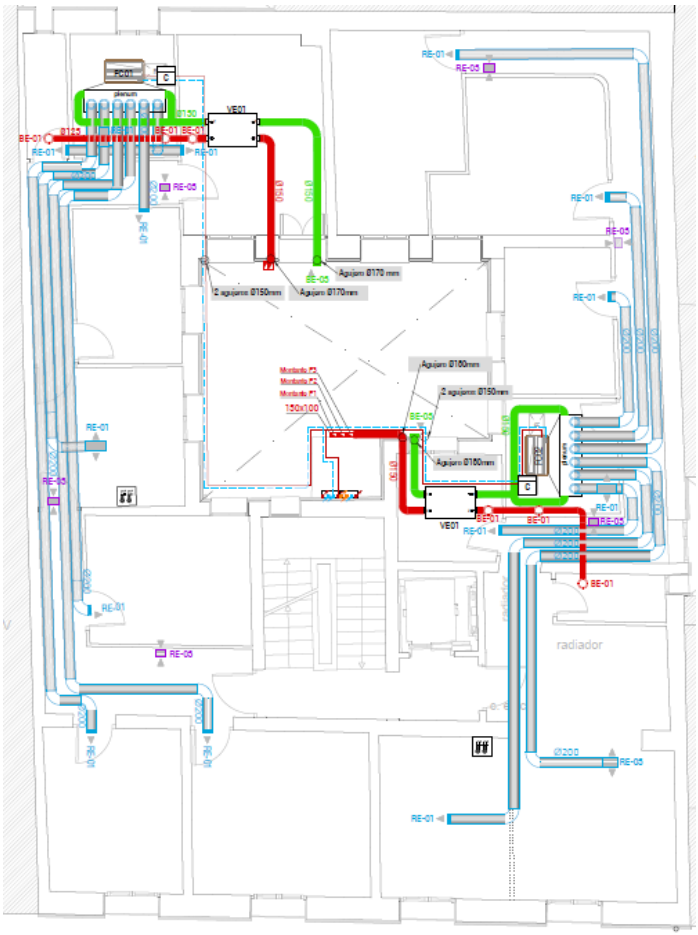


Figure 91: Ventilation ducts (in red and green) and air distribution from the fancoil to the different rooms (ducts in blue)

Baseline

As bills are not available (data protection issues), and people might have been suffering of energy poverty, an energy model in Design Builder 5.5 of the retrofitted building is performed and it will be taken into account as a baseline for SunHorizon performances.

- Cooling peak: 16 kW
- Heating peak: 22 kW
- DHW demand: 1400 liters/day

Internal heat gains have been set in Design builder: The internal loads in a residential building that can be considered are the following according to the energy certification regulations.

- People
- Equipment
- Illumination

In the study the charges for equipment and lighting have been ignored as the schedules or capacities are unknown. The occupational internal heat gains due to people have been taken into account, following the schedules (see image below) to consider the Spanish regulation code (CTE HE) with an occupation of 0.03 people/m^2. A renovation flow rate of 0.1 renovation/hour and infiltrations of 0.1 renovation/hour has been considered.

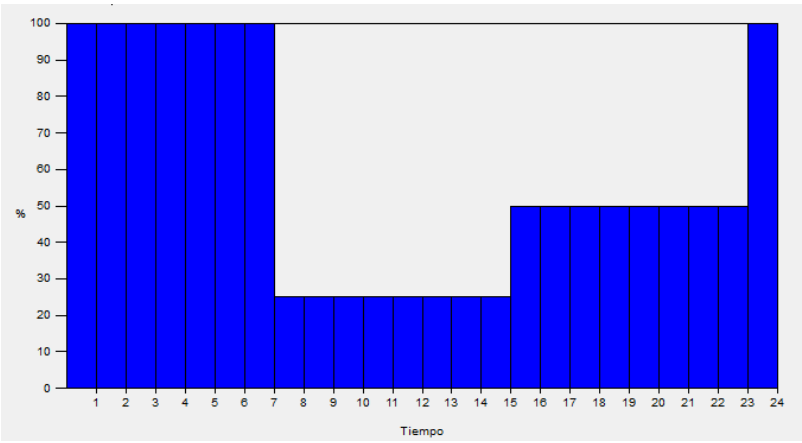


Figure 92: Internal gains in Madrid model in Design Builder

The thermal losses obtained from the energy study of the original building are the following: it is observed how the greatest losses are found in the holes and walls that have been chosen to rehabilitate. The cover, on the other hand, does not have many losses due to its low surface compared to the other typologies.

By rehabilitating the building, it is observed how the greatest losses remain in the holes and walls but have decreased substantially. The following image shows the monthly losses in the enclosures where the action has been foreseen:

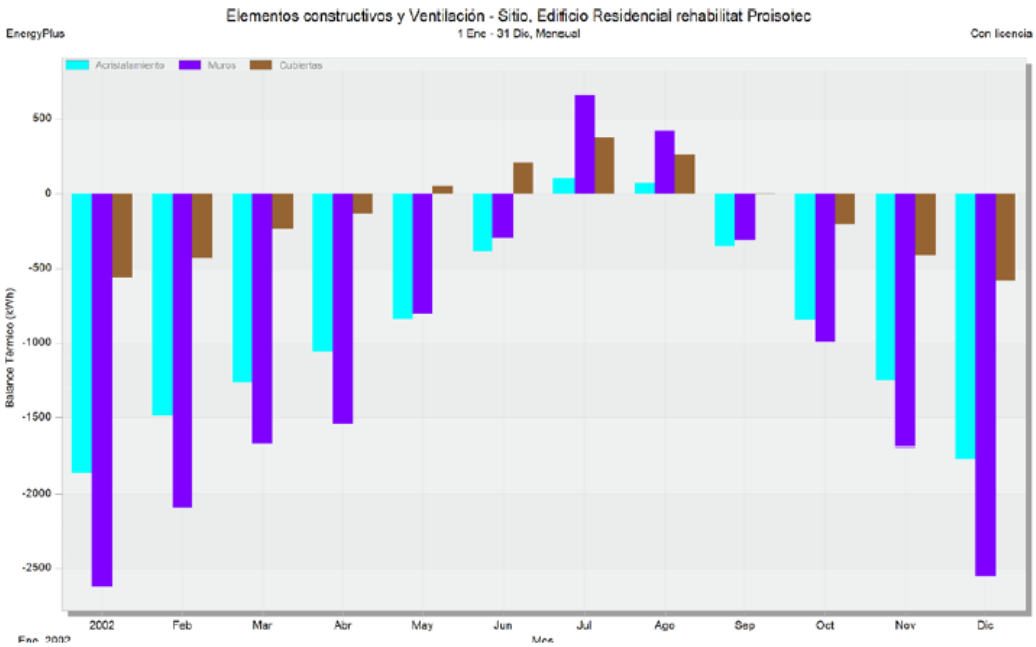


Figure 93: Monthly heat losses due to windows (blue bar), façade (purple) and roof/ceiling (brown).

Due to rehabilitation there is an average thermal loss reduction of 70%, which allows reducing in 52% the demand for heating and 42% the demand for cooling. Assuming that, these demands are met by conventional technologies (i.e. a natural gas boiler for DHW and SH, and a split unit with a EER of 2.5), the baseline estimated consumption for gas and electricity results in 37.8 MWh/year and 17.3MWh/year respectively, which is equivalent to nearly 80MWh/year of non-renewable primary energy. Figure 98 shows the different energy consumptions of the building.

Table 22: Estimation of the thermal losses and thermal losses reduction due to the improvement of the insultation

Thermal Losses	kWh/year	kWh/year	Thermal losses Reduction (%)
Windows	19479	8114	58
Walls	45291	11356	75
Roof	2215	1324	40

Considering the monthly losses, the new windows cause loss savings in wintertime that will result in better maintaining the interior temperature and less use of heating. In summer the rehabilitation does not have the same effect:

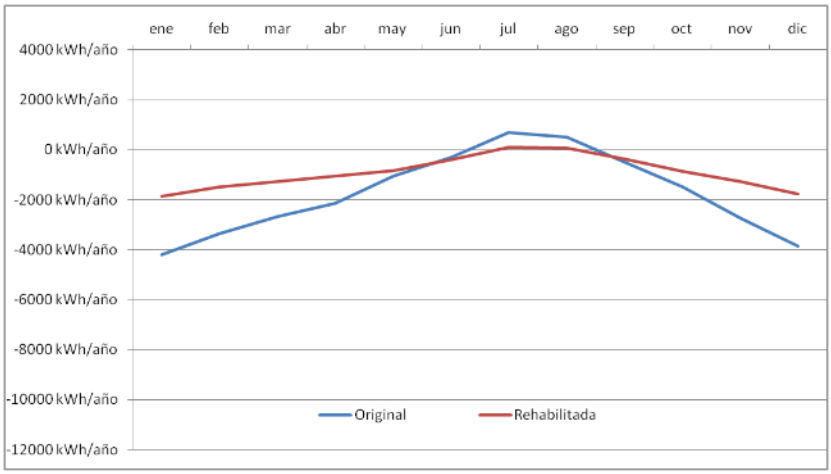


Figure 94: Monthly thermal losses comparison (new windows) between the original (blue line) and rehabilitation (red line)

In exterior walls (including exterior and patio) the decrease in losses is still much more important in winter with reductions of up to 75% in January.

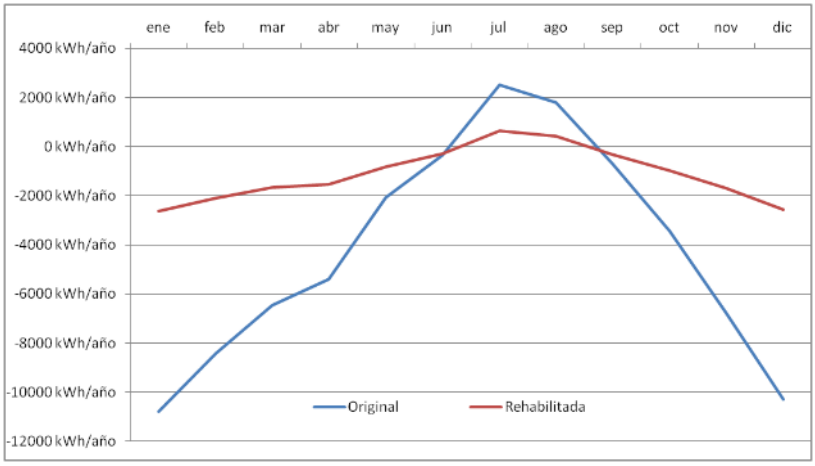


Figure 95: Monthly thermal losses comparison (exterior walls) between the original (blue line) and rehabilitation (red line)

In the case of the roof being of a lower range the total losses do not have as much influence, if we have lower losses in winter, while in summer it has no effect.

The energy assessment carried out through the Spanish certified software (CE3x) presented the following results:

- Base Case:

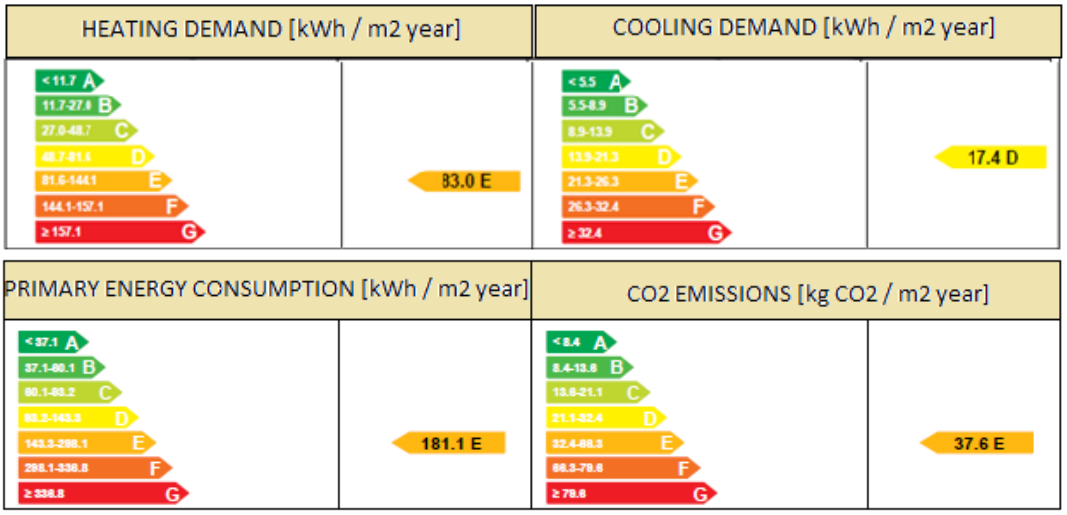


Figure 96: Base Case Energy Certification

- Refurbished Case:

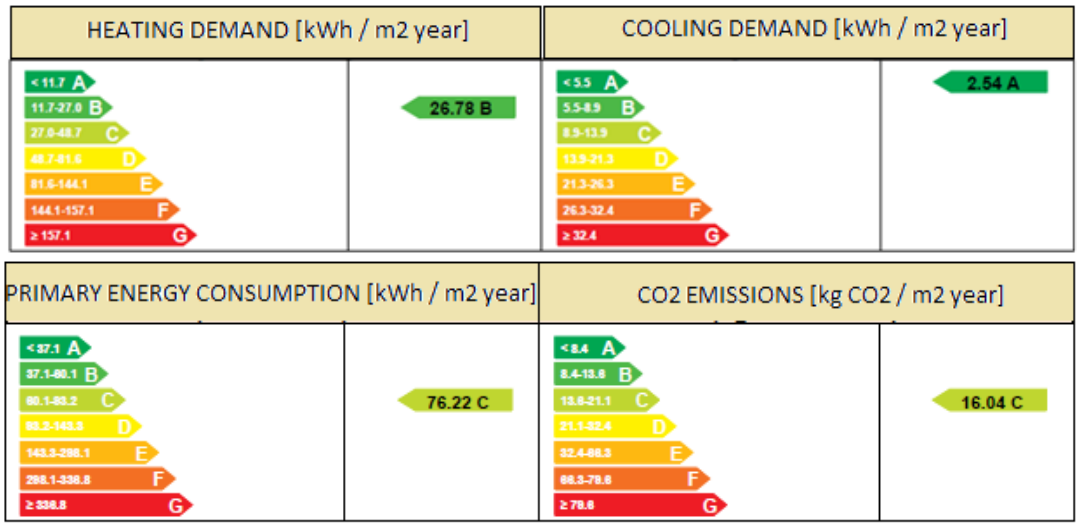


Figure 97: Refurbished case Energy Certification

Comparing both scenarios, it can be concluded that after the building energy renovation it has been achieved a reduction of:

Table 23: Energy Savings and CO2 Reduction

Heating Demand	**68%**
Cooling Demand	**85%**
Primary Energy Consumption	**58%**
CO2 Emissions	**57%**

Considering the previous premises (baseline), the total consumption of the building is estimated as shown in the following figure:

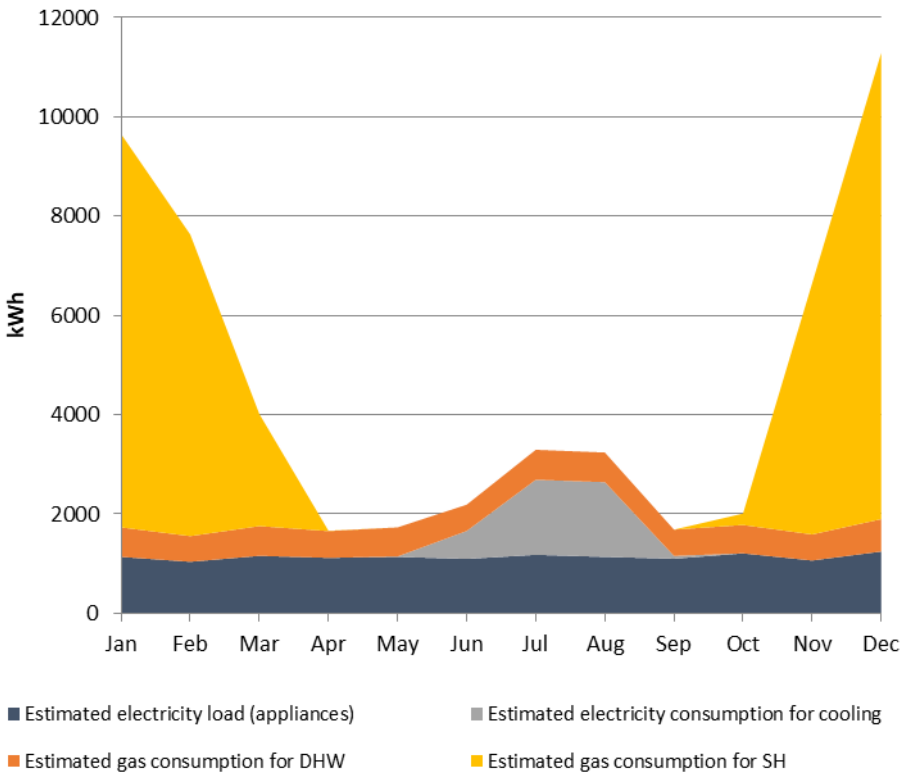


Figure 98: Estimated electricity and gas consumption for Madrid's building.

Considering as conventional system a single split per dwelling with a COP of 2.5 for cooling purposes and a centralized DHW and SH system with natural gas with an overall efficiency of 0.8, the baseline results in 79.4 MWh/year of non-renewable primary energy. For the primary energy conversion factors, the values in Table 24 are considered.

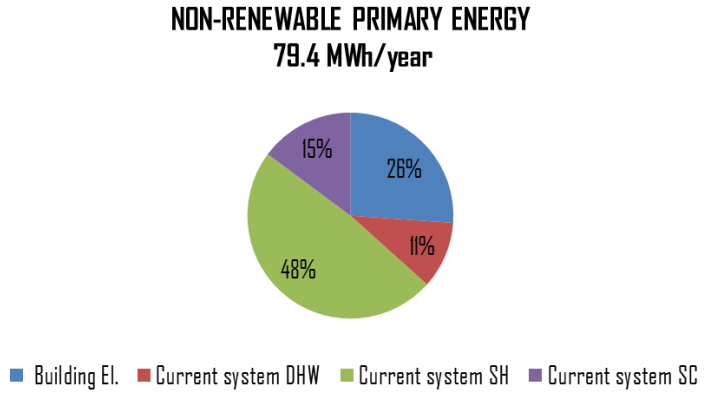


Figure 99: Estimated Baseline in terms of non-renewable primary energy

Table 24: primary energy conversion and GHG emissions factors for Spain (2013)

	PEFnren	PEFren	fGHG	LHV
	-	-	gCO2/kWh	GJ/t

Diesel Oil	1,179[5]	0,003[1]	311[1]	
Wood (except pellets)	0,034[1]	1,003[1]	18[1]	
Wood (pellets)	0,085[1]	1,113[1]	18[1]	
Gas	1,190[1]	0,005[1]	252[1]	48[2]
Coal	1,084[1]	0	472[1]	22.4[6]
Electricity	2,007[1]	0,396[1]	357[1]	

There was no centralized heat distribution system in the existing building.

5.5 Specific requirements for the new heating/cooling system

- Admissible mechanical load (static and dynamic) on the roof for DS panels
- Outdoor unit of the air water heat pump of BDR is located no further than 70 meters distance and 30 meters height from the indoor unit
- BDR indoor unit of the brine water heat pump is located in the technical room upstairs connected to an hydraulic separator (of approximately 200 liters). To this hydraulic separator the DS panels are connected.
- Space reservation during the building renovation for the new centralized heat distribution pipework to integrate in the building to serve all the apartments
- Regulatory compliances such as:
    - Low Voltage Electrotechnical Regulation (REBT), according to RD 842/2002 of 02/08/2002, and specifically the Complementary Technical Instructions.
    - Royal Decree 314/2006, of March 17, which approves the Technical Building Code. According to the latter one, as EMVS is renovating the building in more than 25%(of the area) as well as the heating/cooling system, it is required that a 60% of the DHW consumption is satisfy by renewables. Heat pumps with a seasonal performance factor (SCOP) of 2,5 is considered as a renewable source (Ministerio de Fomento, 2019).
    - Royal Decree 1027/2007, of July 20, which approves the Regulation of Thermal Installations in Buildings
    - Complementary Technical Instructions called ITE. (Ministerial Order of July 31, 1998).
    - Technical Standards of the Ministry of Housing (NTE-ISV / 1975) on Construction and Evacuation Ducts and Chimneys (B.O.E. of July 5 and 12, 1975).
    - Municipal ordinances.
    - First Fire Prevention Ordinance.
    - UNE rules of mandatory compliance.
    - Ordinance on safety and hygiene at work
- Economic constraints
    - Gas: not applicable. The gas installation will be removed from the building.
- Electricity: the photovoltaic production needs to comply with the Royal Decree 244/2019 (from April 5th), in which the self-consumption of electricity is regulated. For installations with less than 15kW do not need permissions, and with less than 100kW (which is the case) is not necessary to do any procedure, but to adhere to "simplified compensation system" in which the trading company compensates you for the surpluses as savings in the electricity bill, month by month. The amount of energy to be compensated may never exceed the monthly energy consumption. A bidirectional electric meter is needed to measure the energy consumed and inject to the grid.

5 https://energia.gob.es/desarrollo/EficienciaEnergetica/RITE/Reconocidos/Reconocidos/Otros%20documentos/Factores_emision_CO2.pdf

6 https://www.miteco.gob.es/es/cambio-climatico/temas/mitigacion-politicas-y-medidas/factores_emision_tcm30-479095.pdf

5.6 Preliminary monitoring plan

All the components will be monitored within WP4. Simulation leaders together with technical partners and demosite responsible are taking care of the detailed definition of it to ensure that all the variables are being measured. Within WP4, a drawing of the preliminary monitoring plans is elaborated showing a diagram of the building main zones to be monitored (See Figure 101) and the sensors at the TP level (see Figure 100). The communication protocol is decided among the partners to be Modbus.

- Ratio will provide S1 to S15 that will be included, except S4 (outdoor sensor)
- Sensor 4: weather data station will be included by Schneider
- Also the heat meters: 18 in the dwellings and 6 to measure the performance of the SunHorizon system will be included by Schneider. At each dwelling the DHW and fan coil supply temperature will be measured to ensure the demand is satisfied.
- Temperature probes such as S18 andS19 will be needed for knowing the supply temperature from the SunHorizon system and S20 and S24 will be needed to assess the performance of the heat pumps (the higher the return temperature, the lower the efficiency). EMVS will provide the necessary temperature probes for controlling the system.
- Thermostats at dwelling level will be included with the fan coil control unit (provided by EMVS)
- The whole communication protocol is Modbus RTU. There will be an additional PLC for controlling the whole system that will communicate with Schneider automation system. The communication protocol will be compatible with the whole system. The specifications of this controller will be included in D6.2

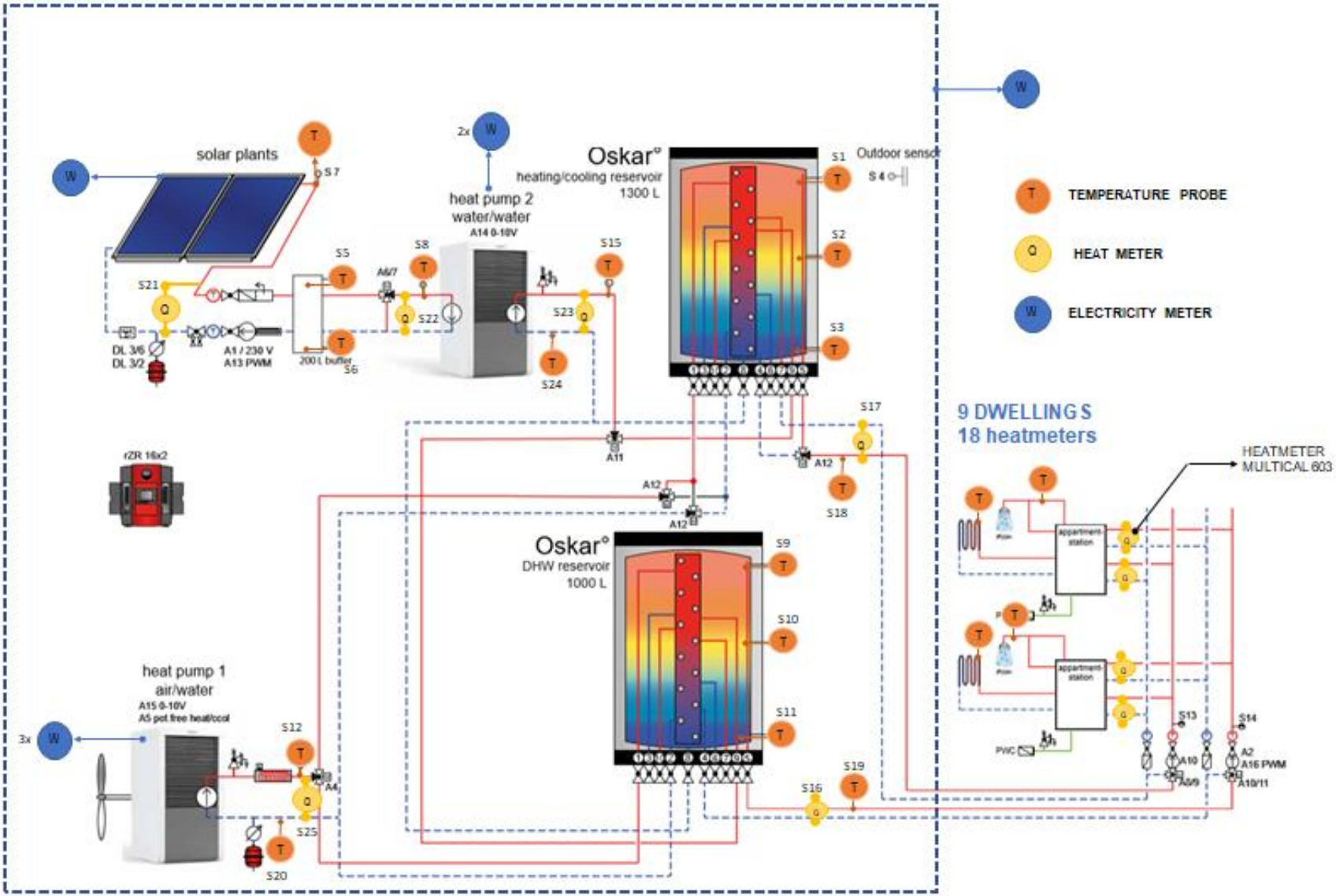


Figure 100: Monitoring schematics(to be confirmed)

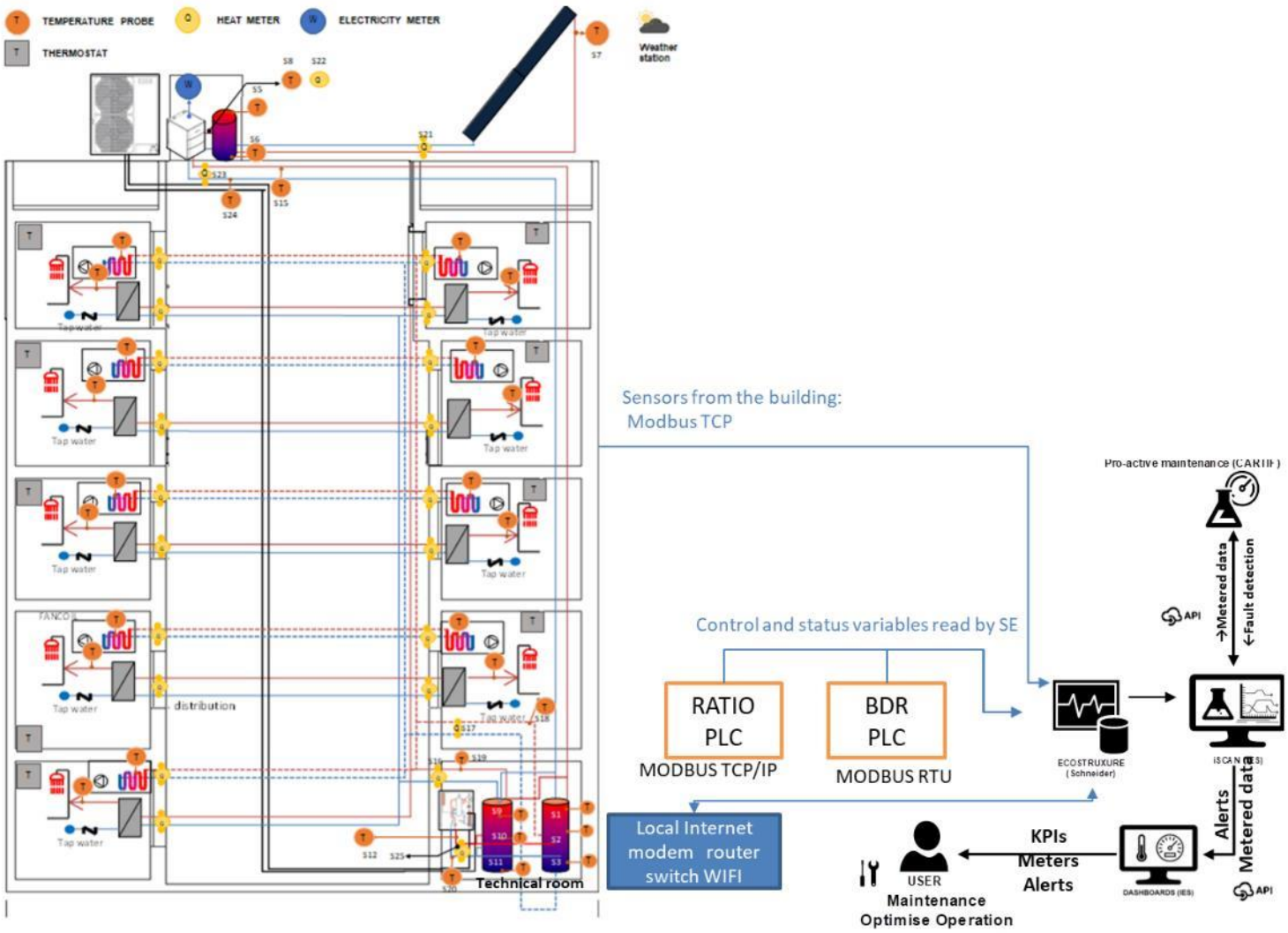


Figure 101: Monitoring schematics at building/dwelling level (to be confirmed)

6 San Lorenço demo site #5

6.1 General description

The San Lorenzo demo site #5 is a single-family house placed in Sant Llorenç d'Hortons, small country located at 40 km from Barcelona. The building is the main residence of a 4-people family. It is a 3 floors house built in 2002.

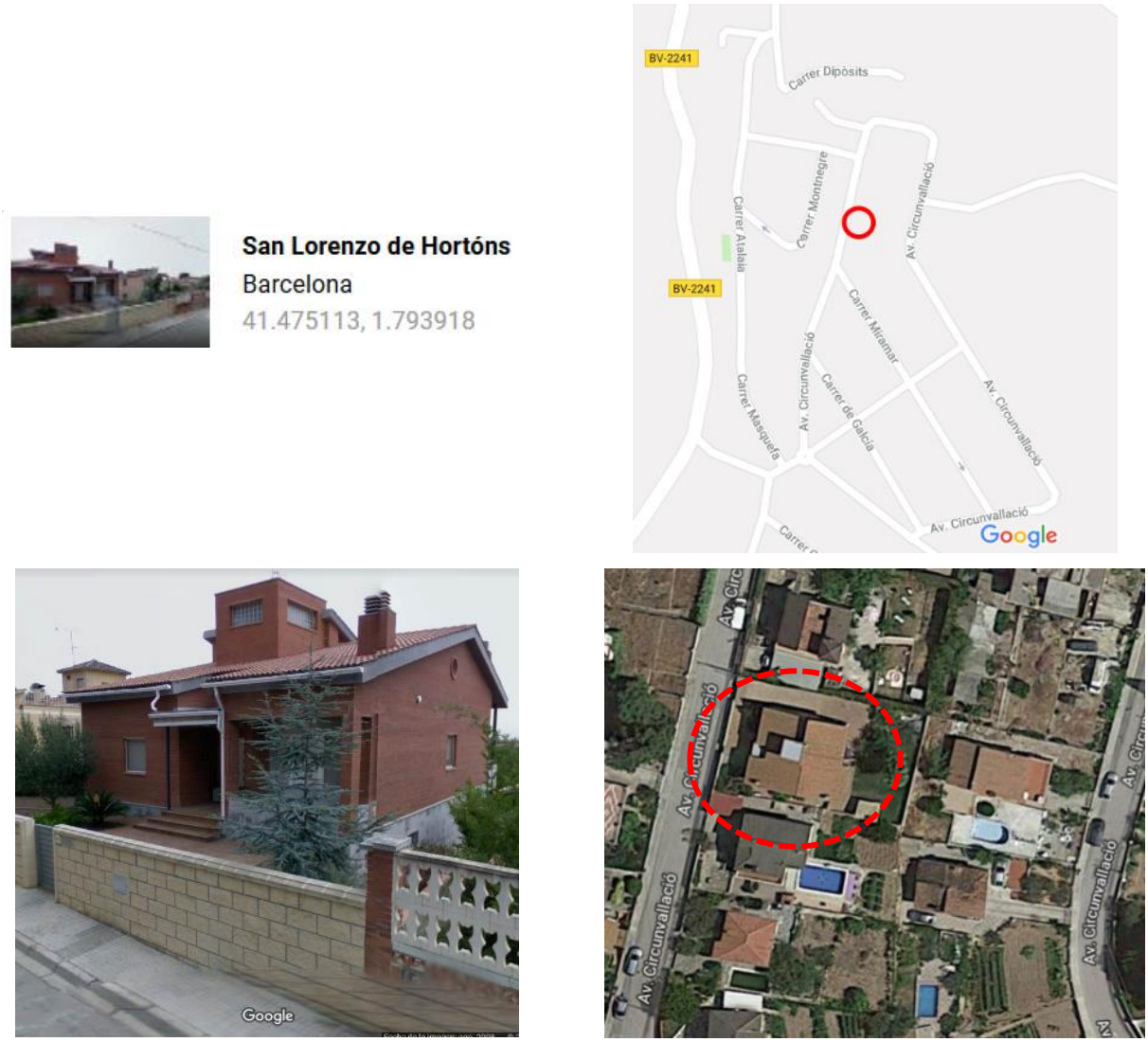


Figure 102 Picture and location of the San Lorenzo demo site #5

6.2 Local weather characteristics

6.2.1 METEONORM data

Weather data for this study are generated using Meteonorm 5.0.13 based on the closest station from San Lorenzo: Barcelona Airport. The resulting Meteonorm file is not real historic year but a typical year representing an average year of the 2000-2009 period.

