This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 691768

Report on the baseline assessment of the demo sites

Project report

NOBATEK, TECNALIA

April 2018

Summary

This document provides the synthesis of the monitoring conducted during the baseline period of the PVSITES project meaning before the installation of the BIPV systems in each pilot site. The main results in terms of energy consumptions and indoor environmental conditions are presented for each of the six pilots.

Originally, it was planned to have a one-year period prior to the retrofitting monitored to assess the initial situation of the pilot sites. Indeed, according to the IPMVP protocol, one full year of monitoring data are required to establish the energy consumption baseline to compare the new consumptions after renovation and then for assessing energy savings. Nevertheless, due to changes in pilot sites selection (change of pilot site #2 and change of carport for pilot site #3) and due to some delays in the monitoring implementation a full one year of data is not available for all the pilot sites. However, results are presented considering different periods of time separately and extrapolating when possible and relevant. Given that the BIPV implementation in the demo sites is suffering some delays, additional data from the following weeks will be available to complement this deliverable and the baseline assessment.

The following table summarises the main KPIs calculated for each pilot site for the baseline period.

	Pilot#1	Pilot#2	Pilot#3	Pilot#4	Pilot#5	Pilot#6
Yearly electricity consumption (kWh)	6 592	342 115	N/A	3 832 366	31 136 (common spaces)	188 834
Yearly electricity consumption per surface (kWh/m²)	23.71	128.13	N/A	281.1	8.56	31.47
Average daily electricity consumption (kWh)	18.33 Winter: 22.04 Summer: 15.58	938.2 Winter: 783.5 Summer: 823.6	N/A	11 940.1	16.14	535.1
Yearly heating consumption (kWh) [HDD]	Electric heater: 423 [2761 HDD] Wood: 3026 [2761 HDD]	420 732 [2801,7 HDD]	N/A	Not measured	Not measured	Not measured
Ratio heating energy/HDD	Electric heater: 0.153 Wood: 1.096	150.2	N/A	--	--	--
Yearly heating consumption per surface (kWh/m²)	Electric heater: 1.52 Wood: 10.88	157.58	N/A	--	--	--
Correlation between heating energy and HDD	Electric heater: Energy=	Energy=168.27 x HDD -3750.5	N/A	--	--	--

	Pilot#1	Pilot#2	Pilot#3	Pilot#4	Pilot#5	Pilot#6
	394.33 x HDD -76249 Wood: Energy= 2.56 x HDD – 389.2					
Percentage of electricity consumed during the night in comparison to total electricity consumption (%)	26	18.9	N/A	38.4	34.5	26.4
Difference between peak power demand and minimum night time demand (W)	8 070	140 800	N/A	1 511 976	4 272	57 112
Average daily and nightly power demand (W)	Day: 899.7 Night: 533.1	Day: 51 233 Night: 19 736	N/A	Day: 469 239 Night: 468 661	Day: 2150 Night: 1890	Day: 26 298 Night: 16 430
Percentage of hours during which the indoor temperature is out of the comfort range	Winter: 28% (average calculated over the 8 sensors for T<18°C) Summer: 2.8% (average calculated over the 8 sensors for T>28°C)	Winter: 0.2% (average calculated over the 3 sensors for T<18°C)	N/A	N/A	Summer: 5.8 % (average value calculated over the two sensors installed in the dwellings for T>28°C)	Winter: about 25-30%; Summer and Autumn: about 10%

Acknowledgements

The work described in this publication has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 691768.

The present report was mainly prepared by PVSITES project partner NOBATEK, with additional contributions from TECNALIA. The report was originally submitted to the European Commission as Project Deliverable D8.9 in April 2018.

Disclaimer

This document reflects only the authors' view and not those of the European Commission. This work may rely on data from sources external to the members of the PVSITES project Consortium. Members of the Consortium do not accept liability for loss or damage suffered by any third party as a result of errors or inaccuracies in such data. The information in this document is provided "as is" and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and neither the European Commission nor any member of the PVSITES Consortium is liable for any use that may be made of the information.

About the PVSITES project

PVSITES is an international collaboration co-funded by the European Union under the Horizon 2020 Research and Innovation program. It originated from the realisation that although building-integrated photovoltaics (BIPV) should have a major role to play in the ongoing transition towards nearly zero energy buildings (nZEBs) in Europe, the technology in new constructions has not yet happened. The cause of this limited deployment can be summarised as a mismatch between the BIPV products on offer and prevailing market demands and regulations.

The main objective of the PVSITES project is therefore to drive BIPV technology to a large market deployment by demonstrating an ambitious portfolio of building integrated solar technologies and systems, giving a forceful, reliable answer to the market requirements identified by the industrial members of the consortium in their day-to-day activity.

Coordinated by project partner Tecnalia, the PVSITES consortium started work in January 2016 and will be active for 3.5 years, until June 2019. This document is part of a series of public reports summarising the consortium's activities and findings, available for download on the project's website at www.pvsites.eu.

The PVSITES consortium:

Tecnalia Research & Innovation	CTCV	FormatD2
Onyx Solar	Flisom	Vilogia
BEAR-iD	Cricursa	R2M Solution Research to Market
Nobatek	CEA	CADCAMation
Film Optics	Acciona Infraestructuras	WIP - Renewable Energies

Contents

Tables

Figures

1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

The general monitoring guidelines have been previously delivered in D8.7 for the PVSITES project. The Measurement & Verification (M&V) plans have been defined and described for each pilot in the project deliverable D8.8 “Specific monitoring plan for every demo site” with a common agreement on the monitoring strategy (what will be measured, which measurement devices will be used, which are the responsibilities of each stakeholder in the monitoring process…). Document D8.10” Installation and execution of monitoring of the demo sites” has reported what has been achieved so far in terms of measurement deployment in all the pilot sites of the PVSITES project. In continuity with this monitoring process, this deliverable (D8.9) provides the results obtained so far for the baseline performance of all the demonstration sites.

This report is one of the documents associated to the task 8.4 “Monitoring of installations” and specifically related with subtask 8.4.2 “Monitoring and evaluation of the baseline of the buildings”. It reports the main results established during the baseline period (meaning before the installation of BIPV systems) in terms of energy consumptions and indoor environmental conditions for all the six pilot sites of the project.

The IPMVP protocol [1] [2] recommends one full year of monitoring data to establish the energy consumption baseline to be compared with the new consumptions after renovation and then for assessing energy savings. Originally, according to the DOA and in accordance with the IPMVP protocol, it was planned to have a one-year period monitored prior to the retrofitting to assess the initial situation of the pilot sites. However, due to changes in pilot sites selection (change of pilot site #2 and change of carport for pilot site #3) and due to some delays in the monitoring implementation, a full one year of data is not available yet for all the pilot sites. However, results are presented considering different periods of time separately and extrapolating when possible and relevant. This methodology also includes possibilities to complete a baseline for minor periods of time when the use of energy is more intense in specific seasons, as happens with heating or cooling.

In the first part of the document (Chapter2), the general methodology used for analysing the data collected in the demonstration sites during the baseline situation is presented.

Chapter 3 reports the main results obtained so far for each pilot in terms of energy performance and indoor environmental conditions.

Chapter 4 provides concise conclusions and identifies the future steps attached to the monitoring activities.

1.2 Relation with other activities in the project

Table 1.1 depicts the main links of deliverable D8.9 to other activities (work packages, tasks, deliverables, etc.) within PVSITES project.

Table 1.1 Relation between D8.9 and other activities in the project

Project activity	Relation with current deliverable
D2.1	D2.1 describes the technical specifications for PVSITES BIPV modules and their manufacturing processes. It also proposes a first monitoring approach and lists the parameters to be measured in order to assess the BIPV system performance.
D8.1	D8.1 provides a pre-dimensioning of BIPV systems for every demo site. This is the main input for the M&V plan definition.
D8.3	D8.3 delivers the final design of the BIPV systems for each demo site.
D8.7	D8.7 introduces a first framework for the M&V Plans to be considered within PVSITES (monitoring guidelines).
D8.8	D8.8 specifies the Measurement and Verification Plans to be deployed for each pilot site and establish the specific details associated to each demonstration building.
D8.10	D8.10 reports the completion of the installation of monitoring equipment in the demonstration sites for the assessment of the baseline situation meaning before installation of BIPV systems.
WP6	Task 8.4 feeds in the planning tool developed within WP6 (Building Energy Management System for different building uses) with data measured on site (data series of PV production, solar radiation).
WP3 and WP4	Simulation tasks conducted within WP3 and WP4 provide expectations in terms of BIPV impact on energy demand of the demo sites. These simulations will be compared with real measurements collected within demonstration activities.

1.3 Reference material

D2.1 “Technical specifications for BIPV modules”, deliverable of the PVSITES project submitted at M06.

D8.1 “Energy audit of buildings and identification of BIPV possibilities in every demo site”, deliverable of the PVSITES project submitted at M15.

D8.3 “Design pack for every demo site”, deliverable of the PVSITES project, in preparation, to be submitted at M29.

D8.7 “Common monitoring guidelines”, deliverable of the PVSITES project submitted at M15.

D8.8 “Specific monitoring plan for every demo site”, deliverable of the PVSITES project submitted at M20.

D8.10 “Installation and execution of monitoring of the demo sites”, deliverable of the PVSITES project submitted at M27.

D8.2 “Result of modelling and BIPV strategies for every demo site”, deliverable of the PVSITES project, to be submitted at M28.

1.4 Abbreviation list

BCC:	Building Control Centre
BEMS	Building Energy Management System
BIPV:	Building-Integrated Photovoltaics
BMS:	Building Management System
CDD:	Cooling Degree Day
CIGS:	Copper Indium Gallium Selenide
DHW:	Domestic Hot Water
DOA:	Description Of Action
ECM:	Energy Conservation Measure
EHG:	Ecole Hôtelière de Genève
EV:	Electrical Vehicle
HDD:	Heating Degree Day
ICT:	Information and Communication Technologies
IPMVP:	International Performance Measurement and Verification Protocol
KPI:	Key Performance Indicators
M&V:	Measurement and Verification
PV:	Photovoltaics
WP:	Work Package

2 GENERAL METHODOLOGY USED FOR ANALYSING THE DATA MEASURED IN THE DEMONSTRATION SITES

This chapter presents the methodology that is applied to analyse the measured data collected in the pilot sites in agreement with the overall objectives of the monitoring activities within the PVSITES project which are the following:

- Assess the impact of BIPV technologies on the building performances
  - In terms of energy performances
  - In terms of indoor environmental conditions
- Assess the BIPV performance once integrated in the demo buildings meaning in real conditions.

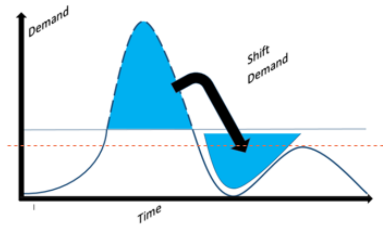
This methodology is based on several KPIs allowing an exhaustive understanding of the functioning, the energy performance and usages of the building.

2.1 General KPIs

First of all, general Key Performance Indicators (KPIs) are defined to provide an overall performance of the buildings in terms of energy consumptions and indoor environmental conditions. The analysis is first focused on heating consumption and indoor comfort conditions to assess the impact of BIPV inclusion as an envelope item of the building. Moreover, electricity consumptions and power demand profiles are also particularly investigated in order to analyse the possible self-consumption potential of the building. With such a purpose, the following table provides the main KPIs retained for the baseline analysis before installation of the BIPV systems:

Table 2.1 KPIs defined for the assessment of the baseline situation of the pilot sites in terms of energy performances and indoor environmental conditions

KPI	Short description	Unit	Comment
Yearly electricity consumption of the whole site	Global electricity consumption of the whole building for a full year	kWh kWh/m²	When possible, several years are considered for the annual consumption calculation (for instance from energy bills analysis). This provides the uncertainty interval associated to the measured value.
Yearly electricity consumption of specific zones defined for the considered pilot site	Global electricity consumption of one specific area or for one specific usage of the building for a full year.	kWh	
Yearly heating consumption	Global heating consumption of the whole building for a full year.	kWh kWh/m²	
Electricity consumption per usage (lighting, HVAC, …) or per submeter	Distribution of electricity consumption over the specific electricity usages (lighting, HVAC, appliances).	kWh	This information can be relevant for the BEMS and decision about self-consumption of the PV production.

KPI	Short description	Unit	Comment
Residual electricity consumptions	It corresponds to the lowest level of electricity consumption that may exist even when the building is unoccupied.	kWh	This KPI is calculated when period of inoccupancy can be identified or during the night.
Average daily electricity consumption	It corresponds to the mean value of electricity consumption per day	kWh/day	It can be provided according to the seasons.
Nightly and daily average power demand	It corresponds to the mean value of electricity power demand per day and per night	W/day W/night	
Peak Power demand	Maximum electricity power measured occurring mostly in day time.	W	Within an energy management approach, one objective may be to reduce the difference between both KPIs (peak shaving of electricity load) and also reduce the peak power demand. This objective may be targeted by the BEMS developed as part of the project. 
Minimum night time demand	Minimum electricity power measured during the night.		
Difference between peak power demand and minimum night time demand	Peak Power demand - Minimum night time demand. This indicator can be applied for establishing energy management strategies using BIPV with or without storage.		
Ratio Inoccupation (or night) consumption/Total consumption	Ratio between the total electricity consumption during inoccupation period (or night period) and total electricity consumption over studied period.	%	This KPI can be used for efficiency evaluation of building energy management
Rate of hours for which the indoor temperature is out of the comfort range	The comfort range is considered to be located between 18°C and 28°C. Beyond these limits, comfort conditions are not satisfied.	%	In addition to Brager index, this KPI provides a quantification of discomfort.

2.2 Analysis conducted in parallel

In parallel to the calculation of the KPIs previously defined, a deeper analysis is conducted on the collected data to highlight specific behaviour or consumption profile that could be relevant for the next steps of monitoring.

For instance, consumption profiles are plotted on daily, weekly, monthly and yearly basis in order to identify peak of consumption, residual electricity consumptions that could be relevant for the BEMS implementation.

Multiple levels of analysis are used: one-month to one-month comparison or season to season comparison but also typical days and weeks analysis (coldest[1] and warmest[2] weeks or days for instance) to highlight singular behaviour of the building or of the usages.

When possible and relevant, models have been established considering heating consumptions using HDD values (Heating Degree Days) as independent and main variable of the model (according to IPMVP approach [1] [2]). HDD measures how much (in degrees) and for how long (in days) outside air temperature is lower than a specific “base temperature”[3] (or “balance point”). Monthly HDD are calculated for the heating period using 18.5°C as base temperature. HDDs are used to adjust heating consumptions and make comparison with heating consumptions measured during other periods of time. Attached to this model, confidence indicators (for instance determination coefficient R^2) are also calculated to show the relevance and quality of the model for comparison purposes.

It should be noticed that in parallel to physical measurements conducted in the buildings, a specific follow-up towards the pilot managers is also achieved in order to identify any other change having occurred in the building in terms of energy usage, control settings parameters, occupancy rates energy tariffs etc… All these parameters constitute static parameters that may impact energy consumptions and that should be considered in specific adjustment for comparison with other period of time.

[1] Week during which the outdoor temperature is the lowest over the period considered.

[2] Week during which the outdoor temperature is the highest over the period considered.

[3] The reference temperature is known as base temperature and is defined as the outdoor temperature at which the heating (or cooling) systems in a building do not need to run to maintain comfort conditions.

3 BASELINE ASSESSMENT OF THE PILOT SITES

This chapter provides the main results obtained for all the pilot sites in terms of energy performances and indoor comfort conditions.

When possible, these measurements are correlated with simulation results provided in D8.2 “Result of modelling and BIPV strategies for every demo site” in order to identify if BIPV impact will be possible to measure.

3.1 DEMO 1 – Format D2 house (Stambruges, BELGIUM)

3.1.1 Reminder on data collected

Table 3.1 summarises the data collected in FD2 house during the baseline period. For this site, an exhaustive amount of data is available and allows comparing the energy consumptions collected since several years.

Table 3.1 Summary of the data collected for Pilot#1 for the baseline period

Data point	Physical correspondence	Units	Sample rate (min)	Data available from
Outdoor Temperature	Outdoor Temperature	°C	10	01/04/2017
Relative humidity outdoor	Outdoor relative humidity	%RH	10	01/04/2017
Atmospheric pressure	Atmospheric pressure	hPa	10	01/04/2017
Wind speed	Wind speed	m/s	10	01/04/2017
Wind direction	Wind direction	degrees	10	01/04/2017
Inclined global irradiation	Global non-corrected solar radiation in the plane of PV panels	W/m²	10	01/04/2017
Corrected inclined global irradiation	Global corrected solar radiation in the plane of PV panels	W/m²	10	01/04/2017
Pyranometer temperature	Outdoor temperature measured by pyranometer in the plane of PV panels	°C	10	01/04/2017
Domestic hot water power and energy consumption	Domestic hot water system electricity consumption	W, Wh	10	01/01/2016
Heater power and energy consumption	Heater electricity consumption	W, Wh	10	01/01/2016

Data point	Physical correspondence	Units	Sample rate (min)	Data available from
Lighting system power and energy consumption	Total lighting electricity consumption of the house	W, Wh	10	01/01/2016
Ventilation system power and energy consumption	Ventilation system electricity consumption	W, Wh	10	01/01/2016
Appliances power and energy consumption	Appliances electricity consumption	W, Wh	10	01/01/2016
Thermal power and energy for domestic hot water	Thermal energy	W, Wh	10	01/01/2016
Wood consumption for heating	Wood consumed for the heating of the house	Kg, kWh	1 month	01/01/2016
Temperature and relative humidity	Temperature and relative humidity in 8 rooms of the building	°C, %RH	10	11/01/2016
General electricity consumption	General electricity consumption of the whole building	kWh	10	02/02/2018

The surface considered for the KPI calculation is the gross conditioned surface equal to 278 m² for the FD2 house.

3.1.2 Energy consumption analysis

The following table summarises the global annual energy consumptions associated with heating and electricity. The yearly electricity consumptions of the whole house show a slight decrease for 2017 in comparison to 2016. Despite a lower value of yearly HDD in 2017, the electricity consumption associated with the radiators shows an increase between 2016 and 2017.

Table 3.2 Summary of yearly energy consumptions of the house

FD2	Annual electricity consumptions (kWh)	Annual electricity consumption for electric heater (kWh)	Energy / HDD	Annual heating consumptions (Wood) (kWh)	Energy / HDD
2016	6821.3	296 [3532 HDD]	0.084	3160.6 [3532 HDD]	0.895
2017	6591.9	422.6 [2761 HDD]	0.153	3025.8 [2761 HDD]	1.096
Evolution	-3.4 %	+82.7 % (Energy / HDD)		+22.5 (Energy / HDD)	

3.1.2.1 *Analysis of electricity consumptions*

The following figures display the distribution of electricity consumption over the different electricity usages of the house. Appliances represent the largest share of the electricity consumptions (75%) followed by the DHW production (10-12%).

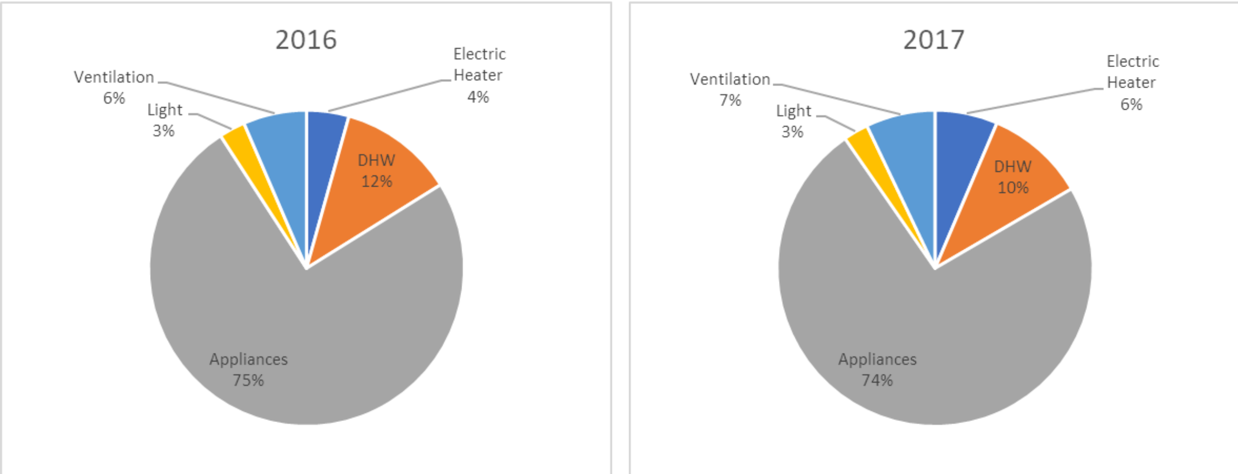


Figure 3.1 Distribution of electricity consumptions over the different usages of the house for 2016 and 2017

Figure 3.2 shows the average daily electricity consumptions for 2016 and 2017. Slightly higher electricity consumptions are observed for the week-ends and are probably due to the occupation rate that may be higher. Moreover, consumptions are also higher for the winter season probably because of lighting and heater consumptions.

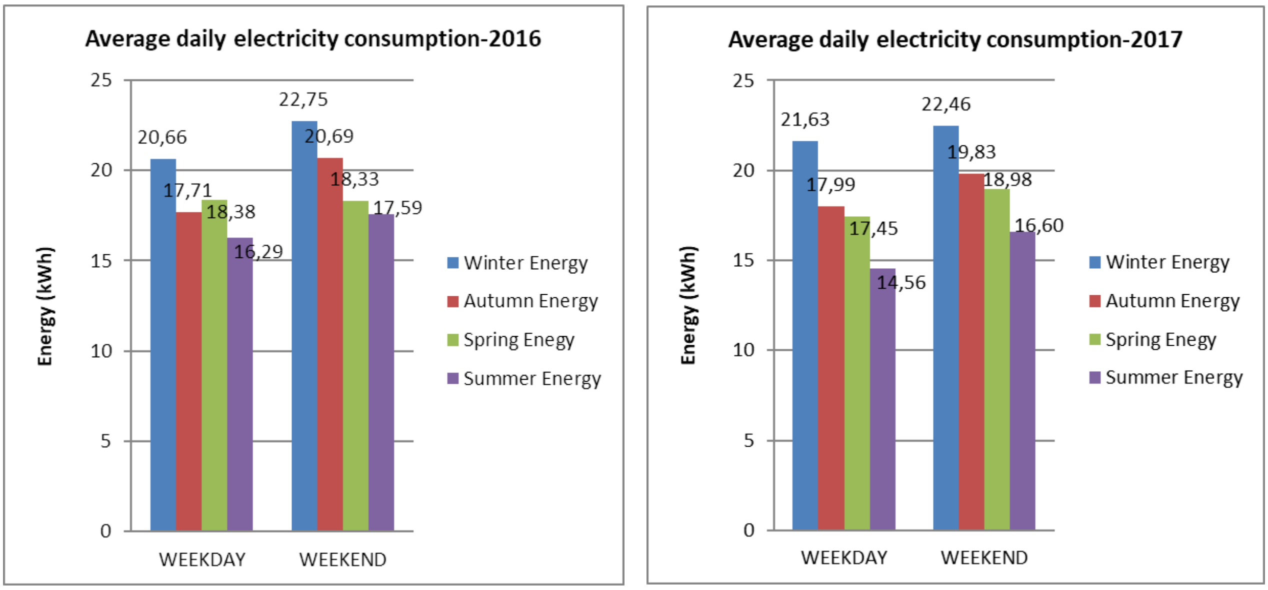


Figure 3.2 Average daily electricity consumption for the different seasons for 2016 and 2017

Based on the analysis of global electricity power demand of the house represented on Figure 3.3, a minimum level of power demand has been identified. It is present even when the house is unoccupied and can be associated with continuous consumption such as ventilation system and electrical appliances (fridge and freezer). The minimum night time demand is 80 W.

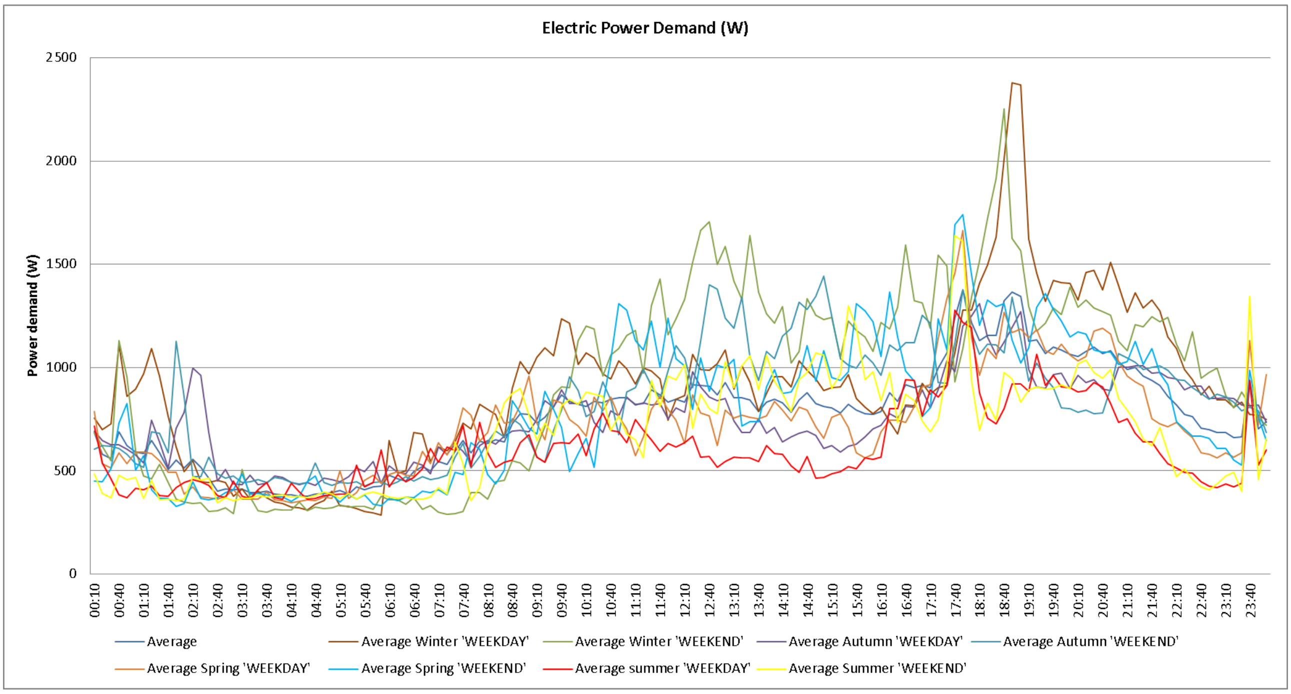


Figure 3.3 Average electricity power demand for different days and seasons

Figure 3.4 and Figure 3.5 show the average power demand respectively for daily and nightly periods. As already pointed out, power demand is slightly higher for 2016 than for 2017. The average nightly power demand shows a minimum value around 400W (this may correspond to the fridge and ventilation system power demand).

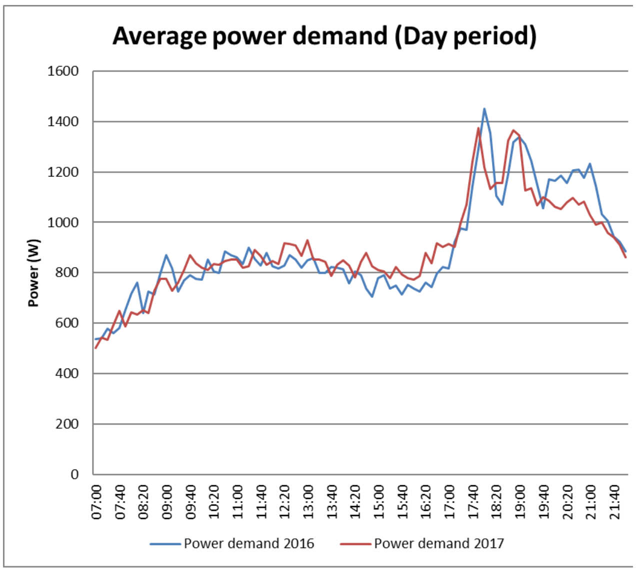


Figure 3.4 Average daily power demand

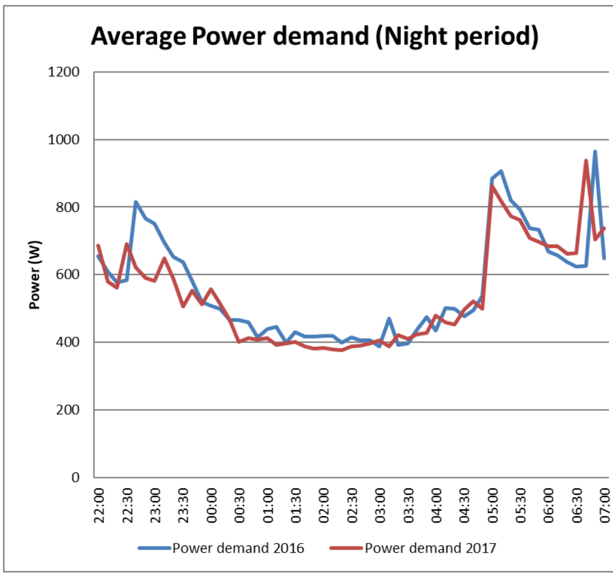


Figure 3.5 Average nightly power demand

The peak power demand of the whole house reached 8150W on the 14th of March 2017. The difference between this value and minimum night time demand is equal to 8070 W.

The electricity consumption during the night (between 22:00 and 7:00) represents 26% of the total electricity consumption measured for the full year 2017.

