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Grant agreement no. 818329

Sun coupled innovative Heat pumps

D5.7 – Control platform modules integration and validation

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Participants : SE, CAR, CEA, CW, RINA-C, VEO, BDR, GRE, TUCN

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1 Introduction

SunHorizon project aims to demonstrate that a proper combination of technologies, also known in the project as Technology Packages (TP), can avoid wasting energy, identifying malfunctioning of equipment, maximizing energy coming from renewables, increasing self-consumption, reducing local energy bills and cut of CO_2 emissions. These TPs include technologies such as solar panels (PV, hybrid, thermal) and heat pumps (thermal compression, adsorption, reversible), managed by a controller with predictive and pro-active maintenance (among other capabilities).The assessment of the TPs deployed in the demo sites will come from the estimate of the energy baseline[1] for each demo site (before SunHorizon was installed) and the analysis of the Key Performance Indicators (KPIs) during the monitoring period, following the methodology described in Work Package (WP)2.

D5.7 is describing in detail the activities performed under task 5.6 "Final release of Data Driven SunHorizon predictive controller for optimized management of H&C technologies and its validation via SunHorizon TPs monitoring results". The first aim of this task is to integrate all the tools (decision-making, self-learning, surveillance and simulation modules) into the cloud-based monitoring platform that will also centrally collect the data from WP4 and will also provide an API to connect to the data in near real-time on the cloud.

Secondly, during T5.6, the aforementioned cloud-based tool will be deployed in the demonstration sites to validate the control strategies and demonstrate the benefits of the hybrid control strategies.

T5.6 started in M24 and was kicked off with some careful planning of the activities. A Gantt chart has been agreed with all the partners participating in the task, and the plan was discussed and adjusted in the general assembly and in regular WP5 meetings. Furthermore, the software architecture has been decided, the integration has been communicated and agreed with all partners involved, as well as the data flow with all data needed for all the tools to be available to communicate via API connections. Unfortunately, due to shortcomings, it was not possible to validate the hybrid controller in the Riga demo site, and it was only validated in Sant Cugat Mirasol building.

Chapter 2 is explaining the software architecture and workflow in a diagram, explaining all the software components integrated to form the SunHorizon Control Platform.

Chapter 3 is about the control modules preliminary integration in Riga Sunisi, with calibration and re-calibration of the building energy model (model created in T5.3), integration and automation of the model and all of the components.

Chapter 4 describes the full integration of all the control modules in Sant Cugat demo site, while Chapter 5 explains the activities performed to validate the control modules.

Finally, Chapter 6 showcases the dashboards created for Type B demo sites.

[1] Baseline refers to the final energy consumption (gas and electricity) of the demo sites before SunHorizon was installed. In WP2 this baseline was already estimated: final energy consumption, (in some) the efficiencies of the existing systems (before SunHorizon) and the thermal demand (domestic hot water, space heating, space cooling, electricity consumption of the building).

2 Control Platform Modules Integration Architecture (including monitoring platform)

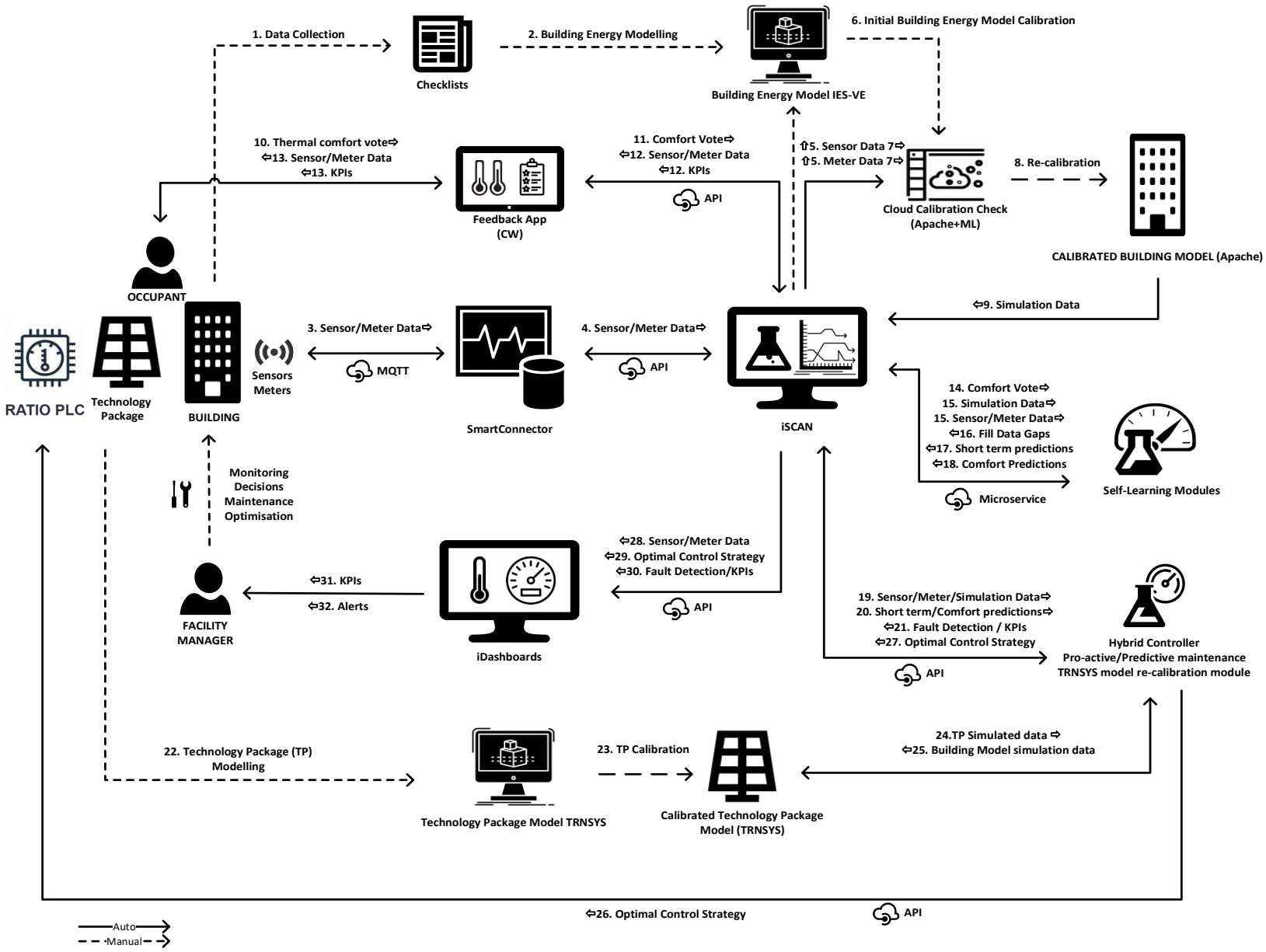


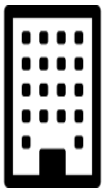
Figure 1: Monitoring and control platform integration and workflow diagram

The diagram above illustrates the full monitoring and control platform integration and workflow. Each icon depicts a module/component/actor/process while connector arrows depict integrations and data flows. REST API from Enterprise Server and iSCAN API from IES were used to achieve all integrations. Below is a detailed list of modules and integrations.

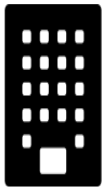
2.1 List of modules

The table below lists all the modules/components/actors/processes found in the workflow and integration diagram in Figure 1.

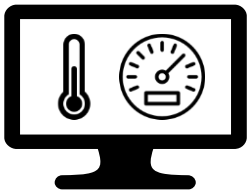
Table 1: List of modules/components/actors/processes in Monitoring and Control Platform

a	 **Checklists**	Standard sheets used to collect energy related information from buildings to enable energy modelling
b	 **Building Energy Model IES-VE**	The energy model of the building in IES-VE[2] software
c	 **Feedback App (CW)**	The app developed in SunHorizon in Task 5.2: Thermal Comfort driven Smart Home End-User Interface
d	 **Cloud Calibration Check (Apache+ML)**	Algorithm developed in SunHorizon to calculate the calibration metrics of a building energy model in IES-VE
e	 **CALIBRATED BUILDING MODEL (Apache)**	Calibrated building energy model in Apache physics based simulation engine of the IES-VE software, modelled for SunHorizon. The building energy model is optimised to match as much as possible the real building (minimised performance gap between actual and simulated data)

[2] iesve.com

f	 BUILDING	The demo site
g	 RATIO PLC	End devices that interact with technology packages, provided by RATIOTHERM
h	 Technology Package	SunHorizon technology package
i	 SmartConnector	The Schneider Electric BMS including the Enterprise Server and the Smart Connector to allow API sharing of BMS data[3]
j	 iSCAN	iSCAN provided by IES allows to centralise any time-series data from different building and energy management systems, IESVE simulations, utility portals, weather data, IoT sensors and historic files in one platform, post process and share.

[3] https://ecostruxure-building-help.se.com/bms/topics/show.castle?id=8061&locale=en-US&productversion=2023

k	 **Self-Learning Modules**	Machine learning models developed in SunHorizon to fill in data gaps, predict time series values in the short term, and predict thermal comfort
l	 **OCCUPANT**	The user of the demo site
m	 **FACILITY MANAGER**	The manager of the demo site
n	 **iDashboards**	Dashboards tool provided by IES that allows creation of custom dashboards and integration with iSCAN
o	 **Hybrid Controller** **Pro-active/Predictive maintenance** **TRNSYS model re-calibration module**	Modules developed by CARTIF in SunHorizon: Hybrid controller to optimise the operation of technology packages, maintenance tools that calculate KPIs
p	 **Technology Package Model TRNSYS**	Energy model of the technology package in TRNSYS software, modelled for SunHorizon

q	 **Calibrated Technology Package Model (TRNSYS)**	Calibrated energy model of the technology package in TRNSYS software modelled for SunHorizon

2.2 List of integrations and workflows

Below is the list of all the integrations achieved and validated in the workflow and integration diagram in Figure 1.

1. Data Collection – [Manual] collect all static information and historical data about the building (performed in T5.3). This is a standard practice to create a building energy model
2. Building Energy Modelling – [Manual] develop the building energy model using the data collected. This is a standard practice to create a building energy model in IESVE software[4] (performed in T5.3)
3. Sensor/Meter Data – [Automated] Integration between field level equipment and Smart Connector via MQTT connection. This is a standard practice by Schneider Electric (performed in WP4)
4. Sensor/Meter Data – [Automated] Integration between Smart Connector and iSCAN via REST API. A new web hook has been developed to allow the integration. (performed in WP4)
5. Sensor/Meter Data – Populate the energy model semi-automatically with real data from sensors and meters. This is a standard practice necessary to perform building energy model calibration
6. Initial Building Energy Model Calibration – [Manual] The model is calibrated as much as possible using the data collected, following CIBSE TM63 guidelines
7. Sensor/Meter Data – [Automated] The model is checked daily for calibration status to allow for accurate simulations and the results of the calibration metrics are uploaded to iSCAN. If the threshold is bypassed, an alert is sent to the user to check.
8. Re-calibration [Semi-automated] The new algorithm to check if the model needs recalibration is scheduled to run every day and compare the measured against the simulated data and return to iSCAN the calibration metric. The model, if needed, is recalibrated using the latest data collected from the building's sensors and meters and recorded in iSCAN.
9. Simulation Data from the calibrated model to iSCAN - The calibrated building energy data is programmed to execute simulations daily at 11.50 pm. The model is having as an input the weather forecasts of the next day,

[4] iesve.com

and returns as output to iSCAN the space conditioning energy demand and environmental variables, such as Air Temperature for the next 2 days.

10. Thermal comfort vote from occupant to Feedback App [Manual] – The building occupant is using the feedback app to submit thermal comfort feedback.
11. Comfort Vote from Feedback App to iSCAN [Automated] - The comfort vote is uploaded to iSCAN using iSCAN-API whenever recorded in the APP automatically
12. Sensor/Meter Data & KPIs [Automated] – The data collected from the demo site equipment, including historical data, is transmitted and displayed in the Feedback App
13. Sensor/Meter Data & KPIs [Automated] – The data collected from the demo site equipment is visualised in a user friendly way and displayed to the user
14. Comfort Vote from iSCAN to ML model [Automated] - The comfort votes from the occupants are transmitted from iSCAN to the Comfort prediction model, and is used to enhance the accuracy of the model predicting the comfort sensation.
15. Sensor/Meter data and simulated data from iSCAN to ML models [Automated] – The Sensor/Meter data and simulated data are transmitted to the machine learning models and used for forecasting of the short term future conditions of the building, to allow comfort predictions in step 14 and other functionalities such as filling data gaps.
16. Fill data gaps self-learning forecasts to iSCAN [Automated] – Whenever required, iSCAN is integrated with a module to fill in the gaps in data using machine learning
17. Short term predictions self-learning forecasts to iSCAN [Automated] – Scheduled to be executed every 30 minutes, the Short term predictions self-learning tool transmitting forecasts for the next 30 minutes to iSCAN
18. Thermal comfort predictions self-learning forecasts to iSCAN [Automated] – Scheduled to be executed every 30 minutes, the comfort forecasting tool transmitting forecasts for the next 30 minutes to iSCAN
19. Real data from sensors and meters are posted to the hybrid control and proactive/predictive maintenance modules using iSCAN-API to enable control and KPIs calculations. Additionally, simulated data from the physics-based energy model of the building are also posted to the same modules [Automated].
20. Forecasts from self-learning are used in the hybrid control and proactive/predictive maintenance modules using iSCAN-API to enable control and KPIs calculations [Automated]
21. KPIs from proactive/predictive maintenance modules to iSCAN [Automated] – Scheduled periodically to transmit the KPIs to iSCAN once calculated

22. Technology Package Energy Modelling – [Manual] develop Technology Package Energy model using the data collected from the demo sites and manufacturers in TRNSYS software[5]
23. Technology package calibration – [Manual] The technology package model is calibrated as much as possible using the data collected
24. Technology package model simulation data transmitted to hybrid control and proactive/predictive maintenance modules [Automated]
25. The Building energy model simulation data are transmitted and becoming input to the Technology package model simulation that optimises the control [Automated]

26. Optimal control strategy to RATIO PLCs [Automated] – The optimised control setpoints are sent to the technology packages directly via API to RATIO PLCs.
27. Optimal control strategy to iSCAN [Automated] – The optimised control setpoints are sent to iSCAN via iSCAN-API
28. Sensor/Meter data from iSCAN to dashboard [Automated] – Data selected by demo site leaders are transmitted from iSCAN to the dashboard every 15 minutes and plotted in selected visualisations by demo site leaders
29. Optimal setpoints from iSCAN to dashboard [Automated] – The setpoints are plotted in the dashboard
30. Fault detection and KPIs from iSCAN to dashboard [Automated] – Fault detection such as data gaps, and the KPIs of the project are integrated with iSCAN and displayed in the dashboard
31. 32. Sensor Meter Data, KPIs and alerts displayed to the end user to enable:
    a. Monitoring of energy and indoor environmental quality
    b. Decision making based on minimising energy use and maximising comfort
    c. Encourage the necessary maintenance required in building devices
    d. Deploy optimised setpoints if needed

[5] trnsys.com

3 Control modules preliminary integration in Riga Sunisi

In Riga Sunisi demo site, the following control modules where partially integrated and tested, until the announcement of the withdrawal of BoostHeat from the project[6]:

- Building simulation module integrated and validated
- Monitoring system (from WP4)
  - Enterprise Server – iSCAN fully integrated and validated (via SmartConnector API)
  - Feedback app – iSCAN integration (via iSCAN-API)
  - iSCAN-Dashboard integration (via iSCAN-API)
  - KPI module integration (via iSCAN-API)
  - Self-learning module partial integration (not automated)
- Self-learning modules partially integrated and validated

Figure 2 graphically depicts the monitoring and control platform integration and workflow diagram with fully automated integrations in green and partial in orange colour.

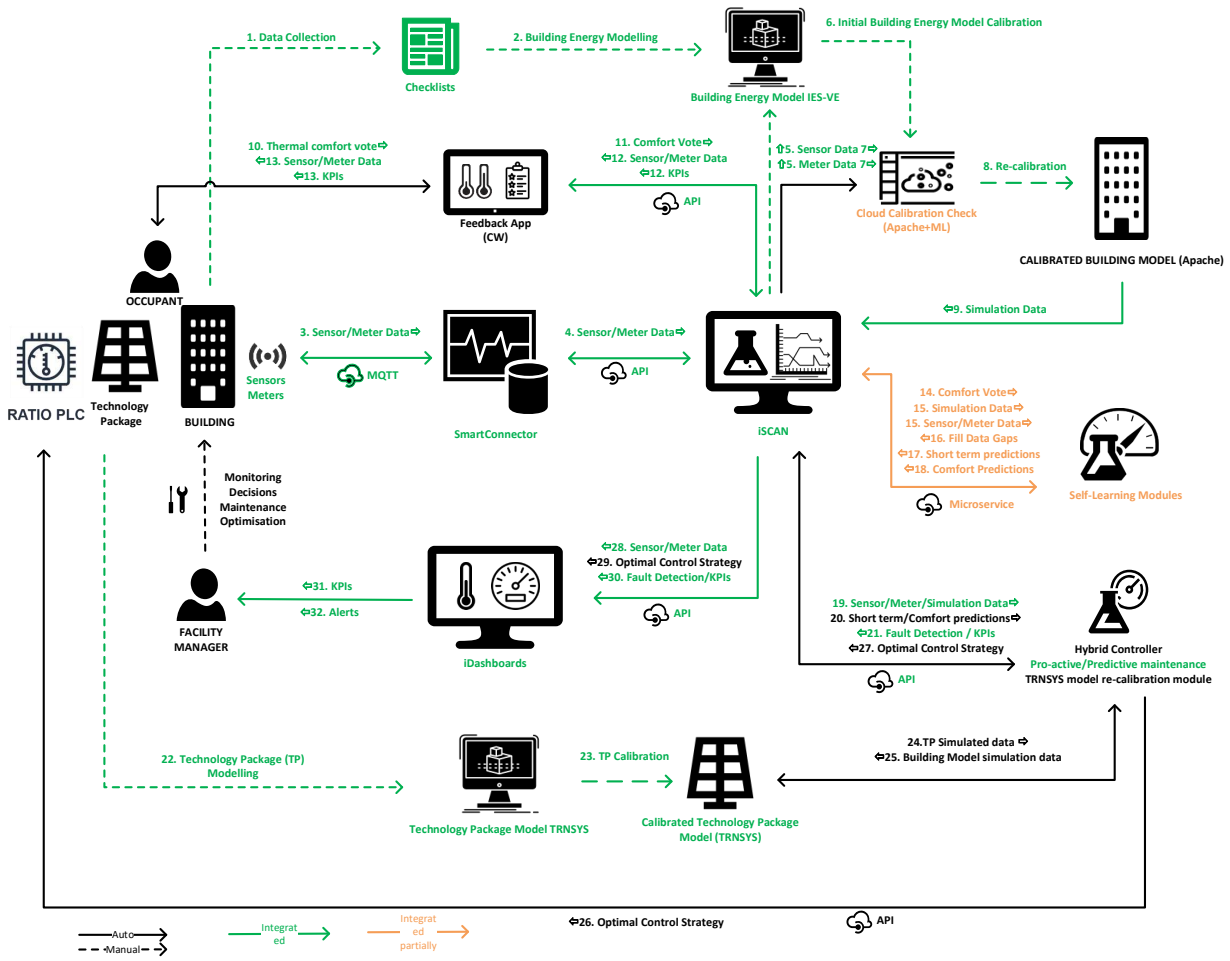


Figure 2: Monitoring and control platform integration and workflow diagram with fully automated integrations in green and partial in orange colour

[6] adopted and formalised with an Amendment in August 2023

The following paragraphs present an analysis of the work performed to integrate and deploy the control modules in the Riga Sunisi demo site.

3.1 Riga Sunisi Building Energy Model in IESVE

This chapter describes the work done to achieve building energy model calibration for Riga Sunisi demo site. This was an ongoing process and the model was calibrated initially, then recalibrated 2 times using the latest data collected in iSCAN by the sensors/meters installed in the demo sites.

3.1.1 Background

The building energy model of the Riga Sunisi demo site was created and presented in in Deliverable 5.3 Annex A. This included steps: 1, 2 in chapter 2.2.

In this document the re-calibration is presented, step 8.

As per CIBSE TM63: 2020 Operational performance: Building performance modelling[7] and calibration for evaluation of energy in-use, the mean absolute error (MAE) and root mean square error (RMSE) were used to assess a room temperature calibration:

MAE (mean absolute error) is an arithmetic average of the absolute errors between the simulated and measured values:

MAE = $\frac{\sum_{i=1}^{n} |m_i - s_i|}{n}$

RMSE (root mean square error) represents the sample standard deviation of the differences between measured and simulated values

RMSE = $\sqrt{\frac{\sum_{i=1}^{n} (m_i - s_i)^2}{n}}$

Where:

$\overline{m}$ is the mean of measured values

m_i is the measured value

s_i is the simulated value

n is the number of data points

Building geometry was created in the ModelIT module in VE using all the drawings available (Deliverable 5.3 Annex A).