The main variables, that are shown in Table 25 ,are:

- Ambient, Water and Ground Temperature, Relative Humidity, Wind speed (average values)

- Solar irradiation on horizontal and the tilted surface (integrated values)

According to the main roof, the tilted surface is oriented at -80° compared to the south axis (almost towards East) and tilted at 17° compared to the horizon.

The water and ground temperature (at 1m depth) are calculated based on the ambient temperature evolution.

Table 25 Meteonorm weather data (2000-2009 typical year of the Barcelona Airport station)

	Ground Temp. [°C]	Water Temp. [°C]	Amb.Temp. [°C]	Rel. Humidity [%]	Wind speed [m/s]	Hor. Irrad. Total [kWh/m2]	Tilted Irrad. Total [kWh/m2]	Tilted Irrad. Diff. [kWh/m2]
JAN	10	14	9	78	4.1	76	82	26
FEB	10	14	9	77	3.9	71	73	39
MAR	12	15	11	79	3.9	119	120	58
APR	14	17	13	77	4.1	162	161	70
MAY	16	19	16	81	3.6	172	171	91
JUN	19	21	19	79	3.5	191	187	89
JUL	20	22	23	76	3.5	203	198	90
AUG	20	23	23	80	3.5	178	176	74
SEP	19	22	21	74	3.7	135	137	66
OCT	17	20	17	80	3.5	96	97	49
NOV	14	18	12	74	3.9	71	75	32
DEC	12	16	10	74	4.1	65	69	25
YEAR	15	18	15	77	3.8	1538	1546	710
MAX	*20*	*23*	*30*	*100*	*17*	*8.3**	*8.1**	*3.7**
MIN	*10*	*14*	*0*	*44*	*0*	*1.1**	*1.0**	*0.5**

*MIN and MAX **daily** solar irradiation

Figure 103 below shows the annual evolution of the monthly average ambient temperature and monthly solar irradiation over the tilted surface.

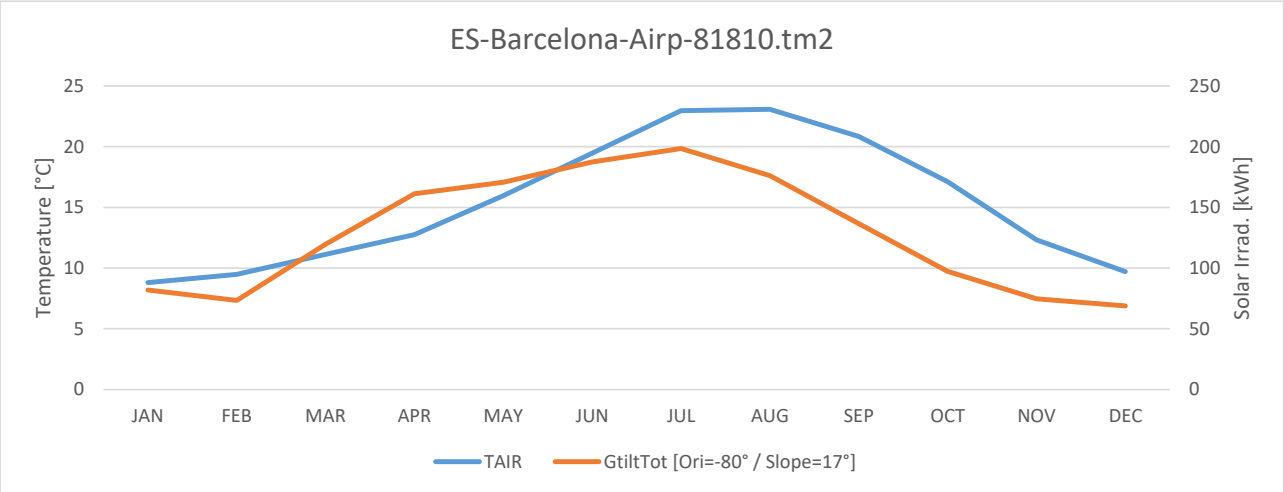


Figure 103 Monthly average ambient temperature and monthly solar irradiation over the tilted surface for the Barcelona Airport meteonorm data.

6.2.2 Comparison with online databases

The Meteonorm data used for the Demo#5 studies are compared with the weather database offered by the "Info Climat" website[7]. Figure 104 shows the monthly average ambient temperature in Barcelona since 2016, year of the first energy data of the Demo#5 building.

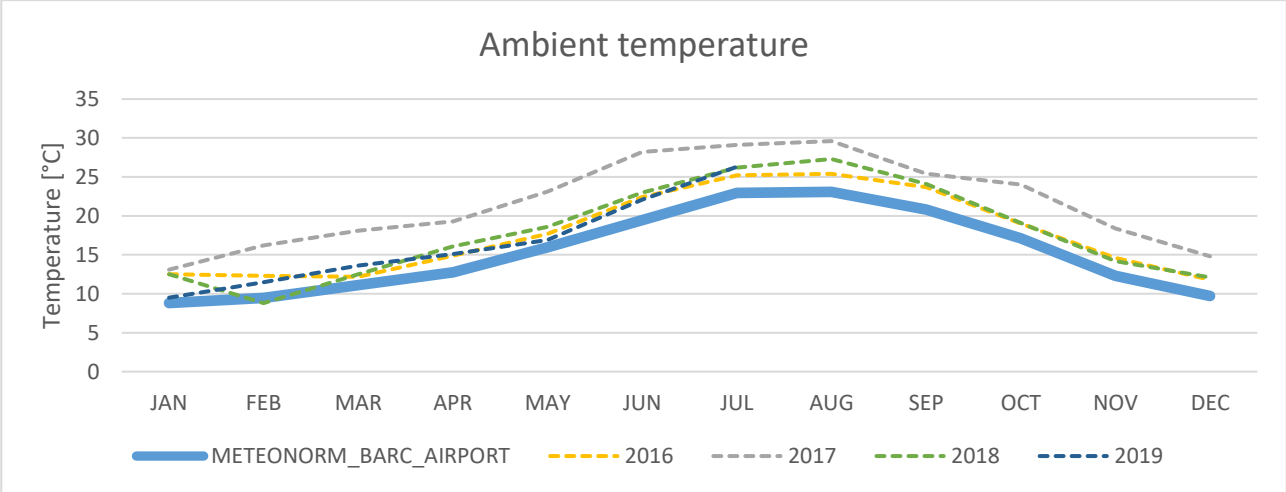


Figure 104 Comparison of the monthly average ambient temperature given by the Meteonorm file and the four past year on Barcelona according to the "Info Climat" website

Ambient temperatures are in the same range with a similar monthly evolution. However, the Meteonorm temperature is below the temperature given for the four past years. No specific correction are considered. Simulation results with the Meteonorm datafile will probably estimate more Space Heating needs and less Space Cooling needs than for the past 4 years.

6.3 Building geometry and use

6.3.1 General description

The main characteristics of the building are:

- Year of construction: 2004
- Inhabitants: 4
- Heating spaces:
  - Basement: 45 m2
  - Main floor: 120 m2
  - Second floor: 39 m2
- Windows: Aluminium and double glass

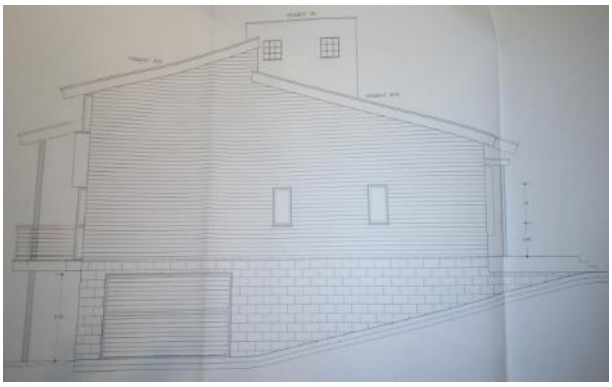
6.3.2 Drawings

The figures below are drawings of the buildings:

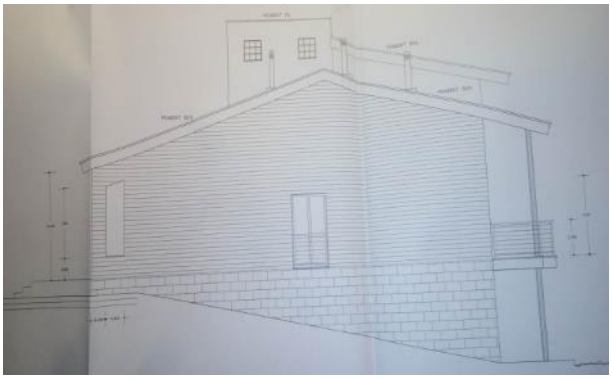
- Figure 105 and Figure 106 : external faces and the roof
- Figure 107 and Figure 108 : internal sections with the considered thermal zones

[7] https://www.infoclimat.fr/climatologie/annee/2017/barcelona-barcelone/valeurs/08181.html

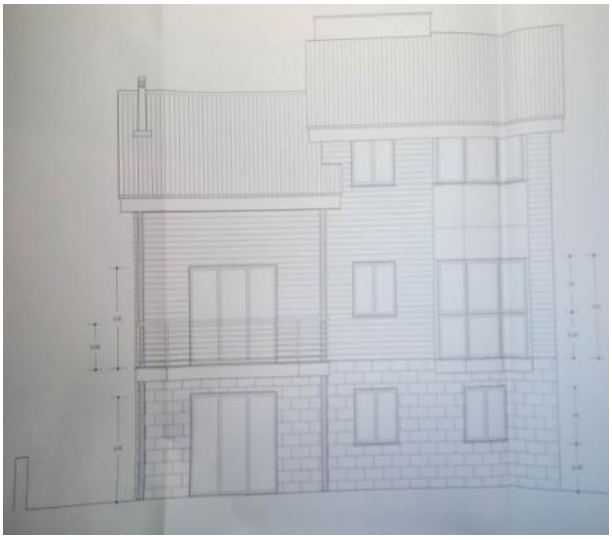
6.3.2.1 External



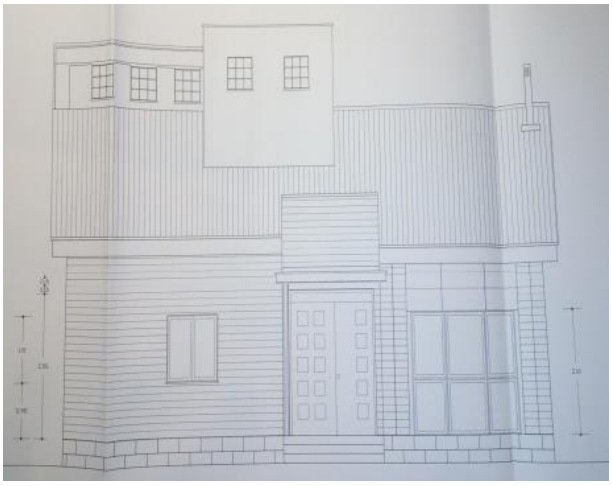
North Face



South Face



East Face



West face

Figure 105 Drawings of the external faces of the house

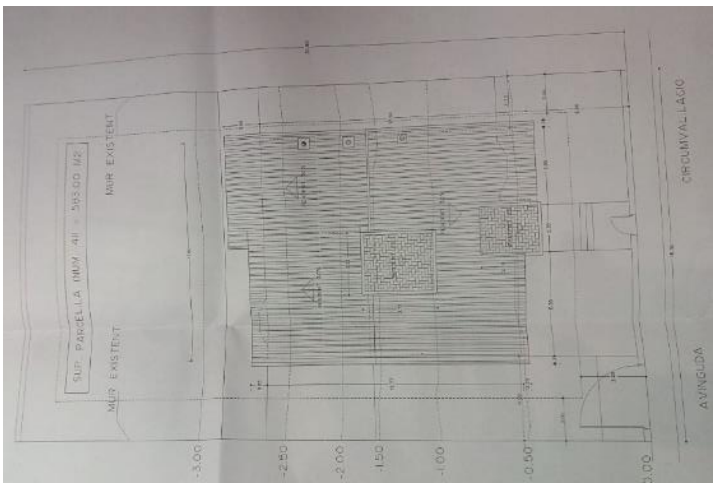
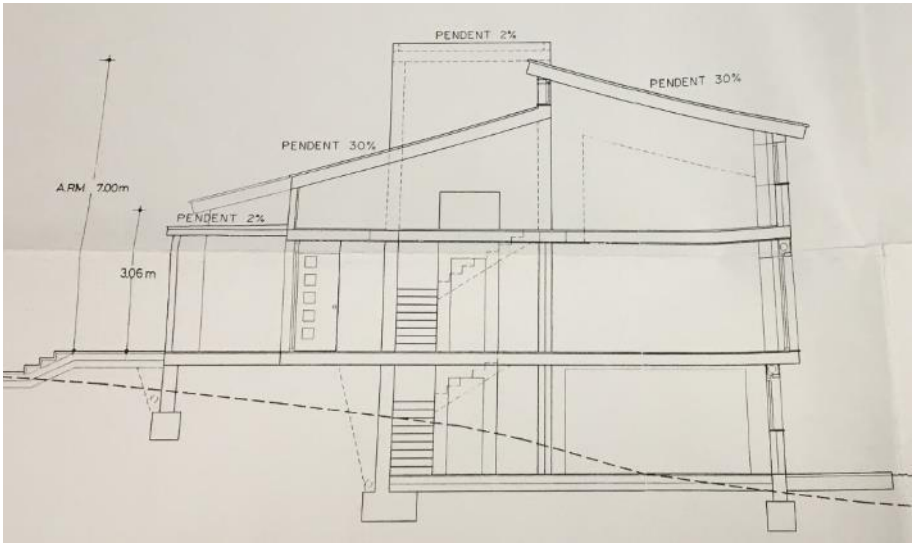


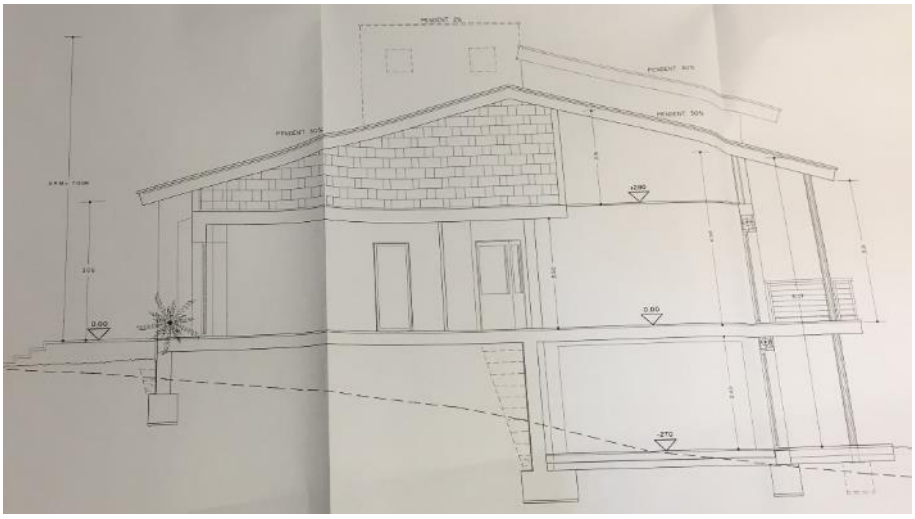
Figure 106 Drawings of the roof

6.3.2.2 Internal

Section AA



Section BB



Section CC

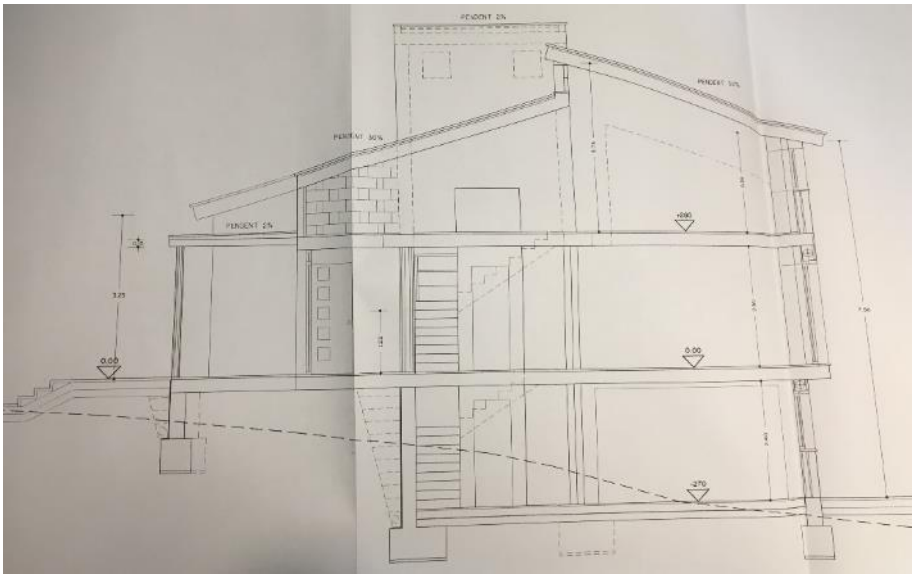


Figure 107 Drawings of three internal sections

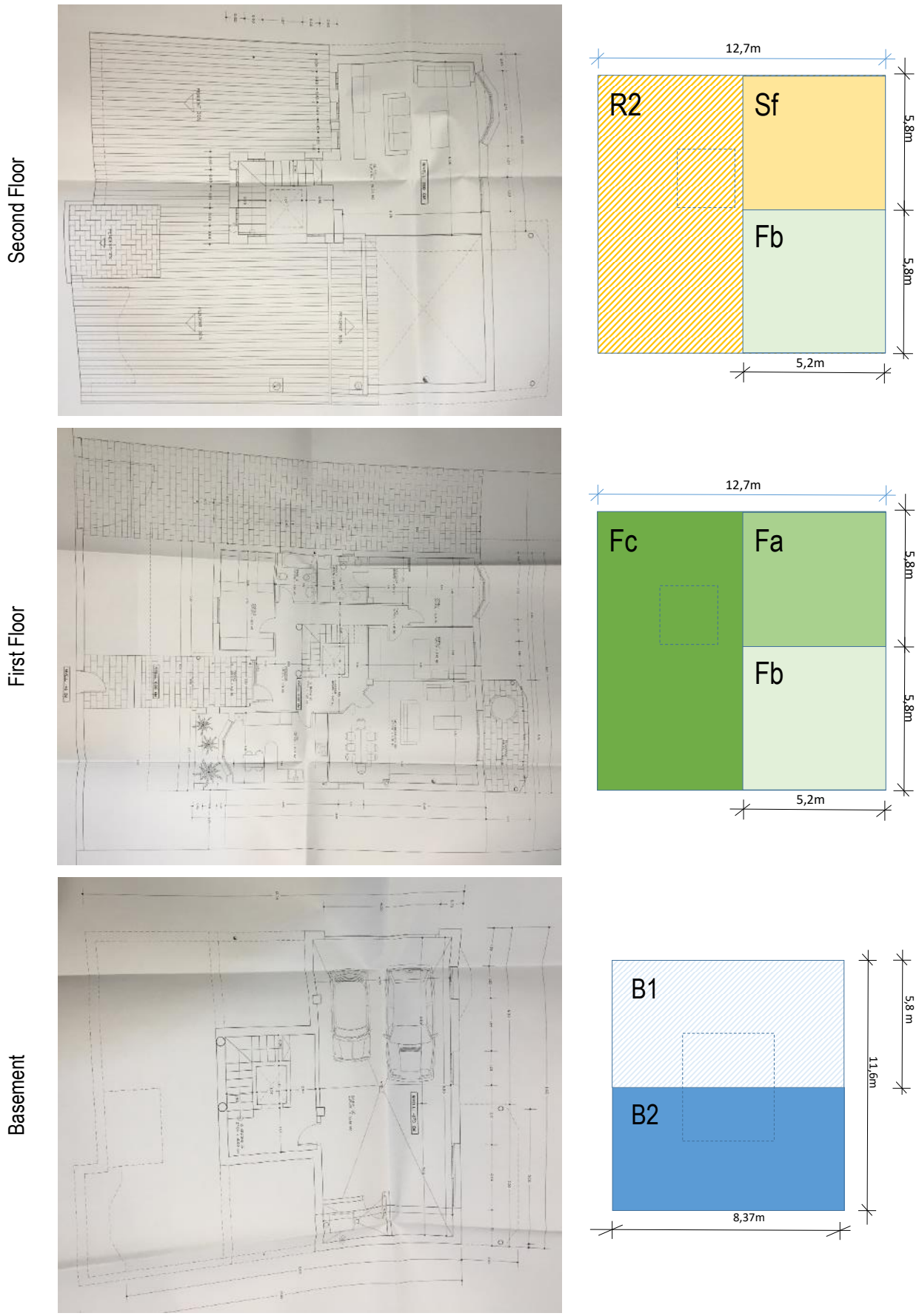


Figure 108 Drawings of the three internal levels of the house and the thermal zones considered

6.3.3 Building model

The main requirements and special features for this case are:

- The thermal zones must describe at least one zone per thermostat (one per floor)
- Since the building geometry is quite complex, some assumption must be taken like:
    - Cross-level thermal zone especially for the main living room across the first and second floor.
    - Some shapes are simplified like the staircase for instance since it is not possible to consider concave thermal zones for internal radiation calculation reasons.

6.3.3.1 Geometry and external shadings

Dimensions and internal thermal zones are represented on Figure 108.

The external view of the final geometry is represented on Figure 109. Specific external shadings (south neighborhood building and overhangs) are represented in purple.

The south wall is considered to be oriented by 10° west against the south axis.

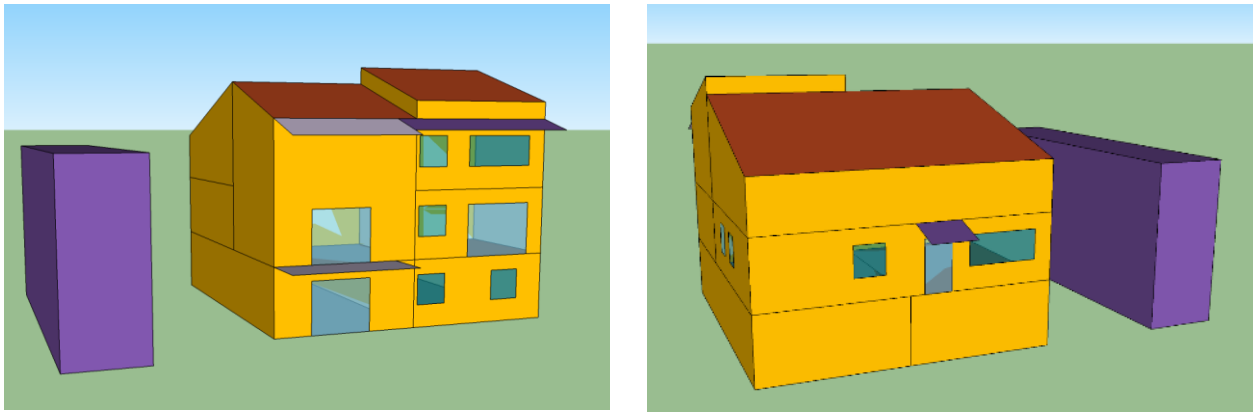


Figure 109 Drawings of the three internal levels of the house

6.3.3.2 Thermal zones

Thermal zones are represented on Figure 108. Their main characteristics are gathered in the Table 26 below. Heating and cooling power are estimated following all the assumptions made within this section 6.3.3. The total area of the heated rooms in the model is the 23% larger than the real case. This is due to the thermal zones shapes that doesn't perfectly fit the breakdown of the real heated zones (shape of the rooms, staircases, entrance, and technical room in the basement for instance). The most important thing is to have a similar global consumption with all the assumptions. The reference area for the results is the real heated area (204m² in this case).

Table 26 San Lorenzo: Thermal zones characteristics

Floor	#	Name	Area [m2]	Volume [m3]	Height [m]	Heated zone?	Max. heating power [kW]	Max. cooling power [kW]	Note
Basement	B1	Basement1	74	199	2.7	N	0.00	0.00	Cellar and garage
	B2	Basement2	74	199	2.7	Y	2.03	0.00	Includes a living room, a bathroom and the technical room
Main floor	Fa	1stfloora	30	81	2.7	Y	0.90	0.55	Bedrooms and closets
	Fb	1stfloorb	30	188	6.2	Y	1.77	0.65	Living room with Mezzanine (ground + second floor)
	Fc	1stfloorc	87	235	2.7	Y	2.07	1.98	Kitchen, bathroom, bedroom, hall
2nd floor	Sf	2ndfloor	30	127	4.2	Y	1.37	0.59	Living room
	R2	Roof2	87	276	3.2	N	0.00	0.00	Attic
TOTAL (Heated rooms)			**251**	**830**	**-**	**-**	**8.15**	**3.78**	**Only considering heated rooms**

6.3.3.3 Walls composition

Five type of external walls are considered in this building. Their composition is gathered in the Table 27 below.

Three faces of the basement (south, west and north) and the ground floor are buried. Their walls are supposed to be in contact with earth, meaning:

- The outside temperature is the ground temperature (see section 6.2).
- No outside convective exchange is considered.

The other faces are supposed to be in contact with the ambient air. The outside convective heat transfer coefficient is set to 18W/m²/K (3W/m²/K for the internal conditions).

Table 27 External walls composition

EXTERNAL WALLS	LAYER	THICKNESS [M]
FIRST FLOOR + BASEMENT (EAST)	Plaster	0.01
	Brick	0.04
	Air Gap	-
	Insulation (polyurethane foam)	0.05
	Brick	0.25
SECOND FLOOR	Plaster	0.01
	Brick	0.09
	Air Gap	-
	Insulation (polyurethane foam)	0.05
	Brick	0.25
BASEMENT (SOUTH / WEST / NORTH)	Plaster	0.01
	Brick	0.04
	Air Gap	-
	Insulation (polyurethane foam)	0.05
	Concrete	0.4
	Plastic blanket	0.001
ROOF	Plasterboard	0.013
	Styrofoam	0.15
	Baked clay	0.03
GROUND FLOOR	Screed	0.05
	Concrete	0.15
	Insulation (polyurethane foam)	0.06

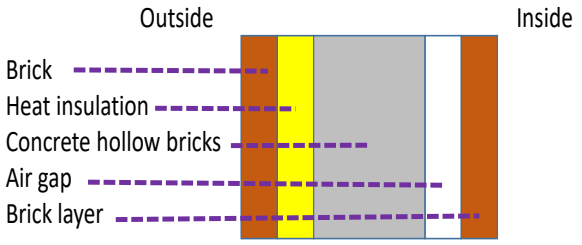


Figure 110 Left: Scheme of the layers of the main external walls. Right: Picture of the wall in the basement.

6.3.3.4 Windows

Standard double glass windows are considered. The main characteristics are introduced in the Table 28

Table 28 Characteristics of the windows

Name	Design	U Value [W/m²/K]	g-value	T-sol	Rf-sol	Frame fraction
ASH140 DBLE-MOD	3.2/13/3.2	2.89	0.789	0.747	0.136	0.3

The windows are set to the different outside wall according to the Table 29.

Table 29 Windows size and position

#	Thermal Zone	Area [m2]	Orientation
10	Fc	3.3	W
11	Fc	1.44	W
12	Fc	1.08	N
13	Fc	1.08	N
28	B1	1.44	E
29	B1	1.44	E
45	Fa	1.44	E
54	Sf	1.44	E
55	Sf	3.3	E
9	B2	5.04	E
37	Fa	5.78	E
44	Fb	5.04	E

Hysteresis shading control are set on windows facing East and South to roughly limit the solar gains:

- Radiation to close the blinds: 140 W/m².
- Radiation to open the blinds: 120 W/m².
- Shading factor (ratio of non-transparent area): 0.8.

6.3.3.5 Ventilation and air infiltration

There is no specific ventilation device in the building.

A global air infiltration rate is considered with a value of 0.8 vol/h.

6.3.3.6 Internal gains

Inhabitants are supposed to bring internal heat according to the following assumptions, based on the "Sedentary activity – Activity level III" values from the EN13779 standard[8]

- Gains: 60W/person, being 0.24W/m²/person in this case (equally split between convective and radiative gains)
- Presence:
  - 4 people (spread in all heated rooms)
  - The gains are reduced by 0.7 when they are asleep
  - The weekly schedule, taken from the French Thermal Regulation RT2012, is on the Figure 111 below.

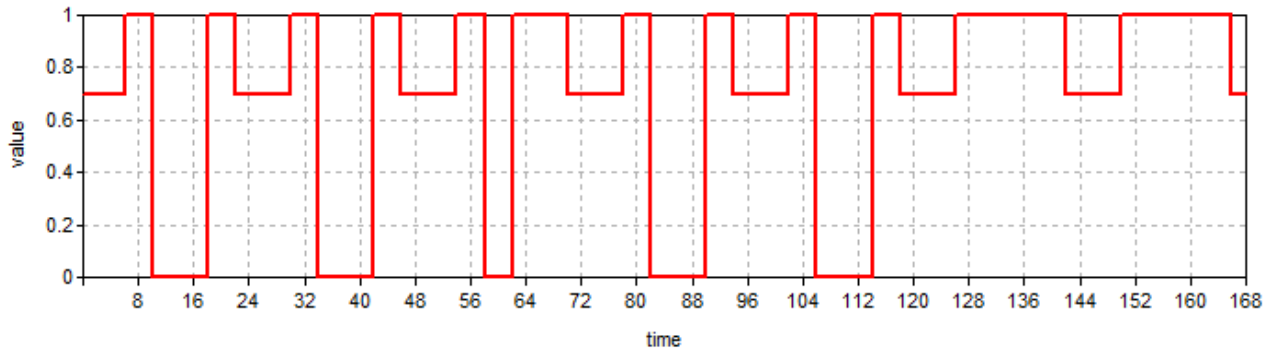


Figure 111 Weekly schedule of the presence and the metabolism of one person

The internal heat gains from equipment is directly taken from the specific electricity load profile (see section 6.3.3.9). It is assumed that 100% of this electricity consumption is turned to internal heat, split between the heated rooms according to their floor area.

6.3.3.7 Set point temperatures

Space Heating and Cooling needs introduced in section 6.3.3.10 are calculated considering constant internal set point temperature throughout the year:

- 20°C for heating (and an additional 21°C in order to assess the variability of the heating needs according to this set point, see section 6.3.3.10).
- 26°C for cooling.

6.3.3.8 Draw offs profile

Regarding DHW needs, inhabitants are supposed to use 50L/person/day at 45°C in average.

Dynamic draw offs follow the 6 minute realistic load profile generated by Jordan and Vajen[9] in the framework of IEA SHC Task26[10]. The histogram on Figure 112 represent the variations in terms of flow rate during this load profile.

[8] DIN EN 13779:2010

[9] Jordan, Ulrike, and Klaus Vajen. "Influence Of The DHW Load Profile On The Fractional Energy Savings:" Solar Energy 69 (July 2001): 197–208. https://doi.org/10.1016/S0038-092X(00)00154-7.

[10] Jordan, Ulrike & Vajen, Klaus. (2005). DHWcalc: PROGRAM TO GENERATE DOMESTIC HOT WATER PROFILES WITH STATISTICAL MEANS FOR USER DEFINED CONDITIONS.

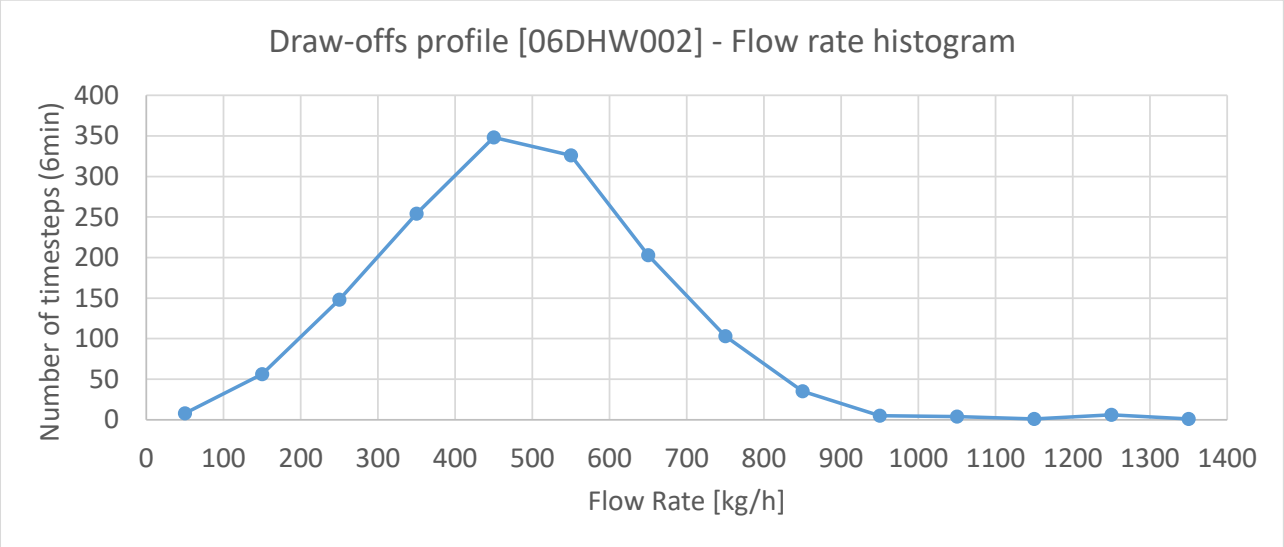


Figure 112 Histogram of the flow rate values from the Draw Offs profile considered for the Demo site #5

6.3.3.9 Specific electricity consumption

The specific electricity load profile is generated using the CREST[11] tool (v2.2.1), considering one detached dwelling without any heating or cooling device. The resulting profile is with an hourly timestep. As explained in section 6.4.3.2, the original profile is corrected with a lower threshold value of 200W (Figure 113).