3.1.2.2 Analysis of heating consumptions

The following figure displays the daily electricity consumption of the electrical radiators which are used for office and bathrooms of the house. These consumptions are concentrated on the period between October up to end of March. This allows selecting the periods over which the model can be built.

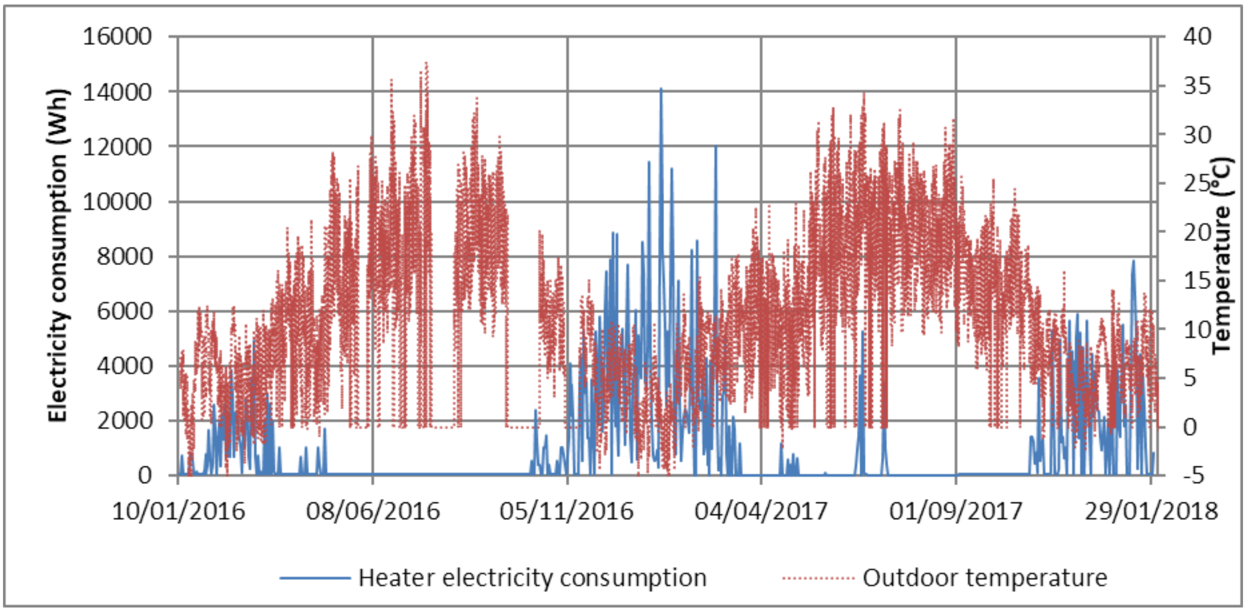


Figure 3.6 Evolution of daily electricity consumption of the heater (blue line) and outdoor temperature (red line) over 2 cold periods 2016-2017 and 2017-2018

Figure 3.7 displays the monthly heating consumptions (only electricity based, wood consumptions are considered separately) versus HDD. The model established on the basis of these data will be used to make a rigorous adjustment to the climate conditions and allow comparison with the reporting period. The determination coefficient greater than 0,8 indicates a good quality of prediction with this model.

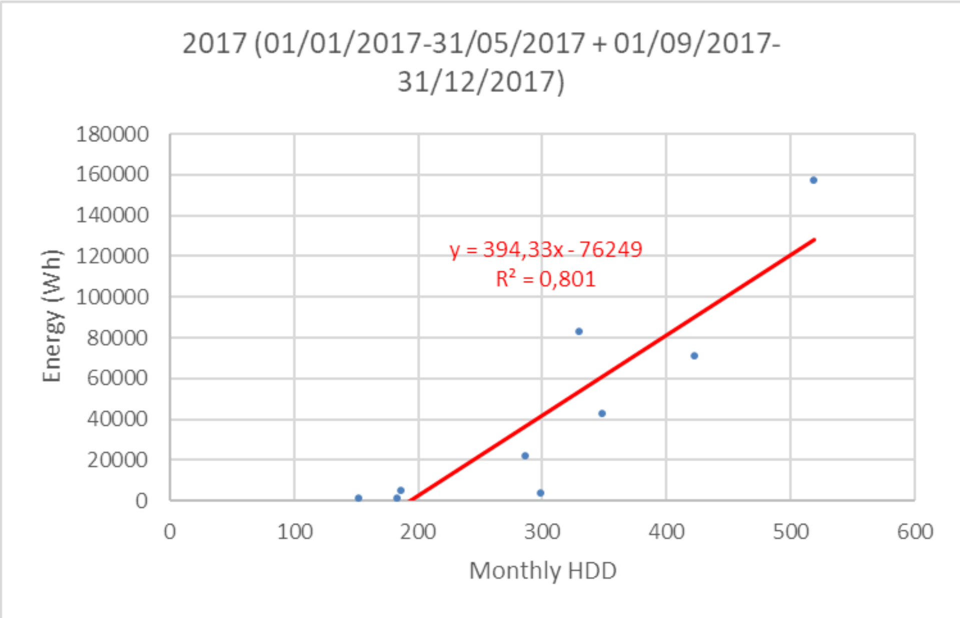


Figure 3.7 Electricity consumption of the heater versus HDD

Table 3.3 provides wood consumptions of the house collected so far. Wood is used for the fire place of the house. The wood used is beech having a heating value of 4 kWh/kg. The efficiency of the fire place is about 83%. So, 1 kg of wood corresponds to 3,32 kWh of heating energy.

Table 3.3 Wood consumption used for heating

	Wood consumption (kg)			Wood consumption (kWh)		
	2016	2017	2018	2016	2017	2018
Jan	200	288.8	135	664	958.8	448.2
Feb	200	142	130	664	471.4	431.6
March	120	85.6	110	398.4	284.2	365.2
Apr	0	0		0	0	
May	0	0		0	0	
June	0	0		0	0	
July	0	0		0	0	
Aug	0	0		0	0	
Sept	0	0		0	0	
Oct	34	50		112.9	166	
Nov	167.5	110		556.1	365.2	
Dec	230.5	235		765.26	780.2	
Total for one year	952	911.4	--	3160.7	3025.8	--
		Ratio Energy / HDD		0.895	1.096	1.026

A model has been built with the wood consumptions as well and is displayed in Figure 3.8. The determination coefficient R^2 is greater than 0.9 meaning that the model is really good and that more than 92% of the heating consumption variations can be explained by HDD variations.

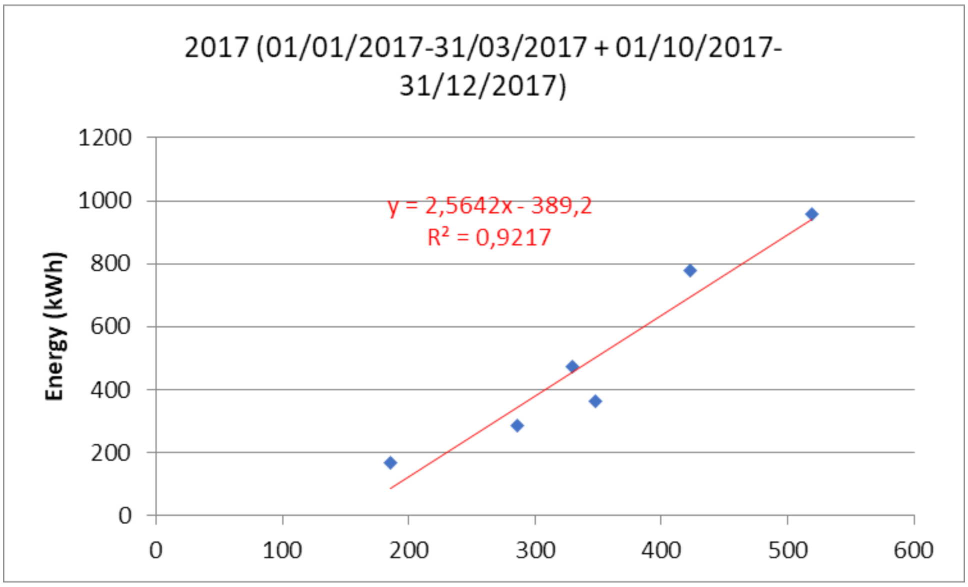


Figure 3.8 Wood consumption versus HDD

The simulations conducted previously revealed that the BIPV installation does not affect the overall building heat needs. The difference of energy needs between the actual house and the building equipped with FLISOM products is less than 0.4%. This is negligible regarding the other approximations made for the simulations and this will be very difficult to show through the measurements in the real demonstration site.

3.1.3 Indoor comfort conditions analysis

Figure 3.9 shows the evolution of indoor temperature in the different rooms of the house in comparison to the outdoor temperature. This allows to identify the coldest and warmest periods and to focus the analysis on these specific periods to illustrate the thermal behaviour of the house.

Figure 3.10 and Figure 3.11 focus respectively on the warmest and coldest periods. A singular behavior is observed for the living-room during summer. Its temperature follows the outdoor temperature whereas bedroom and kitchen temperatures remain below 25°C. For winter period, the effect of the fire place is observed on Figure 3.11 for the rooms located on the ground floor (kitchen and living-room) whereas for the bedroom located on the first floor, the temperature remains stable.

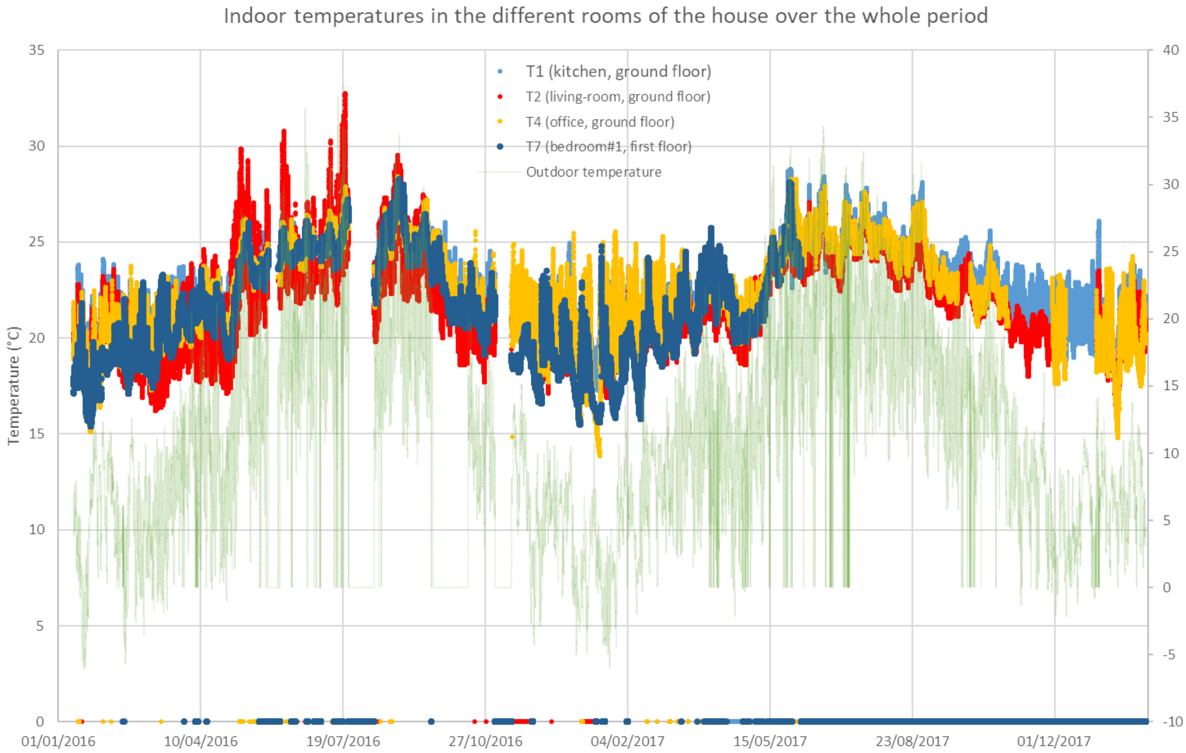


Figure 3.9 Indoor temperatures evolution in the different rooms of the house and outdoor temperature

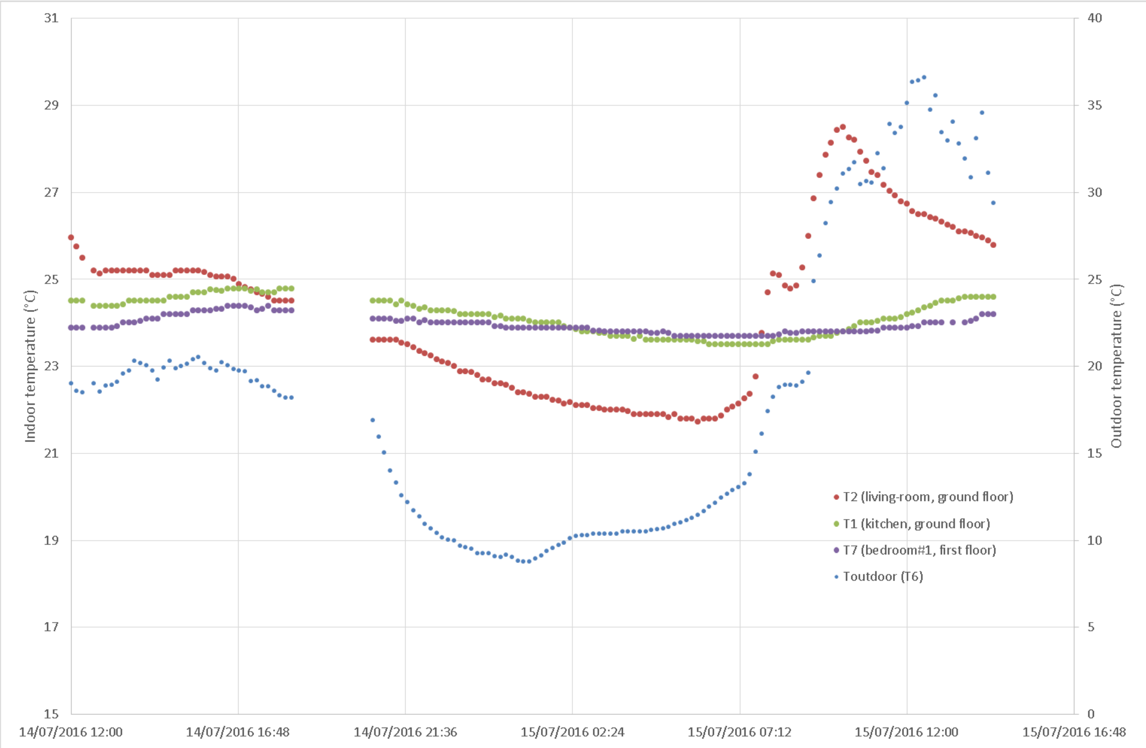


Figure 3.10 Indoor temperatures evolution and outdoor temperature during the warmest period of 2016

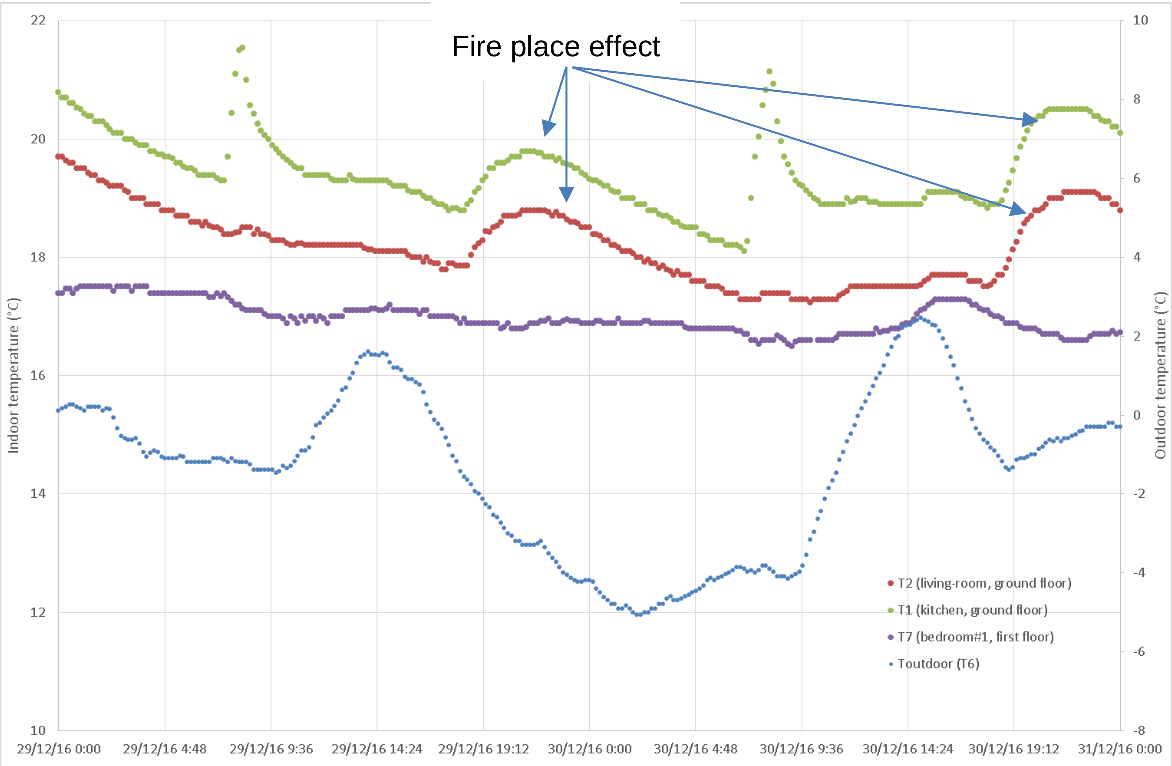


Figure 3.11 Indoor temperatures evolution and outdoor temperature during the coldest period of 2016

In order to get an objective evaluation of the comfort level in the house, the Brager index is calculated and displayed in Figure 3.12 and Figure 3.13 respectively for winter period and summer period for the T2 sensor located in the living room (ground floor). These graphs show that comfort conditions are met most of the time and no overheating is observed neither under temperature conditions. The Brager graphs for the other rooms of the house are provided in annex 1 (paragraph 6.1).

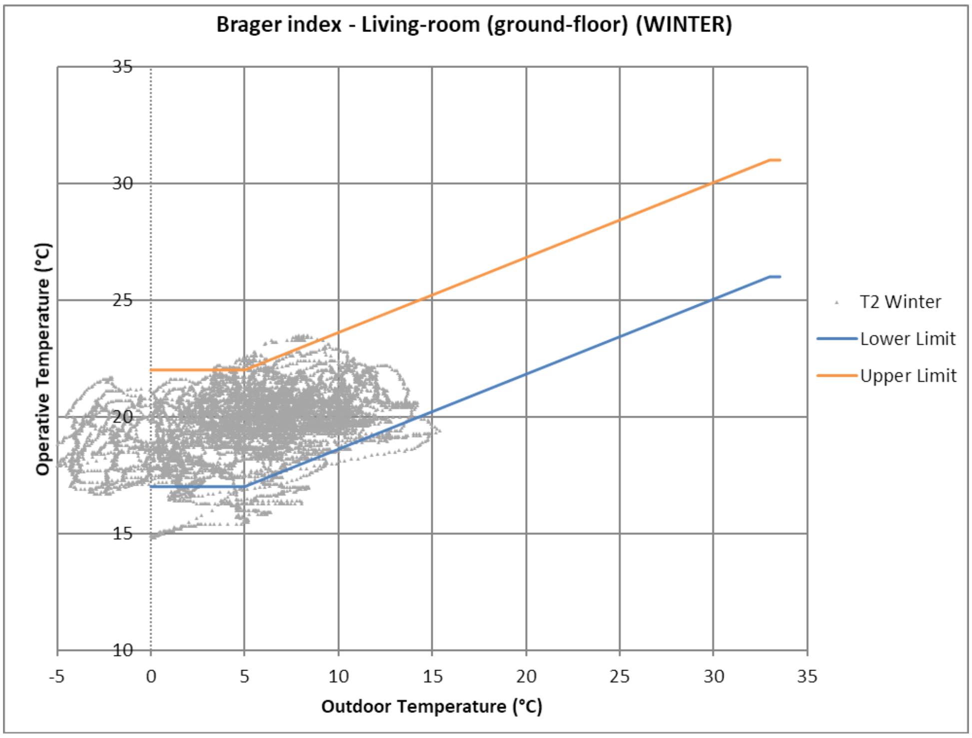


Figure 3.12 Comfort rating according to Brager index (Winter)

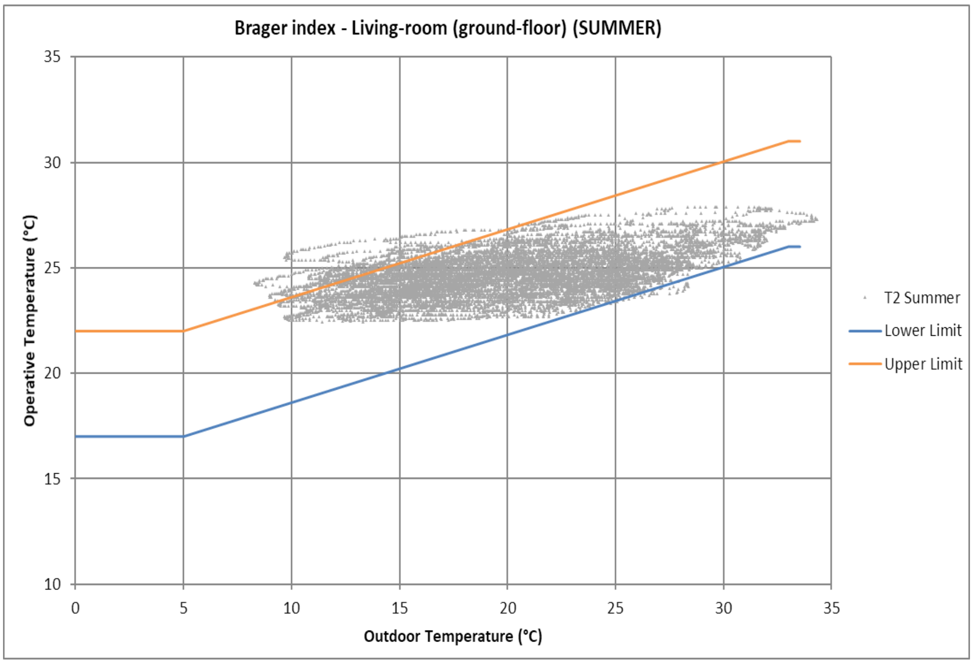


Figure 3.13 Comfort rating according to Brager index (Summer)

Table 3.4 and Table 3.5 show the indoor temperature distribution over different temperature ranges respectively for winter period and summer period for all the temperature sensors.

For winter period, most of the indoor temperatures remain in the comfort zone. The T5 and T9 sensors respectively located on the first floor in the bathroom and second floor in the bedroom show low temperature (lower than 18°C) more than 50% of the time. During the baseline period, a problem has occurred with T7 sensor that showed misfunctioning around beginning of June. This sensor has been replaced by the T8 sensor. Therefore, the overheating observed on this T8 sensor may be probably explained by the indoor conditions of this bedroom which are considerably altered by internal gains produced by a computer and the fact that this room has only one leakage wall.

For summer period, indoor temperatures are most of the time within the comfort range. However, the laundry room shows high temperature especially during summer period and this phenomenon can be explained by the presence of equipment such as fridge, freezer, wine cellar, tumble dryer, server, boiler that may release a lot of heat. During the night, this room is refreshed because the heat pump takes the calories in this room. After BIPV installation, this phenomenon will happen during the day and not during the night as it is now.

Table 3.4 Indoor temperature distribution over the different temperature ranges for winter period

	Indoor temperature distribution over the different temperature ranges for winter period (°C)				
Sensors (location)	**T≤16**	**16<T≤18**	**18<T≤20**	**20≤T≤22**	**22<T**
T1 (kitchen, ground floor)	0,5%	4,9%	27,9%	53,8%	12,9%
T2 (living-room, ground floor)	1,4%	13%	43,9%	38,7%	3%
T3 (laundry room, ground floor)	3,7%	22,2%	50,4%	18,7%	5%
T4 (office, ground floor)	4,8%	12,2%	42,5%	29,6%	10,9%
T5 (bathroom, first floor)	14,8%	38,4%	43,4%	3,4%	0%
T7 (bedroom#1, first floor)[4]	7,2%	35,2%	42,6%	14,1%	0,9%
T8 (storage room, first floor)	0%	3,8%	20,3%	49,3%	26,6%
T9 (bedroom#2, first floor)	14,7%	47,4%	37,5%	0,4%	0%

[4] It should be noted that sensor #7 is not functioning since 06/06/2017.

Table 3.5 Indoor temperature distribution over the different temperature ranges for summer period

	Indoor temperature distribution over the different temperature ranges for summer period (°C)					
Sensors (location)	**18<T<=20**	**20<T<=22**	**22<T<=24**	**24<T<=26**	**26<T<=28**	**T>28**
T1 (kitchen, ground floor)	0%	0%	11,1%	64,9%	23,8%	0,3%
T2 (living-room, ground floor)	0%	0%	28,3%	60,2%	11,6%	0%
T3 (laundry room, ground floor)	0%	0,4%	8,4%	32,4%	42,7%	16,1%
T4 (office, ground floor)	0%	0%	7%	72,6%	20,4%	0,1%
T5 (bathroom, first floor)	0%	6,3%	30,1%	53,1%	10,4%	0%
T7 (bedroom#1, first floor)	0%	0%	33,7%	66,3%	0%	0%
T8 (storage room, first floor)	0%	0%	6,4%	63,3%	24,4%	5,8%
T9 (bedroom#2, first floor)	0%	0%	16,7%	73%	9,9%	0,3%

The simulations performed for this pilot site revealed that there may be no impact on the rooms located on the ground floor of the house in terms of temperature evolution further to the BIPV systems installation. Nevertheless, for the rooms located on the first floor (especially bedrooms 1 and 2), 35% and 26% of evolution on the Givoni indicator have been observed with a maximum difference on temperature of about 0.17°C. The temperature evolution of these rooms will be specifically analysed after BIPV installation in order to detect any impact on their thermal behaviour. Nevertheless, the theoretical evolution calculated through simulation which is very low leads to think that no noticeable evolution will be highlighted during the demonstration.

3.2 Demo 2 – EHG (Genève, SWITZERLAND)

3.2.1 Reminder on data collected

Table 3.6 summarises the data collected in EHG buildings during the baseline period.

It should be noticed that some issues were encountered with the weather station installation and that no data are available from this sensor. An alternative solution has been identified and consists in extracting the outdoor temperature from the pyranometer.

Table 3.6 Summary of the data collected for Pilot#2 for the baseline period

Data point	Physical correspondence	Units	Sample rate (min)	Data available from
Outdoor Temperature	Outdoor Temperature	°C	10	No data
Relative humidity outdoor	Outdoor relative humidity	%RH	10	No data
Atmospheric pressure	Atmospheric pressure	hPa	10	No data
Wind speed	Wind speed	m/s	10	08/07/2017
Wind direction	Wind direction	degrees	10	08/07/2017
Inclined global irradiation	Global non-corrected solar radiation in the plane of PV panels on Pavilion 2	W/m^2	10	30/06/2017
Corrected inclined global irradiation	Global corrected solar radiation in the plane of PV panels on Pavilion 2	W/m^2	10	30/06/2017
Pyranometer temperature	Outdoor temperature measured by pyranometer in the plane of PV panels on Pavilion 2	°C	10	30/06/2017
Inclined global irradiation	Global non-corrected solar radiation in the plane of PV panels on Pavilion 1	W/m^2	10	18/01/2018
Corrected inclined global irradiation	Global corrected solar radiation in the plane of PV panels on Pavilion 1	W/m^2	10	18/01/2018
Pyranometer temperature	Outdoor temperature measured by pyranometer in the plane of PV panels on Pavilion 1	°C	10	18/01/2018
Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions in classroom Salève, Pavilion 1	°C	15	30/06/2017

Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions in classroom Bellevue, Pavilion 2	°C	10	18/01/2018
Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions in classroom Carlton, Pavilion 2	°C	10	18/01/2018
Wall surface temperature Pavilion 1	Wall surface temperature in classroom Salève, Pavilion 1	°C	10	18/01/2018
Wall surface temperature Pavilion 2	Wall surface temperature in one classroom in Pavilion 2	°C	10	18/01/2018
General electricity consumption	Electricity consumption of the whole EHG demo site	kWh	15	01/01/2016
General gas consumption	Gas consumption for heating and cooking for the whole EHG demo site	kWh	Monthly	01/01/2016

3.2.2 Energy consumption analysis

Table 3.7 provides the yearly consumptions for electricity and for gas used for heating for the whole site.

The annual electricity consumptions seem almost constant between 2016 and 2017 whereas annual gas consumptions show a strong decrease between 2016 and 2017. This decrease can be explained by the change of boilers that took place in 2016.

Table 3.7 Summary of yearly energy consumptions of the EHG demo site

	Annual electricity consumptions (MWh)	Annual gas consumption (MWh)	Annual gas consumption for heating (MWh)	HDD	Annual gas consumption / HDD (MWh)
2016	363.8	623.6	564.3	2755.2	0.266
2017	342.1	497.2	420.7	2801.7[5]	0.177
Evolution between 2016 and 2017	-5.9%	--		--	-33%

[5] Due to problems with weather conditions measurement on EHG demonstration site, the data from different sources (pyranometer temperature and external source) have been used as reference for outdoor weather conditions. For HDD data, the source used is: https://www.infoclimat.fr/climatologie/annee/2017/geneve-cointrin/valeurs/06700.html.

3.2.2.1 Analysis of electricity consumptions

The following figure displays the average daily electricity consumption of the whole EHG demonstration site. In line with the occupancy of the site, consumptions are higher during the week days but are still important during the week-ends (about 50%). Electricity consumptions seem almost stable for the four seasons.