[7] https://www.cibse.org/knowledge-research/knowledge-portal/operational-performance-building-performance-modelling-and-calibration-for-evaluation-of-energy-in-use-tm63

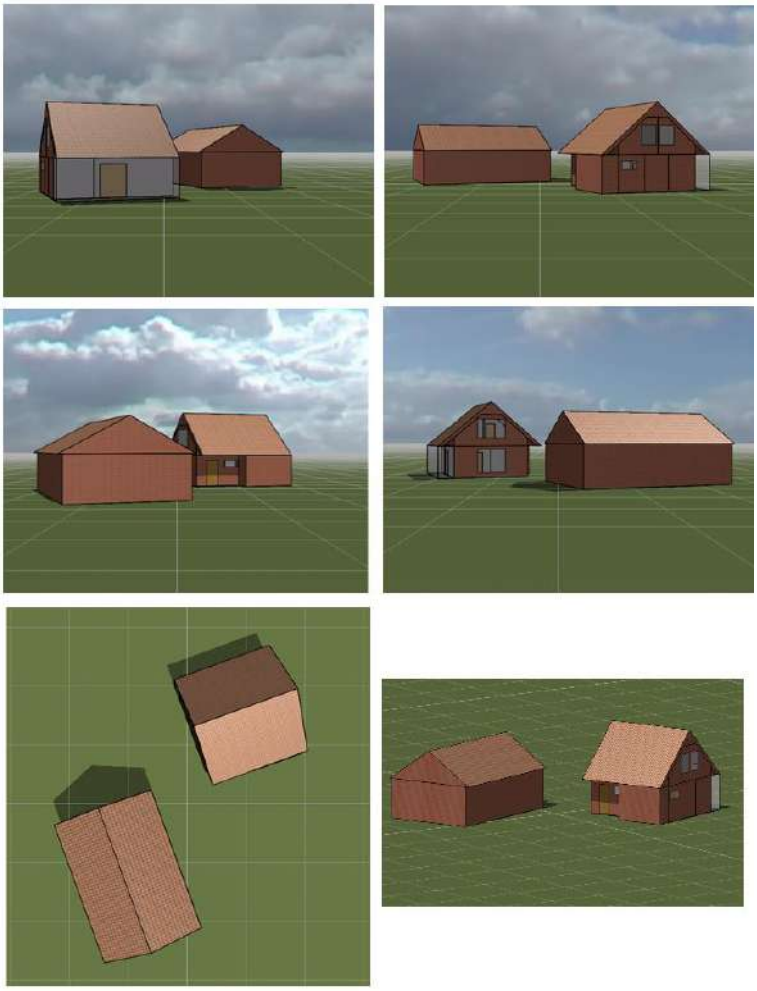


Figure 3: Views of the building case-study. From top left to bottom right: North, East, South, West, Above and orthographic view of the building case-study

A summary of the main surface properties of the constructions included in the energy model is reported below in Table 2 (Deliverable 5.3 Annex A).

Table 2: Main constructions and relative U-values

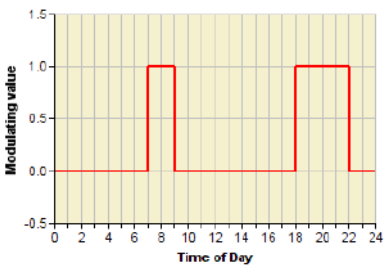
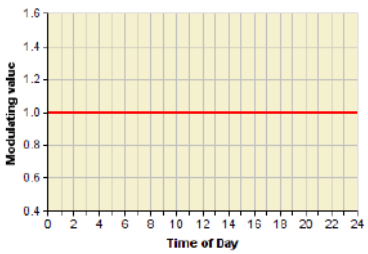
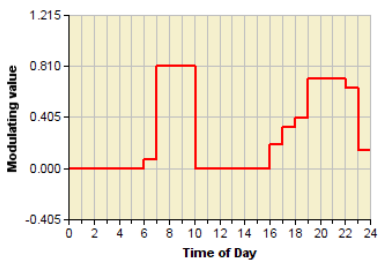
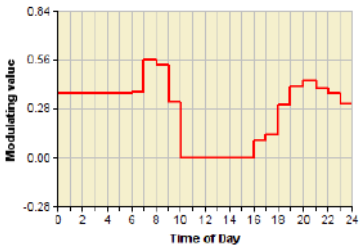
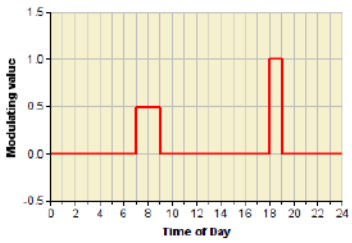
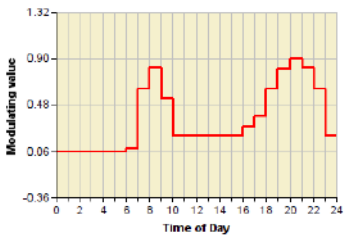
CONSTRUCTION TYPE	NAME	AREA M^2	U-VALUE ($W/M^2.K$)	G-VALUE
EXTERNAL WALL	Sunisi_External_Wall	69.27	0.2	-
	Sunisi_External_Wall_sauna	6.14	0.15	-
	Sunisi_External_Wooden_Frame_Walls	50.99	0.57	-
ROOF	Sunisi_Roof	0.0	0.11	-
GROUND FLOOR	Sunisi_Ground_Exposed	56.05	0.16	-
DOOR	Sunisi_Door	11.16	2.17	-
INTERNAL CEILING/FLOOR	Carpeted 100mm reinforced-concrete ceiling	22.74	2.12	-
	Sunisi_Internal_Ceiling/Floor	77.55	1.05	-

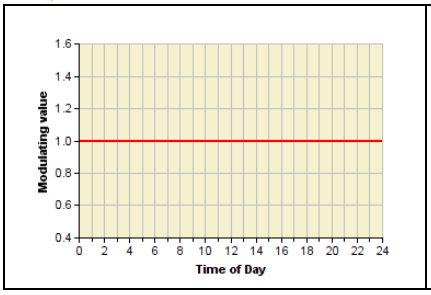
INTERNAL PARTITION	Sunisi_External/Internal_Partitions_sauna	34.11	0.25	-
	Sunisi_Internal_Wall	54.99	0.47	-
EXTERNAL WINDOW	Sunisi_External_window	42.23	1.24	0.41
ROOF LIGHT	Sunisi_Rooflight	8.98	2.19	0.55
INTERNAL WINDOW	Sunisi_Internal_Window	1.12	4.14	0.87

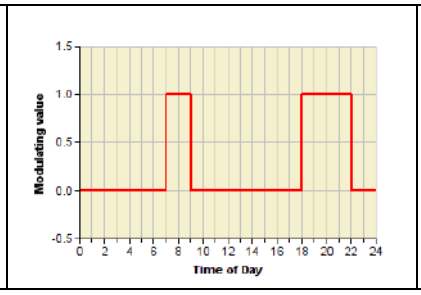
Thermal templates are assigned to rooms within the building energy model. The thermal template encloses data for:

- Heating and Cooling Set Points
- Domestic Hot Water Usage
- Auxiliary plant schedule
- Internal Gains
  - Number of People and Occupancy Schedule
  - Lighting Power Density and usage schedule
  - Miscellaneous equipment density and usage schedule
- Air Exchanges
  - Infiltration (Air Permeability)
  - Auxiliary Ventilation
  - Natural Ventilation

Table 3: Profiles and schedule of the building case study

Heating operation profile	Cooling operation profile	Lights variation profile
		
Occupancy variation profile	Cooking variation profile	Equipment variation profile
		
Infiltrations variation profile	Auxiliary ventilation profile	DHW variation profile





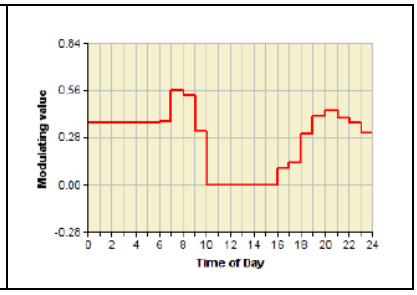


Table 3 summarises the profiles and schedules of the building used to represent the dynamic behaviour of people, systems, internal gains and use of the different rooms. The input data are based on traditional profiles used for similar building typologies (single family detached house). In future refinements of the energy model a survey to gather the actual information from the demo-site about schedules and profiles could be performed to increase the accuracy of the results of simulation.

Systems

The main heating system of the house is an underfloor heating system connected to a central boiler serving the ground floor. The heating system of the first floor is characterised by radiators connected to the main boiler. Cooling when needed is provided to the main rooms by an air to air heat pump in the main house. Domestic hot water is provided by the boiler. The heating set point for the rooms in the main house is of about 23.5 ° C. For the playroom the heating system is air to air heat-pump used for space heating during winter time, almost on continuously, with a constant heating set point between 18 to 20° C. The heating system of the house was modelled using the ApacheSystem module. VE enables the use of two different methods for modelling HVAC systems. A simplified approach based on a high level description of the system used and an accurate modelling approach for HVAC called ApacheHVAC. As initial modelling step the use of ApacheSystem was preferred given the small amount of detailed data for characterisation of the building systems. In a later phase for model calibration an ApacheHVAC model will be created and it will be possible to simulate the entire hydronic systems of the building as well as any air-side systems in details.

3.1.2 Modelling and Calibration

- The VE model used to generate the APR file has heating available in all internal rooms that are being calibrated for air temperature, CO_2 and relative humidity. This has been changed in **follow up calibration**, where only the rooms that have been assigned a share of the power meter readings have a heating system assigned.
- The heating and cooling setpoint ranges have been chosen to avoid an overlap of setpoints that previously resulted in there being both heating and cooling simultaneously.
- A separate calibration has been completed for one winter month and one summer month.

Model Output:

- The output for each space was determined based on the data available.
- The data was exported from the Enterprise Server and manually imported to iSCAN, ensuring a complete data set for a winter month and summer month.

Table 4: Riga Sunisi house data availability

Space	Name	Air temperature	CO_2 concentration	Relative humidity	heatingPlantSensible Load
SN000000	Sauna	Yes	No	No	No
SP000006	Terrace	Yes	No	Yes	No
SP00000A	Bedroom 202	Yes	Yes	Yes	Yes

SP000009	Bedroom 203	Yes	Yes	Yes	Yes
SP00000C	Bedroom 204	Yes	Yes	Yes	Yes
LV000000	Living-Kitchen	Yes	Yes	Yes	Yes
TL000000	Toilet	Yes	No	Yes	No

Winter Calibration and Fine-tuning:

- The winter calibration covers the month of February (01/02/2021-28/02/2021)
- The fine-tuning was run using optimisation with 1,000 simulations.

Table 5: Riga Sunisi House Winter Calibration Metrics

		Air Temperature (degC)				CO_2 Concentration				Relative Humidity (%)				heatingPlantSensibleLoad (W)			
		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning	
Space	Name	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
SN000000	Sauna	41.136	36.163	41.421	36.486												
SP000006	Terrace	17.19	15.035	17.429	15.183					28.96	23.996	27.331	23.179				
SP00000A	Bedroom 202	2.523	2.085	2.978	2.416	350.8	263.411	351.256	265.808	10.154	8.295	10.168	8.411	465.761	294.178	0.68	0.535
SP000009	Bedroom 203	2.102	1.795	2.02	1.701	422.713	354.013	432.301	362.747	10.034	8.188	9.99	8.129	322.907	202.154	0.44	0.341
SP00000C	Bedroom 204	2.934	2.376	2.786	2.236	1265.569	938.312	1160.479	850.282	11.274	9.407	10.412	8.605	295.584	186.432	0.433	0.336
LV000000	Living-Kitchen	3.77	3.285	3.937	3.266	515.743	418.001	435.477	366.884	13.066	10.968	7.793	6.493	927.615	585.831	1.594	1.356
TL000000	Toilet	5.174	4.787	5.131	4.638					22.083	17.509	10.119	8.539				

- The resulting metrics can be seen in the table below (screenshots of the calibration report have been included at the end of the document).

Summer Calibration and Fine-tuning:

- The summer calibration covers the month of June (01/06/2021-30/06/2021)
- The fine-tuning was run using the maco optimisation with 1,000 simulations.
- The resulting metrics can be seen in the table below (screenshots of the calibration report have been included at the end of the document).

		Air Temperature				CO_2 Concentration				Relative Humidity				heatingPlantSensibleLoad (W)			
		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning	
Space	Name	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
SN000000	Sauna	65.071	65.151	65.803	65.884												
SP000006	Terrace	4.576	3.499	4.462	3.4652					38.29	36.175	38.612	35.199				
SP00000A	Bedroom 202	1.242	0.98	1.325	1.043	494.438	413.947	880.093	780.298	20.795	17.53	37.71	36.694	0.071	0.006	0.071	0.006
SP000009	Bedroom 203	1.075	0.878	1.15	0.921	424.442	377.917	349.162	307.485	18.062	14.862	17.541	14.146	0.045	0.004	0.045	0.004
SP00000C	Bedroom 204	1.4	1.152	1.385	1.127	576.863	489.253	1170.075	1078.252	19.954	17.334	36.551	35.393	0.045	0.004	0.045	0.004
LV000000	Living-Kitchen	0.902	0.73	0.861	0.69	526.924	467.238	1028.037	951.689	24.334	21.757	35.533	37.198	0.195	0.021	0.195	0.021
TL000000	Toilet	5.644	1.5259	5.821	1.776					22.602	18.786	19.424	15.743				

Table 6 Riga Sunisi House Winter Calibration Metrics

VE Model with Optimal Parameters:

- Heating and cooling setpoints have been set using an absolute profile for the year
- Cooking latent and sensible gains have an average input value for the year
- Equipment sensible gain has an average input value for the year
- Lighting sensible gain has been set using a modulating dimming profile to account for summer and winter variation
- Infiltration has been set using a modulating profile to account for summer and winter variation
- Occupancy sensible and latent gains have been set using an average value for the year
- DHW consumption has been set using an average value for the year calculated manually

Results:

- Monthly results comparing metered data with VE *Room heating plant sens. load*:

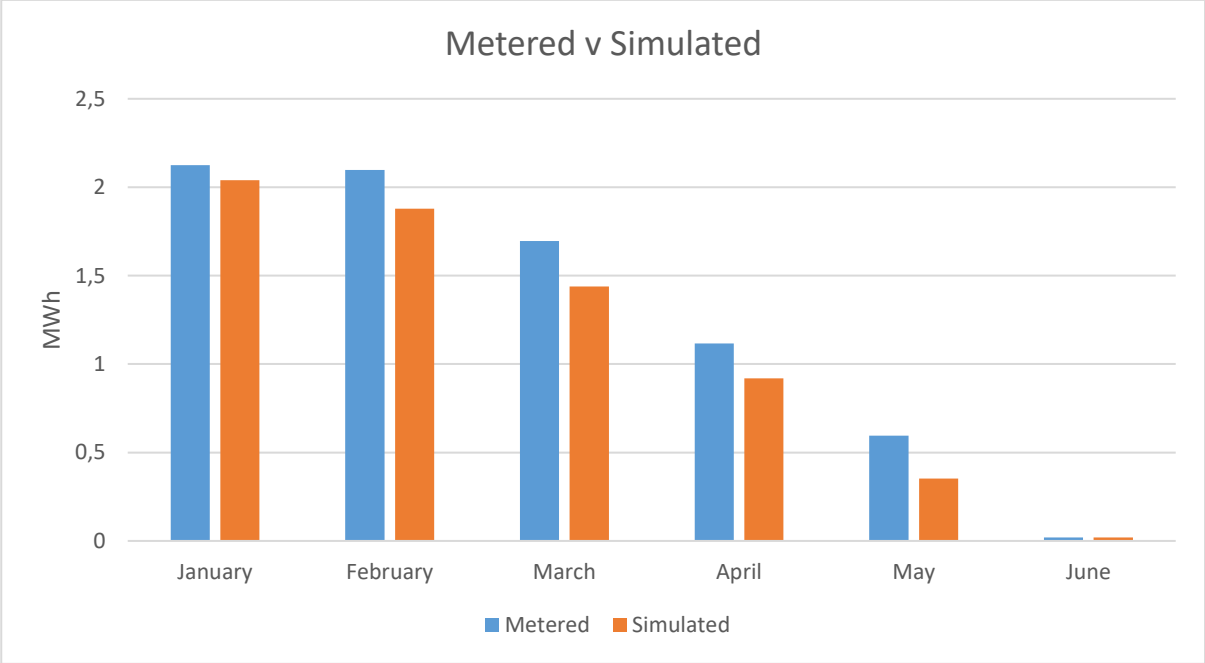
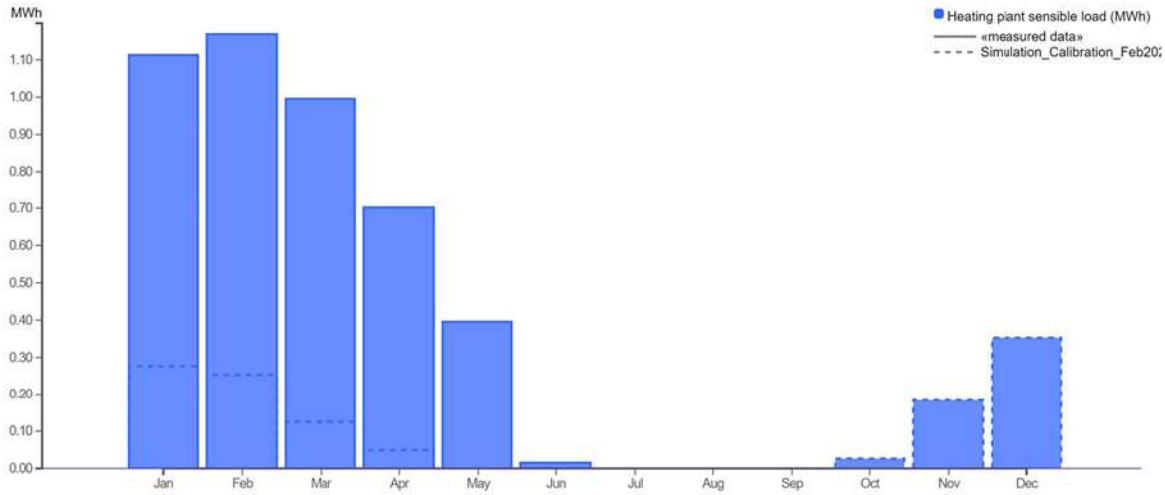


Figure 4: Monthly results comparing metered data with VE Room heating plant sens. load

- Room-level monthly comparison for Living-Kitchen *Heating plant sensible load* (iSCAN Scenario: Simulation_Calibration_Feb2022):



Monthly total	Scenarios	2021-01-01	2021-02-01	2021-03-01	2021-04-01	2021-05-01	2021-06-01	2021-07-01	2021-08-(
Heating plant sensible load (MWh)	«measured data»	1.113	1.169	0.995	0.702	0.396	0.015	0.000	0.0(
	Simulation_Calibration_Feb2022	0.277	0.254	0.125	0.049	0.000	0.000	0.000	0.0(

Figure 5: Room-level monthly comparison for Living-Kitchen Heating plant sensible load (iSCAN Scenario: Simulation_Calibration_Feb2022)

- Room-level day comparison for Living-Kitchen *Heating plant sensible load* (iSCAN Scenario: Simulation_Calibration_Feb2022):