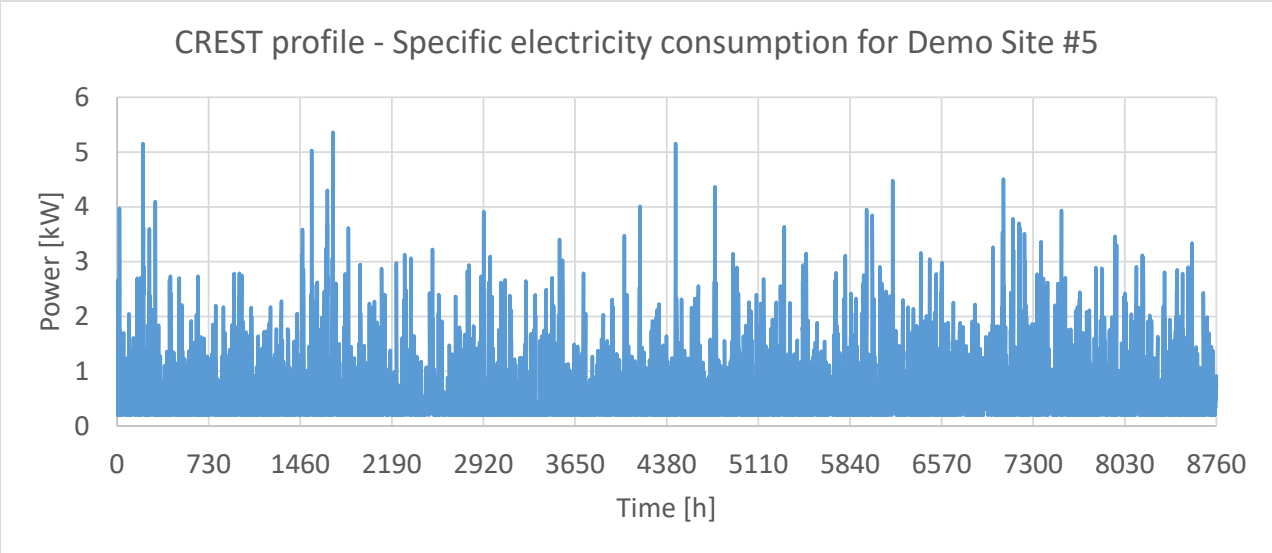


Figure 113 Specific Electricity consumption profile generated for the Demo site #5

6.3.3.10 Results: energy needs estimation

The resulting energy needs are introduced on a monthly basis in Table 30 and Figure 14.

[11] McKenna E., Thomson M. 2016. High-resolution stochastic integrated thermal-electrical domestic demand model. Applied Energy, 165:445. http://dx.doi.org/10.1016/j.apenergy.2015.12.089

Table 30 Estimation of the energy needs

	QH [KWH]	QC [KWH]	QDHW [KWH]	WELEC_SPE [KWH]
JAN	3296	0	258	469
FEB	2857	0	224	382
MAR	2365	0	253	493
APR	1600	0	196	379
MAY	624	0	147	413
JUN	33	7	157	367
JUL	0	278	109	410
AUG	0	261	104	406
SEP	0	84	174	440
OCT	331	0	219	490
NOV	1877	0	184	467
DEC	3053	0	283	461
YEAR *(COMPARED TO LIVING SPACE)*	**16037** *(79 KWH/M²)*	**630** *(3 KWH/M²)*	**2309** *(11 KWH/M²)*	**5178** *(25 KWH/M²)*

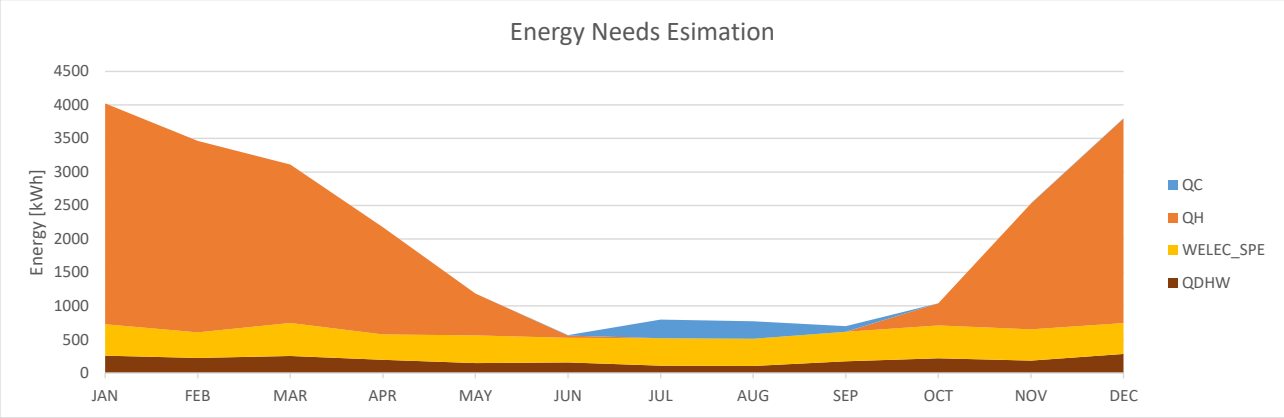


Figure 114 Monthly evolution of the estimated energy needs for the Demo site #5

A temperature set point increased to 21°C raises the SH needs by 18% (18987kWh). This gives an idea about the possible dispersion of the energy needs estimation for comparison with real energy data (see section 6.4.3.4).

6.4 Heating/cooling system with heat, cold and DHW distribution

6.4.1 Overall description

The existing system is a hybrid installation for the heat production (SH and DHW):

- Heat Pump: Baxi
  - A circuit: SH loop for the first and second floor (through a Buffer Tank)
  - B circuit: SH loop for the Basement (no buffer tank)

- DHW circuit: DHW for the whole house
- AUX circuit: back up from the oil boiler

- Oil boiler: Roca Lidia GTA
  - Back up for the HP operation (AUX circuit)
  - Additional set of valves to directly heat up the buffer tank and the DHW loop in case of problem

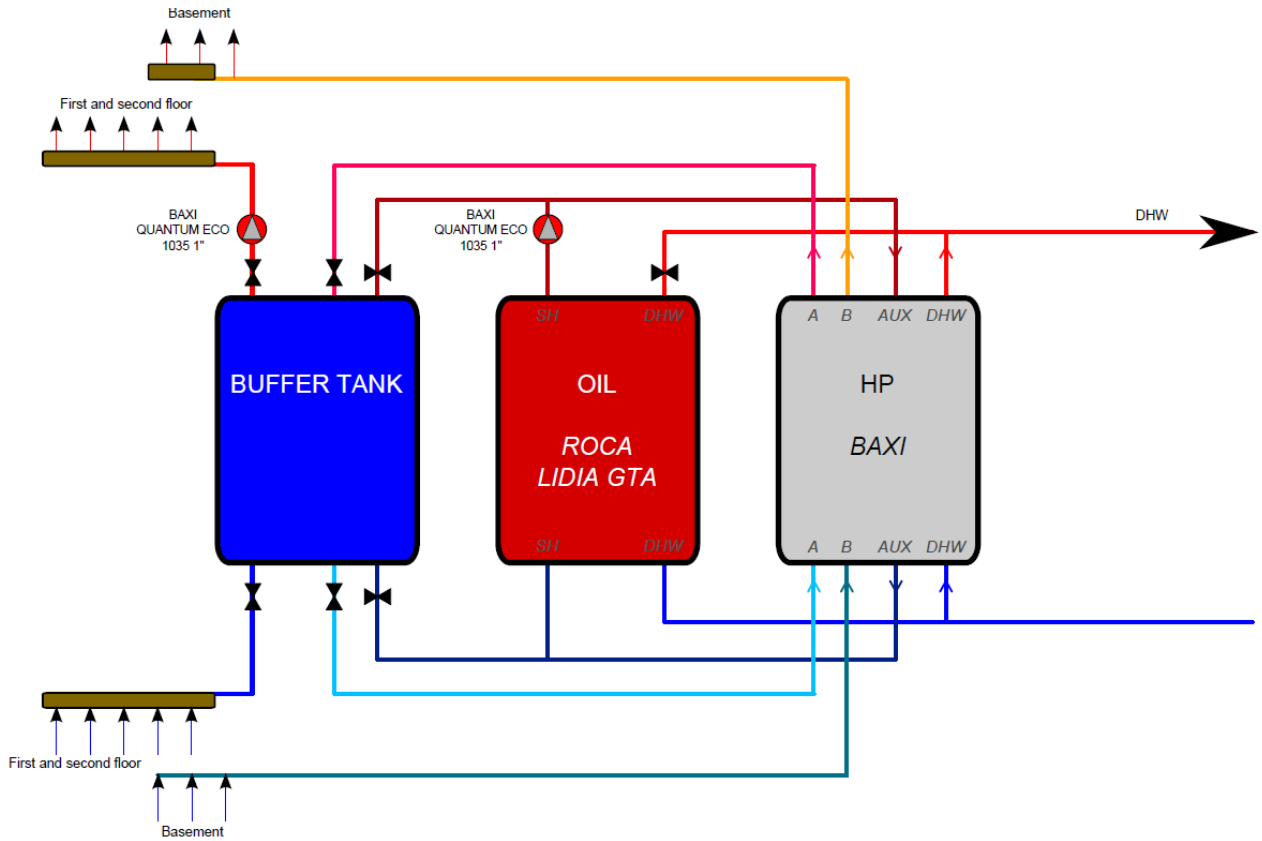


Figure 115 Schematic of the existing H/C system and distribution

All the components are located in a technical room in the basement (Figure 116).

Figure 116 Drawing and picture of the technical room (dimensions in cm)

The heat for SH is distributed in every floor and emitted thanks to 20 radiators:

- 4 in the basement.
- 12 in the first floor.

- 4 in the second floor.

Figure 117 Example of 2 radiators in the demo site #5

6.4.2 Technical information about the existing components

6.4.2.1 Oil boiler

	Service	(heating / DHW / cooling)	Heating / DHW
	Fuel type	(text)	Oil
	Size	(kW)	48,3
	Brand	(text)	BAXI Calefaccion S.L.U.
	Type / Model	(text)	Roca Lidia 40 GTA
	Installed in	(year)	2007
	Thermal efficiency	(%)	90,6
	Backup installed	(yes/no)	no
	Maximum pressure	(bar)	4
DHW tank	Service	(heating / DHW / cooling)	DHW
	Tank Capacity	(L)	150
	Location	(text)	Inside the oil boiler casing

6.4.2.2 Heat Pump

	Service	(heating / DHW / cooling)	Heating / DHW
	Fuel type	(text)	-
	Size	(kW)	16
	Brand	(text)	BAXI Calefaccion S.L.U.
	Type / Model	(text)	AWHP 16 MR-2 / MPI-II/H + 11-16 V200 ES
	Installed in	(year)	2015
	Energy source	(text)	Electricity
	Backup installed	(yes/no)	Oil boiler
	Backup efficiency	(yes/no)	-
	Operating mode (on/off, modulating, etc)	(text)	Modulating
	Refrigerant	(text)	4.6 kg of R410A
	Service pressure	(bar)	HP: 4.15 LP: 2.3
DHW tank	Service	(heating / DHW / cooling)	DHW
	Tank Capacity	(L)	180
	Location	(text)	Inside the HP indoor unit

6.4.2.3 Buffer tank

	Service	(heating / DHW / cooling)	Heating circuit
	Tank Capacity	(L)	50
	Brand	(text)	BAXI Calefaccion S.L.U.
	Type / Model	(text)	ASA 50 - IN
	Technology	(text)	Without coil
	Installed in	(year)	2015
	Maximum pressure	(bar)	6

6.4.3 Consumption data

Several kind of information about the energy consumption are available from the owner.

6.4.3.1 Electricity bill

16 electricity bills from 04/10/2016 to 27/11/2018 are available with variable periods.

Those bills give an indication of the consumption over the period and the global consumption over the past 12 months (moving annual consumption). This global consumption for each bill is represented on Figure 118. Over this period, the global annual electricity consumption is between 8759 and 11730 kWh/year.

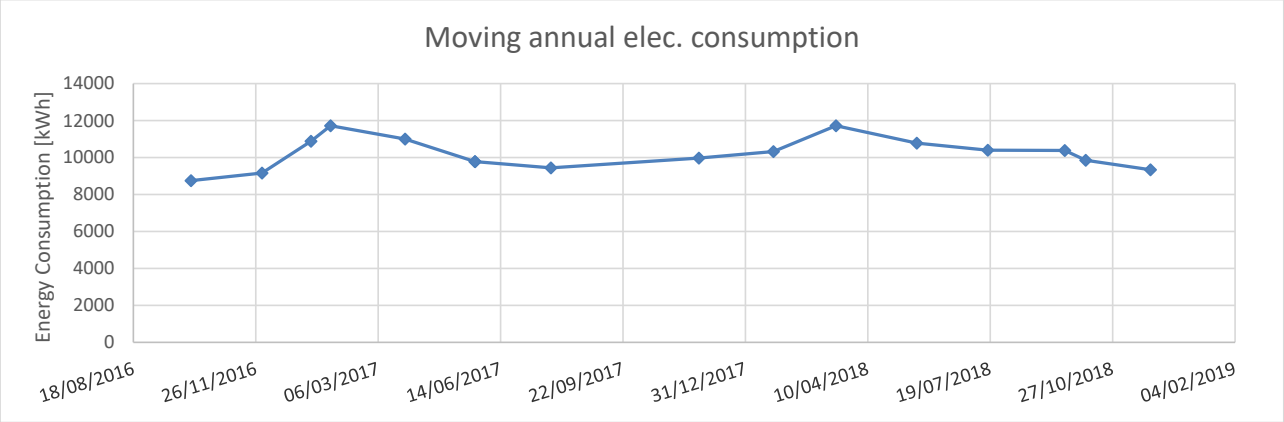


Figure 118 Moving annual electricity consumption between 2016 and 2018

6.4.3.2 Electric consumption monitoring

Hourly data from 24/01/2018 to 21/06/2019 were available from the electricity provider and stored by the owner. There are several periods without any data (Figure 119).

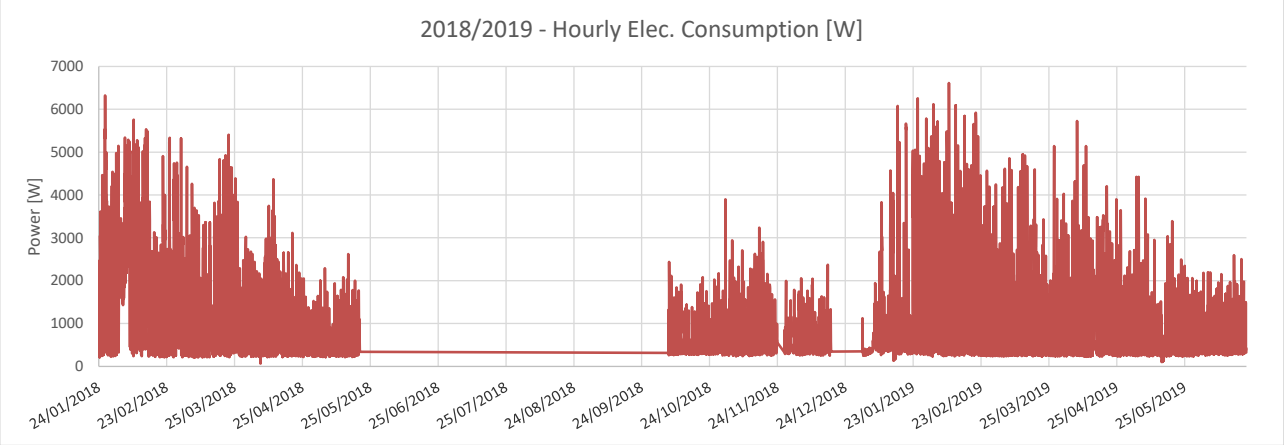


Figure 119 Available hourly electricity consumption

When sorting those available data in decreasing order, this characterizes the electricity load profile – including the heat pump consumption - over the entire period (Figure 120). When comparing with the same curve from the CREST profile (section 6.3.3.9), one can see that the CREST profile (without heat pump consumption) seems relevant: the CREST curve is reasonably below the curve from electricity data. The CREST lowest power values seem however lower than the measured ones: the latter reveals a basis around 200W whereas the CREST profile goes below 200W 40% of the time, down to 20W. The CREST profile probably slightly underestimates the specific electricity consumption. When correcting the CREST profile considering 200W as the lowest value, the specific electricity consumption is increased by 6% (5177kWh). The variation of this consumption is studied in the next section (6.3.3.10).

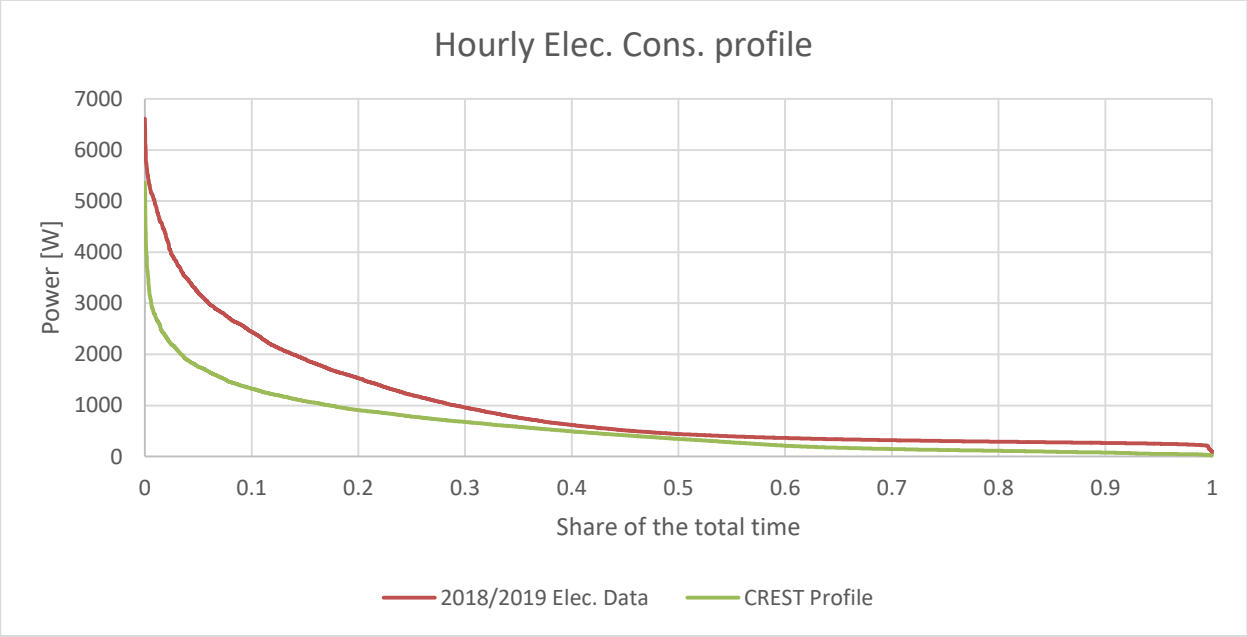


Figure 120 Electricity load profile – comparison between measured data and the CREST profile (without correction)

6.4.3.3 Oil consumption

Between 29/11/2015 and 26/06/2019, the owner has recorded at 7 different dates the approximate filling level of the oil tank and information about two refills.

Given those data:

- The oil volume consumption is estimated for each available period.
- The energy consumption is estimated assuming 10kWh/L of oil.
- Overall consumption: 4426kWh/year approximately
    - 2543kWh/year during 2016/2017.
    - 5187kWh/year during 2018/2019.

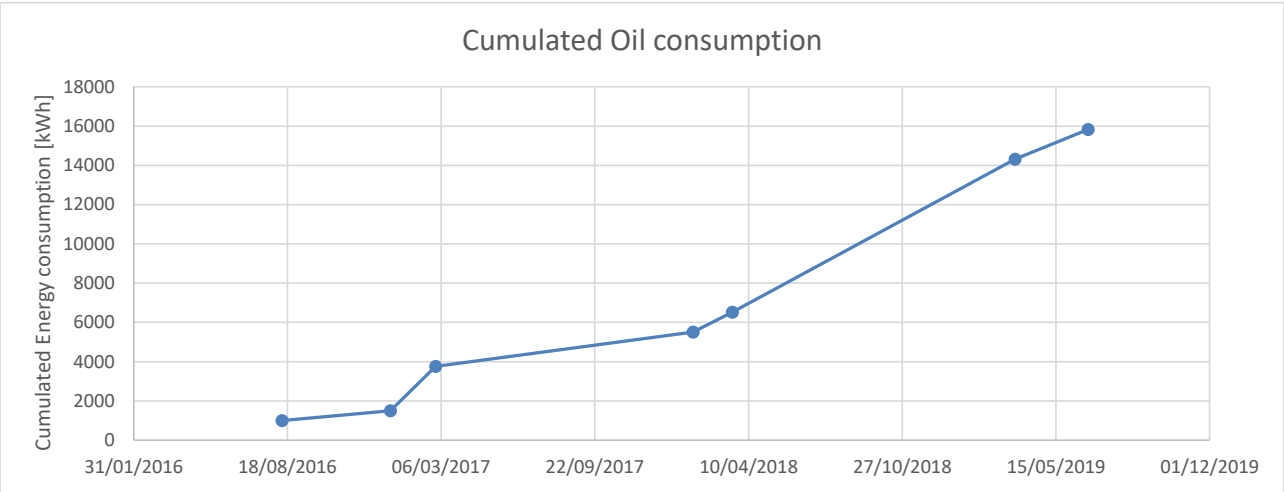


Figure 121 Cumulated Oil consumption

6.4.3.4 Summary

The total annual heat supplied is estimated from those energy data following those assumptions:

- Electricity
  - The total consumption is the specific electricity + the heat pump consumption.
  - The two bounds estimated in section 6.4.3.1 are used.
  - Without any further information, the specific electricity from the CREST profiles are considered (see section 6.3.3.9 : with and without the 200W lowest bound correction).
  - The heat supplied by the heat pump is estimated taking into account the seasonal coefficient of performance (SCOP) given in the HP certificate (3.1).
- Gas
  - The two bounds estimated in 6.4.3.3 are used (2016/2017 and 2018/2019).
  - An annual efficiency of 85% is considered (reference value for gas boilers in IEA SHC Task32[12])
- Heat losses
  - The default heat loss coefficient formula from the standard EN12977[13] is considered.
  - The tanks are supposed to be at a constant temperature throughout the year (60°C for DHW and 30°C for SH).

The calculations are summed in Table 31 hereunder.

Table 31 Supplied heat estimation from Energy Data

		MIN	MAX	
ELEC.	Total cons. [kWh]	8759	11730	Data from elec. Bills
	Spec. El. [kWh]	5178	4873	Taken from the CREST assumptions
	HP cons. [kWh]	3581	6857	Total cons without spec. El.
	SCOP [-]	3.1	3.1	According to the AWHP series certificates
	HP heat [kWh]	***11102***	***21255***	***For SH and DHW from the HP***
OIL	Total cons.	2543	5187	Data from the owner
	Boiler annual efficiency [%]	85%	85%	Ref value for gas boiler
	Boiler heat [kWh]	***2162***	***4409***	***For SH and DHW from the boiler***
TOTAL HEAT PRODUCED [KWH]		**13263**	**25664**	**For SH and DHW**
HEAT LOSSES	DHW tank	219	219	180L @60°C in average
	SK Tank	33	33	50L @30°C in average
TOTAL HEAT SUPPLIED [KWH]		**13011**	**25412**	

Given those assumptions, the thermal needs estimated by the TRNSYS model are within the range of the heat supply estimated from the energy data (Figure 122). Thus, the model seems consistent enough to carry on further analysis.

[12] Heimrath, R, and Michel Y. Haller. "Project Report A2 of Subtask A : The Reference Heating System, the Template Solar System. A Report of IEA SHC - Task 32," 2007. http://task32.iea-shc.org/data/sites/1/publications/task32-Reference_Heating_System.pdf.
[13] EN12977-1:2012

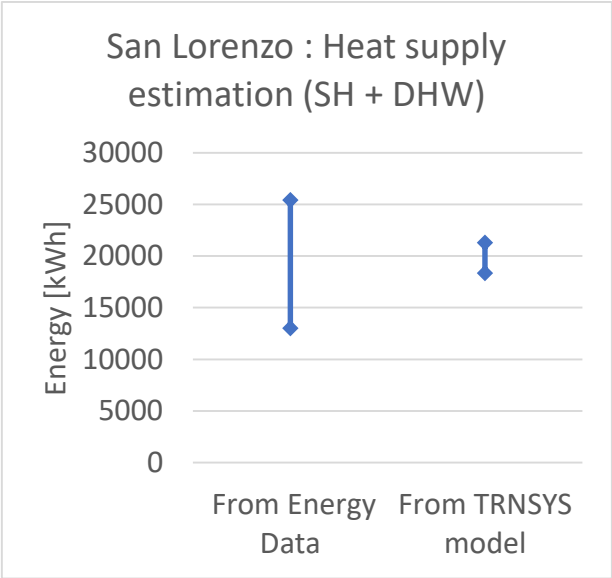


Figure 122 Bounds of heat Supply estimation from energy data and from the TRNSYS model

6.5 Specific requirements for the new heating/cooling system

Other specific considerations of the demo site #5 must be taken into account for the development of the technology package 4.

6.5.1 User requirements

- The owner wants to keep the oil boiler as an emergency auxiliary system, to be used manually, in case of system default.
- The owner would like the new system to provide space cooling during summer. This could be done using 2 additional blowing units in the 2 upper levels.
- The owner would like the control of the new system to be as simple as possible (bad experience with former systems).

6.5.2 Technical constraints

- As described in section 6.4, the size of the technical room is quite limited. This must be taken into account when sizing the system's components.
- The size of the roof dedicated for solar panels is quite limited. There will be only one solar field for both PV and Thermal collectors (using the BDR technologies).
- The size of the roof dedicated for solar panels is quite limited. There will be only one solar field for both PV and Thermal collectors (using the BDR technologies).

6.5.3 Regulation compliance

- All equipment must complied with CE requirements
- Label HP Keymark or NF PAC for the Heat Pump
- Solar Keymark for the thermal panels
- Low Voltage Electrotechnical Regulation (REBT), according to RD 842/2002 of 02/08/2002, and specifically the Complementary Technical Instructions
- Royal Decree 1027/2007, of July 20, which approves the Regulation of Thermal Installations in Buildings (RITE)
- Complementary Technical Instructions called ITE. (Ministerial Order of July 31, 1998)

- Electricity: the photovoltaic production needs to comply with the Royal Decree 244/2019 (from April 5th), in which the self-consumption of electricity is regulated. For installations with less than 15kW do not need permissions.

6.5.4 Other requirements

- The subscription to the electrical network must remain at the same power level to keep the same price.
- PV panels and thermal panels have to be integrated in a homogeneous surface
- Excess PV electricity must be minimized by self-consumption

6.5.5 Economical and environmental reference values of energy

The system in demo site #5 will use electricity and oil as backup energy. The considered reference values for those energy in Spanish context are introduced in Table 32 hereunder.

- Electricity Primary energy factors and GHG emissions are taken from the Spanish Agency[14]
- Electricity prices are taken from the EUROSTAT website[15]
- Oil Primary energy factors and GHG emissions are taken from European values of the ISO52000
- Oil price prices are taken from the owner comments

Table 32 Demo site #5 – Reference values for Electricity and Oil

	Elec.	Oil
Primary Energy Factor PEFnren [-]	2.007	1.1
Primary Energy Factor PEFren [-]	0.396	0
GHG emissions [gCO2/kWh]	357	290
Energy cost - [€/kWh]	0.2404 €	0.0770 €

6.6 Preliminary monitoring plan

The Figure 123 shows the specific sensors to monitor TP4 in San Lorenzo. Based on this preliminary monitoring plan, the comprehensive monitoring architecture with all sensors and communication devices will be further developed by Schneider during the next M18-24 period (T6.2) through iterative process with BDR as TP provider and demo site responsible.

[14] IDAE, 2011. Análisis del consumo energético del sector residencia en España, s.l.: IDAE-Departamento de Planificación y Estudios.
[15] https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

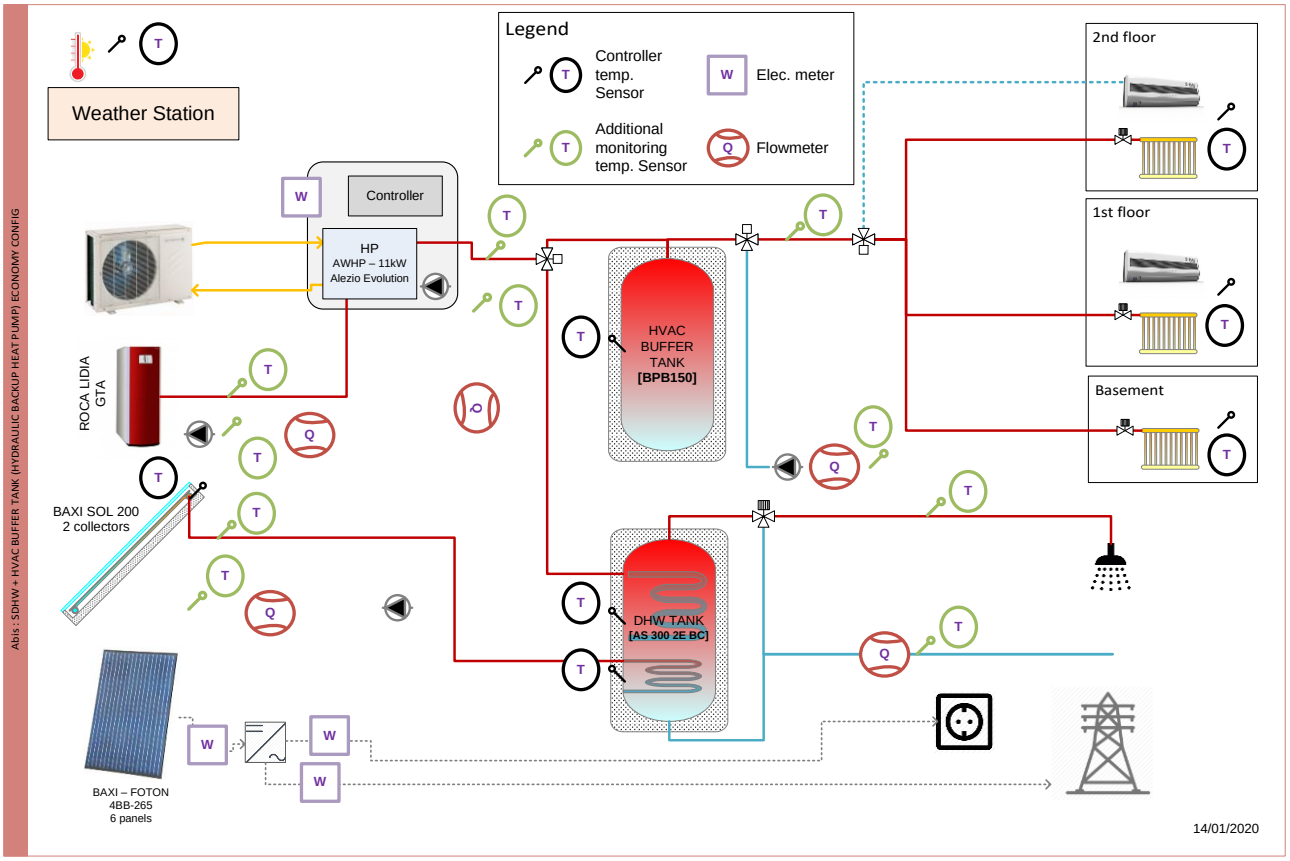


Figure 123: TP4 layout diagram for San Lorenzo demo site with a preliminary set of sensors for TP monitoring

7 Verviers SC demo site #6

The following subsections summarize the available data to describe the existing status of the demo case of Verviers Hall Moray during the year before the deployment of the SunHorizon Technology Package.

7.1 General description

Hall Moray, located in Verviers (Wallonia, Belgium), is a public building owned by the city and managed by Synergis, the agency in charge of managing all the building operations and maintenance. The Albert Moray Sports Center is a sports complex from **2006** and is located on "*rue des Chapeliers No. 2 in Ensival*". The building has four gyms, where basketball, table tennis, fencing and martial arts can be practiced. It also incorporates a cafeteria. The building is 1,515 m^2 and has 2 levels with one basement. It is split into different volumes:

- Large multipurpose room: Moray room
- Small multipurpose room (fencing / dance / martial arts): Giltay Room
- Small room tatami (karate): Room Rando
- Small room tennis table: Raskin room, 8 changing rooms with collective showers, 4 sanitary blocks and Concierge housing.

The building is mainly used from September to June. The detailed occupancy rate is unknown as it is mainly used by sport club outside office hours (no detailed reporting on the number of people using it during sport club hours) and schools (during office hours).

The building is equipped with three condensing gas boilers, two of 232kW and 290kW to cover space heating needs and one of 96kW to cover DHW needs. The former boilers are connected to distribution pipes that are connected to aerotherms and radiators. The average consumption for the period from 2013 to 2019 of the building accounts for up to 91,272 kWh/y of electricity and 28,918 Nm^3 of natural gas. SunHorizon project will mainly address the space heating and domestic hot water (the latter one will be mainly address in summer time). Electricity consumption of the building is out of the scope of this project.

Front picture

Figure 124: Hall Moray pictures (Verviers – Demo 6)

7.2 Local weather characteristics

[16]In Verviers, the summers are comfortable and partly cloudy and the winters are long, very cold, windy, and mostly cloudy. Figure 125 shows the climate summary of the city of Verviers. Closest weather station is located in Stembert, Belgium. Over the course of the year, the temperature typically varies from -0°C to 22°C and is rarely below -7°C or above 29°C. The warm season lasts from June to September (3 months), with an average daily high temperature above 19°C. The cold season lasts from November 18 to March 10, with an average daily high temperature below 8°C. The average annual

[16] Source: weather spark https://weatherspark.com/y/52354/Average-Weather-in-Verviers-Belgium-Year-Round

rainfall is 914 mm[17], with greater amount of precipitation in summer (June-August) and lower in spring or fall (April, September and October). The relative humidity varies from 50 to 80 %, being higher when it is rainy. Wind speed varies from 17.5 km per hour, as an average for the months of October to end of March, to 13.5 km per hour from April to middle of October.

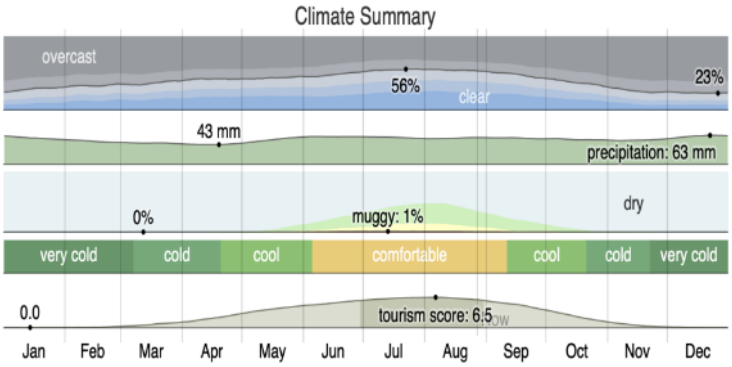


Figure 125 : Climate Summary for Verviers (Source: Weather Spark)

Regarding sunlight hours, winters are characterized of low sunhours especially in November to February, while in summer monthly accumulated sunhours of 200 h is reached in May to August. A global solar irradiance of 1010 kWh/m^2 is found in Verviers, with higher irradiation values in summer (up to 140kWh/m^2/month) than in winter (up to 20kWh/m^2/month). Figure 126 shows the variation of global and direct solar irradiation and average temperature of Verviers[18].