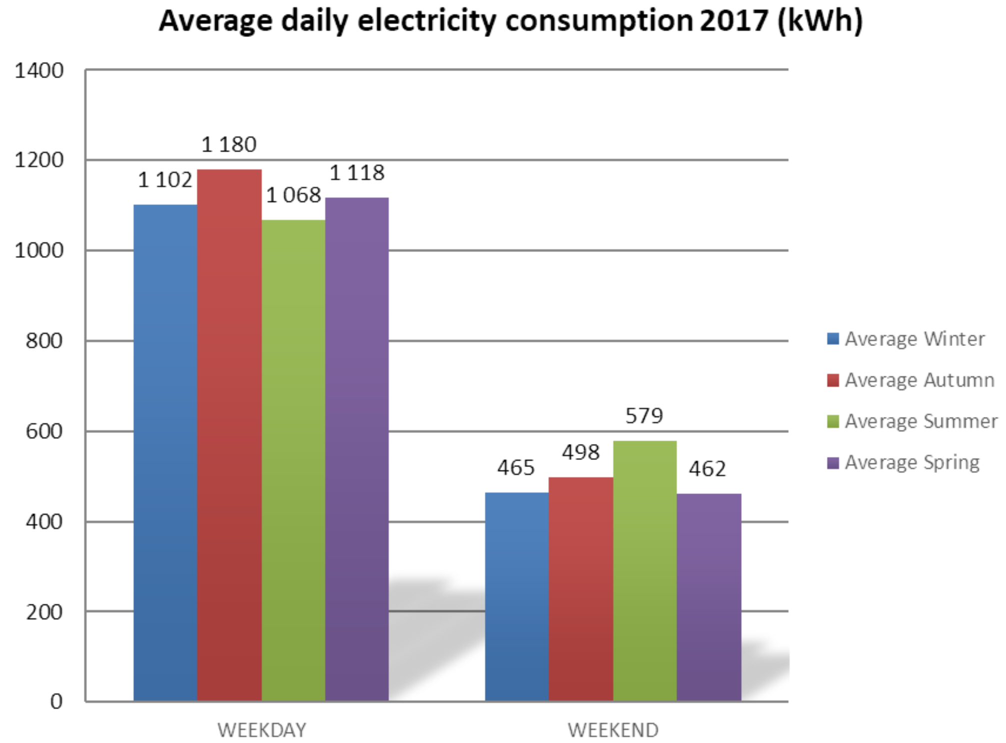


Figure 3.14 Average daily electricity consumption

The daily power demand profiles shown in Figure 3.15 reveals a common shape for the week days whatever the season with a lower demand identified around noon.

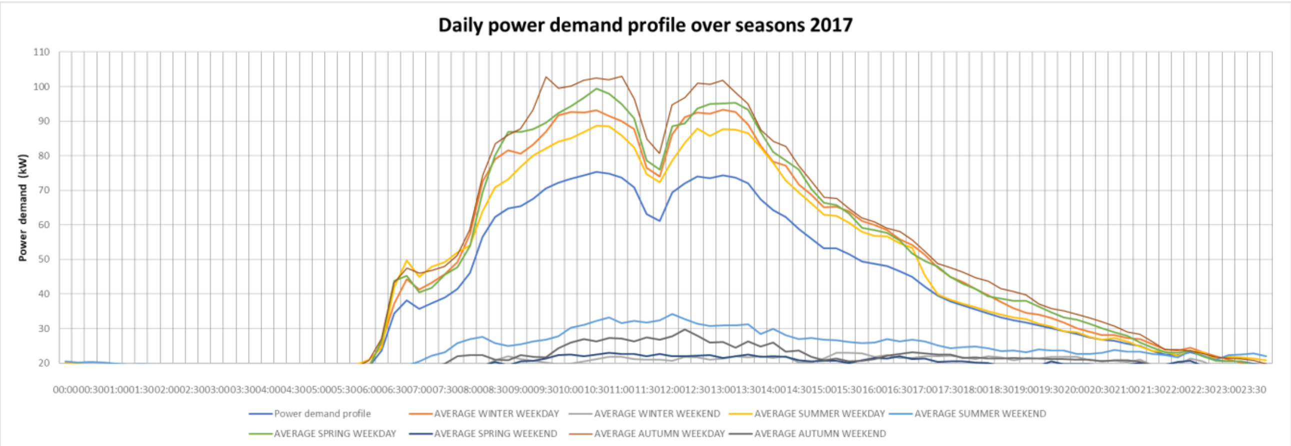


Figure 3.15 Average daily profile of power demand

The electricity consumption during the night (between 22:00 and 7:00) represents 18,9% of total electricity consumption 2017.

Figure 3.16 and Figure 3.17 show the average power demand profiles during the day and during the night (without occupation). A base power demand is observed around 20kW corresponding to permanent electricity consumptions of the whole site.

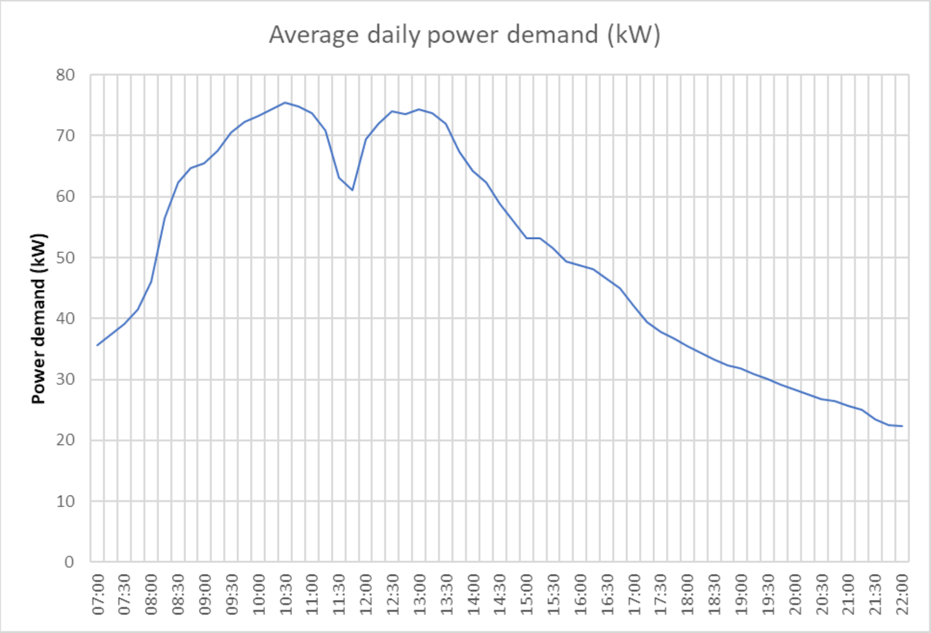


Figure 3.16 Average daily power demand

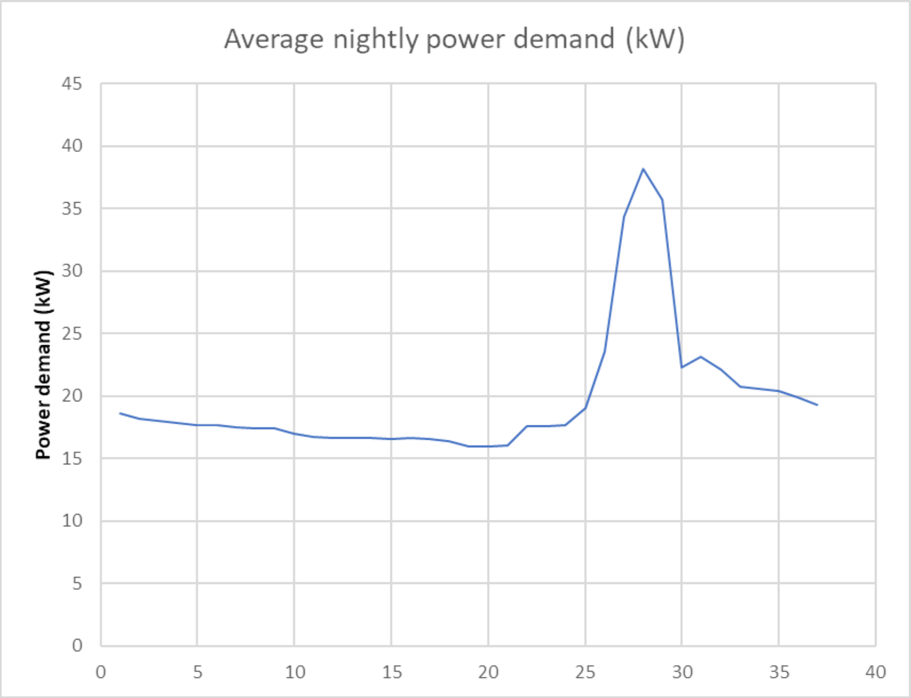


Figure 3.17 Average nightly power demand

Peak power demand over 15 min is equal to 141 kW, and minimum night time power demand is equal to 10.4 kW. These indicators can be applied for establishing energy management strategies using BIPV with or without storage.

3.2.2.2 Analysis of heating consumptions

Figure 3.18 shows the monthly heating gas consumptions evolution of the whole site.

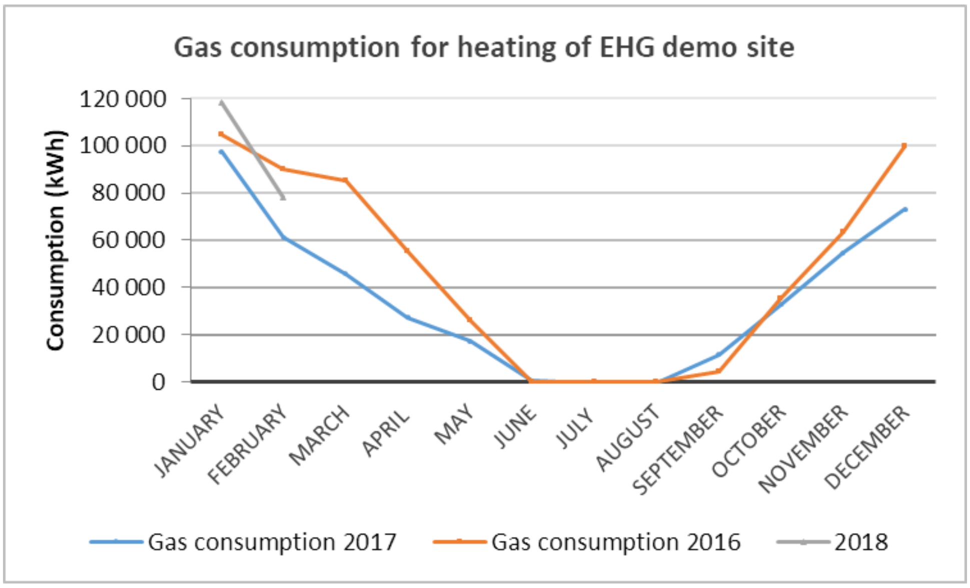


Figure 3.18 Evolution of monthly gas consumption used for heating during 2016 and 2017

A model has been established on the basis of monthly gas consumptions and corresponding HDD for the full year 2017 (considering heating period in 2017). The determination coefficient R^2 is greater than 0.95 meaning that the model is very good and that predictions will be accurate using this model. Nevertheless, at the beginning of 2018, a singular high value has been observed for gas consumption despite the HDDs were lower in comparison to the other years. This will be further investigated in order to provide an explanation (static parameter evolution?) and maybe apply a specific adjustment.

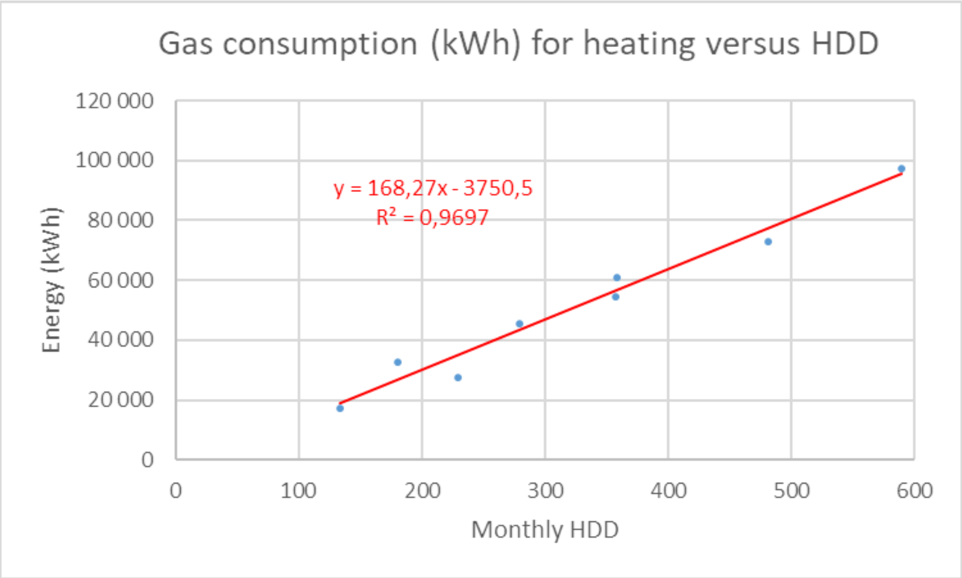


Figure 3.19 Monthly heating consumption versus HDD

It should be noticed that simulations revealed that BIPV installation does not affect the overall building heat needs. The difference of energy needs between the buildings performance and the buildings equipped with FLISOM products is around 1%. This is negligible regarding the other approximations made for simulations. This also highlights the fact that it will be difficult to show any evolution through measurement between both situations (before and after BIPV installation).

3.2.3 Indoor comfort conditions analysis

The following graph shows the evolution of indoor temperature in 2 classrooms of Pavilion 2 and 1 classroom of Pavilion 1. During winter period, the indoor temperature remains around 20°C thanks to regulation system. During summer period, indoor temperature can reach 30°C but the impact is low as the site is supposed to be unoccupied during this period.

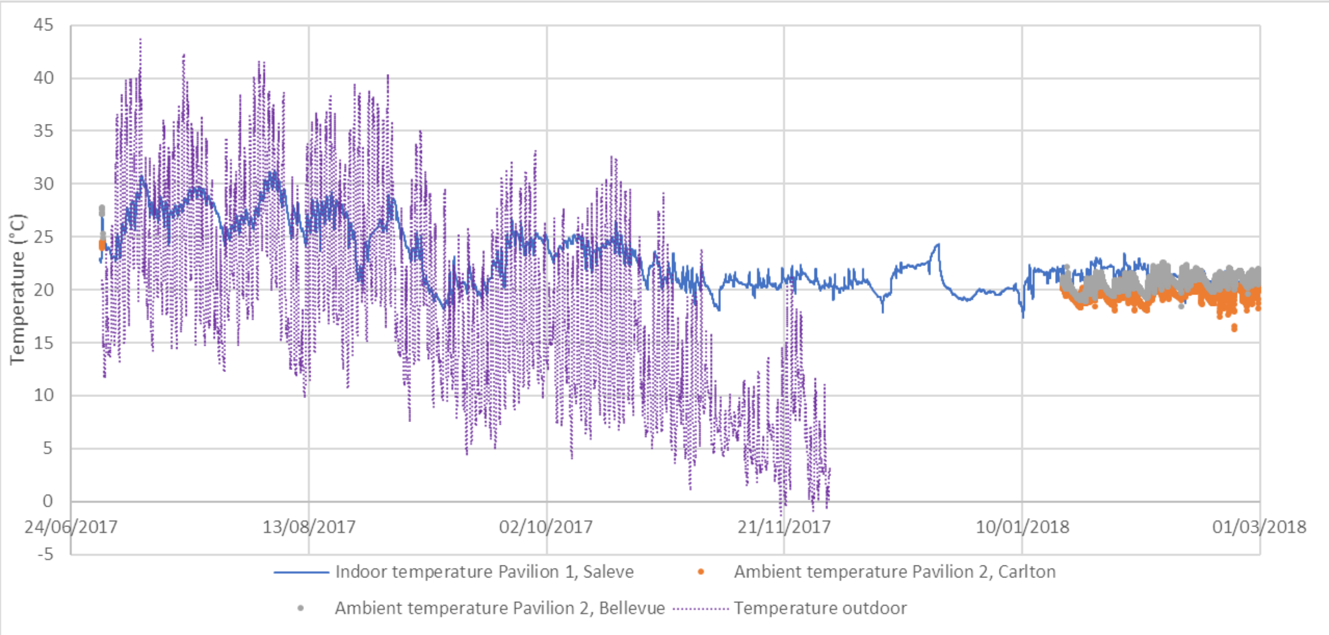


Figure 3.20 Indoor temperatures evolution in the different rooms of Pavilions 1 and 2

The two following figures focuses on the thermal behaviour of the rooms monitored respectively for warmest and coldest periods of 2017. A certain inertia of the building can be observed on Figure 3.21 during summer period whereas for winter period, the temperature regulation ensures an indoor temperature stability around 20-21°C.

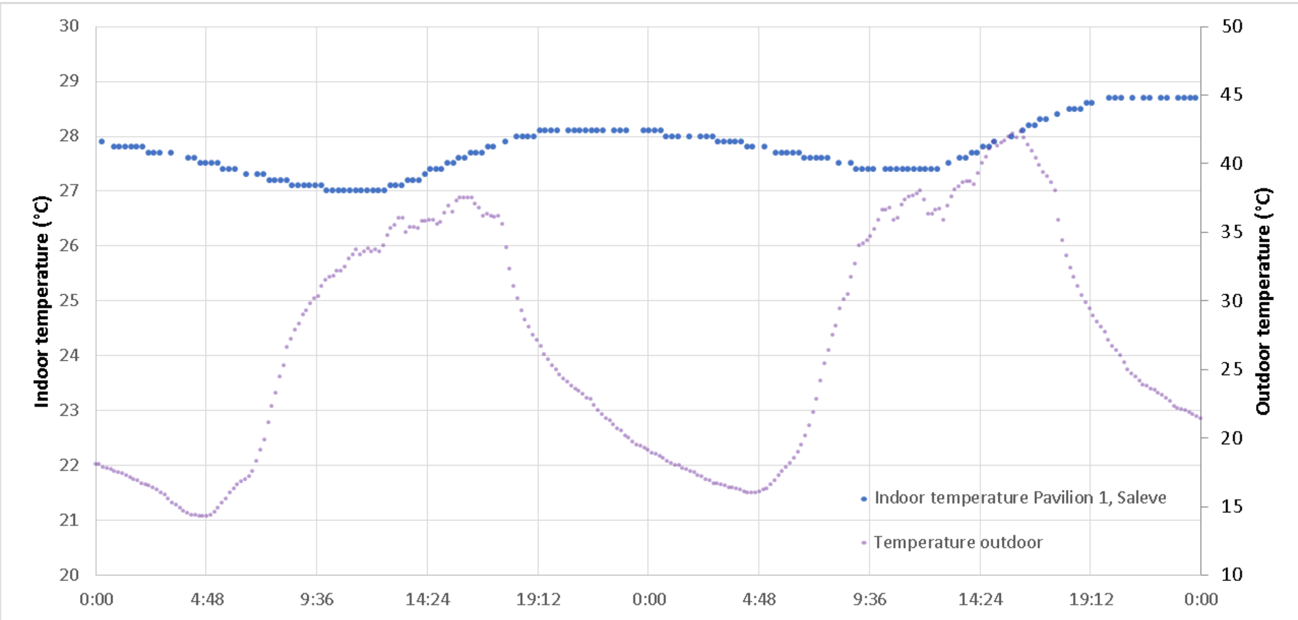


Figure 3.21 Indoor temperatures evolution during the warmest period

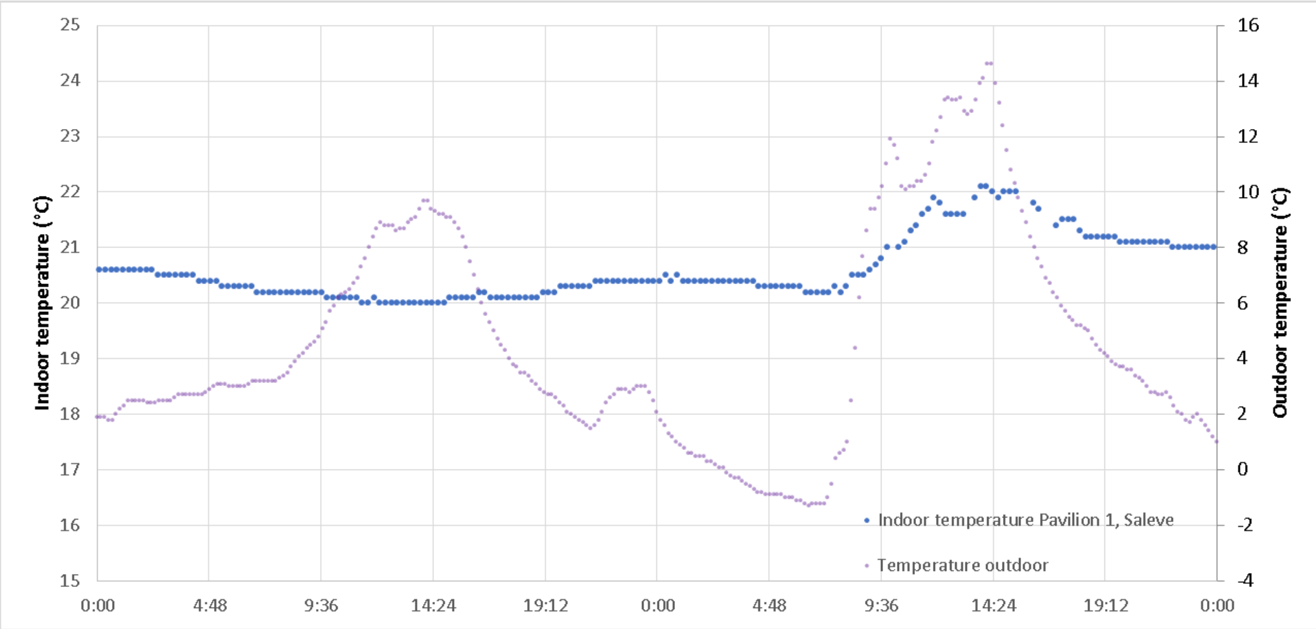


Figure 3.22 Indoor temperatures evolution during the coldest period

In order to get an objective evaluation of the comfort level into the classrooms of Pavilions 1 and 2, the Brager index is calculated and displayed in Figure 3.23 and Figure 3.24 respectively for winter period and autumn period for sensor 2814 (the graphs associated with the other sensors are provided in annex 2 (paragraph 6.2)). These graphs show that ambient conditions into the classrooms are well regulated during winter. For summer period, overheating can be observed a small portion of time but the impact is low as the site is supposed to be unoccupied during this period.

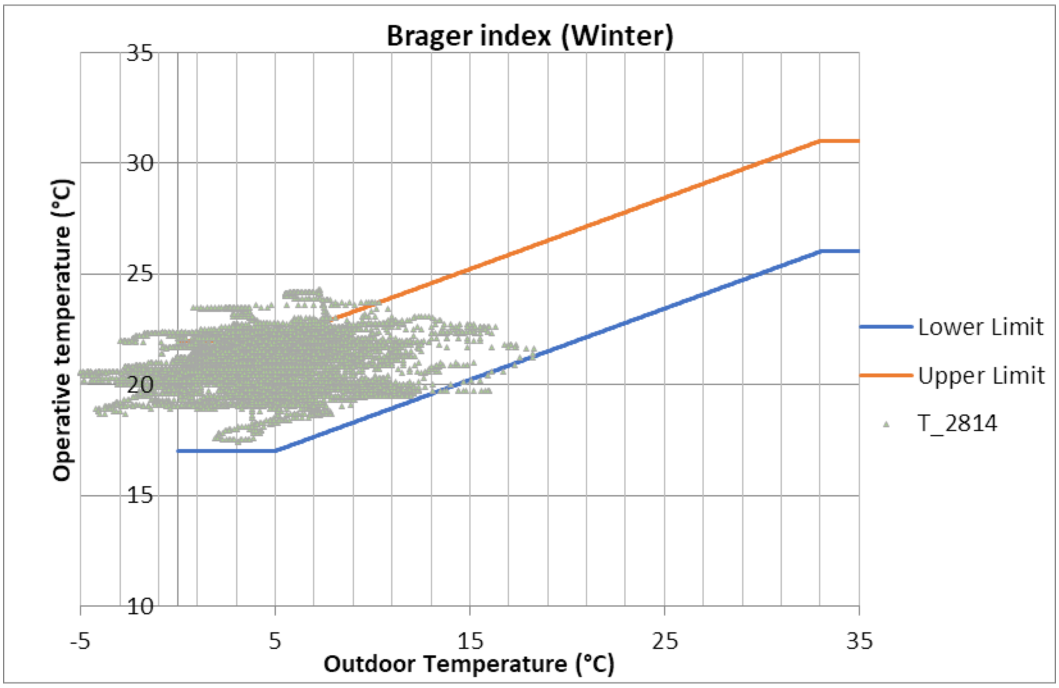


Figure 3.23 Comfort rating according to Brager index (Winter) – T2814 (Pavilion 1 Classroom Saleve)

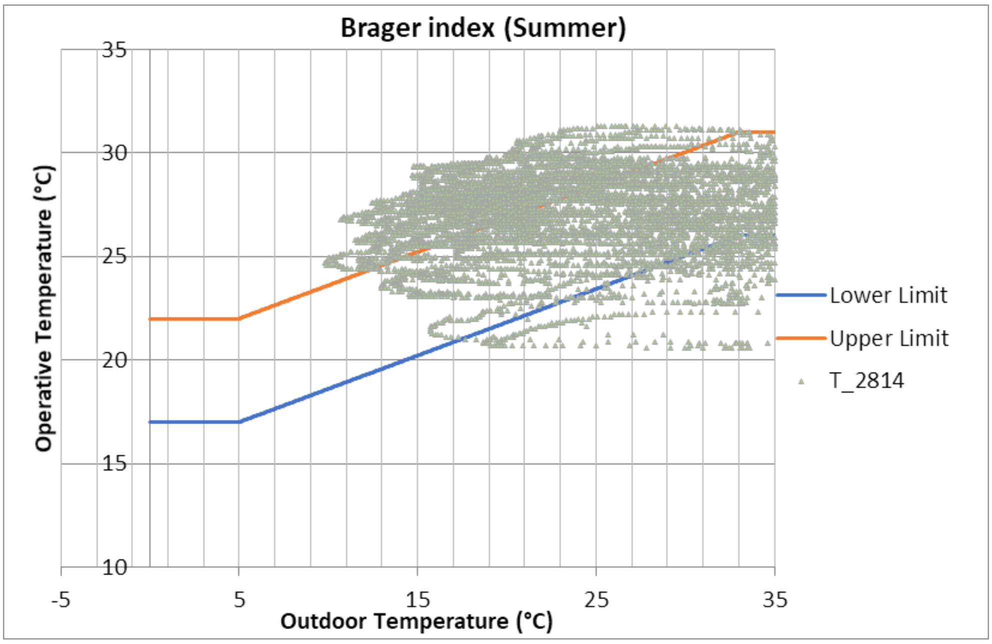


Figure 3.24 Comfort rating according to Brager index (Summer)

Table 3.8 and Table 3.9 show the indoor temperature distribution over different temperature ranges respectively for winter period and summer period. For winter period, most of the indoor temperatures remain in the comfort zone. For summer period, it can be noted that during 30% of time the ambient temperature in Saleve classroom is out of the comfort range.

Table 3.8 Indoor temperature distribution over the different temperature ranges for winter period

Sensors	T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T
Pavilion 1, classroom Saleve	0.6%	29.5%	47.8%	21%	1.1%	0%
Pavilion 2, classroom Carlton	0.1%	76%	20.3%	0%	3.7%	0%
Pavilion 2, classroom Bellevue	0%	41.1%	55.2%	0.1%	3.7%	0%

Table 3.9 Indoor temperature distribution over the different temperature ranges for summer period

Sensors	T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
Pavilion 1, classroom Saleve	0%	0%	1.9%	6.1%	22.5%	37.7%	31.7%

The previous simulations conducted within Task 8.1 “Design of demonstration installations” revealed that for the classrooms, the number of hours the indoor conditions overshoot Givoni first envelope doesn’t increase by more than 4% between both situations (with and without BIPV systems). Moreover, maximum temperatures in these rooms do not increase by more than 0.24°C. These temperature variations are too low to have a noticeable impact on comfort; so according to these simulations, the solar installation will have a negligible impact on the building thermal comfort conditions. So according to these simulation results, we should not be able to highlight any evolution through measurement either.

3.3 Demo 3 – Carport at EMPA facilities (Dübendorf, Switzerland)

Concerning the pilot site#3, the carport initially planned for the demonstration has been replaced by two alternative carports:

- The first one is a new carport built at EMPA facilities,
- The second one is new a carport built at EKZ facilities (EKZ is the local electricity provider for the Zürich canton).

For both carports, there is no power demand directly associated to the carport performance, because it is not illuminated nor has any other permanent power load. As a consequence, no monitoring device has been installed on this pilot site to measure energy consumption.

So far, for EKZ carport, weather conditions (outdoor temperature, wind direction and wind speed) and solar radiation data have been collected from the monitoring devices already present on site. Figure 3.25 displays the outdoor temperature and solar radiation measured in EKZ carport site.