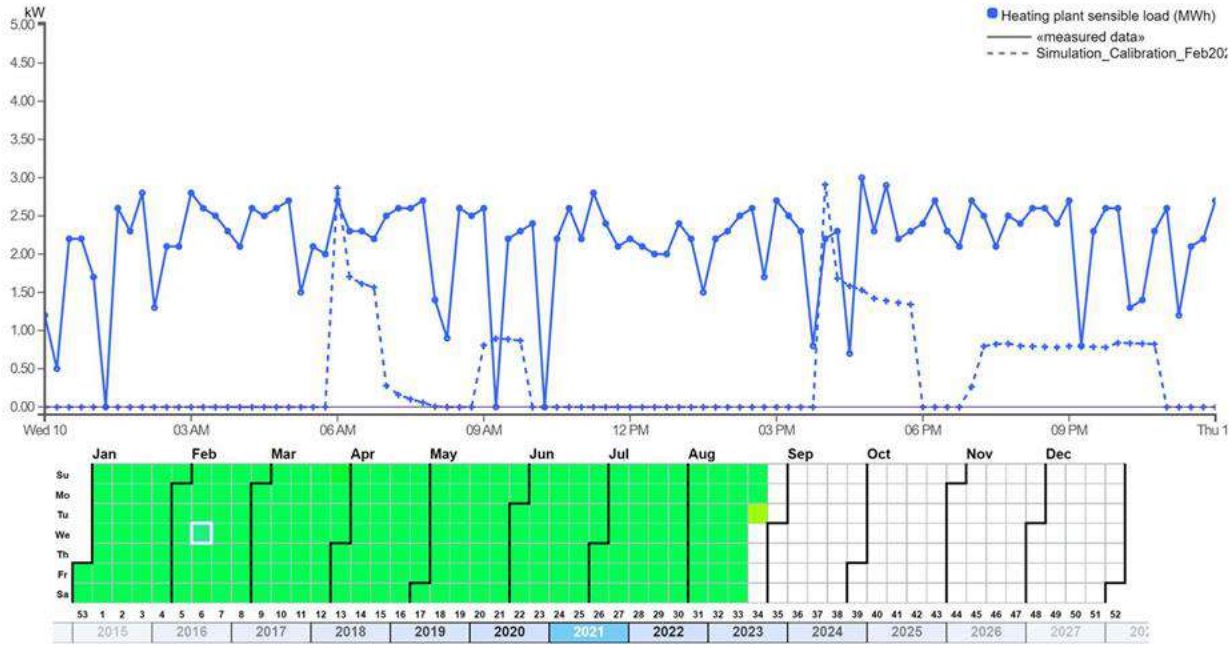


Figure 6: Room-level day comparison for Living-Kitchen Heating plant sensible load (iSCAN Scenario: Simulation_Calibration_Feb2022):

- DHW metered energy compared to *Ap Sys boiler DHW energy* from the VE:

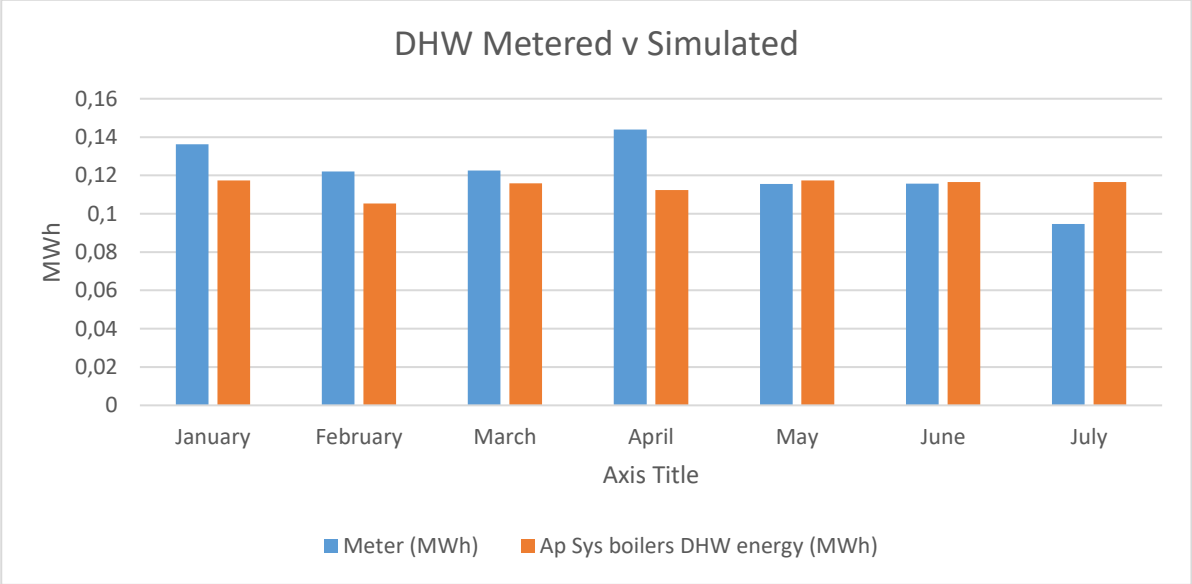


Figure 7: DHW metered energy compared to Ap Sys boiler DHW energy *from the VE*

Riga Sunisi House Follow-up calibration

- In **Riga Sunisi House Follow-up calibration**, only the rooms that have been assigned a share of the power meter readings have a heating system assigned.

Model Output:

- Same as **Riga Sunisi House Calibration 1**

Winter Calibration and Fine-tuning:

- The winter calibration covers the month of February (01/02/2021-28/02/2021)
- Calibration Job ID: 904ba92e-f39e-481f-b881-c1a58699279a
- Fine-tuning Job ID: eaa87493-8ea8-4e56-98c6-c4bb2b8455b9
- The fine-tuning was run using the maco optimisation with 1,000 simulations.
- The resulting metrics can be seen in the table below

Table 7: Riga Sunisi winter calibration metrics

		Air Temperature (degC)				CO_2 Concentration				Relative Humidity (%)				heatingPlantSensibleLoad (W)			
		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning	
Space	Name	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
SN000000	Sauna	37.829	32.422	37.952	32.551												
SP000006	Terrace	5.103	4.293	5.312	4.526					39.216	35.987	39.136	35.738				
SP00000A	Bedroom 202	2.859	2.351	2.928	2.34	350.71	263.346	342.443	258.5	10.737	8.684	9.633	8.021	524.279	332.801	0.686	0.533
SP000009	Bedroom 203	2.485	2.141	2.525	2.108	422.502	353.834	396.05	336.646	10.337	8.453	10.355	8.445	390.919	246.886	0.445	0.348
SP00000C	Bedroom 204	3.432	2.783	3.414	2.774	1265.721	938.407	1116.29	816.242	11.336	9.449	12.111	9.684	357.89	227.583	0.434	0.339
LV000000	Living-Kitchen	4.437	3.807	4.577	3.94	515.415	417.721	456.196	380.837	14.56	12.225	8.258	6.866	1208.541	776.906	1.534	1.28
TL000000	Toilet	9.661	9.507	10.352	10.196					34.98	29.959	20.591	17.348				

Summer Calibration and Fine-tuning:

- The summer calibration covers the month of June (01/06/2021-30/06/2021)
- Calibration Job ID: a3b58f9f-9774-4050-aa00-5cdeea6868e0
- Fine-tuning Job ID: 9be43ad9-d109-4608-8474-c3c336e59d34
- The fine-tuning was run using the maco optimisation with 1,000 simulations.
- The resulting metrics can be seen in table below:

Table 8: Riga Sunisi summer calibration metrics

		Air Temperature				CO_2 Concentration				Relative Humidity				heatingPlantSensibleLoad (W)			
		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning		Calibration		Fine-tuning	
Space	Name	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
SN000000	Sauna	67.87	67.95	68.331	68.409												
SP000006	Terrace	9.863	8.124	9.75	8.02					28.777	23.63	31.178	25.127				
SP00000A	Bedroom 202	1.252	0.993	1.375	1.076	494.434	413.942	497.58	416.366	20.773	17.491	21.075	17.653	0.071	0.006	0.071	0.006
SP000009	Bedroom 203	1.087	0.893	1.206	0.952	424.452	377.924	329.292	285.716	18.037	14.817	16.106	12.398	0.045	0.004	0.045	0.004
SP00000C	Bedroom 204	1.416	1.164	1.383	1.117	576.865	489.257	510.351	383.394	19.921	17.279	17.021	13.656	0.045	0.004	0.045	0.004
LV000000	Living-Kitchen	0.91	0.737	0.814	0.661	526.937	467.246	641.252	573.082	24.256	21.625	22.888	20.356	0.195	0.021	0.195	0.021
TL000000	Toilet	6.669	3.626	6.688	3.653					14.008	10.85	11.349	8.592				

Results:

- Monthly results comparing metered data with VE *Room heating plant sensible load*:

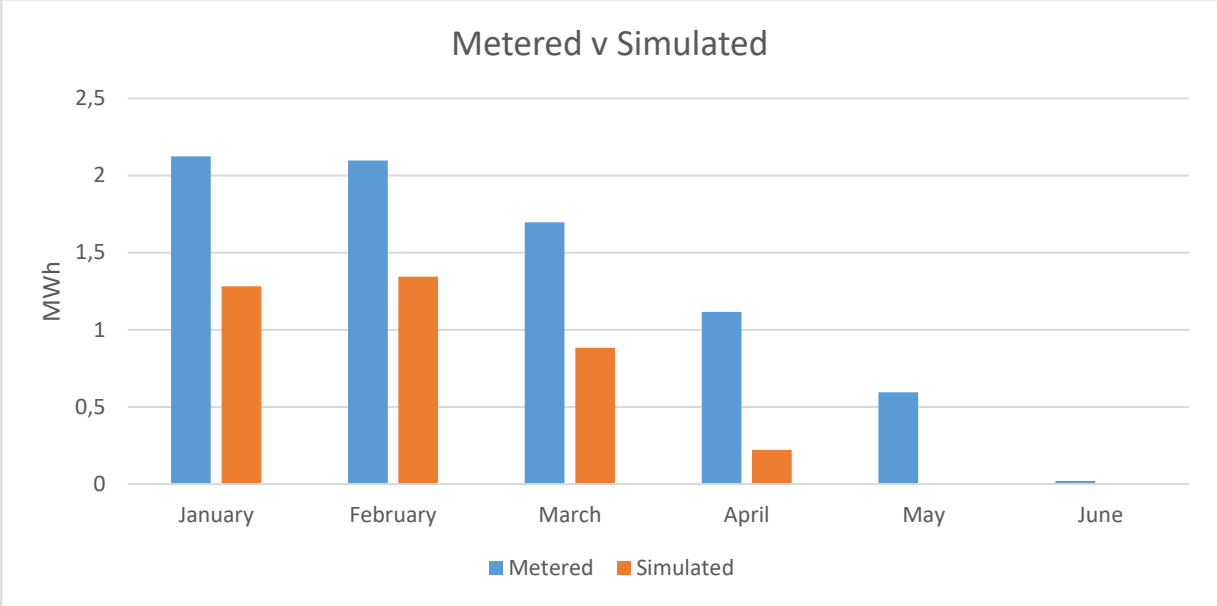


Figure 8: Riga Sunisi building energy model: Monthly results comparing metered data with VE Room heating plant sensible load

- Room-level monthly comparison for Living-Kitchen *Heating plant sensible load* (iSCAN Scenario: Simulation_Calibration_March2022):

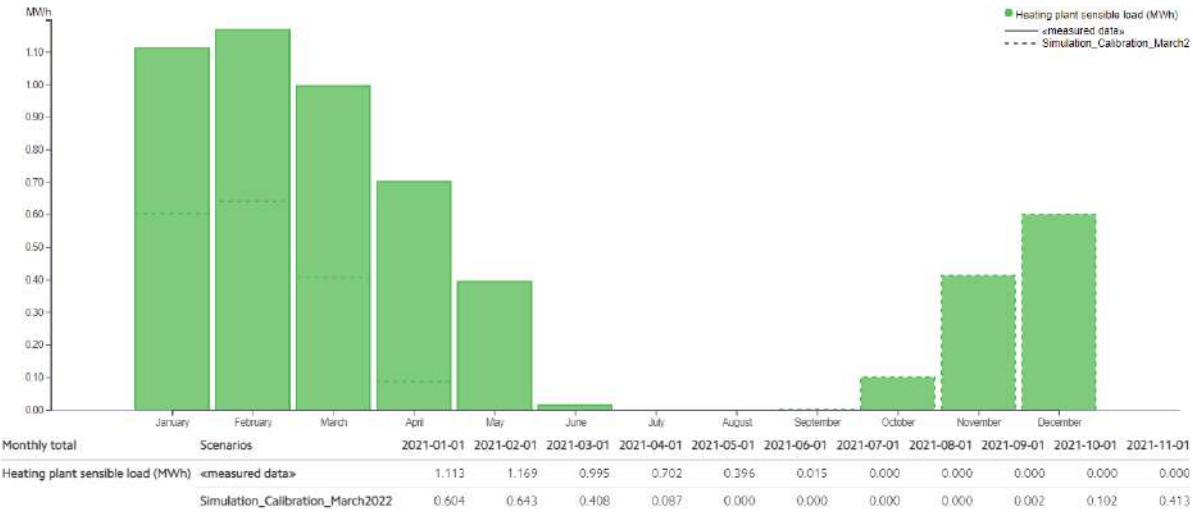


Figure 9: Riga Sunisi building energy model: Room-level monthly comparison for Living-Kitchen Heating plant sensible load (iSCAN Scenario: Simulation_Calibration_March2022)

- Room-level day comparison for Living-Kitchen *Heating plant sensible load* (iSCAN Scenario: Simulation_Calibration_March2022):

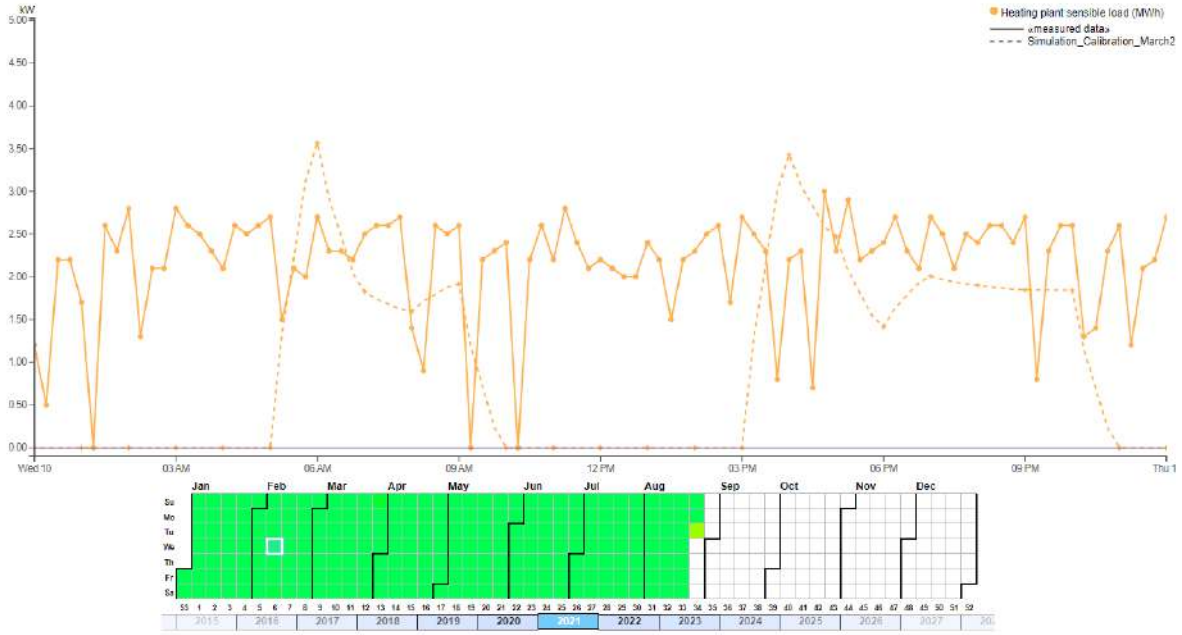


Figure 10: Riga Sunisi building energy model: Room-level day comparison for Living-Kitchen Heating plant sensible load (iSCAN Scenario: Simulation_Calibration_March2022

- DHW metered energy compared to *Ap Sys boiler DHW energy* from the VE:

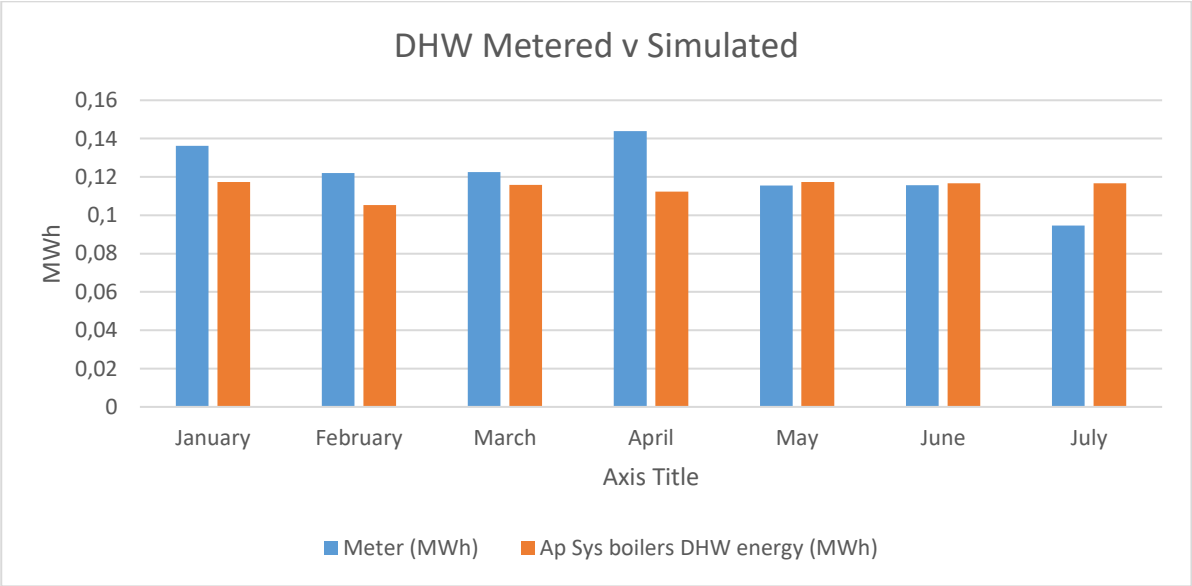


Figure 11: Riga Sunisi building energy model: DHW metered energy compared to Ap Sys boiler DHW energy from the VE

Comments:

- For **Calibration 1** and **Calibration 2**, the same metrics are being returned in the calibration tool for *heatingPlantSensibleLoad* at room-level. However, when using the resulting optimal inputs, the simulation results are not equally close to the metered data. This can also happen when changes are made to an existing model/transform.

- As the calibration uses the room-level variable *heatingPlantSensibleLoad*, the system efficiency cannot be used as a transform for calibration, meaning that the load is entirely dependent on the room conditions. As a result, it is difficult to significantly alter the room load while also calibrating for air temperature.

The model of Riga Sunisi in IESVE software or detailed results can be provided upon request.

3.2 Simulation module Integration and automated simulation

The building energy model simulation module for Riga Sunisi was integrated and automated to run every night at 11pm, and return Heating Sensible Load and Air Temperature results that are consumed by the hybrid controller via iSCAN-API. Steps 3, 4, 5, 9 were integrated and fully automated:

- **Step 3:** Sensor/Meter Data – [Automated] Integration between field level equipment and Smart Connector via MQTT connection. This is a standard practice by Schneider Electric (performed in WP4)

Figure 12: User Interface of Enterprise Server where all the data collected from Riga Sunisi demo site can be accessed

You are running a demo license | Demo license will expire on: 01/11/2023

Save | Go to date | Showing 18,209

Timestamp	ExtLogRoom Humidity	ExtLogRoom Temperature	ExtLogWireless Device 10 - Status	ExtLogWireless Device 11 - CO2	ExtLogWireless Device 11 - Humidity	ExtLogWireless Device 11 - Te
Today						
11:45:00	33 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
11:30:00	33 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
11:15:00	33 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
11:00:00	33 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
10:45:00	38 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
10:30:00	38 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
10:15:00	38 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
10:00:00	38 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
09:45:00	38 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
09:30:00	38 % Rh	23 °C	Closed (2)	0 ppm	0 % Rh	
09:15:00	38 % Rh	24 °C	Closed (2)	0 ppm	0 % Rh	
09:00:00	31 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
08:45:00	31 % Rh	22.5 °C	Closed (2)	0 ppm	0 % Rh	
08:30:00	31 % Rh	23 °C	Closed (2)	0 ppm	0 % Rh	
08:15:00	31 % Rh	24.06 °C	Closed (2)	0 ppm	0 % Rh	
08:00:00	32 % Rh	24 °C	Closed (2)	0 ppm	0 % Rh	

Figure 13: User Interface of Enterprise Server where all the data collected from Riga Sunisi demo site can be accessed

The portal to access the Riga Sunisi data is found below. The login details can be provided upon request.

https://185.168.27.5/

Step 4: Sensor/Meter Data – [Automated] Integration between Smart Connector and iSCAN via REST API. A new web hook has been developed to allow the integration. (performed in WP4). Variables from the technology packages were integrated during WP5 activities.

