Ref. Ares(2023)7770673 - 15/11/2023

H2020-LC-SC3-2018-RES

EUROPEAN COMMISSION

Grant agreement no. 818329

Sun coupled innovative Heat pumps

D6.6 – Final Report on SunHorizon monitoring activities

Due date of deliverable: 30.09.2023

Actual submission date: 30.09.2023

Organisation name of lead contractor for this deliverable: BDR

Participants : RINA, CEA, CARTIF, EMVS, Sant Cugat, ITAE CNR, RTU

Dissemination Level **(Specify with "X" the appropriate level)**		
PU	Public	X
CO	Confidential	

Project Contractual Details

Project Title	Sun coupled innovative Heat pumps
Project Acronym	SunHorizon
Grant Agreement No.	818329
Project Start Date	01-10-2018
Project End Date	30-09-2023
Duration	60 months

Supplementary notes: This document will be publicly available (on CORDIS and project official websites) as soon as approved by EC

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List of acronyms and abbreviations

Abbreviation	Meaning
KPI	Key Performance Indicators
DHW	Domestic Hot Water
SH	Space heating
SC	Space cooling
SHC	Space Heating and Cooling
RES	Renewable energy sources
TP	Technology Packages
AWHP	Air-to-Water heat Pump
WWHP	Water-to-Water heat Pump

Summary

SunHorizon (SH) will demonstrate up to TRL 7 innovative, reliable, cost-effective coupling of solar and HP technologies. SunHorizon addresses three main research pillars that interact each other towards project objectives achievement, demonstration and replication: i) optimized design, engineering and manufacturing of SunHorizon technologies, ii) smart functional monitoring for H&C, iii) Key Performance Indicators (KPI) driven management and demonstration.

T2.4 established a list of indicators to assess the performances of SunHorizon standalone technology and combined packages during their operational phase and for the simulation scenarios to achieve project objectives. In order to calculate these KPIs, within WP4 a proactive KPI-based tool has been developed. The KPI-based maintenance tool will automatically calculate the KPIs of each demo site. T6.4 aims at demonstrating that the actual KPIs are being achieved, and what are the deviations from the grant agreement. The first deliverable is deliverable D6.4, in which the methodology to report KPIs and PIs were reported.

Now in D6.6 the following activities have been conducted:

Review of monitoring data production, collection and operation summary report of the SunHorizon installed TPs

Reporting monitoring and operation summary (KPIs)

The present document will report the operation summary of the demos over the past months (summer period) and detect ways to improve the data collection and control of the TPs.

Keywords

Key performance indicators, monitoring campaign, project demonstration, project results, project impacts

1 Introduction

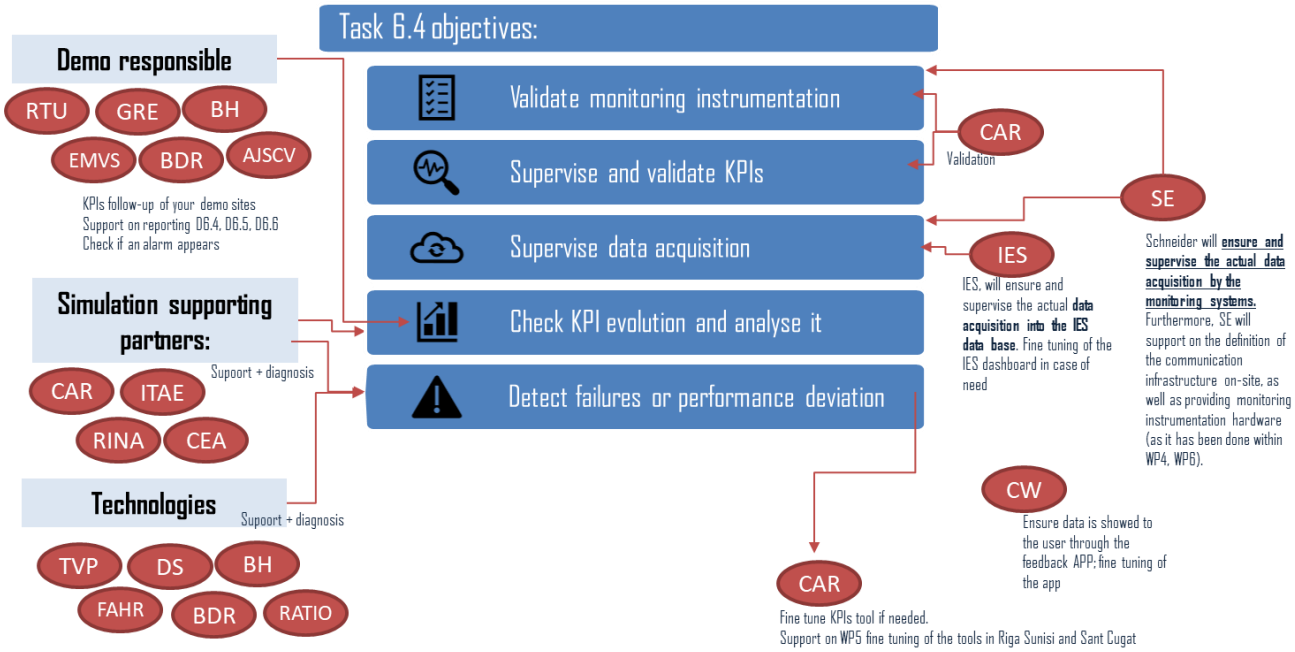


Figure 1- Task 6.4 overview: objectives and responsibilities of partners.

1.1 Task structure

The first activity to be conducted within T6.4, is to continue the way of working established within D6.4.

D6.6 will continue D6.5 with the evolution of KPIs and developments and updates of the monitoring campaign of each demo that should be explained.

Table 1- Deliverables from T6.4

	Content	Due in	Lead beneficiary
D6.4	Establish the common methodology for the demonstration of project KPIs	30/09/2021	CARTIF
D6.5	Report the first 6 months (M42-M48) achievements of project KPIs	31/10/2022	AJSCV
D6.6	Report the last 6 months (M48-M60) achievements of project KPIs	30/09/2023	BDR

The collection of data for the KPIs demonstration is described in the following figure:

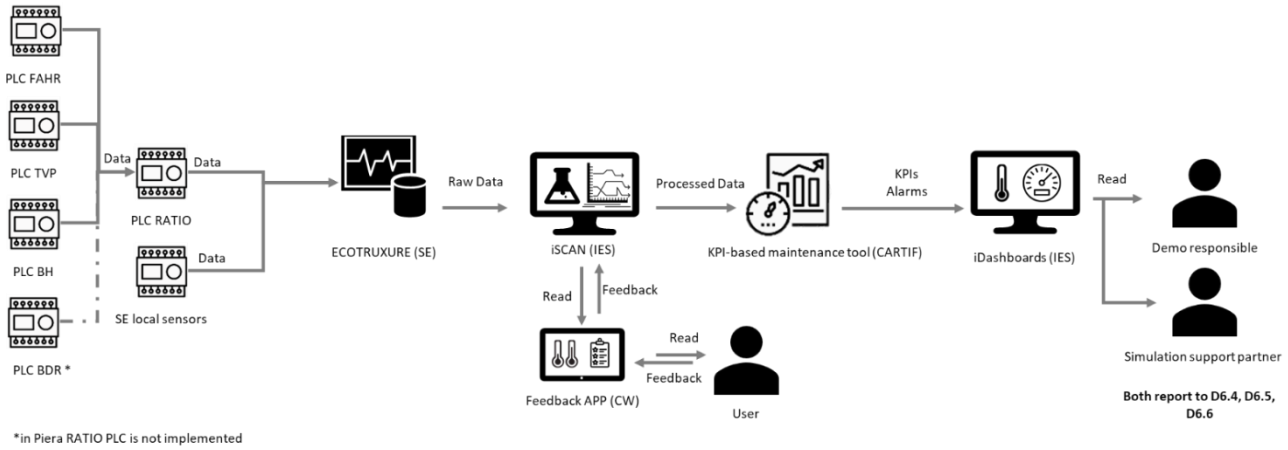


Figure 2- Data collection flow. Demos communicate feedback through the feedback APP and download data from the iDashboard of IES

Generally, in all demo sites the different PLC from the technologies will communicate with RATIO's PLC. RATIO will then communicate the data to the EcoStruxure server[1] from Schneider (SE). In parallel, SE also implemented direct communication with BH (Riga demo, Sunisi and Imanta).

Once the data is gathered by EcoStruxure, iSCAN will get it and process it (filling data gaps, for example). The processed data will be used by the KPI-based maintenance tool to calculate KPIs and alarms, that will be shown: 1) in the dashboard for the demo site responsible and simulation supporting partners; 2) to the user through the feedback App from CW to read and provide feedback. The Dashboard will be used for reporting the project achievements in D6.5 and D6.6

Thus, the responsibilities of each partner will be:

[1] BH's PLC is also testing the direct communication with EcoStruxure. But it is still unclear.

Table 2- Responsibilities within T6.4 of the monitoring campaign and KPIs demonstration

Partner	Main responsibility	Frequency
CARTIF	Lead T6.4. Establish methodology of KPIs gathering and reporting Support on KPIs follow-up of the following demo sites: Riga Sunisi, Madrid Fine tune KPIs tool if needed. Support on WP5 fine tuning of the tools in Riga Sunisi and Sant Cugat	Check if an alarm appears in one of the following demo sites: Madrid. Help to diagnose it Support demo sites in KPIs reporting (every month) Lead reporting D6.4, and support D6.5 and D6.6
ITAE	Support on KPIs follow-up of Sant Cugat Support on reporting D6.4, D6.5, D6.6 when is due Check if an alarm appears Help to diagnose it	Support demo sites in KPIs reporting (every month) Deliverables when are due Alarms when are raised up
CEA	Support on reporting D6.4, D6.5, D6.6 when is due	Deliverables when are due
RINA-C	Support on KPIs follow-up of Riga Imanta Support on reporting D6.4, D6.5, D6.6 when is due Check if an alarm appears Help to diagnose it	Support demo sites in KPIs reporting (every month) Deliverables when are due Alarms when are raised up
CLUJ NAPOCA	Support on reporting D6.6	Deliverables when are due
RTU	KPIs follow-up of Riga-Sunisi and Riga Imanta Support on reporting D6.4, D6.5, D6.6 Check if an alarm appears	KPIs reporting (every month) Deliverables when are due Alarms when are raised up
EMVS	KPIs follow-up of Madrid Support on reporting D6.4, D6.5, D6.6 Check if an alarm appears	KPIs reporting (every month) Deliverables when are due Alarms when are raised up
BDR	Support on reporting D6.4, D6.5, D6.6 Coordinating D6.6 report	Deliverables when are due
AJSCV + VEOLIA	KPIs follow-up of Sant Cugat Support on reporting D6.4, D6.5, D6.6 Check if an alarm appears	KPIs reporting (every month) Deliverables when are due Alarms when are raised up
SE	Schneider will ensure and supervise the actual data acquisition by the monitoring systems. Furthermore, SE will support on the definition of the communication infrastructure on-site, as well as providing monitoring instrumentation hardware (as it has been done within WP4, WP6).	Every time that data flow is broken

IES	IES, will ensure and supervise the actual data acquisition into the IES data base. Fine tuning of the IES dashboard in case of need	Every time that data flow is broken
Technologies: FAHR, BDR, TVP, DS, BH, RATIO	Demonstrate PIs evolution	Help to explain alarms and PIs reporting (Every month) Operation of their technologies goes smoothly (in case of any fault, help demo sites to identify/solve it).
IVL	Ensure the monthly gas consumption and electricity consumption is gathered for LCA	Every 6-month

The monitoring and operation summary (KPIs) tools will be communicated with specific demo responsible and demo support partners in dedicated calls.

As Riga-Sunisi and Sant Cugat are Type A demo sites (i.e. where WP5 tools will be fully demonstrated), pre-monitoring data has been obtained to feed the calibration of the building models and existing energy systems (such as radiators, ground floor heating or the existing heat pumps in Sant Cugat).

As a reminder of D4.2 codification of the demos is listed below:

- [TP1] Berlin #1
- [TP2] Nürnberg #2
- [TP3] Sant Cugat #3
- [TP4] Madrid #4
- [TP4] Piera #5
- [TP1] Verviers public Sport Centre #6
- [TP2] Verviers Swimming Pool #7
- [TP2] Riga Imanta #8.1
- [TP2] Riga Sunisi #8.2
- [TP4] Cluj Napoca #9

As Verviers public sport centre, Berlin, Nürnberg, Piera and Cluj Napoca (demo 1, 2, 5, 6, 7, 9) withdraws from the project, it will not be included in the present deliverable. **Nevertheless, the codification will remain this way to be consistent with the past deliverables.**

2 Methodology

WP2 defined a list of KPIs and PIs within Task 2.3. An estimation of the expected achievements for each KPI was calculated as well. This is known in D2.4 as "threshold". The demo responsible and demo supporting partners will determine whether the KPIs of their demo are within the threshold or not, and will diagnose the reason.

2.1 Summary of what will be reported during the monitoring campaign

WP2 defined a list of KPIs and PIs within Task 2.3. An estimation of the expected achievements for each KPI was calculated as well. This is known in D2.4 as "threshold". The demo responsible and demo supporting partners will determine whether the KPIs of their demo are within the threshold or not, and will diagnose the reason.

Project KPIs (project level)

Table 3- Summary of KPIs: description, code (to know what to download), frequency of acquisition and threshold from WP2. The "Nº" indicates the number of the demo site

KPI	Description	Code in iSCAN	Frequency	Threshold
CAPEX	Capital expenditure	K.CAPex-Nº	One-off	reduction from 5 to 10%
CBR	Costumer's bills reduction	K.CBRsy-Nº-mon	Monthly (and yearly)	up to 60%.
CSAT*	Customer's satisfaction rate	K.CSAtu-Nº	Unknown	No threshold
GHG savings	GHG emissions reduction	K.GHGsa-Nº-mon	Monthly (and yearly)	40 to 60% (expressed in relative values)
HCI	Heating comfort index (building level)	K.HCIsy-Nº-mon	Monthly (and yearly)	7 to 15 °C·h
CCI	Cooling comfort index (building level)	K.HCIsy-Nº-mon	Monthly (and yearly)	7 to 15 °C·h
LCOH	Levelized cost of heat	K.LCOhs-Nº	Yearly	from 2 to 4 cts€/kWh
OPEX	Operational expenditure	K.OPExs-Nº	Yearly	a reduction from 10 to 20% of the OPEX
PESnren (absolute) And relative: $f_{sav,PE_{nren}}$	Non-renewable primary energy savings	K.PESnr-Nº-mon	Monthly (and yearly)	50 to 70% (expressed in relative values)
RER	Renewable energy ratio	K.RERsy-Nº-mon	Monthly (and yearly)	40 to 70% (expressed in relative values)
SCR	Electricity self-consumption fraction	K.SCRsy-Nº-mon	Monthly (and yearly)	up to 80% of self-consumption ratio
SPB	Simple pay back	K.SPBsy-Nº	One-off	10 years

*CSAT frequency will depend on the amount of feedback received from the user.

Besides the threshold, the modelled direct impact of the eight SunHorizon demonstration cases was:

- Primary energy savings: 107 kWh/m²/yr
- Reduction of thermal energy bill: 5.9 €/m²/yr
- GHG emission savings: 23 kg-CO_2/m²/yr

- Share of energy consumption from RES for H&C: 58%
- Investment: 721,510 €

Project PIs (Technologies)

SunHorizon will demonstrate at TRL7 modular, high-performance, integrated, affordable **components** to provide low-carbon heating and cooling in residential and commercial buildings. The solutions will rely on renewable, local energy sources to promote feasible alternatives to traditional fossil fuel-based solutions, as well as on energy storage to flexibly match the thermal energy supply with the demand.

Particularly, each technology aims to improve their components (within WP3) to:

- *TVP aims to achieve an instantaneous solar thermal efficiency of 70% (at 90ºC). Furthermore, TVP aims to achieve an energy output increase of 20% ,*
- *BoostHeat aims to achieve up to 200% of SGUE values (PI BH01). OPEX reduction of 20%[2].*
- *Fahrenheit aims to increase COP by 20-30% and an OPEX and CAPEX reduction of 10-15% and 20%, respectively.*
- *BDR aims to increase the COP of the systems in 15%. It will result in 15% electricity savings and 20% of OPEX reduction[3].*
- *Dual Sun aims to increase of 25% the instantaneous efficiency for low temperature applications and an increase of 60% for DHW preparation. Reduce the CAPEX in 10%.*
- *RATIO aims to increase annual solar energy capture by 20% and O&M cost reduction in 15%.*

The objective is not to achieve the improvements in real time operation (and at a system level), but at component level (in test labs in WP3). Nevertheless, using PIs calculation, it could be analysed if at system level some of these objectives are also achieved.

Table 4- Summary of PIs: description, code (to know what to download), frequency of acquisition and threshold from WP2

PI	Description	Frequency	Technology
$\eta^{gross}_{TVP,at\,T_{supply}}$	Instantaneous thermal efficiency	Monthly	TVP
$f_{sol,th}$	Solar Thermal Fraction	Monthly	TVP
$SGUE$	Seasonal Gas Utilization Efficiency	Monthly	BH
SPF_{BH}	Seasonal Performance Factor	Monthly	BH
$(S)EER$	Seasonal electric EER (cooling)	Monthly	FAHR
SPF_{FAHR}	Seasonal Performance Factor of FAHR unit	Monthly	FAHR
$(S)COP_{BDR}$	Seasonal electric COP (heating)	Monthly	BDR
$(S)EER_{BDR}$	Seasonal electric EER (cooling)	Monthly	BDR
SPF_{BDR}	Seasonal Performance Factor of BDR unit	Monthly	BDR
$\eta^{gross}_{DS,th}$	Instantaneous thermal efficiency:	Monthly	DS
$f_{sol,th}$	Solar thermal fraction	Monthly	DS

[2] BoostHeat withdrew from the project, so there will be no content for the demonstration phase in Berlin, Nurnberg, Riga Imanta and Riga Sunisi.

[3] The demosite of Piera withdraw from the project, so there will be no content for the demonstration phase. The demosites of Madrid, Riga Imanta and Riga Sunisi will demonstrate the performance indicators for BDR technology.

$\eta_{DS,el}^{gross}$	Solar Electric efficiency	Monthly	DS
TER	Thermal-electric Ratio	Monthly	DS
dT	Stratification Efficiency		RATIO

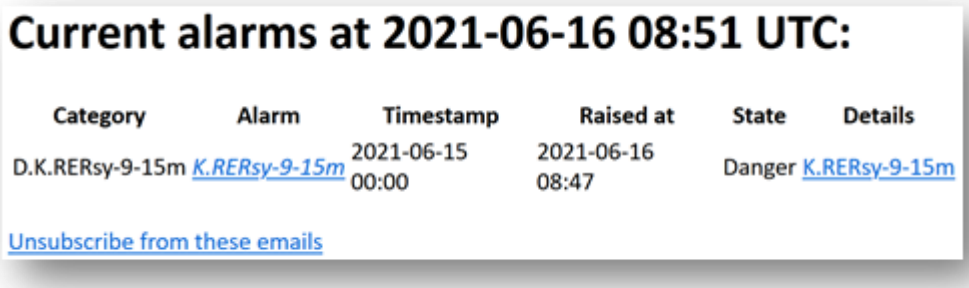
Alarms

An automatic email will be sent by iSCAN to the demo site supervisors

The status of the alarm can be warning or danger.

It is responsibility of demo site supervisors to assess if there is actually something damaged (e.g. the KPI of RER is decreasing from the reference value, due to the decrease of performance of PVT panels, maybe they are not clean) or alarms are being raised very often for no reason (in that case CARTIF revises and fine tunes the tool).

Every time there is an alarm, the alarm needs to be included in table of subsection B of the Annex, indicating when it was raised, what was the problem and if any action was taken/needed to solve the issue.



Current alarms at 2021-06-16 08:51 UTC:

Category	Alarm	Timestamp	Raised at	State	Details
D.K.RERsy-9-15m	K.RERsy-9-15m	2021-06-15 00:00	2021-06-16 08:47	Danger	K.RERsy-9-15m

Unsubscribe from these emails

Figure 3- Example of a typical alarm email. The image was obtained from testing the proactive maintenance tool and communication with iSCAN platform

2.2 How to report the monitoring campaign

Every month, demo site responsible does screenshots of the IES dashboard, including the monthly main 12 KPIs. Figure 5 shows an example of the dashboard. The time frame can be changed according to the needs (last month, last 7 days, etc.) and the KPIs and PIs of previous tables will be there. Screenshots will be taken every month by the demo responsible, and with the support of the simulation supporting partner an analysis will be performed.

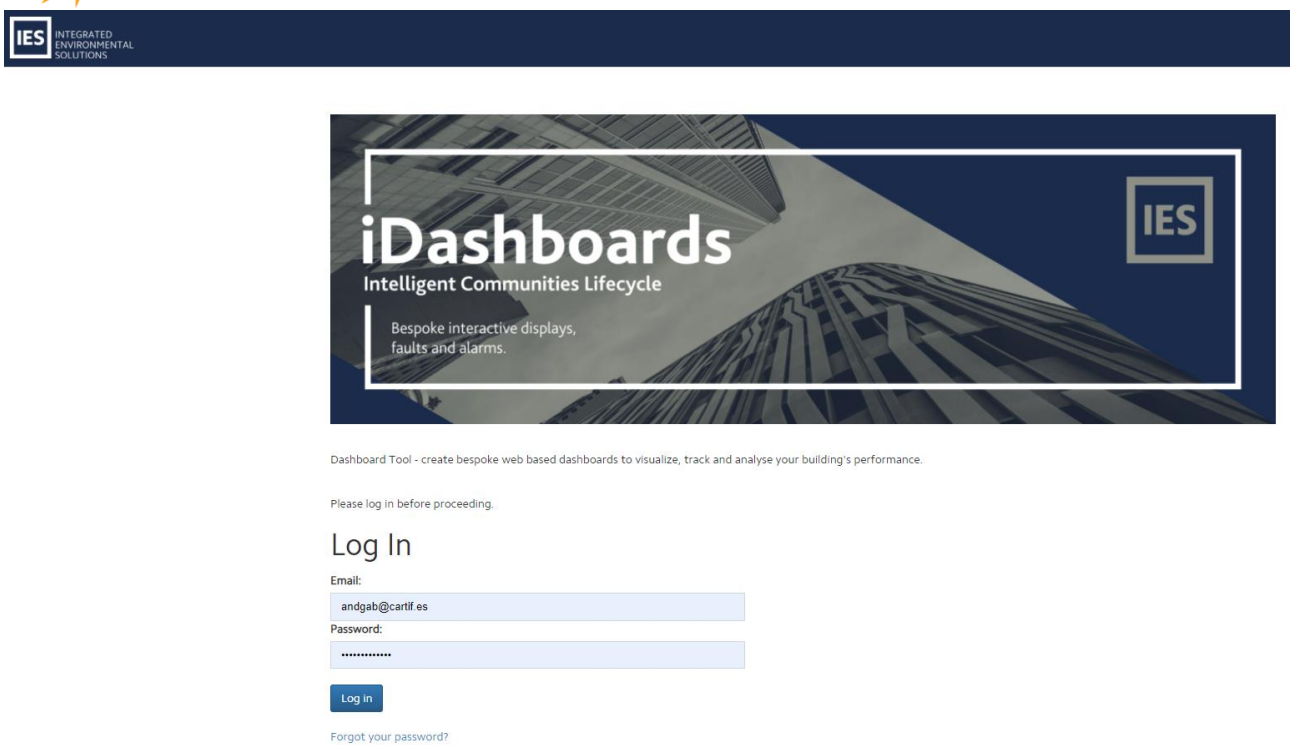


Figure 4 - iDashboard log in

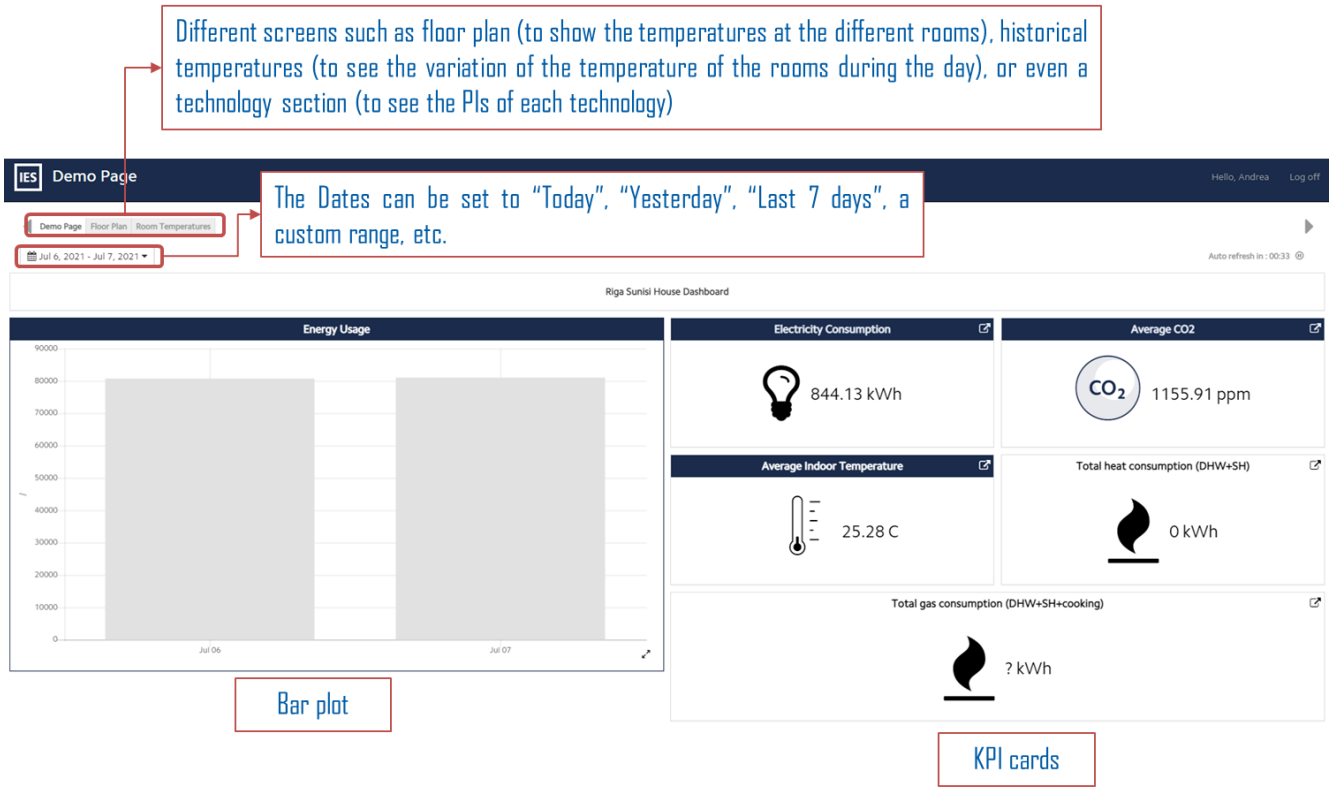


Figure 5 - IES Dashboard example. The Dates can be set to "Today", "Yesterday", "Last 7 days", etc. There will be different screens such as floor plan (to show the temperatures at the different rooms), historical temperatures (to see the variation of the temperature of the rooms during the day), or even a technology section (to see the PIs of each technology)

Then, the monthly 12 KPIs in a 6-month period is obtained (for D6.5 from September 2021 to February 2022, for D6.6 from June 2023 to October 2023). The 6-month average of the main KPIs is obtained from the Dashboard and included in Table

5. In the table if the actual value is compared with the threshold of the KPI and any deviation from the threshold is explained below the table. For example, if it has an impact on scope, and the contingency plan.