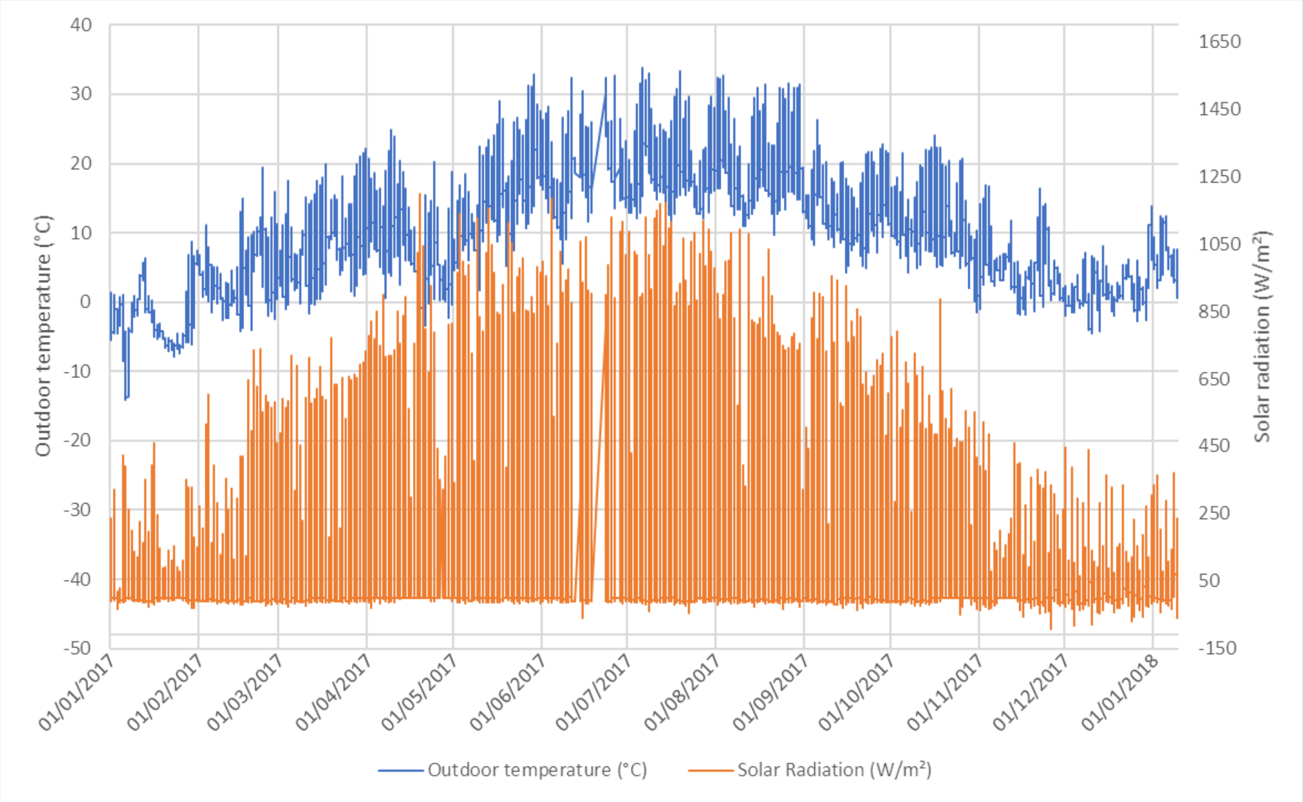


Figure 3.25 Outdoor temperature and solar radiation in EKZ carport site (2017)

For EMPA carport, it was initially planned to match the PV production to the EV charger present on site. Therefore, an analysis has been conducted on the EV charger data made available by the EMPA teams. Figure 3.26 below displays the electricity load profile of the EV charger for the period from 05/12/2017 to 22/01/2018. This figure shows that the load of the EV charger is very low and very punctual. Such a load profile is not sufficient for self-consumption of the BIPV production. This result may affect the virtual use case envisioned for the BEMS on this site that is based on the use of the EV charger as a virtual consumer of the electricity produced by the BIPV system installed on the carport at EMPA facilities.

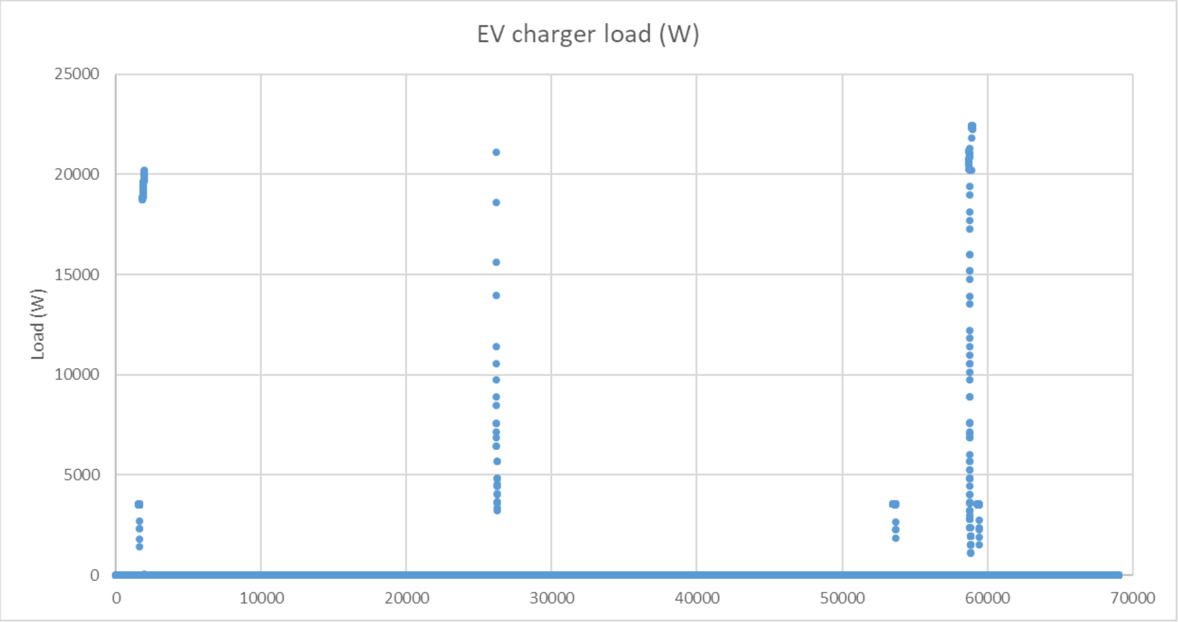


Figure 3.26 Load of the EV charger measured from 05/12/2017 to 22/01/2018

3.4 Demo 4 – CRICURSA building (Granollers, SPAIN)

3.4.1 Reminder on data collected

Table 3.10 summarises the data collected in CRICURSA buildings during the baseline period.

Table 3.10 Summary of the data collected for Pilot#4 for the baseline period

Data point	Physical correspondence	Units	Sample rate (min)	Data available from
Outdoor temperature	Outdoor temperature	°C	10	20/07/2017
Relative humidity outdoor	Outdoor relative humidity	%RH	10	20/07/2017
Atmospheric pressure	Atmospheric pressure	hPa	10	20/07/2017
Wind speed	Wind speed	m/s	10	20/07/2017
Wind direction	Wind direction	degrees	10	20/07/2017
Inclined global irradiation	Global non-corrected solar radiation in the plane of PV panels	W/m^2	10	20/07/2017
Corrected inclined global irradiation	Global corrected solar radiation in the plane of PV panels	W/m^2	10	20/07/2017
Pyranometer temperature	Outdoor temperature measured by pyranometer in the plane of PV panels	°C	10	20/07/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions below the roof at the middle point	°C, %RH	15	20/07/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions below the roof at the edge point	°C, %RH	15	20/07/2017
Indoor roof surface temperature	Surface temperature on the roof at the high point at the location planned for BIPV installation	°C	10	20/07/2017
Indoor roof surface temperature	Surface temperature on the roof at the middle point at the location planned for BIPV installation	°C	10	20/07/2017
Indoor roof surface temperature	Surface temperature on the roof at the edge point at the location planned for BIPV installation	°C	10	20/07/2017
Electricity consumption of	Electricity consumption of the 2 'small' heating/cooling systems used for offices area of the building	W, Wh	60	20/07/2017

heating/cooling systems of offices				
Electricity consumption of heating/cooling systems of offices	Electricity consumption of the 2 'large' heating/cooling systems used for offices area of the building	W, Wh	60	20/07/2017
Electricity consumption of offices	Electricity consumption of offices area of the building	W, Wh	60	05/02/2018
General electricity consumption	Electricity consumption of the whole CRICURSA demo site	kWh	15	31/07/2017

3.4.2 Energy consumption analysis

The following table summarises the global annual electricity consumptions of the whole building. Extrapolations have been established considering theoretical occupation of the building.

Table 3.11 Summary of yearly electricity consumptions of the whole building

	Electricity consumptions (MWh)
2015	4 034.5
2016 (1st January up to 29th June)	2 081.5
Extrapolated 2016	4 214.4
2017 (31st July up to 31st December)	2 077.8
Extrapolated 2017	3 832.4
Evolution between 2015 and 2017	-5 %
Evolution between 2016 and 2017	-9 %

The following figure displays the average daily electricity consumption of the whole CRICURSA demonstration site. The electricity consumptions are almost constant over the seasons except for summer period. The difference between week day and week-end day consumptions is not so high indicating that activities are still present on site even during the week-ends.

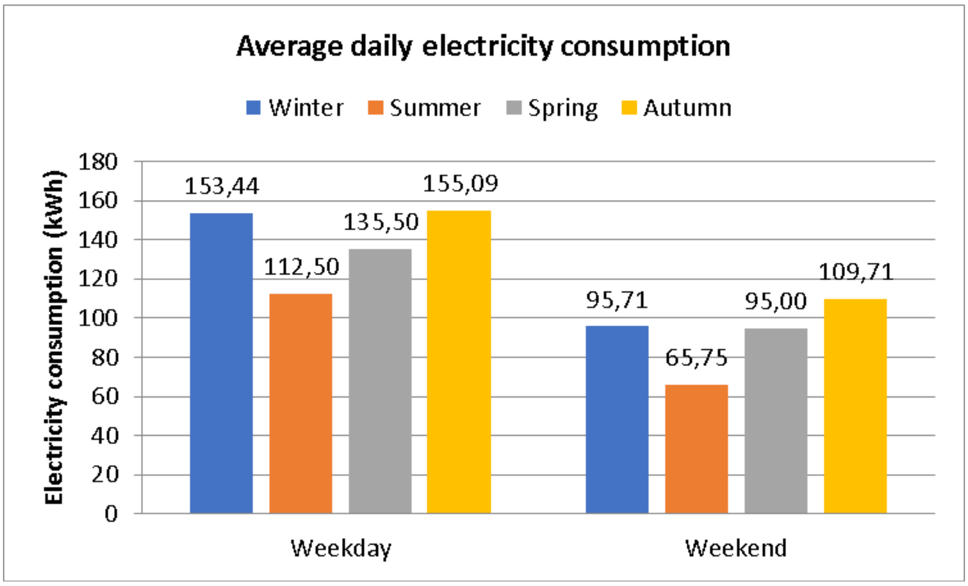


Figure 3.27 Average daily electricity consumption of CRICURSA building for the different seasons

Figure 3.28 shows the average power demand profiles for the different seasons. The profiles are almost flat with fluctuations more important for the autumn season.

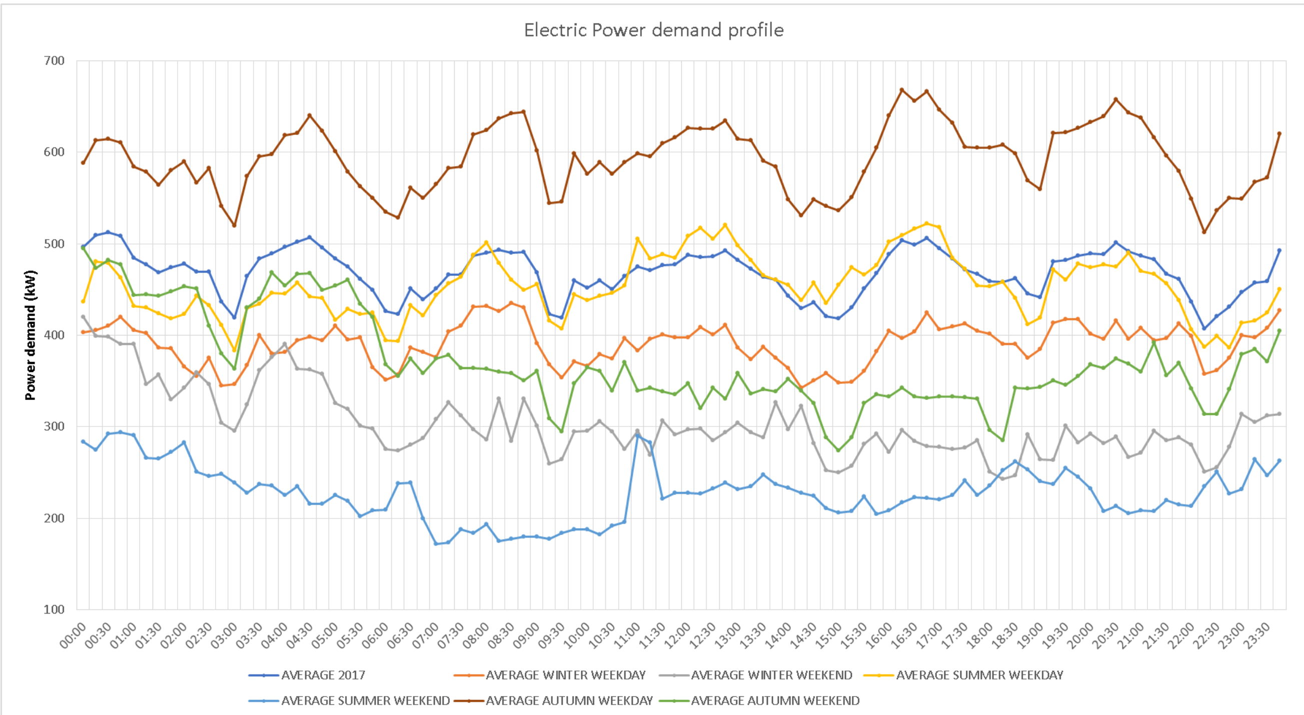
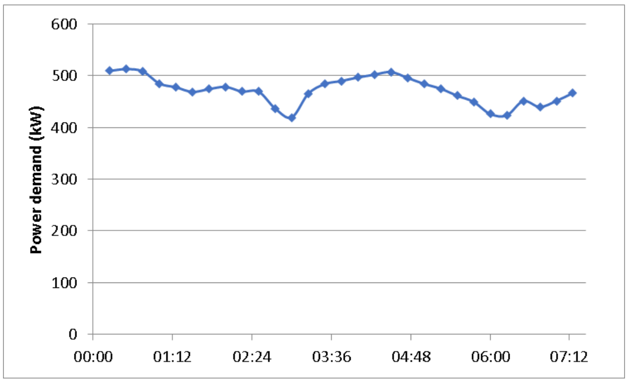


Figure 3.28 Daily profile of power demand of CRICURSA building

Figure 3.29 shows that nightly profiles and daily profiles of power demand are very similar with a similar level at 450 kW that can be explained by the continuous industrial activities of the site.



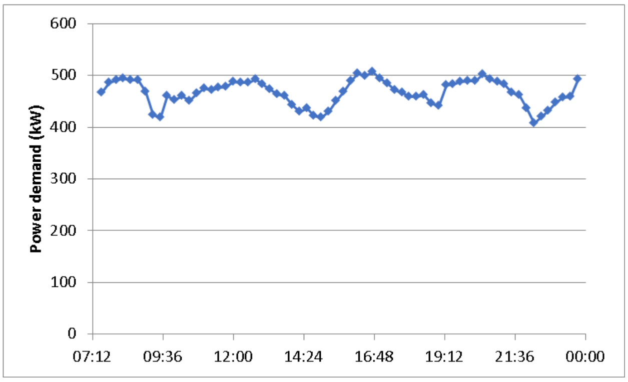


Figure 3.29 Average power demand during night and day periods

Peak power demand over 15 min is equal to 1512 kW, minimum power demand is equal to 24 kW.

The electricity consumption during the night (between 22:00 and 7:00) represents 38.4 % of total electricity consumption 2017.

A specific monitoring has been implemented on separated electrical lines in order to address the objectives of WP6 and BEMS implementation. The lines corresponding to electricity usages of the first floor of the offices area (plugs and lighting) and the one corresponding to the heating and cooling machines related with the offices area are specifically monitored.

Table 3.12 provides the consumptions of the offices area of the building. These consumptions represent a very small share (4%) of the whole electricity consumption of the site.

Table 3.12 Electricity consumptions of offices area of the building

Electricity consumptions (MWh) measured between 31st July up to 31st December 2017	
2 heating/cooling machines	1,69
Power supply of the 1st floor (plugs, lighting & others)	10,8

The daily power demand profile of both electricity usages (heating/cooling machines and power supply of the first floor) are displayed in Figure 3.30 and Figure 3.31.

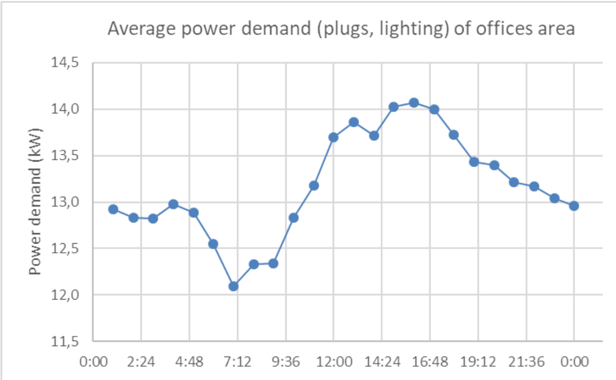


Figure 3.30 Average daily power demand profile of the machines generating heat for the offices area

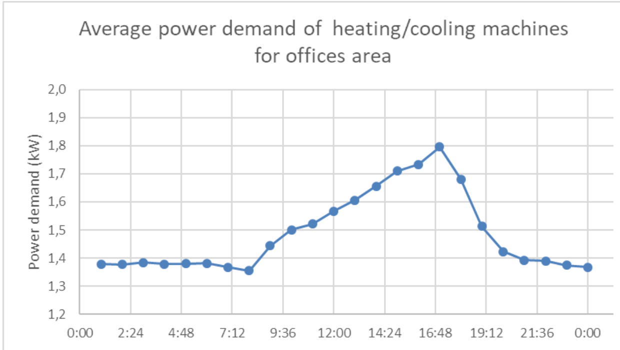
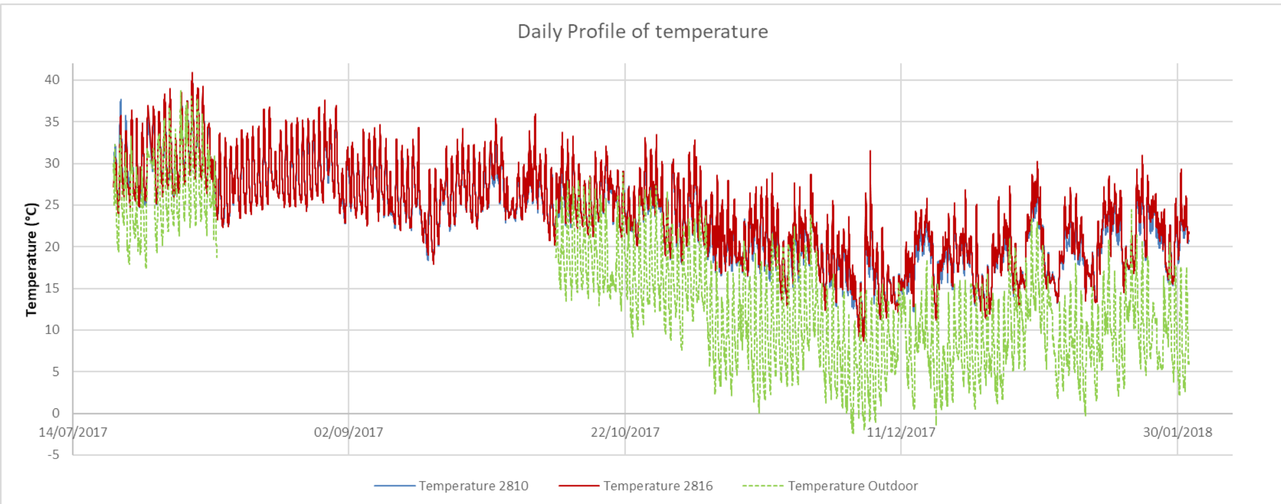


Figure 3.31 Average daily power demand profile of the machines generating heat for the offices area (20/07/2017-20/03/2018)

3.4.3 Indoor conditions analysis

Figure 3.32 shows the air temperature profiles measured by the sensors installed in the workshop just under the roof where the BIPV system will be installed. Temperature profiles follow rigorously the outdoor temperature profile showing the poor inertia of the building envelop. The effect of ovens heat supply is also clearly highlighted on these graphs.



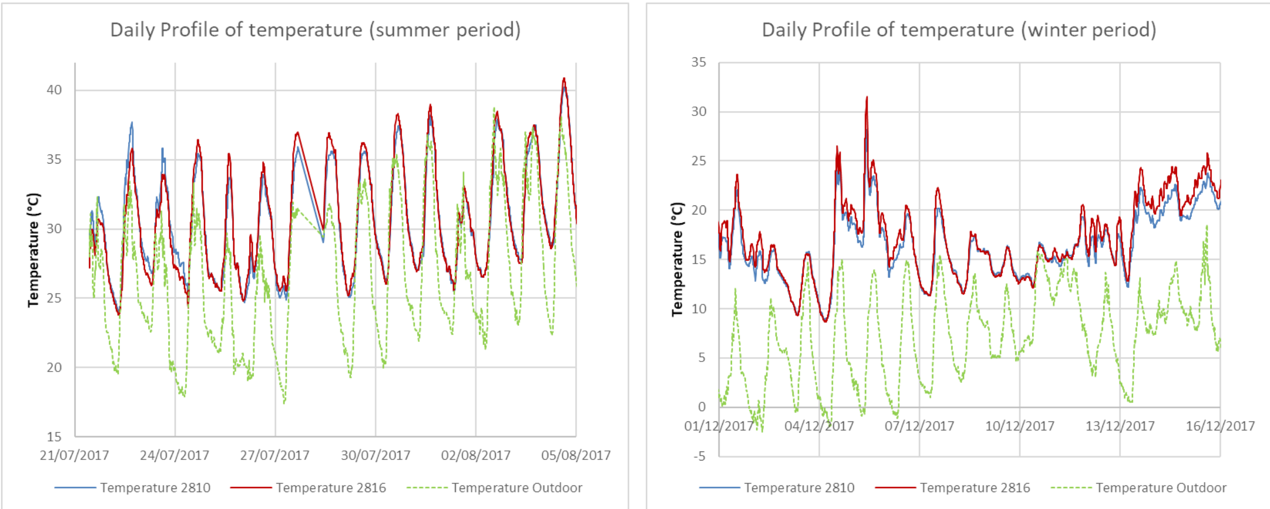


Figure 3.32 Daily profile of air temperature under the roof in the workshop

Table 3.13 and Table 3.14 show the indoor temperature (measured under the roof) distribution over different temperature ranges respectively for winter period and autumn period.

Due to the absence of insulation on the roof, very low temperatures can be observed during the winter period despite the heat generated by ovens and other specific machines present in the workshop. During the summer period, the trend is similar. High outdoor temperatures and cycle of ovens and machines generate high indoor temperatures (greater than 28°C about 60 % of time).

Table 3.13 Indoor temperature distribution over the different temperature ranges for winter period

Sensors	T<=16	16<T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
T2810	21%	18%	21%	19%	13%	6%	2%	1%
T2816	19%	15%	18%	18%	16%	8%	3%	2%

Table 3.14 Indoor temperature distribution over the different temperature ranges for summer period

Sensors	*T<=22*	*22<T<=24*	*24<T<=26*	*26<T<=28*	*28<T*
T2810	0%	4%	14%	21%	60%
T2816	0%	4%	14%	22%	59%

The temperature profiles shown in Figure 3.33, Figure 3.34, Figure 3.35, Figure 3.36 highlight that the indoor temperatures of the workshop are driven by outdoor temperatures and indoor activities (oven functioning).

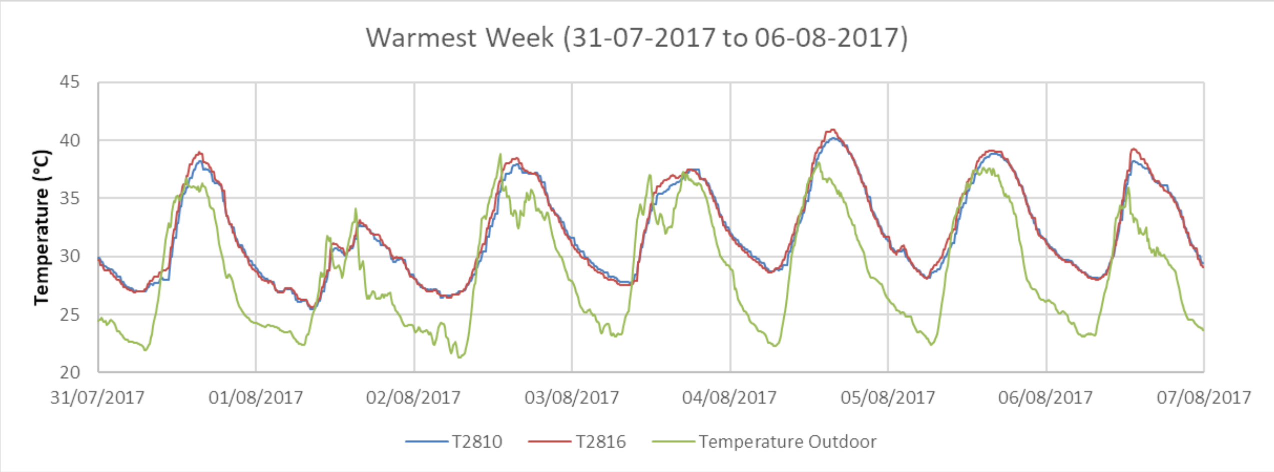


Figure 3.33 Air temperature profile during the warmest week

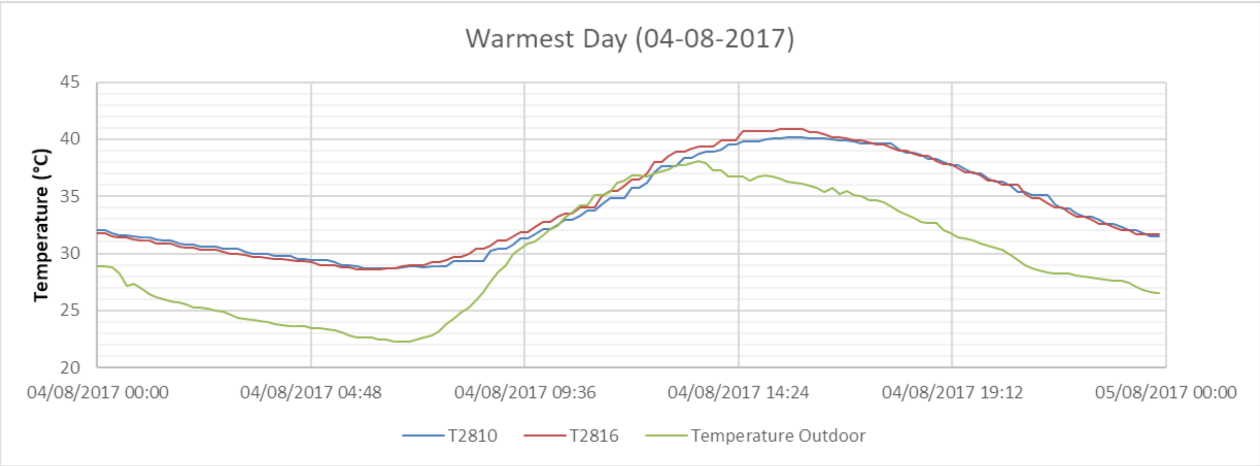


Figure 3.34 Air temperature profile during the warmest day

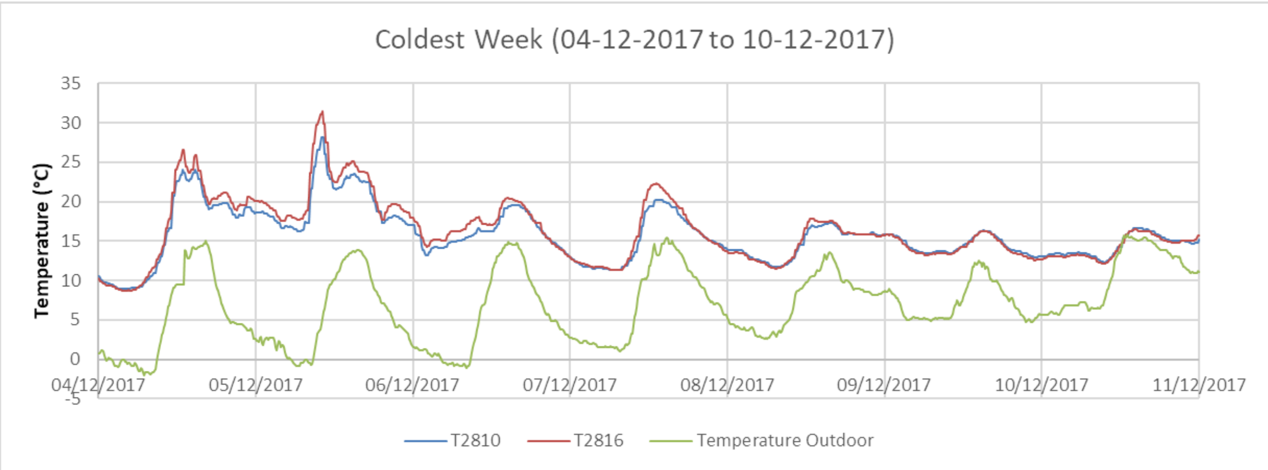


Figure 3.35 Air temperature profile during the coldest week

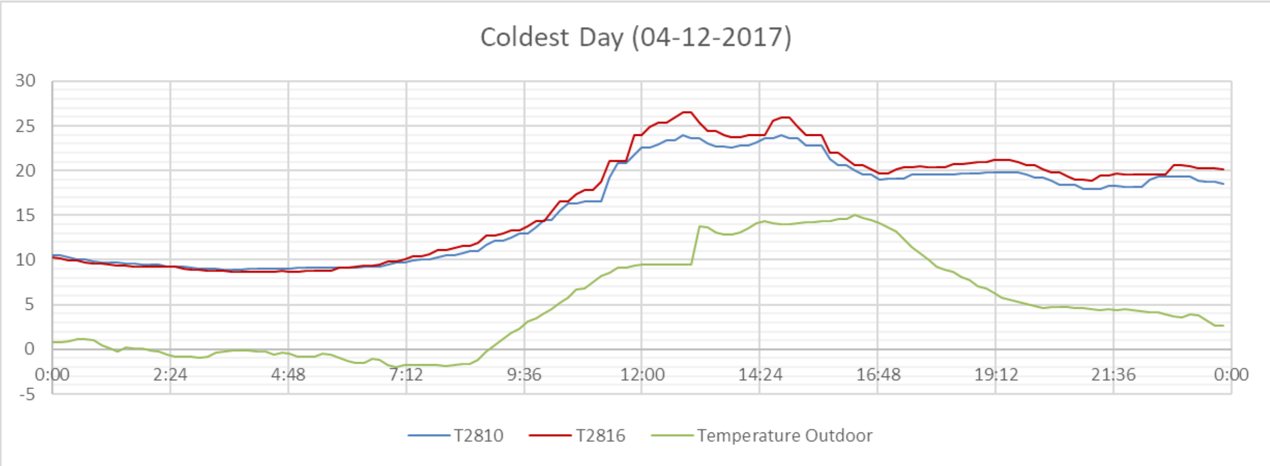


Figure 3.36 Air temperature profile during the coldest day

3.5 Demo 5 – VILOGIA building (Wattignies, FRANCE)

3.5.1 Reminder on data collected

Table 3.15 summarises the data collected in VILOGIA building during the baseline period.