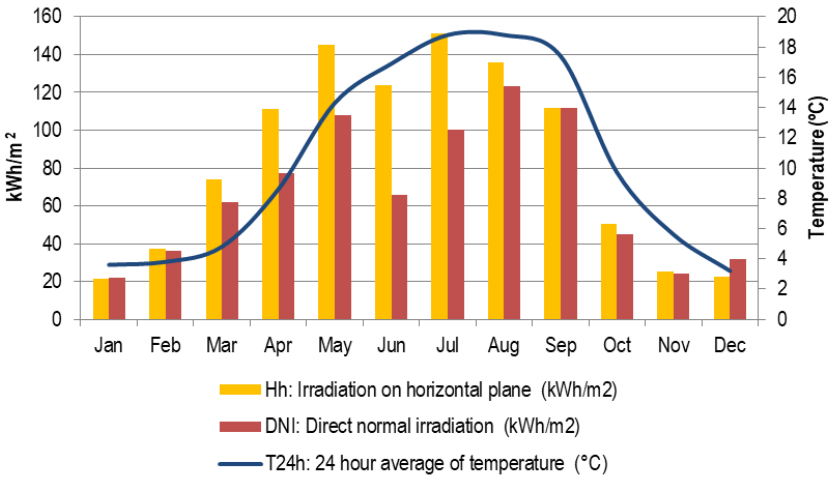


Figure 126 : Monthly values of: Irradiation on horizontal plane and direct normal irradiation (in kWh/m^2) and average temperature

7.3 Building geometry and use

Public sports center was built in 2006 and it is contained within one building, with a total floor area of 1,515 m^2. It includes a large gymnasium, changing rooms, toilet blocks, lodgings for the concierge, as well as three smaller rooms used for fencing, martial arts and table tennis.

[17] https://en.climate-data.org/europe/belgium/wallonia/verviers-14582/
[18] Data from: PVGIS https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#PVP

Figure 127: Aerial View (Source: Bing Maps)

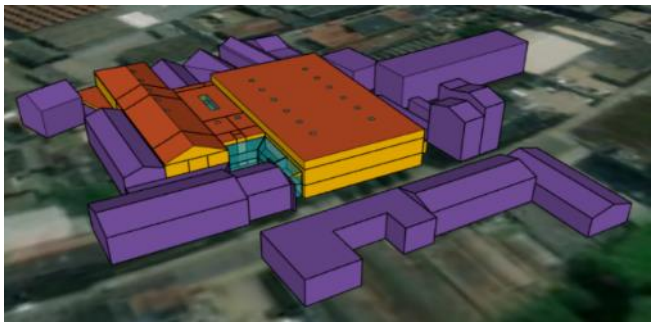


Figure 128: 3D Model of Hall Moray in Sketch up.

The building has two floors above ground and a basement. Figure 129 shows the Ground Floor layout as well as pictures from the main rooms: entrance, Moray (basket court), Giltay (gymnasium room) and Rando (fencing and martial arts room). Figure 130 shows the first floor of Hall Moray, that consists of a cafeteria (with a kitchen and an storage room), bathrooms and showers (top left) and a tennis table room (called Raskin room) which is an open space connected with stairs to the Giltay room located downstairs.

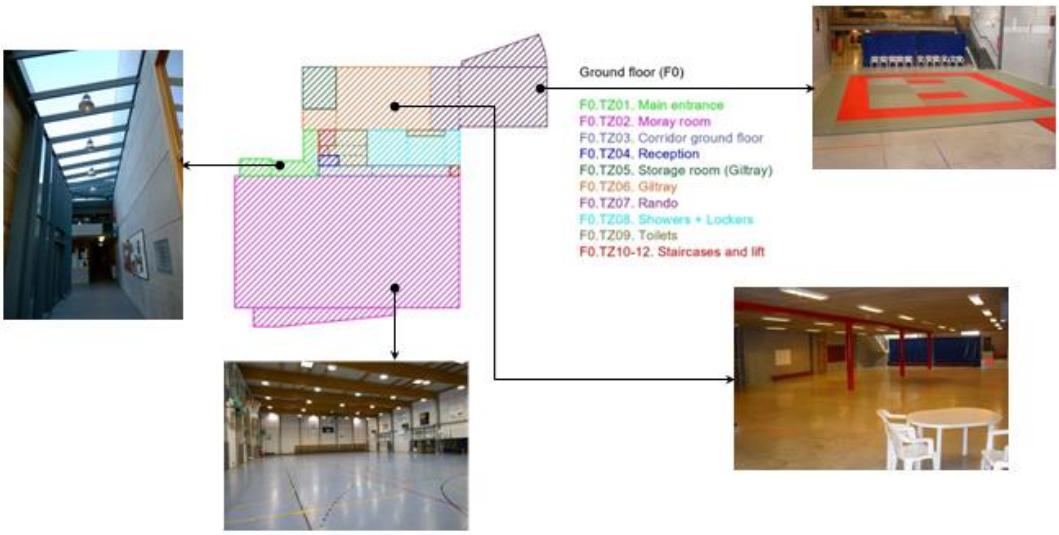


Figure 129: Ground Floor description and division in thermal areas for Hall Moray

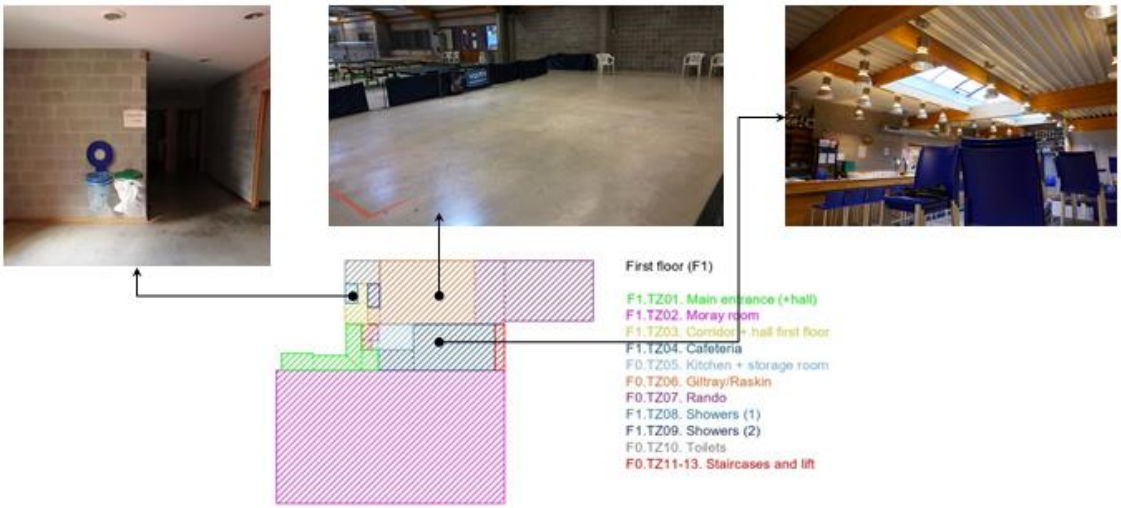


Figure 130: First floor layout, division of thermal zones and pictures

All areas with large heights (high ceiling) have been divided in order to simulate the stratification of air due to the height, and also to have different air temperatures at each air node (node where TRNSYS performs all the thermal calculations). Therefore, the building has been divided in the following areas (See figures below):

- Moray room has been divided in 2 areas and 4 thermal zones: one big space (T1, where people plays) with one thermal zone per height (divided in 3 heights: F0T1, F1T1, F2T1) and small space on the right side of the picture that is used as storage room(F0T2)
- Giltay room (fencing/dance/martial arts): have been divided in two convex areas (T1 and T2) and two heights (F0, F1), resulting in 3 thermal zones: F0T1, F0T2,F1T2.
- Besides that, the Raskin room, located on the top of the Giltay room is the thermal zone called F2T1.
- Rando room is divided in T1and T2(where people plays), and T3 (the storage room on the left side), and 3 heights: F0, F1 and F2(roof). Resulting in: F01T1,F0T2,F0T3, F1T1,F1T2,F2T1,F2T2
- Others: janitor's house, halls, corridors, lockrooms: are separated in different convex areas, resulting in the thermal areas showed in Figure 132

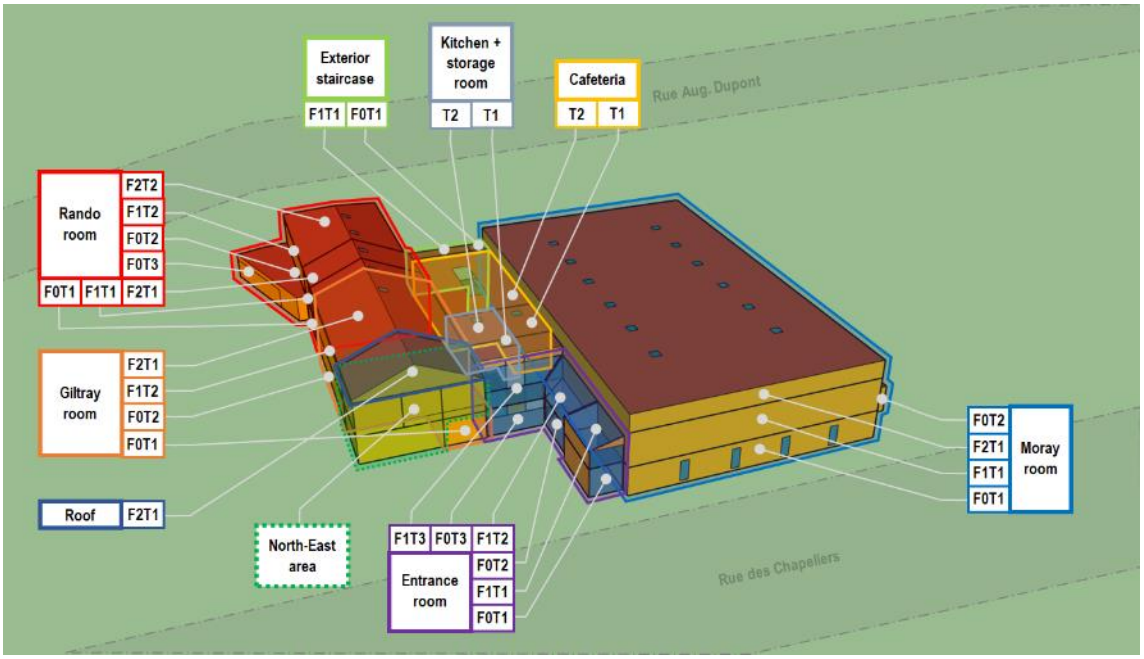


Figure 131: Distribution of thermal areas and subareas in Verviers Sports Centre (I)

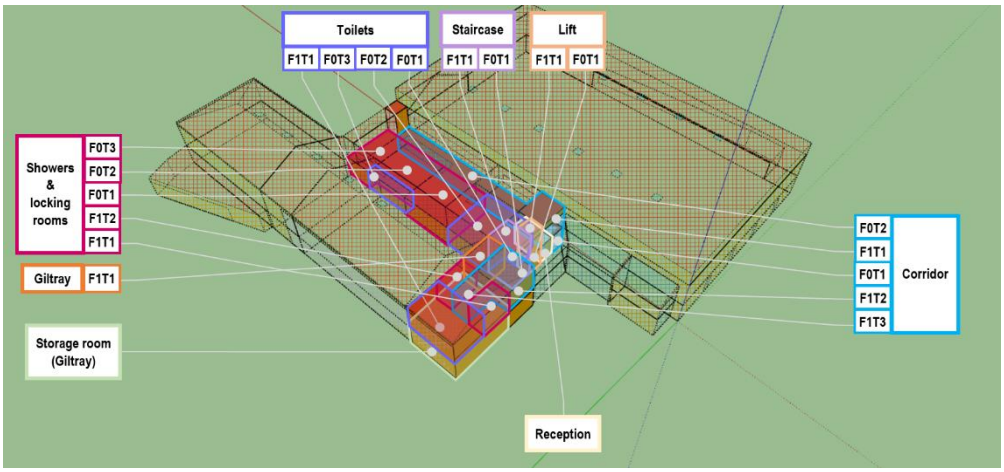


Figure 132: Distribution of thermal areas and subareas in Verviers Sports Centre (II): North-East area and central-building ground floor.

For each thermal zone, their schedule is considered. Generally, Hall Moray is open from Monday-Saturday from 8:30 to 00:00, with specific schedule for each room (see: Figure 133). The Moray room is also open on Sundays.

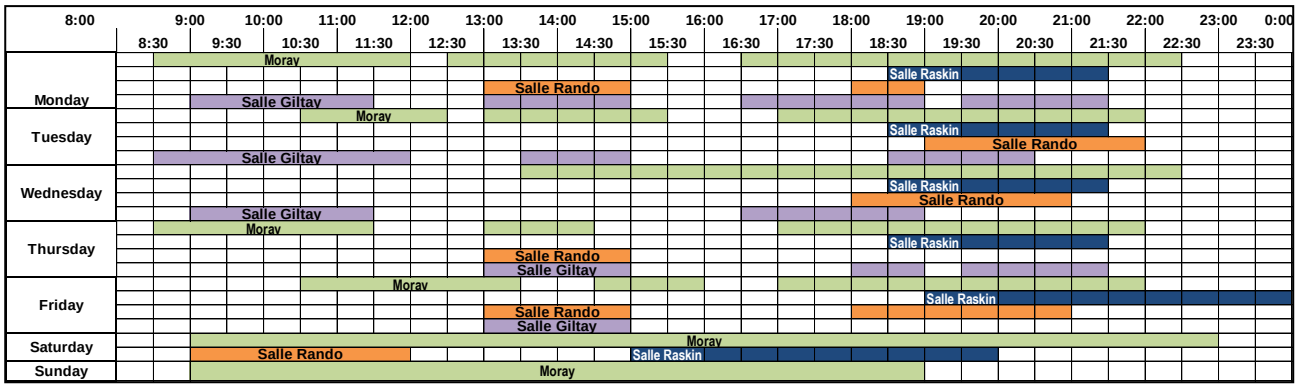


Figure 133: Schedule of each Room

The owner provided the total number of hours that each room is open to the public:

- Salle moray: 66,5 hours/week. 2.879 hours/ year. Closed 20dec-6jan ; 1july-10august
- Salle rando: 28 hours /week 1.212 hours /year
- Salle raasking: Table-tennis. 43,75 hours/week. 1.894 hours/year

All rooms have a fixed setpoint of 19ºC for heating, and no cooling is applied. The main heated areas are shown in Table 33.

Table 33: Main heated areas: use, surface (m^2) and volume (m^3)

HEATED			
	VOLUME	AREA TOTAL	USE
Reception	23.43 m³	7.32 m²	-
Basket Court	4'006.46 m³	1'252.02 m²	Basket tournaments, training
Cafeteria	698.58 m³	183.84 m²	-
Corridors	349.14 m³	101.01 m²	-
Showers	472.98 m³	144.30 m²	-
Giltay	1'887.97 m³	541.14 m²	Gymnasium
Entrance	231.45 m³	72.33 m²	-

Rando	958.33 m³	299.48 m²	Martial arts and fencing room
Rangement	188.90 m³	59.03 m²	-
Toilets	320.16 m³	94.01 m²	-
TOTAL	9'137.39 m³	2'754.47 m²	

Within the scope of SunHorizon a thermal decomposition study of the envelope was performed to obtain the thermal transmittance rate (U value) of the walls and windows of the building. The study covered the main external walls and windows, for adjacent walls an EU building study was considered to estimate the U-value[19].

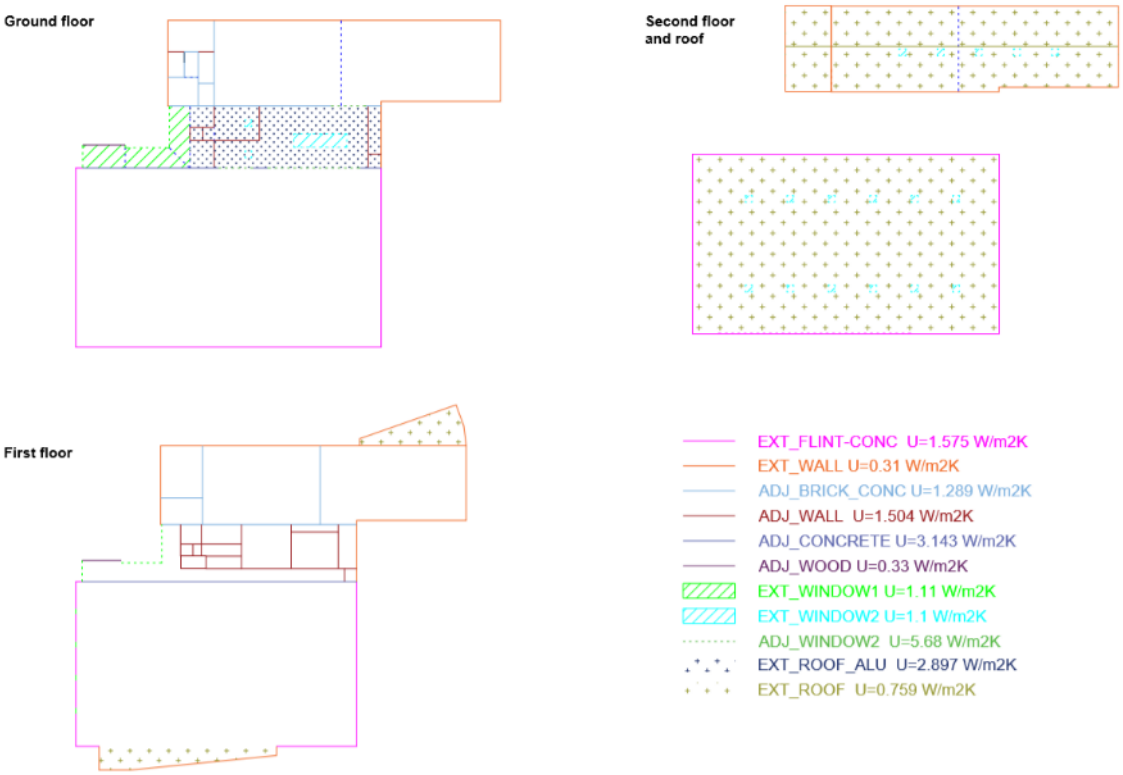


Figure 134: Materials defined in TRNSYS by floor (virtual walls/windows are not drawn) for Hall Moray

Figure 135 shows the two roofs available: the top picture is from the roof on the top of the cafeteria and the bottom one is the roof of the basket room. The latter one is where the TVP panels will be installed.

SunHorizon components such as TVP panels, will be installed in the roof on the top of the basket court room. A picture of the roof can be seen in Figure 135.

[19] https://ec.europa.eu/energy/en/eu-buildings-database

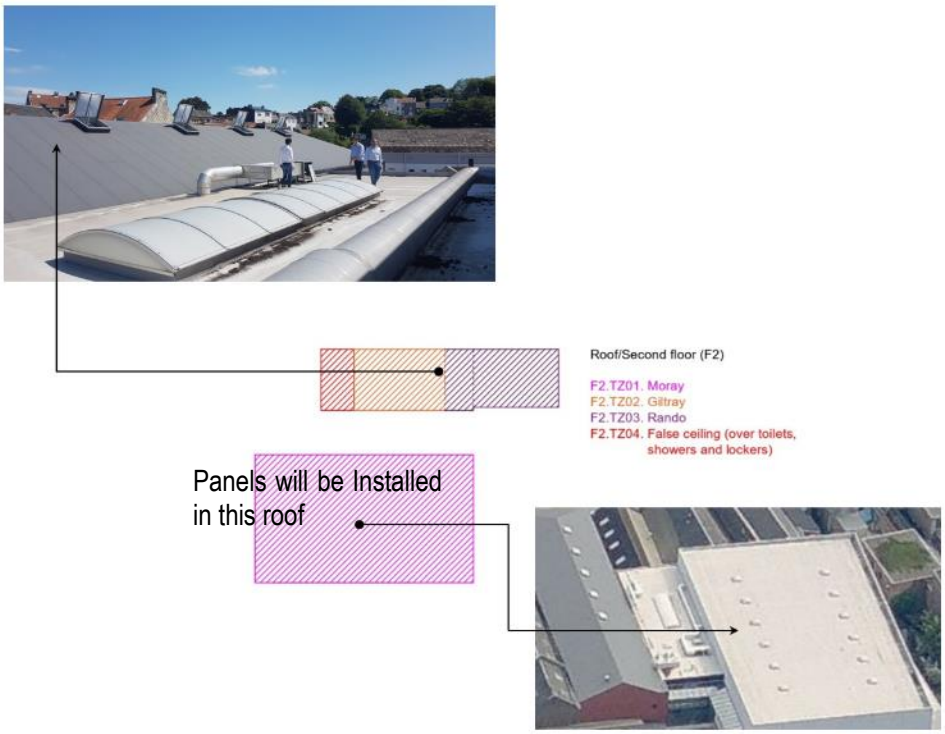


Figure 135: Hall Moray's Roof

7.4 Heating/cooling system with heat, cold and DHW distribution

Existing system is the following: two boilers of 232 kW and 290 kW to cover space heating needs (radiators, air heaters) and one boiler of 96kW to cover DHW needs. In total 618kW to cover all needs. Table 34 shows the technical characteristics of the DHW gas boiler (ACV 100N-101) and the space heating boilers (Optimagaz 232 and 291).

Table 34: HeatMaster 101 (ACV 100N-101) and Optimagaz technical characteristics

HeatMaster 101 (ACV 100N-101) condensing boiler		Optimagaz condensing boiler	232	291
Max/Nominal/Min power	107/96.3/23 (80/60º)	Nominal useful power (kW)	232	290
Performance at 80/60ºC	90.2%	Nominal heat flow (kW)	249.5	306
Combustion efficiency	92%	Absorbed electricity (W)	330	430
Total capacity	320 Liters	Min. water temperature (return, ºC)	45	45
Primary circuit capacity	124 Liters	Max. water temperature (ºC)	90	90
DHW circuit capacity	196 LITERS	Maximum water pressure (bar)	4	4
Diameter connection to DHW	1"	Nominal gas pressure (mbar) G20	20	20
Maximum flow at 40ºC/45º for 10'	898/774 liters/10'	Minimum trigger pressure (mbar)	15	15

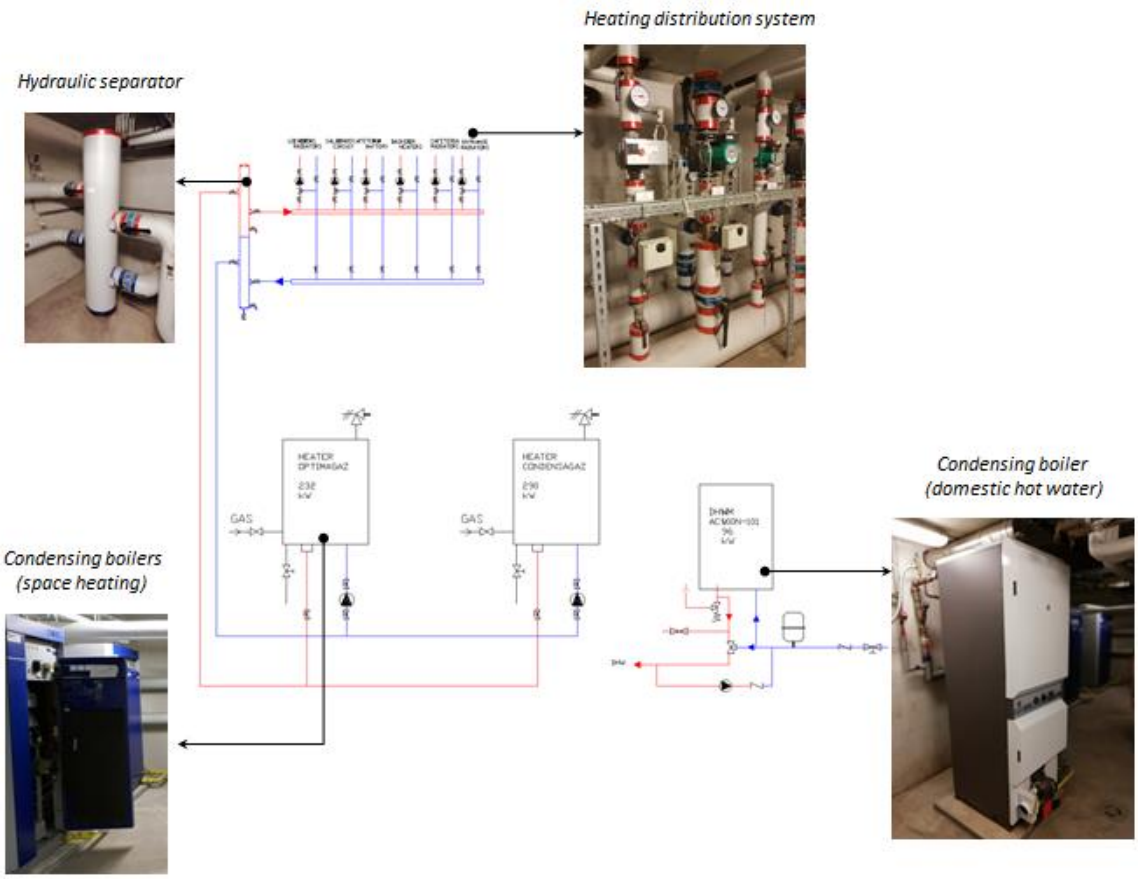


Figure 136: Space heating and DHW generators and distribution pipes

Temperatures of the emitters/demands are very high (70ºC for the space heating system and 60ºC for DHW. As stated by BH: The best application of BH technology is the same as all heat pumps: working at the lowest temperature as possible. The actual application in Hall Moray is not the ideal connection way to maximise BH efficiency. However, BH could work at high temperature (70ºC at -10ºC, 70ºC at 2ºC, 60ºC at 7ºC, 50ºC at 10ºC. Find the graph below), but his efficiency will be very impacted. But thanks to TVP, the whole TP may have a good global efficiency.

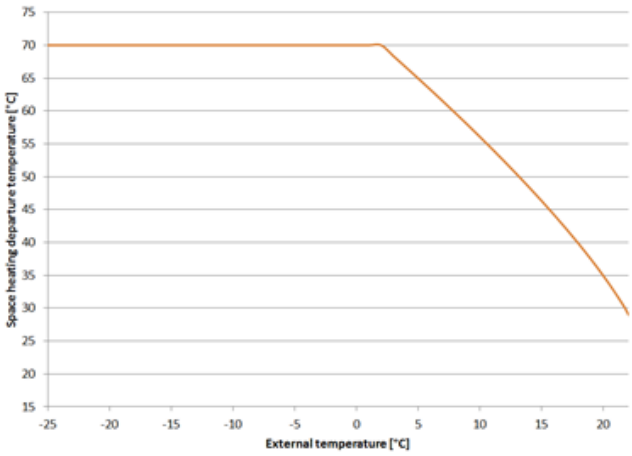


Figure 137: BOOSTHEAT highest water law

Baseline

Based on the provided data (i.e. water consumption, gas bills, and electricity bills), the different demands have been estimated. From the water consumption bills in Figure 138 and assuming 25 litres per use[20] for DHW, the number of average shower-uses per day are obtained on a monthly basis. The equivalent gas consumption used for DHW expressed in energy units (i.e. kWh) has been obtained assuming: constant DHW setpoint of 60ºC, a calorific value[21] of gas of 10 kWh/m³, an efficiency of the existing boiler of 90%, the tap water temperature and a 60% of total used water been constituted by DHW. The rest of the gas consumption has been assumed to cover the space heating needs, resulting in 249.87 MWh. These values have been used for the calibration of the model, and are shown in Figure 139.

The greatest DHW consumption happens in February and October, and the lowest in the summer months.

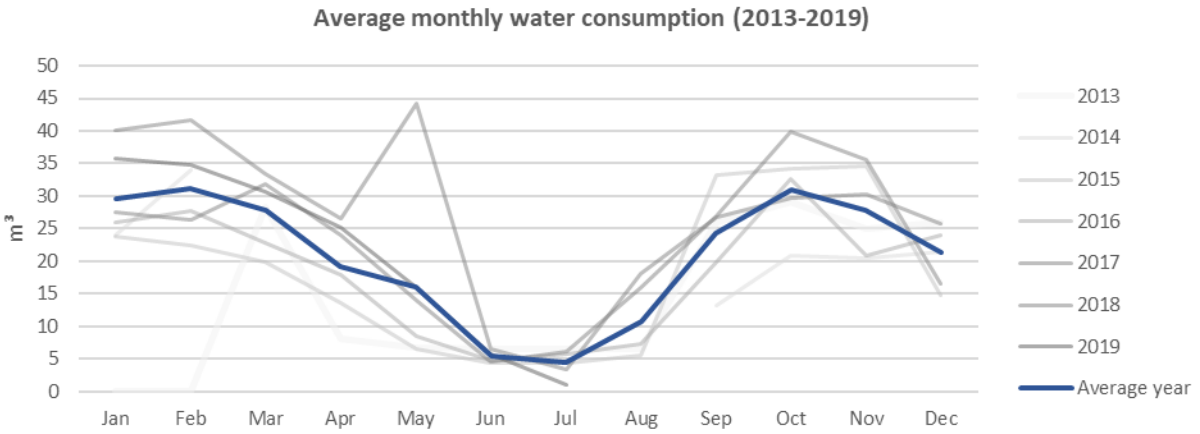


Figure 138: Average monthly water consumption (bills)

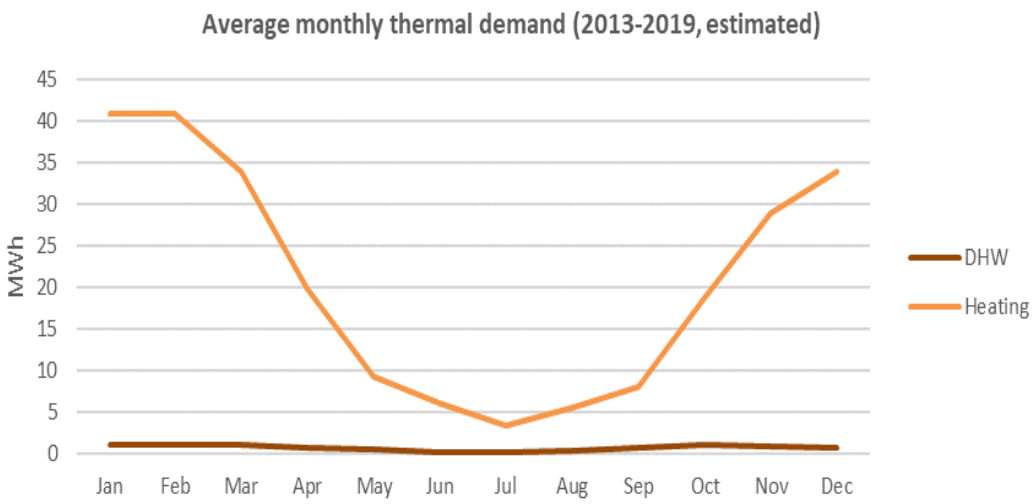


Figure 139: Average monthly thermal demand of DHW and Heating

Regarding the heat demand per room, from the model in TRNSYS the following demands are obtained (Table 35). The rooms that require more heat are the Moray room, Giltay Room, the Rando room and the Cafeteria, with heat peaks of 69.3 kW, 19.5, 18.5, 11.3, and 30.7 kW respectively.

[20] https://www.idae.es/uploads/documentos/documentos_5654_ST_Pliego_de_Condiciones_Tecnicas_Baja_Temperatura_09_082ee24a.pdf

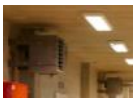
[21] https://www.energuide.be/en/questions-answers/how-is-gas-consumption-calculated/24/

Table 35 : Building energy demand summary (only heated zones)

Thermal area	Peak demand kW	Total demand MWh	Fraction of total demand %
Entrance	9.9	9.3	3.8
Moray	69.3	92.2	37.3
Corridor ground floor	5.4	5.8	2.3
Reception	0.6	0.5	0.2
Storage room	4.1	6.3	2.5
Rando	19.5	28.6	11.6
Giltray	18.5	23.0	9.3
Raskin	11.3	14.4	5.8
Toilets ground floor	4.4	5.6	2.3
Showers + locking rooms ground floor	9.0	12.7	5.1
Showers first floor	1.6	2.2	0.9
Corridor + hall first floor	4.6	5.5	2.2
Cafeteria	30.7	37.4	15.2
Total	**191.2**	**246.9**	

To provide these heat demands, 35 radiators and 15 air heaters were installed in the building. The sports halls are mainly covered by aerotherms. Lockers, corridors, showers and bar have radiators. And some rooms are not heated: reserve areas, kitchen, toilets, and technical cellar. Table 36 shows the type of emitters find in each room and the total estimated capacity

Table 36: Type of emitter and estimated capacity per room

Room	Emitter	Total estimated capacity	Comments
Local Laurenty	1 radiator (100x70 cm)[22]	2,481 W	
Main entrance	6 radiators (70x100 cm) 1 air heater (1st floor "balcony")	14,149 W (radiators only)	
Technical room	1 radiator (50x100 cm)	1,695 W	
Toilets (ground floor)	2 radiators (100x100 cm)	6,589 W	
Locker rooms and showers (ground floor)	12 radiators (8u. 70x100 cm; 3u. 50x100 cm; 1u. 100x100 cm)	27,246 W	6 locker rooms; 2 radiators per locker room
1st floor corridor and hall	1 radiator (100x100 cm) 1 air heater (balcony in the hall)	3,294 W	
Locker rooms (1st floor)	2 radiators (70x100 cm)	4,716 W	
Toilets (1st floor)	3 radiators (1u. 100x100 cm; 2u. 70x100 cm)	8,011 W	
Giltray room	2 air heaters	Unknown	
Storage room Giltray	1 radiator (120x100 cm)	3,957 W	
Rando room	2 air heaters	Unknown	
Storage room Rando	2 radiators (120x100 cm)	7,914 W	

[22] Dimensions given as length x height, in cm.