It must be considered that some KPIs will be very affected by seasonal variability, and the threshold is an annual value. Therefore, in D6.6 an average within the 12-month monitoring campaign should be also calculated.

Table 5- KPIs summary template for demonstration campaign

KPI name	Threshold	Actual value	Deviation	Impact on scope
			Yes/No	

Contingency plan of deviations can be described afterwards (e.g., set a different control strategy, refine the KPI calculation or alarm notification, etc.).

Disclaimer:

This reporting methodology was defined at the beginning of the project, and it is not adjusted to the real monitoring situation. The remaining demosites have experienced different issues that did not allow to capture monthly screenshots of the dashboards; each demosite issues and current status will be defined on their respective sections, also describing the data analysis approach carried out, with the aim to obtain as much results as possible.

3 Sant Cugat demo site #3

3.1 Status update of the demo site

The Sant Cugat demosite installation is composed of the following technologies [as shown in the table below, and connected as pictured in the diagram below]

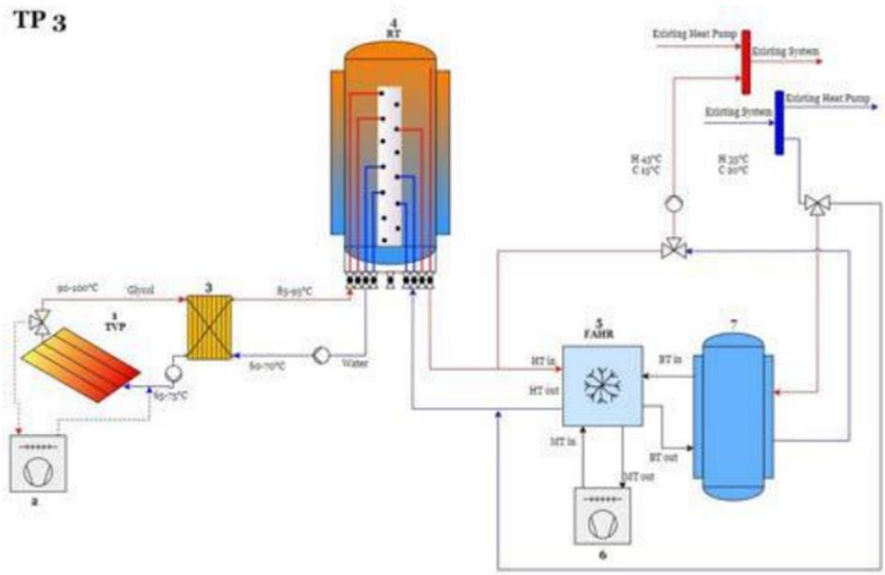


Figure 6 - Diagram of Sant Cugat demosite TP

Sant Cugat -SunHorizon TP (Technology Package) is composed of

- 98 solar panels and 192 m² TVP panels on the roof (192 m2 if referred to WP7 LCA excel file)
- Hybrid chiller 60 kW
- Ratiotherm thermal tank 10.000 L, Oskar tank DHW of 2.000L.
- Monitoring & Controls Schneider

The system has been operational since mid-August. However, the building was closed during August, so reliable data starts to be available.

-4 of the 7 circuits of the solar collectors are at full capacity. The other 3 are below their ordinary performance. Adjustments are needed. During the month of October 2023, TVP visited the site (11/10/2023) to check the installation to try to solve the problems. There is no budget in 2023 because we did not have permanent safety lines included. Sant Cugat paid the provisional safety lines for these 4 circuits. Next year 2024 we will be able to connect all circuits because the municipality will assume the cost to install the permanent safety lines on the roof with Sant Cugat municipal budget. As an outcome of the onsite visit a to-do list has been drawn including actions for: (I) stabilising the internet connection, (ii) resetting sunrise and sunset values, (iii) filling glycol into the system, (iv) sharing weekly maintenance reports, (v) covering the solar panels from the string currently not in use, (vi) replacing a damaged panel.

-Design review after commissioning (e.g. alarm signals). The lack of some alarms means the maintenance operators have to carry out an almost daily check to follow the correct operation of the system.

3.2 Status update of the monitoring system

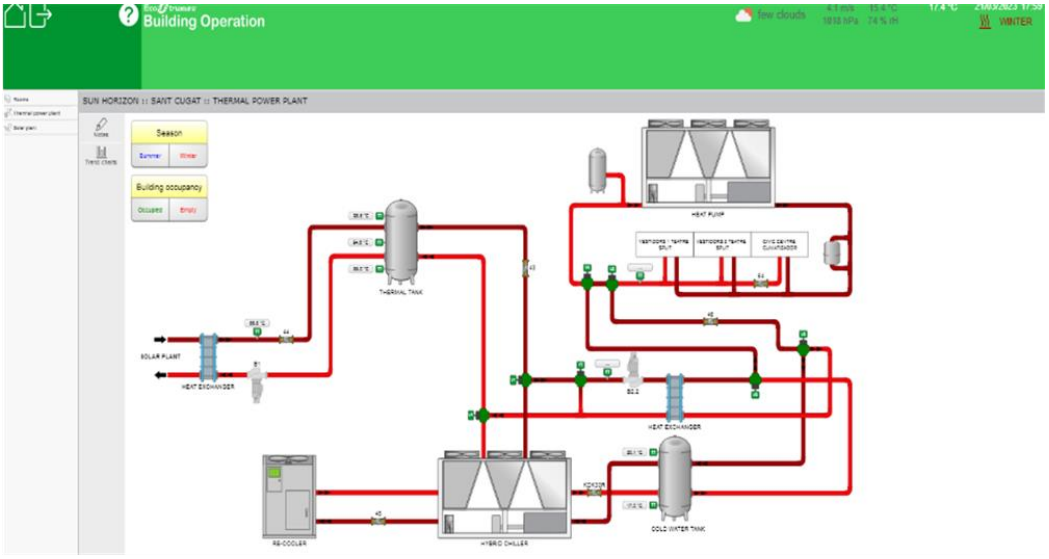


Figure 7 : BMS Sant Cugat demosite

Sant Cugat dashboards are fully operative. Hybrid controller (Cartif): in Sant Cugat demo site is working.

Next steps: validation of hybrid controller in Sant Cugat, predictive maintenance tool and submission of D5.7 (IES).

The dashboards will be available for the demos also after the project if the connections will still work. The solar thermal system will keep working for the pilot managers also after the project.

The solar system will be running but the connection to iSCAN and other tools won't work after the project is finished. The license is paid but it will expire (see date) as long as the server in which the system is on to send the data is in charge of an external partner so after the end of the current year it will no longer work; In fact, no budget has been allocated for it. In the Grant Agreement monitoring should continue for 5 years so this could be a problem.

Sant Cugat demo site does not collect and store the data on a private server, therefore after SE switches it off they won't have the same data available. It is possible to solve this problem, but Sant Cugat must pay with a private budget not included in SunHorizon project to keep collecting data in the coming years as well. SE now has a single connection to exchange data with each other, after the Sant Cugat project demo site can change the connection to work on the local system, so it can collect and store data.

3.3 KPIs summary

During the monitoring period (September and October 2023) of the Sant Cugat demo it was possible to calculate the KPIs summarized in Table 6.

Table 6: KPIs evaluated in Sant Cugat.

KPI	Sant Cugat
CAPEX	457633 €
CBR	60 €/day
GHG savings	-42.45 kgCO2eq
HCI	0.06 °C
OPEX	2288.17 €
PESnren (absolute) And relative:	30363.26 kWh
RER	11.75%

Unfortunately, the data availability was not sufficient to evaluate KPIs on monthly and seasonal basis, since the system was not properly operating for some months after the installation and some issues arose regarding the proper communication between the different technologies and the monitoring platform.

For this reason, the reported KPIs must be considered only as partially reliable and not able to represent the complete yearly operation of the installation. Further data collection, if available after the project' end, shall be used to further validate the energy and economic performance of the TP3.

3.4 KPI and PIs screenshots

The monitoring period lasted from June 2023 to October 2023, with an interruption during July, due to a malfunctioning of the system and August, when the building was almost empty. Below, the KPIs and the most relevant PIs and monitoring parameters, such as indoor temperature, renewable energy and primary energy savings are summarized for the last 2 months of continuous monitoring of the demo site.

As it can be analysed, the system was running achieving performance which are lower than expected. The motivation for such a discrepancy is still under analysis. Clearly, a lack of proper inter-operation between solar field and hybrid chiller was highlighted, which will need to be solved in the future to make the system running at its maximum efficiency. Nevertheless, the temperatures of the building were properly controlled inside the comfort interval and up to 11.7% of renewable energy was exploited in the monitoring period.

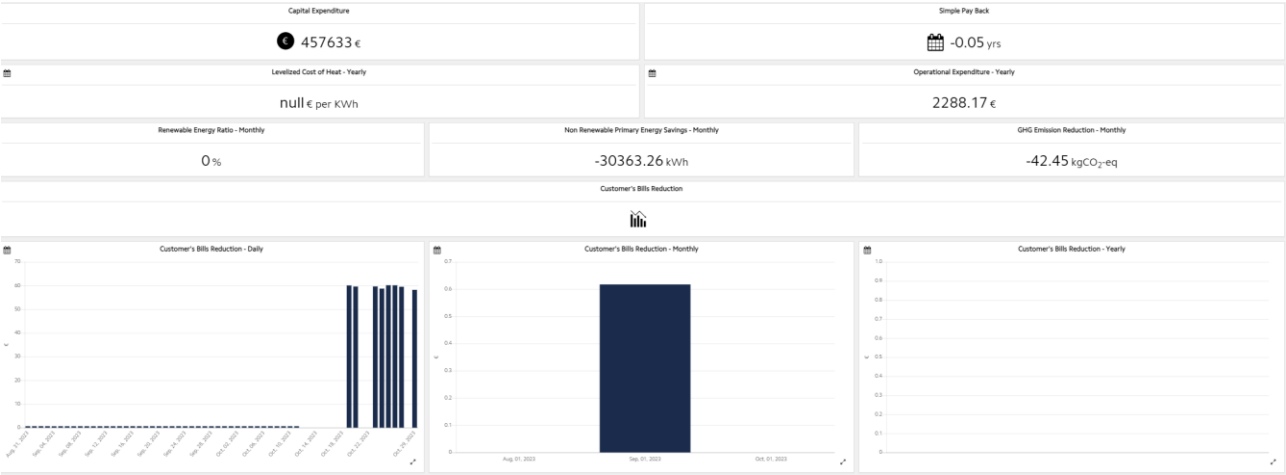


Figure 8: Sant Cugat KPIs dashboard for the last 2 months of acquisition.

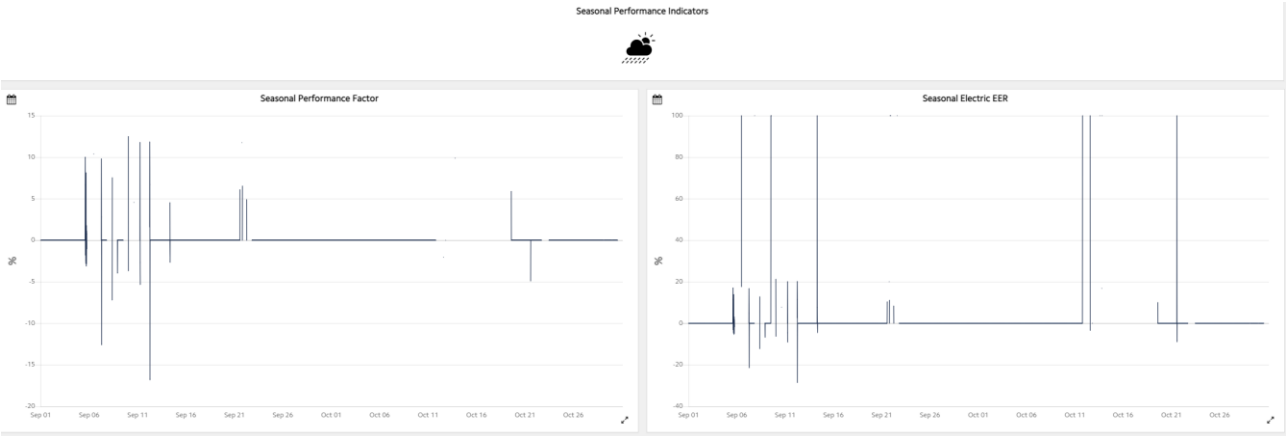


Figure 9: Seasonal performance indicators Sant Cugat PIs dashboard for the last 2 months of acquisition.

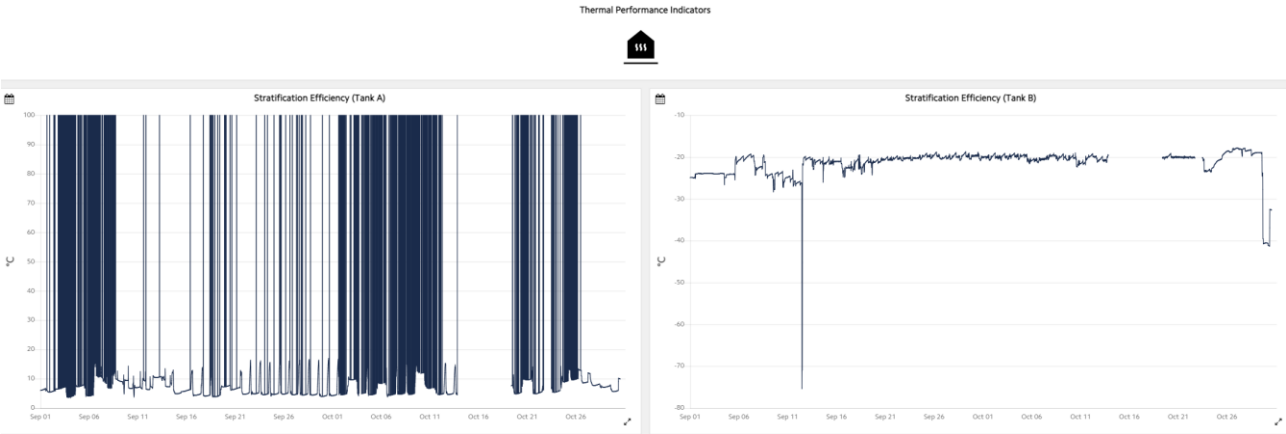


Figure 10: Thermal performance indicators Sant Cugat PIs dashboard for the last 2 months of acquisition.

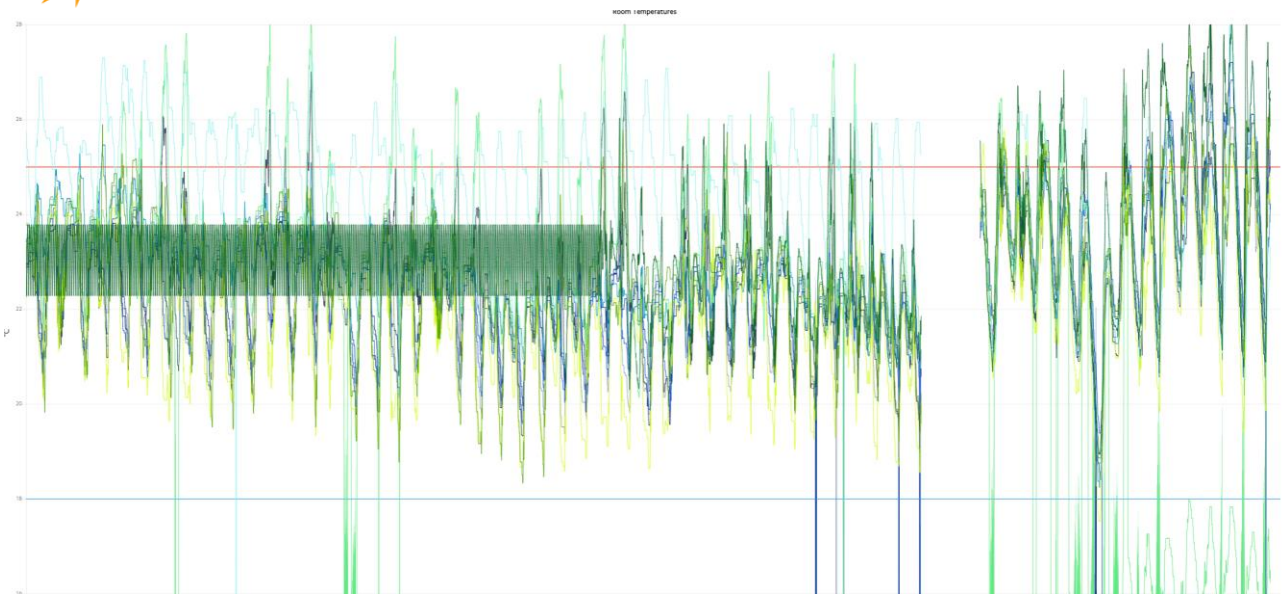


Figure 11: Monitoring of the room's temperatures in Sant Cugat demo site for the last 2 months of acquisition.

Figure 12: Renewable energy ratio in Sant Cugat demo site.

Figure 13: Non-renewable Primary energy savings for Sant Cugat demo site.

3.5 Alarms logging

Alarms will be reported here. An automatic email will be sent to the building staff (to be confirmed), demo responsible, and the simulation supporting partner. No alarm notification has been set yet for this demo site.

Table 7 - Alarm receivers (Sant Cugat)

ROLE IN THE PROJECT	PROJECT PARTNER
Building Staff	VEOLIA/Silvia Jané
Demo Responsible	AJVSC/ Gerard Riba and Anna Mundet
Simulation Supporting partner	CNR-ITAE/Andrea Frazzica CARTIF/Alejandro Hernández

4 Madrid demo site #4

The Madrid demosite installation is composed of the following technologies [as shown in the table below, and connected as pictured in the diagram below]

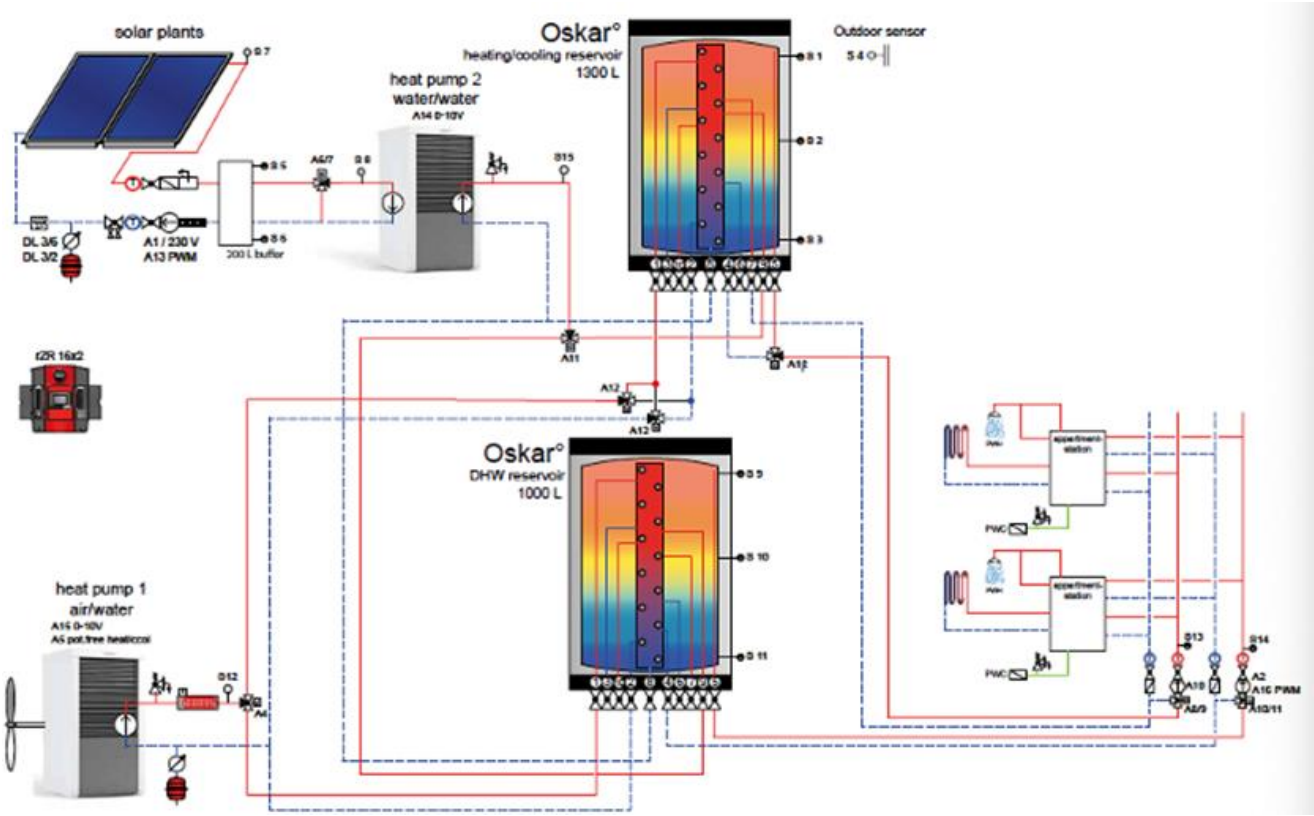


Figure 14 - Madrid diagram

Madrid -SunHorizon TP (Technology Package) is composed of

- 50m² DualSun PVT panels on the roof (51.15m2 if referred to WP7 LCA excel file)
- SHC / 1.3DHW m3 Ratiotherm tank
- BDR Brine Water Heat Pump (WWHP) of 9kW
- BDR Air Water Heat Pump (AWHP) of 27kW
- RATIO glycol tank 200L, Oskar tank DHW of 1.300L and SHC tank 1000L (see D2.5)
- Monitoring & Controls Schneider

At Dwelling level, the following technologies were implemented :

- Fan Coils for SHC
- Heat Recovery Units for Ventilation
- Heat Exchanger for instantaneous DHW preparation

4.1 Status update of the demo site

The renovation works to integrate the SunHorizon project technology package was completed in September 2022.

During the following months, various equipment commissioning's were carried out following the diagram shown below:

- October 2022: Commissioning of the Air-Water Heat pump, Distribution System and Dwellings. It began the supply of Space heating and Domestic Hot water to the nine dwellings.

- December 2022: Administrative legalization, commissioning, and energy contract of the PV field and inverter. Beginning of the self-consumption.
- March 2023: Solve blocking issue and Commissioning of the Water-Water Heat pump
- June 2023: Reparation of the piping of the PVT solar panels

During the whole year, it has been solved minor problems regarding electric meters, control system, etc. It has also been made some modifications and updates into the control strategy to increase the performance and the energy savings of the system.

4.2 Status update of the monitoring system

The monitoring system architecture is shown in the following figure.