Table 3.15 Summary of the data collected for Pilot#5 for the baseline period

Data point	Physical correspondence	Units	Sample rate (min)	Data available from
Outdoor Temperature	Outdoor Temperature	°C	10	11/04/2017
Relative humidity outdoor	Outdoor relative humidity	%RH	10	11/04/2017
Atmospheric pressure	Atmospheric pressure	hPa	10	11/04/2017
Wind speed	Wind speed	m/s	10	11/04/2017
Wind direction	Wind direction	degrees	10	11/04/2017
Inclined global irradiation	Global non-corrected solar radiation in the plane of PV panels	W/m^2	10	21/06/2017
Corrected inclined global irradiation	Global corrected solar radiation in the plane of PV panels	W/m^2	10	21/06/2017
Pyranometer temperature	Outdoor temperature measured by pyranometer in the plane of PV panels	°C	10	21/06/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions in dwelling 3	°C, %RH	15	01/08/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions in dwelling 11	°C, %RH	15	19/09/2016
Temperature and relative humidity ambient conditions	Temperature and relative humidity ambient conditions in dwelling 15	°C, %RH	15	19/09/2016
Inside wall surface temperature	Inside wall surface temperature on the wall planned for BIPV installation in dwelling 3	°C	10	23/10/2017
Inside wall surface temperature	Inside wall surface temperature on the wall planned for BIPV installation in dwelling 11	°C	15	10/04/2017
Inside wall surface temperature	Inside wall surface temperature on the wall planned for BIPV installation in dwelling 15	°C	15	11/04/2017

Outside wall surface temperature	Outside wall surface temperature on the wall planned for BIPV installation	°C	10	15/06/2017
Elevator electricity consumption, entrance 12	Electricity consumption of the lift located in entrance 12	W, Wh	10	01/12/2017
Elevator & Ventilation electricity consumption, entrance 13	Electricity consumption of the lift and ventilation system located in entrance 13	W, Wh	10	01/12/2017
General services electricity consumption, entrance 13	Electricity consumption of general services of the 3 entrances of the whole building	W, Wh	10	01/12/2017
Elevator electricity consumption, entrance 14	Electricity consumption of the lift located in entrance 14	W, Wh	10	01/12/2017
General electricity consumption	Electricity consumption of common spaces	kWh	Monthly	10/12/2015

3.5.2 Energy consumption analysis

The following table summarises the global annual electricity consumptions associated with common spaces of the building.

An increase is observed between 2016 and 2017 (+20.4%). Regarding the submeters values, the main contributor to this important increase is lift and ventilation of gate 13 of the building.

Table 3.16 Summary of yearly electricity consumptions of common spaces of the building

	Annual electricity consumptions of the common spaces (MWh)	Annual electricity consumptions (MWh) for each electric meter covering the common spaces usages			
		Lift gate 12	Lift/HVAC gate 13	Building general services gate 13	Lift gate 14
2016	25.85	1.82	11.9	10.42	1.7
2017	31.14	1.86	17.19	10.39	1.69
Evolution	+20.4 %	+2.1 %	+44.4%	-0.3%	-0.7%

The following figure displays the average daily electricity consumption of common spaces of the whole Vilogia building. The electricity consumption level is very similar for weekdays and for weekends.

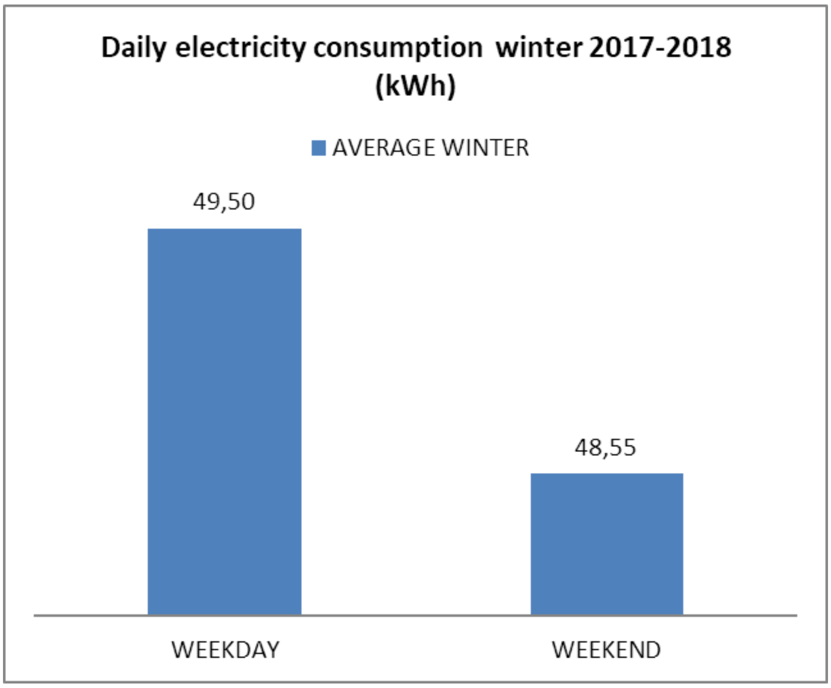


Figure 3.37 Daily electricity consumption of common spaces of the whole Vilogia building during winter 2017-2018

The average daily power demand displayed on Figure 3.38 shows a base value at 1900 W.

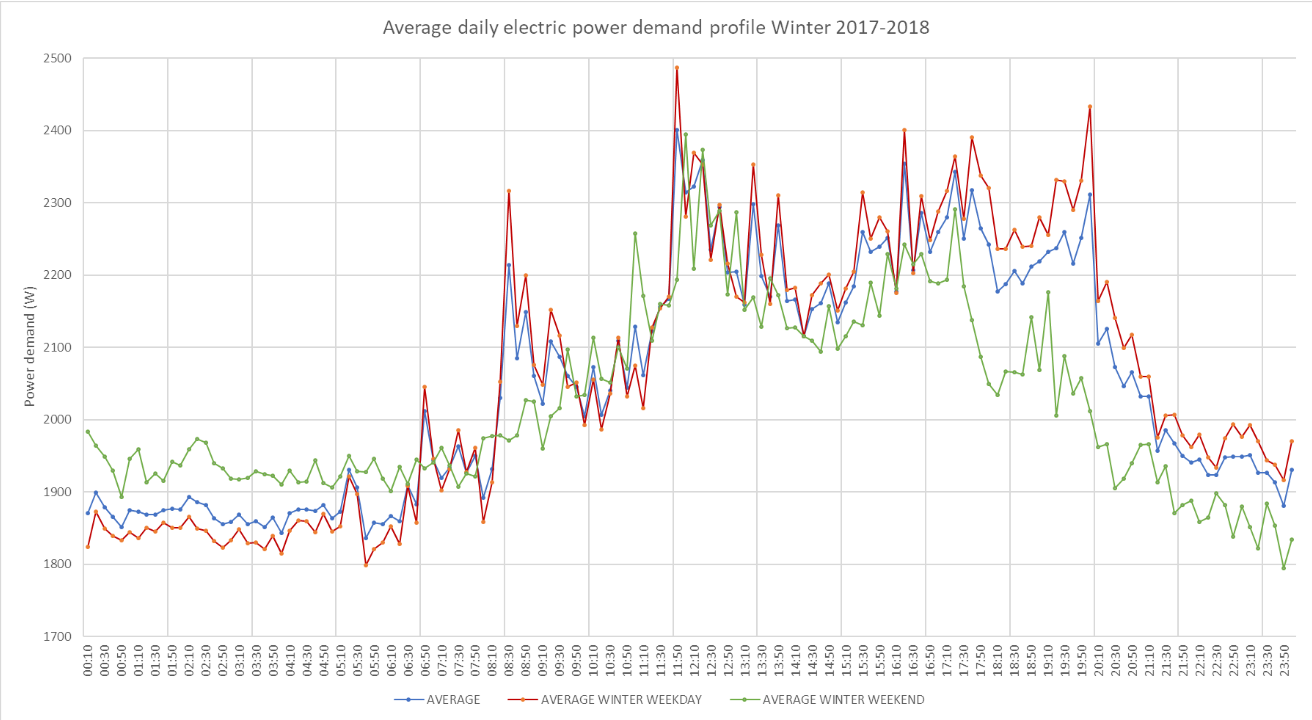


Figure 3.38 Average daily electricity power demand profile (calculated from 12/2017 to 02/2018)

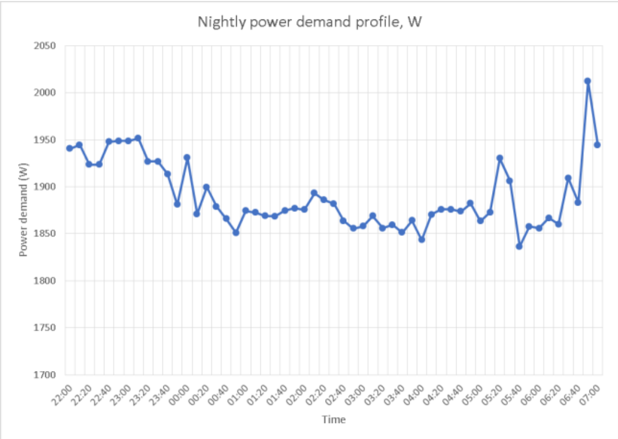


Figure 3.39 Average nightly power demand

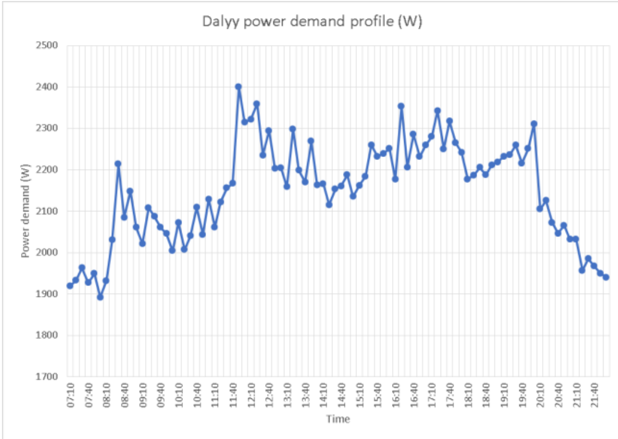


Figure 3.40 Average daily power demand

The electricity consumption during the night (between 22:00 and 7:00) represents 34,5% of total electricity consumption for the year 2017.

Peak power demand over 10 min is equal to 5388 W, minimum night time power demand is equal to 1116 W. The difference between these is 4272 W.

3.5.3 Indoor comfort conditions analysis

The following graphs show the evolution of indoor temperature measured in the dwellings in comparison to the outdoor temperature.

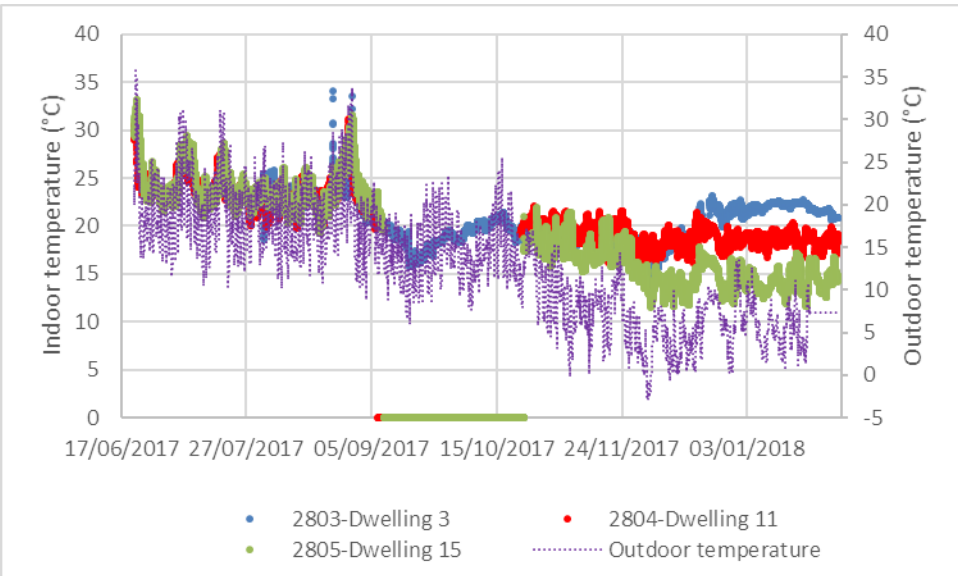


Figure 3.41 Indoor temperatures evolution and outdoor temperature

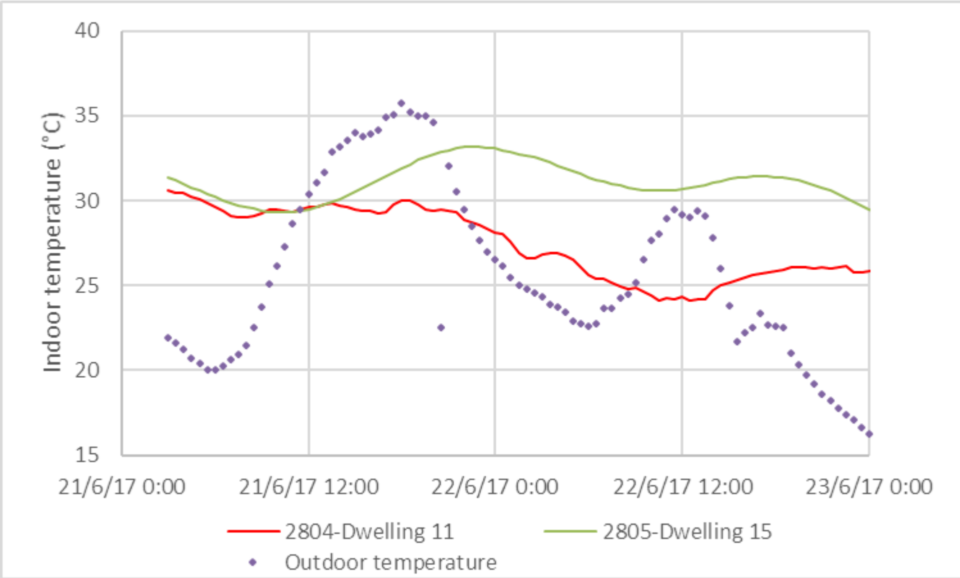


Figure 3.42 Indoor temperatures evolution and outdoor temperature during the warmest period of 2017

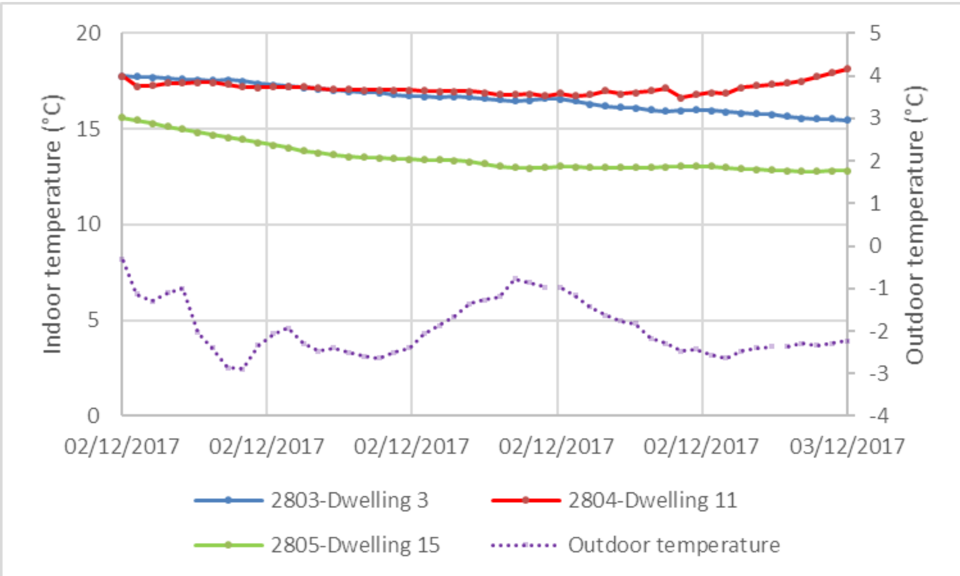


Figure 3.43 Indoor temperatures evolution and outdoor temperature during the coldest period of 2017

In order to get an objective evaluation of the comfort level in the dwellings, the Brager index is calculated and displayed in Figure 3.44 and Figure 3.45 respectively for winter period and summer period fro dwellings 11 and 15. The other graphs are provided in annex 3 (paragraph 6.3).

For summer period, the Brager diagrams show some overheating conditions in both dwellings (same orientations) currently monitored. This phenomenon is stronger for dwelling #15 which is located on the 7th level and reflects a temperature stratification effect. For winter period, the dwelling located on higher level presents strong discomfort conditions.

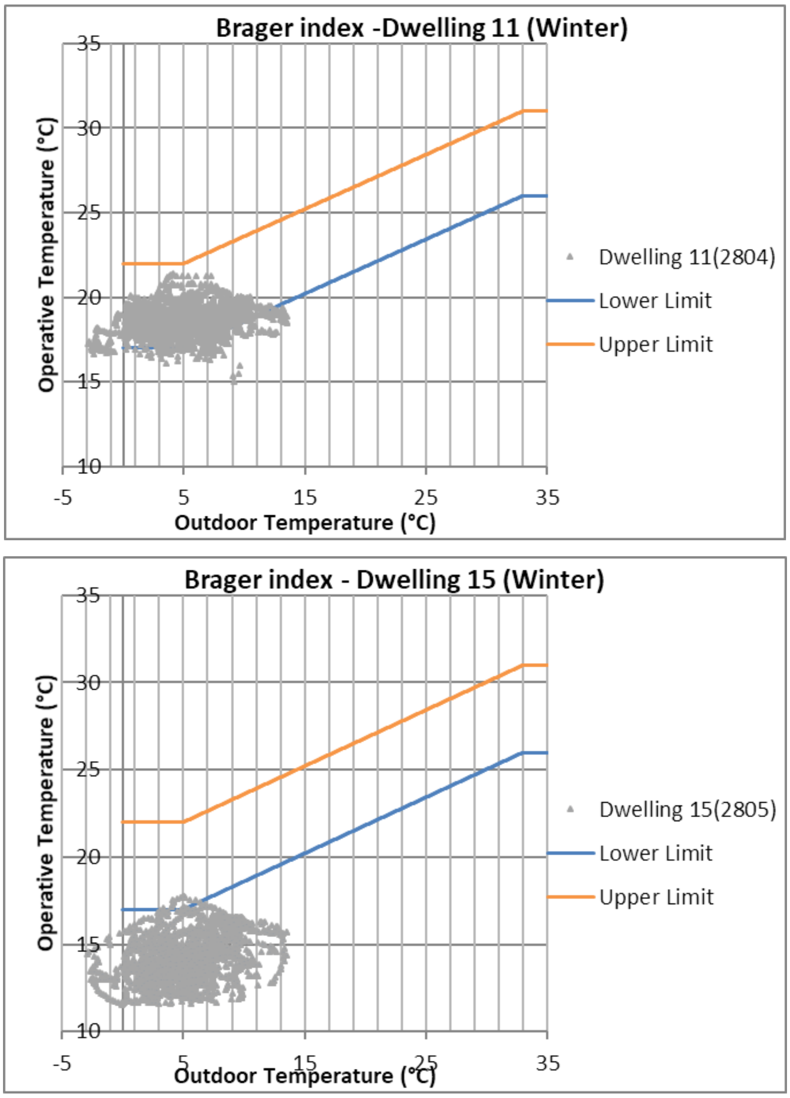


Figure 3.44 Brager diagram for the living room of dwellings 11 and 15 (Winter)

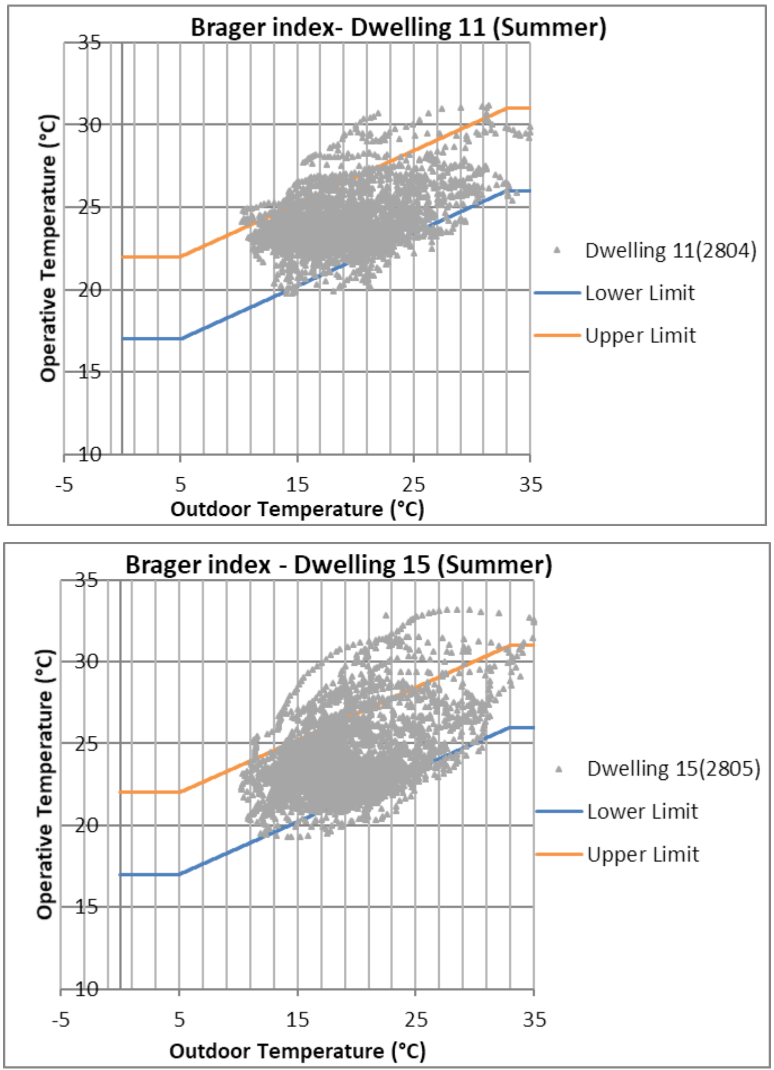


Figure 3.45 Brager diagram for the living room of dwellings 11 and 15 (Summer)

Table 3.17 and Table 3.18 show the indoor temperature distribution in dwellings 11 and 15 over different temperature ranges respectively for summer period and winter period. During summer, indoor temperatures are most of the time within the comfort range. The temperatures measured in dwelling 11 are greater than 26°C only 10,7 % of time whereas this value reaches 18,6 % for dwelling 15.

For winter period, very strong discomfort is highlighted for dwelling 15 whereas dwelling 11 shows comfort conditions most of the time.

Table 3.17 Indoor temperature distribution over the different temperature ranges for summer period.

	T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
Dwelling 3	0.3%	6.8%	66.8%	23.8%	12%	1.1%
Dwelling 11	0.2%	4.6%	55.4%	27.1%	9.7%	3.1%
Dwelling 15	0.5%	13.9%	46.5%	21%	10.6%	7.4%

Table 3.18 Indoor temperature distribution over the different temperature ranges for winter period.

	T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T
Dwelling 3	2.1%	12.8%	16.9%	38.5%	29.7%	0%
Dwelling 11	0.1%	21.5%	73.5%	4.9%	0%	0%
Dwelling 15	87.8%	12.2%	0%	0%	0%	0%

Simulations conducted previously have revealed that solar installation will have nearly no impact on the apartments summer thermal comfort. The variations are too low to have a relevant impact on the indicators.

3.6 Demo 6 – TECNALIA building (San Sebastian, SPAIN)

3.6.1 Reminder on data collected

Table 3.19 summarises the data collected in TECNALIA building during the baseline period.

Table 3.19 Summary of the data collected for Pilot#6 for the baseline period

Data point	Physical correspondence	Units	Sample rate (min)	Data available from
Outdoor Temperature	Outdoor Temperature	°C	1	04/03/2017
Relative humidity outdoor	Outdoor relative humidity	%RH	1	04/03/2017
Atmospheric pressure	Atmospheric pressure	hPa	1	04/03/2017
Wind speed	Wind speed	m/s	1	04/03/2017
Wind direction	Wind direction	degrees	1	04/03/2017
Inclined global irradiation	Global non-corrected solar radiation in the plane of PV panels	W/m^2	10	22/08/2017
Corrected inclined global irradiation	Global corrected solar radiation in the plane of PV panels	W/m^2	10	22/08/2017
Pyranometer temperature	Outdoor temperature measured by pyranometer in the plane of PV panels	°C	10	22/08/2017
Outdoor illuminance	Outdoor global illuminance on the roof	lux	10	14/03/2018
DHI irradiation (diffuse horizontal irradiation)		W/m2	10	22/08/2017
DNI (direct normal irradiation)		W/m2	10	22/08/2017
GHI (global horizontal irradiation)		W/m2	10	22/08/2017
Angle zenith			10	22/08/2017
Daily sunshine duration			10	22/08/2017
Indoor inclined global irradiation	Indoor non-corrected solar radiation in the vertical plane in the room behind the location planned for BIPV installation	W/m^2	10	12/07/2017

Indoor temperature-corrected inclined global irradiation	Indoor temperature-corrected irradiation in the vertical plane in the room behind the location planned for BIPV installation	W/m^2	10	12/07/2017
Indoor pyranometer temperature	Indoor temperature measured by pyranometer in the vertical plane	°C	10	12/07/2017
Inside window surface temperature	Inside surface temperature of the window on the first floor planned for BIPV installation	°C	10	12/07/2017
Operative temperature	Operative temperature in the room located behind the glass façade planned for BIPV installation	°C	15	12/07/2017
Occupancy at the offices part of the first floor right	Occupancy data (occupied/no occupied) in the offices located in the right area of the first floor	Occupied/ not occupied	Change of value	12/07/2017
Occupancy at the offices part of the first floor left	Occupancy data (occupied/no occupied) in the offices located in the left area of the first floor	Occupied/ not occupied	Change of value	12/07/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity conditions in the left area located on the first floor (T1L)	°C, %RH	10	12/07/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity conditions in the right area located on the first-floor (T1R)	°C, %RH	10	12/07/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity conditions in the left area located on the second-floor (T2L)	°C, %RH	10	12/07/2017
Temperature and relative humidity ambient conditions	Temperature and relative humidity conditions in the right area located on the second-floor (T2R)	°C, %RH	10	12/07/2017
Electricity consumption of the first-floor right area	Electricity consumption of lighting and plugs of the right area on the first floor of the building	W, Wh	10	22/08/2017
Electricity consumption of the first-floor left area	Electricity consumption of lighting and plugs of the left area on the first floor of the building	W, Wh	10	22/08/2017
Electricity consumption of the second-floor right area	Electricity consumption of laboratories located in the right area of the second floor of the building	W, Wh	10	22/08/2017
Electricity consumption of the second-floor left area	Electricity consumption of laboratories located in the left area of the second floor of the building	W, Wh	10	22/08/2017

3.6.2 Energy consumption analysis

The following table provides the electricity consumptions of the different areas monitored in the building.

Table 3.20 Summary of yearly electricity consumptions of the building

	Total electricity consumption of the first and second floors of the building (kWh)			
	First-floor right part 1R	First-floor left part 1L	Second-floor right part 2R	Second-floor left area 2L
5,5 months real consumption	3963.4	4292.6	43584.4	31948.6
Annual consumption extrapolated to a full year	188 834			

Figure 3.46 and Figure 3.47 show the average power demand during day and night periods that means when the building is occupied and non-occupied. The power demand during the day is twice as high as the one measured during the night period. The electricity consumption during the night (between 22:00 and 7:00) represents 26,4 % of total electricity consumption 2017.