Moray Room	8 air heaters	Unknown	
Cafeteria	Ventilation 11 radiators (1u. 100x70 cm; 1u. 120x70 cm; 9u. 170x70 cm)	43,411 W	

SunHorizon system will be couple in parallel with the existing system, deriving part of the flow from the cold water pipe connected to the hydraulic separator to a heat exchanger (that exchanges heat with SunHorizon system) and goes back to the Hydraulic separator to be supply to the building. SunHorizon system will be also connected in the water mains pipe connected to the condensing boiler ACV-100N-101, in order to preheat the water to be sent to the showers and sinks.

There is an air handling unit (AHU) for the cafeteria, but the technical specifications of the unit are not available. If the cooling of the building is foreseen, it might be interesting to install a cooling battery in the AHU connecting it to the outlet of the adsorption unit.

Figure 140: Air handling unit in cafeteria GE2_GE3_GE4 Group Extraction

To estimate the cooling needs, a 3D model in TRNSYS is simulated from May to October with a setpoint of 21ºC, in order to study the cooling demand of the building. Table 37 shows the cooling demand of each thermal zone in terms of maximum peak power (to possibly size the cooling systems in that areas), average power, and total power (in kWh). The most demanding areas of cooling are the Cafeteria, the Giltay room, main entrance, and the Basket court. The instantaneous peak (at the same time) of all the areas is 38.74 kW and the total cooling demand is 8763.5 kWh for the whole season.

Table 37: Cooling demand of Hall Moray (maximum peak demand and average power in kW, Total in kWh from May to October)

21ºC setpoint(in rooms)	Basket Court F0T1	Main Entrance F0T1	Main Entrance F0T2	Main Entrance F0T3	Main Entrance F1T1	Corridor F0T1
MAX	7.74	3.07	2.50	3.47	2.99	2.43
AVERAGE	2.75	0.83	0.80	0.91	0.79	0.77
TOTAL	204.45	1038.63	674.99	1088.72	1329.28	1462.11
21ºC setpoint(in rooms)	**Rando F0T1**	**Giltay F0T1**	**Giltay F0T2**	**Accueil T1**	**Corridor F1T1**	**Giltay F1T1**
MAX	0.44	0.12	0.32	0.23	0.64	0.10
AVERAGE	0.13	0.04	0.10	0.06	0.12	0.03
TOTAL	1.38	1.59	0.53	88.37	88.94	13.79

21ºC setpoint(in rooms)	Giltay F1T2	Giltay F2T1	Corridor F1T2	Cafeteria T1	Toilets F0T1	Toilets F0T2	Cafeteria T2

MAX	1.88	8.24	0.38	1.88	0.01	0.19	5.97
AVERAGE	0.47	2.33	0.08	0.54	0.01	0.08	1.64
TOTAL	74.36	1258.45	55.62	476.24	0.50	5.85	899.71

For what it respects to the SunHorizon scope, SunHorizon will be coupled in parallel with the existing system and it will mainly address the space heating and domestic hot water (especially in summer time). A provisional location of the equipment inside the building is shown in Figure 141. Outdoor unit of Boostheat is located in the patio. BH unit can be located inside the technical room, next to the electric box or in the room

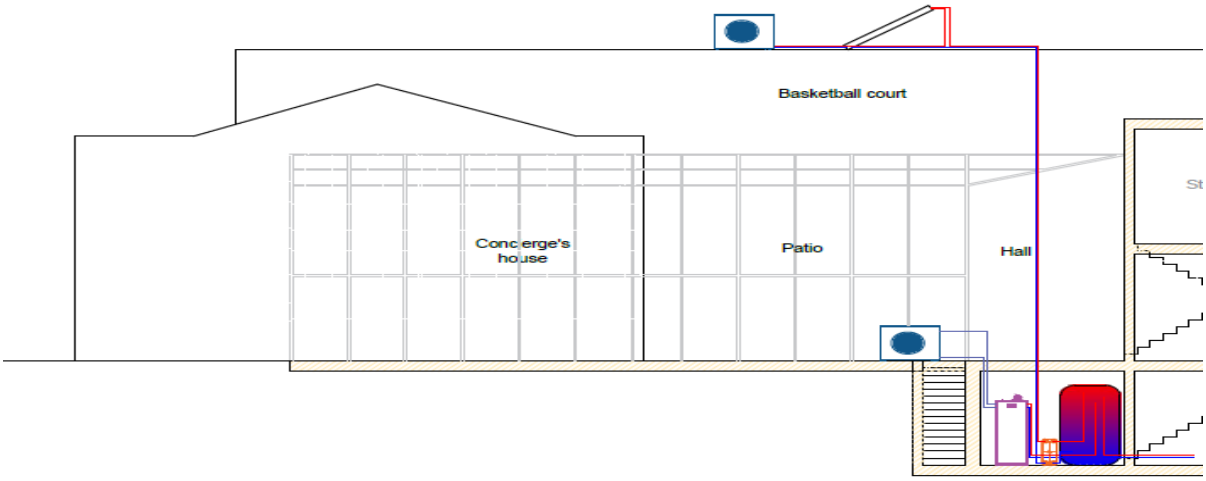
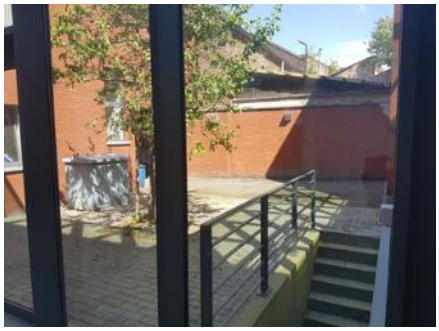


Figure 141 : Location of the SunHorizon components (preliminary. It might change)



Patio

Electric box and room next to the technical room (picture shows the door to exit to the patio)

Figure 142 : Pictures of the underfloor room (next to the technic room) and patio

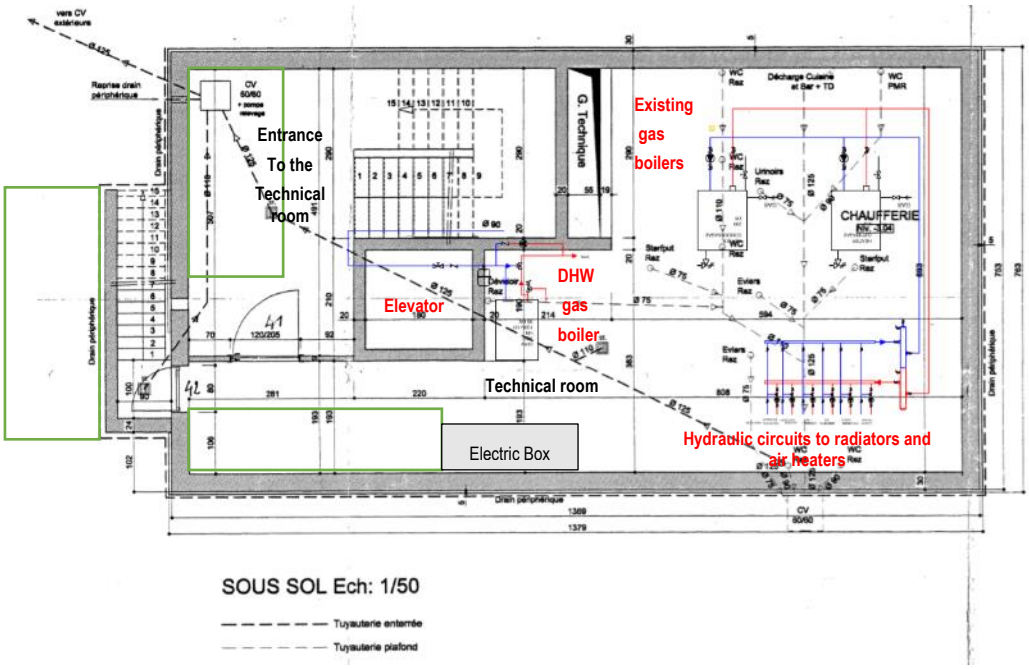


Figure 143 : Technical room (space available in green). The stairs take to the patio. Next to the stairs (in the patio) there is space available for the outdoor unit of Boostheat

The existing heating system (gas boilers) for space heating and DHW in Hall Moray is shown in Figure 144 and the location of it is shown in Figure 143.

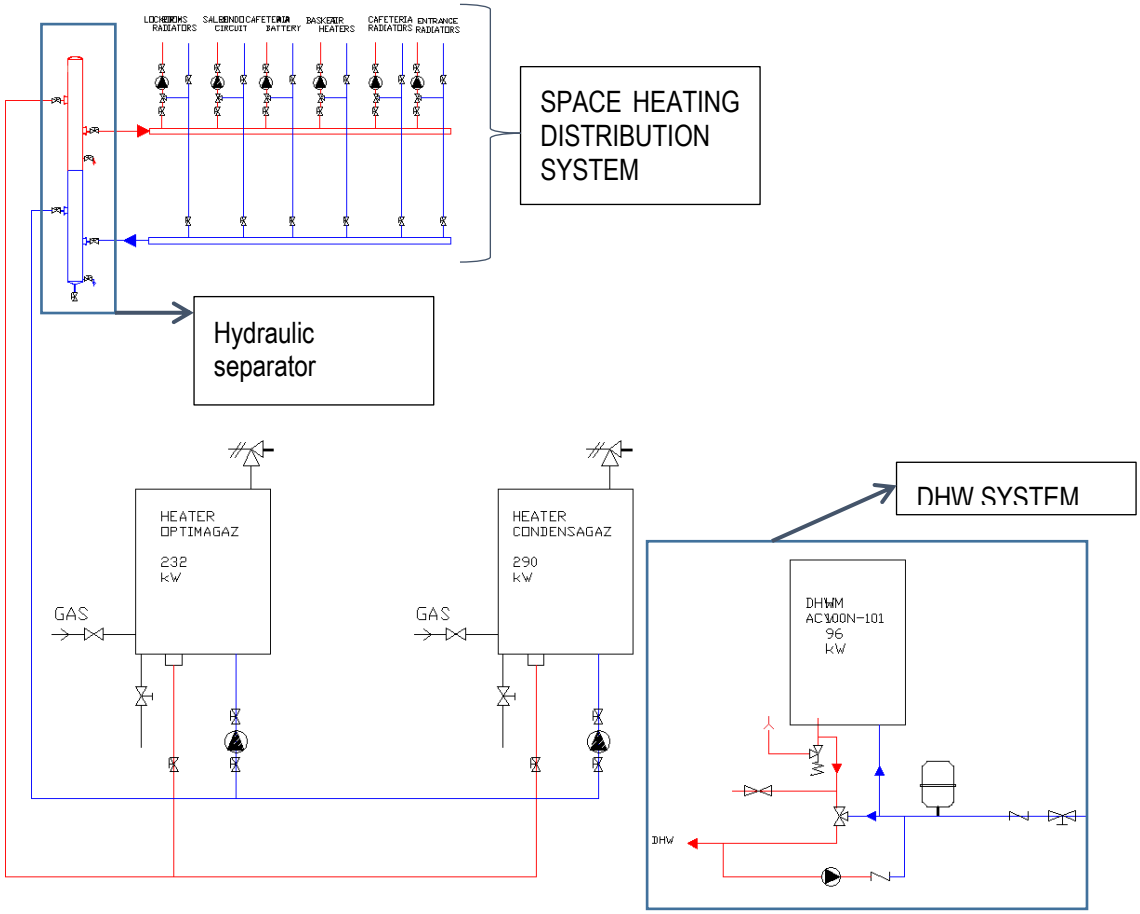


Figure 144: existing heating system (gas boilers) for space heating and DHW in Hall Moray

SunHorizon will be installed in parallel to this system, preheating with a heat exchanger (exchanging heat with Ratio tank) the cold water stream from the DHW system and connecting SunHorizon to the hydraulic separator (or, if an indirect system is preferred, a heat exchanger in parallel to the hydraulic separator can be connected to exchange heat with SunHorizon system). The cold water stream is accessible at the entrance of the technical room (See Figure 143)

7.5 Specific requirements for the new heating/cooling system

- Admissible mechanical load (static and dynamic) on the roof for TVP panels
- The TVP solar field will be designed to not exceed the stagnation temperature (120ºC). The following components will be needed: Safety valves, expansion vessel, dry cooler, pumps, valves, etc. All selected components in this circuit withstand high temperatures and fluid pressures, which can be high enough to cause damage to people and objects. It necessary the use of components rated for the temperatures and pressures required for this application. Figure 146 shows a typical solar field assembly of TVP
- Outdoor unit of Boostheat is located no further than 20 meters from the indoor unit. Observe the minimum distances shown on Figure 147 integrating the outdoor unit.
- The BOOSTHEAT.20 can then be against the wall or disengaged as needed. Indoor unit measures: 1796mm (height)x2004(length)x 892(width) mm (See Manual for more information). A clearance of 1.5 m is required on the front of the apparatus during installation and maintenance phases. Indoor unit weights 501kg. it must be installed on a ground plane whose resistance is adjusted.
- During the visit of Verviers demosite, the following space was found in the electric box of Hall Moray. Possibly, the SunHorizon system will be fit in this space. Schneider will measure from it only the electricity consumption of the SunHorizon system. There is no need of measuring the existing electric energy consumption.
- In addition to the standards imposed by the specifications, it is the contractor's responsibility to comply with the other standards and directives in force in the field of construction, solar thermal panels. It is also the contractor's responsibility to use the equipment provided by the partners and to respect an implementation that guarantees the safety of people.
- The fire safety regulations approved by decree of 25 June 1980 and its subsequent amendments must be complied with.
- Unless express authorisation to deviate from this has been requested by the successful tenderer and accepted by the Consortium, one of the following two minimum certifications will be required:
    - RESCert (https://rescert.be/fr)
    - Solar PV (Quest)

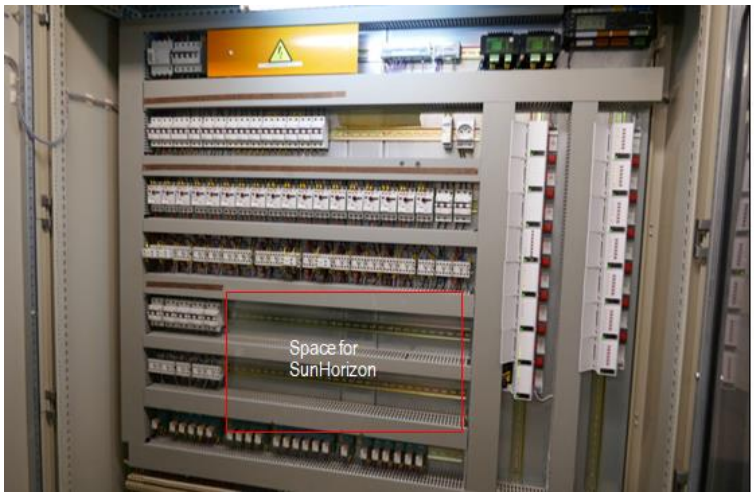


Figure 145: Electric box at demosite level.

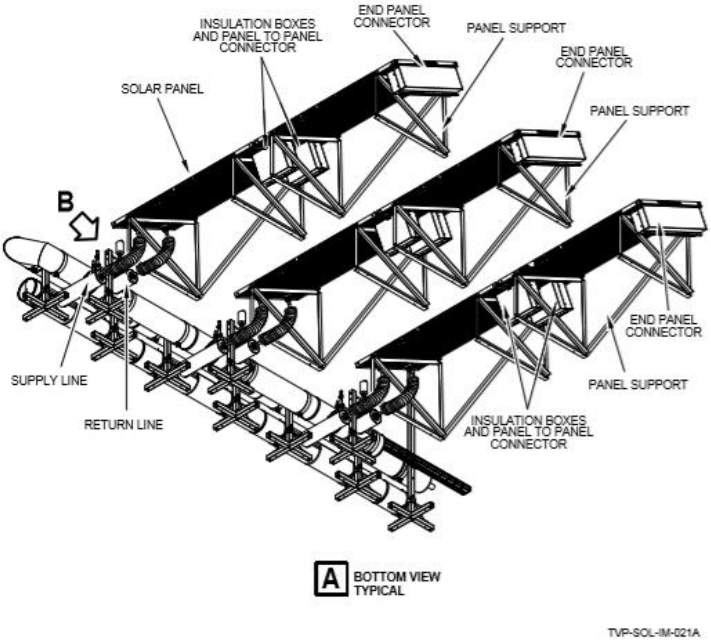


Figure 146: Solar field typical assembly

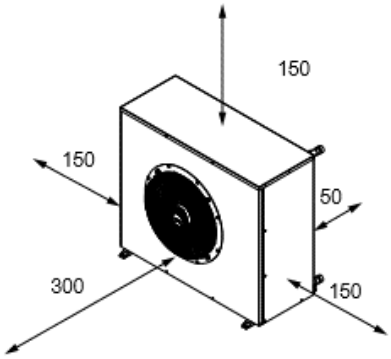


Figure 147: Minimum distances to avoid for the outdoor unit of BoostHeat. Outdoor unit measures: 1018(height)x1134(length)x618(width) mm (See Manual for more information).

7.6 Preliminary monitoring plan

Within WP4, a drawing of the preliminary monitoring plans is elaborated showing a diagram of the building main zones to be monitored and the sensors at the TP level. The communication protocol is decided among the partners to be Modbus TCP/IP with Ratiotherm, TVP and BoostHeat PLCs and Schneider (Figure 148). Flowmeters (See Figure 150) and comfort measurements (Figure 149) in Verviers building will communicate via Modbus RTU protocol. Data exchange between the existing monitoring system (from Honeywell) and SunHorizon will be foreseen in next steps (Figure 151).

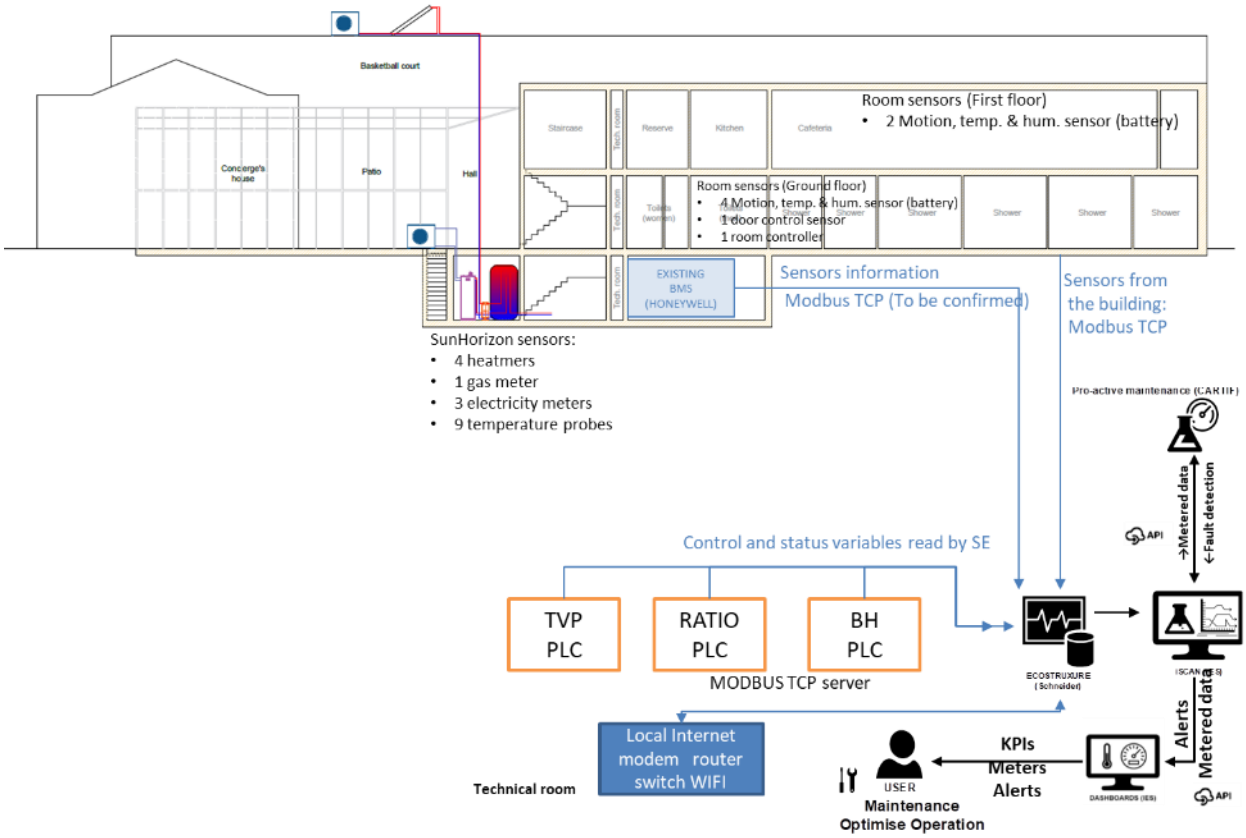
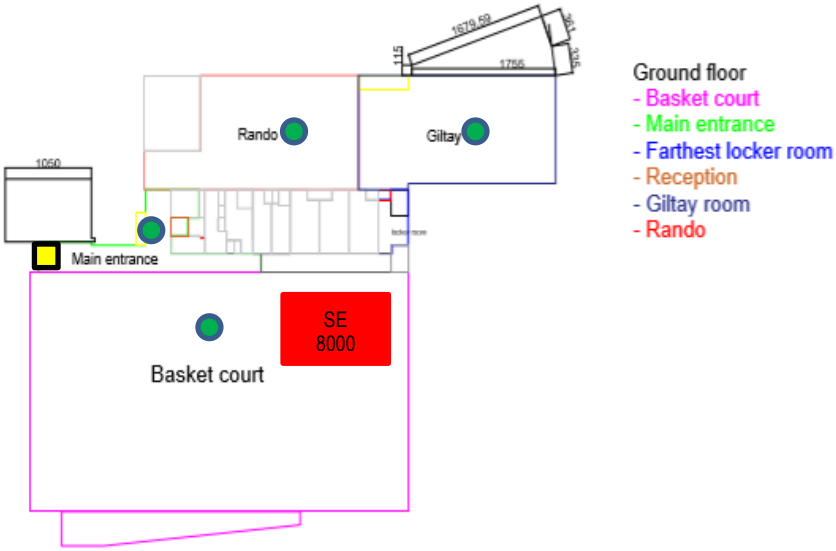
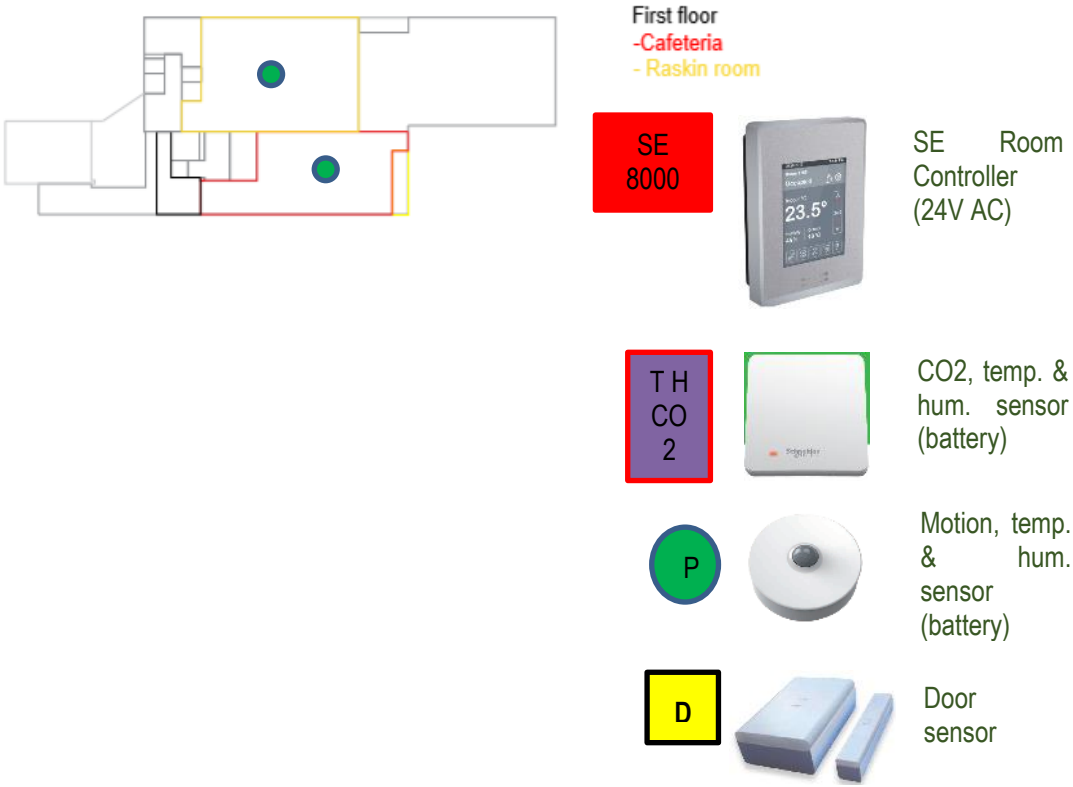


Figure 148: preliminary monitoring and WP4 architecture

Figure 149: preliminary monitoring plan at demo level





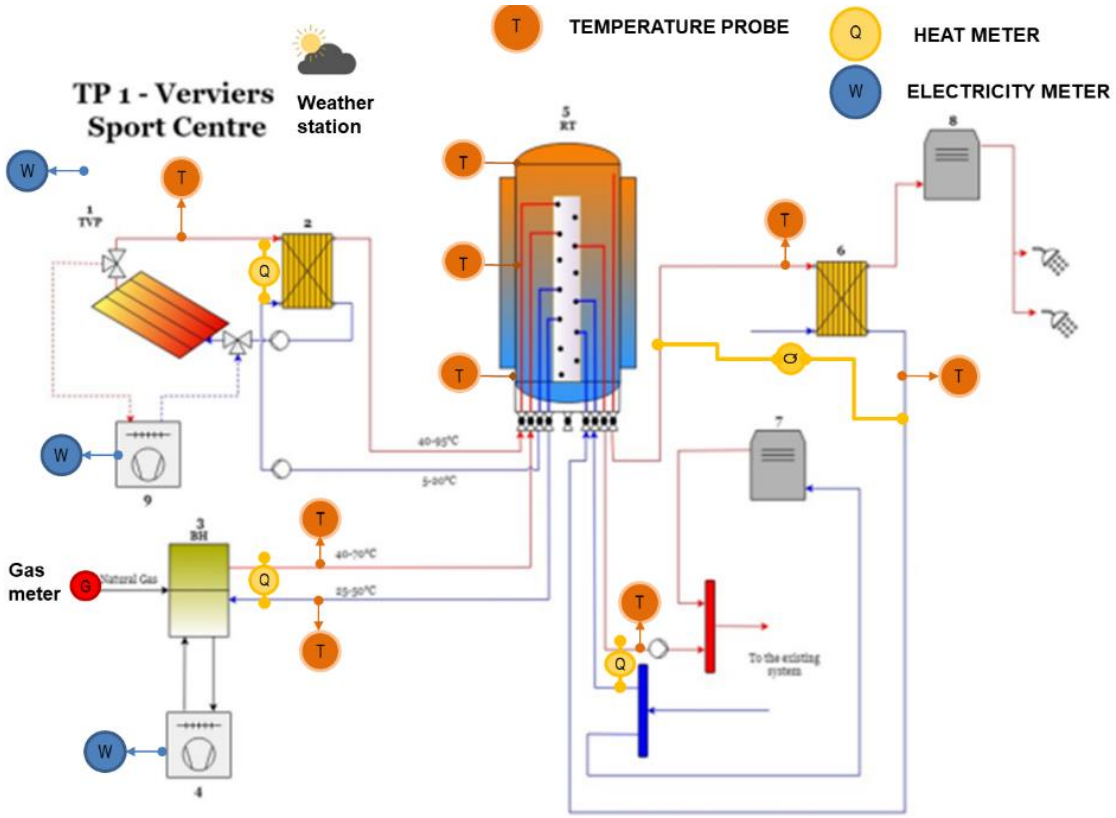


Figure 150: preliminary monitoring plan at SunHorizon system

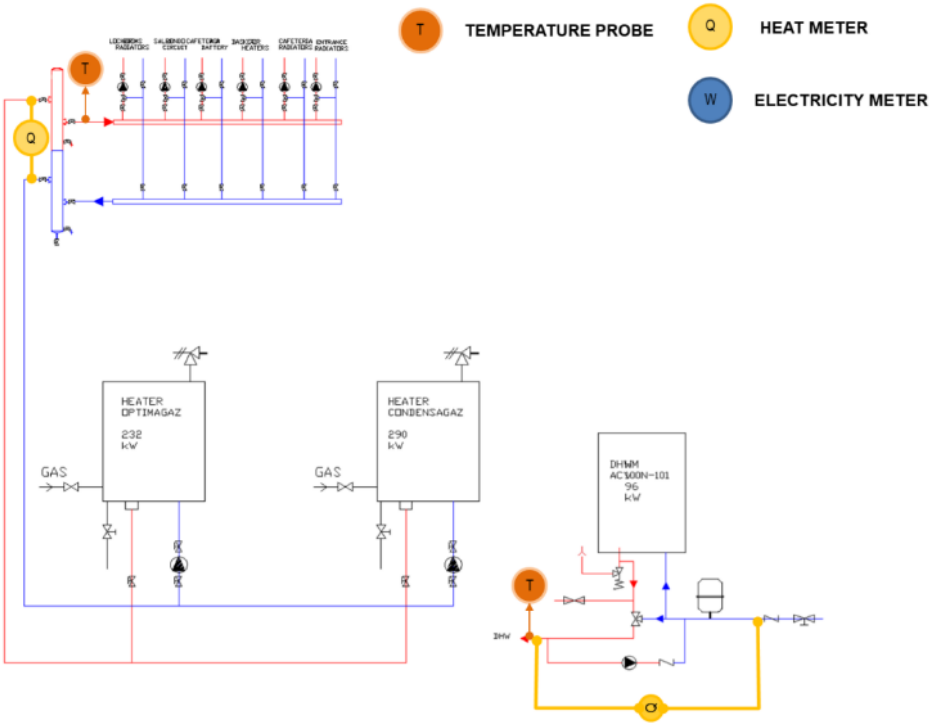


Figure 151: Monitoring at existing system level (from Honeywell or to be included)

8 Verviers SP demosite #7

8.1 General description

Demo-site 7 is a public pool located in Verviers. The users are mainly people living in Verviers, such as children, adults and elderly people. The occupancy rate in the building is 165,000 people per year and it is open from 7 am to 10 or 11pm, depending on the days and the club occupancy (365 days per year). The building's consumption is very high, accounting up to 293,300kWh/y of electricity where 39% of it comes from the pool pumps, 22,073 m^3 of water and 196,910m^3 of natural gas. The total install capacity of the boilers is 1.6 MW to address space heating, ventilation, DHW and swimming pool needs. SunHorizon project will mainly address the small swimming pool.

Figure 152 - Swimming pools room

Figure 153 – Verviers Swimming Pool Building

The swimming pool's room contains the two swimming pools: the big one with a size of 25x14 (depth: 1.25 to 3.75 m) and the small one with a size of 10x20 (depth: from 0.5 m to 1m). It results in a total volume of 950 m^3, with specific surfaces of: 350 m^2 for the big pool and 200 m^2 for the small one.

8.2 Local weather characteristics

Weather characteristics is described in demosite 6 (same location).

8.3 Building geometry and use

The present study concerns the swimming pool of Verviers, whose current building is composed of several distinct areas with different architectural features. In fact, the building also hosts other sports activities: martial arts, weightlifting, among others. The 3D model is performed for the areas in red, which are the ones affecting the pool's model.

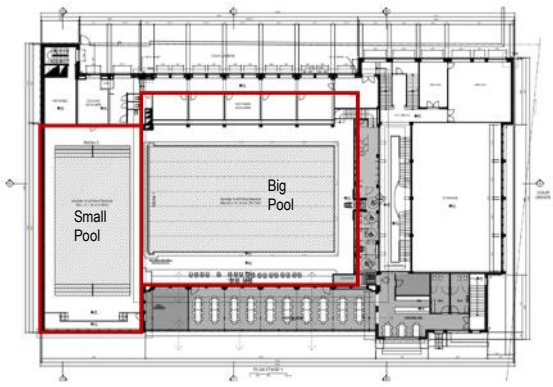


Figure 154 : overall layout of the building that includes the swimming pool.

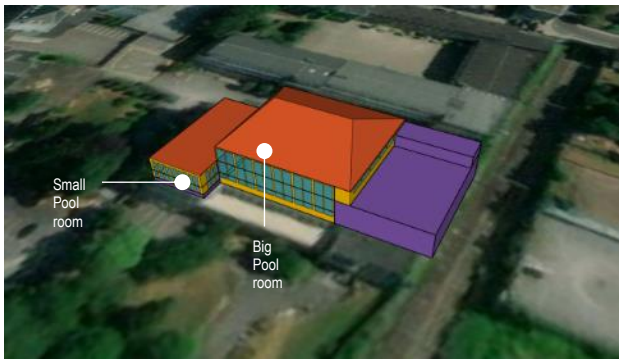


Figure 155 : Swimming Pool SketchUp model

The small swimming pool area is divided in two heights/thermal zones: F1 and F0. The Big swimming pool area is divided in the east and south stands, where people can watch the pool matches, and the big area containing the big swimming pool that is divided in three heights. It results in a model with nine convex thermal zones. The building was built in 1963. There are no data available on the walls and windows. But it seemed that it was white concrete and double layer windows on aluminium frame in the pool, single layer everywhere. As construction types for the energy model, the following values are used.