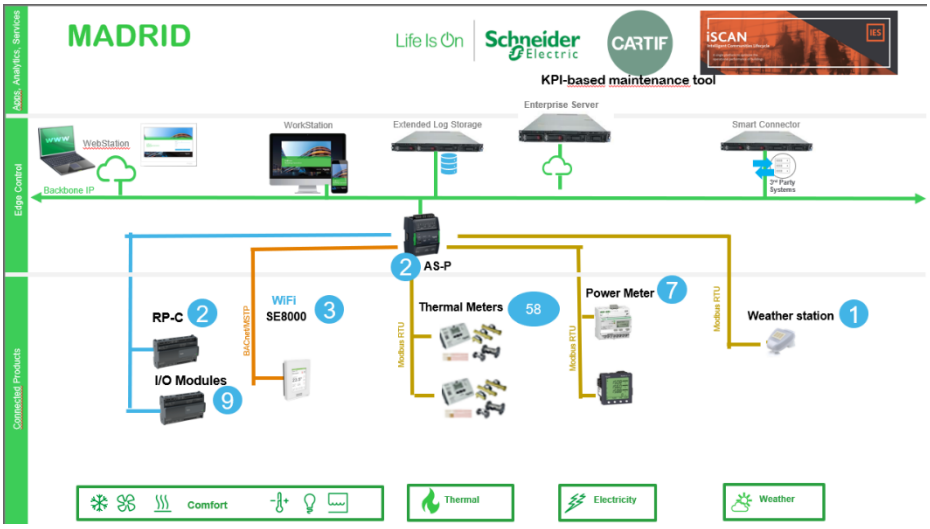


Figure 15. Monitoring architecture (Madrid)

The complete list of sensors has been already defined in the previous deliverable D6.5, based on the list of sensors we can see what variables the system is measuring, from the generation and consumption of the installed equipment, to the individual heat meters and temperature sensors for each of the nine dwellings; this allows to measure the real energy consumed per user; plus estimate the losses of the distribution system for Space heating and Cooling (SHC) and Domestic Hot water (DHW). This system also has onsite meteorological data and temperatures: from each dwelling to measure indoor comfort, and from the tank temperatures and outlet temperatures of the equipment to calculate the system's efficiency.

Code	Description	Variables included in the sensor
T1	Solar module temperature	Temperature
T8	Top solar tank temperature	Temperature
T10	Top DHW tank temperature	Temperature
T12	Bottom DHW tank temperature	Temperature
T13	Top SH tank temperature	Temperature
T15	Bottom SH tank temperature	Temperature
C1	General SHC heat meter	Heat Energy C1, T1, T2

Code	Description	Variables included in the sensor
C2	General DHW heat meter	Heat Energy C2, T1, T2
C3	Aw heat pump heat meter	Heat Energy C3, T1, T2
C4	WW heat pump consumption side heat meter	Heat Energy C4, T1, T2
C5	WW heat pump source side heat meter	Heat Energy C5, T1, T2
C6	Solar heat meter	Heat Energy C6, T1, T2
C7-C15	Dwelling DHW heat meter	Heat Energy C7-C15, and from each T1, T2
C16-C24	Dwelling SHC heat meter	Heat Energy C16-C24, and from each T1, T2
DW1-DW9	Dwelling interior temperature	Temperature (one per dwelling)
EM1	SHC and DHW general board elec. meter	Active energy total import
EM2	FV generation electric meter	Active energy total import, Active energy total export
EM3	AWHP elec. meter	Active energy total import
EM4	Electric resistor WW HP elec. meter	Active energy total import
EM5	Electric resistor AW HP elec. meter	Active energy total import
EM6	Electric resistor WW HP elec. meter	Active energy total import
MS	Meteorological station	Temperature, wind velocity

Table 8 – List of variables for the Madrid demosite

4.3 KPI and PIs analysis

The performance of Madrid demosite TP has been analysed applying the defined formulas on the SunHorizon project's deliverable *D2.4 KPIs assessment based methodology*. In the following section an overview of the different results will be made, comparing the obtained results from the IES dashboard with an internal excel file created for the validation of the applied formulas. Due to data gaps and continuous refining of the formulas and data; monthly indicators are not comparable, but an internal validation of this formulas has been carried out for smaller data periods.

In this section the reader will find data availability and quality, then estimated results applying the aforementioned formulas directly onto the monitored data on the Schneider platform, extending this way the monitoring period since January 2023; and finally, the available data for demosite users from the IES platform.

4.3.1 Electricity balance

For the analysis and calculation of the electric energy, the following variables will be used and are connected as shown in the following diagram, with this configuration the electric consumption of the SunHorizon TP will be studied.

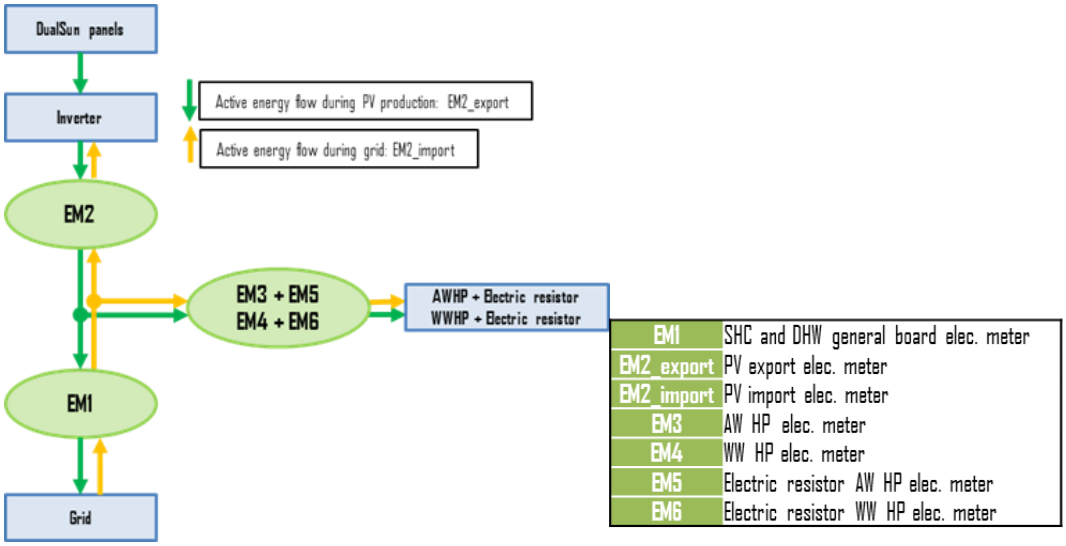


Figure 16: Madrid: Electric diagram

In the table below, there are monthly summed values of the electric meters in kWh since January to October in green; with some monthly indicators like Renewable energy ratio (RER) and Self-consumption ratio (SCR) in blue. The renewable energy ratio shows higher values when there is higher exported energy to the grid (e.g. May, RER: 93.5% and exported energy is greater than grid imports; 1036.79kWh and 715,99kWh respectively). Self-consumption ratio shows its peak values in January to February and from July to August, coincident with the higher SunHorizon electrical demand. As it can be seen in the Daily DualSun electrical generation and exports to the grid, the peak in grid imported energy is from January to March, when there was a high demand from the dwellings due to climatic conditions and because they were given a special tariff which was more economical that led into high thermal demands. The other period with high consumption is July to August, there was a heat wave in Spain which led to high space cooling demand, as it can be seen in the thermal energy balance.

Madrid [kWh]	Grid imported [kWh]	Grid exported [kWh]	DualSun elec gen [kWh]	SunHorizon elec. cons. [kWh]	Renewable Ratio [%]	Self-cons. Ratio [%]
1	4137.56	150.15	932.99	3660.35	34.1%	95.4%
2	3570.16	107.85	1098.92	3098.75	26.4%	91.0%
3	2189.36	693.93	1540.73	2075.57	53.3%	56.7%
4	858.87	917.73	1711.40	1035.95	90.4%	46.8%
5	715.99	1036.79	1581.56	657.97	93.5%	35.3%
6	843.75	789.96	1518.88	945.70	80.3%	48.6%
7	1903.67	203.89	1776.43	2595.19	41.5%	88.5%
8	2005.57	211.48	1713.63	2592.21	40.7%	87.8%
9	1012.23	587.23	1256.17	928.28	63.5%	56.8%
10	1394.87	415.30	1051.33	1272.17	46.1%	64.0%
Total	18632.03	5114.33	14182.05	18862.15	56.98%	67.09%

Figure 17: Madrid: Monthly electricity data

In the energy balance we can see how the electricity is being consumed within the TP. On the left there is the balance for the whole monitoring period since January to October 2023, then there is July balance to represent the month with higher Self-consumption ratio 88.5%, which is one of the months with greater Space cooling consumption as it can be seen in the Thermal energy balance.

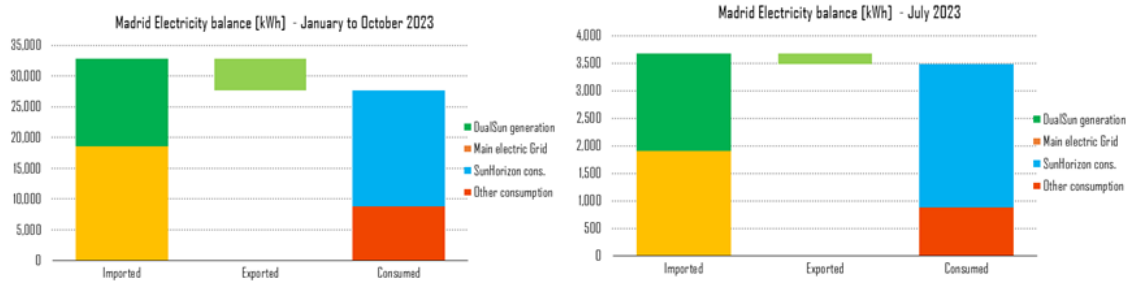


Figure 18: Madrid: Electrical energy balances [Left: Whole monitoring period, Right: July].

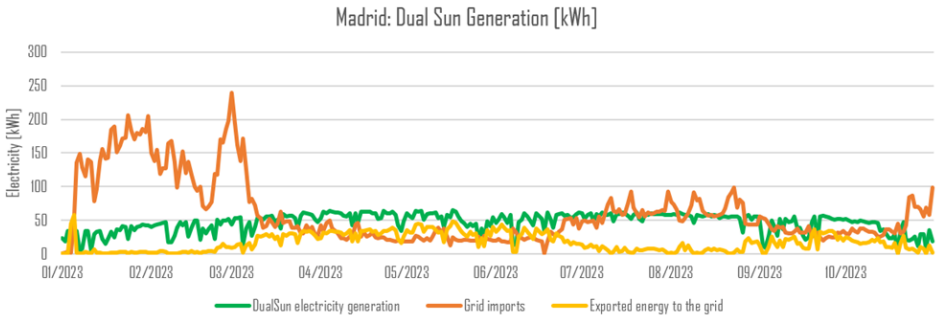


Figure 19 - Madrid: Daily DualSun electrical generation and exports to the grid

The electrical fraction of generation form DualSun units and the electricity balance is calculated in the IES dashboards, in the graph below, there are daily electricity generation and consumption data, which has been smoothly running since May 2023.

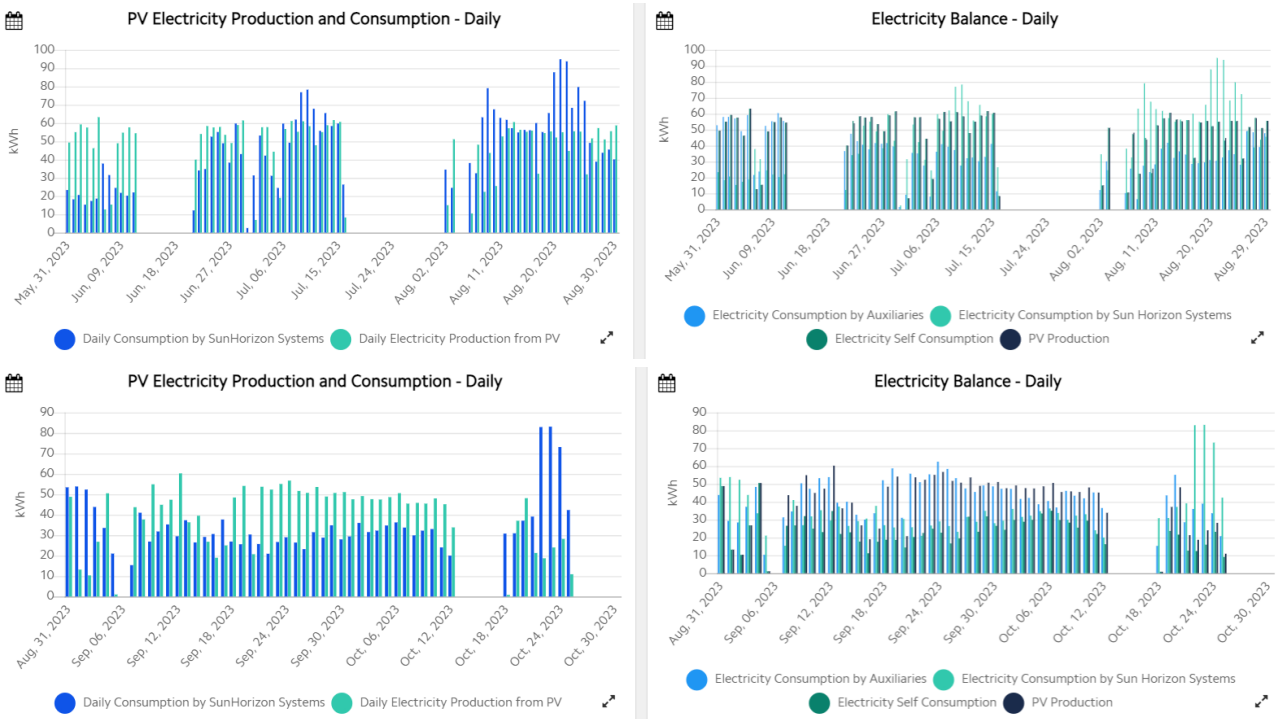


Figure 20 - Madrid: Daily electricity balance

The daily renewable energy ratio for this period is not comparable with the previously calculated before, because PV exported energy to the grid data was not implemented until September 2023, then the formula had to be adapted to avoid negative values, which occur when the exported energy is higher that the imported one; now it is smoothly running.

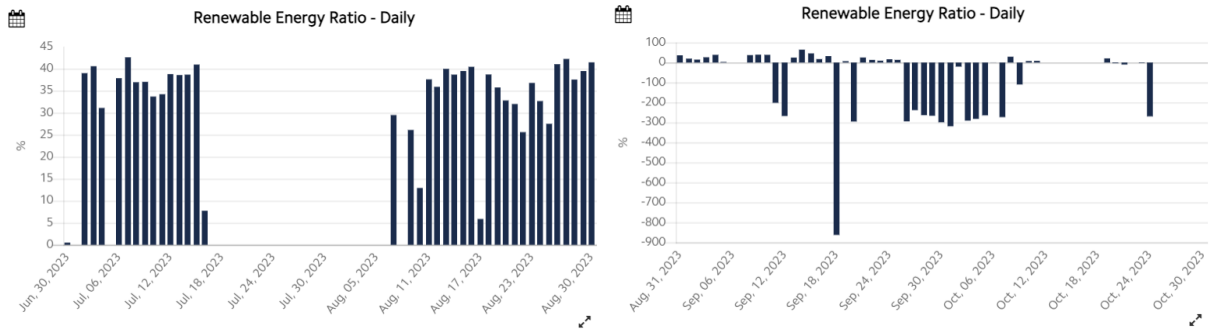


Figure 21: Madrid: Daily Renewable Energy Ratio

For Non-Renewable Primary energy savings and Green House Gas emissions savings indicator, this issue did not have a negative impact; but we can appreciate an increase at the end of October, due to an update on the baseline data. Below there are daily and monthly graphs.

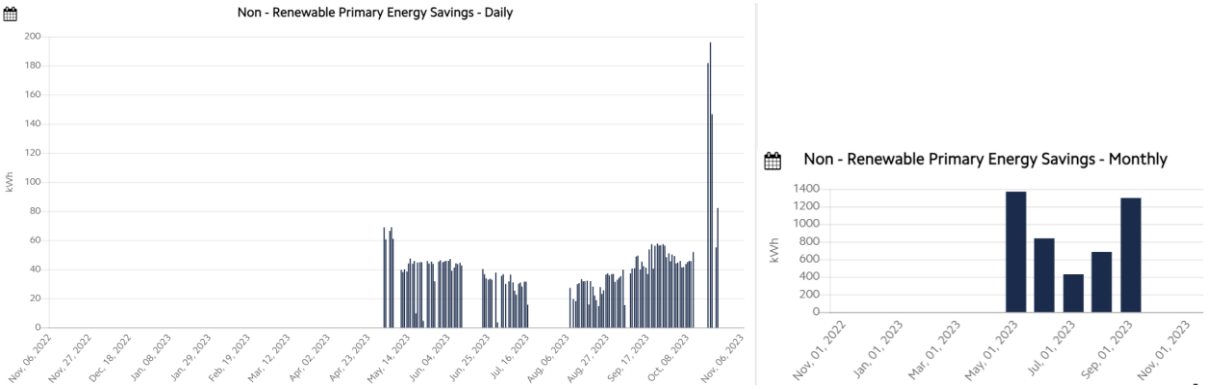


Figure 22: Madrid: Daily and monthly Non-Renewable Primary energy savings

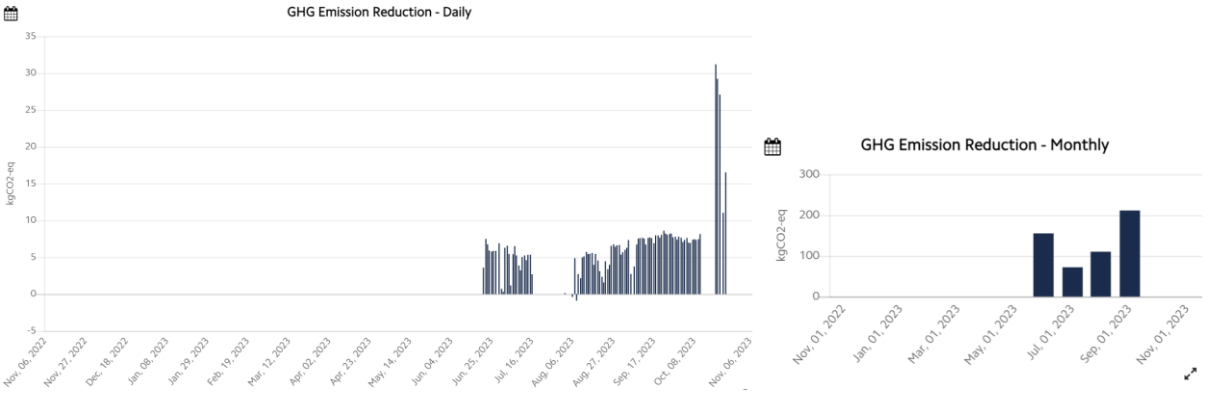


Figure 23: Madrid: Daily and monthly GHG emissions reduction

4.3.2 Thermal balance

In the table below, includes monthly values of the different heat meters of the installation, starting with the useful heat and cool energy generated by each heat pump on the left, followed by the general meters, and lastly the sum of the individual heat meters, which allows to estimate the thermal distribution losses within the system, as it can be seen in the thermal energy balance below.

Heat [kWh]	AWHP Heat	AWHP Cooling	WWHP Heat	General SH	General DHW	General SC	SH Dwelling cons.	DHW Dwelling cons.	SC Dwelling cons.
1	10136.3		0.0	7630.8	3228.7	0.0	6048.4	3394.5	0.0
2	7926.2	24.3	1055.1	6524.4	2534.0	0.0	5194.0	3188.6	0.0
3	4280.3	37.1	1885.8	3518.9	2632.8	20.0	2703.5	2422.5	0.0
4	1559.3	33.2	2044.8	763.0	2308.5	10.0	500.4	1688.9	0.0
5	1958.2	32.1	200.2	46.9	1565.6	840.0	104.3	1142.7	0.0
6	547.5	1341.0	1362.9	0.1	1343.4	1590.0	97.8	1023.3	1030.0
7	49.8	6041.7	1768.3	0.3	1261.7	7300.0	107.9	889.1	5605.5
8	23.2	6085.8	1836.2	0.1	1314.5	8350.0	135.2	924.4	5588.1
9	25.9	1360.8	2302.7	2.8	1684.0	2120.0	155.6	1176.7	1318.0
10	1169.0	891.4	2514.5	1176.9	2079.4	1380.0	795.6	1401.5	714.9
Total	27675.8	15847.4	14970.3	19664.3	19952.6	21610.0	15842.7	17252.2	14256.6

Figure 24: Madrid: Monthly thermal data

In the thermal energy balance it can be seen how the energy is being consumed in the demosite. On the left there is the useful heat and cooling generated by the AWHP and WWHP, then there is a block of the "Building cons." measured by the general meters; lastly on the right there is the sum of individual dwelling meters, the difference in height between "Building cons." and "Dwellings final cons." are the thermal loses on the distribution system. The balance on the left represents the whole monitoring period from January to October 2023; the other one represents July thermal balance as one of the months with higher Cooling demand, and higher Self-Consumption ratio with 88.5% as it can be seen in the previous electrical energy balance.

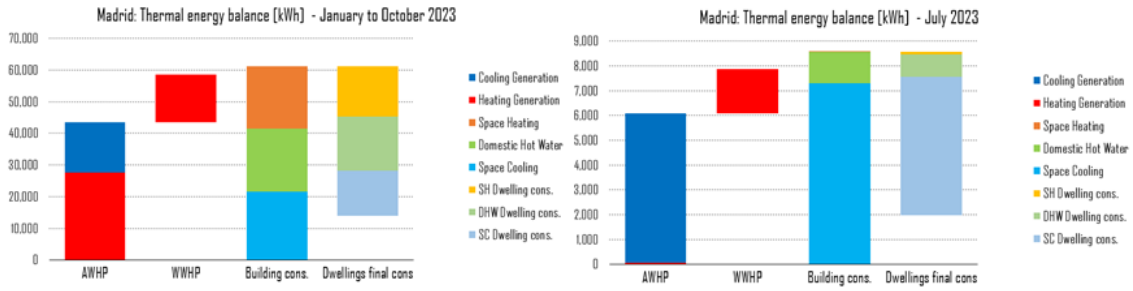


Figure 25: Madrid: Thermal energy balances [Left: January-October, Right: July].

Below there are two daily plots showing the trend for the general heat meters compared to the exterior temperature, and the thermal generation of each equipment for the same period. In these graphs it can be seen how the thermal demand peaked in January until March due to climatic conditions and because they were given a special tariff which was more economical that led into high thermal demands. IT can also be appreciated how DualSun and the WWHP starting to work by mid-February to March with a stable generation trend around 50kWh, except for May, when DualSun piping was replaced.

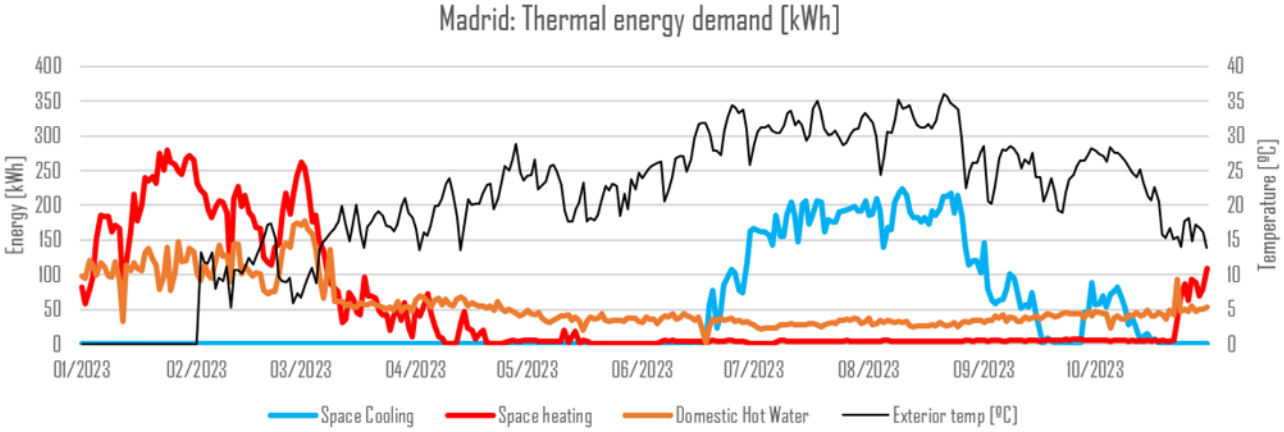


Figure 26: Madrid: Daily thermal energy demand

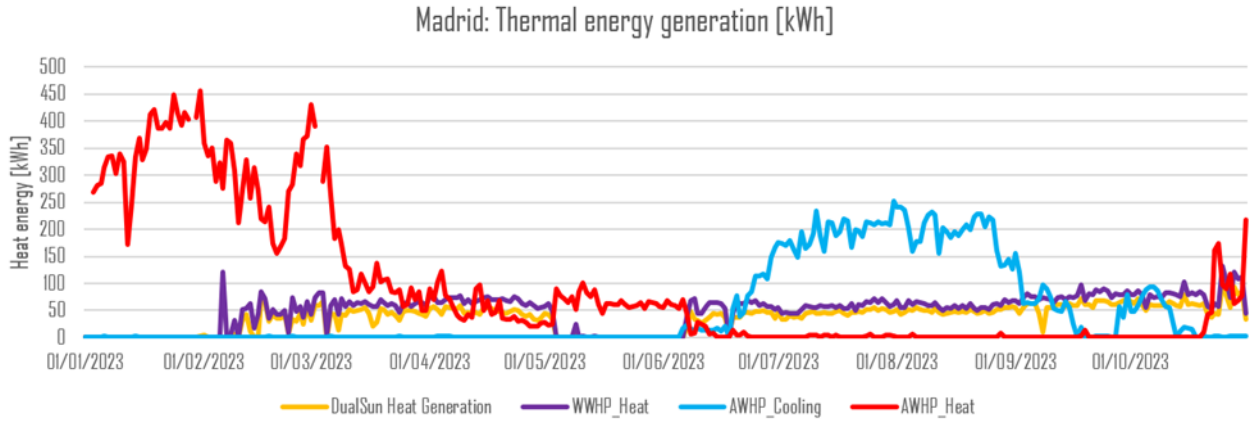


Figure 27: Madrid: Daily thermal energy generation

In the following graph the average monthly working hours of both heat pumps have been plotted alongside its average COP, it can be noted the high increase in July and August of the AWHP working hours for Space Cooling generation; while the WWHP has a more stable demand profile mainly due to DHW production, except for May because of the maintenance works on the DualSun piping system.