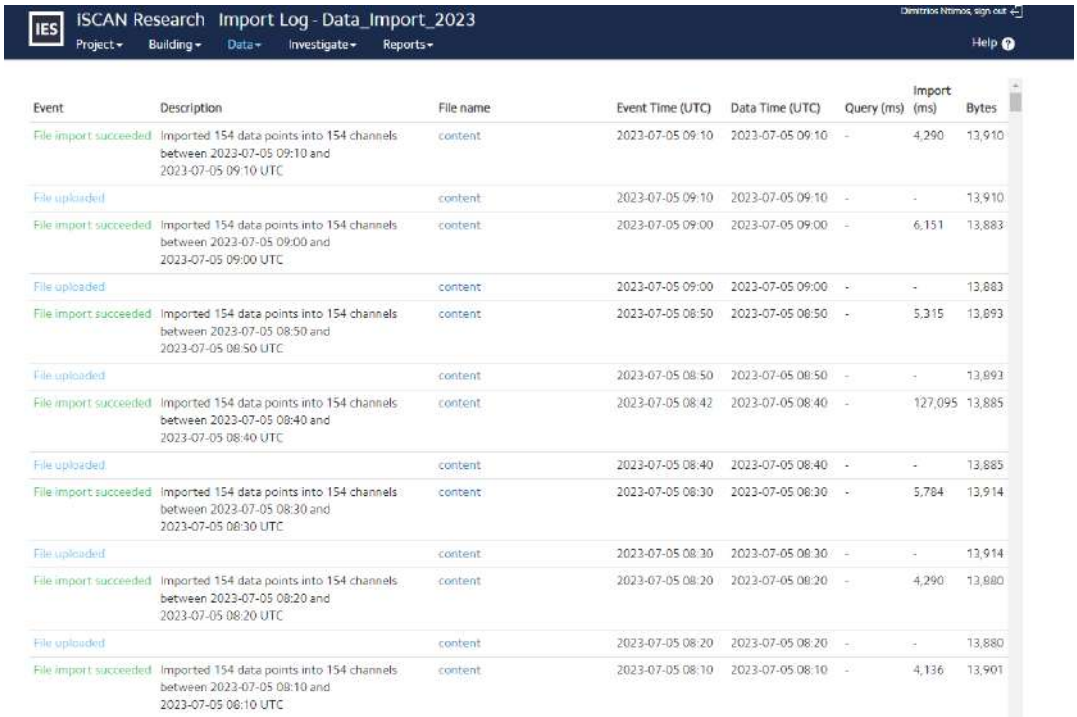
Access: https://iscan-research.iesve.com/building-visualise/SUNHORIZON/RigaSunisiHouse1 (The login details can be provided upon request)

A data dictionary was created with API endpoint and corresponding iSCAN channel names, used to develop the automated data import

	A	D	E	F
1	Building	Variable	Ids	ISCANCHANNEL
2	Sunisi	DualSun thermal energy output to Glycol	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/90-Multical_GlycolTank/Variables/W_Heat_energy_E1/Value	I.QFDgl-9-15m
3	Sunisi	DualSun thermal energy output	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/88-Multical_PVT/Variables/W_Heat_energy_E1/Value	I.QFDus-9-15m
4	Sunisi	Stratified thermal Tank temperature at top	11/AS-P - Riga - Sunisi/Interfacce/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T.Oskar top/Value	I.STA01-9-tem1-15m
5	Sunisi	S 2: Temperature Oskar center top	11/AS-P - Riga - Sunisi/Interfacce/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T.Oskar mid/Value	I.STA01-9-tem2-15m
6	Sunisi	S11: Temperature Oskar bottom	11/AS-P - Riga - Sunisi/Interfacce/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T.Oskar bottom/Value	I.STA01-9-tem3-15m
7	Sunisi	Glycol Tank temperature at top	11/AS-P - Riga - Sunisi/Interfacce/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T.Glycol Buffer top/Value	I.STG01-9-tem1-15m
8	Sunisi	Glycol Tank temperature at bottom	11/AS-P - Riga - Sunisi/Interfacce/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T.Glycol Buffer bottom/Value	I.STG01-9-tem2-15m
9	Sunisi	Status electricity heater ON/OFF	11/AS-P - Riga - Sunisi/Interfacce/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/Smart Energy_Sts/Value	I.ELH01-9-stat-15m
10	Sunisi	Smart electric heater thermal output to Oskar (estimated from heater electricity consumption)	11/AS-P - Riga - Sunisi/Interfacce/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/Smart Energy/Value	I.ELHus-9-15m
11	Sunisi	Technical room [house] electricity meter current Phase A	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3000_Current_Phase_1/Value	I.TECro-9-Cur1-15m
12	Sunisi	Technical room [house] electricity meter current Phase B	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3002_Current_Phase_2/Value	I.TECro-9-Cur2-15m
13	Sunisi	Technical room [house] electricity meter current Phase C	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3004_Current_Phase_3/Value	I.TECro-9-Cur3-15m
14	Sunisi	Technical room [house] electricity meter voltage AB	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3020_Voltage_L1L2/Value	I.TECro-9-V12-15m
15	Sunisi	Technical room [house] electricity meter voltage BC	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3022_Voltage_L2L3/Value	I.TECro-9-V23-15m
16	Sunisi	Technical room [house] electricity meter voltage CA	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3024_Voltage_L3L1/Value	I.TECro-9-V31-15m
17	Sunisi	Technical room [house] electricity meter voltage AN	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3028_Voltage_L1N/Value	I.TECro-9-V1N-15m
18	Sunisi	Technical room [house] electricity meter voltage BN	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3030_Voltage_L2N/Value	I.TECro-9-V2N-15m
19	Sunisi	Technical room [house] electricity meter voltage CN	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3032_Voltage_L3N/Value	I.TECro-9-V3N-15m
20	Sunisi	Technical room [house] electricity meter power Phase A	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3054_Active_Power_Phase_1/Value	I.TECro-9-PA-15m
21	Sunisi	Technical room [house] electricity meter power Phase B	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3056_Active_Power_Phase_2/Value	I.TECro-9-PB-15m
22	Sunisi	Technical room [house] electricity meter power Phase C	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3058_Active_Power_Phase_3/Value	I.TECro-9-PC-15m
23	Sunisi	Technical room [house] electricity meter active power	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3060_Active_Power_Total/Value	I.TECro-9-AP-15m
24	Sunisi	Technical room [house] electricity meter reactive power	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3068_Reactive_Power_Total/Value	I.TECro-9-RP-15m
25	Sunisi	Technical room [house] electricity meter apparent power	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3076_Apparent_Power_Total/Value	I.TECro-9-APP-15m
26	Sunisi	Technical room [house] electricity meter active energy total import	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3204_Active_Energy_Total_Import/Value	I.TECro-9-ETimA-15m
27	Sunisi	Technical room [house] electricity meter active energy total export	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3208_Active_Energy_Total_Export/Value	I.TECro-9-ETexA-15m
28	Sunisi	Technical room [house] electricity meter reactive energy total import	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3220_Reactive_Energy_Total_Import/Value	I.TECro-9-ETimR-15m
29	Sunisi	Technical room [house] electricity meter reactive energy total export	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/02-IEM3155_House/Variables/W3224_Reactive_Energy_Total_Export/Value	I.TECro-9-ETexR-15m
30	Sunisi	Technical room heat meter DHW heat energy E1	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/Multical 603-1.5/Variables/W_Heat_energy_E1/Value	I.TECroo-9-H1dhw-15m
31	Sunisi	Technical room heat meter DHW T1	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/Multical 603-1.5/Variables/W_t1_actual/Value	I.TECroo-9-T1dhw-15m
32	Sunisi	Weather station rain	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_B/WeatherStation/Variables/W_Rain/Value	I.RGSwe-9-rain1-15m
33	Sunisi	Weather station sunsensor east (klux)	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_B/WeatherStation/Variables/W_SunSensor_East/Value	I.RGSwe-9-SunE-15m
34	Sunisi	Weather station sunsensor west (klux)	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_B/WeatherStation/Variables/W_SunSensor_South/Value	I.RGSwe-9-SunW-15m
35	Sunisi	Weather station sunsensor south (klux)	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_B/WeatherStation/Variables/W_SunSensor_West/Value	I.RGSwe-9-SunS-15m
36	Sunisi	Weather station wind (m/s)	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_B/WeatherStation/Variables/W_Wind/Value	I.RGSwe-9-Wind1-15m
37	Sunisi	Weather station temperature (°C)	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_B/WeatherStation/Variables/W_Temp/Value	I.RGSwe-9-Tou1-15m
38	Sunisi	Technical room electricity meter Solar Current Phase A	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3000_Current_Phase_1/Value	I.ESOLar-9-Cur1-15m
39	Sunisi	Technical room electricity meter Solar Current Phase B	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3002_Current_Phase_2/Value	I.ESOLar-9-Cur2-15m
40	Sunisi	Technical room electricity meter Solar Current Phase C	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3004_Current_Phase_3/Value	I.ESOLar-9-Cur3-15m
41	Sunisi	Technical room electricity meter Solar Voltage AB	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3020_Voltage_L1L2/Value	I.ESOLar-9-V12-15m
42	Sunisi	Technical room electricity meter Solar Voltage BC	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3022_Voltage_L2L3/Value	I.ESOLar-9-V23-15m
43	Sunisi	Technical room electricity meter Solar Voltage CA	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3024_Voltage_L3L1/Value	I.ESOLar-9-V31-15m
44	Sunisi	Technical room electricity meter Solar Voltage AN	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3028_Voltage_L1N/Value	I.ESOLar-9-V1N-15m
45	Sunisi	Technical room electricity meter Solar Voltage BN	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3030_Voltage_L2N/Value	I.ESOLar-9-V2N-15m
46	Sunisi	Technical room electricity meter Solar Voltage CN	11/AS-P - Riga - Sunisi/Interfacce/Modbus Master Network_A/11-IEM3155_Solar/Variables/W3032_Voltage_L3N/Value	I.ESOLar-9-V3N-15m

Figure 14: Riga Sunisi House data dictionary and API endpoints to achieve ES-iSCAN integration

Using the web hook and the REST API endpoints the automated data import was achieved. The screenshot below demonstrates a sample of automated data imports from Enterprise Server to iSCAN every 10 minutes for 154 variables collected from sensors/meters in Riga Sunisi House.



Event	Description	File name	Event Time (UTC)	Data Time (UTC)	Query (ms)	Import (ms)	Bytes
File import succeeded	Imported 154 data points into 154 channels between 2023-07-05 09:10 and 2023-07-05 09:10 UTC	content	2023-07-05 09:10	2023-07-05 09:10	-	4,290	13,910
File uploaded		content	2023-07-05 09:10	2023-07-05 09:10	-	-	13,910
File import succeeded	Imported 154 data points into 154 channels between 2023-07-05 09:00 and 2023-07-05 09:00 UTC	content	2023-07-05 09:00	2023-07-05 09:00	-	6,151	13,883
File uploaded		content	2023-07-05 09:00	2023-07-05 09:00	-	-	13,883
File import succeeded	Imported 154 data points into 154 channels between 2023-07-05 08:50 and 2023-07-05 08:50 UTC	content	2023-07-05 08:50	2023-07-05 08:50	-	5,315	13,893
File uploaded		content	2023-07-05 08:50	2023-07-05 08:50	-	-	13,893
File import succeeded	Imported 154 data points into 154 channels between 2023-07-05 08:40 and 2023-07-05 08:40 UTC	content	2023-07-05 08:42	2023-07-05 08:40	-	127,095	13,885
File uploaded		content	2023-07-05 08:40	2023-07-05 08:40	-	-	13,885
File import succeeded	Imported 154 data points into 154 channels between 2023-07-05 08:30 and 2023-07-05 08:30 UTC	content	2023-07-05 08:30	2023-07-05 08:30	-	5,784	13,914
File uploaded		content	2023-07-05 08:30	2023-07-05 08:30	-	-	13,914
File import succeeded	Imported 154 data points into 154 channels between 2023-07-05 08:20 and 2023-07-05 08:20 UTC	content	2023-07-05 08:20	2023-07-05 08:20	-	4,290	13,880
File uploaded		content	2023-07-05 08:20	2023-07-05 08:20	-	-	13,880
File import succeeded	Imported 154 data points into 154 channels between 2023-07-05 08:10 and 2023-07-05 08:10 UTC	content	2023-07-05 08:10	2023-07-05 08:10	-	4,136	13,901

Figure 15: Automated data import from Enterprise Server to iSCAN every 10 minutes for 154 variables collected from sensors/meters in Riga Sunisi House

In iSCAN all the data can be analysed, visualised, and used in simulation. Additionally, weather data and weather forecasts for Riga Sunisi was activated (existing feature of iSCAN software).

Figure 16: iSCAN User Interface where all data from Riga Sunisi House can be visualised and shared via iSCAN API

Step 9 :Simulation Data from the calibrated model to iSCAN - The calibrated building energy data is programmed to execute simulations daily at 11.50 pm. The model is having as an input the weather forecasts of the next day, and returns as output to iSCAN the space conditioning energy demand and environmental variables, such as Air Temperature for the next 2 days.

The process was deployed for Riga Sunisi demo site in September 2022 and was running automatically until February 2023. Below is a screenshot of iSCAN showing the heating plant sensible loads calculated for all rooms in Riga Sunisi demo site using the building energy model of the building. However, since the installation of new technology packages was delayed due to unforeseen withdrawal of BoostHeat, the validation didn't go though.

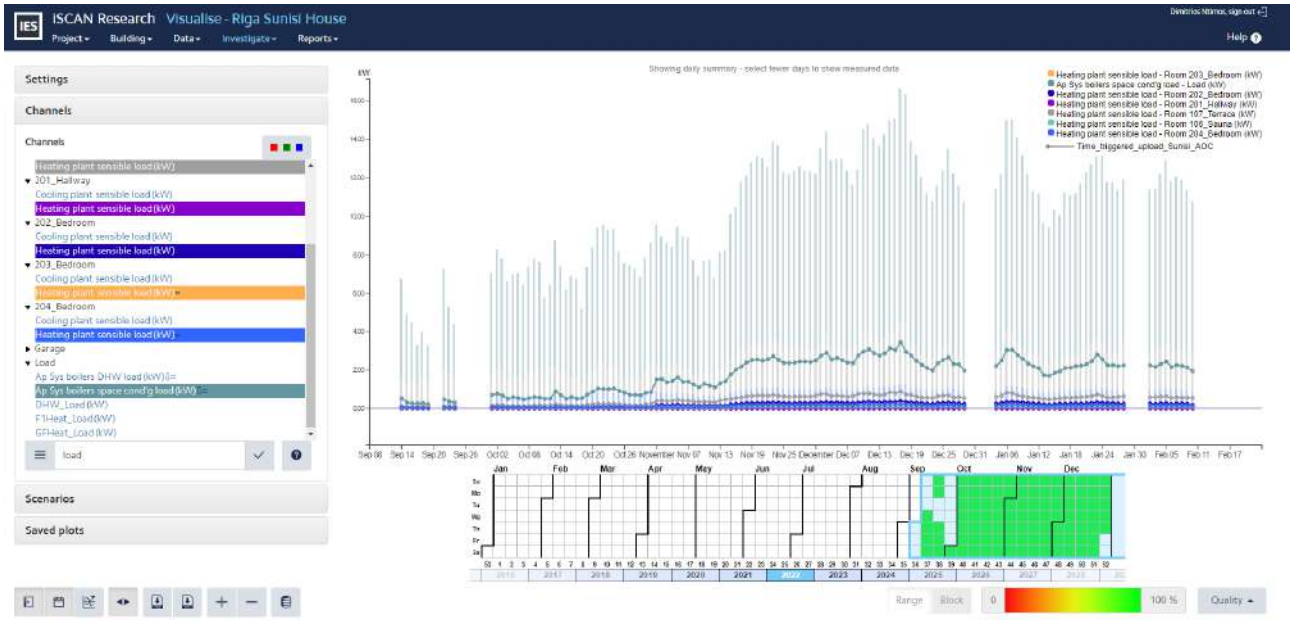


Figure 17: Heating plant sensible load (kW) calculated daily for all rooms in Riga Sunisi demo using the calibrated building energy model and displayed in iSCAN

Finally, all the real and simulated data are available to access in real time using the iSCAN-API, where documentation can be found below.

https://iscan-research.iesve.com/api-reference

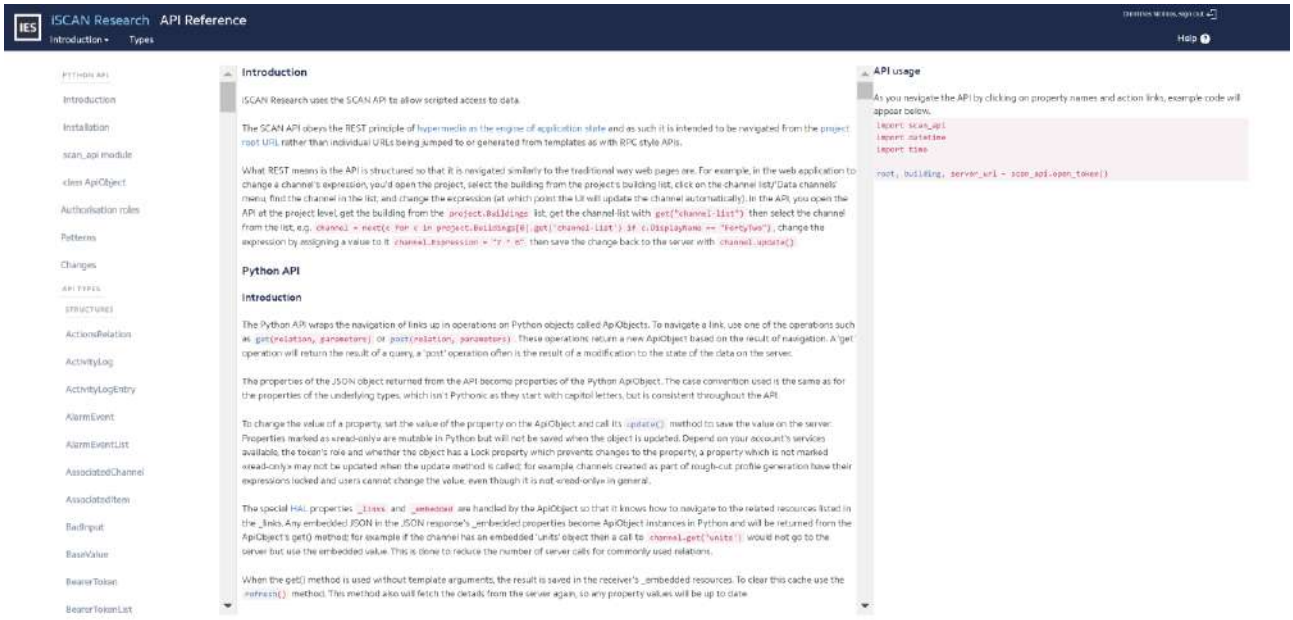


Figure 18: Screenshot of the iSCAN API reference page

3.3 Feedback APP-ISCAN integration

The feedback app, also called SunHorizon app, for the Riga Sunisi site was configured to work for a private building where the end-users are the family living in the house. The purpose of the app is to provide the user with real-time values on their indoor climate as well as energy consumption. But also, as a tool for the end-users to provide feedback about their indoor comfort levels to the ISCAN system for further elaboration.

The integration with the ISCAN system consisted of the following main steps:

- ISCAN authentication and authorization: for the app to have access to ISCAN-data it needed a way to authenticate itself, for this an authentication token was provided by IES. This token is used both to get and send data from and to the app via the APP API (see image below).
- Rooms and sensor reference to retrieve data: to display real-time data on indoor temperature, humidity etc. The app had to know which reference to use for a specific room and a specific sensor in that room. These references were added manually and stored in the app database. The Overview section in the SunHorizon app is an example where real-time data from ISCAN is used (see image below.
- Reference to feedback channel: The final integration step was to create a data-import channel (see image below) in ISCAN including data format of feedback message. Once this was done it could be added to the app configuration. All feedback messages sent from the app can be accessed from the ISCAN import log (see image below).