Construction type name	U-value (W/m2K)
EXT_WALL	1.806
EXT_ROOF	2.014
ADJ_CEILING	2.003
EXT_WINDOW1	5.44 (ID 106)

Construction type name	U-value (W/m2K)
EXT_FLOOR	0.837
ADJ_WALL	0.648
POOL_SURFACE	2.988 (Water layer)
EXT_WINDOW2	1.1(ID 201)

Table 38: Swimming's Pool Verviers U values of the building model in Type 56

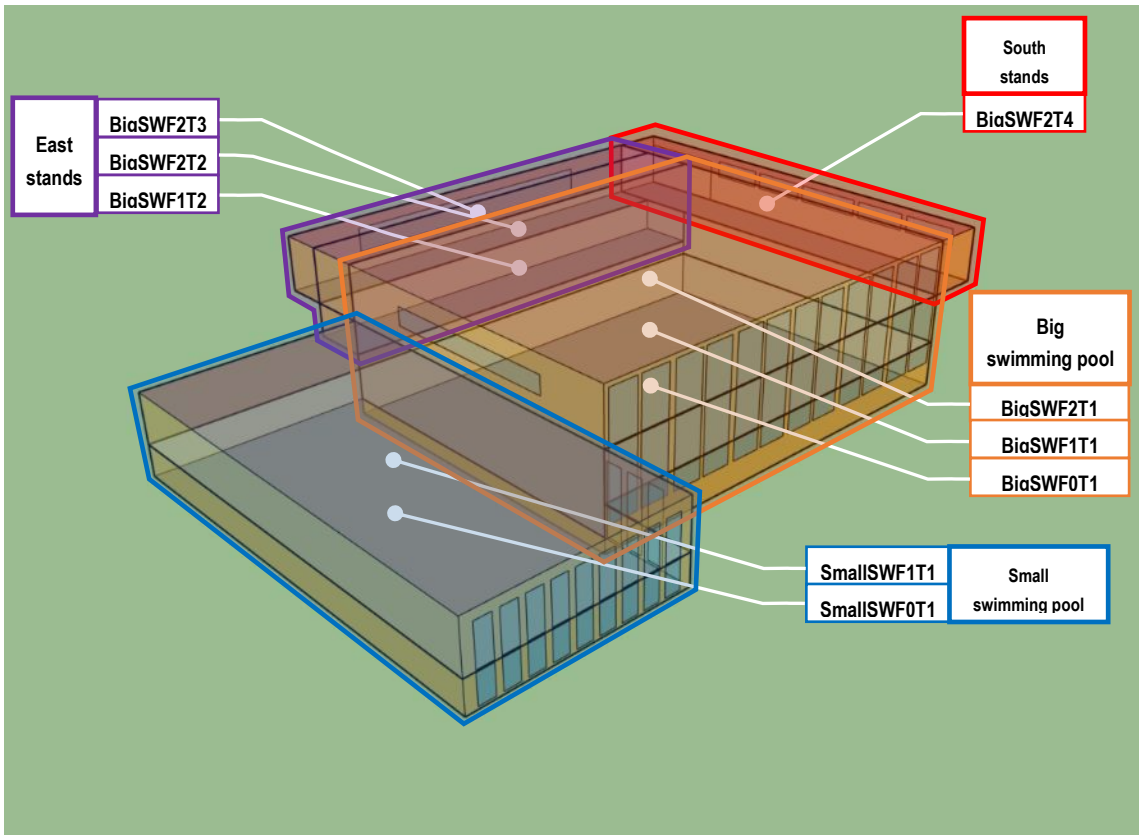


Figure 156 : Airnodes distribution within the swimming pool's thermal zone (only volumes corresponding to this thermal zone are displayed).

The two swimming pools are contained in a room of 322,2 m^2 which is heated up by an air handling unit. The heating battery inside the AHU is provided by the main system and air coming from outside is mixed up. This heat is provided by the same boilers heating the pools. Ventilation flow rate is unknown. Despite this value should be confirmed with updated analysis, a ventilation rate of 4 renovations per hour[23] and an infiltration 0.6 ren/h has been assumed for the moment in the present model. An ideal heating system with a setpoint temperature equal to 29.5ºC (setpoint temperature schedule is set according to the schedule of Figure 158), a night set off setpoint of 15ºC and relative humidity controlled to be below 65% at all times is set in the building model.

Regarding the ventilation, there are several phases/components: Intake, filtration, pre-heating, fan, heating. It is directed towards: Windows of the big pool, side of the pool big, windows of the small pool, and side of the small pool. Under the

[23] *"To meet air distribution requirements, ASHRAE recommends a supply air delivery rate of 4 to 6 air changes per hour(ach) for recreational pools and 6 ach to 8 ach for competition pools with spectators" from* http://www.innoventair.com/Portals/3/PDFs/ASHRAE%20Journal%20Article%20July%202017%20Pool%20Ventilation.pdf

stands of the big pool, the air is recycled (30-50% air is recycled) underneath the spectators seats and directed towards the AHU. Air valves are open 100% to maintain the full capacity required by public pool regulations laws on air turnover. Extraction system is in the false roof of the big pool and almost 40% is extracted without heat recovery and it is 100% open 24/24h. There are separated extractions in each pool. There is also air extraction in the lockers and showers rooms.

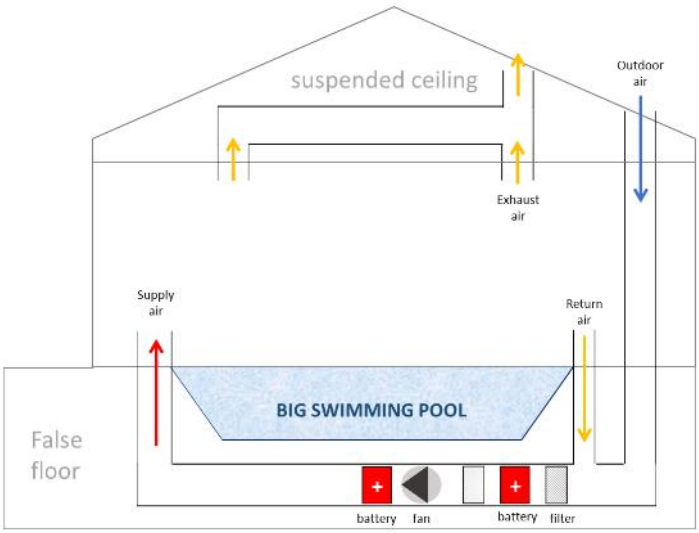


Figure 157 :Air handling unit of the Swimming Pool (Simplified schematics of the air flows; profile view of the building).

The small swimming pool is scheduled for classes within 8:30 to 12:30 every day and from 13:00 to 16:00 and 17:30-21:30 every weekday except Wednesday and Friday (with a different schedule). There are some days that the building is open until 23:00. During the weekends is open to the public most of the time, with some classes during the morning and afternoon. The average crowd in the building (including staff) is 500 people per day. The owner estimated that the pool is opened during 95 h/week 363 days/year (accounting up to 4.102 hours/year and 165.000 entries in 2017). For what it respects to the rest of the building, the gym is open 20,25 h/week, 876 hours/year, the room for powerlifting 8 h/week, the "escale" classes is opened 19,75 h/week, and the "dojo" room 4,5 h/week.

Piscine de Verviers : GRILLE HORAIRE D'OCCUPATION DE LA PISCINE 2019

	06:15	07:00	07:30	8.00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:15	16:30	17:00
LUNDI	Verviers natatic		public				natation scolaire					AQUAGYM				natation scolaire							A
	entraînements		public 0730-1800				public									public							
MARDI	Verviers natatic		public				natation scolaire					AQUAGYM				natation scolaire							A
	entraînements		public 0730-1800				public									public							
MERCREDI	Verviers natatic		public				natation scolaire				AQUAGYM					public				1600-1800ENSIVAL Natation			
	entraînements		public 0730-1800				public									public							V
JEUDI	Verviers natatic		public				natation scolaire					AQUAGYM				natation scolaire							A
	entraînements		public 0730-1800				public									public							
VENDREDI	Verviers natatic		public				natation scolaire					AQUAGYM				natation scolaire					Ac.Prov.1615-1730		
	entraînements		public 0730-1800						public							public							
SAMEDI						Verviers natatic		public							1300-1500 ENSIVAL NATATION- Ecole natation								
						entraînements		public															

Figure 158 : Detailed schedule of the sport complex

According to the owner every day the water in the pools are renovated (30 liters per bath), which means 15m^3 are taken from the pools, filtrated and heated up until the desire temperature. 9 cubic meters of fresh water are added every day. The temperature of the pool varies very little (~ 1%) on a full day. And this, despite a night cut of the two main boilers.

The setpoint temperature of the big pool is 27,5°C and the setpoint temperature of the small pool is 28°5°C. The desired temperature of that space is 28.5 ° C for the large pond, 29.5 ° C for the small pond. The humidity level must be kept below 65%. Regarding space heating needs, there are 120 radiators and the desire temperatures are 21 ° C office and 17 ° C for sports halls. Heating consumption peaks are linked to filling or maintenance operations of the pools. The infill temperature varies from 9 to 14°C.

Domestic hot water is an isolated system with one boiler (ACV HM 150 JUMBO model, 139kW nominal power). It supplies 60ºC to the system to cover shower's needs. The annual water consumption is around 10,000 m³ / year (hot and cold water). Regarding space heating needs, there are 120 radiators and the desire temperatures are 21 ° C office and 17 ° C for sports halls

During an energy audit performed in 2014, a monitoring campaign was performed (see Figure 159). From this figure, it can be seen that the room temperature variates from the setpoint (30ºC) to minus 2ºC under the setpoint from 5am to 11pm and after 11 the temperature drops exponentially until 19ºC (approximately), which can mean that the heating system schedule is from 5am to 11 pm. The setpoint temperature is 65ºC for the heating system, except during the night(during 11pm to 3 am) that the heating system is set to 80ºC and it is mentioned in the energy audit that at 3am "the swimming pool heating system stops", thus it seems that the heating system reached 80ºC during that time (it can be due to maintenance activities).

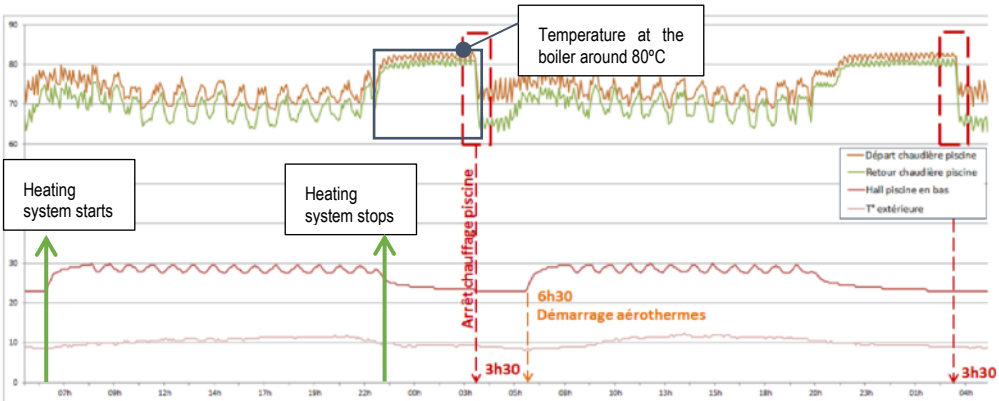


Figure 159 – Temperature of the pool's hall (red line in graph) during an energy Audit performed in 2014. The supply and return temperature of the boiler (Chaudière) of the pool is represented in orange and green lines (measurements performed during 27/02/2014 until 6/03/2014)

The thermal configuration of the area where the swimming pools are located intends to represent a realistic approach of this space. Thus, only two thermal zones have been represented; one for the volume of air where both swimming pools are placed, and one for the false ceiling adjacent to this volume and the external roof.

Thermal zone	Volume (m^3)	Surface (operative, m^2)
Swimming pool	9,234.333	1,271.61
False ceiling (roof)	2,397.48	895.842

Table 39 : Thermal zones and main characteristics

8.4 Heating/cooling system with heat, cold and DHW distribution

The heating system in demo-site 7 covers space heating, ventilation, DHW and swimming pool needs. The overall schematics are the following:

The bottom part of the system hydraulics shows two gas boilers heating the swimming pool loops and the space heating coils. The small swimming pool loop consists of one primary loop that recirculates water from the pool and one secondary loop that comes from the heating system. The primary loop water is filtrated and mixed with water from the tap (water is lost through evaporation processes), after it, the water is heated up to the desired temperature (28ºC in case of the small swimming pool) in a heat exchanger (See Figure 161). The major contributor of the heating losses is the water evaporation (60%) and water renovation, conduction (1-5% of the losses) can be neglected according to literature (Kampel, 2015). The heating system should make up all the heating losses (Evaporation, water renovation, etc.) to maintain the swimming pool at the desired temperature. Therefore, a model of the swimming pool is performed to estimate the needed heating for both pools.

The total estimated demand for both pools is 910 MWh/year and the total demand in the heating system is 1883MWh/year (assuming an efficiency of 90% for the gas boilers). Therefore, the rest (973 MWh/year) accounts to the space heating and DHW consumption of the building. These values will be calibrated in later steps of the project.

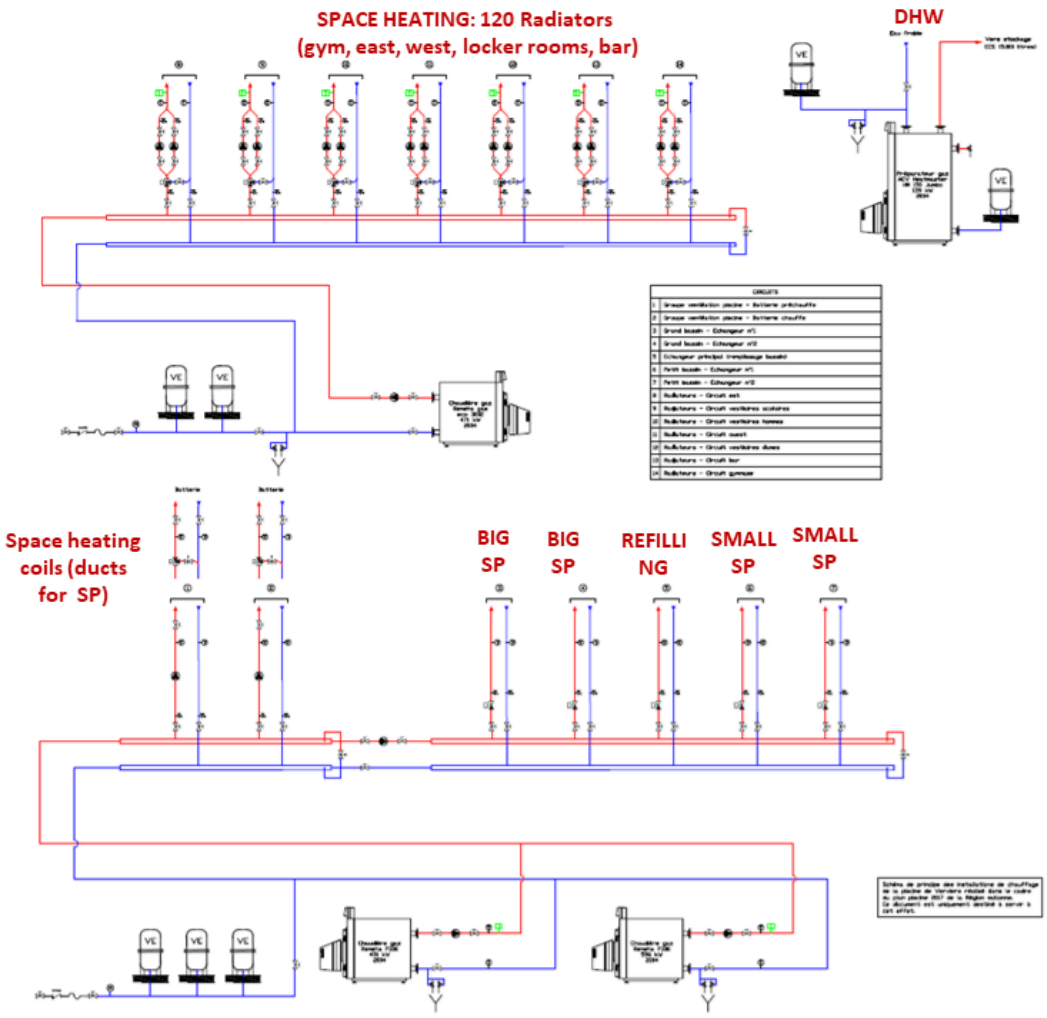


Figure 160 – System hydraulics (Verviers Swimming Pool (SP) – Demo-site 7)

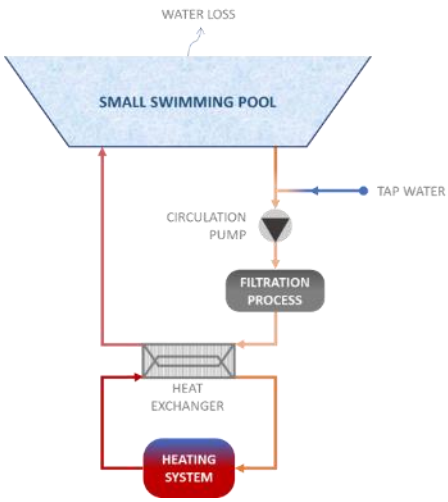


Figure 161 : Schematics in Hall Moray

Figure 162 – swimming pool heat exchangers

Baseline

The swimming pool consumption during the year of 2018 is shown in Figure 163. It can be deduced from these graphics that the site consumes gas even during the summer months, as the pool and domestic hot water demands happen over all the year. Only the boiler allocated to the radiators can be shut down during the summer. The electricity consumption of the Swimming Pool is higher during winter time than in summer time. Probably this is due to the AHU, as it requires more ventilation to maintain the pool room at the desired temperature (29ºC). In the last energy audit, the electricity consumption was disaggregated and it can be seen in Table 40 that most of the electricity demand comes from the pumps' and fan consumption.

Table 40 : Electricity loads.

	nº of items	kWh a year	%
Pumps	5	129,600	39%
Lights	-	63,671	19%
Ventilation	1	86,948	26%
Heating circuit	-	29,952	9%
Food Machines	-	10,800	3%
Others	-	12,692	4%

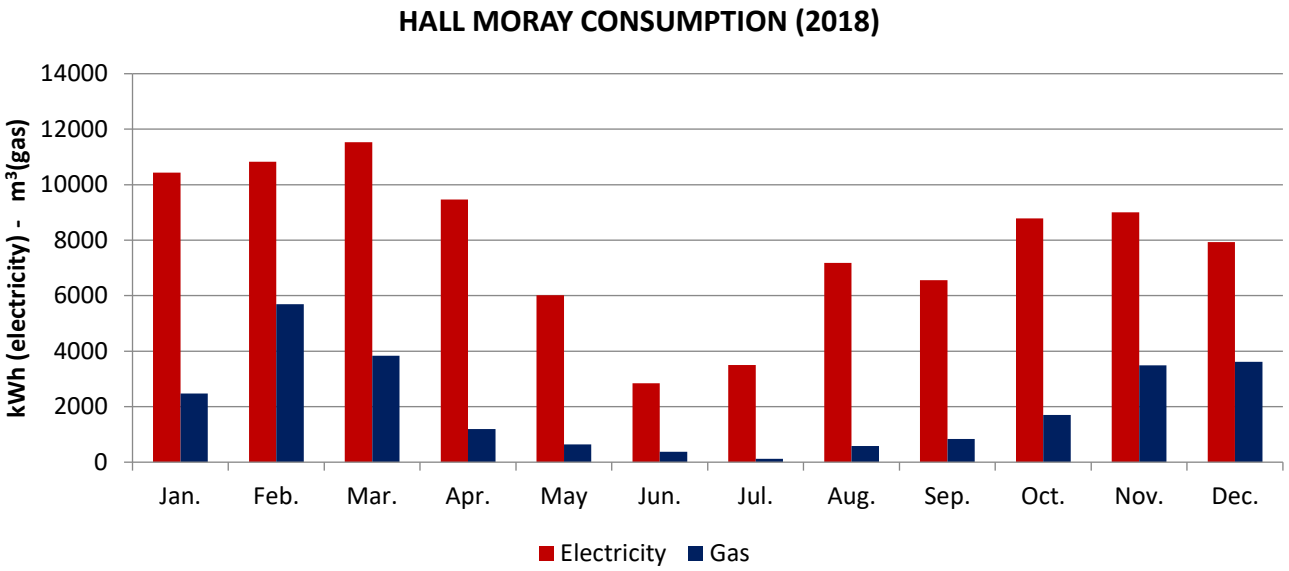


Figure 163: Hall Moray electricity and gas consumption in 2018.

The gas demand (i.e. the thermal demand) has not been analysed in the last energy audits, thus, a benchmarking of different swimming pools (in Europe, from project step2sport) to compare Verviers swimming pool (VSW) with other pools. Figure 164 a) shows the typical % range of electricity and thermal consumption out of the total energy consumption per demosite and the yearly energy consumption of different building swimming pool's in Europe compared with VSW. It can be seen that VSW has a yearly consumption of 2'254 MWh/year from which 13% is electricity consumption and 86% thermal consumption. From step2sport project, the demand in relative values is close to the minimum electricity typical range and close to the maximum thermal typical range (See Figure 164 b). Figure 165 shows the demand disaggregated into the different energy needs (over the total energy consumption). It can be seen, that the ranges variate a lot, especially for the thermal systems (HVAC, DHW, Pool heating) and the pumping system. Thus, it is difficult to obtain the pool heating demand from these data, but the graphic in Figure 165 will be used later on as a reference for once the thermal demand is disaggregated into the different demands.[24]

The baseline of the demo is 1083 MWh/year of non-renewable primary energy.

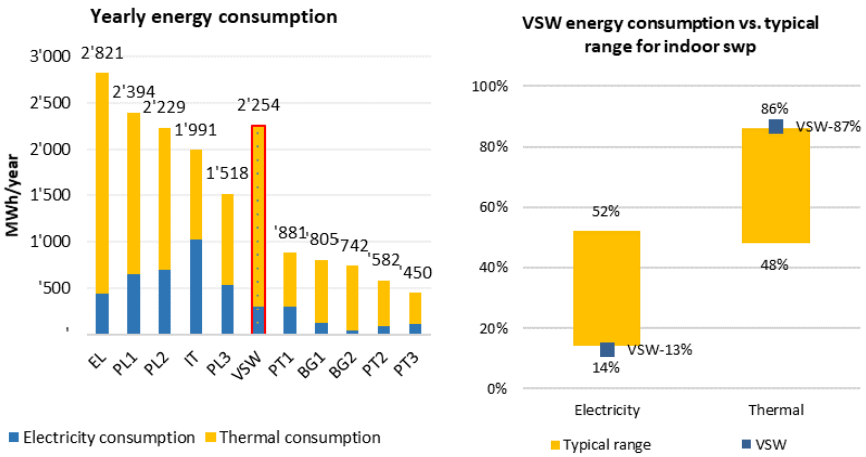


Figure 164 : a) Yearly thermal and electricity consumption of different sport centres with swimming pools in Europe (EL=Greece, VSW=Verviers Swimming Pool, PL=Poland, IT=Italy, BG=Bulgaria, PT=Portugal) b)Typical range of electricity and thermal demand compared to Verviers's swimming pool based on (step2sport, 2019)

[24] D2.5 SunHorizon TPs and demosite conceptual design and simulations (SUNHORIZON)

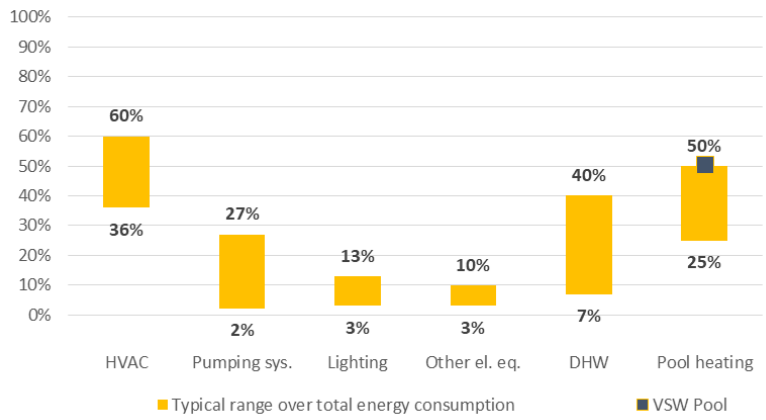


Figure 165 :Typical range over total energy consumption of the different disaggregated demands (from Step2sport project) based on (step2sport, 2019)

8.5 Specific requirements for the new heating/cooling system

- Admissible mechanical load (static and dynamic) on the roof for Dual Sun.
- Due to the fact that the building owner has decided to build one level up on the top of the current cafeteria, that leads to a lower solar field in the roof and possible shadows. Thus, the maximum panels to be installed are finally 244 panels. The following Figure 166 shows the location and orientation of the DS panels:

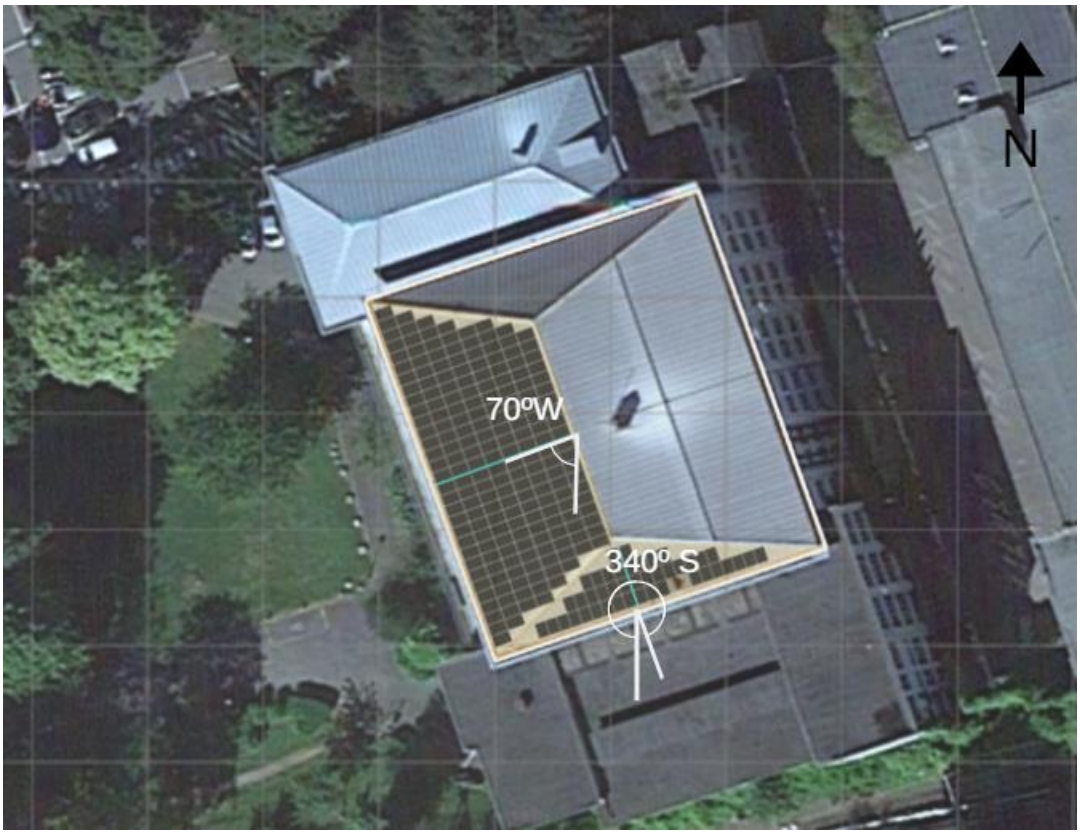


Figure 166: Location and orientation of the DS panels (reference: South is 0º)

  - Solar field with orientation 70ºWest (South is 0º) and 25º inclination: 201 panels on the west side. The right amount of DS panels should be checked carefully
  - Solar field with orientation 340º South and inclination 45º: 43 panels on the south side. The right amount of DS panels should be checked carefully

- From D2.5, the recommended setpoints for RATIO tank and BOOSTHEAT controllers are: 44ºC for RT tank and from 42ºC for the BH setpoint.
- Outdoor unit of Boostheat is located no further than 20 meters from the indoor unit. Observe the minimum distances shown on Figure 147 integrating the outdoor unit.

The BOOSTHEAT.20 can then be against the wall or disengaged as needed. Indoor unit measures: 1796mm (height)x2004(length)x 892(width) mm (See Manual for more information). A clearance of 1.5 m is required on the front of the apparatus during installation and maintenance phases. Indoor unit weights 501kg. it must be installed on a ground plane whose resistance is adjusted.

- Specific regulatory aspects for PVT technology to be installed are listed :
    - As a minimum, the installer of the PV panels must have the Walloon NRQual PV label given by the Walloon Region.
    - The filed / Photovoltaic modules must meet the certifications and approvals in their latest version in force and applicable within the European Union.
- In addition to the standards imposed by the specifications, it is the contractor's responsibility to comply with the other standards and directives in force in the field of construction, solar thermal panels and photovoltaics. It is also the contractor's responsibility to use the equipment provided by the partners and to respect an implementation that guarantees the safety of people.
- The fire safety regulations approved by decree of 25 June 1980 and its subsequent amendments must be complied with.
- Unless express authorisation to deviate from this has been requested by the successful tenderer and accepted by the Consortium, one of the following two minimum certifications will be required:
    - RESCert (https://rescert.be/fr)
    - Solar PV (Quest)

8.6 Preliminary monitoring plan

Within WP4, a drawing of the preliminary monitoring plan at demosite level is elaborated showing a diagram of the swimming pool room to be monitored (Figure 167) and the sensors at the TP level (Figure 168). The communication protocol is decided among the partners to be Modbus TCP/IP with Ratiotherm and BoostHeat PLCs and Schneider. Data exchange between the existing monitoring system (from Honeywell) and SunHorizon will be foreseen in next steps.

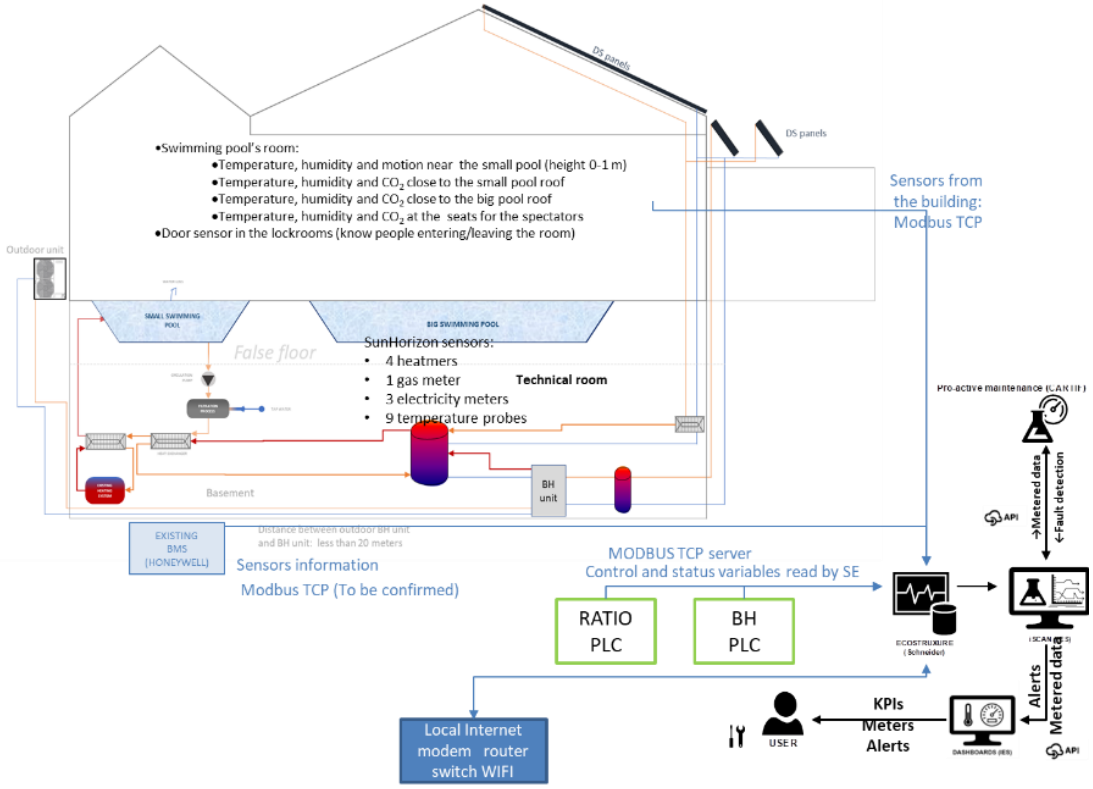


Figure 167: preliminary monitoring plan at demosite level

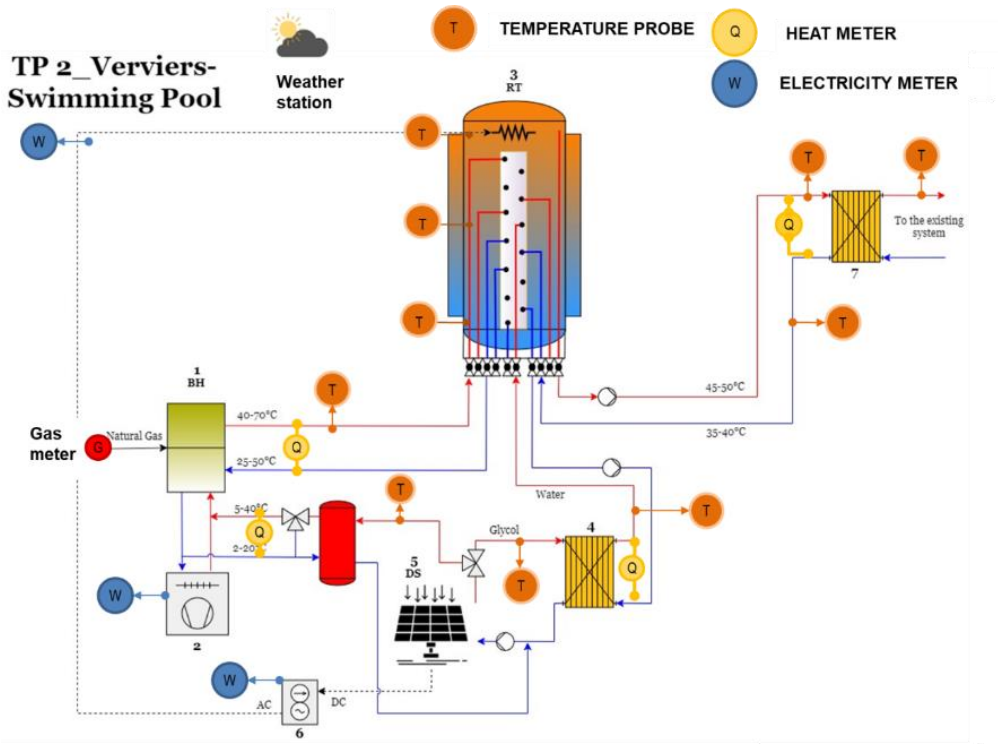


Figure 168: preliminary monitoring plan at SunHorizon level

9 Riga demo site #8

9.1 General description

Riga demo-site consists of two small residential houses, called Imanta and Sunisi, located in the proximity of Riga Technical University (Riga, Latvia) and with a distance of approximately 20 km between each other.

Imanta is a privately owned single-family residential house. The house is normally occupied by three people, but there are commonly several guests being hosted during holiday period.

Sunisi is a residential house composed by a main house and a large garage building, half of which is used as playroom. It is occupied by three people, but it occasionally welcomes also additional hosts.