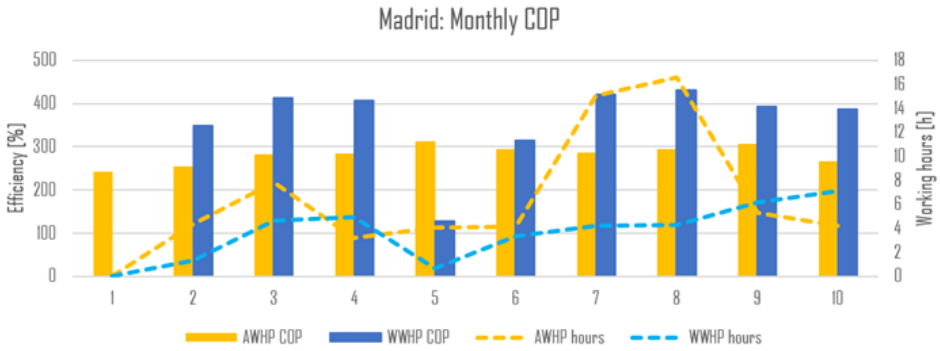


Figure 28: Madrid: Monthly average heat pump performance

Below there is also the seasonal performance factor and COP from the IES platform, calculated for both heat pumps, with the AWHP as “air-water” and the WWHP as “brine-water”. These indicators started to be calculated in May 2023. Below there are the calculated values for October 2023, in the graphs we can appreciate some data gaps and that values have been greatly reduced due to continuous fine-tuning of the formulas to more reasonable values.

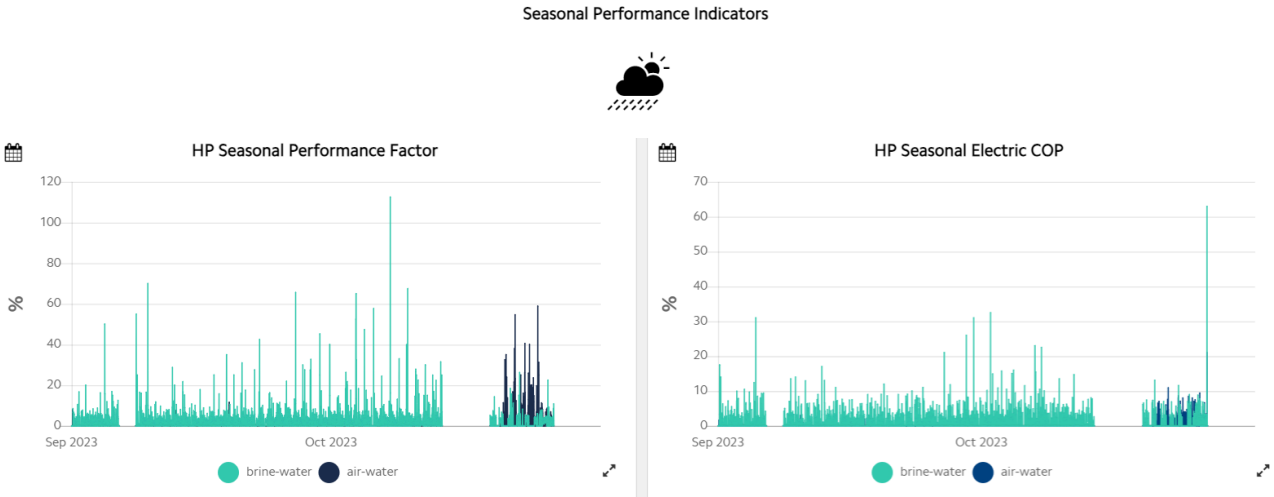


Figure 29: Madrid: Seasonal performance indicators

Regarding DualSun solar performance indicators in the plots below we have the calculated Solar thermal Faction and the electric efficiency from the IES platform, which have been calculated since May 2023. Despite some higher peak values at the beginning of the integration, now shows better behaviour with high values for Solar thermal fraction up to 100% but lower values for electric efficiency. Below there are the calculated values for October 2023

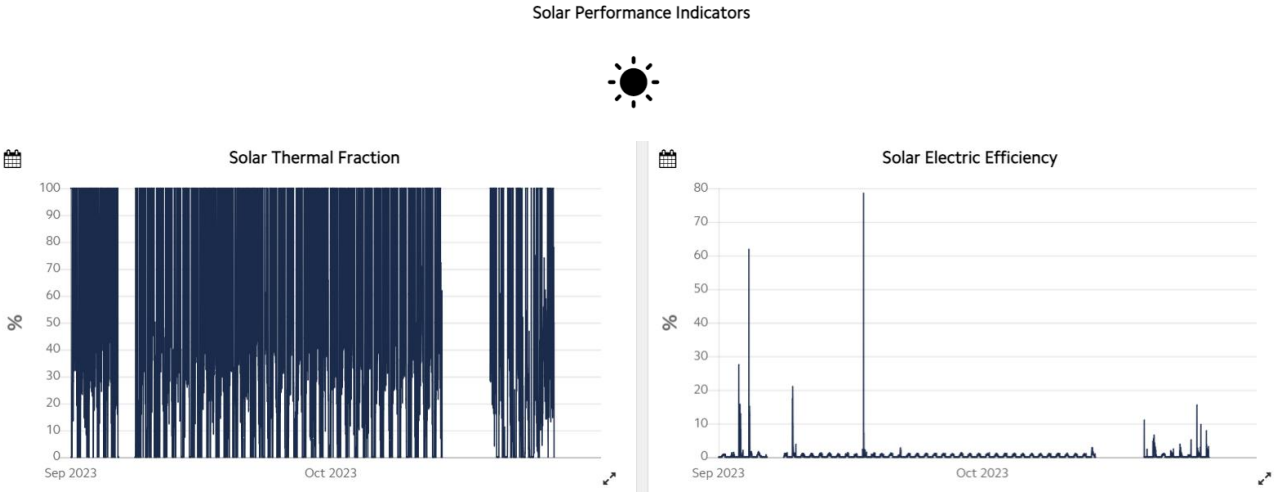


Figure 30: Madrid: Solar performance indicators

Finally, the thermal performance indicators are calculated, also since May 2023; in this case we have Thermal electric ratio from the output of the DualSun panels, and the stratification efficiency of the RATIO water tanks (A and B), measured as the difference between top and bottom temperatures. Below there are the calculated values for the whole period January to October 2023, and a closer look to October 2023.

Figure 31: Madrid: Thermal Performance indicators

4.3.3 Heating comfort index

Indoor temperatures are registered for each of the nine dwellings, and the monitoring period started in mid-February or March. Except for the Dwelling nine, because that apartment is unoccupied at the moment.

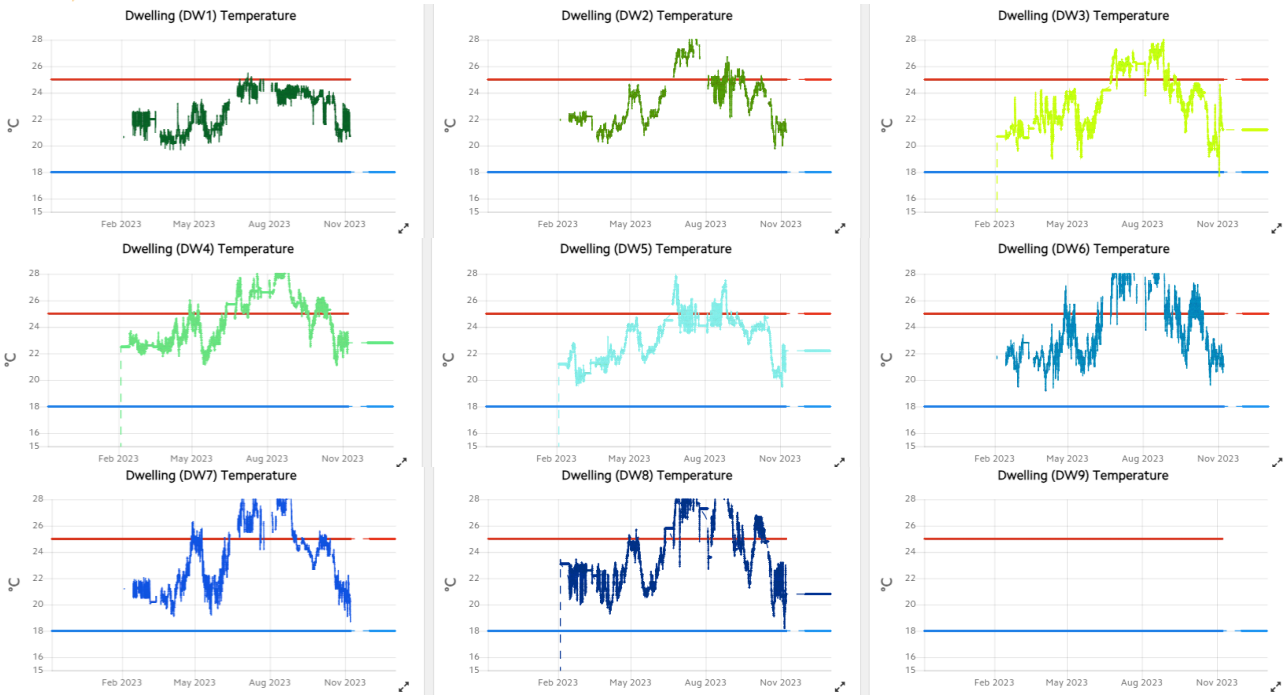
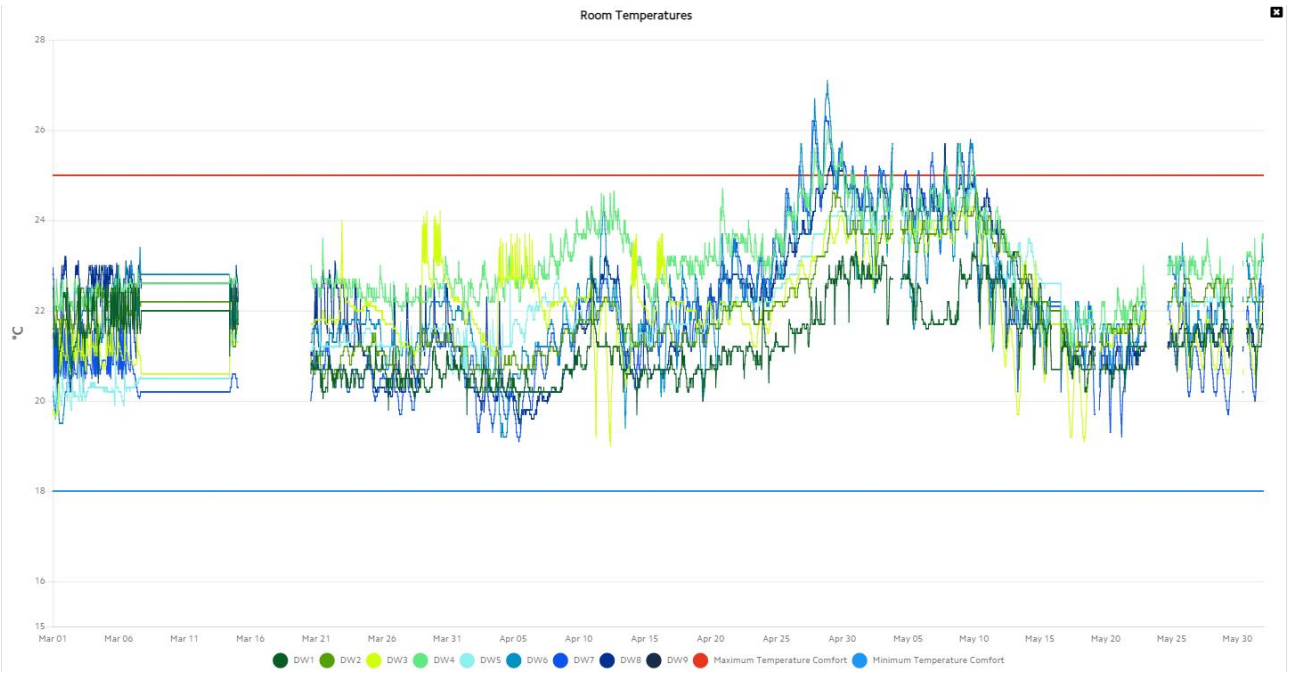


Figure 32 -Madrid: Individual dwelling indoor temperatures since January to October 2023



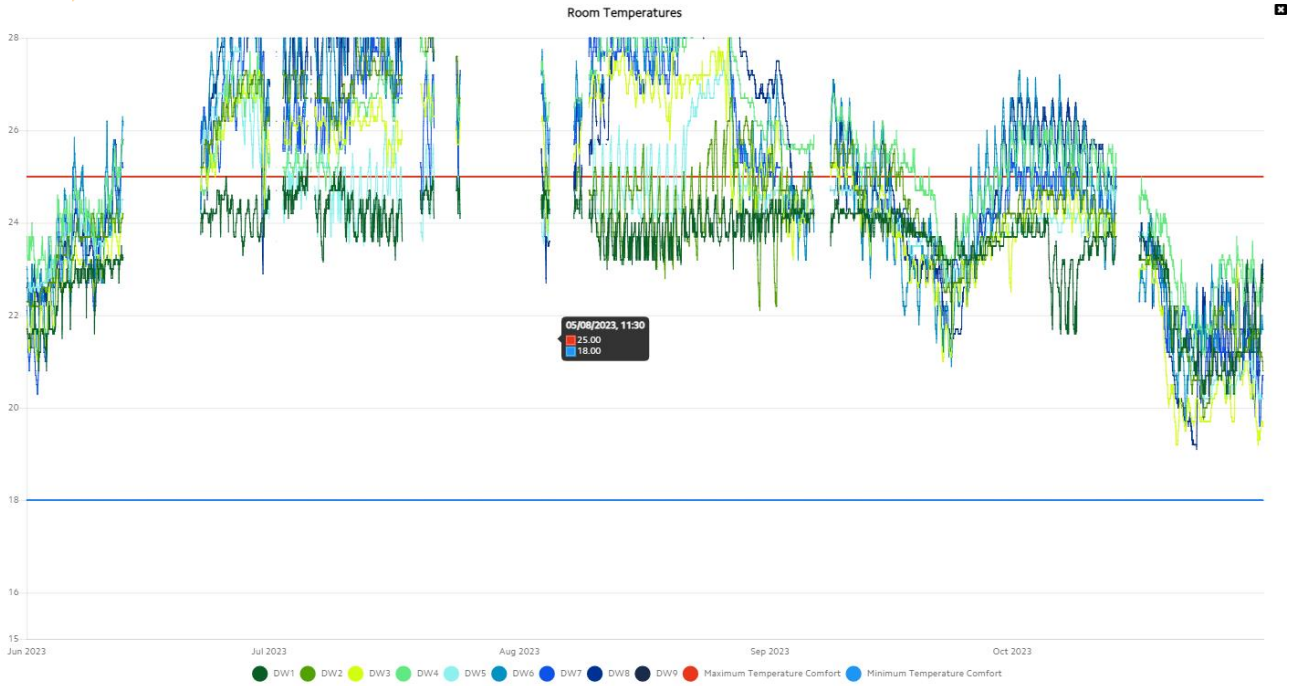


Figure 33 - Madrid: Dwelling indoor temperatures since January to October 2023

Heating and cooling comfort has been also calculated for the monitoring period, which registers when the average dwelling indoor temperature is not within the defined temperature range and for how long, 25ºC for summer and 18ºC for winter. For this period Madrid only has registered some discomfort during the summer period with a maximum of 5ºC degrees above the 25ºC limit.

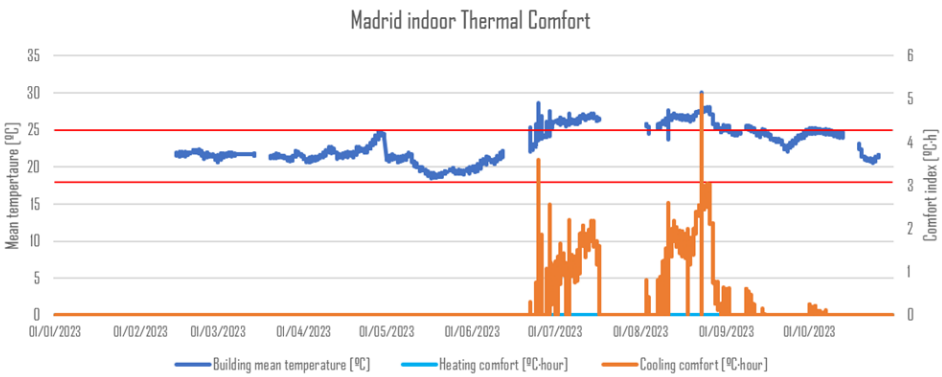


Figure 34: Madrid: Hourly indoor thermal comfort

4.4 KPI summary

In this section monthly indicators in the monitoring period from January to October of 2023 will be calculated, including self-consumption ratio, renewable energy ratio and indoor comfort index. Including emissions, non-renewable energy and energy bills savings, for which the measured data have been compared to the yearly baseline, which was defined on the deliverable *D2.5 SunHorizon TPs and demosite conceptual design and simulations* and collected in the table below. It has to be mentioned that the electricity market scenario has changed in these years, the electricity price used for baseline calculation was 0.033 €/kWh, while the average Day-Ahead prices from January to October 2023 is 0.091€/kWh, which reduces the economic savings on the energy bills.

Madrid Baseline	Description	Yearly value
I.EFEbs-9 [kWh]	Total electricity consumption (baseline)	17144.89
I.QFEbs-9 [kWh]	Total gas demand (baseline)	37778.90
I.CELbs-9 [€]	Electricity costs (baseline)	566.13
I.CFUbs-9 [€]	Fuel costs (baseline)	2497.84
PENnb-9 [kWh]	Non-renewable primary energy (baseline)	79372.18
I.GHGbs-9 [kgCO2]	GHG emissions (baseline)	15646.50

Table 9 - Madrid baseline

Monthly main results achieved in the monitoring period are included in the figure below, where negative values in red shows when GHG emissions, Non-renewable energy consumption and estimated energy bill had higher values than the baseline. Despite these punctual negative results for January and February, which coincides with the period of higher thermal demand due to dwellings tariff reduction; it has overall positive results, which are within the defined threshold of yearly KPIs as represented in the table below.

Madrid 2023	GHG savings [kg CO2]	PE_nren savings [kWh]	Customer Bills Reduction [€]	Renewable Ratio [%]	Self-cons. Ratio [%]	Mean temp. [ºC]	Heating comfort [ºC·h]	Cooling comfort [ºC·h]
1	-94.6	-1261.5	-9.3	34.1%	95.4%	0.0	0.0	0.0
2	-35.8	-860.0	-237.7	26.4%	91.0%	21.8	0.0	0.0
3	795.0	3739.9	18.6	53.3%	56.7%	21.5	0.0	0.0
4	1307.0	6641.9	191.5	90.4%	46.8%	22.1	0.0	0.0
5	1443.4	7385.0	207.5	93.5%	35.3%	20.0	0.0	0.0
6	1266.8	6415.8	172.6	80.3%	48.6%	22.1	0.0	0.1
7	722.1	3329.8	87.5	41.5%	88.5%	26.4	0.0	0.6
8	688.4	3140.5	62.8	40.7%	87.8%	26.5	0.0	1.2
9	1134.3	5670.8	148.4	63.5%	56.8%	24.2	0.0	0.0
10	979.2	4775.2	141.6	46.1%	64.0%	23.5	0.0	0.0
Total	8205.8	38977.2	783.5	56.98%	67.09%	23.3	0.0	2.0

Figure 35: Madrid: Monthly KPIs [January to October 2023]

KPI	Name	Actual Value	Threshold	Deviation
GHG savings	Avoided GHG emissions	8.21 tons of CO2eq; or 62.65%.	40 to 60%	No
PESnren	Non-renewable energy savings	38.98 MWh; or 58.61%	50 to 70%	No
CBR	Customer Bills Reduction	783.5€; or 29.79%	Up to 60%	No
RER	Renewable Energy Ratio	56.98%	40 to 70%	No
SCR	Self-Consumption Ratio	67.09%	Up to 80%	No
HCI	Heating Comfort Index	0	7 to 15 ºC·h	No
CCI	Cooling Comfort Index	2	7 to 15 ºC·h	No

Table 10: Madrid: Monthly KPIs [January to October 2023]

4.5 Alarms logging

Alarms will be reported here. An automatic email will be sent to the building staff (to be confirmed), demo responsible, and the simulation supporting partner.

No alarm notification has been set yet for this demo site.

Table 11 - Alarm receivers (Madrid)

ROLE IN THE PROJECT	PROJECT PARTNER
Building Staff	EMVS
Demo Responsible	EMVS/Diego Romera
Simulation Supporting partner	CARTIF/Carolina Pastor

5 Riga Imanta demo site #8.1

5.1 Status update of the demo site

As reported in D6.5, the initial TP2 configuration including the BH unit[4] was operational from December 2021 until September 2023 when the BH machine was replaced with BDR equipment following BH withdrawal from the consortium. The final TP2 upgrade (Figure 36) involved installation of a BDR heat pump, a back-up gas boiler, both integrated into TP2 via the existing storage tanks, and minor interventions in the space heating loop and DHW loop previously controlled by BH. SunHorizon TP2 in Riga, Imanta demo site is composed of the following components:

- DS PVT Panels (52.8 m^2, 10.24 kW$_p$);
- BDR heat pump GSHP 9 TR-E (9 kW) and backup condensing gas boiler MCR 24/28 MI (24 kW), both installed in 2023;
- BH heat pump with integrated gas boiler (20 kW), installed in 2021 and decommissioned in 2023;
- RATIO Oskar tank 1300 L (stratified thermal storage);
- RATIO glycol storage tank 200 L.