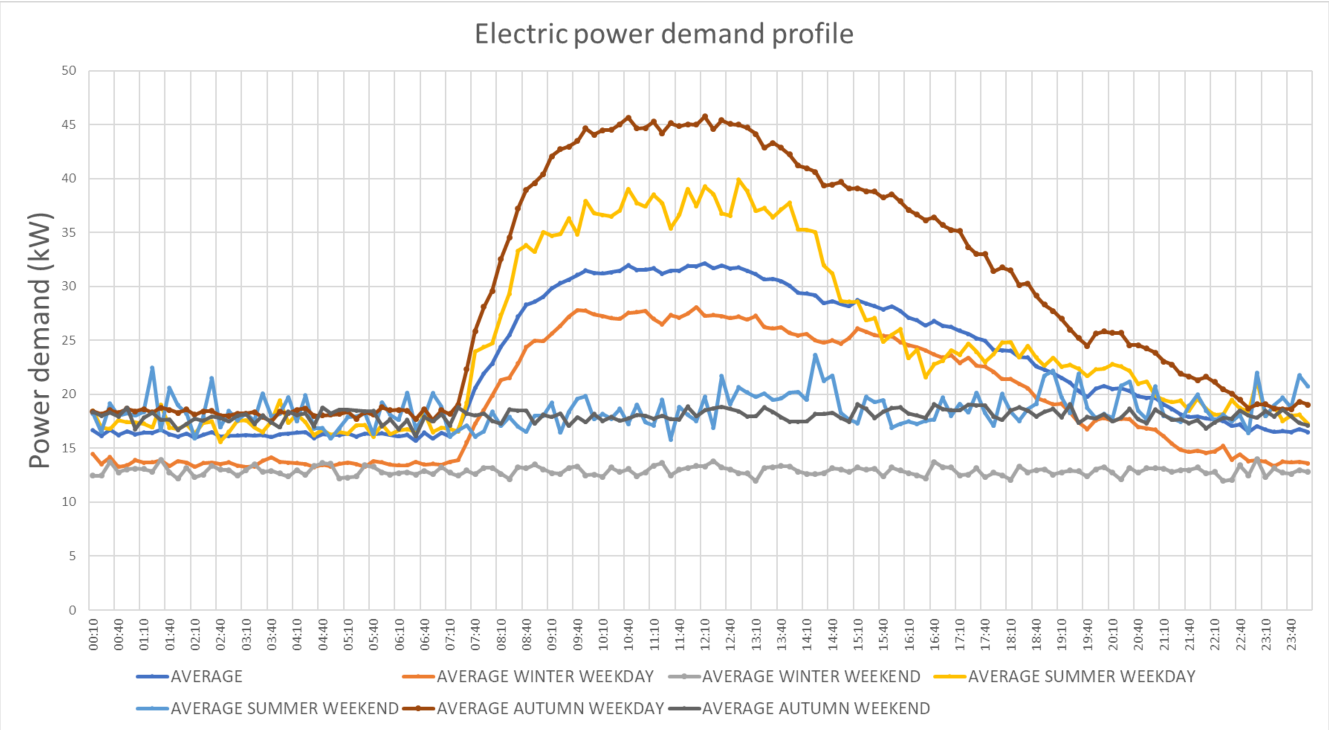


Figure 3.46 Daily profile of power demand of the first and second floors of TECNALIA building

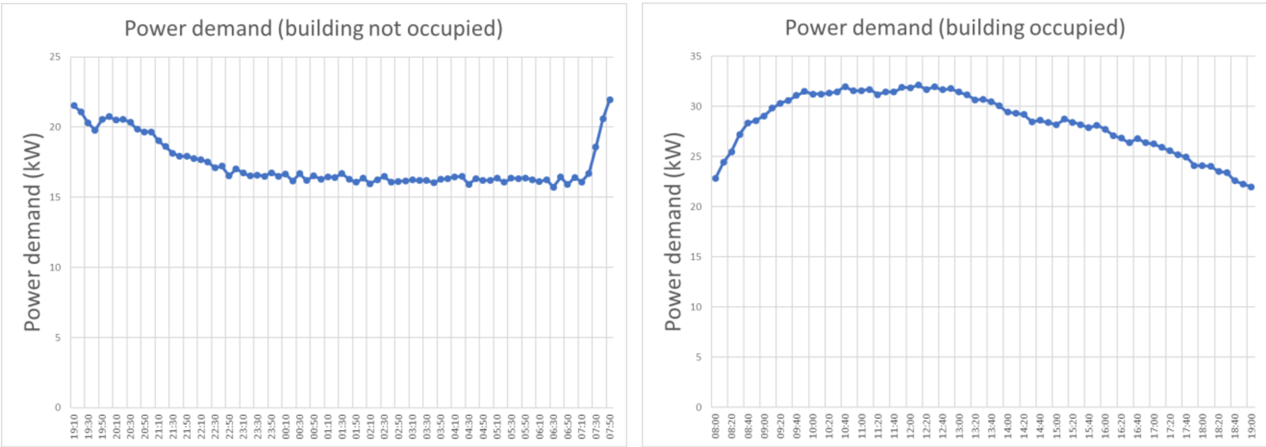


Figure 3.47 Average power demand during periods of occupation and vacancy of the building

The following figure shows the share of electricity consumptions between the two levels of the building. The second floor is by far the highest consumer of electricity and this can be explained by the presence of laboratories spaces on the second floor requiring high electricity loads (sun irradiation machines, ovens etc.).

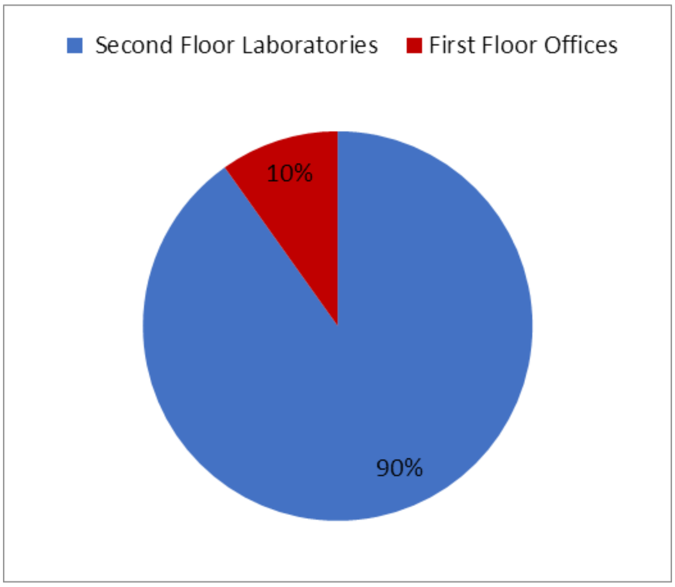


Figure 3.48 Distribution of electricity consumption between first and second floors

Consumption are similar for week days and week-ends during spring period whereas they are notably different for the other seasons.

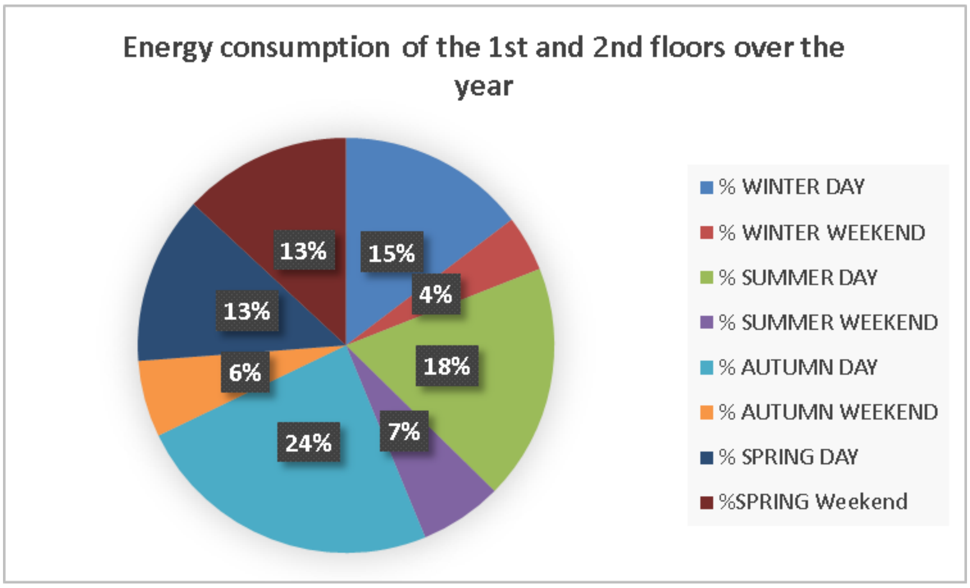


Figure 3.49 Distribution of electricity consumption over the year for Tecnalia building

Table 3.21 provides the values for peak power demand (measured over 10 minutes) and minimum night time power demand for the different seasons 2017-2018 and the difference between both values as well. Very similar differences are obtained for autumn and winter whereas values obtained for summer season are notably lower.

Table 3.21 Difference between peak power demand and minimum night time power demand over the seasons 2017-2018

	Peak power demand per season (kW)	MIN power demand per season (kW)	MAX-MIN (kW)
SUMMER	30.7	12.7	18
AUTUMN	65.2	8.1	57.1
WINTER	59.9	5.5	54.4
Average	51.9	8,7	43.2

3.6.3 Indoor comfort conditions analysis

The following graph shows the evolution of indoor temperature in 2 rooms of the first floor and 2 rooms of the second floor just behind the glass facade. During winter period, the indoor temperature remains around 20°C. During summer period, indoor temperature can reach 30°C, but the impact is low as these rooms have not permanent occupancy.

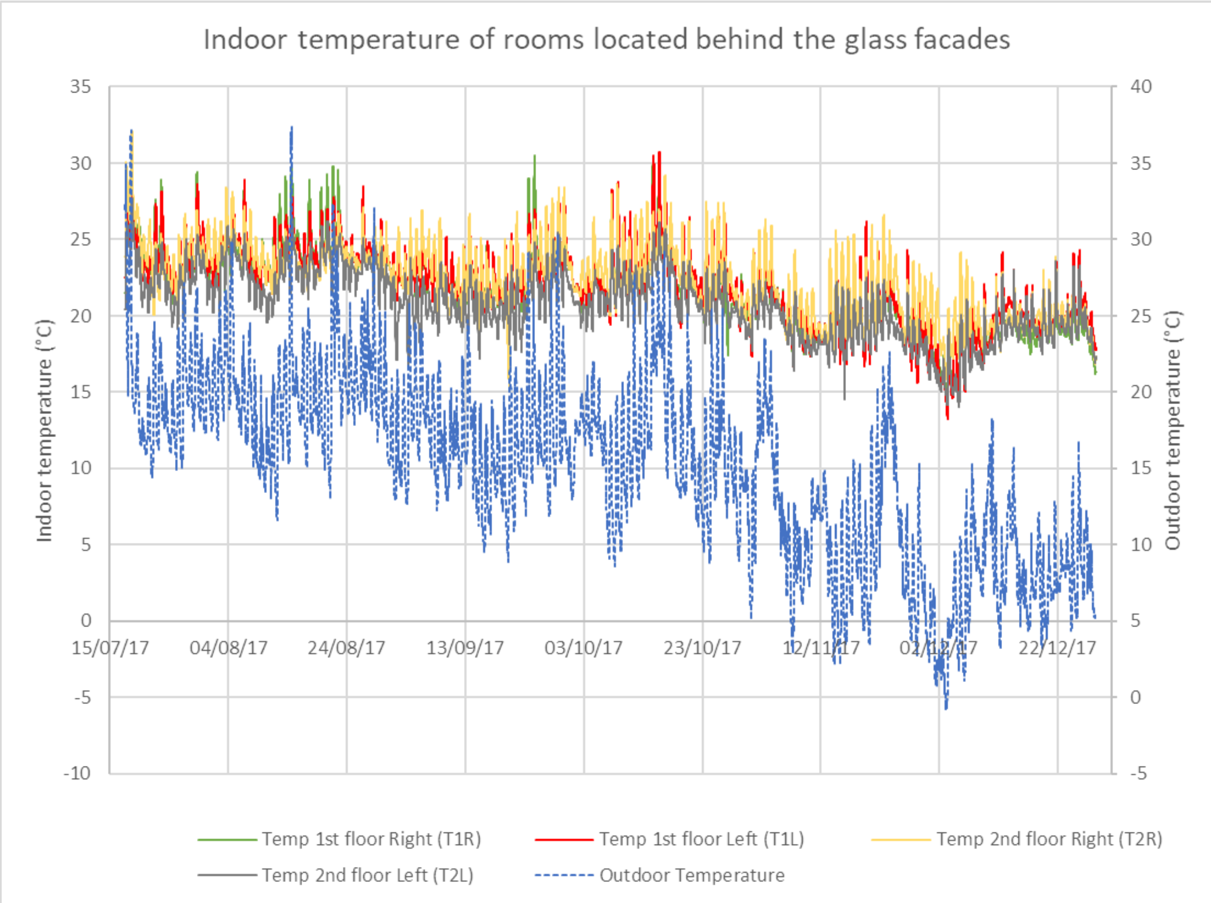
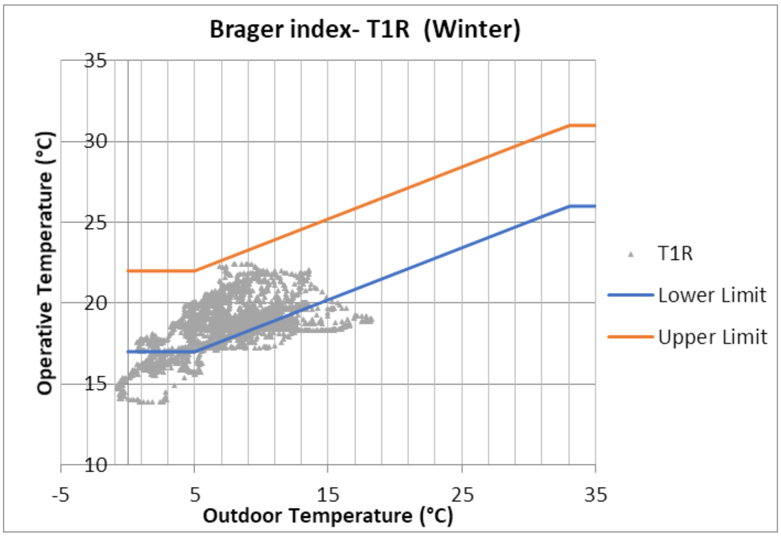


Figure 3.50 Indoor temperatures evolution in the different rooms of the first and second floors behind the glass facade

In order to get an objective evaluation of the comfort level in these rooms of the first and second floors, the Brager index is calculated and displayed in Figure 3.51 for winter and summer periods. These graphs show that ambient conditions into the rooms are not well regulated with frequent periods of overheating and under temperature conditions. The Brager graphs corresponding to all the sensors installed are provided in Annex 4 (paragraph 6.4).



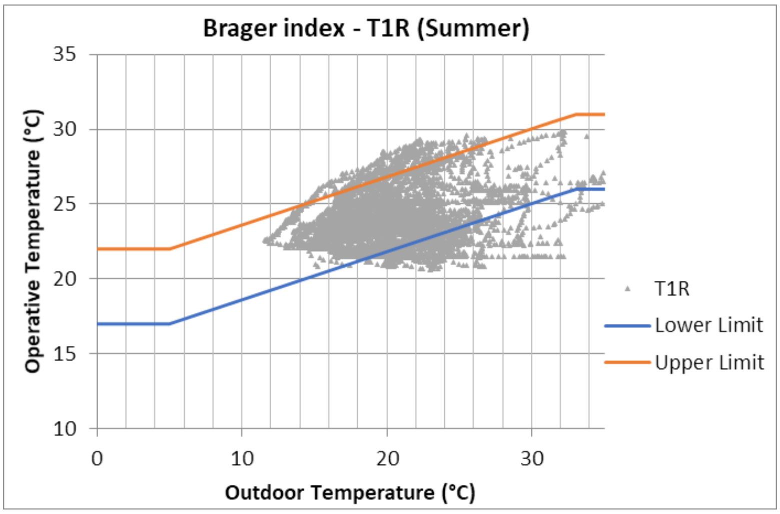


Figure 3.51 Brager index (Winter and Summer) for sensor T1R

Table 3.22, Table 3.23 and Table 3.24 show the indoor temperature distribution over different temperature ranges respectively for winter, summer and autumn periods.

Ambient conditions are out of comfort range:

- About 25-30% of time during winter;
- About 10% of time during summer and autumn.

Table 3.22 Indoor temperature distribution over the different temperature ranges for winter period

Sensors	T<=16	16<T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26
T1L	6.3%	21.7%	61%	10.5%	0.5%	0%
T1R	11.4%	16%	35.4%	33%	4.1%	0.2%
T2L	0.8%	9%	58.6%	25.7%	5.4%	0.5%
T2R	13.9%	27.2%	45.1%	11.8%	2%	0%

Table 3.23 Indoor temperature distribution over the different temperature ranges for summer period

Sensors	T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
T1L	0%	0%	14.1%	42%	32.1%	8.4%	3.4%
T1R	0%	0%	3.6%	50%	36.8%	8.5%	1%
T2L	0%	0%	5.4%	47.8%	29.6%	15.4%	1.8%
T2R	0%	1.6%	31.6%	50.3%	15.3%	1.2%	0%

Table 3.24 Indoor temperature distribution over the different temperature ranges for autumn period

Sensors	T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
T1L	3.6%	15%	36.6%	33.7%	8.5%	1.4%	1.2%
T1R	4%	13.1%	34.8%	32.3%	11.8%	2.9%	1%
T2L	0.7%	12.6%	29%	34.4%	17%	5.9%	0.5%
T2R	7.7%	29.2%	44%	16%	3%	0.1%	0%

The following tables show the same information but focused on periods of occupation of the building (from 08:00 AM to 19:00). During periods of occupation of the building, the comfort conditions are met most of the time.

Table 3.25 Indoor temperature distribution over the different temperature ranges for summer period during occupation

Sensors	T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
T1L	0%	0%	21.4%	45.6%	23.3%	5.3%	4.4%
T1R	0%	0%	7.4%	60.1%	25.6%	6.3%	0.6%
T2L	0%	0%	6.1%	44.1%	29.3%	16.6%	3.8%
T2R	0%	4.8%	51.5%	35.1%	7.6%	1%	0%

Table 3.26 Indoor temperature distribution over the different temperature ranges for Autumn period during occupation

Sensors	T<=16	16<T<=18	18<T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
T1L	0%	2.4%	14.5%	45.1%	27.4%	10%	0.6%	0%
T1R	0%	2.1%	10.7%	44.3%	29.1%	12.2%	1.7%	0%
T2L	0.4%	0.2%	4.1%	21.4%	34.1%	25.7%	12.9%	1.1%
T2R	0.3%	10.5%	38.2%	34.7%	14.6%	1.7%	0%	0%

Table 3.27 Indoor temperature distribution over the different temperature ranges for Winter period during occupation

Sensors	T<=20	20<T<=22	22<T<=24	24<T<=26	26<T<=28	28<T
T1L	0%	0%	60%	32.5%	6.4%	1.1%
T1R	0%	0%	45.4%	45.2%	8.9%	0.6%
T2L	0%	0,2%	59.9%	35.5%	4.5%	0%
T2R	0%	10.3%	72.8%	16.9%	0%	0%

Figure 3.52, Figure 3.53, Figure 3.54 and Figure 3.55 shows the stratification effect observed. Moreover, at the beginning of the warmest day, the indoor temperature is still very high despite a decrease in outdoor temperature showing the inefficiency of the regulation applied in this room.

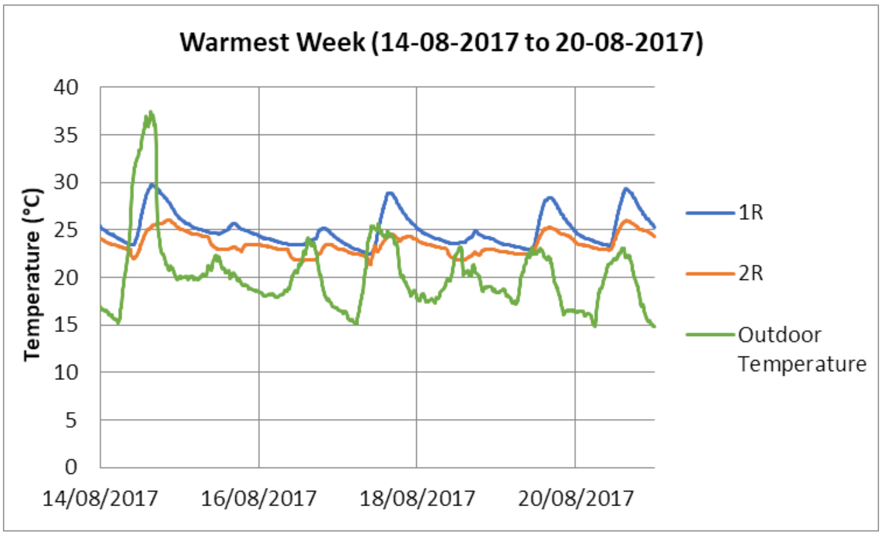


Figure 3.52 Air temperature profile during the warmest week

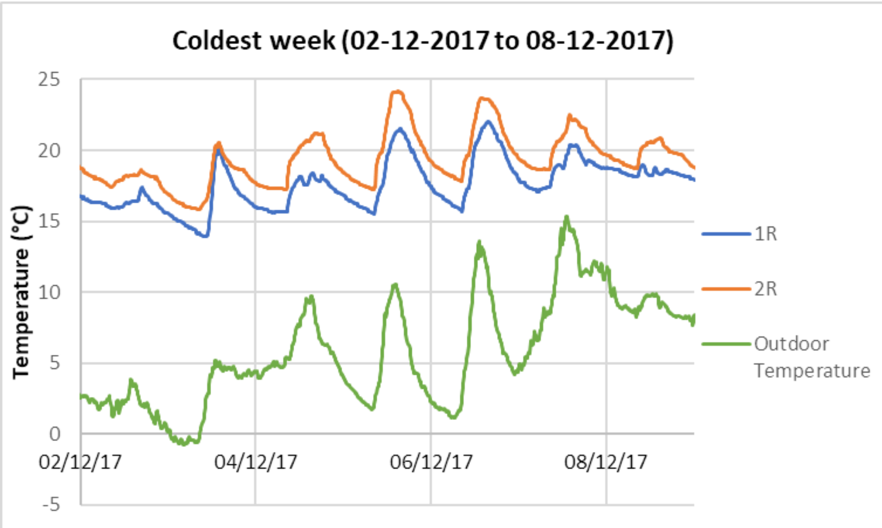


Figure 3.53 Air temperature profile during the coldest week

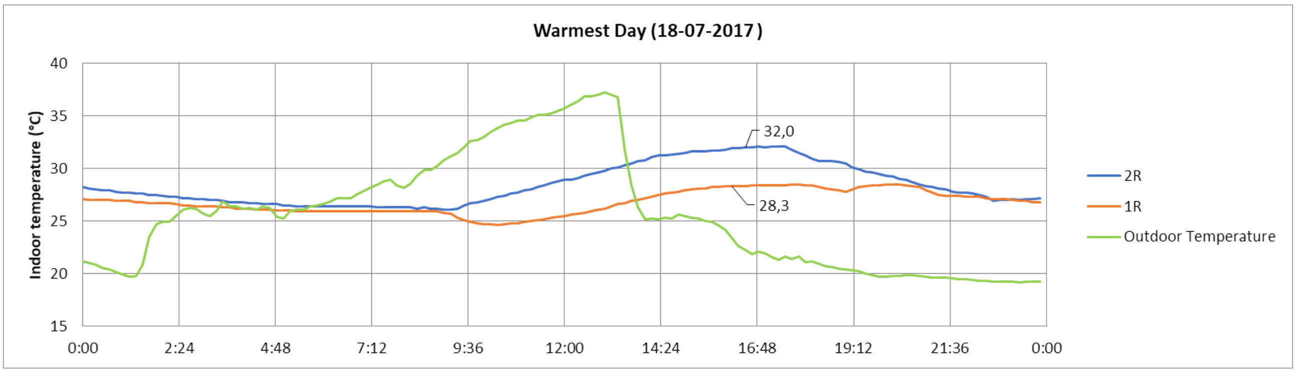


Figure 3.54 Air temperature profile during the warmest day

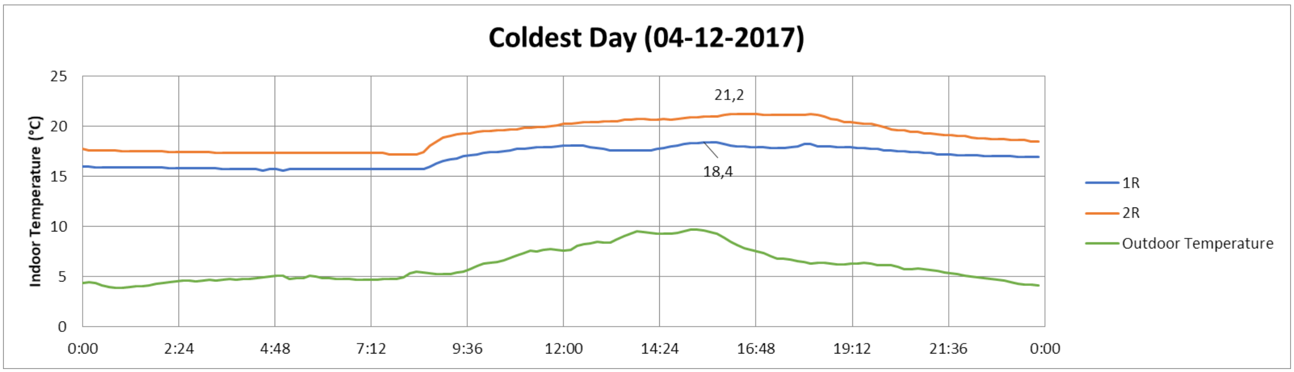


Figure 3.55 Air temperature profile during the coldest day

The following graph shows the evolution of operative temperature measured by the black globe sensor installed in the room located just behind the glass façade on the first floor. Although a temperature regulation is applied in this room, the operative temperature is closely following the outdoor temperature, especially during warm periods. This can be explained by the important solar energy supply occurring in this room.

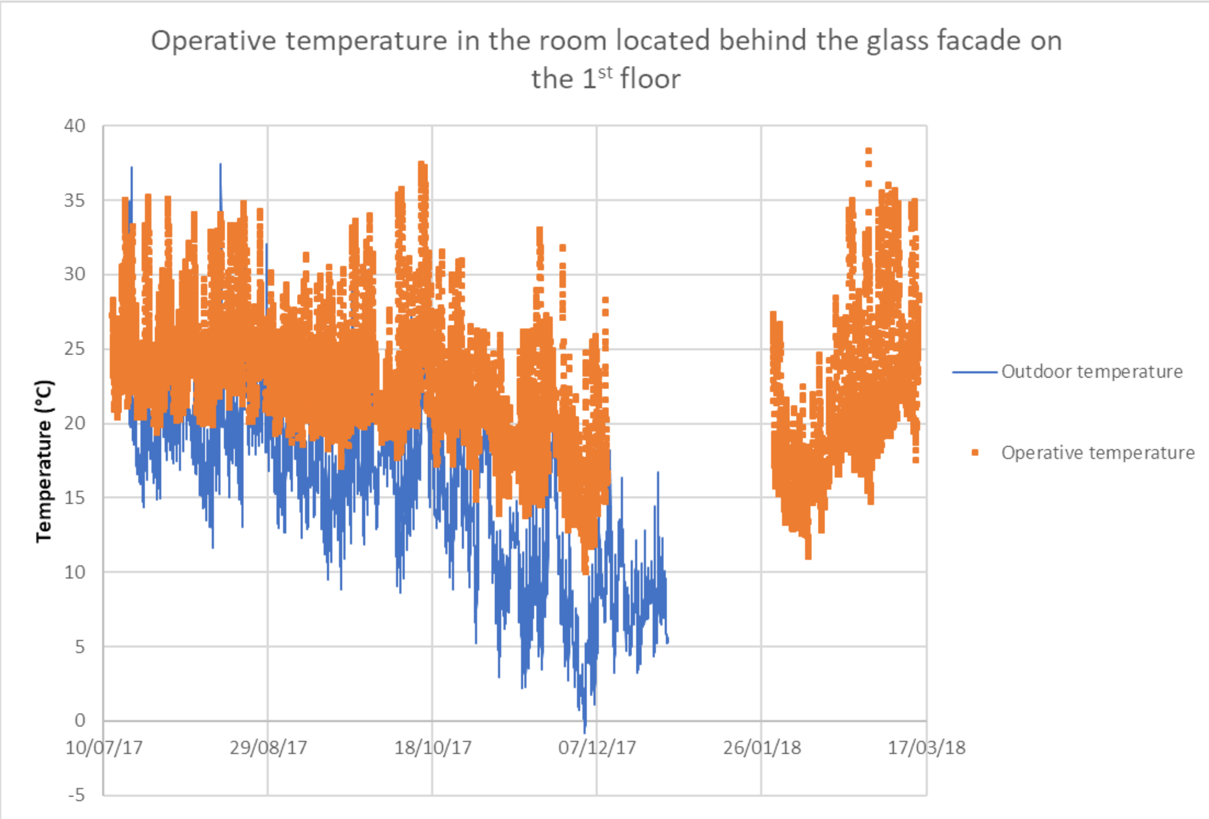


Figure 3.56 Operative temperature measured in the room behind the glass facade

The following graphs show the outdoor vertical solar radiation compared to the indoor vertical solar radiation measured in the room behind the glass façade. The first graph indicates that solar protections are continuously closed during summer period. During winter period, solar protections seem to be closed during the week-ends and open during the week days. These different levels of transmission will be compared to the one measured after BIPV systems installation.