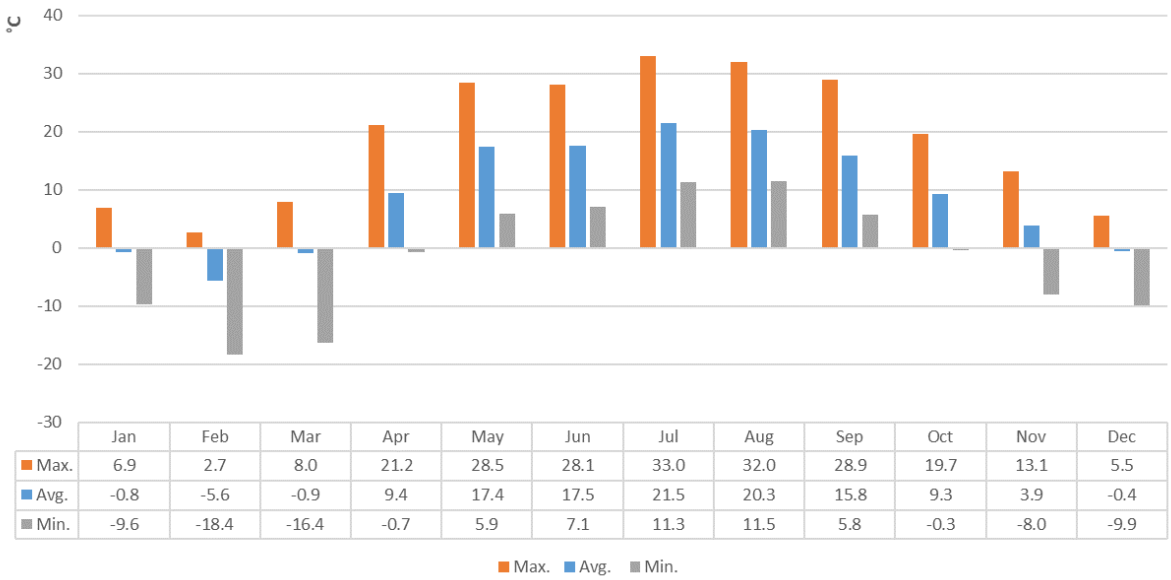
Considering the geographic location of both sites, the expected energy uses are aimed at guaranteeing indoor thermal comfort during cold season and also at assuring production of hot water for sanitary purposes. In the case of Sunisi only, a cooling demand during summer season exists.

9.2 Local weather characteristics

The main weather data relevant for the purpose of SunHorizon installation include minimum, average and maximum temperature measurements, humidity measurements and solar irradiation.

Being the two sites very close one to each other, the local temperatures are retrieved in general terms for both of them, considering the nearest weather station, installed at Riga University[25].

The monthly temperatures in 2018 are reported in Figure 169 below. Average temperatures are calculated as average values from hourly records, while maximum and minimum temperatures are extracted directly from hourly records, available for minimum and maximum temperatures respectively.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max.	6.9	2.7	8.0	21.2	28.5	28.1	33.0	32.0	28.9	19.7	13.1	5.5
Avg.	-0.8	-5.6	-0.9	9.4	17.4	17.5	21.5	20.3	15.8	9.3	3.9	-0.4
Min.	-9.6	-18.4	-16.4	-0.7	5.9	7.1	11.3	11.5	5.8	-0.3	-8.0	-9.9

Figure 169: Monthly temperatures (2018)

It is clear that at monthly scale, there are significant variations in the temperatures recorded. As an example, in March, maximum and minimum hourly temperatures differ by 24.4°C. On annual basis, maximum hourly temperature in 2018 is recorded as 33.0°C, while the minimum is -18.4 °C.

As an additional analysis, in Figure 170 below, the average temperatures in 2018 are compared to the correspondent values in 2017. It is noticed that 2018 has been sensibly warmer than 2017, except for the months of February, March, and December.

[25] https://www.meteo.lv/en/meteorologija-datu-meklesana/?nid=924

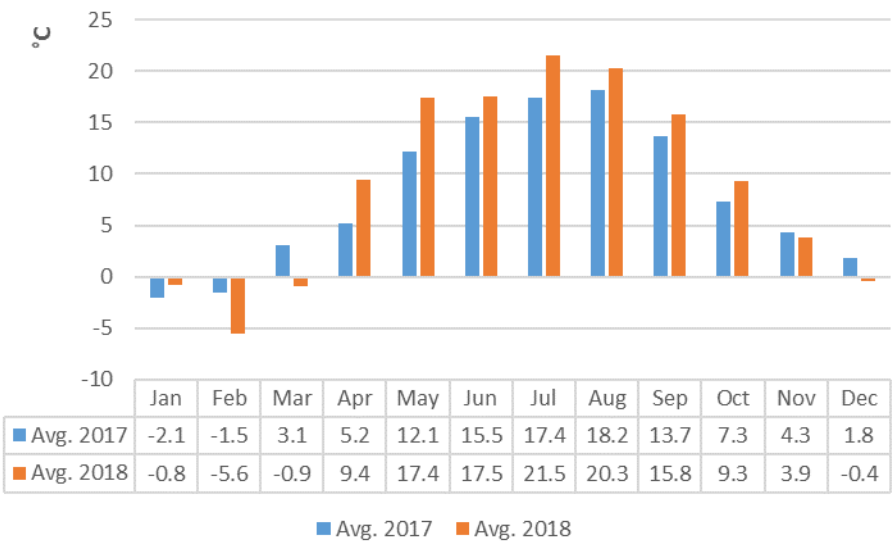


Figure 170: Monthly average temperatures (2017 and 2018)

From the same database, average monthly values of actual relative humidity are extrapolated, starting from hourly records. Monthly average humidity values are shown Figure 171 in below.

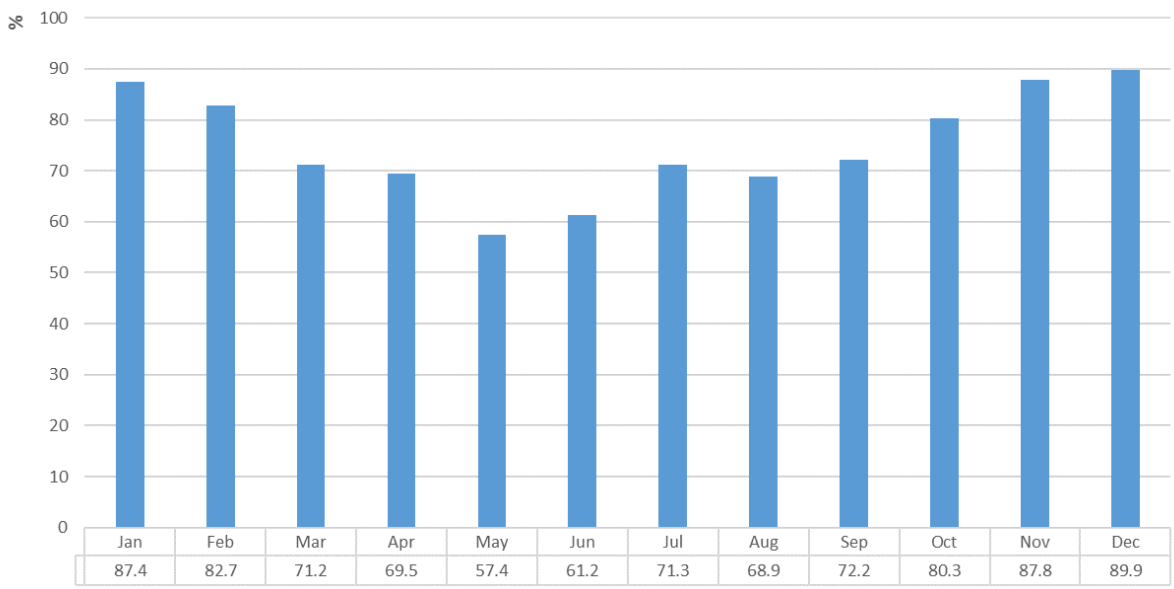


Figure 171: Monthly average relative humidity (2018)

Furthermore, PV-GIS website[26] is taken as source of data about solar irradiation and about potential performance of solar systems.

As for Imanta, the optimum slope angle for the installation of PV panels is about 41°. In such configuration, the annual in-plane irradiation is 1,230 kWh/m^2 (with a standard deviation of approximately 5% from one year to the other, on the basis of available statistical data) and the annual PV energy production is in the order of 997 kWh/kWp.

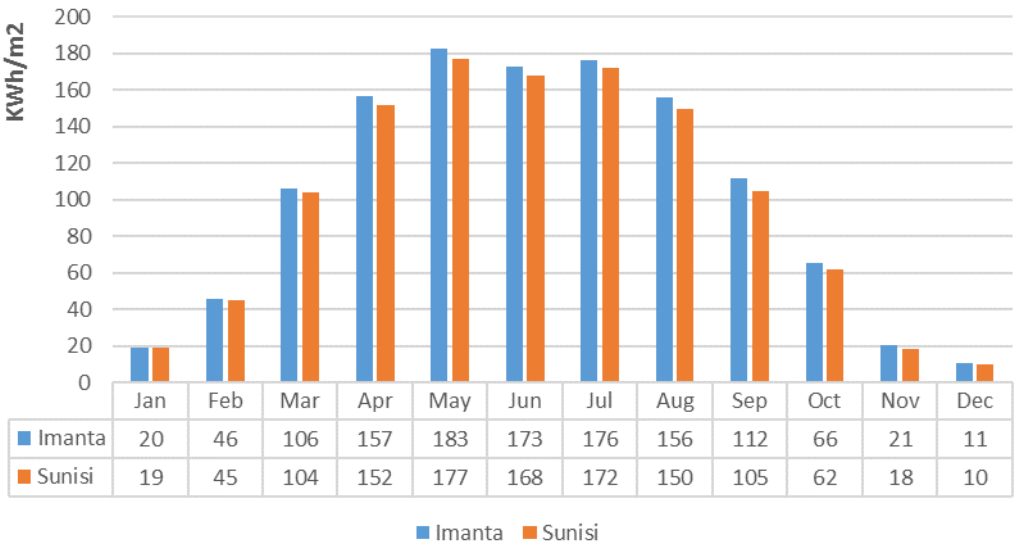
As for Sunisi, the optimum slope angle for the installation of PV panels is about 40°. In such configuration, the annual in-plane irradiation is 1,180 kWh/m^2 (with a standard deviation of approximately 5% from one year to the other, on the basis of available statistical data) and the annual PV energy production is in the order of 929 kWh/kWp.

If specific slopes of Sunisi surfaces for potential installation of the panels are considered (i.e. roof slope), the following variations are registered:

[26] https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html

- 20° slope: the yearly in-plane irradiation is 1,140 kWh/m² and the yearly PV energy production is in the order of 893 kWh/kWp;
- 35° slope: the yearly in-plane irradiation is 1,180 kWh/m² and the yearly PV energy production is in the order of 927 kWh/kWp.

Typical in-plane monthly irradiation values for the two sites are reported in Figure 172 below.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Imanta	20	46	106	157	183	173	176	156	112	66	21	11
Sunisi	19	45	104	152	177	168	172	150	105	62	18	10

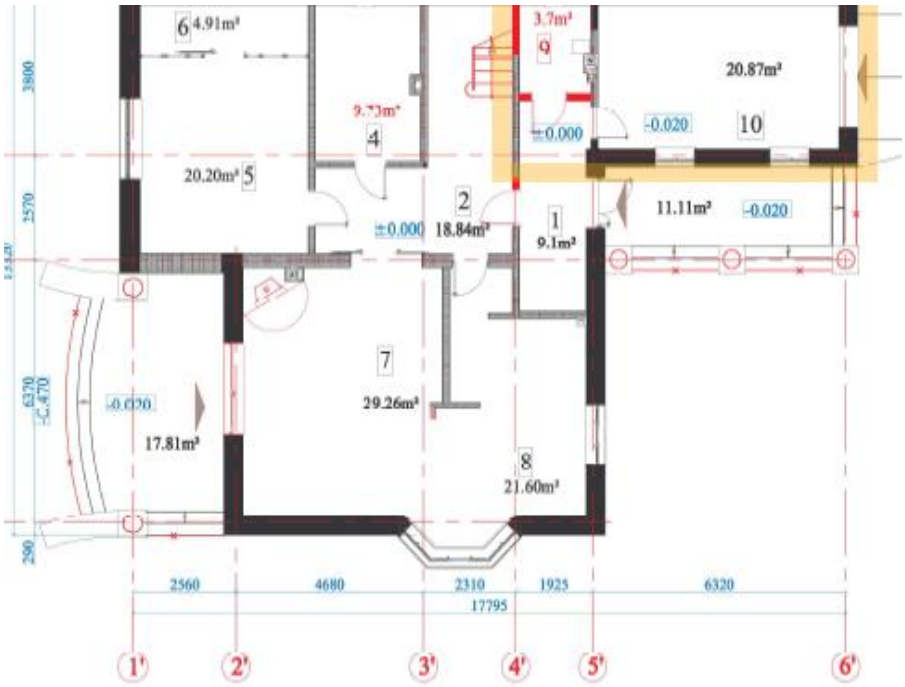
Figure 172: Monthly global solar irradiation (optimum angle)

9.3 Building geometry and use

9.3.1 Imanta

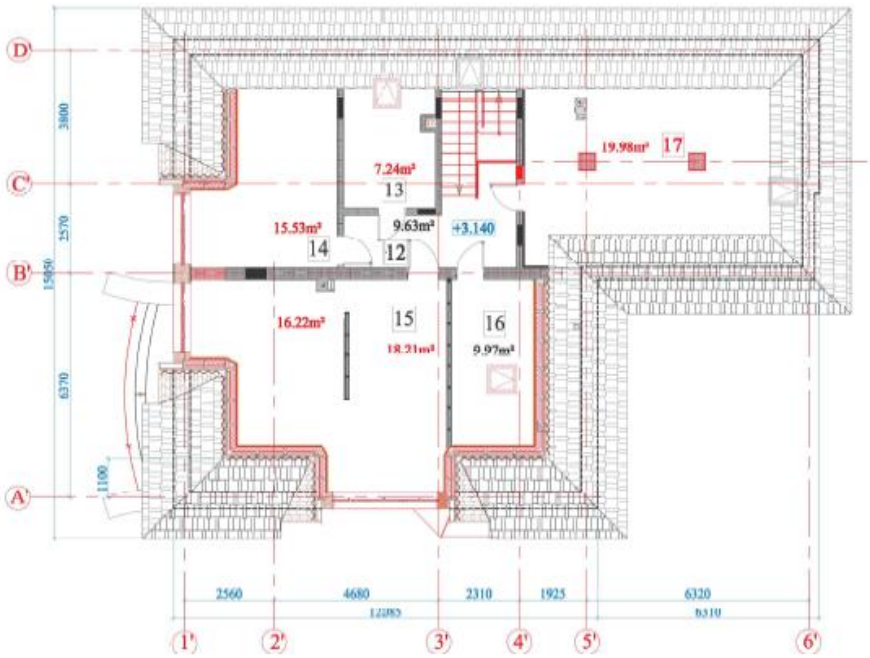
Imanta building was erected in 2013 and has a heated area of 234.8 m² distributed into two floors.

As shown in the drawings below (Figure 173 and Figure 174), the ground floor – with a total area of 234.8 m² – hosts a large living room, a bedroom, a bathroom with shower and the kitchen, plus a garage and boiler room. The first floor – with a total area of 96.8 m² – includes two additional bedrooms, one bathroom with shower and another room.



Ground floor	
Rooms | Space, m² (incl. changes marked red)	
1. Entryway, wardrobe	9.1
2. Hall	18.8
3. –	
4. Bathroom	9.7
5. Bedroom	20.0
6. Wardrobe	4.9
7. Living-room	29.3
8. Kitchen	21.6
9. Boiler room	3.7
10. Garage	20.9
Total ground floor	**138.0**
Total 1st floor	**96.8**
Total	**234.8**

Figure 173: Ground floor – Imanta



1st floor (attic)	
Rooms | Space, m² (incl. changes marked red)	
12. Corridor	9.6
13. Bathroom	7.24
14. Bedroom	15.53
15. Bedroom	34.43
16. Wardrobe	10.0
17. Room	20.0
Total 1st floor	**96.8**

Figure 174: First floor – Imanta

External walls are constituted by expanded clay blocks type “Fibo”, with a thickness of 300 mm and by a 100 mm layer of stone wool insulation. Finally, a plaster layer is superposed as finishing.

The main roof is composed by clay tiles, laid on a 50 mm lath and on a ventilated air gap of 25 mm and on rafters of 400 mm. insulation is realized through various type of stone wool layers, with an overall thickness of 250 mm. A plaster layer is superposed as finishing.

Some variations in the roof stratigraphy exist in the area above the garage and on the eaves.

Window ratio is calculated as 0.10, leading to a glazed area of approximately 24 m^2 in the entire building. Windows are of double-glazed type with a PVC frame. Such components usually present a transmittance of 2.0 W/m^{2}K, depending of the specific dimensions of the window.

Number of windows based on their size, including velux roof windows, is summarized in Table 41 below.

Table 41: Number and size of windows – Imanta

Size	Number
500 mm x 1,632 mm	2
1,000 mm x 1,132 mm	2
1,500 mm x 1,632 mm	1
1,000 mm x 1,632 mm	1
2,000 mm x 1,632 mm	1
1,495 mm x 1,632 mm	1
940 mm x 1,632 mm	2
1,000 mm x 1,050 mm	7
780 mm x 980 mm	6

As detailed also in D2.5, the building can be modelled considering a thermal zone per room (according to the radiators distribution – at least one element in each room). To the 15 thermal zones modelled following this approach, other 9 thermal zones have been added considering both the geometric features of the building and the Trnsys3D limitations, to make the model as accurate as possible. For these 9 zones, that are not divided from the proper 15 thermal zones by internal walls, massless walls have been used. These types of wall are composed by very thin layers with a negligible thermal mass. In particular, this approach was used to obtain an accurate model of the quite geometrically complex roof.

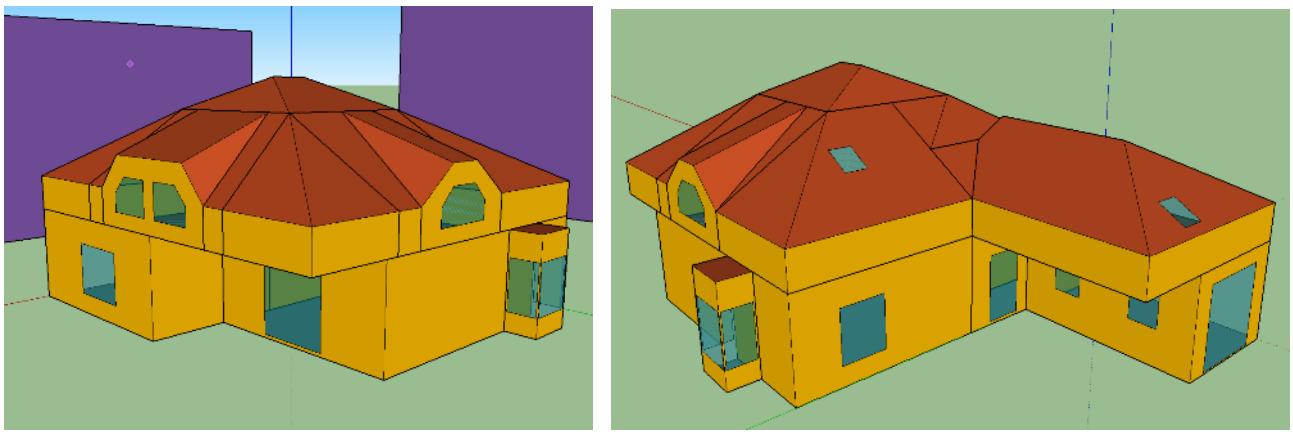
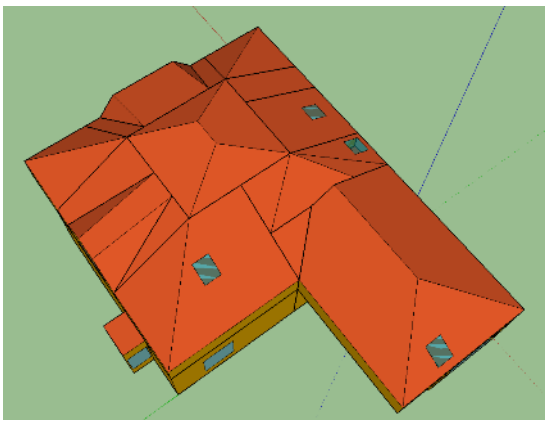


Figure 175: The 3D model divided into thermal zones



Thermal zones – floor division:

- *Ground Floor: Zones 1 – 4*
- *1st Floor: Zones 5 – 18*

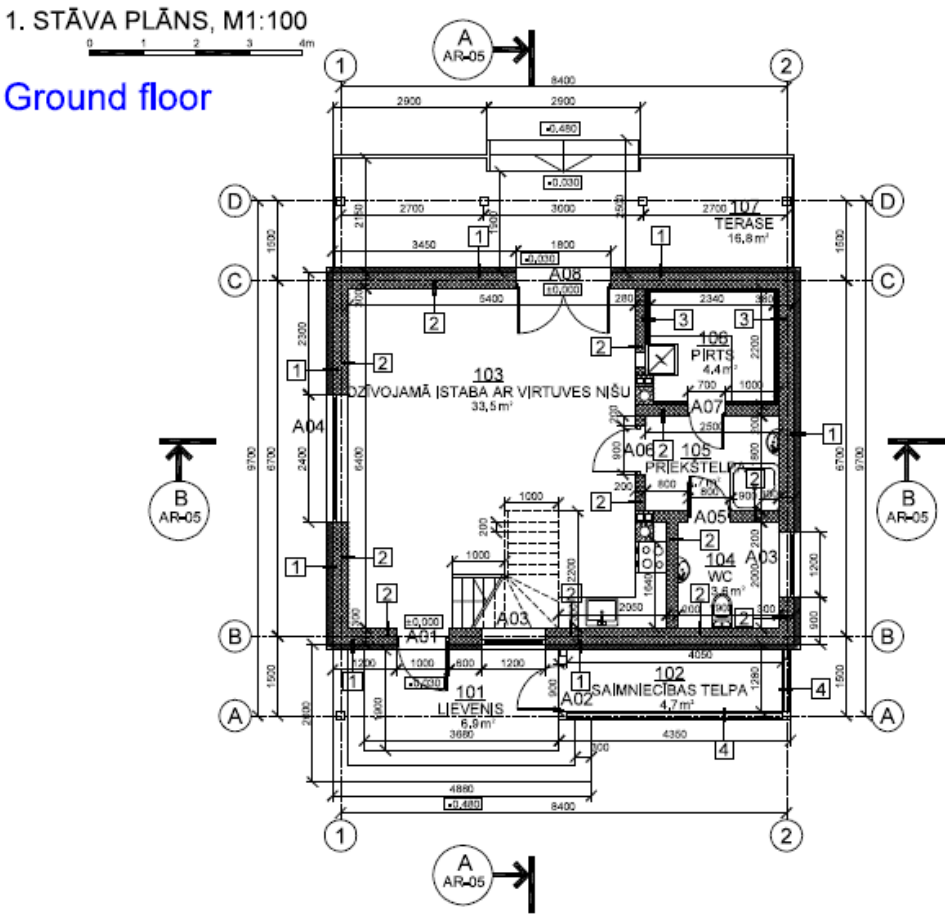
The characteristics of the so created 3D model, considering some assumptions, are:

- Total heated zones area and volume: 234.8 m^2 and 946 m^3
- Capacitance: 1146 kJ/K
- Heated zones total area and volume per floor: Ground Floor – 138 m^2 and 480 m^3, 1st t Floor –96.8 m^2 and 466 m^3
- Total glazed area: ~30 m^2.

9.3.2 Sunisi

Sunisi building was erected in 2015. Total area of the main (residential) house is 108.8 m^2, of which 80.4 m^2 are heated. Nearby there is an 88.9 m^2 large garage building, part of which (42.7 m^2) is used for parking cars and the other part (46.2 m^2) is dedicated to a playroom. This playroom is heated only occasionally, by an air-air heat pump and a wood burning fireplace. Technology package (TP2) installed within the SunHorizon project won't be used for covering the heat demand of the garage building, therefore it is to be excluded from further analysis for SunHorizon purposes.

As shown in the drawings below (Figure 176**Error! Reference source not found.** and Figure 177**Error! Reference source not found.**), the main house has two floors: the ground floor – with a total indoor area of 50.9 m^2 – hosts the kitchen, the living room, the utility room, hall, toilet, sauna and shower, and the first floor – with a total indoor area of 34.2 m^2 – hosting three bedrooms.

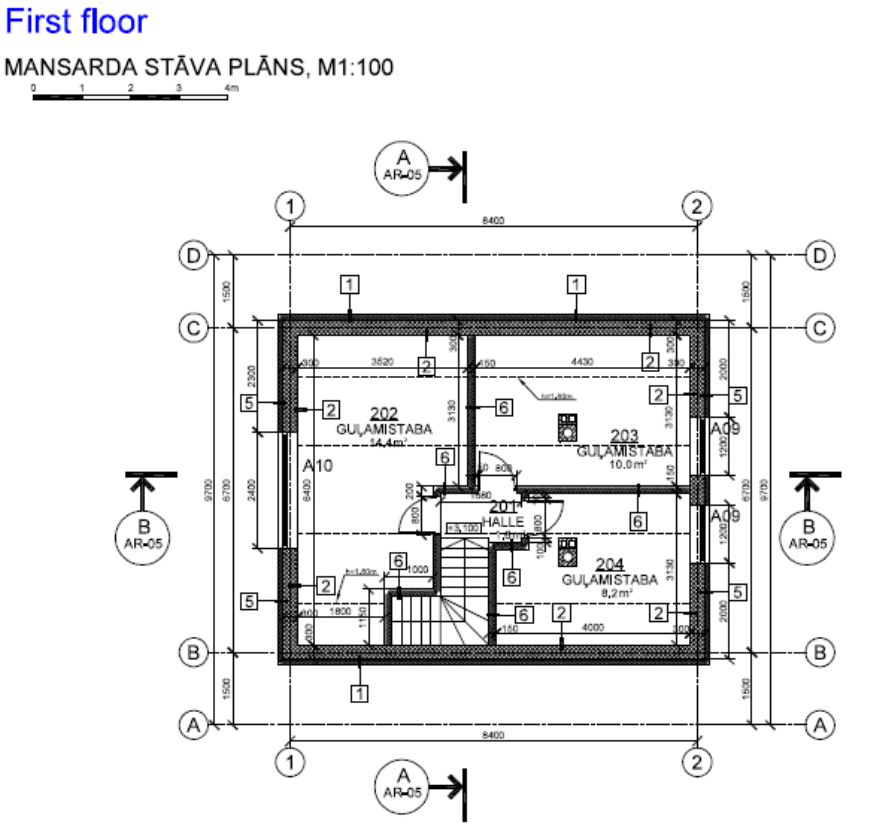


TELPU EKSPLIKĀCIJA

Rooms & space

Nr.	Nosaukums	Platība m²	Piezīmes
101	LIEVENIS	6,9	Porch
102	SAIMNIECĪBAS TELPA	4,7	Utility room
103	DZĪVOJAMĀ ĪSTABA AR VĪRTUVES NIŠU	33,5	Living room with kitchen niche
104	WC	3,6	Toilet
105	PRIEKŠTELPA	4,7	Hall
106	PĪRTS	4,4	Sauna
107	TERASE	16,8	Terrace
	Kopā:	50,9	Total space (inside): 50,9 m²

Figure 176: Ground floor – Sunisi



TELPU EKSPLIKĀCIJA

Rooms & space

Nr.	Nosaukums	Platība m²	Piezīmes
201	HALLE	1,6	Hall
202	GUĻAMISTABA	14.4	Bedroom
203	GUĻAMISTABA	10,0	Bedroom
204	GUĻAMISTABA	8,2	Bedroom
	Kopā:	34.2	

Figure 177: First floor – Sunisi

External walls are constituted by aerated concrete blocks type “AEROC”, with a thickness of 300 mm and by a 100 mm layer of stone wool insulation. Finally, a plaster layer is superposed as finishing.

The roof is composed by polymeric sand tiles, laid on a mesh of battens and on a ventilated air gap. Insulation is realized through various types of stone wool layers, with an overall thickness of 280 mm. A12.5 mm plaster layer is superposed as finishing.

Windows are of double-glazed type. Number of windows based on their size is summarized in Table 42**Error! Reference source not found.** below.

Table 42: Number and size of windows – Sunisi

Size	Number
1,200 mm x 600 mm	2
2,400 mm x 2,000 mm	1
1,200 mm x 1,400 mm	2
2,400 mm x 1,600 mm	1

For the purpose of thermal simulation of Sunisi behaviour, only the main building has been modelled considering a thermal zone per room (according to the heating systems distribution – at least one radiator in each room for the first floor and the underfloor heating circuits in the ground floor). To the 9 thermal zones modelled following this approach, other 2 thermal zones have been added considering both the geometric features of the building and the Trnsys3D limitations, to make the model as accurate as possible. For these 2 zones, that are not divided from the proper 9 thermal zones by internal walls, massless walls have been used, as previously described for Imanta model.

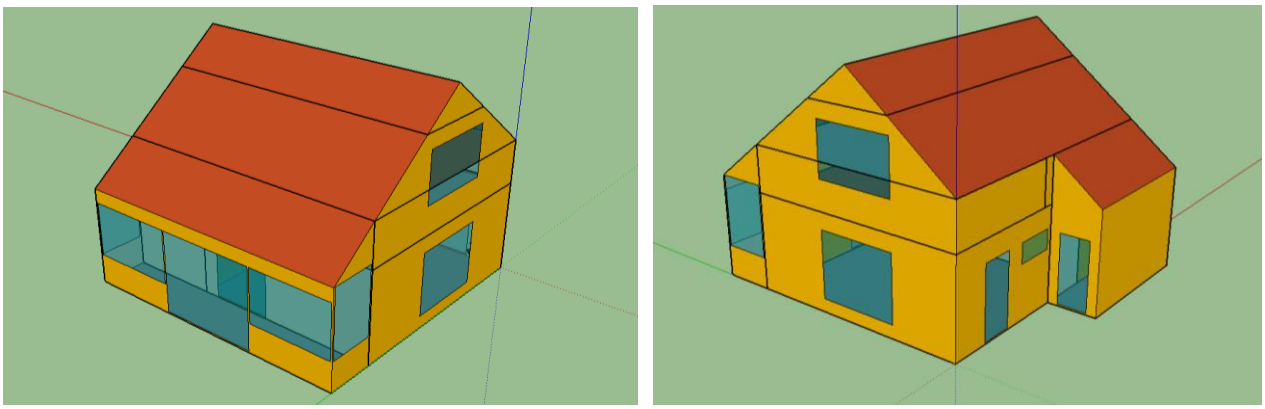


Figure 178: The 3D model divided into thermal zones

Thermal zones – floor division:

- Ground Floor: Zones 1 – 6
- 1st Floor: Zones 7 – 11

The characteristics of the so created 3D model, considering some assumptions, are:

- Total heated zones area and volume: 96 m^2 and 285 m^3
- Capacitance: 461 kJ/K
- Heated zones total area and volume per floor: Ground Floor – 50.9 m^2 and 145 m^3, 1st Floor – 34.2 m^2 and 140 m^3
- Total glazed area: ~40 m^2.

9.4 Heating system with heat and DHW distribution

9.4.1 Imanta

The existing heating system is constituted by a Bosch gas boiler with a capacity of 28 kW, dedicated also to hot water production. In addition, there is also a wood-burning fireplace in the living-room on the ground floor as shown in Figure 179**Error! Reference source not found.**.

The boiler - Junkers Ceraclass Excellence ZWC28-3MFK model - has an efficiency of 90.5% at rated power and of 89.6% at 30% of the rated power. It is capable of producing hot water with a rate of 13.4 l/min, at a temperature that can be set between 40°C and 60°C.

Currently, there is not any solution in place to provide hot water storage.

Space heating is distributed through 19 radiators and it is complemented by electrical underfloor heating in bathrooms. Figure 179**Error! Reference source not found.** and Figure 180**Error! Reference source not found.** show size and location of each radiator for ground floor and first floor respectively.

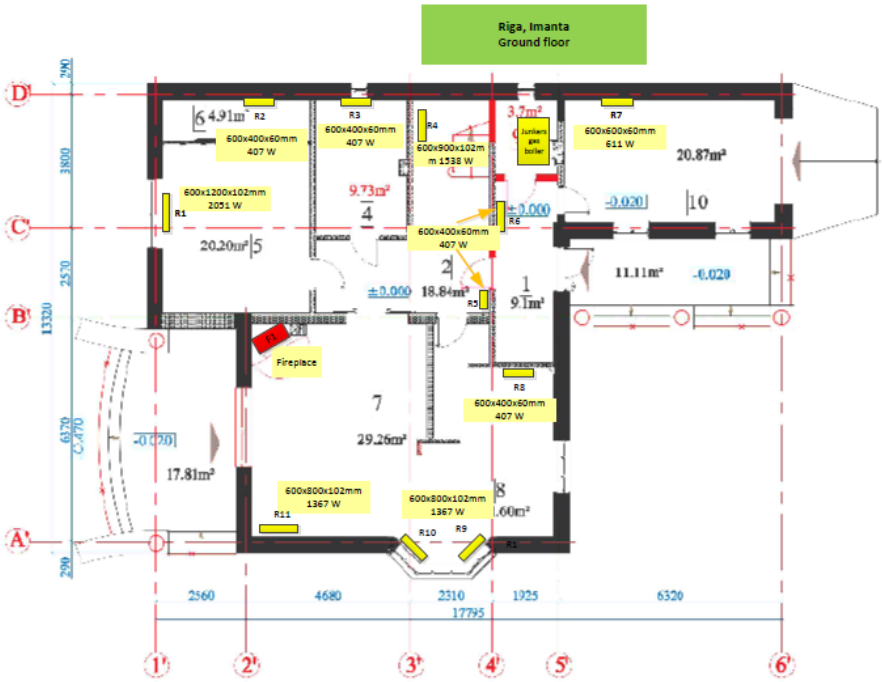


Figure 179: Existing heating systems – Ground floor, Imanta

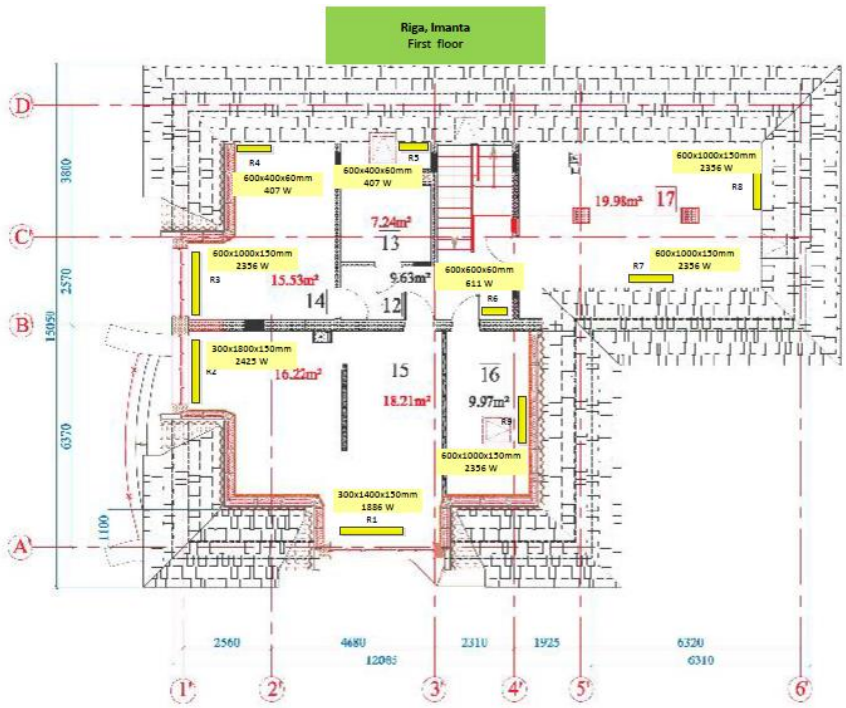


Figure 180: Existing heating systems – First floor, Imanta

The available data about annual gas consumption, including gas used for cooking purposes, indicate an average demand of approximately 39.6 MWh/y. Specifically, a consumption of 41.9 MWh is recorded for 2017 and of 37.3 MWh in 2018: the decrease in consumption is likely related to an increase of average temperatures in 2018, as described in the previous section.