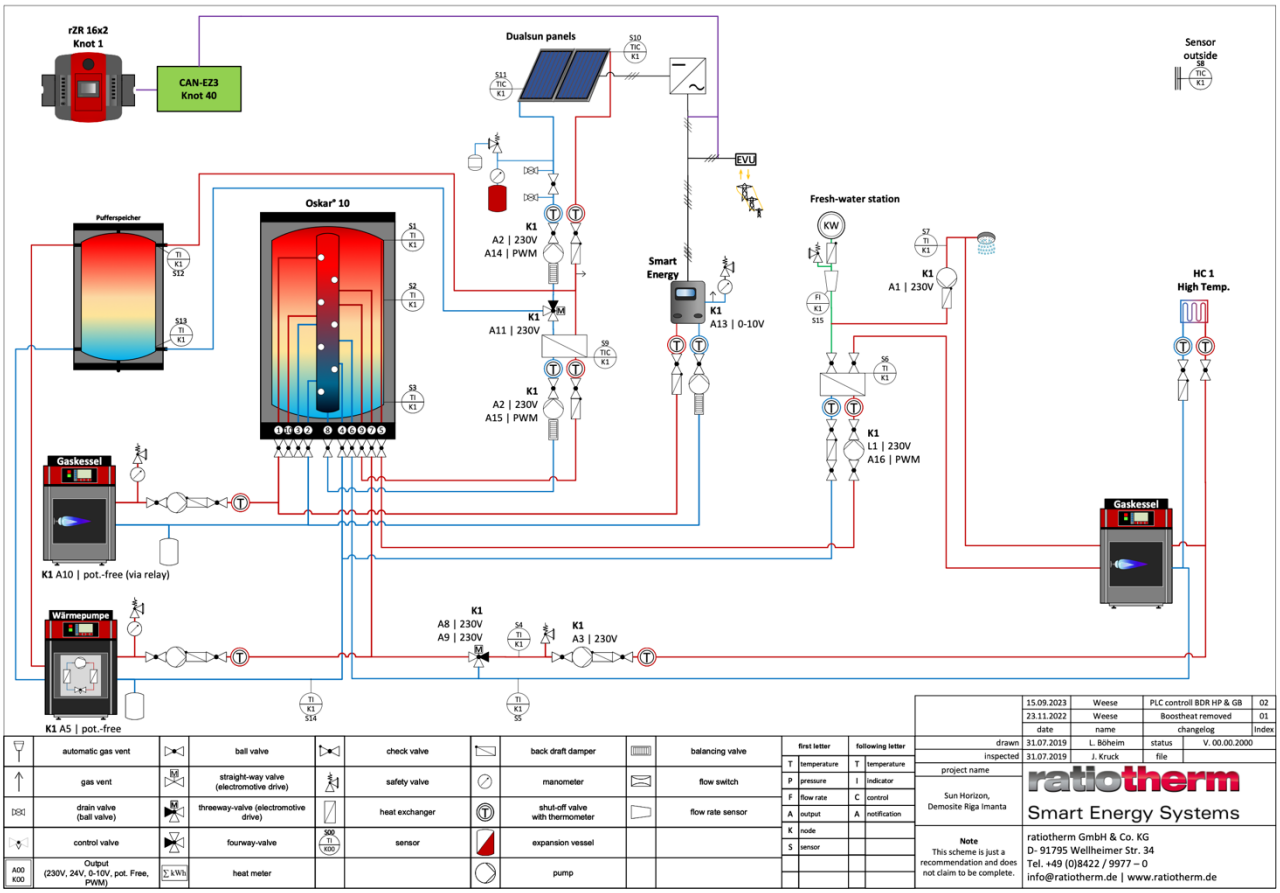


Figure 36. Final TP2 configuration for Imanta demo site with BDR heat pump, in operation since September 2023

The BH unit in Imanta demo was decommissioned on 13 September 2023. After that, the BDR gas boiler was installed and commissioned followed by the BDR heat pump. Hence, soon after BH decommissioning the thermal needs were already covered by the BDR equipment. However, several challenges were faced and needed to be solved, mainly related

[4] It must be noted that the BH unit was only operating as a condensing gas boiler, even though it had a thermodynamic heat pump block as well. BH was unable to operate as a heat pump during the whole demonstration period due to various technical issues of the machine despite the efforts of the involved partners, especially BH.

to the TP2 control (reported in more detail D6.7), therefore the final commissioning incl. full control of the integrated TP2 with RATIO PLC took place on 29 September 2023. Some fine-tuning of the controls was still necessary based on the first observations of the upgraded TP2 operation during the next days, and the final corrections of the PLC program were implemented by RATIO on 4 October 2023. Hence, during the three-week TP2 upgrade period some inefficiencies in TP2 operation could be noticeable.

5.2 Status update of the monitoring system

The monitoring architecture implemented by SE in Imanta is illustrated in Figure 37. Additionally, SE also collects data from RATIO PLC, and was collecting data from BH until its decommissioning. Furthermore, as BH was equipped with a gas meter and heat meter as part of their "external instrumentation", SE developed a solution of how to reuse those two meters after the TP2 upgrade in order to measure the BDR gas boiler's consumption and space heating flow of the upgraded TP2. Location of the meters reused from BH is shown in Figure 38 (red ovals). However, integration of the additional meters required reconfiguration of some of the already existing meters, also affecting the data flow to iSCAN and the KPI calculation tool. Hence, the involved partners needed to integrate a number of new variables from the affected meters based on the updated configuration.

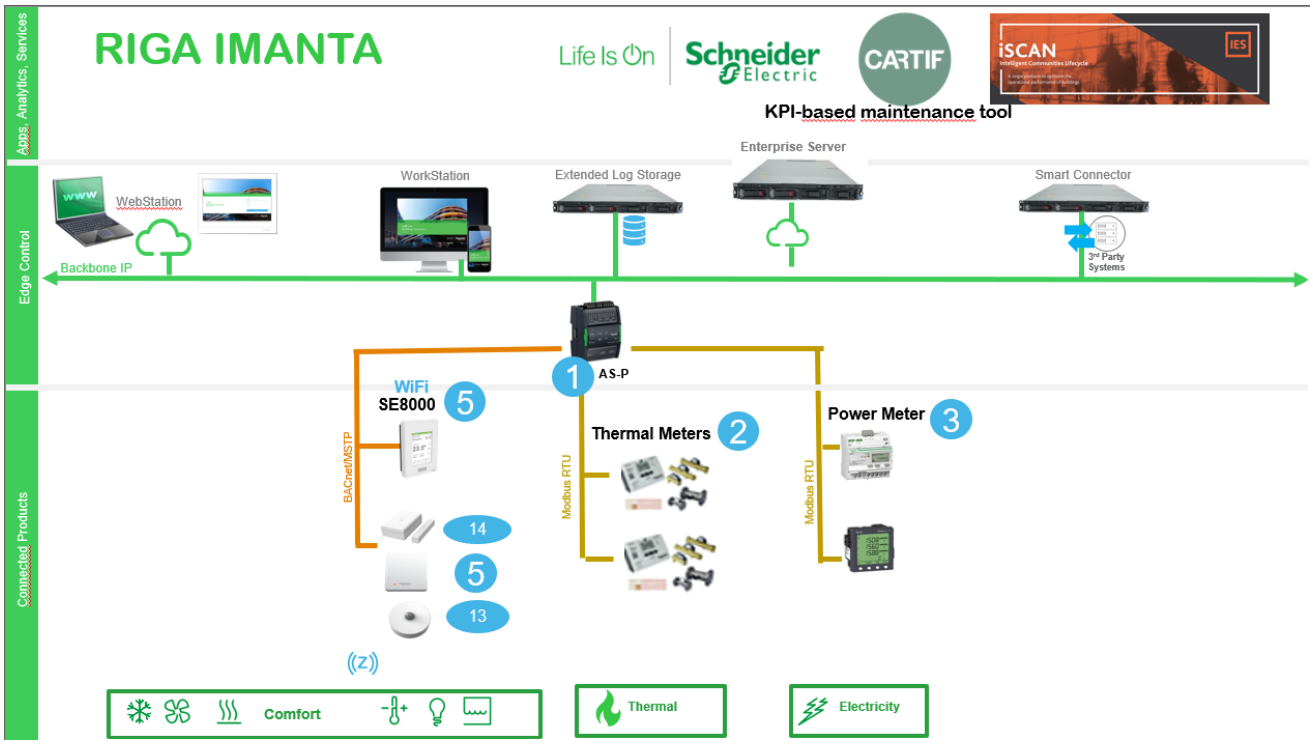


Figure 37. Monitoring architecture (Riga Imanta)

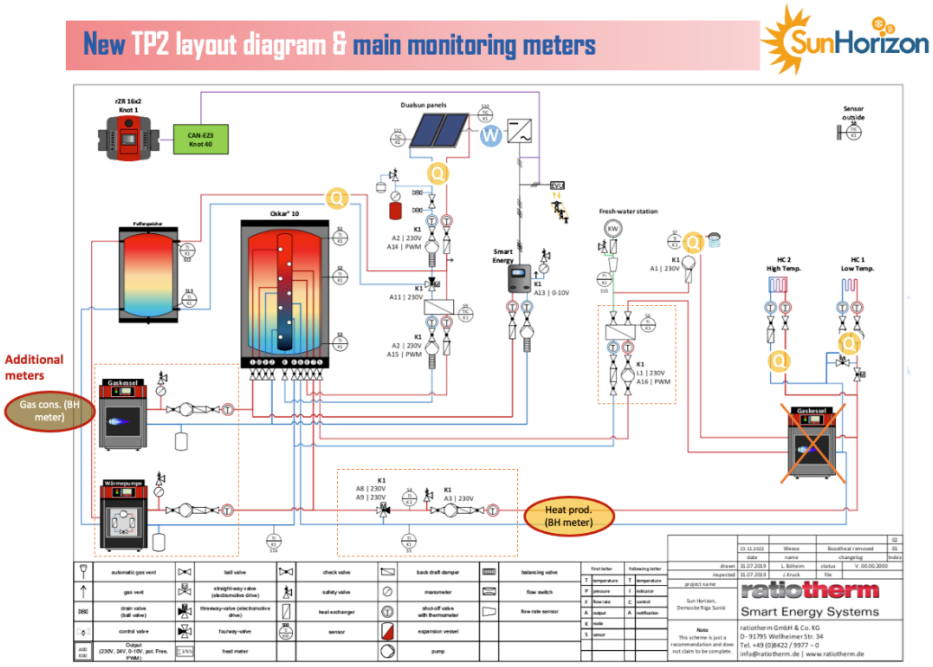


Figure 38. Final TP2 configuration in Riga demo (Imanta and Sunisi) with the meters reused from BH

Table 12: Data collection progress (Riga Imanta)

Relevant events	Date when discovered	Action taken	Mitigation plan	Date when solved
Some **SE8000** room controllers are going offline and data is intermittent	June 2022	Even with two Wi-Fi repeaters installed, some room controllers keep going offline. As it is not feasible to install additional ICT devices, the only solution was to request the residents to do regular restarts of the repeaters which can often solve at least part of the issues.	For indoor comfort monitoring data, we can more rely on Space 10 (Office) which is above the technical room and has much better signal quality and less data gaps compared to other rooms.	Ongoing
Inconsistent data from the PVT and glycol tank energy meter	September 2023	During onsite inspection of the meters, wrong labelling/wiring of the two respective heat meters was identified.	For energy assessment, data previously labelled as the "PVT meter" should be swapped with the "glycol meter". (If need to double-check, PVT energy is always higher than the Glycol tank energy.)	September 2023
Technical challenges of SE to read the data from the two BH meters	September 2023	After the physical meter connections were established onsite, SE was unable to read the data from the gas meter and space heating meter. Additional documentation was	SE managed to integrate the meters despite the missing documentation. However, the Modbus connection sometimes fails unexpectedly. Data collection ongoing, albeit with some gaps. This can be	October 2023

		requested from BH (not received) and from the manufacturer.	alleviated since the meters provide the cumulative energy, so in case of connection issues, the total energy is still accounted for.	
Reconfiguration of the existing heat meters due to the need to integrate the two BH meters	September 2023	In order to integrate the two BH meters, some existing meters needed to be reconfigured and reintegrated by the involved partners (SE, CAR, IES).	To consider in the KPI assessment: before the reconfiguration is complete, some data gaps can occur. This period partially coincides with fine-tuning of the upgraded TP2 operation.	October 2023
After changing the meter configuration, on the SE portal there are only 0s for the Imanta DHW heat meter.	since ~19 Sept 2023	Modify Modbus ID settings as per SE instructions (16 Oct).	To consider in the KPI assessment: there could be some data gaps before the issue was fixed.	October 2023
Intermittent data from the solar power meter	since ~21 Sept 2023	Issue gone at the same time as other meter settings where changed (16 Oct).	To consider in the KPI assessment: there could be some data gaps before the issue was fixed.	October 2023
On SE portal: PVT heat meter values not changing	since 2 Oct 2023 ~20:30	Data collection renewed from 3 Oct 2023 11:45	To consider in the KPI assessment: there could be some data gaps until the issue was fixed.	October 2023
iSCAN alarms not being sent to the demo manager (and the simulation support partner?)	September 2023	IES to set alarms that if there is a data gap of more than 24 h, it informs the demo group to be able to react more quickly	/	/

5.3 KPIs analysis

To calculate the KPIs the electrical and thermal balance is performed considered the different variables from the meters (heat, electricity meters)

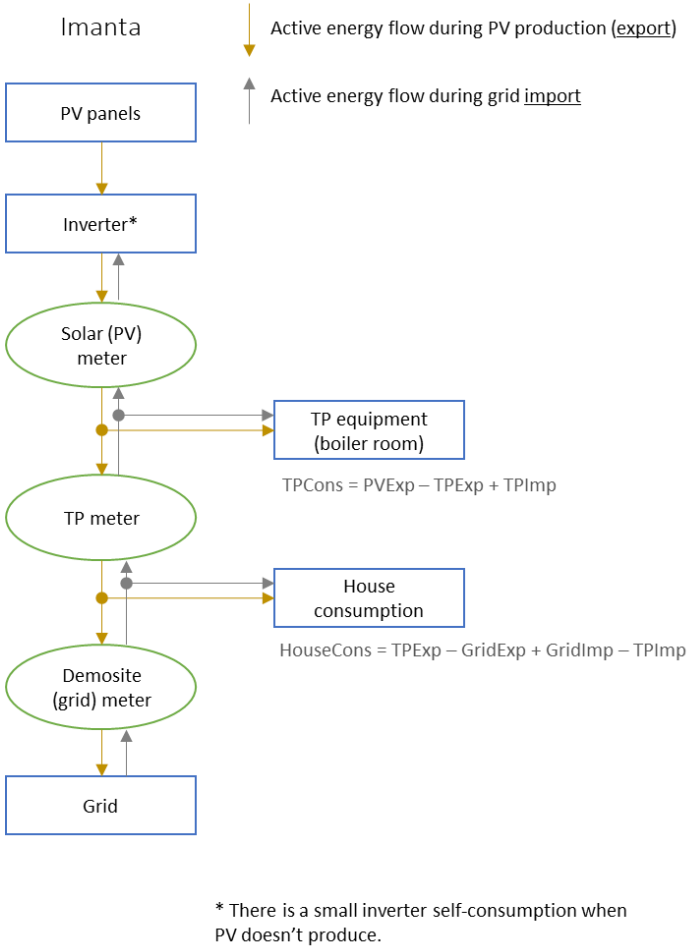


Figure 39: Electrical balance

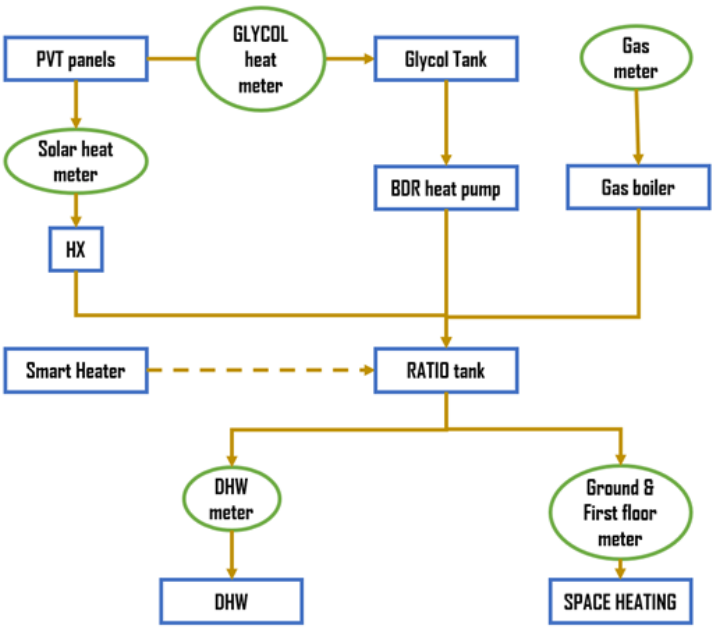


Figure 40 - Thermal balance

5.3.1 Electrical balance

The electrical balance covers the period from November 2022 and October 2023. For each month, the electricity balance is calculated as shown in Figure 12. Moreover, the electricity balance related to the month of October 2023 is shown in Figure 13 below.

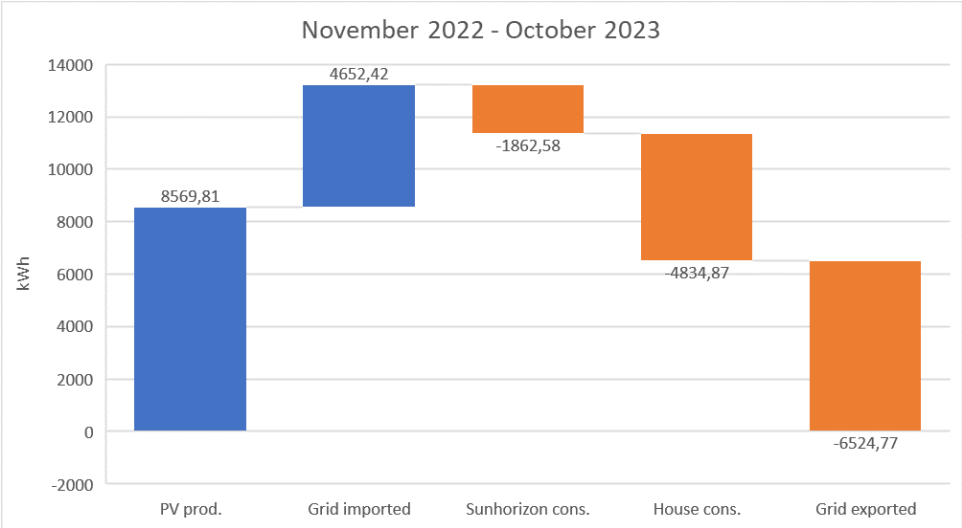


Figure 41 - Electrical Balance: November 2022- October 2023

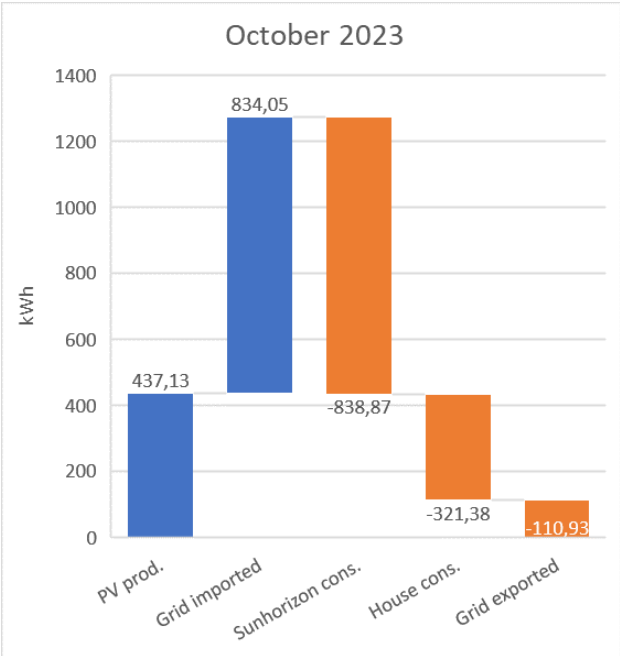


Figure 42 - Electrical Balance: October 2023

Production and consumptions data regarding the twelve months are shown in the table below.

The electricity consumption of the house is quite similar in every month (slightly higher in November 2022 and December 2022) with an average consumption of 402.9 kWh per month.

The exported energy to the grid is higher in May, June, July and August 2023 due to the higher PV generation during May-July 2023, resulting in reduced SunHorizon electricity consumption. Production from photovoltaic plant (PV production-

kWh) is also higher in spring- summer periods (April – September 2023) mainly due to a higher solar radiation in these periods.

During the whole period of its operation (December 2021–September 2023), BH was able to function only as a gas boiler, hence it did not contribute significantly to the TP2 electricity consumption, named as SunHorizon consumption in the figure below. Instead, since its commissioning in late September 2023, the BDR heat pump has been operating successfully.

Therefore, in October 2023 there was a sharp increase of SunHorizon electricity consumption (around 840 kWh) due to the BDR HP operation.

The self-consumption ratio varies from 13% (May 2023) to 95% (December 2022).

Table 13 - Electricity balance results from November 2022 to October 2023

	Months - year 2022/2023	PV Production (kWh)	Grid Imported (kWh)	SunHorizon consumptions (kWh)	House consumptions (kWh)	Grid Exported (kWh)	PV self-consumptions (kWh)	Self-consumption ratio (kWh)
Nov-22	11	66.94	616.83	106.71	563.93	13.14	66.94	80%
Dec-22	12	21.34	758.07	146.72	631.65	1.04	778.37	95%
Jan-23	1	54.06	552.68	148.40	448.62	9.73	597.01	82%
Feb-23	2	157.61	443.39	159.84	386.06	55.09	545.91	65%
Mar-23	3	530.31	324.24	257.01	342.72	254.82	530.31	52%
Apr-23	4	1,171.79	197.40	193.19	330.30	845.70	523.49	28%
May-23	5	1,695.26	165.90	40.10	345.53	1.475.53	385.63	13%
Jun-23	6	1,543.08	138.82	26.60	350.12	1.305.18	376.72	15%
Jul-23	7	1,256.53	172.87	29.15	390.58	1.009.67	419.73	20%
Aug-23	8	985.00	224.86	29.97	422.57	757.32	452,54	23%
Sep-23	9	857	223.30	92.24	301.43	686.63	650.77	20%
Oct-23	10	261	834.05	838.87	321.38	110.93	437.13	59%

Solar electric efficiency is calculated for the PVT panel and the results are shown in the following table:

Table 14 - PVT solar efficiency

2022/2023	Oct-23	Sep-23	Aug-23	Jul-23	Jun-23	May-23	Apr-23	Mar-23	Feb-23	Jan-23	Dec-22	Nov-22
PV Energy Exported [kWh]	261	857	985.00	1,256.53	1,543.08	1,695.26	1,171.79	530.31	157.61	54.06	21.34	66.94
Solar Eff.	16%	19%	13%	15%	17%	19%	17%	12%	11%	13%	50%	30%

The PVT solar efficiency ranges between 11% (February 2023) and 50% (December 2022).

5.3.2 Thermal balance

Monthly domestic hot water (DHW) consumptions are shown in table below.

Table 15 - monthly DHW consumption

2022/2023	Oct-23	Sep-23	Aug-23	Jul-23	Jun-23	May-23	Apr-23	Mar-23	Feb-23	Jan-23	Dec-22	Nov-22
DHW Consumption [kWh]	76.00	194.00	220.00	201.00	193.00	204.00	191.00	215.00	176.00	231.00	256.00	166.00

Some inconsistencies in the data have been discovered, those can impact on a proper thermal energy balance. As seen, the thermal energy measured on the production side of the PVT panels does not match the one measured on the glycol side. The mentioned difference is reported in the figure below, where the gap between the two variables is above 100%. This is mainly due to the fact that the BDR operation started, allowing the intense use of the glycol tank.

Specifically, it is worth mentioning the following two points:

- High value (much more than the other values for the other months) for Heat PVT and Glycol Thermal Energy in October 2023. This is since BDR heat pump started operating;
- Heat PVT is equal to zero in July and August 2023 due to works regarding replacement of BH heat pump with BDR heat pump.

Table 16 - Thermal PVT Production vs Glycol Thermal Energy

2022/2023	Oct-23	Sep-23	Aug-23	Jul-23	Jun-23	May-23	Apr-23	Mar-23	Feb-23	Jan-23	Dec-22	Nov-22
Heat PVT [kWh]	1,152.00	103.00	0.00	**0.00**	33.00	31.00	13.00	1.00	0.000	0.000	0.000	0.000
Glycol Thermal Energy [kWh]	1,103.00	68.00	163.00	164.00	235.00	230.00	87.00	2.00	0.000	0.000	0.000	0.000
Difference	-4%	-51%	100%	100%	86%	87%	85%	50%	105%	#DIV/0!	#DIV/0!	#DIV/0!

This difference is because part of the PVT energy can flow directly to the Oskar tank. The “glycol” meter only accounts part of the PVT energy flowing to the glycol tank.

5.3.3 Quality of measured data

Regarding quality of measured data in some cases there are few gaps as shown in the following graphs.

For example, as regards the office air temperature, quality of measured data for some months of year 2023 is good enough, as shown in the following figure.

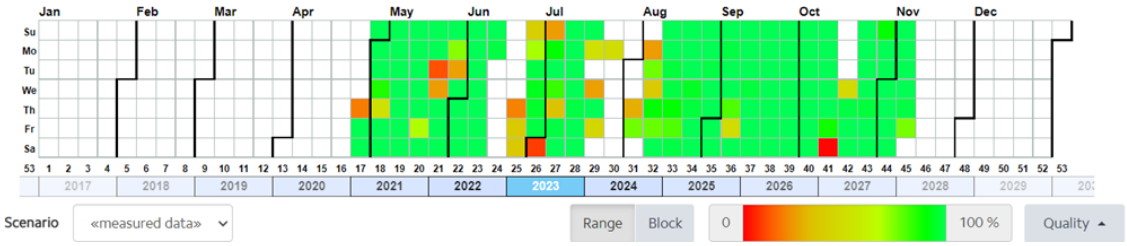


Figure 43 - Office air temperature - Data quality

Similarly for the humidity in the office whose quality of data, measured in year 2023, is shown below:

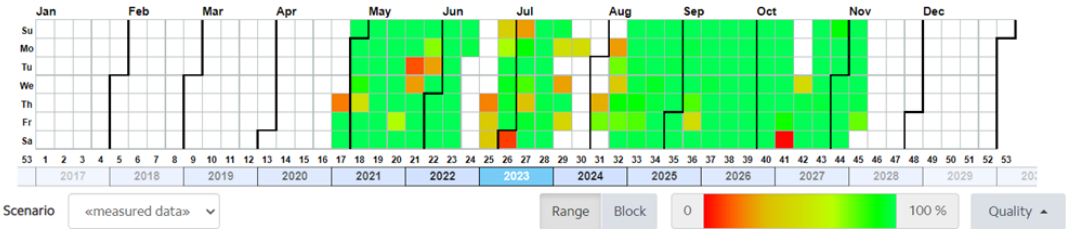


Figure 44 -Office air humidity - Data quality

5.3.4 Gas consumption

As regards gas consumption, trend concerning the period November 2022 – October 2023 is shown in the following table.