Screenshots of integrations are found below

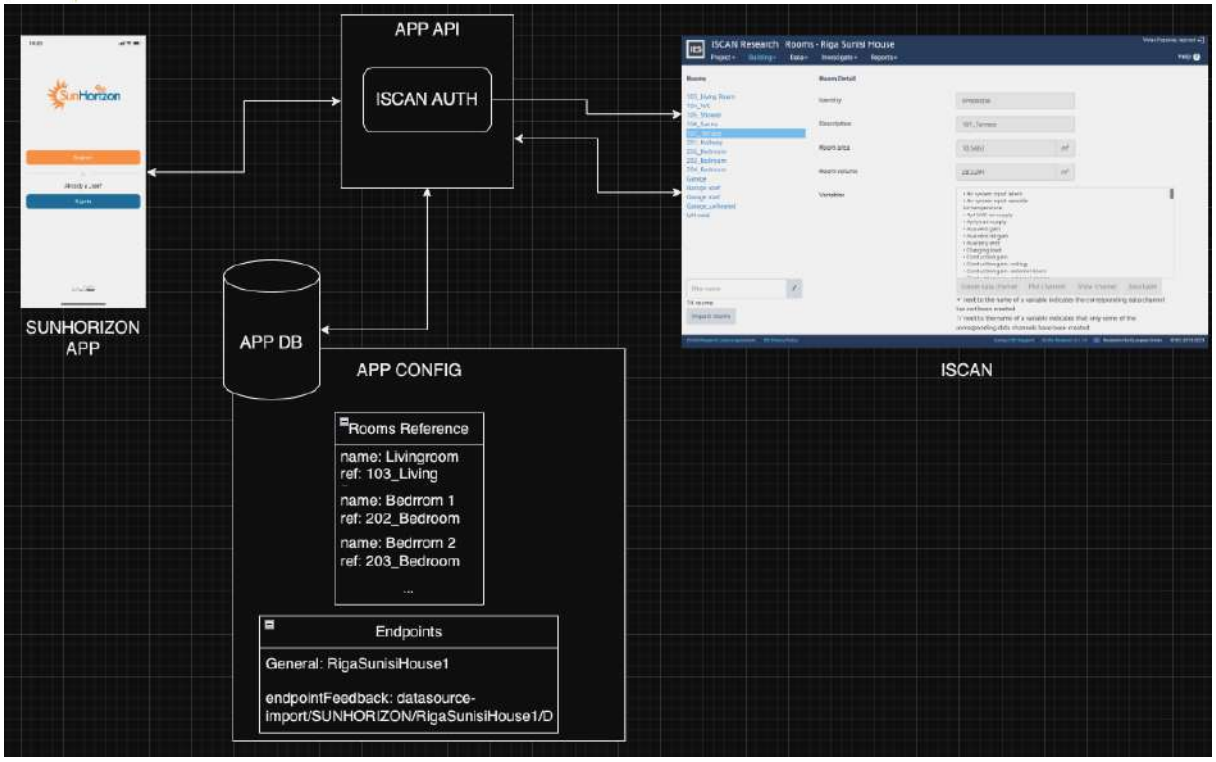


Figure 19: Feedback App – ISCAN integration overview

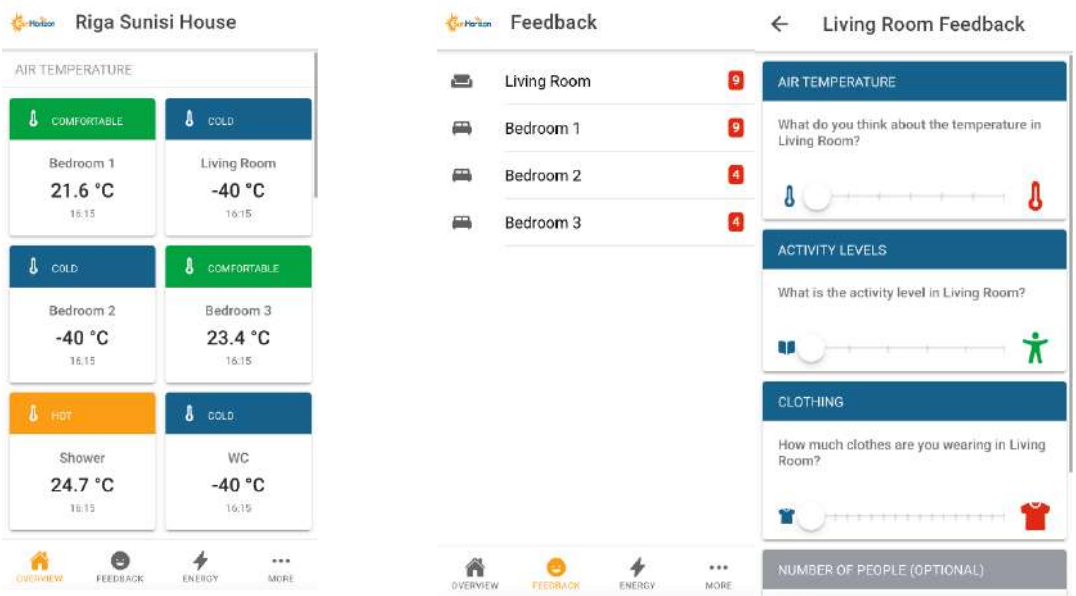


*Figure 20:*SunHorizon app, Sunisi overview and feedback view

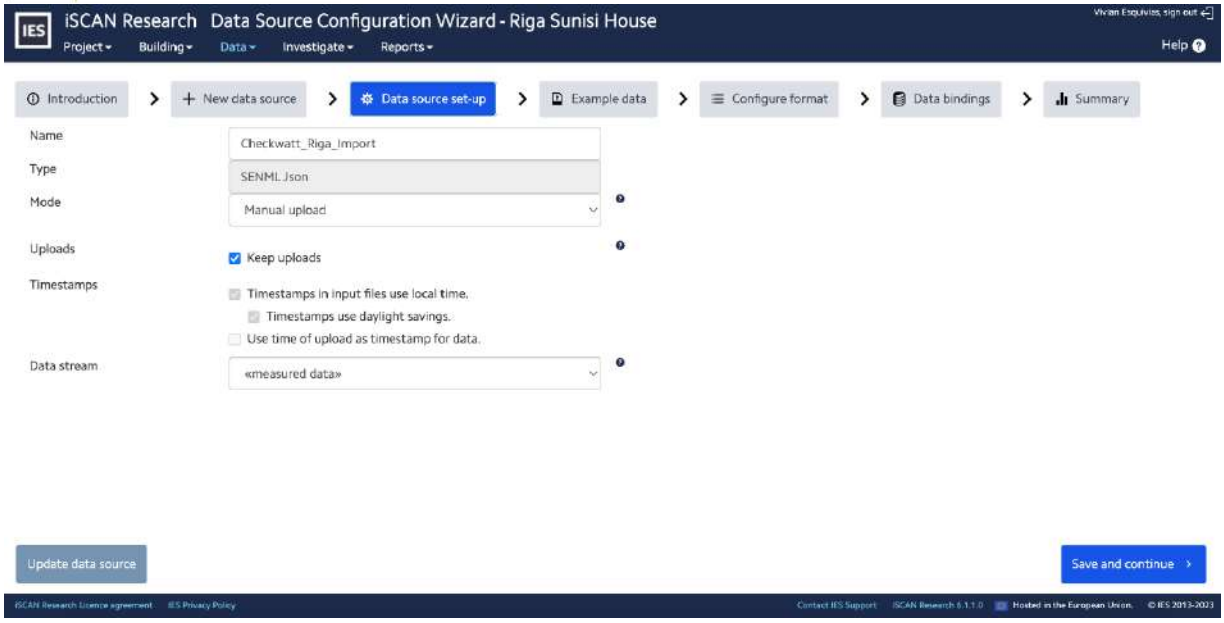
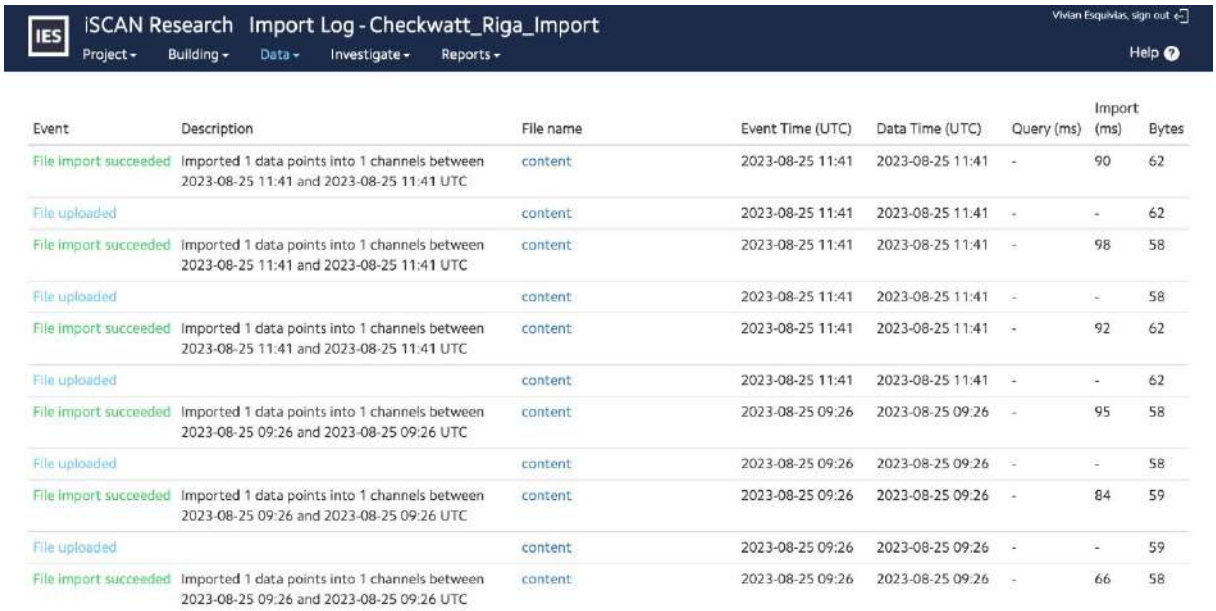


Figure 21: Data-import configuration in ISCAN for feedback from app for Sunisi



Event	Description	File name	Event Time (UTC)	Data Time (UTC)	Query (ms)	Import (ms)	Bytes
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:41 and 2023-08-25 11:41 UTC	content	2023-08-25 11:41	2023-08-25 11:41	-	90	62
File uploaded		content	2023-08-25 11:41	2023-08-25 11:41	-	-	62
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:41 and 2023-08-25 11:41 UTC	content	2023-08-25 11:41	2023-08-25 11:41	-	98	58
File uploaded		content	2023-08-25 11:41	2023-08-25 11:41	-	-	58
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:41 and 2023-08-25 11:41 UTC	content	2023-08-25 11:41	2023-08-25 11:41	-	92	62
File uploaded		content	2023-08-25 11:41	2023-08-25 11:41	-	-	62
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 09:26 and 2023-08-25 09:26 UTC	content	2023-08-25 09:26	2023-08-25 09:26	-	95	58
File uploaded		content	2023-08-25 09:26	2023-08-25 09:26	-	-	58
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 09:26 and 2023-08-25 09:26 UTC	content	2023-08-25 09:26	2023-08-25 09:26	-	84	59
File uploaded		content	2023-08-25 09:26	2023-08-25 09:26	-	-	59
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 09:26 and 2023-08-25 09:26 UTC	content	2023-08-25 09:26	2023-08-25 09:26	-	66	58

Figure 22: Import log in ISCAN showing a list of feedback data sent from the SunHorizon app for Riga Sunisi demo site.


```
[
  {
    "bt": 1692963092,
    "v": -1,
    "n": "I.WOHtf-9_Temperature_Feedback"
  }
]
```


Figure 23: Data format of feedback messages sent to ISCAN.

3.4 Predictive Maintenance APP-ISCAN integration

The predictive maintenance tool was developed in T5.5 in order to predict when the system will fail and then schedule the appropriate maintenance or repair action that guarantee the lowest cost associated to the repairing time. Figure 24 shows the general approach of the maintenance software tools of SunHorizon defined in D4.4, which is composed of predictive

maintenance tool and control algorithms. As the current section is focused in the predictive maintenance tool, the aim is to predict the evolution of the detected faults that generate the alarms, trying to estimate the RUL or time-to-fault.

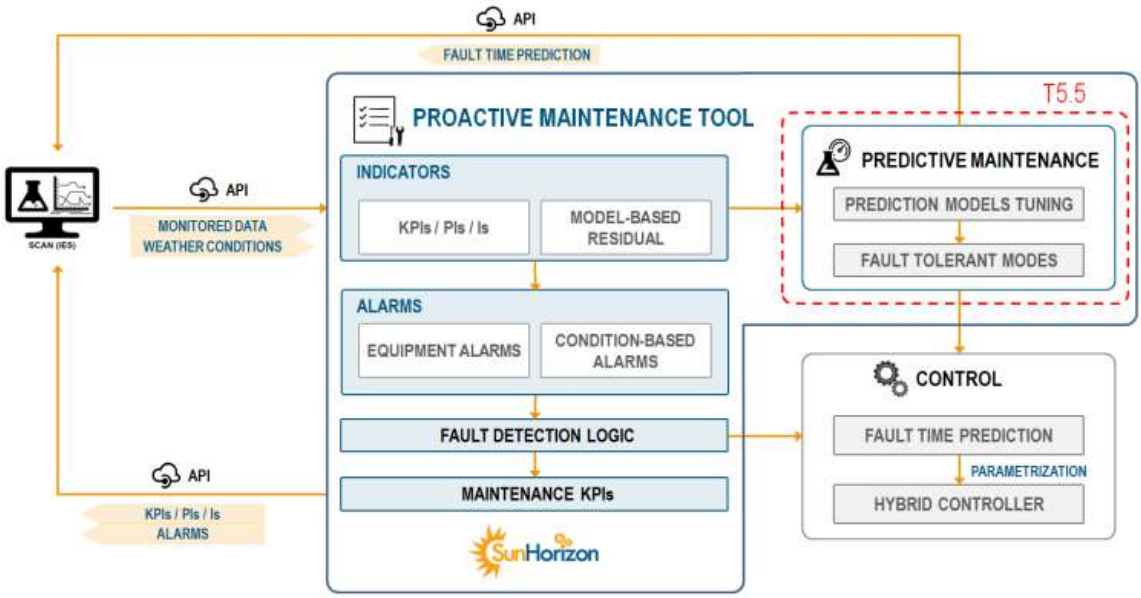


Figure 24: Sunhorizon maintenance tools flow

To deployment of the predictive maintenance tools, two modules have been developed with different objectives:

- Indicators: The KPIs and PIs developed and defined in both D2.4 and D4.2 will be used by the predictive tools in order to the surveillance, fault detection and fault prediction. Then the module is focused on the calculation of all KPIs and PIs.
- Prediction models tuning: The predictions skills are based on the historical evolution of the indicators commented previously

The two modules have been used for the predictive maintenance and displayed the prediction through iSCAN platform. Furthermore, the KPIs and PIs that will be used the predictive maintenance in Riga-Sunisi demonstrator are exposed below, which have been obtained from D2.4 and D5.6.

Table 9: KPIs and PIs for the predictive tool in Riga Sunisi

Code	REF	Description	Unit	Sampling time
K.RERsy-9-15m	EN02	Renewable Energy Ratio	% or ratio	15 min
K.HCIsy-9-15m	COM01	Heating Comfort Index	% or ratio	15 min
P.EFTds-9	DS01	DualSun solar thermal efficiency	% or ratio	15 min
P.FSOds-9	DS02	DualSun solar thermal fraction	% or ratio	15 min
P.EFEds-9	DS03	DualSun solar electric efficiency	% or ratio	15 min
P.TERds-9	DS04	DualSun thermal-electricity ratio	% or ratio	15 min
P.SGUbh-9-mon	BH01	BOOSTHEAT seasonal gas utilization efficiency	% or ratio	Month
P.SPFbh-9-mon	BH02	BOOSTHEAT seasonal performance factor	% or ratio	Month
P.RATdt-9	RT01	Ratiotherm tank stratification efficiency	°C	15 min
P.STGdt-9	GT01	Glycol tank stratification efficiency	°C	15 min

Figure 25: Sample of KPIs and PIs integrated with iSCAN

However, to calculate the KPIs and PIs exposed, some indicator are needed to calculate, all of which are shown below, where the information have been obtained from D5.6

Table 10: Indicators used by the predictive tool in Riga Sunisi

Code	Description	Unit	KPI/ PI for whose calculation is used
I.QFEfu-9	Final gas demand (post-retrofit)	kWh	EN02, BH01, BH02
I.EFEsy-9	Final electricity demand (post-retrofit)	kWh	EN02
I.PENnp-9	Non-renewable primary energy (post-retrofit)	kWh	EN02
I.PENre-9	Renewable primary energy	kWh	EN02
I.PENto-9	Final primary energy	kWh	EN02
I.LIVgr-9-Tem1	Living room temperature sensor 1	°C	COM01
I.LIVgr-9-Tem2	Living room temperature sensor 2	°C	COM01
I.RO1f1-9-Tem1	Bedroom left temperature sensor 1	°C	COM01
I.RO1f1-9-Tem2	Bedroom left temperature sensor 2	°C	COM01
I.RO2f1-9-Tem1	Bedroom right-top temperature sensor 1	°C	COM01
I.RO2f1-9-Tem2	Bedroom right-top temperature sensor 2	°C	COM01
I.RO2f1-9-Tem3	Bedroom right-top temperature sensor 3	°C	COM01
I.RO3f1-9-Tem1	Bedroom right-bottom temperature sensor 1	°C	COM01
I.RO3f1-9-Tem2	Bedroom right-bottom temperature sensor 2	°C	COM01
I.RO3f1-9-Tem3	Bedroom right-bottom temperature sensor 3	°C	COM01
I.RGSwe-9-Its1	Solar irradiation on the tilted surface	W/m2	DS01, DS03
I.QFDus-9	DualSun thermal power output	W	DS01, DS02, DS04
I.QFBoh-9	BOOSTHEAT thermal power output	W	DS02, BH01, BH02
I.QFElh-9	Electric heater thermal power output	W	DS02
I.EPVto-9	DualSun electric power output	W	DS03, DS04
I.EFBoh-9	BOOSTHEAT electric power consumption	W	BH02
I.STA01-9-tem1	Top ratiotherm tank temperature	°C	RT01
I.STA01-9-tem3	Bottom ratiotherm tank temperature	°C	RT01
I.STG01-9-tem1	Top glycol tank temperature	°C	GT01
I.STG01-9-tem2	Bottom glycol tank temperature	°C	GT01

Figure 26: Sample of indicators integrated with iSCAN

3.5 Hybrid Controller integration with iSCAN and RATIO PLC

A general approach about the hybrid controller (HyC) and its intricate communication protocols with APIs, which are developed in Python code, will be explained in the current section in order to elucidate the continuous data flow from the HyC integrated in the A-type demo-sites (Sant Cugat and Riga Sunisi).

It should be noted that the HyC has notable variations in its control strategy for each A-type demo-site, which both will be discussed in section 3.5.2 and 4.5.2. The overall objective of the HyC is twofold: to reduce user bills by leveraging both renewable technologies and the technologies packages deployed at the demo-sites, and to improve the self-consumption rate.

To predict the optimal control strategy for the next 24 hours, the controller relies on a collaborative co-simulation framework between Python and TRNSYS. In T2.4, within WP2, the TRNSYS demonstration were elaborated to resemble real-world scenarios, facilitating model execution and ensuring accurate performance of the optimisations performed in Python. So that Python can treat TRNSYS as thread and started from the code, Python invokes a TRNSYS executable (TRNSYS18.exe) and its *.dck* file, which serves as a text file generated by the TRNSYS application in Simulation Studio, containing model-specific settings. The controller dynamically adjusts both variables and parameters within these files to synchronise them with the current state of the system, using data collected from IES. The synchronisation is vital for launching the TRNSYS model and retrieving its results as shown in Figure 27. The essential inputs are specified in INI and text files, while the control variables are modified within a separate text file that aggregates the decision outputs of the algorithms.

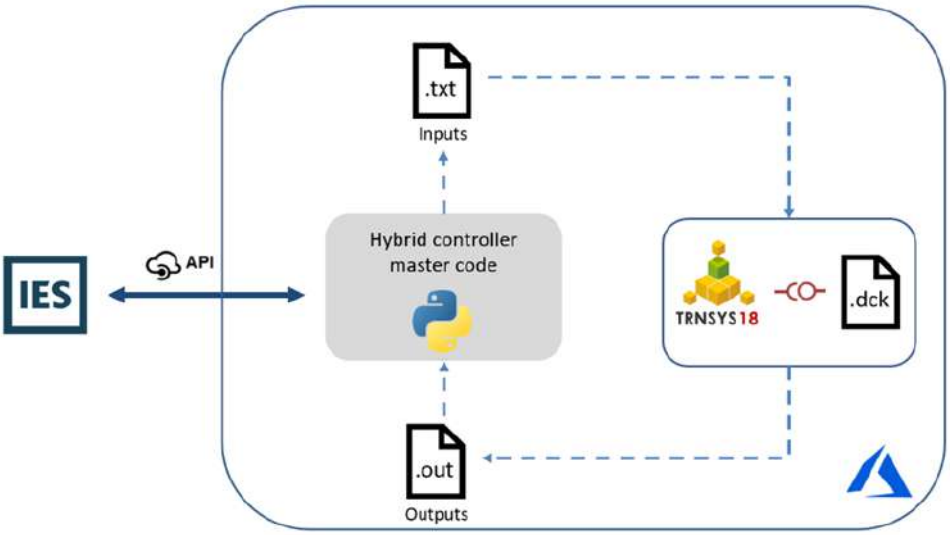


Figure 27: General hybrid controller approach

The HyC, equipped with predictive capabilities to anticipate the next 24 system values through TRNSYS, has several functionalities, including self-algorithms aimed at avoiding energy waste and optimising the utilization of Renewable Energy Sources (RES). To illustrate the intricate connections within the HyC system, Figure 28 delineates the composition of five distinct blocks (IES communication, Schneider communication, Configuration interface, Execution supervisor and High-level controller), integrated through the utilization of APIs from both iSCAN and Schneider platforms.