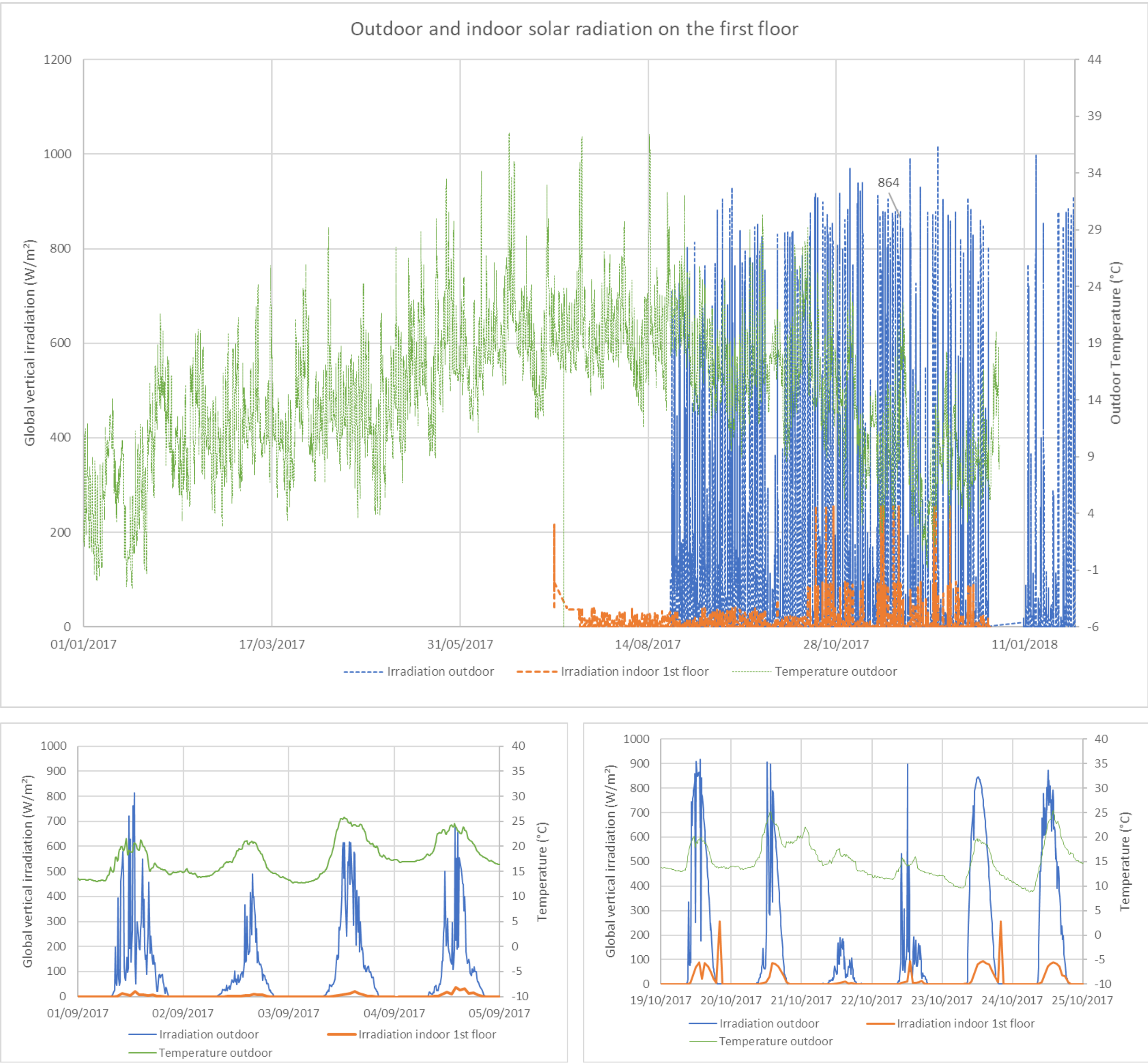


Figure 3.57 Indoor and outdoor solar radiation measured in the room located behind the glass façade on the first floor

4 CONCLUSIONS

This report describes the main results related with energy performance of the pilot sites monitored during the baseline period. The following table summarizes the KPIs calculated for all the pilot sites monitored during this baseline period.

Table 4.1 Summary of KPIs calculated for the baseline period

	Pilot#1	Pilot#2	Pilot#3	Pilot#4	Pilot#5	Pilot#6
Yearly electricity consumption (kWh)	6 592	342 115	N/A	3 832 366	31 136 (common spaces)	188 834
Yearly electricity consumption per surface (kWh/m²)	23.71	128.13	N/A	281.1	8.56	31.47
Average daily electricity consumption (kWh)	18.33 Winter: 22.04 Summer: 15.58	938.2 Winter: 783.5 Summer: 823.6	N/A	11 940.1	16.14	535.1
Yearly heating consumption (kWh) [HDD]	Electric heater: 423 [2761 HDD] Wood: 3026 [2761 HDD]	420 732 [2801,7 HDD]	N/A	Not measured	Not measured	Not measured
Ratio heating energy/HDD	Electric heater: 0.153 Wood: 1.096	150.2	N/A	--	--	--
Yearly heating consumption per surface (kWh/m²)	Electric heater: 1.52 Wood: 10.88	157.58	N/A	--	--	--
Correlation between heating energy and HDD	Electric heater: Energy= 394.33 x HDD -76249 Wood: Energy= 2.56 x HDD – 389.2	Energy=168.27 x HDD -3750.5	N/A	--	--	--
Percentage of electricity	26	18.9	N/A	38.4	34.5	26.4

	Pilot#1	Pilot#2	Pilot#3	Pilot#4	Pilot#5	Pilot#6
consumed during the night in comparison to total electricity consumption (%)						
Difference between peak power demand and minimum night time demand (W)	8 070	140 800	N/A	1 511 976	4 272	57 112
Average daily and nightly power demand (W)	Day: 899.7 Night: 533.1	Day: 51 233 Night: 19 736	N/A	Day: 469 239 Night: 468 661	Day: 2150 Night: 1890	Day: 26 298 Night: 16 430
Percentage of hours during which the indoor temperature is out of the comfort range	Winter: 28% (average calculated over the 8 sensors for T<18°C) Summer: 2.8% (average calculated over the 8 sensors for T>28°C)	Winter: 0.2% (average calculated over the 3 sensors for T<18°C)	N/A	N/A	Summer: 5.8 % (average value calculated over the two sensors installed in the dwellings for T>28°C)	Winter: about 25-30%; Summer and Autumn: about 10%

General figures associated with energy consumptions have been calculated and a deep analysis of measured data has been conducted providing the general baseline situation of the sites before installation of the BIPV systems.

In terms of indoor environmental conditions, a baseline situation has been established as well leading to an overview of the level of comfort achieved in each of the areas where BIPV may have an impact. For all the demonstration sites, the measurements of indoor environmental conditions conducted during the baseline period and the first results obtained with the simulation of the pilot sites indicates that it will be difficult to highlight a noticeable temperature evolution due to BIPV installation during the demonstration.

The next steps associated with monitoring activities will consist in installing additional instrumentation allowing the monitoring of BIPV installations performances. Once BIPV systems are installed and fully operational, the measured data will be compared to the baseline data in order to highlight possible impact of the BIPV systems on the buildings energy performances and indoor environmental conditions.

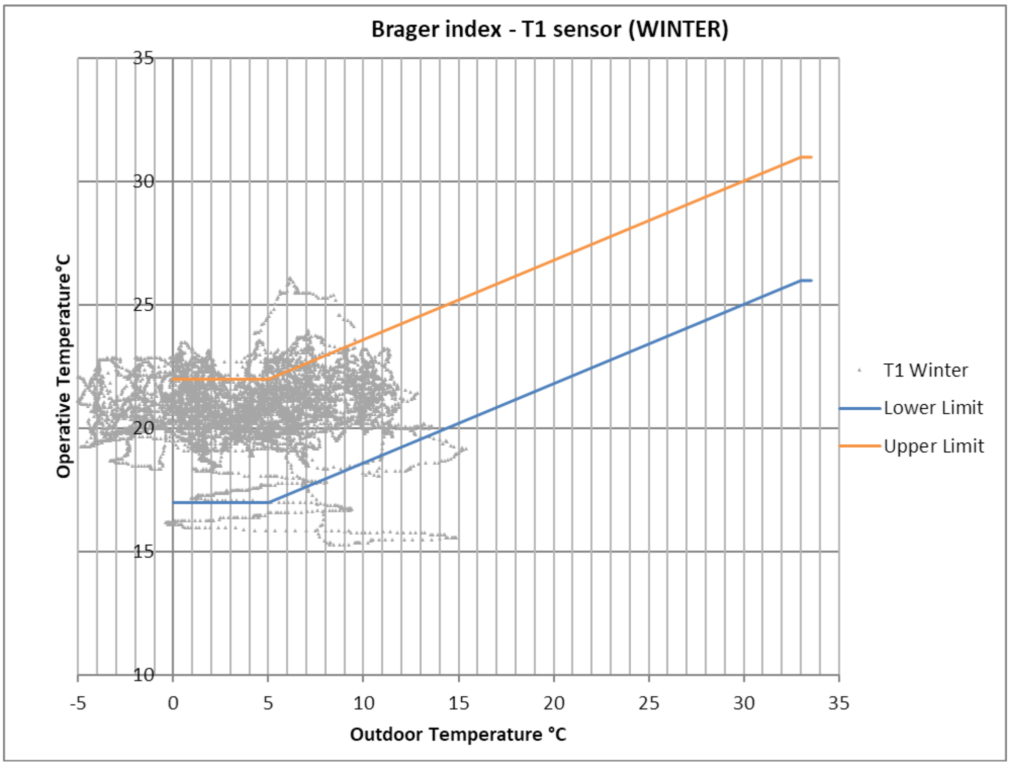
5 REFERENCES

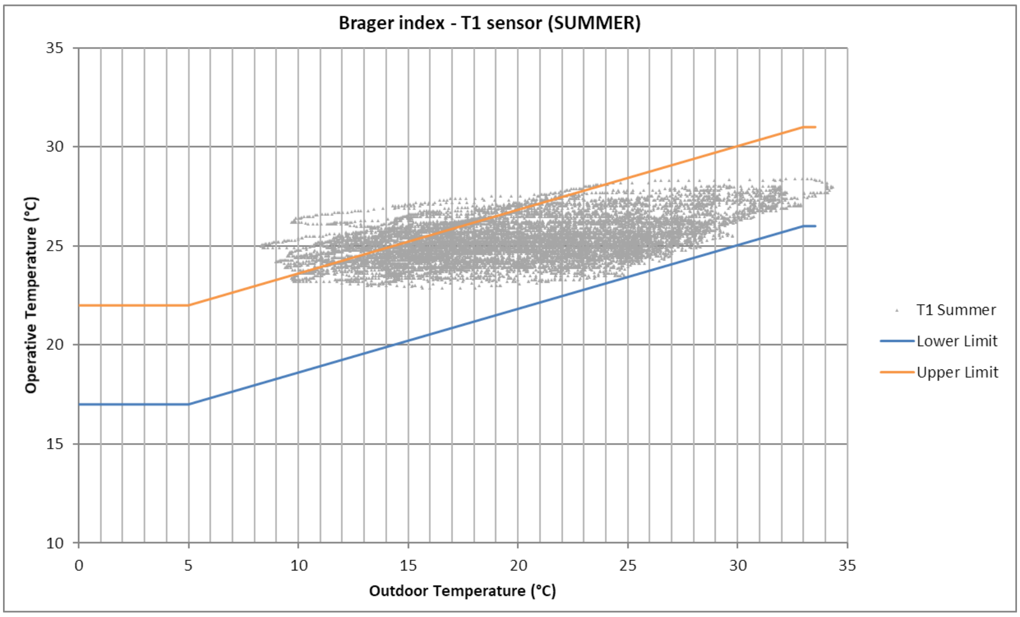
[1] EVO, International Performance Measurement and Verification Protocol, Concepts and Options for Determining Energy and Water Savings, Volume 1, EVO 10000-1, 2012.

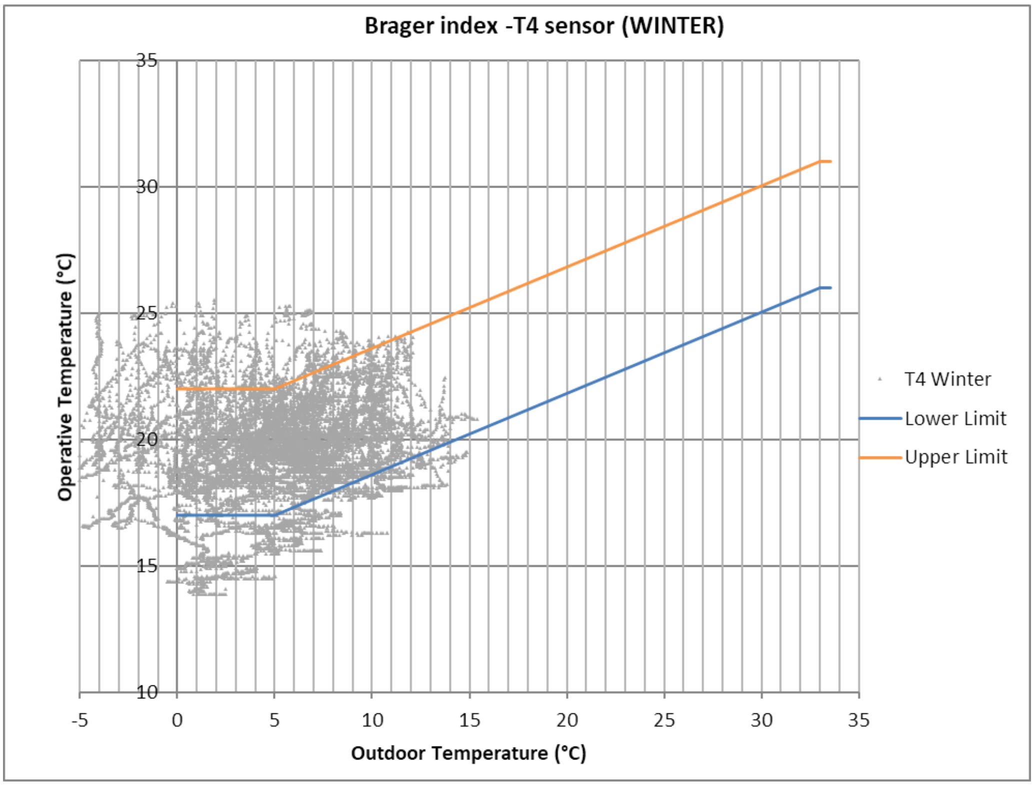
[2] EVO, International Performance Measurement and Verification Protocol, Concepts and Practices for Determining Energy Savings in Renewable Energy Technologies Applications, Volume III, August 2003.

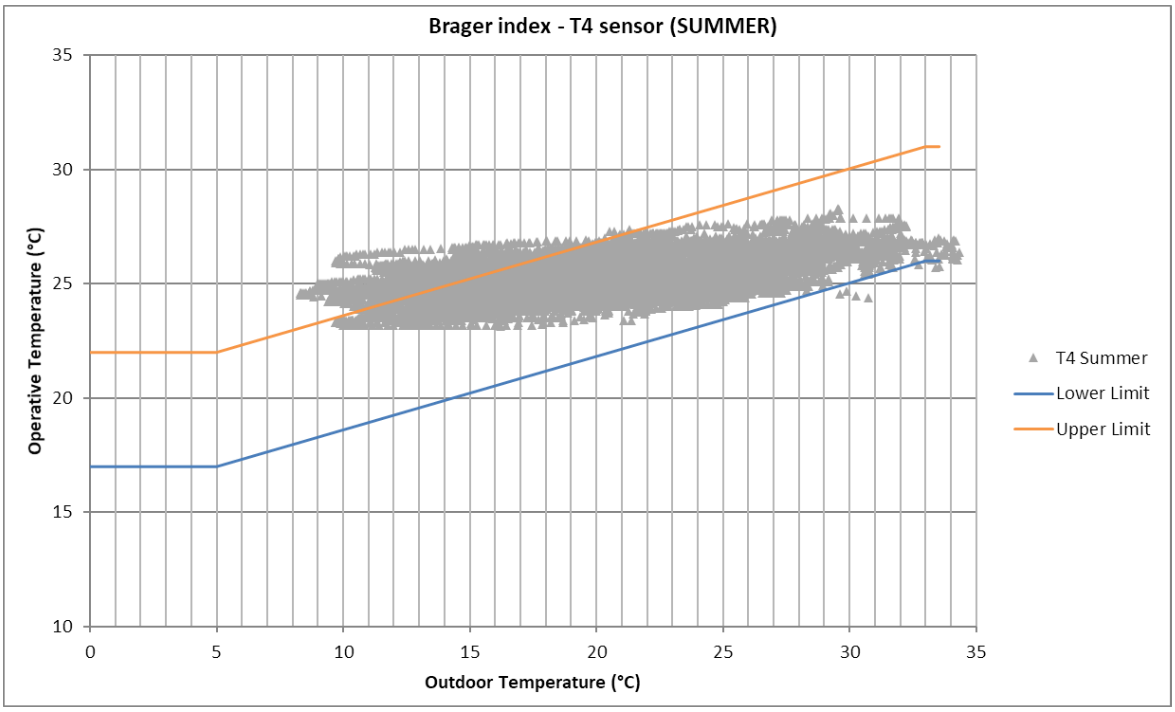
6 ANNEXES

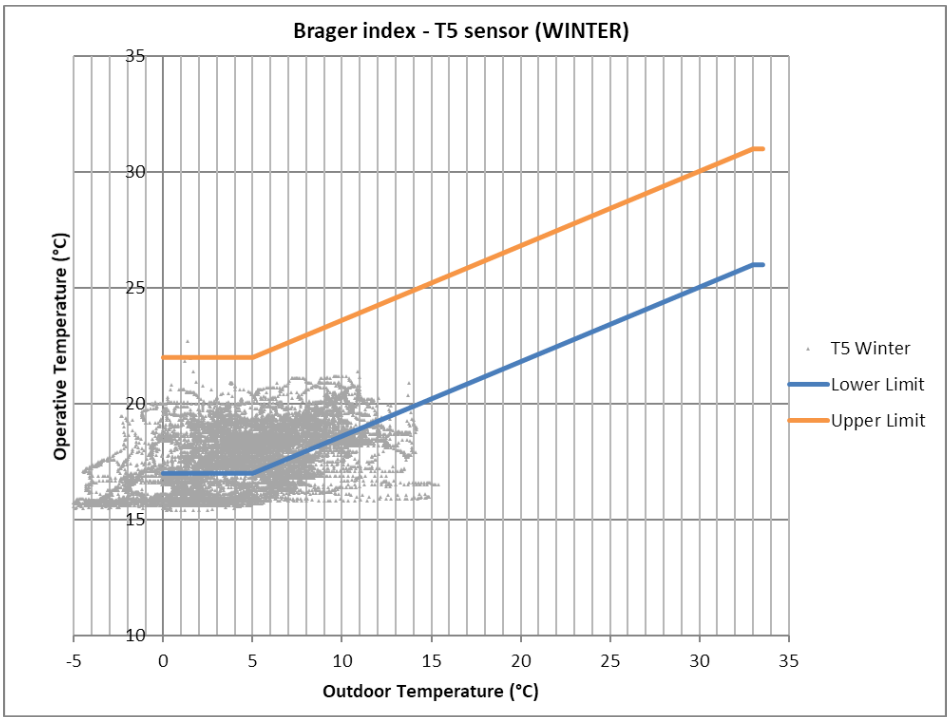
6.1 Annex 1. Brager diagrams for the different rooms of FD2 demo site

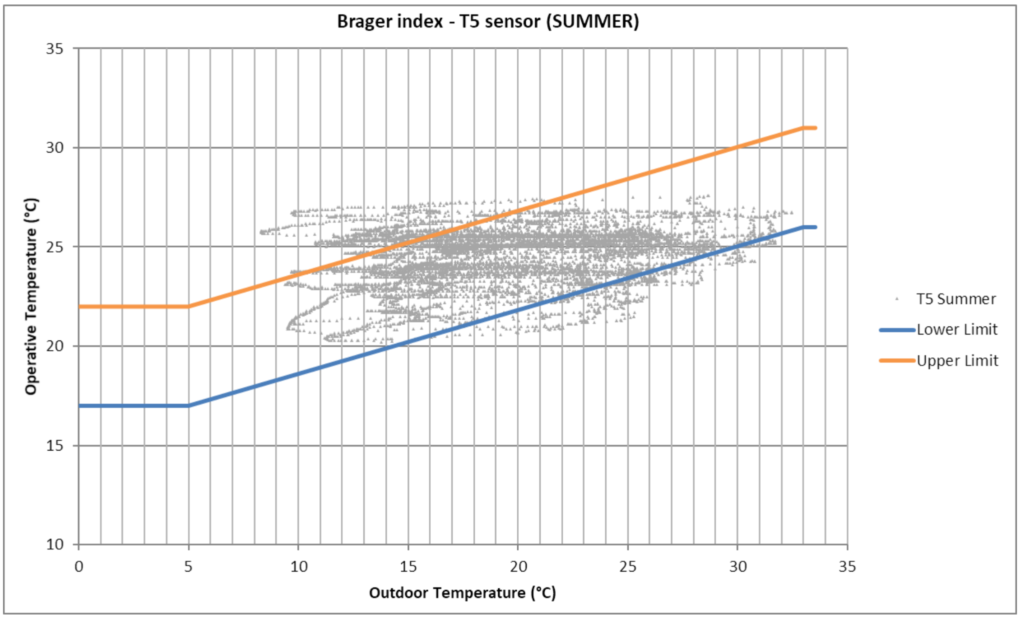


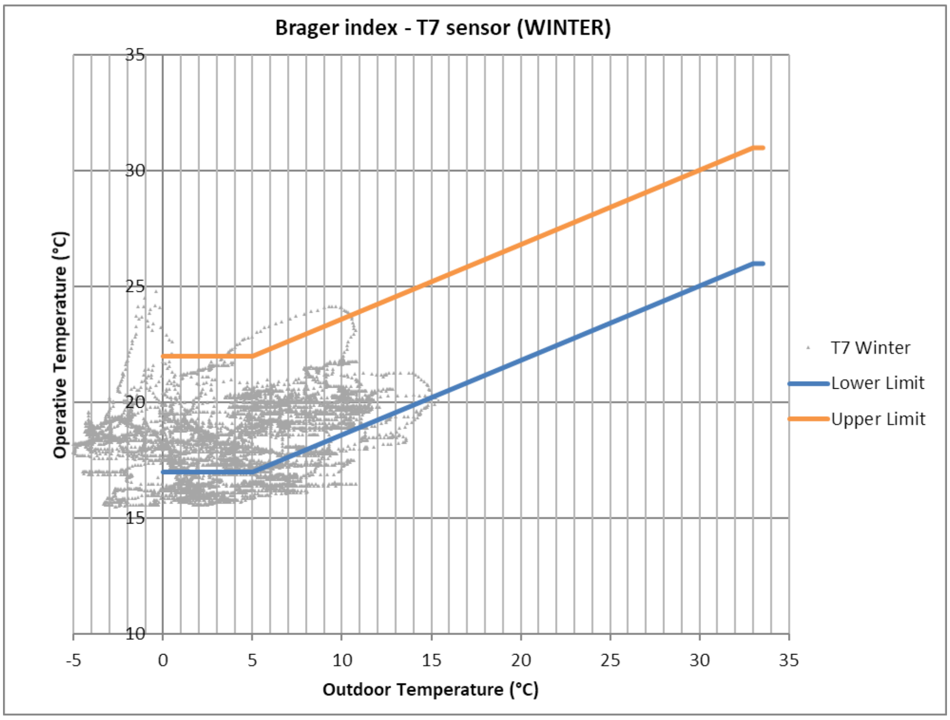


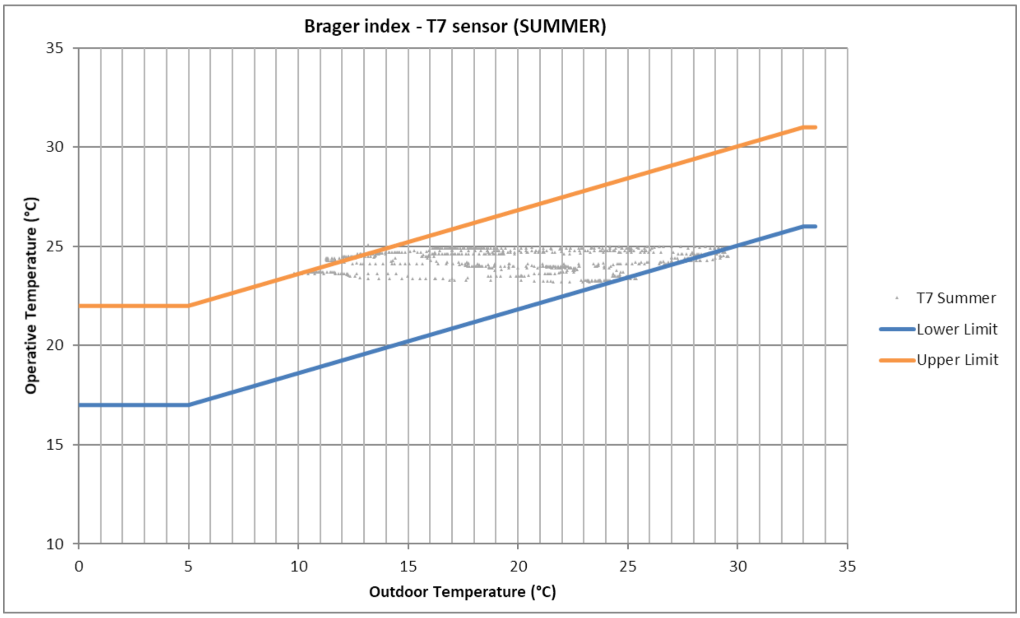

Brager index -T4 sensor (WINTER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
-5
0
5
10
15
20
25
30
35
T4 Winter
Lower Limit
Upper Limit

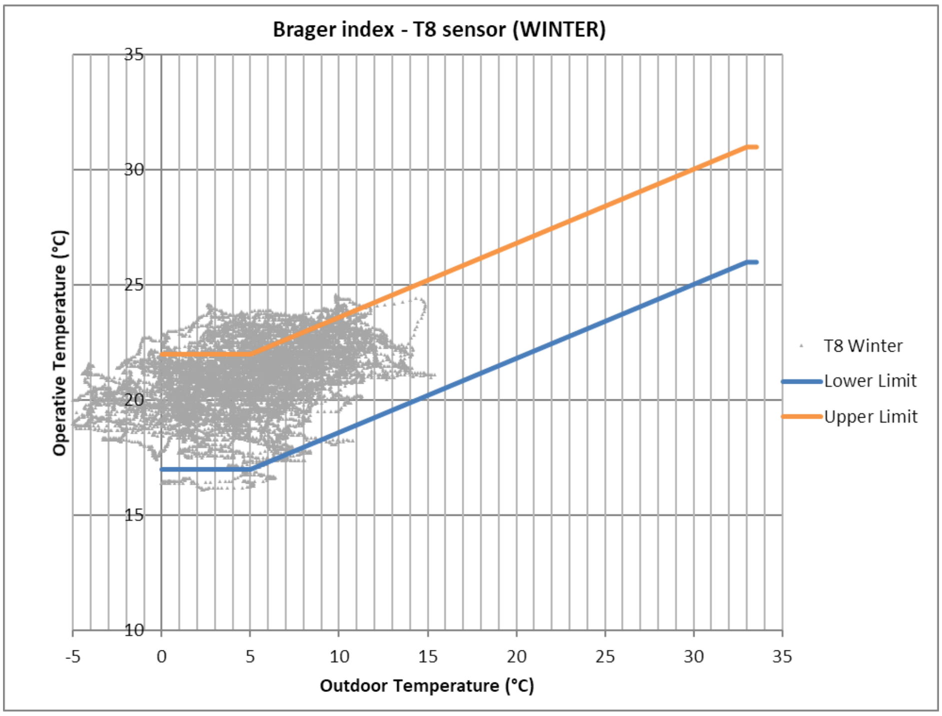

Brager index - T4 sensor (SUMMER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
0
5
10
15
20
25
30
35
T4 Summer
Lower Limit
Upper Limit

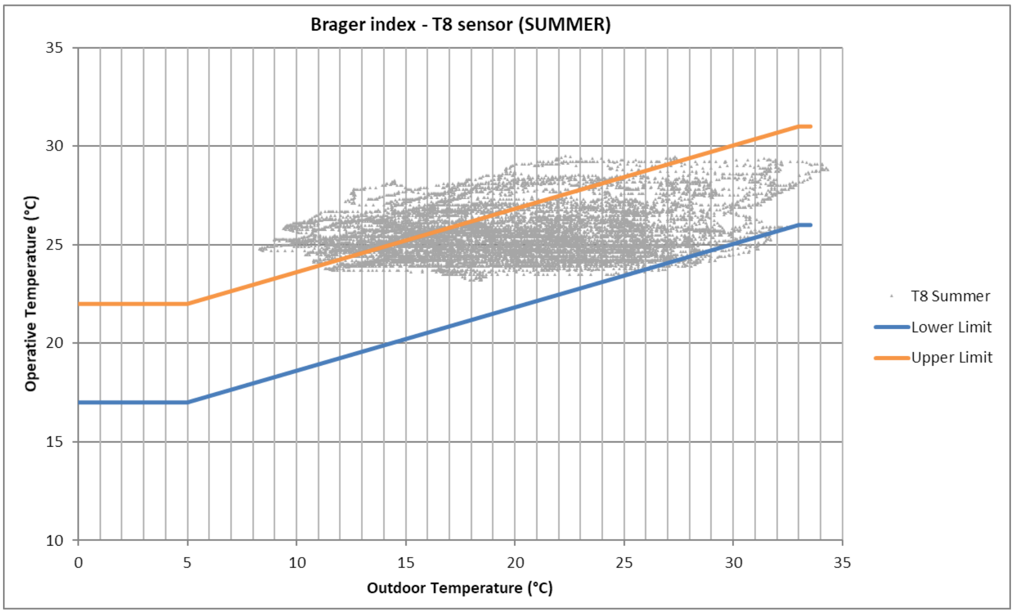

Brager index - T5 sensor (WINTER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
-5
0
5
10
15
20
25
30
35
T5 Winter
Lower Limit
Upper Limit