Table 17 - Gas consumptions

2022/2023	Oct-23	Sep-23	Aug-23	Jul-23	Jun-23	May-23	Apr-23	Mar-23	Feb-23	Jan-23	Dec-22	Nov-22
Gas Consumption [kWh]	364.80	833.08	191.04	155.46	208.14	473.94	1,633.94	3,734.46	4,495.56	4,406.60	4,348.75	2,969.18
PV production [kWh]	261	857	985.00	1256.53	1543.08	1695.26	1171.79	530.31	157.61	54.06	21.34	66.94

Gas consumptions were obtained from the Schneider platform in m^3 and converted in kWh considering a natural gas Low Heating Value (LHV) equal to 9.94 kWh/m^3.

As shown in the table above, gas consumptions are higher in the period between November 2022 and April 2023 when production from PV plant is lower.

5.4 KPI summary

In this section monthly savings indicators are reported, as well as self-consumption ratio, renewable energy ratio. In order to estimate the savings on emissions, non-renewable energy and energy bills, the measured data is compared to the baseline, which was defined on the deliverable *D2.5 SunHorizon TPs and demosite conceptual design and simulations.*

The chosen period to be analysed is from November 2022 to October 2023 (in the deliverable D6.5 the period chosen was from February 2022 to October 2022). It is worth mentioning that BH unit was operational (only as condensing gas boiler) from December 2021 until September 2023 when it was replaced by a new BDR heat pump whose installation and integration within the TP was finalised in September 2023, followed by some fine-tuning of controls also in October and the final integration of the final monitoring meters by SE in the second half of October 2023, so there are not enough data to obtain monthly indicators for this equipment.

Due to the issues previously defined the integration of data on the IES dashboards and the KPIs formulas had to wait until October 2023. For this reason, the formulas have been directly applied on downloaded data from the Schneider platform, to extend the monthly KPI analysis period from November 2022 to October 2023.

Monthly main results achieved in this monitoring period are included in the table below.

The savings in the energy bills are calculated employing the hourly day-ahead electricity market prices for Latvia obtained from the ENTSO-E transparency platform[1] and the regulated natural gas tariff for residential end-users with gas heating[2], it has also been taken into account that within the net metering system, the PV surplus exported to the distribution grid is discounted from the energy bill at the same price if consumed within the defined 12-month period for net metering.

Electricity bill savings are higher due to PV electricity generation which is either self-consumed or exported to the grid for later use and provides a significant discount from the final energy bill. The savings can be observed despite the surge of electricity prices which increased a few times in 2022.

Table 18 - Riga_Imanta: Monthly KPIs from November 2022 to October 2023

KPI_2022-2023	Name	Actual Value	Threshold	Deviation
CAPEX	Capital Expenditure	133,757€	-	-
CBR	Customer Bills Reduction	1%	Up to 60%	No
GHG savings	Avoided GHG emissions	98%	40 to 60%	No
OPEX	Operation Expenditure	168.37 €	-	No
PESnren	Non-Renewable Energy Savings	47%	50 to 70%	No
RER	Renewable Energy Ratio	18%	40 to 70%	No
SCR	Self-Consumption Ratio	42%	Up to 80%	No

[1] ENTSO-E Transparency Platform webpage: https://transparency.entsoe.eu/dashboard/show

[2] Regulated natural gas tariff for residential end-users with gas heating (Latvia): https://lg.lv/en/for-home/tariffs-and-calculator

5.5 Alarms logging

Alarms will be reported here. An automatic email will be sent to the building staff (to be confirmed), demo responsible, and the simulation supporting partner. No alarm notification has been set yet for this demo site.

Table 19 - Alarm receivers (Riga Imanta)

ROLE IN THE PROJECT	PROJECT PARTNER
Building Staff	Not registered yet
Demo Responsible	RTU/Zane Broka
Simulation Supporting partner	RINA/ Diego Rattazzi - Carlo Barbieri

6 Riga Sunisi demo site #8.2

6.1 Status update of the demo site

As reported in D6.5, the initial TP2 configuration including the BH unit[5] was operational from April 2022 until September 2023 when the BH machine was replaced with BDR equipment following BH withdrawal from the consortium. The final TP2 upgrade (Figure 36Figure 36) involved installation of a BDR heat pump, a back-up gas boiler, both integrated into TP2 via the existing storage tanks, and minor interventions in the space heating loop and DHW loop previously controlled by BH. SunHorizon TP2 in Riga, Sunisi demo site is composed of the following components:

- DS PVT Panels (49.5 m^2, 9.6 kW$_p$);
- BDR heat pump GSHP 9 TR-E (9 kW) and backup condensing gas boiler MCR 24/28 MI (24 kW), both installed in 2023;
- BH heat pump with integrated gas boiler (20 kW), installed in 2021 and decommissioned in 2023;
- RATIO Oskar tank 1300 L (stratified thermal storage);
- RATIO glycol storage tank 200 L.

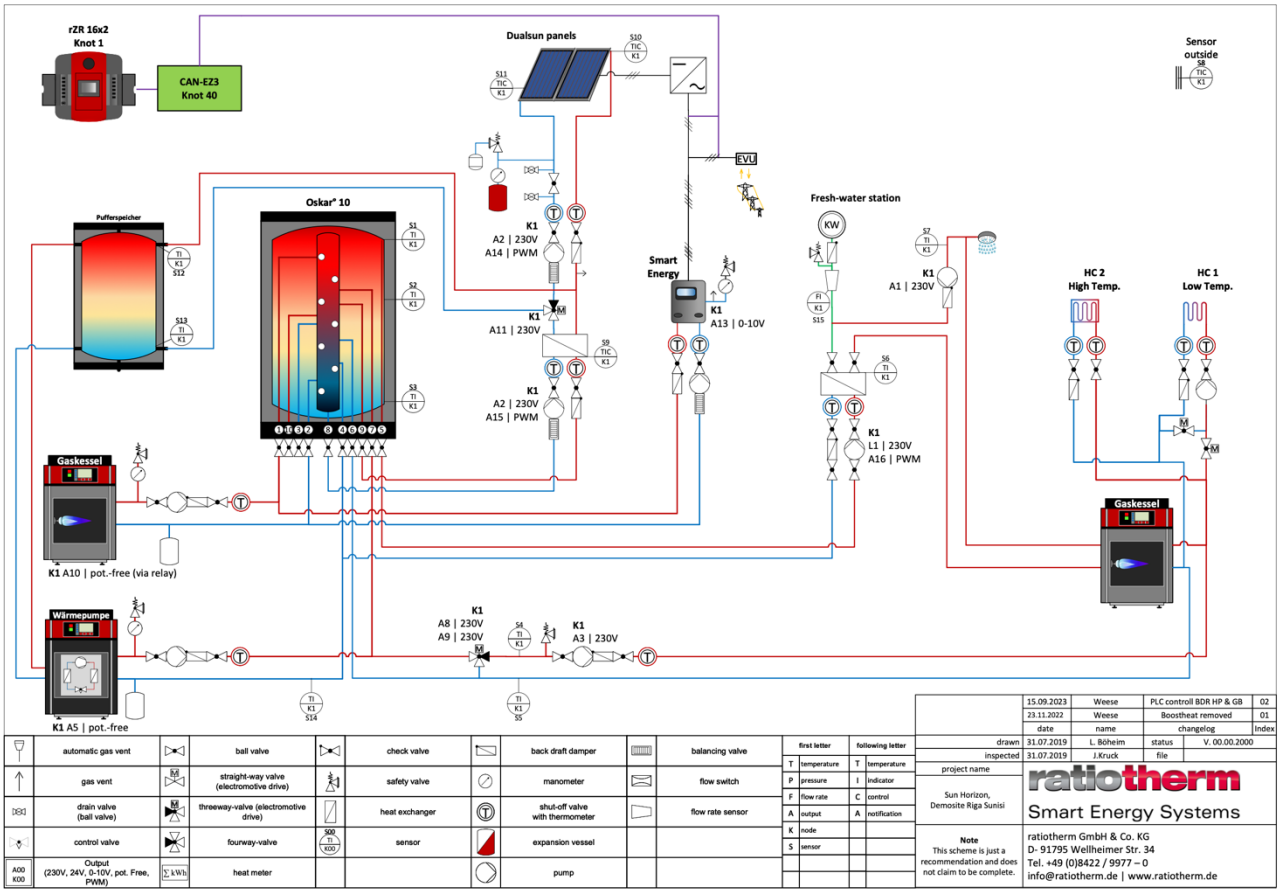


Figure 45. Final TP2 configuration for Sunisi demo site with BDR heat pump, in operation since September 2023

The BH unit in Sunisi demo was decommissioned on 20 September 2023. However, even before that (since 3 August 2023) BH was not operating and had stopped providing heat after an electricity outage when it became impossible to turn the machine on at all. BoostHeat was unable to provide any technical support as they did not have the personnel nor the

[5] It must be noted that the BH unit was only operating as a condensing gas boiler, even though it had a thermodynamic heat pump block as well. BH was unable to operate as a heat pump during the whole demonstration period due to various technical issues of the machine despite the efforts of the involved partners, especially BH.

remote monitoring in place anymore, hence from August until September, the demo site was using the old gas boiler (not integrated within TP2) for DHW production.

After BH decommissioning, the BDR gas boiler was installed and commissioned followed by the BDR heat pump. Hence, right after BH decommissioning the thermal needs were already covered by the BDR equipment. However, several challenges were faced and needed to be solved, mainly related to the TP2 control (reported in more detail D6.7), therefore the final commissioning incl. full control of the integrated TP2 with RATIO PLC took place on 28 September 2023. Some fine-tuning of the controls was still necessary based on the first observations of the upgraded TP2 operation during the next days, and the final corrections of the PLC program were implemented by RATIO on 6 October 2023. Hence, during the two-week upgrade period some inefficiencies in TP2 operation could be noticeable.

6.2 Status update of the monitoring system

The monitoring architecture implemented by SE in Sunisi is illustrated in Figure 46. Additionally, SE also collects data from RATIO PLC, and was collecting data from BH until its failure in the beginning of August 2023. Furthermore, as BH was equipped with a gas meter and heat meter as part of their "external instrumentation", SE developed a solution of how to reuse those two meters after the TP2 upgrade in order to measure the BDR gas boiler's consumption and space heating flow of the upgraded TP2. Location of the meters reused from BH is shown in Figure 38 (red ovals). However, integration of the additional meters required reconfiguration of some of the already existing meters, also affecting the data flow to iSCAN and the KPI calculation tool. Hence, the involved partners needed to integrate a number of new variables from the affected meters based on the updated configuration.

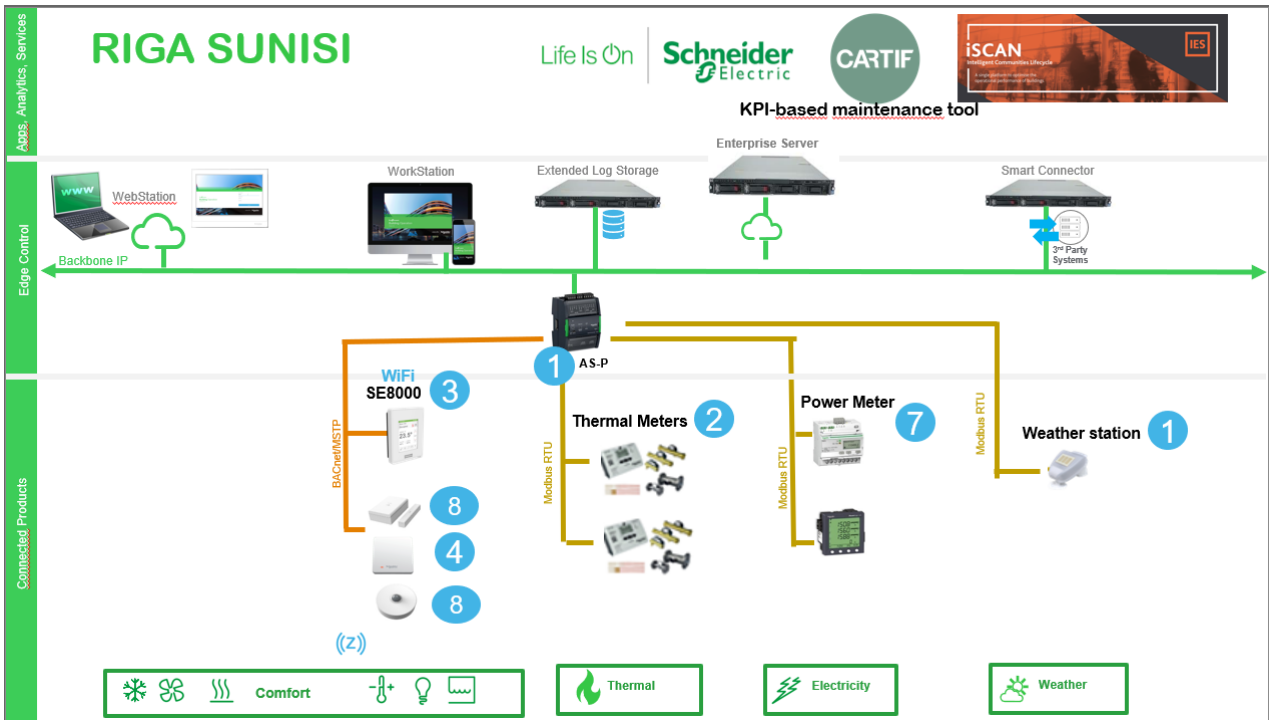


Figure 46. Monitoring architecture (Riga Sunisi)

Table 20: Data collection progress (Riga Sunisi)

Relevant events	Date when discovered	Action taken	Mitigation plan	Date when solved
Inconsistent data from the PVT and glycol tank energy meter	September 2023	During onsite inspection of the meters, wrong labelling/wiring of the two	For energy assessment, data previously labelled as the "PVT meter" should be swapped with	September 2023

		respective heat meters was identified.	the “glycol meter”. (If need to double-check, PVT energy is always higher than the Glycol tank energy.)	
Technical challenges of SE to read the data from the two BH meters	September 2023	After the physical meter connections were established onsite, SE was unable to read the data from the gas meter and space heating meter. Additional documentation was requested from BH (not received) and from the manufacturer (*SE to update*)…	SE managed to integrate the meters despite the missing documentation. However, the Modbus connection sometimes fails unexpectedly. Data collection ongoing, albeit with some gaps. This can be alleviated since the meters provide the cumulative energy, so in case of connection issues, the total energy is still accounted for.	October 2023
Reconfiguration of the existing heat meters and weather station due to the need to integrate the two BH meters	September 2023	In order to integrate the two BH meters, some existing meters needed to be reconfigured and reintegrated by the involved partners (SE, CAR, IES).	To consider in the KPI assessment: before the reconfiguration is complete, some data gaps can occur. This period partially coincides with fine-tuning of the upgraded TP2 operation.	October 2023
Large fluctuations of RATIO Oskar top temperature (T.Oskar top) on SE portal	September 2023	Ratiotherm confirmed they don’t observe the same in their data logs. Issue fixed itself after reconfiguration of some sensors connected to the PLC.	Invalid values should be ignored if inconsistent with the Oskar mid and bottom temp or nearby datapoints. As the issue was only with SE data, more accurate data logs can be obtained from RATIO.	October 2023
Long data gaps from some room monitoring sensors	October 2023	After checking onsite, some sensors were found to be moved by the residents together with some furniture without informing RTU. Some sensors’ batteries also needed to be replaced.	Discuss with the residents. For KPI assessment, as several sensors provide the room temperature and humidity, the other nearby sensors can be used in case of long data gaps.	October 2023
iSCAN alarms not being sent to the demo manager (and the simulation support partner?)	September 2023	IES to set alarms that if there is a data gap of more than 24 h, it informs the demo group to be able to react more quickly	/	/
BH failed permanently in the beginning of August 2023	August 2023	From August until BDR replacement in September, the demo site used their old gas boiler for DHW production, which is not integrated within the TP2.	To consider in the KPI assessment: DHW production during the transition period was not monitored as the old boiler was used and the TP2 did not contribute with any heat.	September 2023

6.3 KPI and PIs analysis

Monitoring started in November 2020 for the indoor comfort data and building thermal and electrical consumption, then some TP data as DualSun started to be monitored since mid-January 2022, so the chosen period to be analysed is from January 2022 to October 2023. Also bear in mind that BH unit was operational (only as a condensing gas boiler) from April 2022 until September 2023 when it was replaced with a new BDR heat pump whose installation and integration within the TP2 was finalised in September 2023, but SE experienced challenges in integrating the additional meters until mid-October 2023, so there are not enough data to obtain monthly indicators for this equipment.

Due to the issues previously defined; the integration of data on the IES dashboards and the KPIs formulas had to wait until October 2023. For this reason, the formulas have been directly applied onto downloaded data from the Schneider platform, to extend the monthly KPI analysis period from January 2022 to October 2023.

6.3.1 Electricity balance

For the analysis and calculation of the electric energy, the following variables will be used and are connected as shown in the following diagram, with this configuration the electric consumption of the SunHorizon TP will be studied.

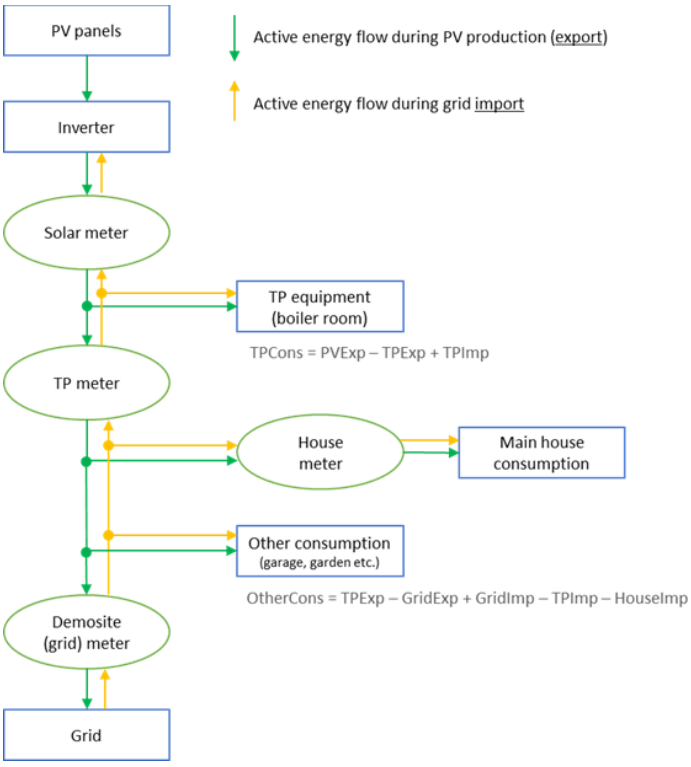


Figure 47: Riga, Sunisi: Electric diagram

In the table below (Figure 48), we have the monthly summed values (in kWh) obtained from the four electricity meters from January 2022 until October 2023. Starting from the left side, the table displays the electricity *imported from the grid* and *exported* to it as well as the *electricity generated* by the PVT panels, which altogether are important indicators for the net metering applied in this demo site and have strong influence on the economic indicators. The solar generation is either self-consumed (shown as a monthly ratio in the last column) or exported to the grid.

Next, as concerns the consumption, it is split in three categories based on the demo site and monitoring system configuration: *main house consumption* reflects the electricity consumed in the main residential building and, thus, does not variate a lot during the year; *SunHorizon consumption* reflects the total amount of electricity consumed by the equipment in the boiler room; *other consumption* reflects the remaining consumption of the household in addition to the first two categories and includes the garage and the playroom, garden, pump for the tap water (obtained from a ground drill) etc. Hence, this consumption can vary a lot depending on the season or specific activities/projects ongoing in the household. For example, during hot weather in summer it can significantly increase due to watering of the garden.

The main house electricity consumption remains about 300 kWh/month, but exported energy to the grid is greater in 2023 mainly due to optimised operation of the TP2 resulting in reduced SunHorizon electricity consumption. For example, RATIO Smart Energy electric heater was extensively operating during April–July 2022, thus significantly contributing to the electricity consumption which reached up to 496.6 kWh/month (May 2022) compared to 30–40 kWh/month before and after this period when Smart Energy was not operating. The electric heater is supposed to convert the surplus PV electricity production into heat to store it in the Oskar tank, which is especially useful if the feed-in to the grid is not reimbursed (as is the case in Germany for which the heater has been primarily designed). In order to accommodate the heater control strategy to the Latvian rules where the feed-in of PV electricity within the net metering system is beneficial allowing to "store" electricity in the grid for later use, RATIO modified their control strategy so that the Smart Energy heater consumes only that part of electricity which is not consumed within the course of the year. However, the strategy was difficult to be implemented as it required measuring and estimating the imported and exported electricity during the year (net metering period lasts from March until February next year). Eventually, during TP2 operation in summer 2022, it was observed that the electric heater consumes too much electricity, reducing the amount that can be fed into the grid for later use. The reason for that could be inaccuracies in the implementation of the rather complex control strategy and also sub-optimal location of the current clamps (due to space restrictions and insufficient cable length). In order to maximise the economic benefits, as it was impossible to easily correct the control strategy, the electric heater was turned off manually in the beginning of July 2022. Consequently, the SunHorizon TP2 electricity consumption decreased during the next months.

During the whole period of its operation (April 2022–August 2023), BH was able to function only as a gas boiler, hence it did not contribute significantly to the TP2 electricity consumption, named as *SunHorizon consumption* in the Figure 48. Instead, since its commissioning in late September 2023, the BDR heat pump has been operating successfully. Therefore, in October 2023 there is a sharp increase of SunHorizon electricity consumption due to the BDR HP operation. Meanwhile, this resulted in a much lower consumption of gas as can be seen further on.

The same electricity consumption trends are evident from the aggregate daily data (Figure 49) where we can observe sharp increase of TP2 consumption in May–July 2022 due to the Smart Energy electric heater and then again from the end of September 2023 due to the BDR HP. Interestingly, from the charts we can also see significant differences in solar generation in the same month between both years. For example, in March 2022 the PVT panels were able to generate more than twice the amount of electricity than in March 2023 (990 kWh vs 424 kWh). This is due to the weather conditions as a very similar trend was observed also in Riga, Imanta demo site.

Regarding the self-consumption of PV electricity, it has an average ratio of 40%. It can also be seen that DualSun solar electric generation yearly generation follows the same trend and efficiency. The self-consumption ratio during winter months is much larger than during summer as the weather conditions are not generally beneficial leading to a small amount of PV electricity generation, most of which can be instantaneously consumed by the household. The whole set of electricity meters deployed in the demo site provide valuable insights on the self-consumption ratio. Those data are normally not available from a standard PV installation since only the net import/export is accounted for by the DSO.