- IES communication: The hybrid controller must be in constant communication with iSCAN to obtain the predicted data, read requests and write the optimal operation of the systems. In case the connection fails, the error will be reported in a log file, including each time the code tries to communicate with the iSCAN platform. This part of the master code is referred to "*communication validation*".
- Schneider communication: The hybrid controller will communicate the control strategies to Schneider's automation server and RATIO PLC will read from it. A watchdog variable (binary) will be also communicated so as to make the PLC know the hybrid controller is functioning and there is no lack of communication.
- Configuration interface: based on a INI file, it will allow the operation and configuration of the hybrid controller during runtime without interrupting its continuous execution. Example of possible modifications are the API key or iSCAN channels name, allowing the hybrid controller to be updated avoiding that any error can be produced.
- Execution supervisor: using a LOG text file, in the case any error occurs during the code execution, it is reported in through file, including the current date and the part of the code where the error has been raised.
- High-level controller: It is associated with the core of the Python code, where the optimization and TRNSYS simulations are carried out.

The iSCAN API serves the main role of acquiring predictive data, read requests, and write operations for system operations. In parallel, the Schneider API acts as a conduit to transmit control strategies to Schneider's automation server, which the RATIO Programmable Logic Controller (PLC) extracts instructions from this source. In the event of a potential failure, the HyC controller maintains surveillance and promptly reports any anomalies in a logfile, inherently linked to a "communication validation" mechanism. In addition, it enforces a high-level control shutdown/start-up, represented as a binary variable, across the respective channels of both iSCAN and Schneider platforms to ensure the integrity of the system.

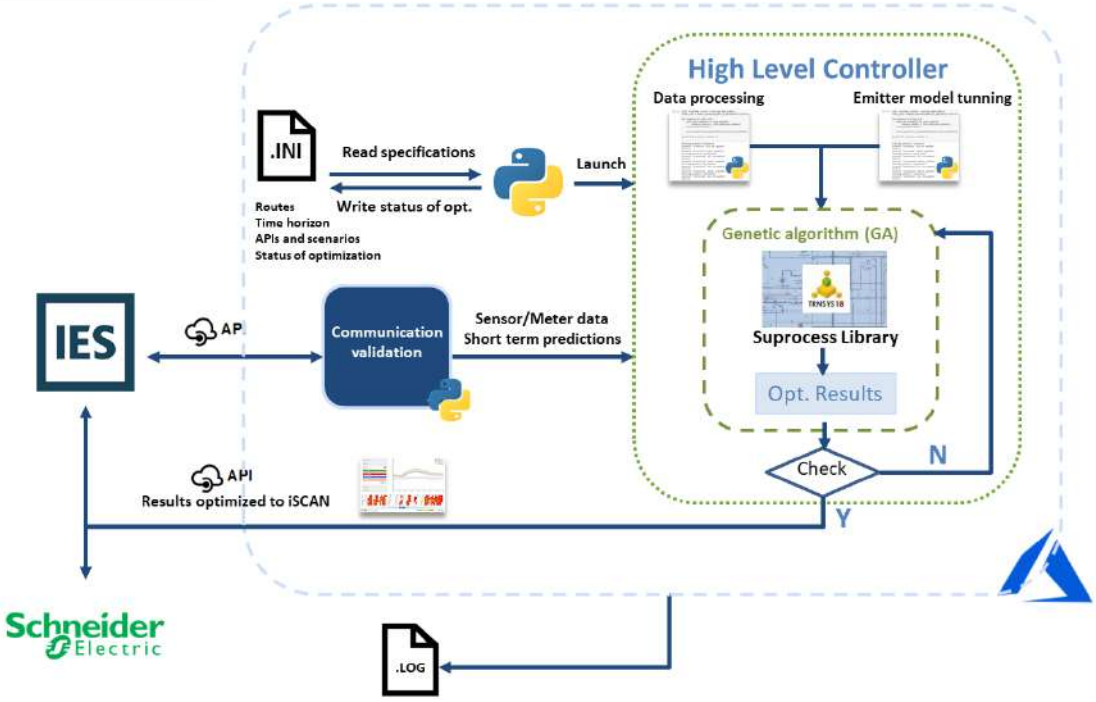


Figure 28: Hybrid controller structure

The controller operates under the guidance of different files, INI and text files discussed, and takes advantage of the forecast data previously computed within the iSCAN platform. After the execution of the controller and the generation of results, these are seamlessly transmitted to the iSCAN platform, simultaneously generating a logfile to record any potential errors. However, two crucial pre-optimisation processes, namely data processing and emitter model tuning, require execution. The first process involves monitoring of the time steps, aligning the data collected by iSCAN with the agreed-upon time step required for TRNSYS. On the other hand, the latter, known as emitter model tuning, pertains to demand characterization. Subsequently, the heart of the controller lies a genetic algorithm (GA), which assumes the central role in determining the optimal control strategy. Once the GA identifies the best-suited control strategy, the projected optimal values are seamlessly integrated into the appropriate iSCAN channel for the ensuing 24-hour period.

The algorithm employed is rooted in the scientific Python library, Pygmo [1], with a selection of three distinct algorithms, specifically Extended Ant Colony Optimization (GACO), Simple Genetic Algorithm (SGA), and Improved Harmony Research (IHS), chosen based on their compatibility with the HyC architecture. Although Task 5.3 involved the testing of additional algorithms such as differential evolution (utilizing SciPy, [2]) and NSGA2 [3], these were excluded from Task 5.4 due to their suboptimal performance. GACO and IHS exhibited the most promising outcomes. Consequently, a comprehensive examination was conducted within the context of Riga Sunisi optimization to assess the impact of utilizing these algorithms both jointly and independently. The results demonstrated that despite the increased computational load incurred by employing both algorithms in tandem, it yielded superior results concerning the tested objective cost function.

As for the demand characterisation of each demo-site, and according to Figure 28, the controller reads these forecast data through a Python API. To manage the demand characterization, it is divided in forecast electrical and thermal demand, where the controller read the corresponding iSCAN channels and built a readable by TRNSYS. However, the thermal part has been managed differently, as in the Riga demo site are two thermal loads: first and second floor. Instead of including the thermal demand directly on the TRNSYS model and launch the control optimization, a secondary optimization exists in the current demo site. Secondary optimisation is associated with parametrisation of the model, it is performed to calculate the profile of the heat load pumps feeding to radiators models in order to reduce the optimisation error between thermal demand downloaded from iSCAN and the simulate one, and to build a model close to the real case. In Riga Sunisi case, the hybrid controller has to create two text files. One of them associated to the current system operation (e.g weather conditions, initial conditions of the energy systems), and the last file is based on the incorporation of the heat load pumps

profile both the first and the ground floor. While the algorithms to optimise the whole system is IHS, in the secondary optimisation is used GACO, where will be explained in the following sections

Both predictive and control module are launched in a virtual machine in Microsoft Azure platform, which is a public could computing platform that offers software services (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS), and has many advantages such as scalability, interoperability, backups and security. This platform was selected related to the scalability of the server performance, which allows developing the system from a simple machine and increase its capabilities according to project evolution, and the maintainability of the server. Related to SunHorizon project and deliverable 5.5 [4], two main approached have been evaluated:

- Cloud services provider: The virtual server or a set of services can be installed or fitted to perform the same functions as a proprietary server (e.g database, execute application)
- Proprietary server: This server could be installed in CARTIF's facilities and be connected to the internet, providing dedicated access from any of the demos to the high-level control decisions

The initial configuration of the virtual server in Microsoft Azure is showed in Table 11.

Table 11: Virtual server specifications

Hardware
Installed Memory (RAM): 16 GB
Storage capacity: 126 GB
Processor: Intel(R) Xeon(R) CPU E5-2673 v4 @ 2.3GHz 2.29GHz
Number of Processors: 4 main and 4 logic
BIOS version: American Megatrends Inc. 090008
Software
Operating system: Windows Server 2019 Datacentre (64 bits)

3.5.1 Refinement of the model

During the SunHorizon project life, the configuration of the facilities at Riga Sunisi demo-site has involved during the development both T5.4 and the system model. Changing both in the tuning of technologies types and the adaptation of hybrid controller workflow, reported the changes in box on the Figure 29 and compared with the last model in Figure 30,which is the model that currently the controller works.

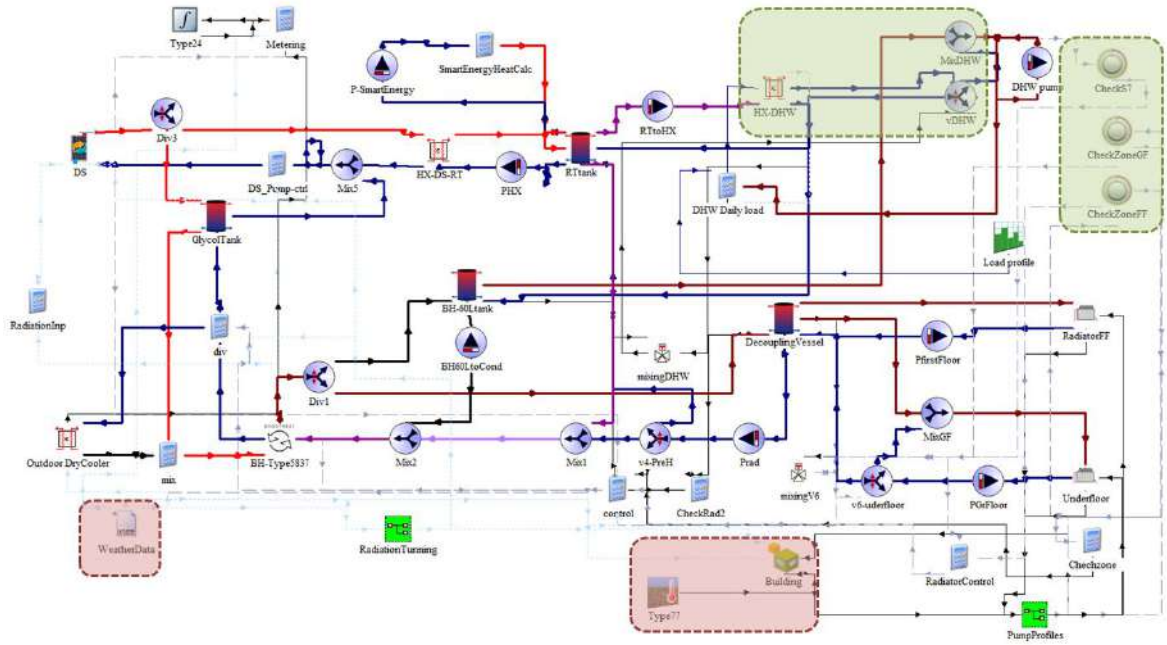


Figure 29: Old TRNSYS model for Riga Sunisi case

The changes performed are related to the hydraulic system (marked in green) where two model sections have been affected. The first model is associated with both first and ground floor thermostats with the objective of speeding up the simulations and preventing some possible errors. The thermostat type was removed and replace within the macro called *PumpsProfile*. The other hydraulic model affected is connected to the DHW flow due to the change in hydraulic flow. In Figure 29 shows that the load flow from exchanger HX-DHW, which is influenced by DHW demand profile generated in Load Profile type, is taken to vDHW valve. Subsequently, the low-level control subsystem is tasked with making a determinative decision: it must ascertain whether to direct this flow towards the DHW tank or to incorporate it into the flow emerging from the DHW tank, thus serving the purpose of temperature reduction. However, Figure 30 the load flow, which is influenced by iSCAN DHW demand and the latest TRNSYS demonstrator model, is taken to DHW tank directly.

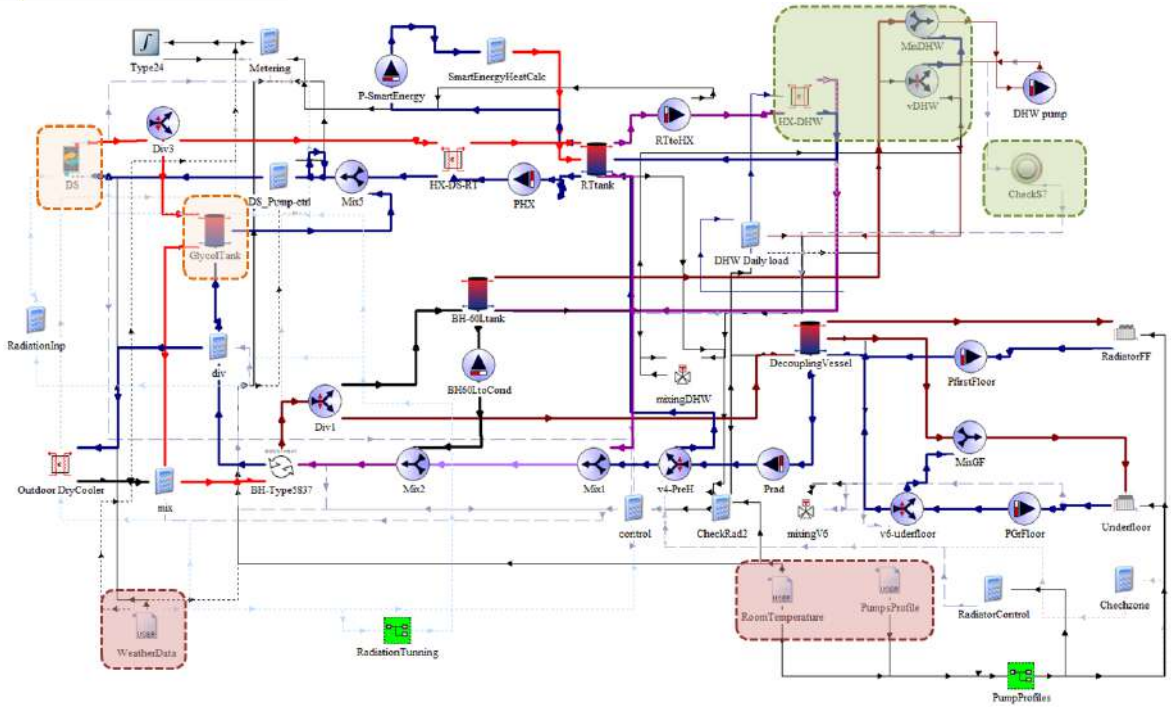


Figure 30: Latest TRNSYS model for Riga Sunisi case

In addition to changing the hydraulic system, the design parameters of some technologies, which are Dual Sun and Glycol tank, have been changed as well and marked in orange in the Figure 30.

- Dual sun panels: The current PVT panels installed in Sunisi are 30. Moreover, the photovoltaic nominal power has been modified from 315W to 320W
- Glycol tank: The glycol tank volume was designed with 400l, but it has been reduced until 200L

The incorporation of different text files into the model have been implemented in order to introduce both the data previously collected from iSCAN, such as: room temperatures, DHW demand or electric demand, and the control variables. To deal with the objective proposed, the Building type that is located in initial TRNSYS model (Figure 29) has been removed and the inputs types, which are called type9e, have been implemented. Moreover, as the Building type had great dynamics, once the proposal way was implemented, several calculations building have been eliminated and the execution time has been significantly reduced.

3.5.2 Control strategy

The initial strategy pertains to minimise the use of the BOOSTHEAT heat pump. This approach is implemented when the electrical demand has been adequately covered, and there is surplus electricity available for supplying the Smart Heater to heat the RATIO tank. Moreover, this strategy serves to reduce the reliance on BOOSTHEAT by optimizing the ratio of thermal demand coverage. Execution of this strategy involves the manipulation of the power injected into the Smart Heater, denoted as PO. This variable is constrained within the range of 0 to 9.3 kW, representing the maximum production capacity of Dual Sun panels under normal conditions.

The final strategy focuses on improving the efficiency of the BOOSTHEAT heat pump by using the thermal production of Dual Sun panels to heat the glycol tank while ensuring that the heat stored in the RATIO tank remains unaffected. The strategy is implemented through a binary variable, denoted as ForcedGlycol, which determines when the thermal production should be directed to the glycol tank or the RATIO tank. This allocation is associated with valve 5, as indicated in Figure 31.

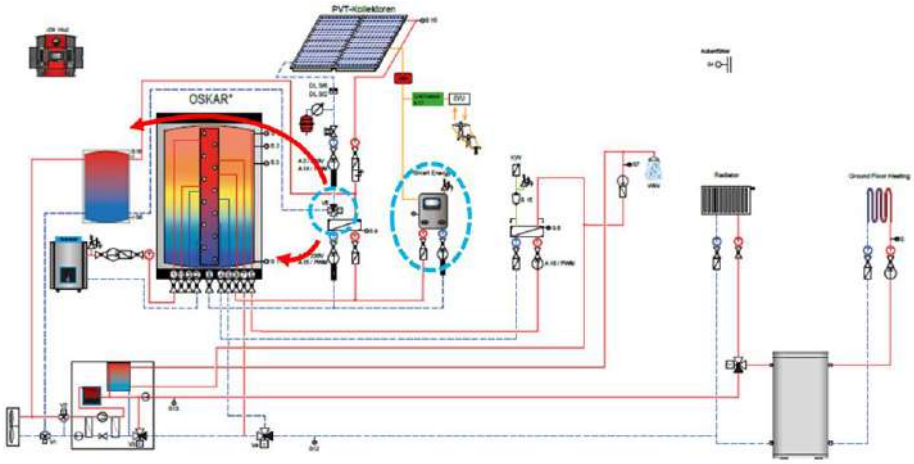


Figure 31: Control variables flow chart for Riga Sunisi

The strategies mentioned above are formulated using several objective functions that are based on WP2 KPIs. One of these target functions focused on the dual objective of reducing both electrical and thermal system costs and the user's bill reduction:

$$Net\ Cost(€) = Gas * PrcGas + (GridCn - ExcessToGrid) * PrcGrid + ExcessToGrid * Pnet,$$

GridCn represents energy consumption, *ExcessToGrid* denotes the electricity power injected into the grid, *Gas* signifies gas consumption, *PrcGas* corresponds to the gas price, *PrcGrid* pertains to the electricity price, and *Pnet* indicates the net balance discount price. This formula is applicable when energy consumption exceeds the electricity power injected into the grid. If energy consumption is lower than electricity power injected to the grid, the energy consumption is billed at the net price, as articulated in the following equation.

$$Net\ Cost(€) = Gas * PrcGas + GridCn * Pnet$$

However, recognising that there exists a portion of energy supplied without compensation, the algorithm is tasked with achieving a balance between the electricity power injected into the grid and the self-consumed electricity while concurrently minimising the user's cost outlay. The second objective function that has been assessed pertains to the optimisation of renewable technology utilization by reducing the power factor associated with primary non-renewable energy sources.

$$PEnren\ (kWh) = GridCn * Pnrel - ExcessToGrid * Pnrel + QgasBH * Pngas$$

3.6 Self-Learning Modules integration with iSCAN

The self-learning modules where integrated partially for Riga Sunisi demo site:

1. Comfort Vote from iSCAN to ML model [Integrated] - The comfort votes from the occupants are transmitted from iSCAN to the Comfort prediction model, and is used to enhance the accuracy of the model predicting the comfort sensation.

2. Sensor/Meter data and simulated data from iSCAN to ML models [Integreated] – The Sensor/Meter data and simulated data are transmitted to the machine learning models and used for forecasting of the short term future conditions of the building, to allow comfort predictions in step 14 and other functionalities such as filling data gaps.

3. Fill data gaps self-learning forecasts to iSCAN [Tested] – Whenever required, iSCAN is integrated with a module to fill in the gaps in data using machine learning

4. Short term predictions self-learning forecasts to iSCAN [Tested] – Scheduled to be executed every 30 minutes, the Short term predictions self-learning tool transmitting forecasts for the next 30 minutes to iSCAN

5. Thermal comfort predictions self-learning forecasts to iSCAN [Tested] – Scheduled to be executed every 30 minutes, the comfort forecasting tool transmitting forecasts for the next 30 minutes to iSCAN

In the screenshot below, a sample of results of filling data gaps and short term future predictions are shown, which are automatically send to iSCAN after the data gap filling and interpolation jobs. Each time whenever required, the self-learning modules are downloading data from iSCAN, perform data gap filling and short term prediction job with the most appropriate machine leaning model, and return results as long as metrics such as estimated accuracy (R^2) and Root Mean Squared Error (RMSE). Finally, if the result of self-learning job is positive, the item in iSCAN is coloured Green, if Moderate it is coloured Orange, if not accurate it is coloured Red.