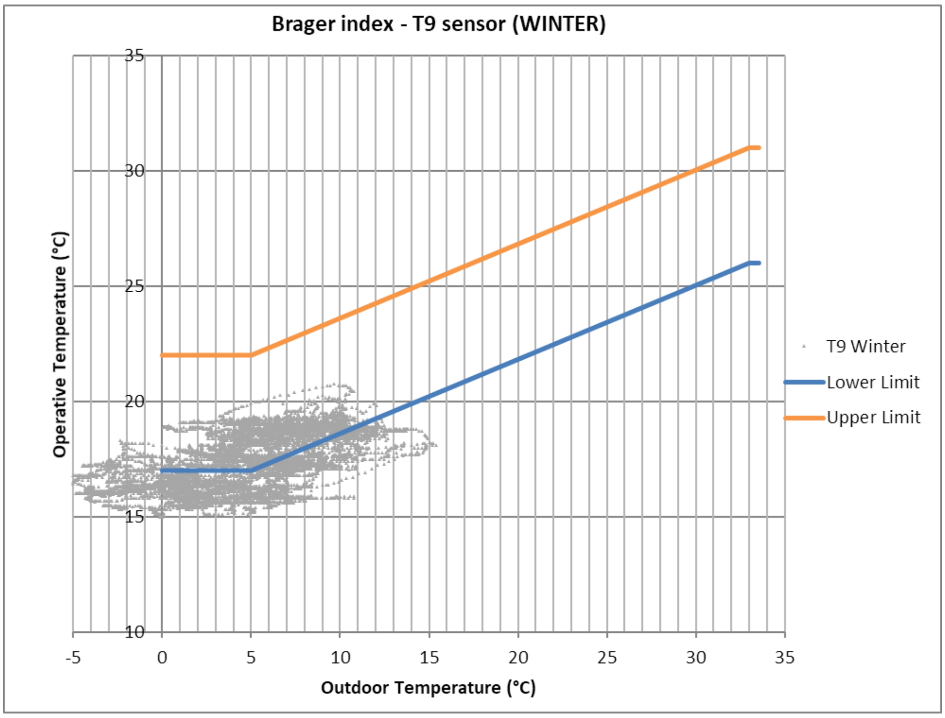

Brager index - T5 sensor (SUMMER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
0
5
10
15
20
25
30
35
T5 Summer
Lower Limit
Upper Limit

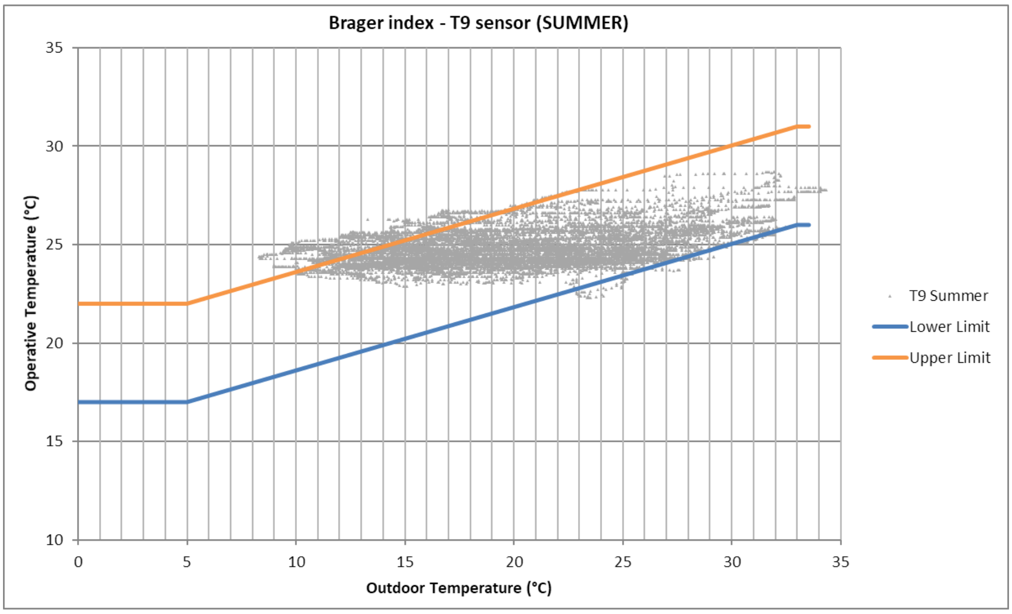

Brager index - T7 sensor (WINTER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
-5
0
5
10
15
20
25
30
35
T7 Winter
Lower Limit
Upper Limit


Brager index - T7 sensor (SUMMER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
0
5
10
15
20
25
30
35
T7 Summer
Lower Limit
Upper Limit

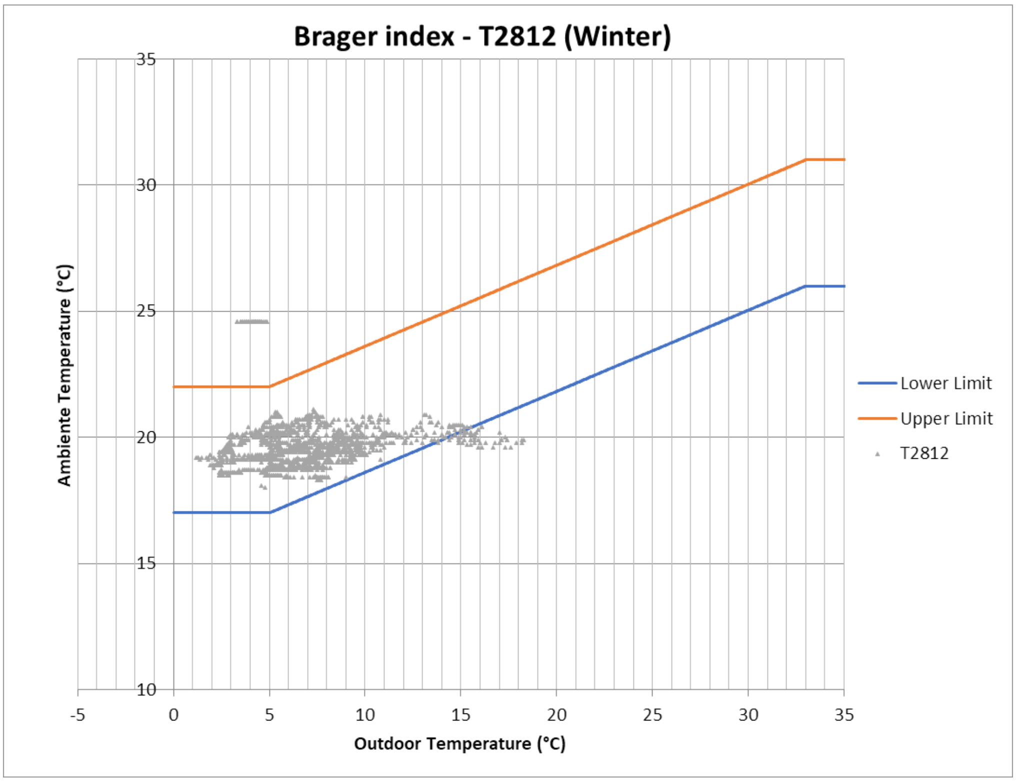

Brager index - T8 sensor (WINTER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
-5
0
5
10
15
20
25
30
35
T8 Winter
Lower Limit
Upper Limit

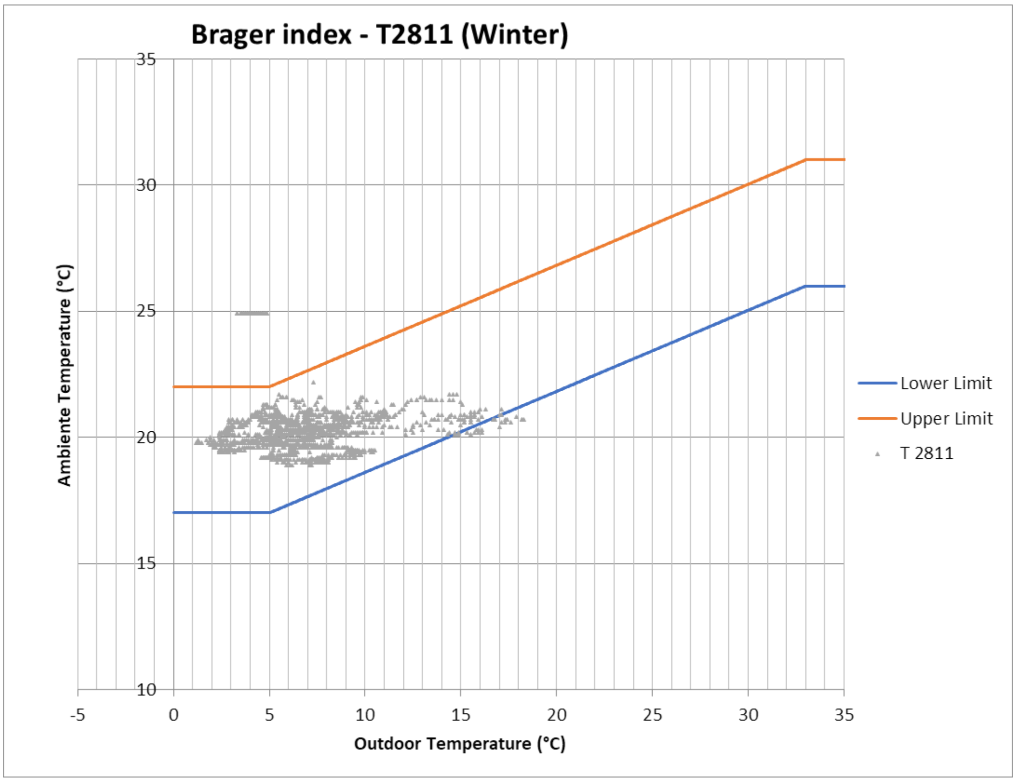

Brager index - T8 sensor (SUMMER)
Operative Temperature (°C)
Outdoor Temperature (°C)
35
30
25
20
15
10
0
5
10
15
20
25
30
35
T8 Summer
Lower Limit
Upper Limit


Brager index - T9 sensor (WINTER)
Operative Temperature (°C)
Outdoor Temperature (°C)
T9 Winter
Lower Limit
Upper Limit

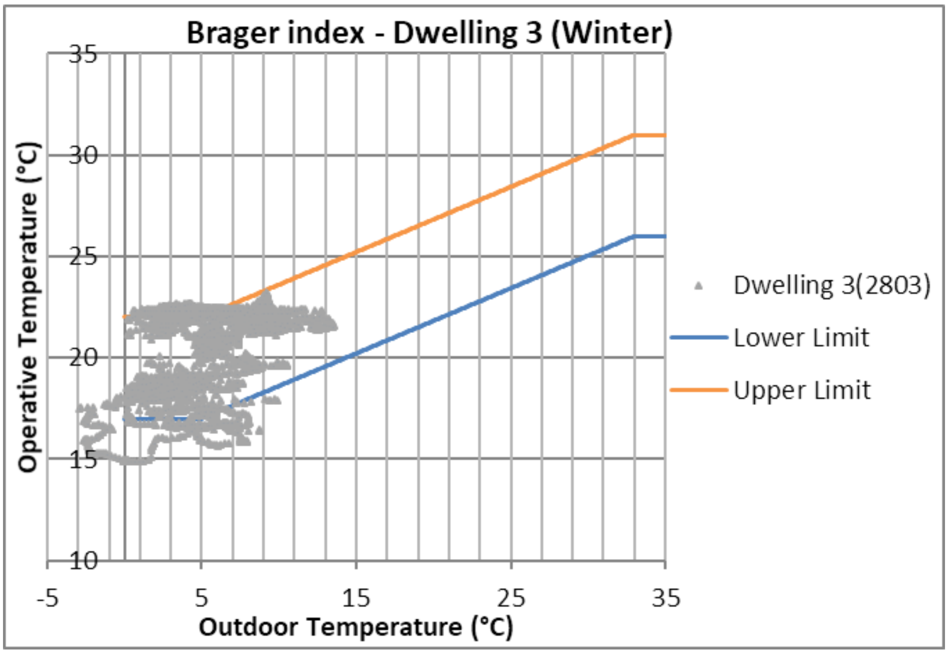

Brager index - T9 sensor (SUMMER)
Operative Temperature (°C)
Outdoor Temperature (°C)
T9 Summer
Lower Limit
Upper Limit

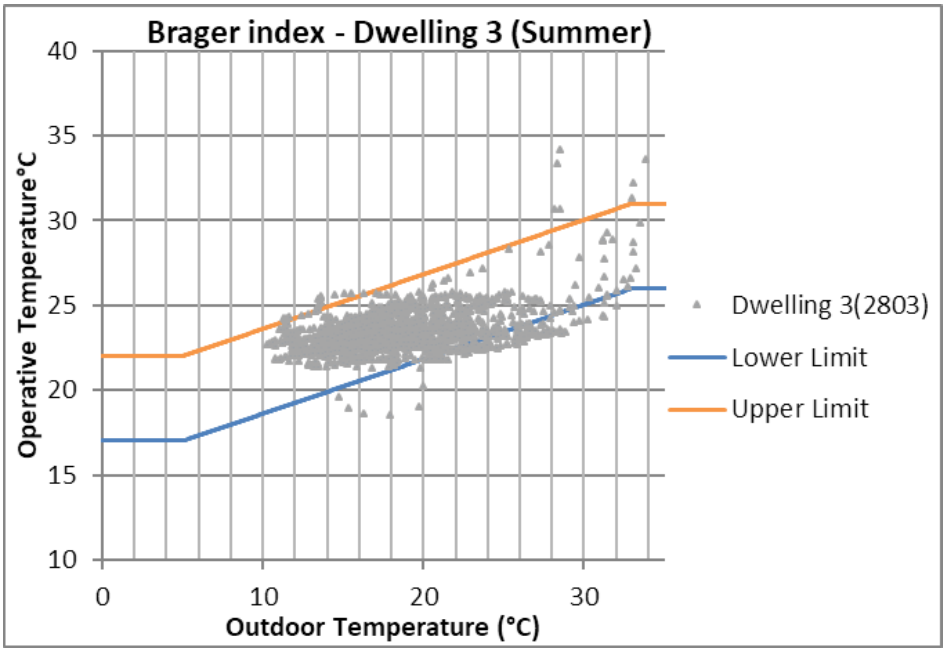
6.2 Annex 2. Brager diagrams for the 2 other rooms of EHG demo site



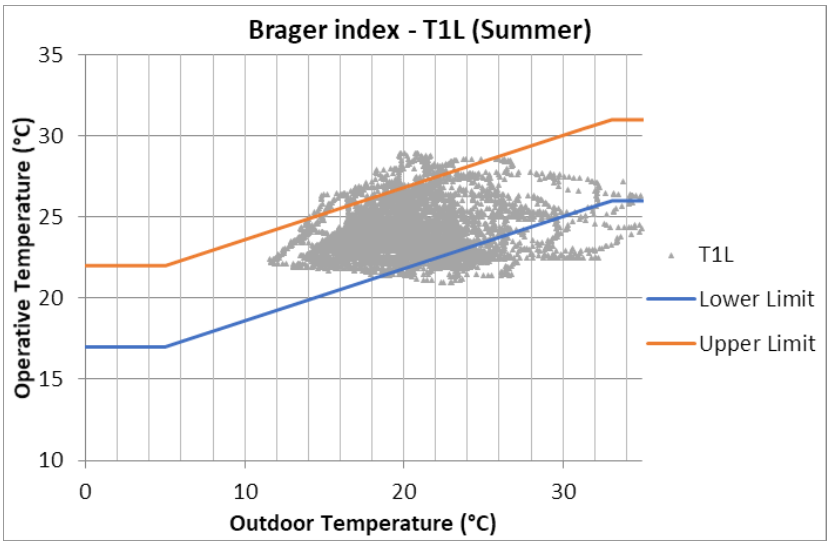


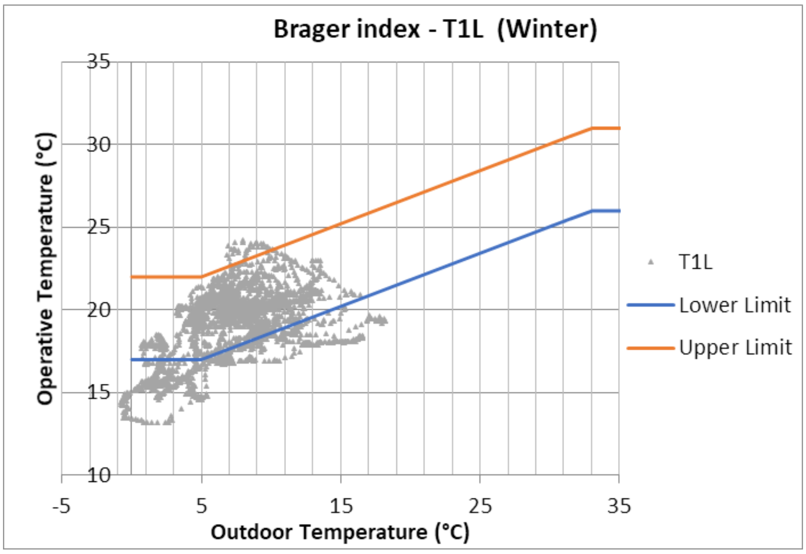
6.3 Annex 3. Brager diagrams for dwellings 3 of VILOGIA demo site

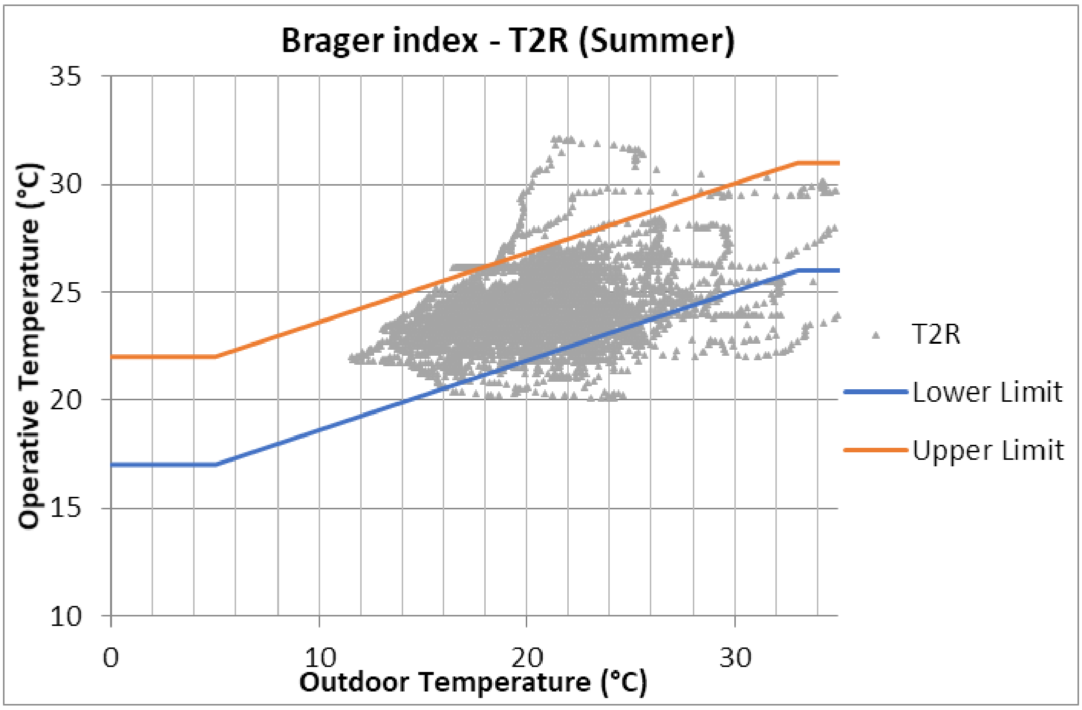




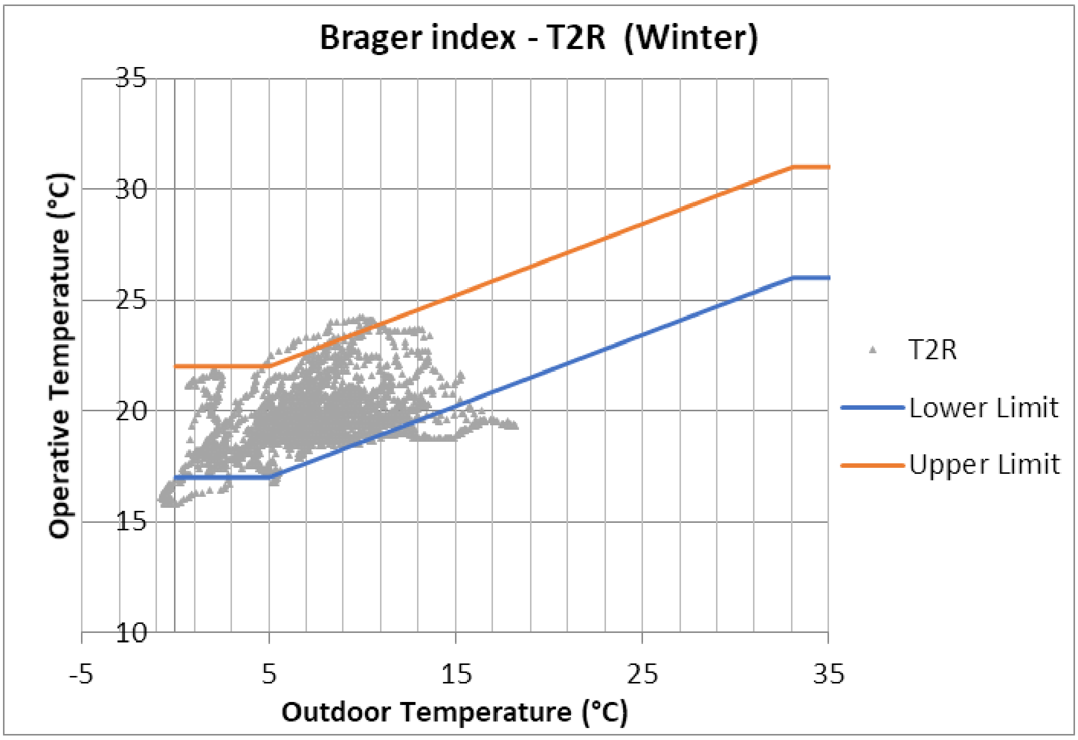
6.4 Annex 4. Brager diagrams for the 3 other rooms of TECNALIA demo site



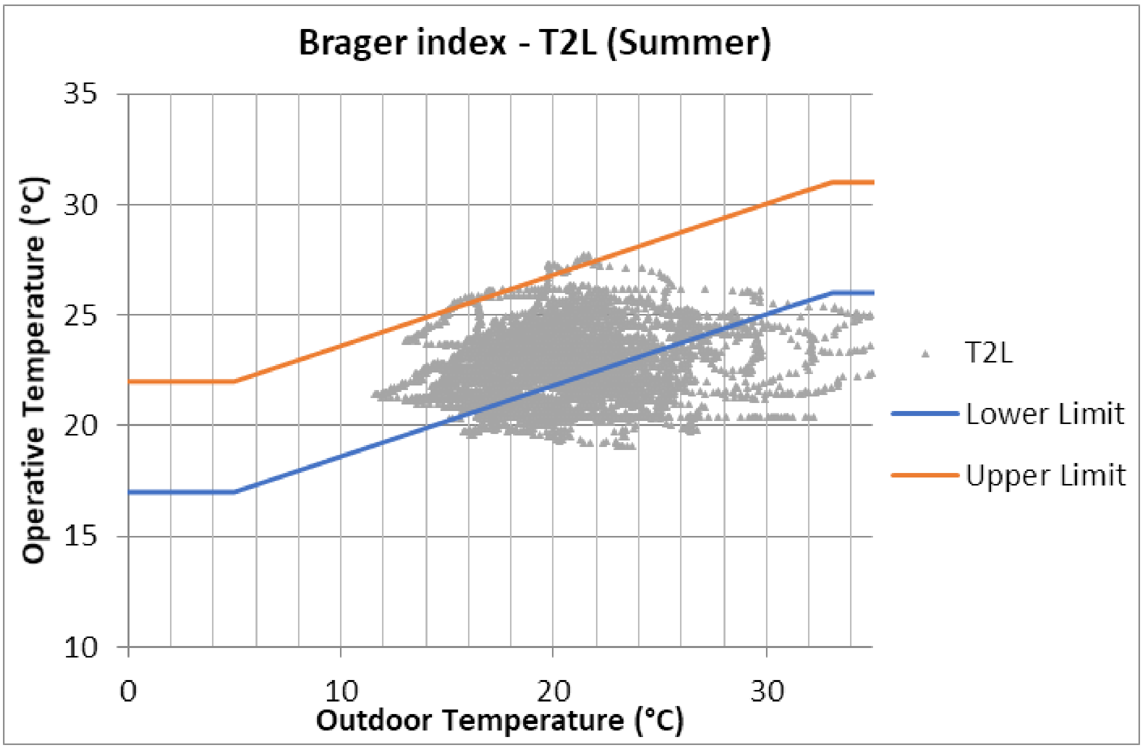


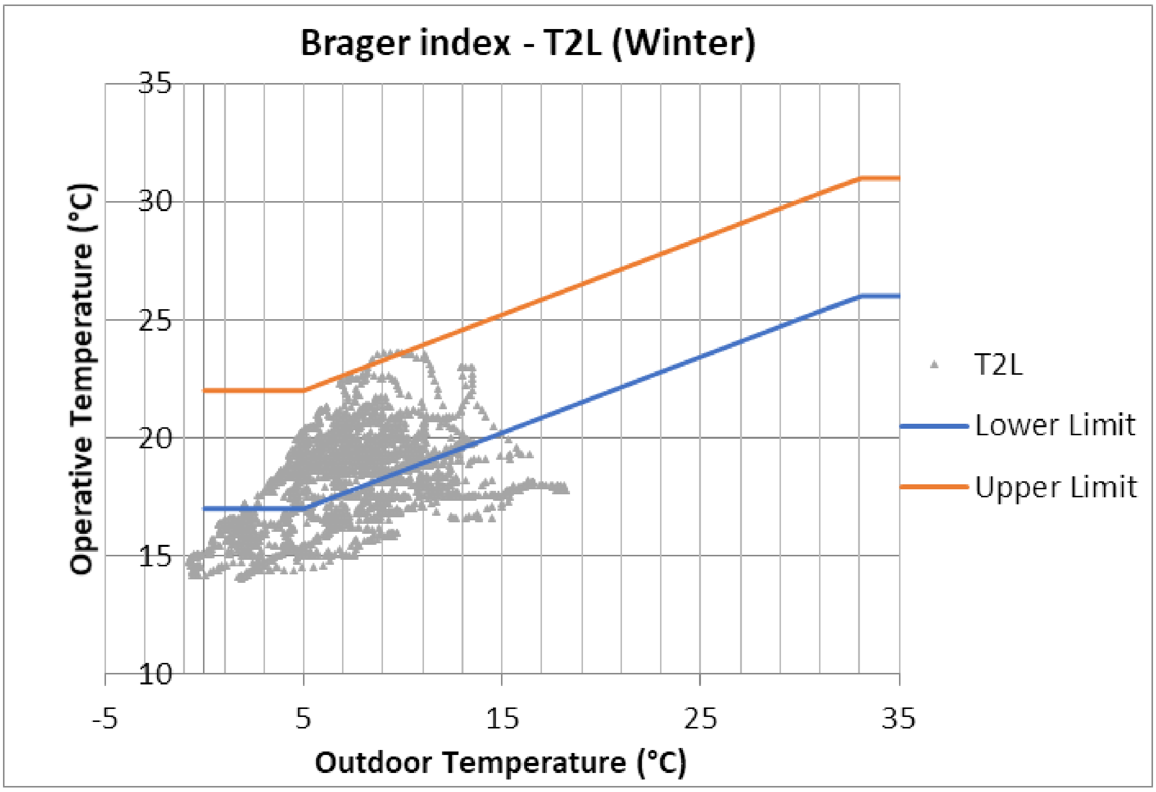


Brager index - T2R (Summer)
35
30
25
20
15
10
Operative Temperature (°C)
0
10
20
30
Outdoor Temperature (°C)
T2R
Lower Limit
Upper Limit



Brager index - T2R (Winter)
35
30
25
20
15
10
Operative Temperature (°C)
-5
5
15
25
35
Outdoor Temperature (°C)
T2R
Lower Limit
Upper Limit


Brager index - T2L (Summer)
35
30
25
20
15
10
0
10
20
30
Outdoor Temperature (°C)
Operative Temperature (°C)
T2L
Lower Limit
Upper Limit


Brager index - T2L (Winter)
35
30
25
20
15
10
-5
5
15
25
35
Outdoor Temperature (°C)
Operative Temperature (°C)
T2L
Lower Limit
Upper Limit