Elec.	kWh	Grid imports	Grid exports	Solar generation	Main House cons.	SunHorizon cons.	Other cons.	Self-consumption ratio
2022	1	169.7	0.0	0.0	121.5	9.6	39.6	0%
2022	2	464.0	48.9	74.4	232.6	23.1	236.0	34%
2022	3	316.6	711.4	990.0	386.3	32.9	177.7	28%
2022	4	267.9	761.4	1146.8	337.1	266.5	51.1	34%
2022	5	619.7	604.6	1333.1	352.1	497.8	499.5	55%
2022	6	464.0	549.8	1380.2	363.1	415.5	516.8	60%
2022	7	368.6	822.9	1345.4	385.3	111.4	395.5	39%
2022	8	273.0	950.5	1251.5	334.6	33.7	207.2	24%
2022	9	237.6	662.8	844.0	317.0	39.9	63.6	21%
2022	10	334.6	262.2	393.2	304.3	74.3	89.0	33%
2022	11	377.3	21.4	61.8	270.8	61.8	87.8	65%
2022	12	551.0	0.8	12.9	324.8	62.4	179.3	94%
Total 2022		4444.1	5396.6	8833.1	3729.7	1629.0	2543.0	40.7%
Elec.	kWh	Grid imports	Grid exports	Solar generation	Main House cons.	SunHorizon cons.	Other cons.	Self-consumption ratio
2023	1	818.5	11.4	65.4	378.8	65.2	431.6	83%
2023	2	638.5	79.0	188.0	296.7	53.0	400.0	58%
2023	3	630.5	227.0	423.7	382.4	57.1	389.7	46%
2023	4	289.5	812.5	1074.8	308.9	47.7	196.5	24%
2023	5	356.3	1074.8	1608.5	308.2	41.6	541.3	33%
2023	6	541.4	964.4	1530.7	211.9	36.5	860.3	37%
2023	7	234.9	951.5	1251.3	277.7	36.3	221.9	24%
2023	8	278.9	756.8	1031.6	268.4	73.2	213.4	27%
2023	9	257.1	708.6	912.2	296.1	63.0	103.1	22%
2023	10	847.4	94.9	253.4	301.2	622.7	83.9	63%
Total 2023		4893.1	5680.9	8339.6	3030.3	1096.3	3441.8	41.7%

Figure 48: Riga, Sunisi: Monthly electricity data

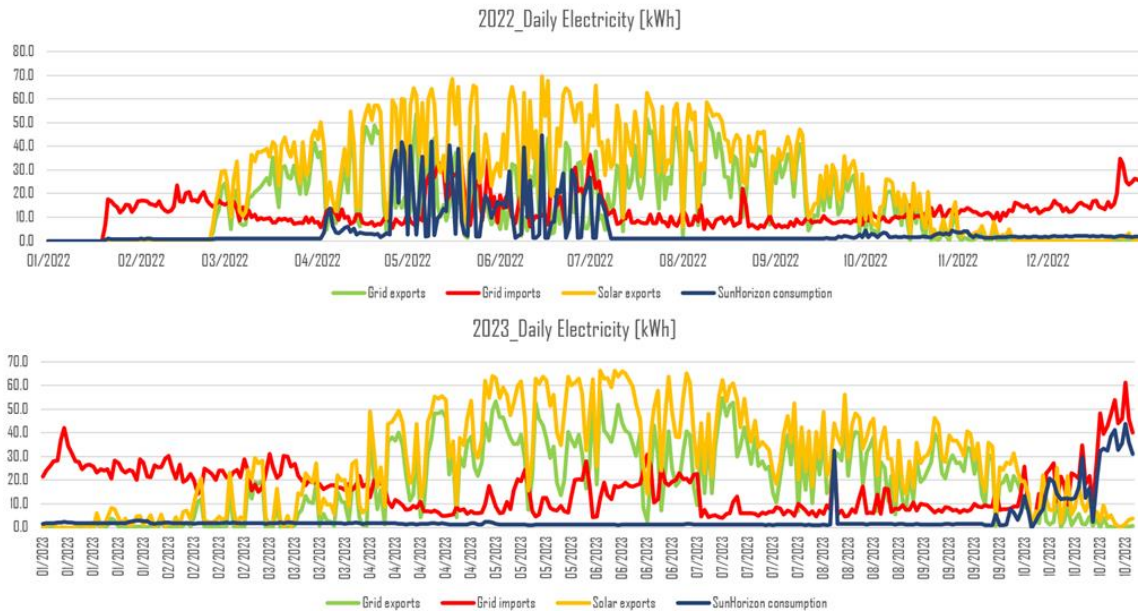


Figure 49: Riga, Sunisi: Daily DualSun electrical generation and exports to the grid

In the energy balance (Figure 50) we can see how the electricity is being consumed within the household and considering the TP2 operation. From the total numbers in 2022, we can observe that the whole household electricity consumption was covered by the PVT generation throughout the year. Hence, the household could significantly benefit employing the net metering system, especially considering the sharp increase of electricity market prices in 2021/2022. On the right there is the energy balance for October 2023 where a sharp increase of SunHorizon consumption due to the BDR heat pump

operation is evident, leading to an increase of the energy imported from the grid. It also showcases the efficiency of the BDR HP as its electricity consumption was twice less than the gas consumption of BH (gas boiler) during the same month in the year before (2022) despite the fine-tuning of TP2 controls which was still ongoing in October 2023.

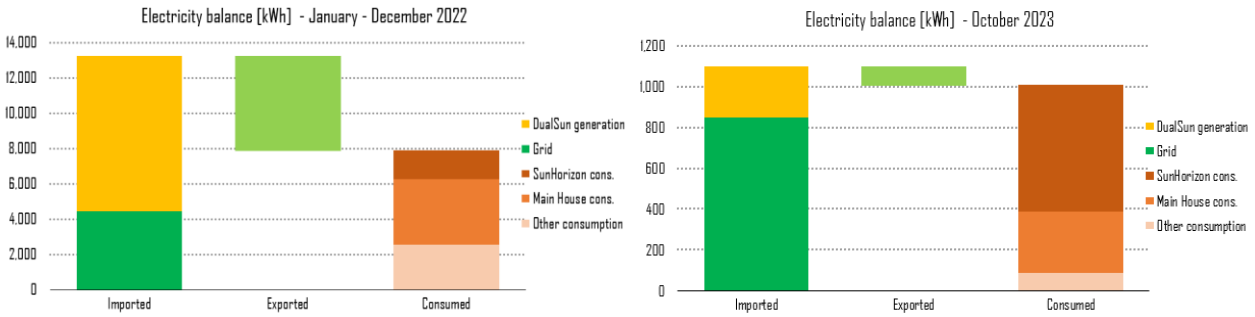


Figure 50: Riga_Sunisi: Electrical energy balances [Left:2022, Right: October 2023].

Onto the IES dashboard platform there are some plots available since the integration of the channels in October 2023, in Figure 51 there is a daily energy balance, including onsite PV generation with DualSun, the imported and exported electricity to the distribution grid and different consumptions (House, SunHorizon Systems and Other), which seems consistent; but monthly indicators could not be considered for this period due to data gaps.

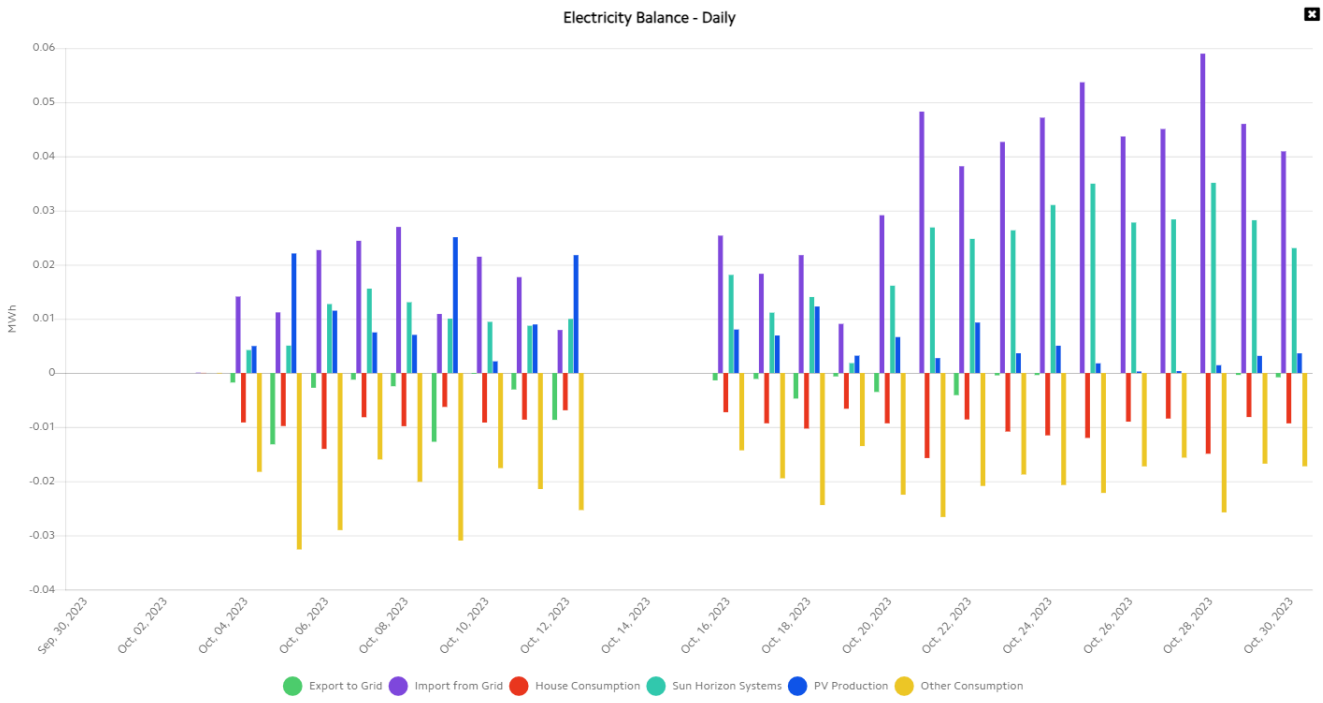


Figure 51: Riga, Sunisi: Electricity overview

In order to obtain the thermal balance and a detailed overview of all the heat flows, the demo site was equipped with six heat meters and a gas meter. Three meters (DHW, ground floor and first floor space heating) were installed for the pre-monitoring in October 2020 and the other three were mounted together with TP2 installation in order to monitor the heat produced by the TP2 and its different components (e.g. the thermal contribution of PVT panels). A simplistic diagram of the TP2 components and meter configuration is shown in Figure 52.

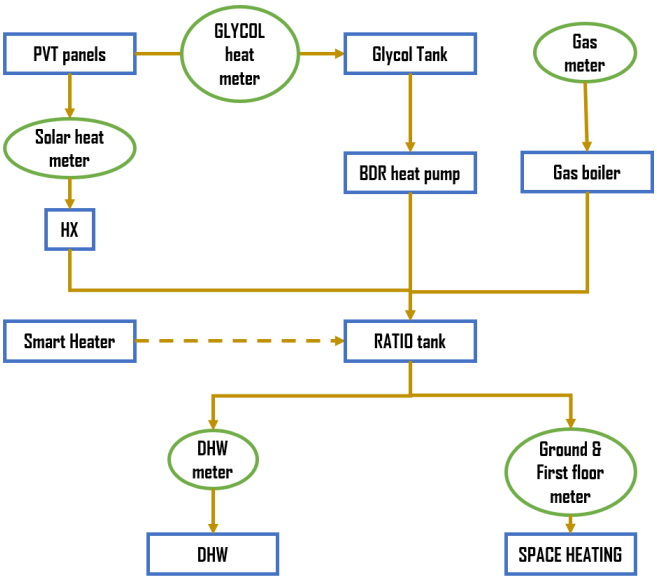


Figure 52: Riga, Sunisi: Thermal diagram

In the table below (Figure 53), we have the monthly summed values of the different heat meters, starting with the heat meter of the PVT field, glycol tank meter, gas consumption followed by the useful heat energy generated by the heat pump and the whole TP2. Furthermore, the space heating consumed in the main house is metered for the ground floor and first floor separately followed by the DHW consumption, as it can be seen in the thermal energy balance below.

The data derived from the various heat meters reflects both the period before BH operation when the previous conventional gas boiler was still employed (until April 2022), TP2 operation with the BH (from April 2022 until August 2023) and TP2 operation with BDR (since October 2023). Compared to electricity meters, the thermal meters suffered more issues due to different reasons as summarised in Table 20, hence the data must be treated with caution, especially in the periods affected by the issues. Moreover, the heat meters are very sensitive with respect to their location and mounting specifics. For example, to achieve the best accuracy, long sections of pipes without any bends are required. It was impossible to fully follow this guideline as the meters for the ground floor, first floor and DHW were installed in a small bathroom where the respective pipes were already mounted in a very compact and tight space without very long straight sections. Furthermore, the accuracy of the PVT and glycol tank meter is affected by the glycol-based heat carrier concentration which varied during the whole TP2 operation (e.g. dilution was performed as requested by BH followed by top-up a few times in order to increase the pressure according to BH requirements).

Heat	kWh	PVT	Glycol tank	BH gas cons.	BH SH generation	SH Ground floor cons.	SH first floor cons.	DHW cons.
2022	1	0.0	0.0	2676.7	0.0	1331.0	692.0	84.0
2022	2	0.0	0.0	2160.3	0.0	1102.0	553.0	72.0
2022	3	0.0	0.0	1991.7	0.0	1026.0	503.0	81.0
2022	4	0.0	0.0	1422.6	0.0	725.0	278.0	11.0
2022	5	0.0	0.0	685.0	83.0	242.0	84.0	0.0
2022	6	19.0	16.0	314.2	0.0	4.0	0.0	0.0
2022	7	135.0	28.0	102.0	0.0	2.0	0.0	0.0
2022	8	185.0	28.0	134.1	0.0	3.0	0.0	0.0
2022	9	62.0	12.0	431.2	120.0	82.0	30.0	0.0
2022	10	10.0	3.0	1274.7	728.0	499.0	165.0	13.0
2022	11	0.0	0.0	2059.7	1405.0	802.0	477.0	39.0
2022	12	0.0	0.0	2929.0	2150.0	1204.0	765.0	40.0
Total 2022		411.0	87.0	16181.2	4486.0	7022.0	3547.0	340.0

Heat	kWh	PVT	Glycol tank	BH gas cons.	BH SH generation	SH Ground floor cons.	SH first floor cons.	DHW cons.
2023	1	0.0	0.0	2488.4	1861.0	1058.0	625.0	45.0
2023	2	0.0	0.0	2277.9	1669.0	873.0	626.0	64.0
2023	3	0.0	0.0	2111.1	1494.0	844.0	512.0	81.0
2023	4	0.0	0.0	1229.1	694.0	418.0	231.0	83.0
2023	5	0.0	0.0	1124.1	191.0	108.0	65.0	127.0
2023	6	35.0	2.0	437.8	1.0	0.0	0.0	111.0
2023	7	100.0	0.0	349.0	0.0	0.0	0.0	72.0
2023	8	89.0	0.0	35.2	0.0	0.0	2.0	50.0
2023	9	100.0	49.0	0.0	0.0	10.0	10.0	44.0
2023	10	482.0	571.0	35.0	0.0	831.0	360.0	69.0
Total 2023		806.0	622.0	10087.5	5910.0	4142.0	2431.0	746.0

Figure 53: Riga, Sunisi: Monthly thermal data

From Figure 53 as well as the thermal energy balance in Figure 54 we can observe that the heat consumption is less than the gas consumption due to the gas boiler efficiency (< 100%) and also due to the heat losses in the buried heat transfer line (~30 m) from the technical room to the main house. Furthermore, part of the DHW consumption was not accounted by the respective meter following BH commissioning until it was relocated in October 2022 as already described in D6.5. Generally, compared to the electricity charts, we can observe that the thermal energy is consumption is about twice larger,

hence the gas consumption will be the main contributor to the customer bills, especially considering that all the gas is imported from the grid while electricity was generated onsite by the PVT panels.

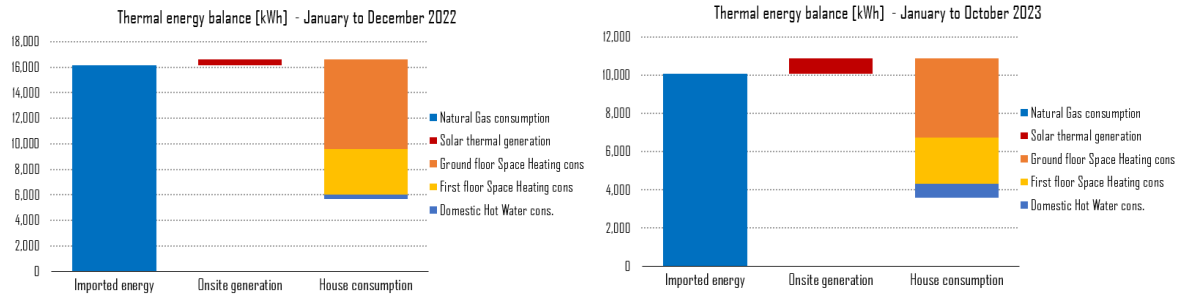


Figure 54: Riga, Sunisi: Thermal energy balances [Left:2022, Right: January to October 2023].

In the daily thermal energy graphs (Figure 55), we can observe that space heating comprises the largest consumption of space heating, and more consumption can be observed on the ground floor. This corresponds also to the room monitoring data whereby the ground floor rooms have usually higher temperature than the rooms located on the first floor. The temperature in the living room on the ground floor often reached ~25 °C and more during the heating season in 2022 according to user preferences. This aspect contributes to energy consumption and reducing the setpoint could provide some significant energy efficiency gains. Furthermore, in the bottom chart we can observe that the heating season started around October 2023, and since the end of October there is also data from the new TP2 heat meter including the heat generated by the BDR heat pump. Some of the daily values are higher than before due to connection issues of this Modbus meter (Table 20) which meant that some values were "frozen" for a few days and then provided in fact a cumulative value including a duration of several days.

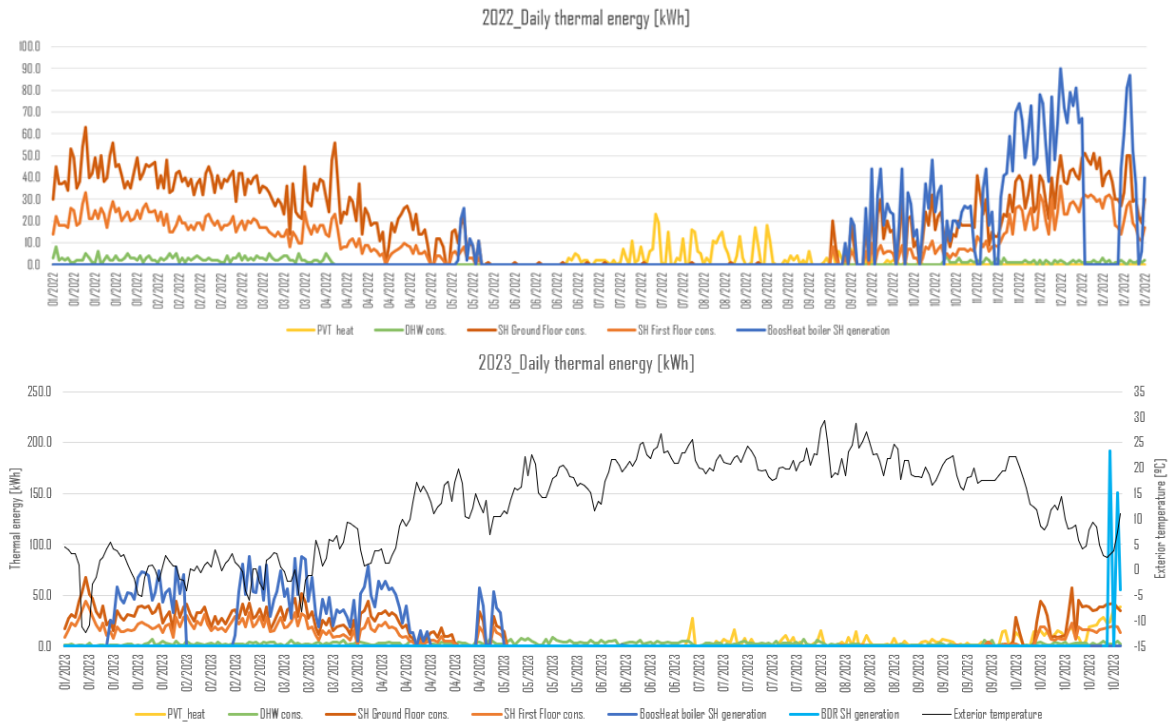


Figure 55: Riga, Sunisi: Daily thermal energy demand and generation

To estimate gas savings a regression model has been performed to adjust the gas consumption values of 2021 to climatic conditions of 2022 and 2023, this relation has been represented in Figure 56 below for the volume of natural gas consumed in 2021 in comparison to the external weather conditions expressed as heating degree hours (HDh). The resulting data though should be treated with caution since a single year only was used for the reference and the monthly gas consumption

was obtained from bills where the monthly values are already an estimation. Usually, the users read the meter manually only ~2 times per year, and the gas DSO provides an estimated monthly distribution for billing purposes.

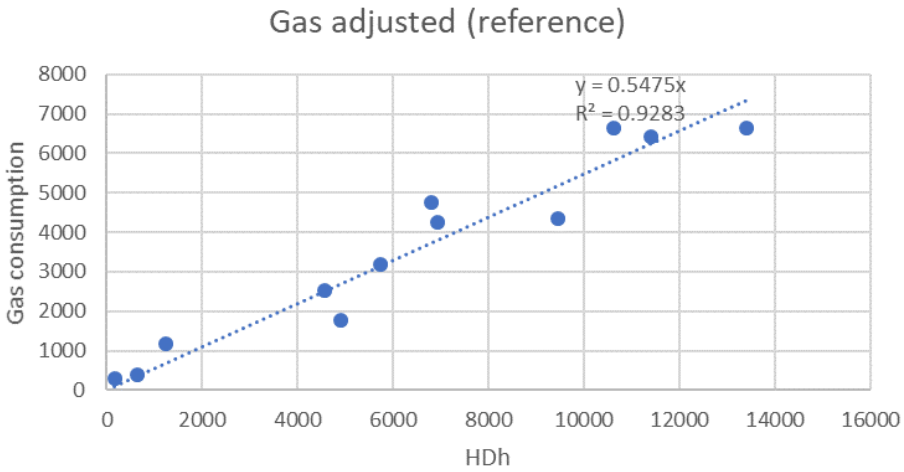
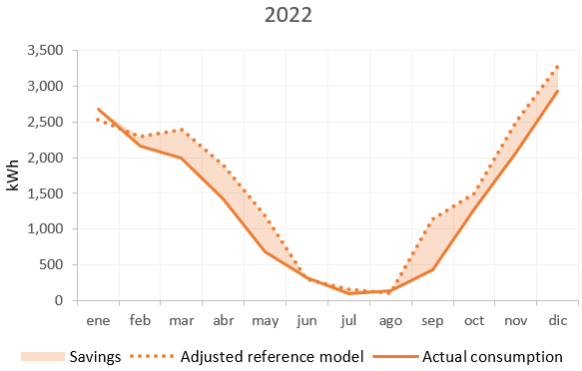


Figure 56: Riga, Sunisi: Gas consumption adjusted reference model

The estimated savings since January 2022 are depicted in the graphs below (Figure 57). It can be observed that there were some savings even before the BH commissioning (i.e. February–March 2022) and similar trend continued with BH operation from April 2022. A negative value actually implies increase consumption, and this could be observed especially in summer 2023. One reason for that could be the issue with BH operation which did not function as a heat pump, so did not provide significant benefit as such compared to the old gas boiler. Moreover, the old gas boiler was located in the main house (compared to BH and TP2 in the garage building ~30 m away), so with TP2 operation there are more losses due to the buried heat transfer line. Also, the old gas boiler provided instantaneous DHW (without a water tank), which might be more efficient with less losses compared to the BH which had its own internal DHW tank (60 L capacity). The BH tank top temperature was set to 65 °C even though the users don't need it to be so hot, hence this certainly contributed to thermal losses from the tank. Moreover, it meant that the heat from the PVT panels (which was usually less than 50 °C) during summer could not be used more efficiently as the BH would always operate its gas burner to supplement the heat provided by PVT panels.

2022	Gas consumption [kWh]	Gas savings [kWh]	Gas costs [€]
1	2676.7	-132.29	105.6
2	2160.3	135.47	85.2
3	1991.7	409.70	78.6
4	1422.6	454.68	56.1
5	685.0	468.28	27.0
6	314.2	-62.06	12.4
7	102.0	8.23	7.8
8	134.1	-83.79	10.2
9	431.2	674.38	32.9
10	1274.7	200.69	97.3
11	2059.7	449.30	157.2
12	2929.0	389.58	223.5
Total	16181.2	2912.2	893.8



2023	Gas consumption [kWh]	Gas savings [kWh]	Gas costs [€]
1	2488.4	545.04	274.7
2	2277.9	651.91	251.5
3	2111.1	654.94	233.1
4	1229.1	384.99	135.7
5	1124.1	-137.51	89.2
6	437.8	-142.29	34.7
7	349.0	-168.65	27.7
Total	10017.3	1708.4	1046.7

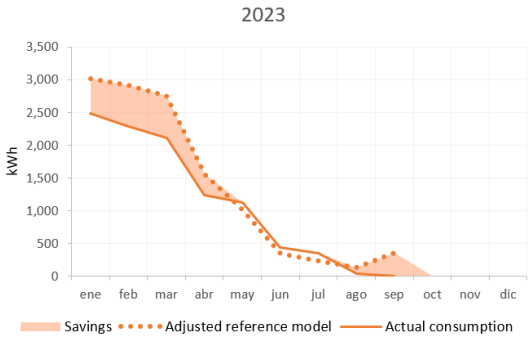


Figure 57: Riga, Sunisi: Estimated gas savings [Left:2022, Right: January to October 2023].

6.3.2 Heating comfort index

For Riga Sunisi demosite, the indoor comfort monitoring includes data of indoor temperature [ºC] for each room of the house, as well as the humidity [%] and CO2 levels [ppm]. The monitoring started in November 2020, there is a closer look for the chosen time period for study since January 2022 to October 2023 in the graphs below.