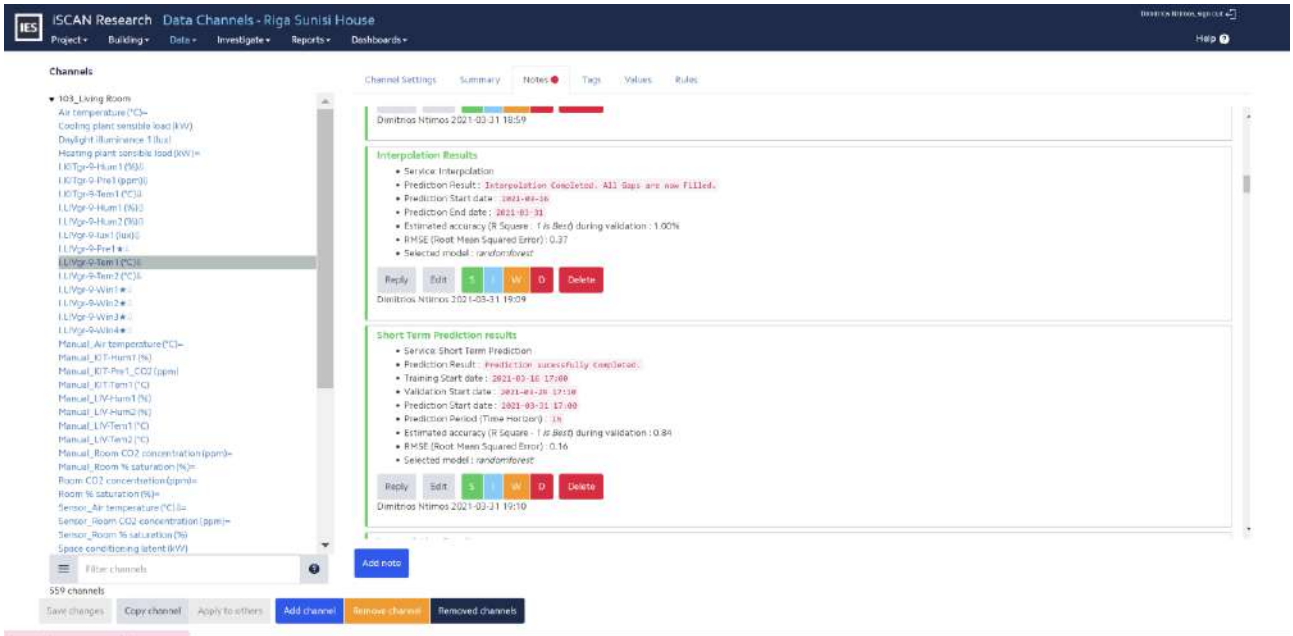


Figure 32: Self Learning modules return fill in data gaps results and predict the future values in short term in iSCAN for Riga Sunisi demo site

3.7 Dashboard integration and hand over to demo sites

The following integrations where fully achieved and automated (follow-up work from WP4), to allow the full deployment of the Monitoring Platform (dashboard) to allow demonstration and KPI calculation in WP6:

3. Sensor/Meter Data – [Automated] Integration between field level equipment and Smart Connector via MQTT connection. This is a standard practice by Schneider Electric (performed in WP4)

4. Sensor/Meter Data – [Automated] Integration between Smart Connector and iSCAN via REST API. A new web hook has been developed to allow the integration. (performed in WP4)

19. Real data from sensors and meters are posted to the hybrid control and proactive/predictive maintenance modules using iSCAN-API to enable control and KPIs calculations

21. KPIs from proactive/predictive maintenance modules to iSCAN [Automated] – Scheduled periodically to transmit the KPIs to iSCAN once calculated

28. Sensor/Meter data from iSCAN to dashboard [Automated] – Data selected by demo site leaders are transmitted from iSCAN to the dashboard every 15 minutes and plotted in selected visualisations by demo site leaders

30.Fault detection and KPIs from iSCAN to dashboard [Automated] – Fault detection such as data gaps, and the KPIs of the project are integrated with iSCAN and displayed in the dashboard

31.32. Sensor Meter Data, KPIs and alerts displayed to the end user to enable:

a.Monitoring of energy and indoor environmental quality

b. Decision making based on minimising energy use and maximising comfort

c.Encourage the necessary maintenance required in building devices

d.Deploy optimised setpoints if needed

The dashboard can be accessed at: https://dashboards.iesve.com/dashboard/1496/KPIs/SunHorizon-RigaSunisi (contact Dimitrios.ntimos@iesve.com to request access)

Screenshots are found below:

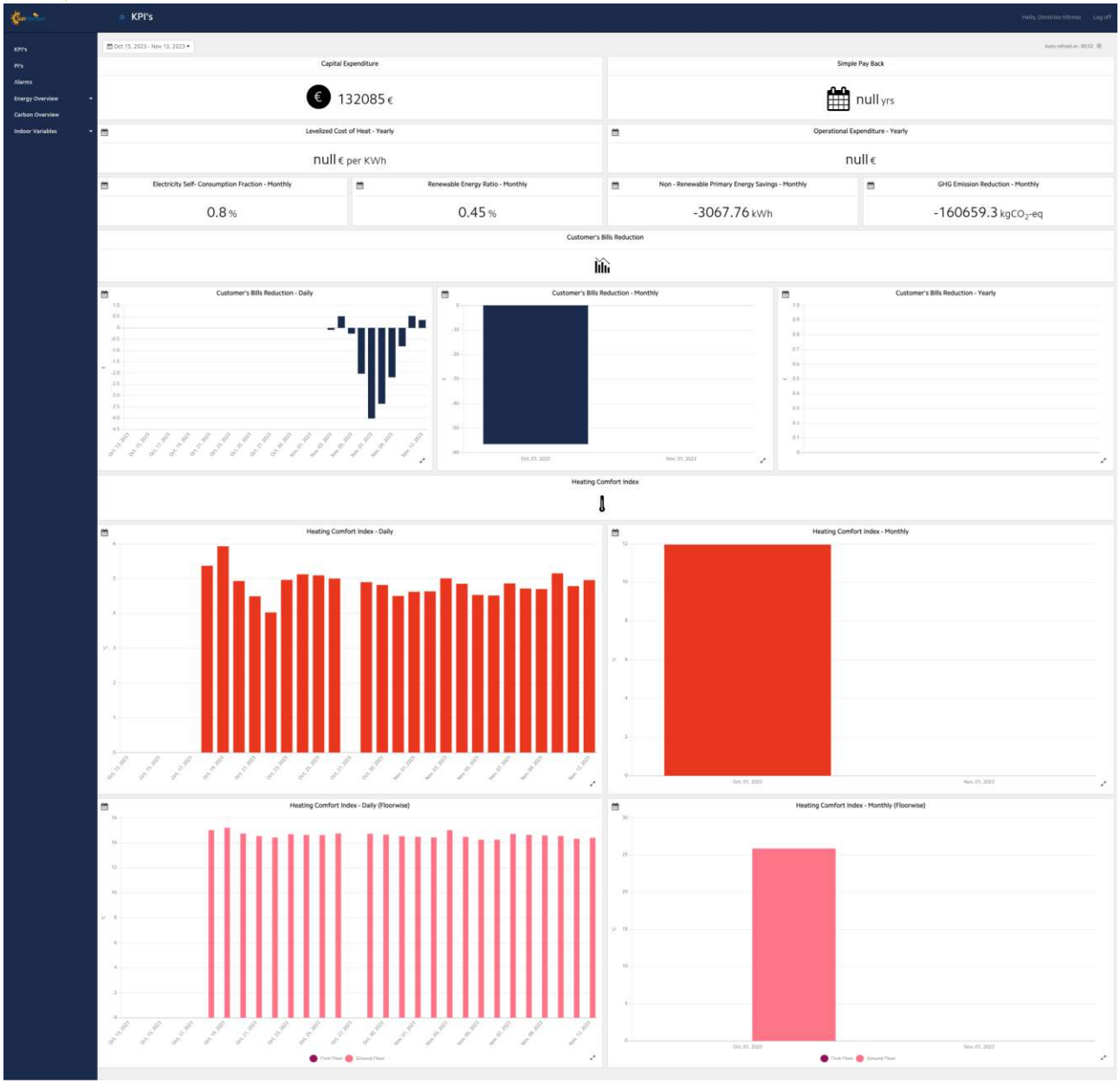


Figure 33: Riga Sunisi KPI dashboard

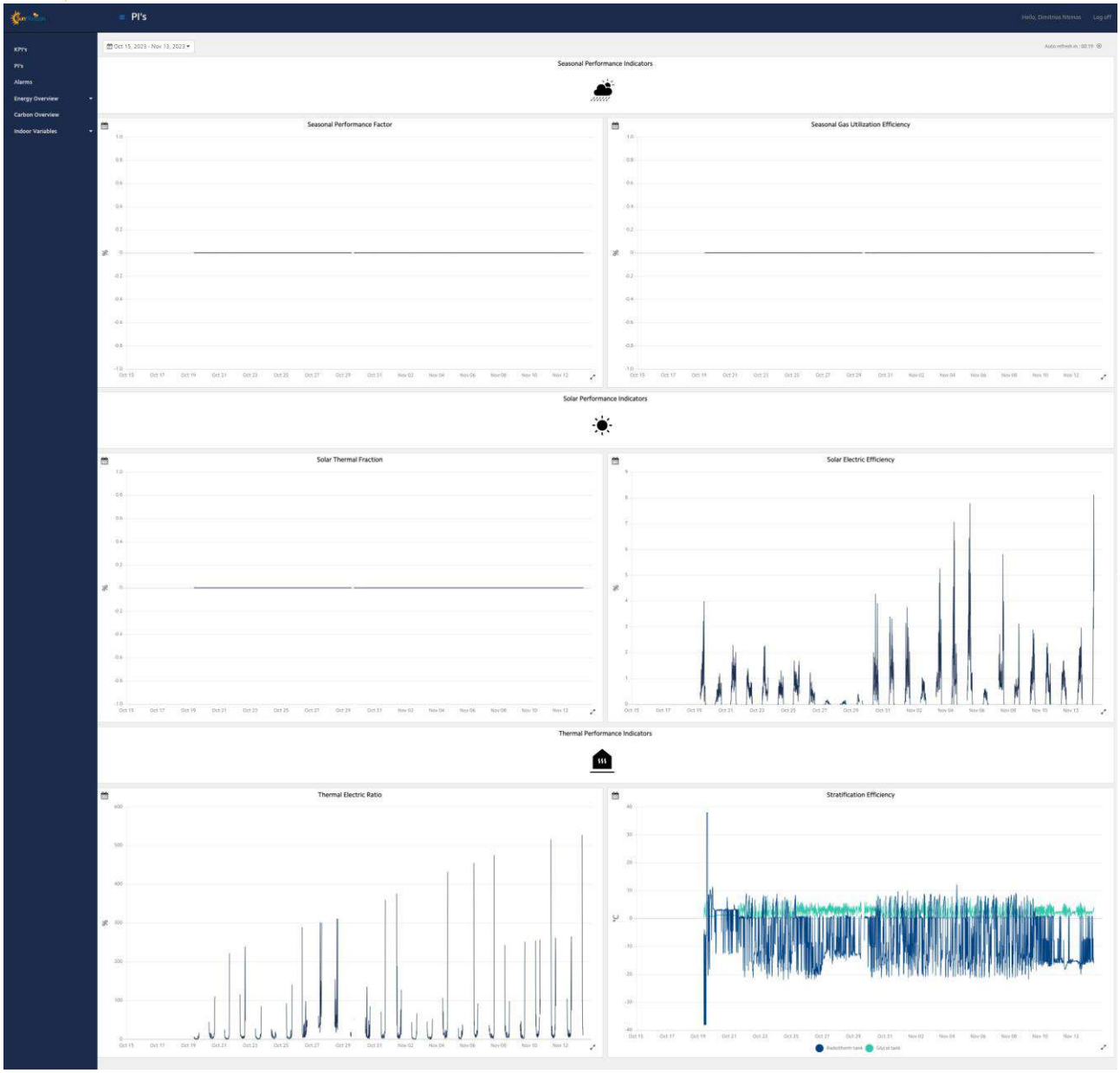


Figure 34: Riga Sunisi KPI dashboard (PI page)

4 Control modules full integration in Sant Cugat

In Sant Cugat demo site, the following control modules where partially integrated and tested:

- Building simulation module integrated and validated
- Monitoring system (from WP4)
  - Enterprise Server – iSCAN fully integrated and validated (via SmartConnector API)
  - Feedback app – iSCAN integration (via iSCAN-API)
  - iSCAN-Dashboard integration (via iSCAN-API)
  - KPI module integration (via iSCAN-API)
  - Self-learning module partial integration (not automated)
- Self-learning modules partially integrated and validated

Figure 2 graphically depicts the monitoring and control platform integration and workflow diagram with fully automated integrations in green and partial in orange colour.

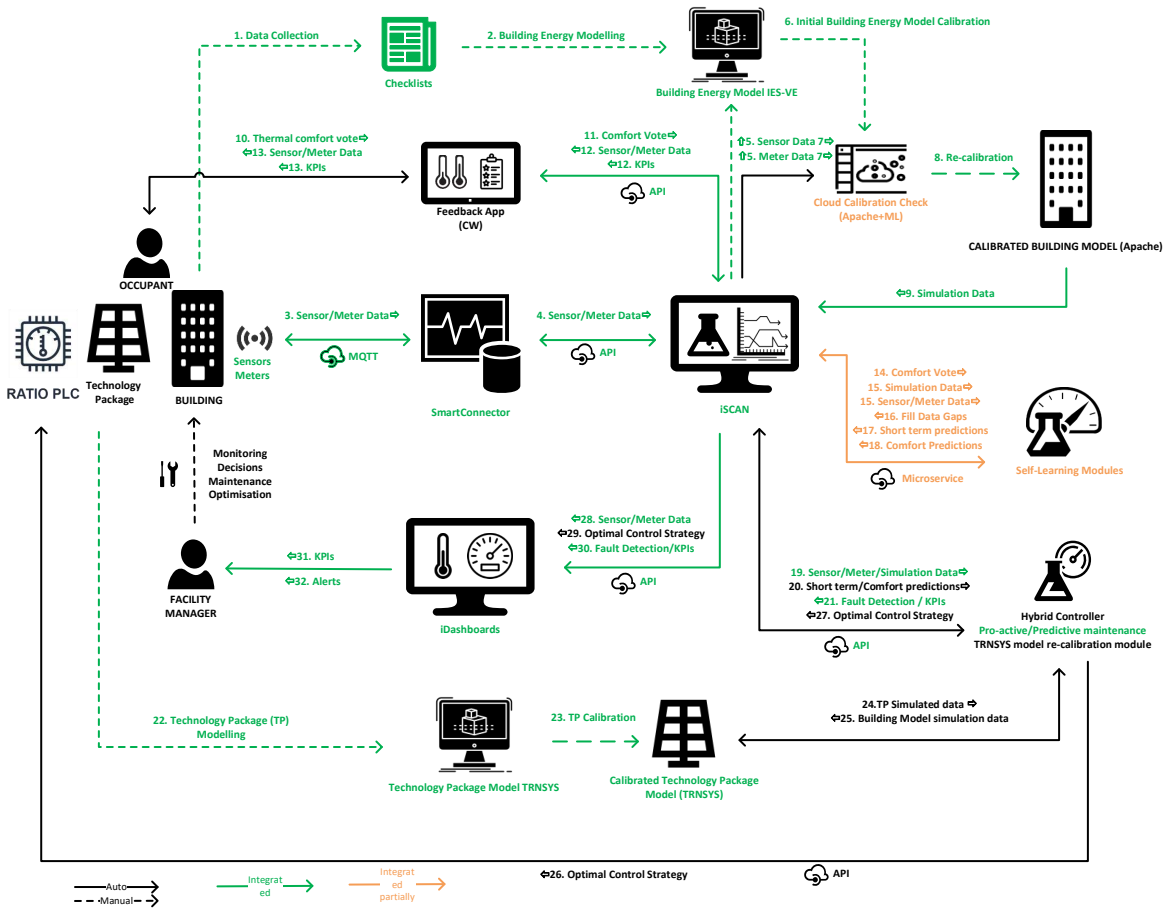


Figure 35: Monitoring and control platform integration and workflow diagram with fully automated integrations in green and partial in orange colour

The following paragraphs present an analysis of the work performed to integrate and deploy the control modules in the Riga Sunisi demo site.

4.1 Sant Cugat Building Energy Model in IESVE

This chapter describes the work done to achieve building energy model calibration for Sant Cugat demo site. This was an ongoing process and the model was calibrated initially, then recalibrated 2 times using the latest data collected in iSCAN by the sensors/meters installed in the demo sites.

4.1.1 Background

Modelling of the Sant Cugat Building Energy Model in IESVE is presented in Deliverable 5.3 Annex A. The entire property is formed by a number of rooms dedicated to different use in the civic centre: among those it is possible to find assembly halls, exhibition room, music classrooms, warehouses, workshop classrooms, a theatre etc.

Figure 36: Building geometry in 3D model (left-Google Maps, right- IESVE model)

Only a portion of the entire building is considered for the heating and cooling load calculation during the energy model creation as indicated in Figure 37.

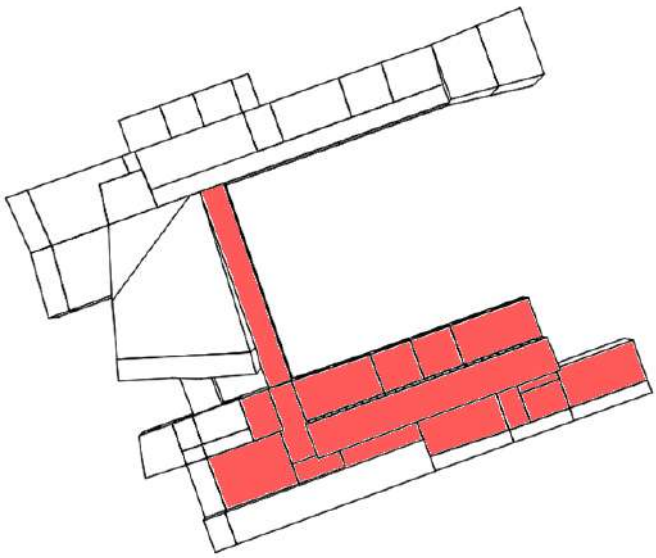


Figure 37: Part of the building considered as conditioned spaces during the energy model creation.

Building geometry was created using the ModelIT module in VE.

Thermal templates are assigned to rooms within the building energy model. The thermal template encloses data for:

- Heating and Cooling Set Points
- Internal Gains
    - Number of People and Occupancy Schedule

- Lighting Power Density and usage schedule
- Miscellaneous equipment density and usage schedule

- Air Exchanges
  - Infiltration (Air Permeability)
  - Auxiliary Ventilation
  - Natural Ventilation
- Ventilation rates has been evaluated for each space considering the following equation:
  - V = RpPz+ RaAz
- Where: Rp = outdoor flow rate per person, L/s; Pz = number of people; Ra = outdoor flow rate per area, L/s; Az = floor area, m^2

Table 12: Geometric characteristics before geometric correction of the rooms in the energy model

Space Name	Volume (m^3)	m^2 person	Floor Area (m^2)	Ventilation per m^2	Number of People	Ventilation per person	Total l/s	Total m3/h
Corridor - Corredor exposicions	208.0	20	82.5	0.7	4	9	50	180
Workshop classroom - Taller gran	180.2	5	60.3	0.7	12	9	150	540
Local entities and collective room - Taller Petit	89.3	5	29.9	0.7	6	9	75	270
Dance and movement activities room 2 - Biblioteca	170.3	5	57.0	0.7	11	9	140	504
Civic centre direction office - Ludoteca grans	88.7	10	29.7	0.7	3	9	48	172
Warehouse-Espai Jove	161.5	2.7	54.1	0.7	20	9	218	784
Music classroom - Aula de Musica 1	64.6	5	21.6	0.7	4	9	52	187
Music classroom - Aula de musica 2	48.4	5	16.2	0.7	3	9	40	144
Dance and movement room - Aula de expressio	180.1	5	60.3	0.7	12	9	150	540
Exhibition room - Sala de exposictions	170.0	5	56.9	0.7	11	9	140	504
Hall	161.1	15	53.9	0.7	3	9	64	233
Assembly hall Events room - Bar Concerts	217.8	1.215	72.9	0.9	60	9	605	2180
Bathrooms - Lavabos	70.5	10	23.6	0.7	2	9	35	125
Main Corridor - Espai Multiusos	1032.1	20	147.7	0.7	7	9	166	600

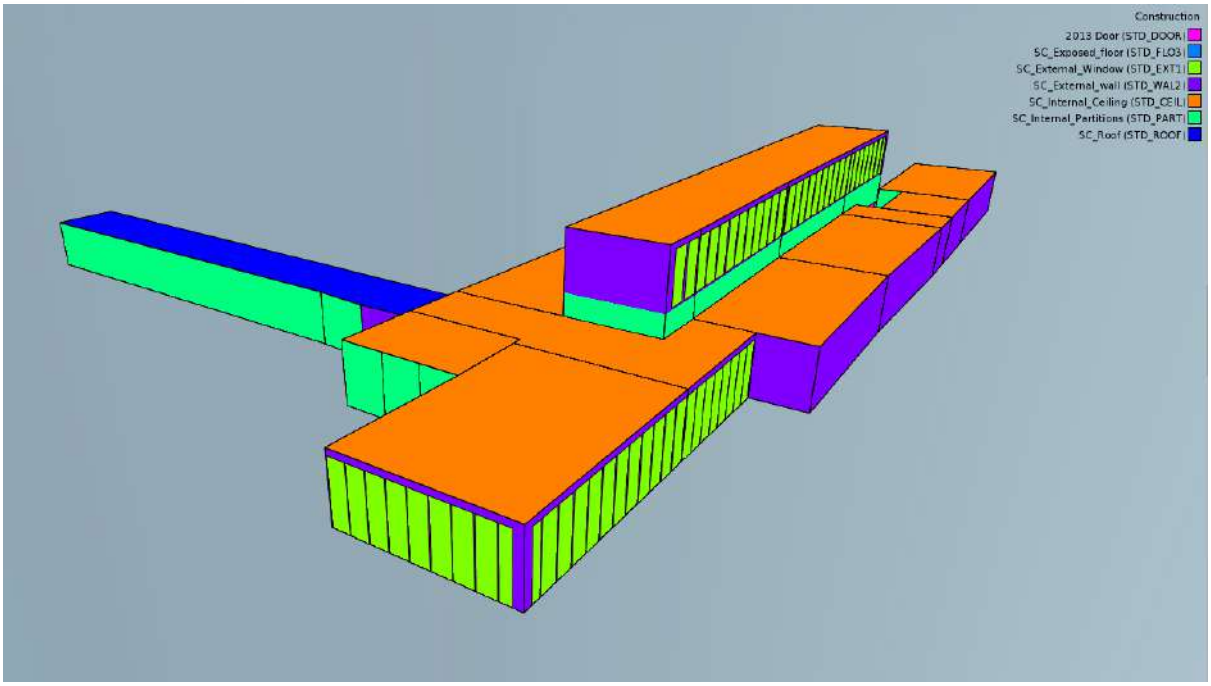


Figure 38: Construction assignment.