In order to investigate the annual profile of natural gas demand for space heating purposes only, the methodology below is followed:

1. Estimation of annual gas consumption for cooking and for domestic how water production – this step is based on the approach proposed by the standard UNI11300, which has been validated through comparison with measured consumption data for the case of Sunisi and thus it is considered as reliable also for Imanta case. Specifically,

gas consumption for cooking is calculated on the basis of a specific daily consumption of 6 kWh/day, provided by the standard on the basis of the dimensions of the house, leading to an annual consumption of 2.2 MWh. Gas consumption for domestic hot water is calculated considering a specific water demand of 1.3 l/m²/day and an input water temperature of 15°C and output water temperature of 40°C. Calculation yields to an annual consumption of 2.9 MWh.
The annual gas consumption for space heating purposes is then obtained by difference from the total gas consumption (average 2018 and 2019) and it is calculated as 34.5 MWh.

2. Annual gas consumption for heating purposes has then been distributed along the heating season (Oct-Apr) proportionally to HDD calculated in the proximity of the demo site location at daily scale. Monthly average values are then calculated and reported as a result in Figure 181**Error! Reference source not found.** below.

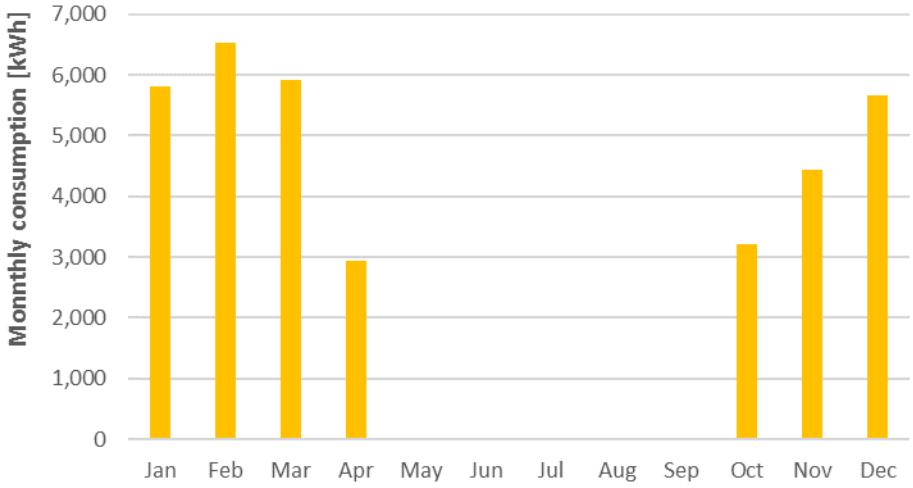


Figure 181: Monthly gas consumption for space heating - Imanta

Internal gains that can be deducted by the monthly consumption for space heating purposes are evaluated considering the UNI11330 and EN13790 with some assumptions adapted to the residential usage. Estimation considered 3 people living in the house and the internal gains were divided by days (workdays and weekend) and by zone:

- living room and kitchen;
- other heated rooms.

The gain card was set defining an absolute value for the kitchen and living room zone (the values do not change during the week) and a schedule for the other zones with the different behaviour during the weekdays and the weekends.

Table 43**Error! Reference source not found.** shows the main parameters of the estimation:

Table 43: Internal Gains – Imanta

Week Day	Time	Internal Gain [W/m²]		Internal Gain [W]	
		Kitchen and living room	Other	Kitchen and living room	Other
Monday to Friday	Day time	8	1	407	160
	Evening	20	1	1,018	160
	Night time	2	6	102	957
	Daily avg.	*9*	*3*	*458*	*426*
Saturday and Sunday	Day time	8	2	407	319
	Evening	20	4	1,018	638
	Night time	2	6	102	957
	Daily avg.	*9*	*4*	*458*	*611*

In addition, although not related to consumptions for heating purposes, an electricity consumption of 4.4 MWh/y is recorded through a smart electricity meter with hourly resolution. Figure 182**Error! Reference source not found.** shows monthly electricity consumptions made available from the electricity provider. On average, monthly electricity consumption is in the order of 360 kWh/month, and it is observed that the consumption is quite homogeneous along the year, with slight deviation in June (lowest consumption) and in December (highest consumption).

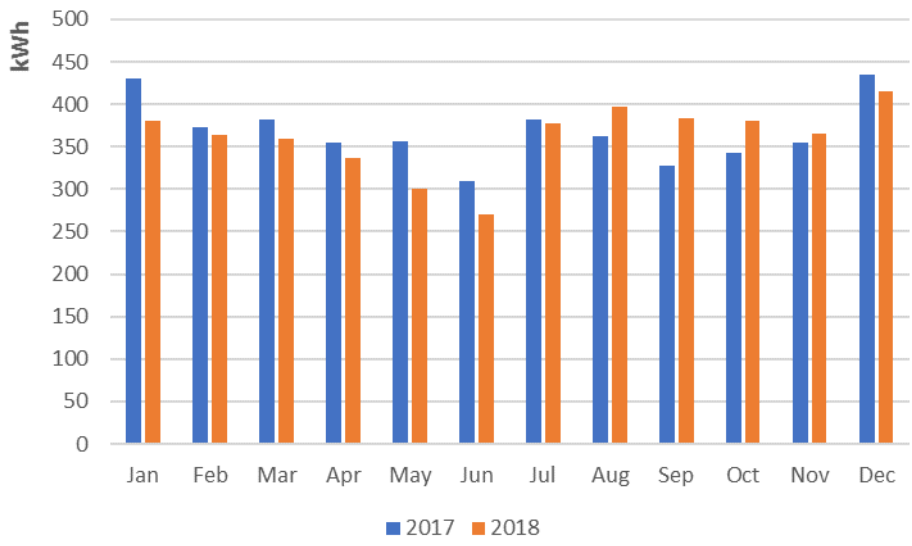


Figure 182: Monthly electricity consumption - Imanta

The total water consumption is calculated from bills, indicating a demand of 80 m^3 in six months (46 m^3 from January to March and 34 m^3 from April to June).

9.4.2 Sunisi

The existing heating system is constituted by a Bosch gas boiler with a capacity of 24 kW, dedicated also to hot water production and two heating pumps, one in the main house, used for cooling purposes during summer period, and the other one in the garage. Finally, the garage is equipped with a large wood stove.

The boiler - Junkers Ceraclass Excellence ZWC24 model - has an efficiency of 92.2% at full rated power. It is capable of producing hot water with a rate of 6.9 l/min, at a temperature that can be set between 40°C and 60°C.

Heat pumps are released by Panasonic.

The heat pump located in the main house is HE12 model, with a cooling capacity of 3.5 kW (0.6 kW – 4.0 kW), a EER of 3.98 (5.00 – 3.81); according to the datasheet, its consumption is estimated of approximately 440 kWh/y, assuming on average 500 annual working hours in cooling mode.

The heat pump located in the garage is NE12 model, with a heating capacity of 4.0 kW (0.6 kW – 6.0 kW) and a COP of 4.17 (5.22 - 3.57).

For both pumps, rating conditions foresee an inside air temperature of 27°C dry bulb (or 19°C wet bulb) and an outside air temperature of 35°C dry bulb (or 24°C wet bulb).

Currently, there is not any solution in place to provide hot water storage.

Space heating is carried out through three radiators located on the first floor and through three underfloor heating circuits with water on the ground floor.

Figure 183**Error! Reference source not found.** and Figure 184**Error! Reference source not found.** show size and location of underfloor circuit for ground floor and each radiator and for first floor respectively.

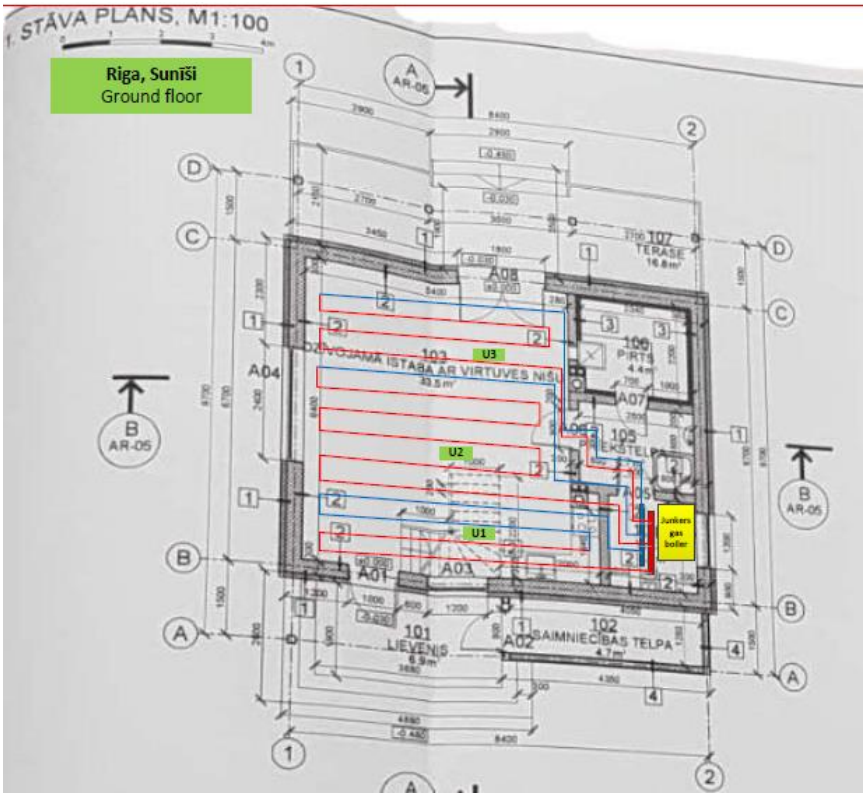


Figure 183: Existing heating systems – Ground floor, Sunisi

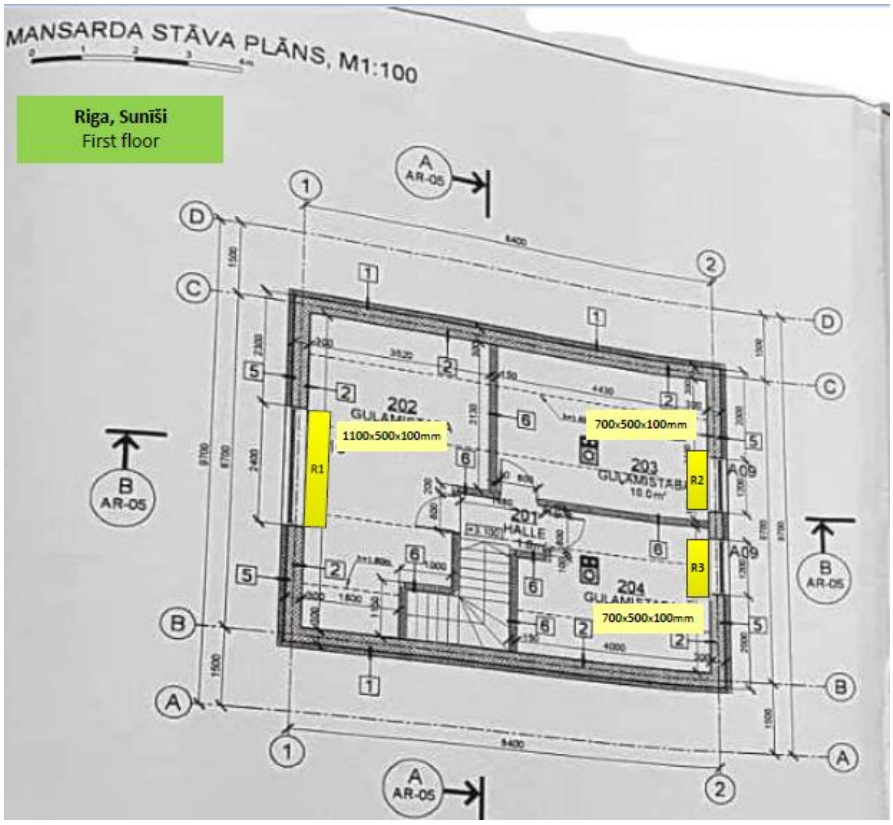


Figure 184: Existing heating systems – First floor, Sunisi

The available data about annual gas consumption, including gas used for cooking purposes, indicated a demand of approximately 21.08 MWh/y. This value is available from the readings of the existing gas meter, performed manually for billing purposes three/four times per year. Following the methodology already described in the previous section, monthly gas consumption for space heating purpose is calculated, as shown in Figure 185**Error! Reference source not found.**.

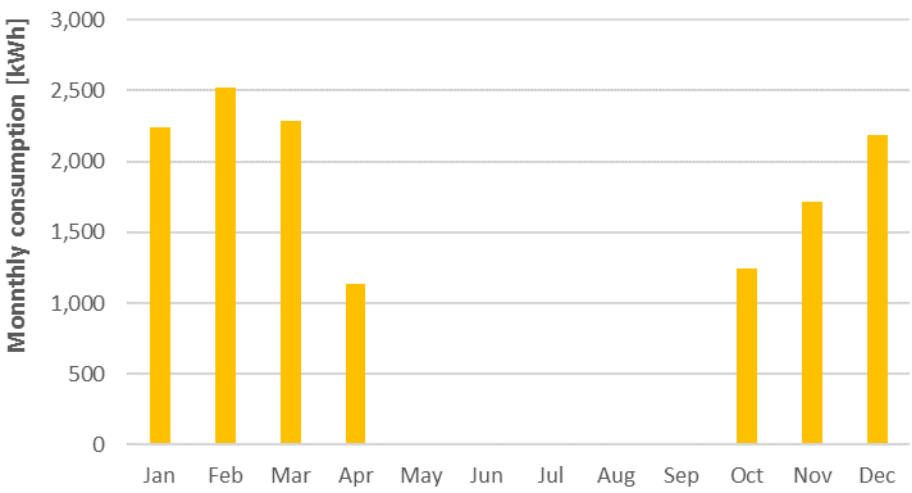


Figure 185: Monthly gas consumption for space heating - Sunisi

Internal gains that can be deducted by monthly consumption for space heating are calculated as described in the case of Imanta. Table 44**Error! Reference source not found.** shows the main parameters of the estimation:

Table 44: Internal Gains – Sunisi

Week Day	Time	Internal Gain [W/m²]		Internal Gain [W]	
		Kitchen and living room	Other	Kitchen and living room	Other
Monday to Friday	Day time	8	1	768	63
	Evening	20	1	1,920	63
	Night time	2	6	192	375
	Daily avg.	*9*	*3*	*864*	*167*
Saturday and Sunday	Day time	8	2	768	125
	Evening	20	4	1,920	250
	Night time	2	6	192	375
	Daily avg.	*9*	*4*	*864*	*239*

In addition, the total electricity consumption is estimated as 7.2 MWh/y, from monthly manual readings of the meter; the electricity consumption includes both the uses of the heat pumps and those of all electric appliances in the house. Figure 186**Error! Reference source not found.** shows monthly electricity consumptions made available. On average, monthly electricity consumption is in the order of 720 kWh/month, and it is observed that the consumptions do not have a clear trend along the year and across the two years considered. Main reason for that could be the employment of a "balanced payment" to the electricity supplier which implies that the end-user may record its electricity consumption only once per quarter instead of reading the electricity meter every month. However, it is also possible to make the readings more often if the end-user wishes to change the average amount to be paid. Consequently, the historic consumption reported in Figure 186**Error! Reference source not found.** shows the averaged values for some months. Therefore, for simulations the total annual consumption was used for obtaining hourly profiles with a CREST model (D2.5).

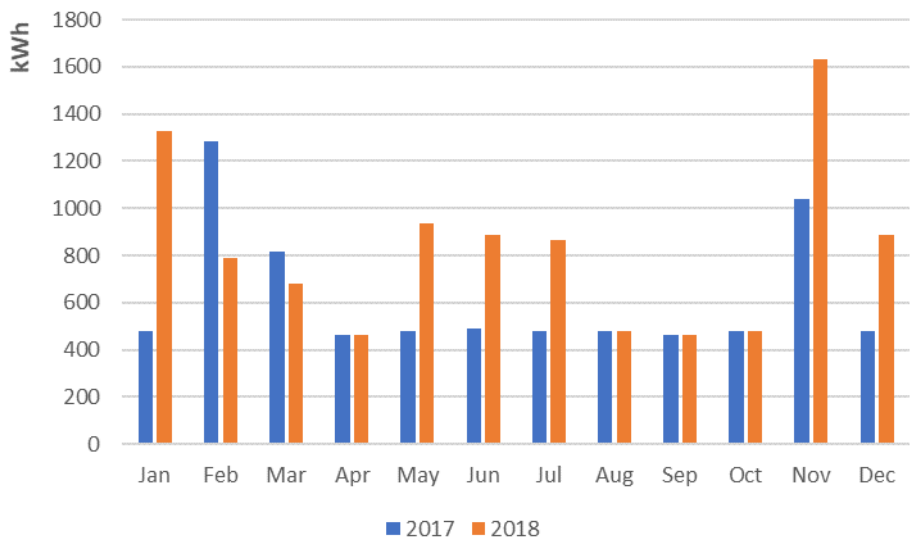


Figure 186: Monthly electricity consumption - Sunisi

9.5 Specific requirements for the new heating/cooling system

Before installation of new gas-consuming and electricity-generating equipment, the house owner needs to receive approvals from certain institutions:

1) for installation of new type of gas equipment, gas piping design is developed by a licenced gas system engineer in line with the technical conditions provided by the gas system operator. After approval of the design by the gas system operator, the piping work as specified in the design diagrams is performed by certified gas system installers. The completed work needs to be verified on-site by the gas system operator, after which the new equipment may be commissioned;

2) before installation of microgeneration which is the case with PV-T panels, the house owner submits an application to the distribution system operator (DSO) indicating the power of generation and inverter specification, including its serial number. After approval, the PV-T panels may be connected to the electricity distribution grid by a certified electrician. The DSO verifies the installation on-site and replaces or reprograms the electricity meter for it to be able to meter the electricity flow in both directions. The house owner may conclude an agreement with the DSO on net metering or, instead, conclude an agreement with an electricity supplier who agrees to purchase the surplus electricity fed into the grid;

3) the municipality may require approvals for installation of heat pumps or solar panels outside the house if they are visible from the surrounding. However, it depends on the specific municipality. For example, in Riga, the City Council Construction Board requires a sketch and visualisation showing the planned placement of the equipment on the specific land plot. After approval of the documentation, the installation may take place.

In both Imanta and Sunisi demo sites, it is planned to employ net metering for the electricity produced by PV-T panels. As per the current legislation in Latvia, the maximum allowed installed capacity of a microgenerator used for net metering is 11.1 kW. It means that the number of PV-T panels (0.31 kW PV capacity per module, 1.7 m^2) in each demo site should not exceed 35. Below are additional technical requirements to be considered for planning of TP in each house.

9.5.1 Imanta

The indoor unit of the BH heat pump will be placed in the boiler room and its outdoor unit outside, next to the boiler room wall (Figure 187**Error! Reference source not found.**).

RT stratified storage tank, due to its large dimensions, will be installed in the storage room (unused garage) next to the boiler room, so the piping from the tank to the rest of heating equipment will need to go through the inner wall between the boiler room and storage room (garage). Though there is already one radiator in the storage room, it needs to be checked if additional insulation or heating might be necessary to prevent excessive thermal losses from the storage tank during cold spells.

DS PV-T panels are planned to be installed on the ground in the yard, at a maximum distance of ~ 50 m to the boiler room and garage (TBC). For installation of PV-T panels, ~40 m^2 are available. For optimal positioning of panels, it needs to be

considered though that there are some fruit trees in the yard covered by leaves in summer and a larger dwelling on the adjacent land plot with some trees near it, located 10 m from the South façade.

Figure 187. Overall Imanta demo site setup and yard for installation of PV-T panels on ground

The boiler is not equipped to precisely regulate the set-point, thus an ambient temperature of 20°C can be assumed.

As for domestic hot water, Latvian legislation foresees that in order to avoid legionella risk, hot water temperature in apartments should be between 55°C and 70°C. In practice, for single-family houses the choice of the temperature is up to the owner. In case lower temperatures are foreseen, occasional thermal disinfection of the DHW system (preferably automatic, i.e. programmable) should be performed.

9.5.2 Sunisi

Since the single-family residential house in Sunisi does not have enough technical space for placing SH technologies, the owner has decided to install the TP2 in a retrofitted shipping container which will be placed just next to the garage building (Figure 188**Error! Reference source not found.**). Container size is L 12.2 m x W 2.4 m x H 2.6 m, and the owner plans to split it in ~3 parts: storage room, shower and technical room for the heating equipment. Thus, there would be ~10 m^2 for installation of SH technologies.

To avoid extensive thermal losses from the storage tank and ensure proper functioning of the heat pump, it is required to insulate the container and install radiator(s) inside it. For the heat pump operation, it is needed to keep the temperature in the technical room above ~7°C. Thus, there will be additional heating demand for space heating and DHW in the container as compared to the existing situation.

DS PV-T panels can be installed on the container roof (29.3 m^2) and/or possibly on the garage or main house roof, depending on the required total number of panels. When selecting exact locations, it needs to be checked that the weight of panels is admissible for the particular roof construction.

With the proposed setup, the distance from the container to the main house will be ~ 20 m (TBC).

Figure 188. Overall Sunisi demo site setup and container for installation of SH technologies

The target set-point temperature for space heating is 23.5 °C. Domestic hot water temperature follows the same concepts already introduced for Imanta building.

9.6 Preliminary monitoring plan

Since Sunisi house has been selected as one of the SunHorizon demo sites for the hybrid controller deployment (to be developed in WP5), a pre-monitoring strategy has been developed for this house in order to collect the data required for refining the energy baseline. It will involve installation of a set of sensors defined within WP4 for monitoring of indoor and outdoor conditions, occupancy, heat demand and electricity consumption. The list of sensors selected for pre-monitoring is shown on the left part of Figure 189**Error! Reference source not found.**, whereas the right section shows a preliminary layout of the main control components to be launched when upgrading the demo site with TP2. A preliminary set of sensors for monitoring of the different components of TP2 is illustrated in Figure 190**Error! Reference source not found.**. A similar approach will be implemented in Imanta where the same TP2 is going to be installed employing a standard controller. For monitoring, the same type of sensors will be used as in Sunisi, the exact location and number of which is to be defined in the upcoming months. No pre-monitoring is planned for Imanta house, so the sensors will be deployed together with the upgrade of the house with TP2.

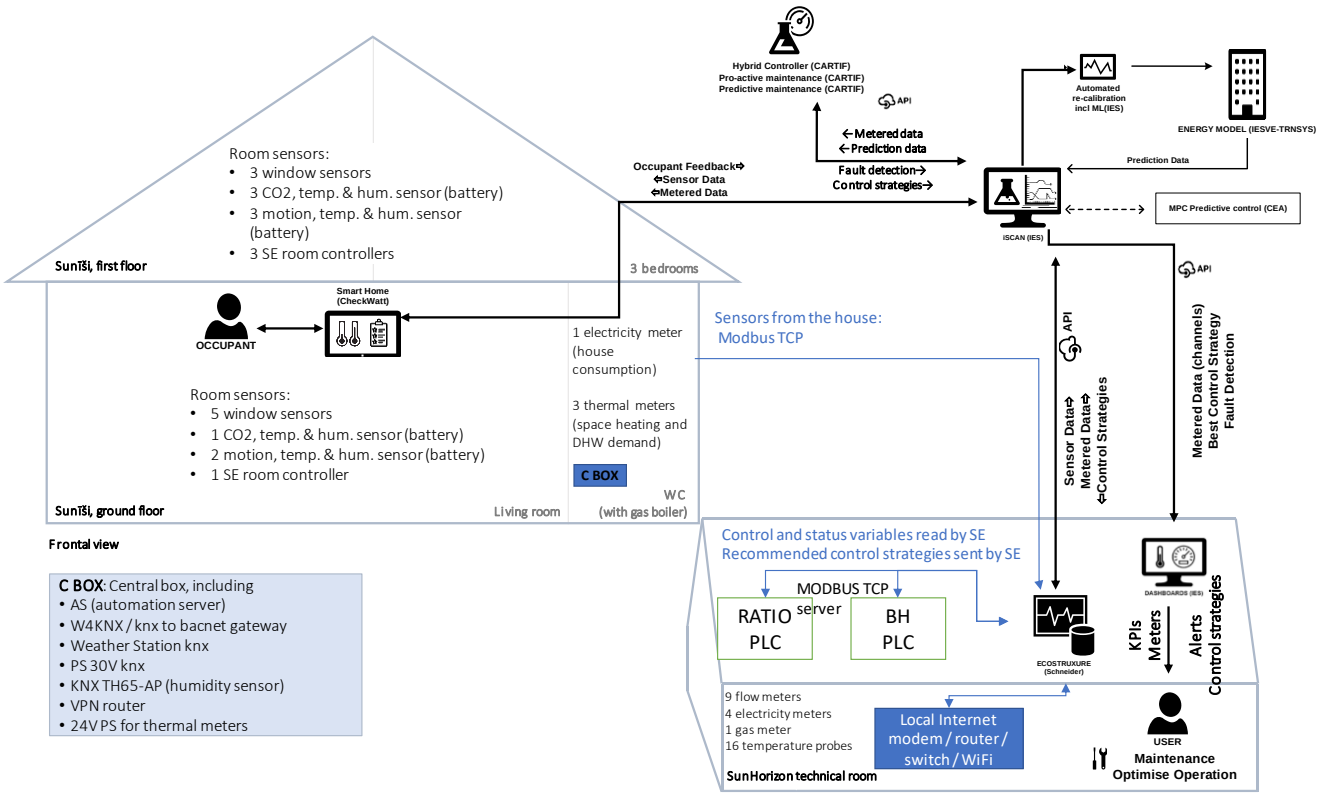


Figure 189. Diagram for Sunisi demo site with the confirmed pre-monitoring sensors and preliminary control schematics

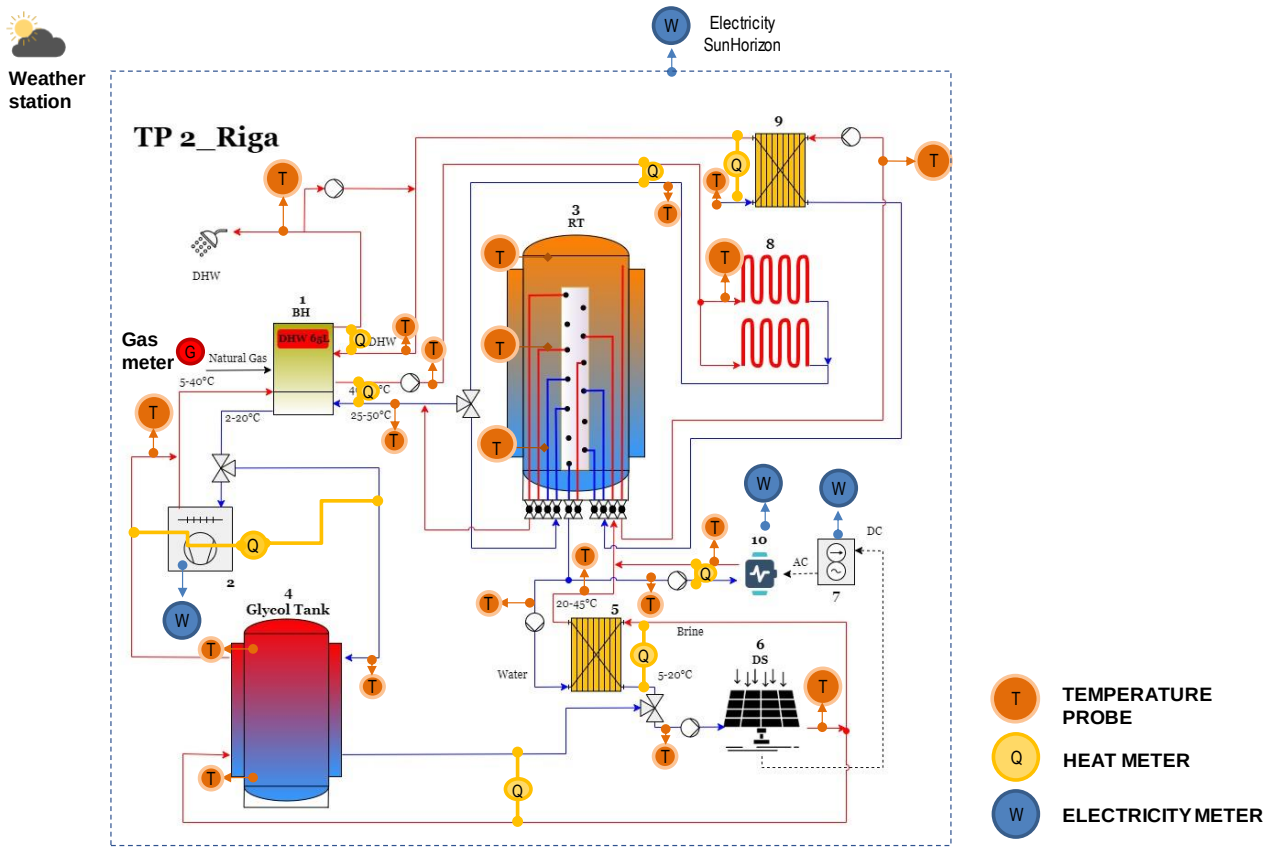


Figure 190. TP2 layout diagram for Riga demo sites with a preliminary set of sensors for TP monitoring

10 Conclusion

The cross-work performed in task T6.1 and T2.4 allowed to draw the energy baseline for the 8 Sunhorizon demo cases. It is required to design and size the components of TP1-4, including the control, prior the detailed engineering in the T6.2 next phase of the demonstration. The previous sections give details for each case while Table 45 shows an overview of the key aspects of the 8 demo cases from T2.4 building energy baseline simulation work. It emphasizes that the demo case groups working in parallel had to consider very different integration constraints (single family to multi-apartment buildings or type of building's use like swimming pool, sport center, civic center, or variations in envelope's renovation level, or variations in availability of the monitoring data details). Some demo cases show already good energy efficiency performance level for the envelope (range 32-250 kWh/m² in space heating) or the primary energy consumed by the existing heating / cooling system (range 100-495 kWh/m² as whole non-renewable primary energy demand) or both, while others show poor ones. The report highlights also different system boundaries when including the specific electricity consumption of the whole building for the evaluation of the TP2 and TP4 with PV electricity production or only the electricity consumed by the DHW / heating / cooling system for the evaluation of the TP1 and TP3 with renewable solar thermal production.

Table 45: overview of SUNHORIZON 8 demo cases' energy baseline

Demo building case	Technology package	Baseline annual SH – COOL [kWh/m²] / DHW [kWh/pers]	Baseline annual electricity consum Boundaries [kWh/m²]	Baseline annual PEnren [MWh]	Baseline annual OPEX [k€]
#1 Berlin **2 apart. , 3 floors, 284 m², 7 inhab.**	TP1:TVP, RATIO, BH20	88.8 - 0 / 639.3	System 2.1	40.5 142 kWh/m²	2.34 8.2 €/m²
#2 Nurnberg **4 apart., 4 floors, 330 m², 12 inhab.**	TP2: DS, Ratio, 2*BH20	250.3 - 0 / 568.6	Building 131.6	163.5 495 kWh/m²	16.71 50.6€/m²
#3 Sant Cugat **Civic center, 806 m² , 120 people**	TP3:TVP, RATIO, FAHR sorption+compression	44.34 – 104.6 / 0	System 95.98	155.3 192 kWh/m²	18.6 23.07 €/m²
#4 Madrid **778.5m2, 5 people/9 dwellings**	TP4: DS, RATIO SH/SC/DHW, BDR BWHP, AWHP	31.8 – 9.36 / 121.72	Building 17.49	78.3 100 kWh/m²	10.8 13.9€/m²
#5 San Lorenço **1 household, 208m², 4 inhab.**	TP4'-BDR: AWHP, DHW - buffer 200-150L tank ; PV, Th	79 - 3 / 577	Building 48	25 120 kWh/m²	2.73 13.1€/m²
#6 Verviers SC **10145 users/year, 2754.5 m2**	TP1: TVP, RATIO, 2xBH20	97.1 - 0 / 0.97	System NA	287.56 104 kWh/m²	11.5 4.17€/m²
#7 Verviers SP **1 small pool of 100 m3, 500 people/year**	TP2: DS, RATIO, 2xBH20	298 MWh	Building 293.3 MWh	1083.6	60.1 601€/m³
#8a Sunis **1 household, 96 m², 3 inhab.** **#8b Imanta** **1 household, 234.8 m², 3 inhab.**	TP2: DS, RATIO, BH20 TP2: DS, RATIO, BH20	138.5 / 533 146.9 / 967	Building 90 Building 18	27.9 328 kWh/m² 47.7 203 kWh/m²	1.6 8.02 €/m2 1.8 11.3 €/m2