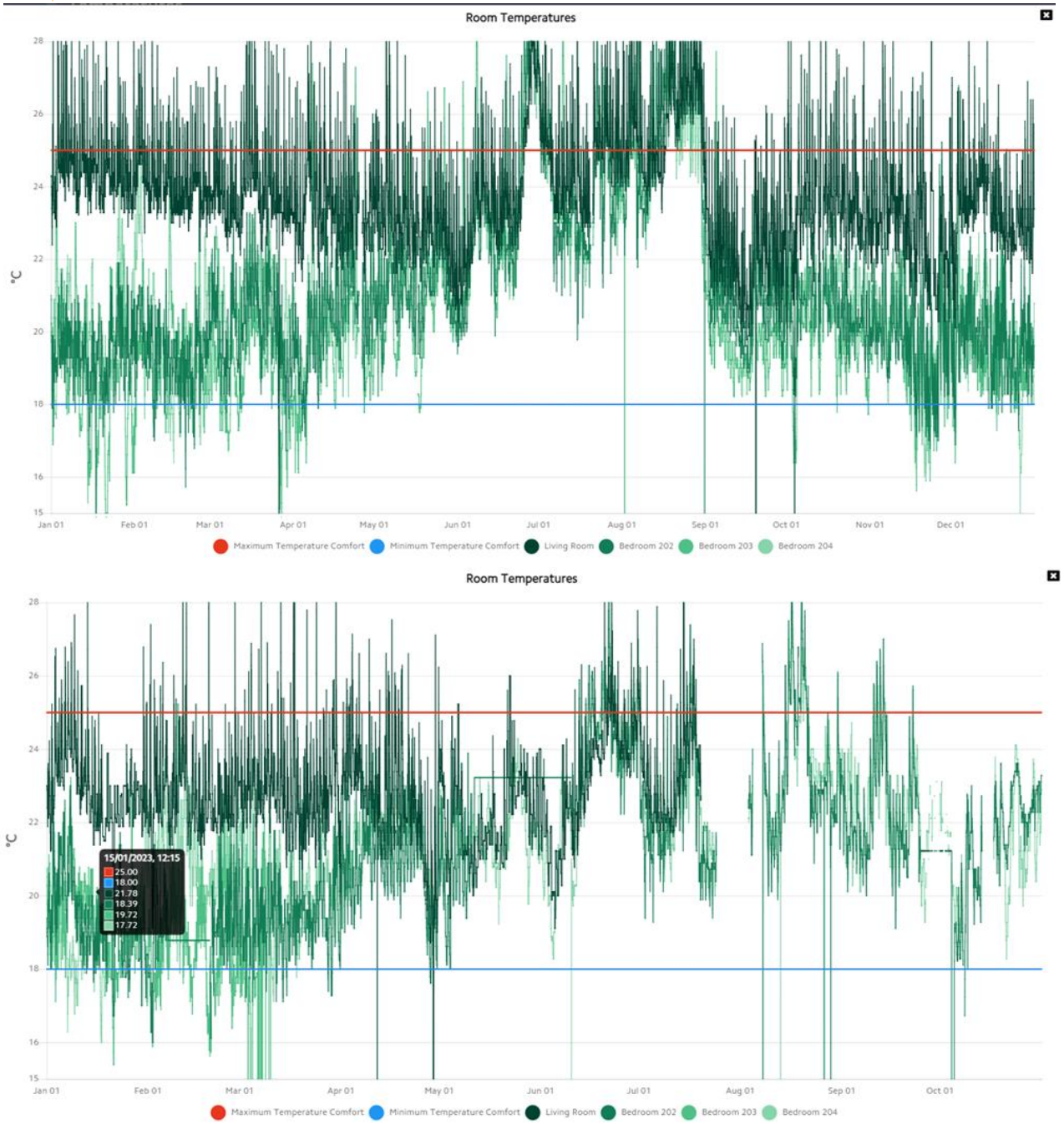


Figure 58: Riga, Sunisi: Room temperatures [From January 2022 to October 2023]

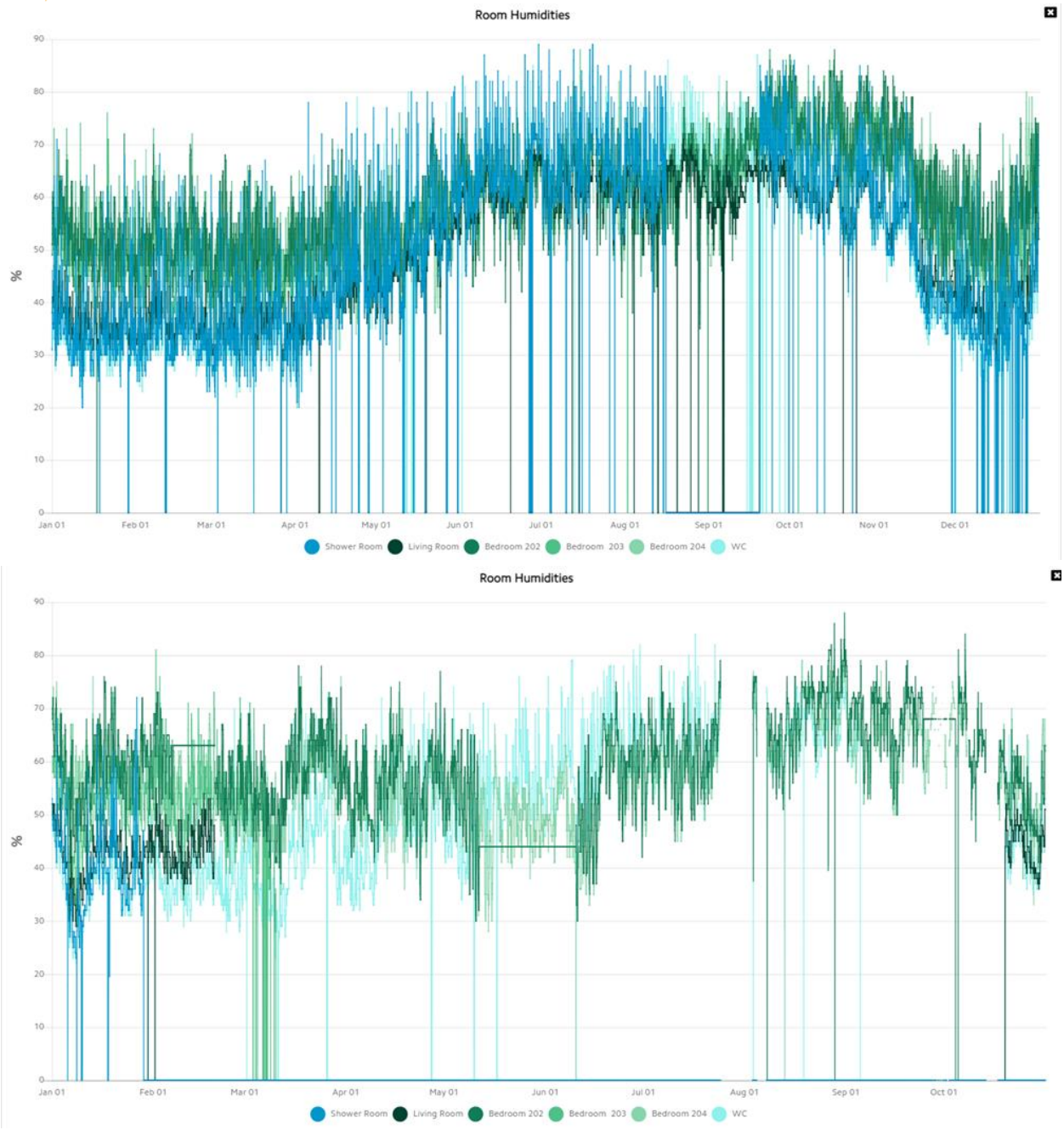


Figure 59: Riga, Sunisi: Room humidities [From January 2022 to October 2023]

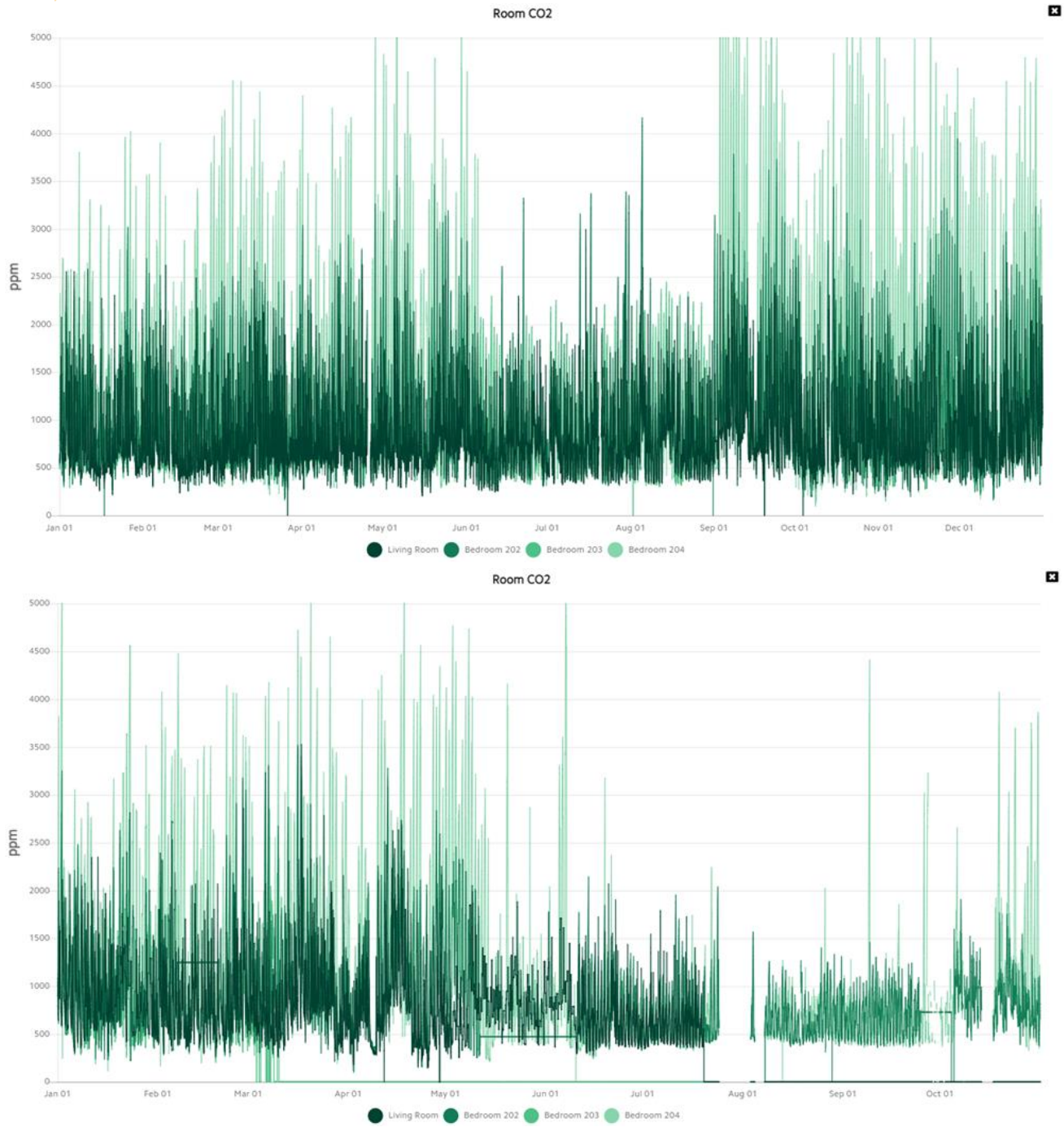


Figure 60:Riga Sunisi: Room CO2 [From January 2022 to October 2023]

Heating and cooling comfort has been also calculated for the monitoring period considered, from January 2022 to October 2023. This indicator registers when the indoor temperature is not within the defined temperature range, 25ºC for summer and 18ºC for winter. For this period Riga, Sunisi only has registered some cooling discomfort on the ground floor specially during wintertime because dwellings like higher indoor temperatures so, discomfort could be measured as 6.0ºC·h from May to August instead of yearly 14.72ºC·h for 2022, same happened for 2023 in this case it would be just 7.5ºC·h from May to August.

This discomfort registered are not a deviation from the defined threshold for these indicators but serves as an example that gas savings could be higher if the dwellings reduce their indoor temperature setpoint.

Comfort	Sunisi	Ground floor Mean	First floor Mean temp. [ºC]	Ground floor HCI [ºC·h]	Ground floor CCI [ºC·h]	First floor HCI [ºC·h]	First floor CCI [ºC·h]
2022	1	26.0	17.6	0.0	1.0	0.4	0.0
2022	2	26.4	17.9	0.0	1.4	0.1	0.0
2022	3	26.4	18.4	0.0	1.4	0.0	0.0
2022	4	28.4	18.9	0.0	3.4	0.0	0.0
2022	5	28.8	19.3	0.0	3.8	0.0	0.0
2022	6	26.3	18.9	0.0	1.3	0.0	0.0
2022	7	25.1	18.7	0.0	0.1	0.0	0.0
2022	8	25.9	18.9	0.0	0.9	0.0	0.0
2022	9	25.2	17.6	0.0	0.2	0.4	0.0
2022	10	25.6	17.6	0.0	0.6	0.4	0.0
2022	11	25.8	17.3	0.0	0.8	0.7	0.0
2022	12	24.9	17.8	0.0	0.0	0.2	0.0
Total 2022		26.22	18.23	0.00	14.72	2.26	0.00

Comfort	Sunisi	Ground floor Mean	First floor Mean temp. [ºC]	Ground floor HCI [ºC·h]	Ground floor CCI [ºC·h]	First floor HCI [ºC·h]	First floor CCI [ºC·h]
2023	1	25.3	17.7	0.0	0.3	0.3	0.0
2023	2	25.7	17.6	0.0	0.7	0.4	0.0
2023	3	25.5	17.6	0.0	0.5	0.4	0.0
2023	4	25.6	18.1	0.0	0.6	0.0	0.0
2023	5	27.4	19.1	0.0	2.4	0.0	0.0
2023	6	26.3	19.4	0.0	1.3	0.0	0.0
2023	7	27.0	18.7	0.0	2.0	0.0	0.0
2023	8	26.8	19.0	0.0	1.8	0.0	0.0
2023	9	25.1	18.1	0.0	0.1	0.0	0.0
2023	10	24.3	17.9	0.0	0.0	0.1	0.0
Total 2022		25.89	18.35	0.00	9.60	1.06	0.00

Figure 61: Riga, Sunisi: Monthly indoor thermal comfort per building floor [Left:2022, Right: January to October 2023]

Figure 62: Riga, Sunisi: Hourly indoor thermal comfort per building floor

6.3.3 KPI summary

In this section monthly savings indicators are reported, as well as self-consumption, renewable energy ratio and indoor comfort index. In order to estimate the savings on emissions, non-renewable energy and energy bills, the measured data is compared to the baseline, which was defined on the deliverable *D2.5 SunHorizon TPs and demosite conceptual design and simulations,* which are collected in the table below. The savings in the energy bills are calculated employing the hourly day-ahead electricity market prices for Latvia obtained from the ENTSO-E transparency platform[6] and the regulated natural gas tariff for residential end-users with gas heating[7], it has also been taken into account that within the net metering system, the PV surplus exported to the distribution grid is discounted from the energy bill at the same price if consumed within the defined 12-month period for net metering (March to February).

[6] ENTSO-E Transparency Platform webpage: https://transparency.entsoe.eu/dashboard/show
[7] Regulated natural gas tariff for residential end-users with gas heating (Latvia): https://lg.lv/en/for-home/tariffs-and-calculator

Table 21 -Riga, Sunisi: Yearly baseline data from D2.5

Riga, Sunisi Baseline	Description	Yearly value
I.EFEbs-9 [kWh]	Total electricity consumption (baseline)	7700
I.QFEbs-9 [kWh]	Total gas demand (baseline)	13300
I.CELbs-9 [€]	Electricity costs (baseline)	1155
I.CFUbs-9 [€]	Fuel costs (baseline)	532
PENnb-9 [kWh]	Non-renewable primary energy (baseline)	26180
I.GHGbs-9 [kgCO2]	GHG emissions (baseline)	3579.8

The monthly KPIs calculated since January 2022 to October 2023 appear in the figure below, plus its aggregated values for each year in the tables below, comparing the relative values obtained with the defined threshold in order to detect deviations. Negatives values printed in red shows that there were no gas bill savings due to a slightly higher natural gas consumption than the one obtained from the model. Furthermore, in terms of gas cost, we see a sharp increase as a result of energy crisis and the resulting surge of gas prices starting from 2022. Comparing to the baseline gas tariff (~0.04 EUR/kWh) and the actual price in 2020 (0.028 EUR/kWh), the gas price in 2022–2023 increased 2–4 times reaching more than 0.11 EUR/kWh in the beginning of 2023 even considering the state support which was in place during several months. The largest increase of gas bills in the results (Figure 63) is in line with the increase of the gas tariff, which is reviewed a few times per year.

In comparison, electricity bill savings are higher due to PV electricity generation which is either self-consumed or exported to the grid for later use and provides a significant discount from the final energy bill. The savings can be observed despite the surge of electricity prices which increased a few times in 2022.

Since the amount of thermal energy consumption sourced from the gas-based heating until BDR HP installation is overall larger than the electricity consumption, it contributes to an overall negative Customer Bill Reduction (CBR) value on average, except for the summer months when there is no space heating and the benefits from PV electricity generation are the most pronounced.

Sunisi 2022	Gas consumption [kWh]	Gas costs [€]	Gas bill savings [%]	Grid imports	Grid exports	Elec. Costs	Elec bill savings	CBR
1	2676.7	105.6	-138%	169.7	0.0	49.1	49%	-10%
2	2160.3	85.2	-92%	464.0	48.9	37.7	61%	13%
3	1991.7	78.6	-77%	316.6	711.4	30.5	68%	22%
4	1422.6	56.1	-27%	267.9	761.4	68.9	28%	11%
5	685.0	27.0	39%	619.7	604.6	139.9	-45%	-19%
6	314.2	12.4	72%	464.0	549.8	108.4	-13%	14%
7	102.0	7.8	82%	368.6	822.9	89.2	7%	31%
8	134.1	10.2	77%	273.0	950.5	69.9	27%	43%
9	431.2	32.9	26%	237.6	662.8	62.8	35%	32%
10	1274.7	97.3	-119%	334.6	262.2	82.4	14%	-28%
11	2059.7	157.2	-254%	377.3	21.4	33.5	65%	-36%
12	2929.0	223.5	-404%	551.0	0.8	42.0	56%	-89%
Total	16181.2	893.8	-68.0%	4444.1	5396.6	814.3	29.5%	-1.3%

Sunisi 2023	Gas consumption [kWh]	Gas costs [€]	Gas bill savings	Grid imports	Grid exports	Elec. Costs	Elec bill savings	CBR
1	2488.4	274.7	-520%	818.5	11.4	49.1	49%	-130%
2	2277.9	251.5	-467%	638.5	79.0	37.7	61%	-106%
3	2111.1	233.1	-426%	630.5	227.0	30.5	68%	-87%
4	1229.1	135.7	-206%	289.5	812.5	68.9	28%	-46%
5	1124.1	89.2	-101%	356.3	1074.8	139.9	-45%	-63%
6	437.8	34.7	22%	541.4	964.4	108.4	-13%	-2%
7	349.0	27.7	38%	234.9	951.5	89.2	7%	17%
8	35.2	0.3	99%	278.9	756.8	69.9	27%	50%
9	0.0	0.0	100%	257.1	708.6	62.8	35%	55%
10	35.0	0.0	100%	847.4	94.9	82.4	14%	41%
Total	10087.5	1047.0	-136.2%	4893.1	5680.9	738.8	23.2%	-27.0%

		GHG savings [kg CO2]	PE_nren savings [kWh]	Energy bills Savings [€]	Renewable Ratio [%]	Elec. Self-cons. Ratio [%]
2022	1	-262.6	-1017.2	-14.1	1%	0%
2022	2	-186.2	-817.2	17.6	5%	5%
2022	3	-58.2	583.0	31.5	31%	29%
2022	4	68.2	1357.0	15.6	42%	35%
2022	5	158.2	1405.4	-26.3	63%	56%
2022	6	244.8	1964.7	19.7	80%	63%
2022	7	330.4	2750.9	43.6	93%	41%
2022	8	349.8	3050.3	60.4	91%	27%
2022	9	260.5	2345.1	44.9	66%	25%
2022	10	32.4	670.9	-39.0	22%	47%
2022	11	-159.0	-617.9	-50.0	5%	54%
2022	12	-357.2	-1865.7	-124.9	3%	44%
Total 2022		421.7	9809.5	-21.1	41.8%	35.6%

		GHG savings [kg CO2]	PE_nren savings [kWh]	Energy bills Savings [€]	Renewable Ratio [%]	Elec. Self-cons. Ratio [%]
2023	1	-298.0	-1766.3	-183.3	5%	84%
2023	2	-226.7	-1163.4	-148.7	8%	82%
2023	3	-174.9	-745.7	-123.0	15%	63%
2023	4	110.7	1614.2	-64.0	44%	32%
2023	5	154.6	2023.0	-88.5	57%	34%
2023	6	259.0	2334.6	-2.6	76%	40%
2023	7	310.9	2872.6	23.7	78%	27%
2023	8	346.6	2859.8	70.4	97%	30%
2023	9	350.7	2858.9	77.8	100%	25%
2023	10	204.0	1014.4	58.2	43%	71%
Total 2023		1036.9	11902.1	-380.0	52.3%	48.8%

Figure 63: Riga, Sunisi: Monthly KPIs

KPI_2022	Name	Actual Value	Threshold	Deviation
GHG savings	Avoided GHG emissions	0.42 tons of CO2eq; or 11.8%.	40 to 60%	Yes, due to natural gas consumption
PESnren	Non-renewable energy savings	9.81 MWh; or 37.5%	50 to 70%	Yes, due to natural gas consumption
CBR	Customer Bills Reduction	-21.1€; or-1.3%	Up to 60%	Yes, no savings from baseline scenario
RER	Renewable Energy Ratio	41.8%	40 to 70%	No
SCR	Self-Consumption Ratio	35.6%	Up to 80%	No
HCI	Heating Comfort Index	14.72	7 to 15 ºC·h	No major deviation
CCI	Cooling Comfort Index	2.26	7 to 15 ºC·h	No

Table 22: Riga, Sunisi: Monthly KPIs for 2022

KPI_2023	Name	Actual Value	Threshold	Deviation
GHG savings	Avoided GHG emissions	1.04 tons of CO2eq; or 34.8%.	40 to 60%	Yes, due to natural gas consumption
PESnren	Non-renewable energy savings	11.9 MWh; or 54.6%	50 to 70%	No
CBR	Customer Bills Reduction	-380.0€; or -27%	Up to 60%	Yes, no savings from baseline scenario
RER	Renewable Energy Ratio	52.3%	40 to 70%	No
SCR	Self-Consumption Ratio	48.8%	Up to 80%	No
HCI	Heating Comfort Index	9.60	7 to 15 ºC·h	No major deviation
CCI	Cooling Comfort Index	1.06	7 to 15 ºC·h	No

Table 23: Riga_Sunisi: Monthly KPIs for 2023 from January to October

Alarms logging

Alarms will be reported here. An automatic email will be sent to the building staff (to be confirmed), demo responsible, and the simulation supporting partner.

No alarm notification has been set yet for this demo site.

Table 24 - Alarm receivers (Riga Sunisi)

ROLE IN THE PROJECT	PROJECT PARTNER
Building Staff	Not registered yet
Demo Responsible	RTU/Zane Broka
Simulation Supporting partner	CARTIF/ Alejandro Hernández

7 Conclusion

A. Project KPIs summary (at the conclusion section of D6.5 and D6.6)

Table 25 - Summary of KPIs

KPI	Sant Cugat #3	Madrid#4	Riga Imanta #8	Riga Sunisi #9
Monitoring period	06/2023 to 10/2023	01/2023 to 10/2023	11/2022 to 10/2023	01/2022 to 10/2023
CAPEX	457633 €	317501€	133757€	132085€
CBR	60 €/day	783.5€ 29.8%	11.29€	-401.11€ -12.97%
CSAT	-	-	-	-
GHG savings	-42.45 kgCO2eq	8205.8kgCO2eq 62.7%	98%	1458.57kgCO2eq 22.22%
HCI	0.06 °C	0.0ºC	-	14.7ºC·h [2022] 9.6ºC·h [2023]
CCI	-	1.95ºC	-	2.3ºC·h [2022] 1.1ºC·h [2023]
LCOH	-	-	-	-
OPEX	2288.17 €	1587.54€	300€	300€
PESnren (absolute) And relative:	-30363.26 kWh	38977.2kWh 58.6%	47%	21711.56kWh 45.24%
RER	11.75%	56.98%	18%	46.58%
SCR	-	67.09%	42%	41.61%
SPB[8]	10*	8.8*	-	-

[8] Simple Payback values calculated in SunHorizon deliverable *D7.3 – SunHorizon Business and ESCO Model*

A. ANNEXES - Templates

B. KPI table every 6 months

Table A: KPIs summary template for demonstration campaign

KPI name	Threshold	Actual value	Deviation	Impact on scope
			Yes/No	

C. Alarm table

Table B: Alarm summary template for demonstration campaign

Alarm code	Raised at	State	Explanation
		Danger/warning	

D. Data collection problems and progress

Table C: Data collection progress

Relevant events	Date when discovered	Action taken	Mitigation plan	Date when solved

E. Project KPIs summary (at the conclusion section of D6.5 and D6.6)

Table D: Summary of KPIs

KPI	Sant Cugat #3	Madrid #4	Riga Imanta #8	Riga Sunisi #9
Monitoring period				
CAPEX				
CBR				
CSAT				
GHG savings				
HCI				
CCI				
LCOH				
OPEX				

PESnren (absolute) And relative: $f_{sav,PE_{nren}}$				
RER				
SCR				
SPB				

F. Project PIs (Technologies)

Table E: Summary of PIs

PI	Sant Cugat #3	Madrid #4	Riga Imanta #8	Riga Sunisi #9
Monitoring period				
$\eta^{gross}_{TVP,at\ T_{supply}}$				
$f_{sol,th}$				
$SGUE$				
SPF_{BH}				
$(S)EER$				
SPF_{FAHR}				
$(S)COP_{BDR}$				
$(S)EER_{BDR}$				
SPF_{BDR}				
$\eta^{gross}_{BDRcol,th}$				
$f_{sol,th}$				
$\eta^{gross}_{BDRcol,el}$				
$\eta^{gross}_{DS,th}$				
$f_{sol,th}$				
$\eta^{gross}_{DS,el}$				
TER				
dT				