Each room was characterised by a number of thermal data. To overcome missing data some assumptions were made to populate the energy model. Those assumptions reflect typical input data for the building typology and the room under investigation.

Profiles and schedules have been used for the definition of the operation of the building and thermal template data. All the profile and schedules selected as input to the model have been simplified to follow a general operation of the building on extended hours. This schedule of operation has been considered as an ideal operation of the building throughout the year and has been considered for the estimation of the ideal heating and loads of the building. Surveys on the building may provide more appropriate schedules for the building and will be used at a later stage to bring the energy model toward calibration.

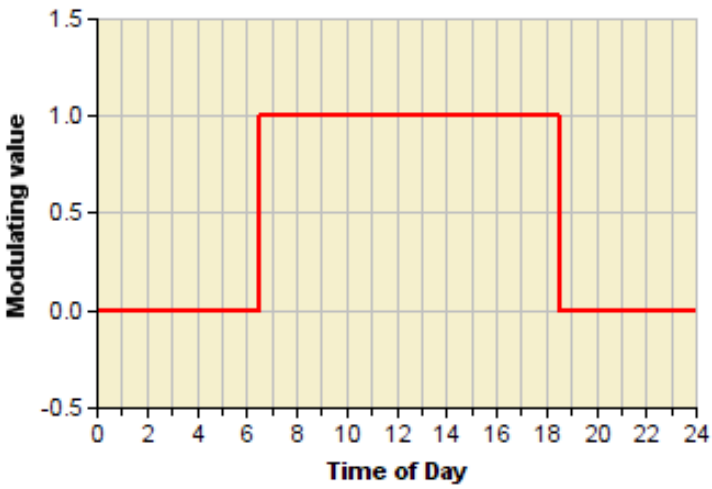


Figure 40 Schedule of the building

The HVAC system of the building was modelled using the ApacheSystem module. VE enables the use of two different methods for modelling HVAC systems. A simplified approach based on a high level description of the system used and an accurate modelling approach for HVAC called ApacheHVAC. As initial modelling step the use of ApacheSystem was preferred given the small amount of detailed data for characterisation of the building systems. In a later phase for model

calibration an ApacheHVAC model will be created and it will be possible to simulate the entire hydronic systems of the building as well as any air-side systems in details.

An ideal system with unlimited capacity has been used for the evaluation of the heating and cooling loads of the building.

In this section, dynamic simulation of the building has been performed to estimate load profiles of the building and the different rooms. Simulation has been run considering an ideal heating and cooling system with unlimited capacity.

The heating system characterised by a seasonal efficiency of 0.89 and the cooling system characterised by a Seasonal EER of 2.5.

The Heating peak demand for the system is reached on Monday 10th of February with a value of 96.37 kW. Cooling peak demand is reached on the 7th of August with a value of 96.42 kW.

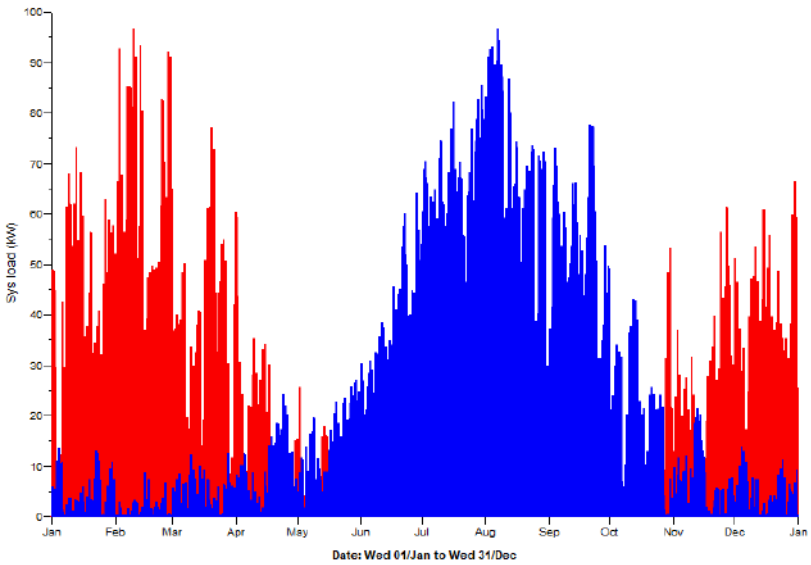


Figure 42 Ideal Heating and Cooling profile of the building during 2018

The modification on the existing building energy model included:

1. Use of a different weather file: this is a standard weather file used by CNR for the design of the technology packages: ES-Barcelona-City-81800.tm2. The weather file in format .tm2 has been converted in format .epw which is readable by VE.
2. The use of actual schedules of operation of the building as reported below. These schedules of operation have been gathered directly from a survey of the building. It should be noted that those schedules are not the operative schedules of the building. A data analysis procedure has been carried out on the BMS data from Veolia in iSCAN to identify the actual schedules of operation of the AHU and therefore create profiles of operation to be used in VE.

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

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

Those schedules have been identified as the most frequent for the operation of the building although there is not distinction between summer and winter periods.

The aim of this section is to describe some modelling updates for the Sant Cugat baseline model. After receiving the energy bills from the Ajuntament de Sant Cugat, CNR completed a review of the energy use of the building for the period

Sept 2016 – Nov 2019. In that analysis, CNR evaluated a possible repartition of the electric load between the two areas of the building. From the analysis 'Sant Cugat electrical load assessment', consumption values have been extracted for comparison with the VE model. Discrepancies between the combined simulation model VE-TRNSYS and the actual energy bills suggest that, currently, it is not possible to fully appreciate a breakdown of the load in the different parts of the buildings. In particular, sources of uncertainties may be related with the estimation of the electric load on the part of the building not simulated within SunHorizon. That portion of the building may have large electric load consumptions that impact on the total bill such as the one due to the energy use of the theatre.

4.1.2 Modelling and Calibration

The calibration and recalibration of the model was performed 3 times throughout WP5 activities, using the latest data collected in iSCAN.

4.1.2.1 1st calibration

In order to make scenario evaluations of the part of the electric load associated with the portion of the building simulated within SunHorizon, some additional simulations are required. The simulations will take the form of parametric analysis, where influential variables for the energy consumption will be varied to provide a broader picture of the possible electric use of the building. As first step, an updated baseline model was generated. From the baseline model, five different scenarios were analysed each one with increasingly worst values for the energy efficiency of the building and more energy demanding in terms of electric use for the series of tests. The results of this analysis, going from realistic values to extreme conditions, can provide additional insight for the design of the components of the technology packages. Clearly, without additional measurements in terms of the breakdown of the electric load, the simulation method is one of the few options available to provide estimations of the expected energy use of the building.

The following changes were implemented to the existing model in order to generate a baseline for comparison with the energy bills. Coefficients of performance for heating and cooling of the heat pump: from the technical specification of the heat pump and its efficiency curve an estimated average value of the coefficient of performance for heating and cooling was used. The overall capacity of the heat pump was set to be about 130kW. Infiltration rates were modified from the initial value of 0.25 ach to 0.5. Occupancy sensible gains due to people were revised and updated with values for the type of activities done in the building. Internal gains due to light and miscellaneous equipment were revised and modified. Ventilation rates per unit area of the building was incremented to improve the comparison between the nominal flow rate of the AHU and the total ventilation rate in the rooms. Schedules of use of the building were updated to reflect the trend indicated in the metered data from the BMS. Schedules of the building in August were changed to reflect an unusual low consumption for the building. The building during this month seems to be closed or only partially used. As assumption, only the electric load due to lights was considered during the simulation for this month. All these changes constitute the main modifications to the previous version of the model. The update version called 'baseline' was produced and compared to the estimated bills of the building.

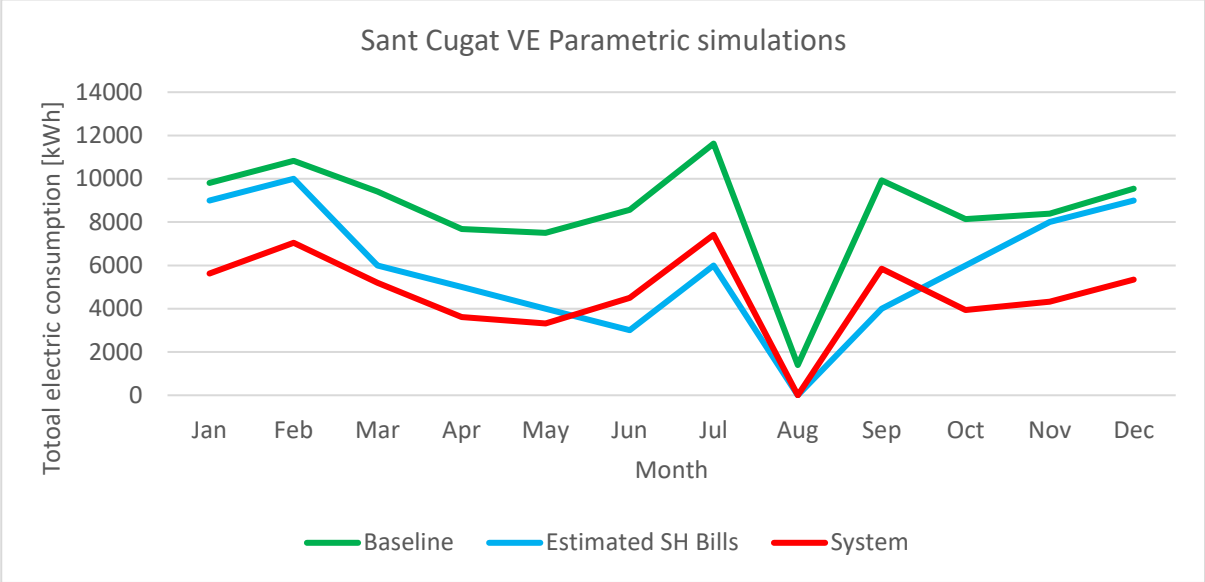


Figure 39: Comparison estimated bills vs simulation results

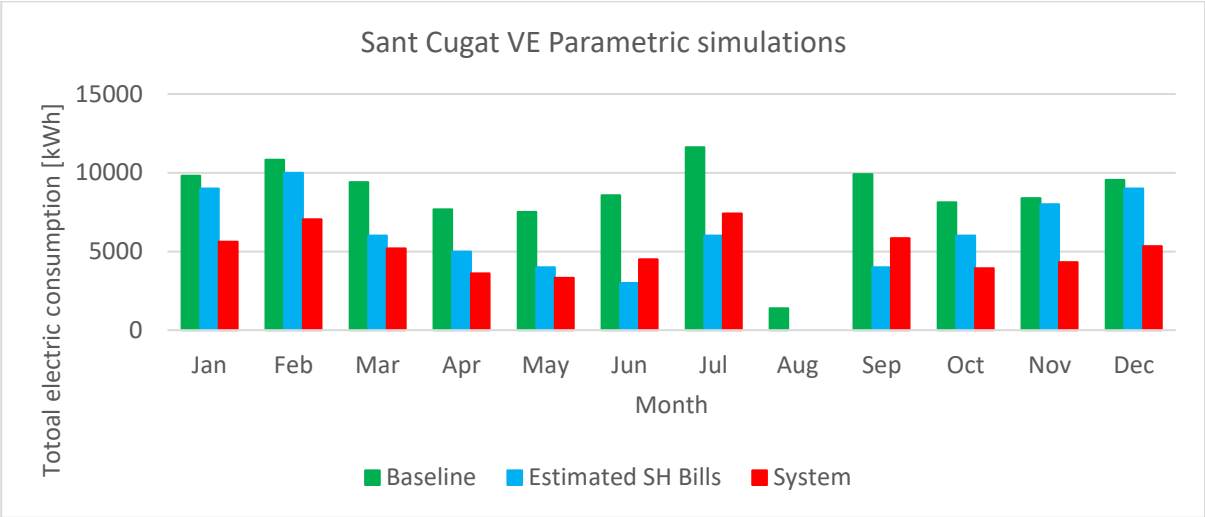


Figure 40: Comparison estimated bills vs simulation results

The trend of the consumption of the baseline model follows quite well the trend of the estimated energy bills for that portion of the building. The major differences are recorded for the summer month where the consumption of the building seems to be lower of the one calculated by the dynamic simulation software. A comparison of the trend of only the heating and cooling consumption of the systems in the building for the summer months shows that the estimation of the energy use is close to the one reported on the bills. Therefore, discrepancies of the baseline model may be due to a variety of assumption on the internal gains and air flow rates for which there are not precise data to enhance the simulation. The following parametric simulation focused on these aspects of the model and five different scenarios were compared to the energy bills.

Summer calibration and fine-tuning for air temperature:

Table 13: Sant Cugat Building Energy Model: Summer calibration and fine-tuning for air temperature

		Air Temperature			
		Calibration		Fine-tuning	
Space	Name	RMSE	MAE	RMSE	MAE
SS000000	Assembly hall events room - bar concerts	1.908	1.433	1.904	1.428
CV000000	Civic centre direction office - Ludoteca grans	2.312	1.861	2.302	1.846
DN000000	Dance and movement activities room 2- Biblioteca	1.839	1.393	1.818	1.365
DN000002	Dance and movement room - Aula de expressio	1.871	1.561	1.778	1.441
XH000000	Exhibition room - Sala de exposictions	1.74	1.197	1.754	1.213
LC000000	Local entities and collective room - Taller Petit	1.385	0.959	1.378	0.949
MS000000	Music classroon - Aula de Musica 1	3.586	3.308	3.564	3.28
MS000002	Music classroon - Aula de Musica 2	3.395	3.131	3.336	3.054
WR000002	Warehouse-Espai Jove	2.612	2.331	2.556	2.249
WR000000	Workshop classroom - Taller gran	1.576	0.934	1.582	0.933

- Winter calibration and fine-tuning for air temperature:

Table 14: Sant Cugat Building Energy Model: Winter calibration and fine-tuning for air temperature

		Air Temperature			
		Calibration		Fine-tuning	
Space	Name	RMSE	MAE	RMSE	MAE
SS000000	Assembly hall events room - bar concerts	2.685	2.053	2.673	2.035
CV000000	Civic centre direction office - Ludoteca grans	2.824	2.384	2.686	2.272
DN000000	Dance and movement activities room 2- Biblioteca	2.402	1.741	2.405	1.746
DN000002	Dance and movement room - Aula de expressio	2.363	1.751	2.368	1.716
XH000000	Exhibition room - Sala de exposictions	2.228	1.439	2.171	1.374
LC000000	Local entities and collective room - Taller Petit	1.915	1.314	1.905	1.301
MS000000	Music classroon - Aula de Musica 1	2.847	2.46	2.679	2.286
MS000002	Music classroon - Aula de Musica 2	2.868	2.289	2.647	2.018
WR000002	Warehouse-Espai Jove	3.152	2.355	2.993	2.185
WR000000	Workshop classroom - Taller gran	2.129	1.481	2.106	1.448

Modifications to IES VE Apache Systems were made to better reflect the new system and correlate better with the measured data.

Calibration for 16 parameters based on hourly temperature time series for each of the rooms, using NSGA2 (Non-dominated Sorting Genetic Algorithm 2).

Table 15: Sant Cugat Building Energy Model: Calibration for 16 parameters based on hourly temperature time series for each of the rooms

Parameters	Range	Calibrated Value	Unit
Heating setpoint	19 - 23	22.8	C
Lighting gains	2 - 10	7.35	W/m^2
People gains (sensible)	70 - 95	91.75	W/per
People gains (latent)	35 - 70	50.87	W/per
Equipment gains	0 - 20	14.83	W/m^2
Infiltration	0.1 - 0.75	0.16	ACH

Ventilation	3.5 - 4.2	3.54	ACH
Room occupancies			
Workshop classroom - Taller gran	4 - 10	8	Persons
Local entities and collective room - Taller Petit	2 - 8	7	Persons
Dance and movement activities room 2 - Biblioteca	5 - 15	7	Persons
Warehouse-Espai Jove	10 - 20	19	Persons
Music classroom - Aula de Musica 1	1 - 5	3	Persons
Music classroom - Aula de musica 2	1 - 5	4	Persons
Dance and movement room - Aula de expressio	5 - 15	13	Persons
Exhibition room - Sala de exposictions	5 - 15	10	Persons
Assembly hall Events room - Bar Concerts	20 - 60	48	Persons

The following diagrams show a comparison of the initial calibration and re-calibration and measured air temperature data. The re-calibration is a lot more accurate than the initial calibration.

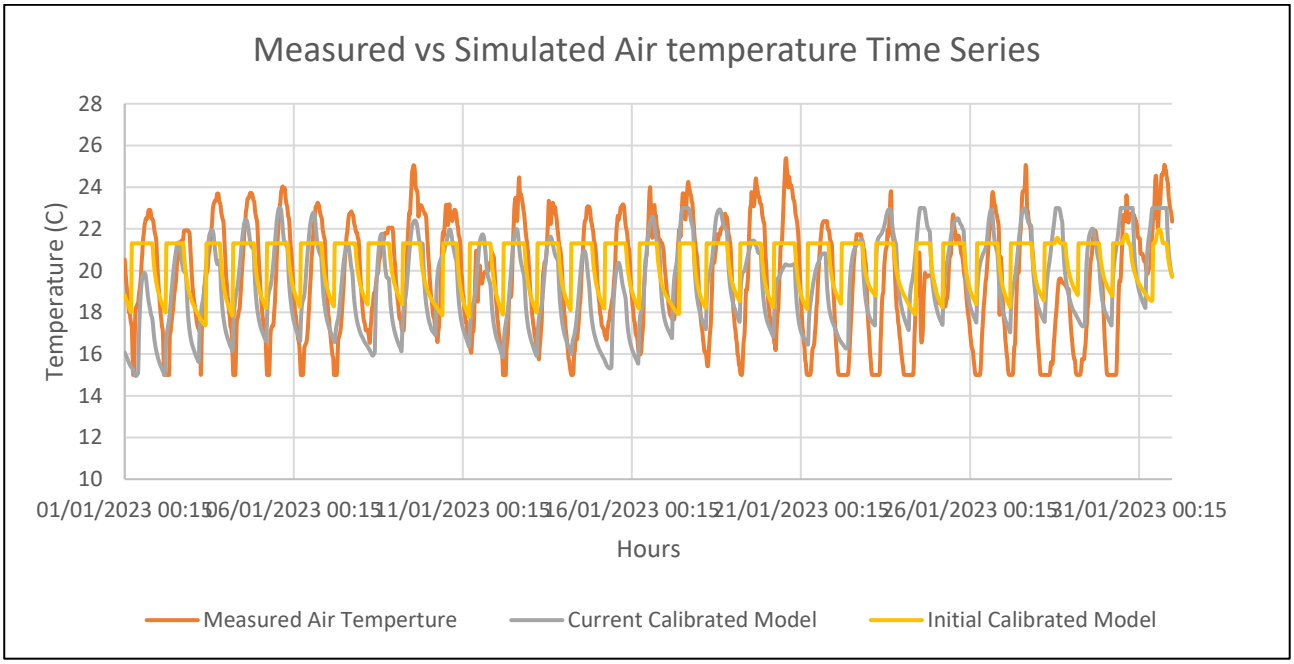


Figure 41: Air Temperature calibration result for example of the "Dance and movement room - Aula de expression"

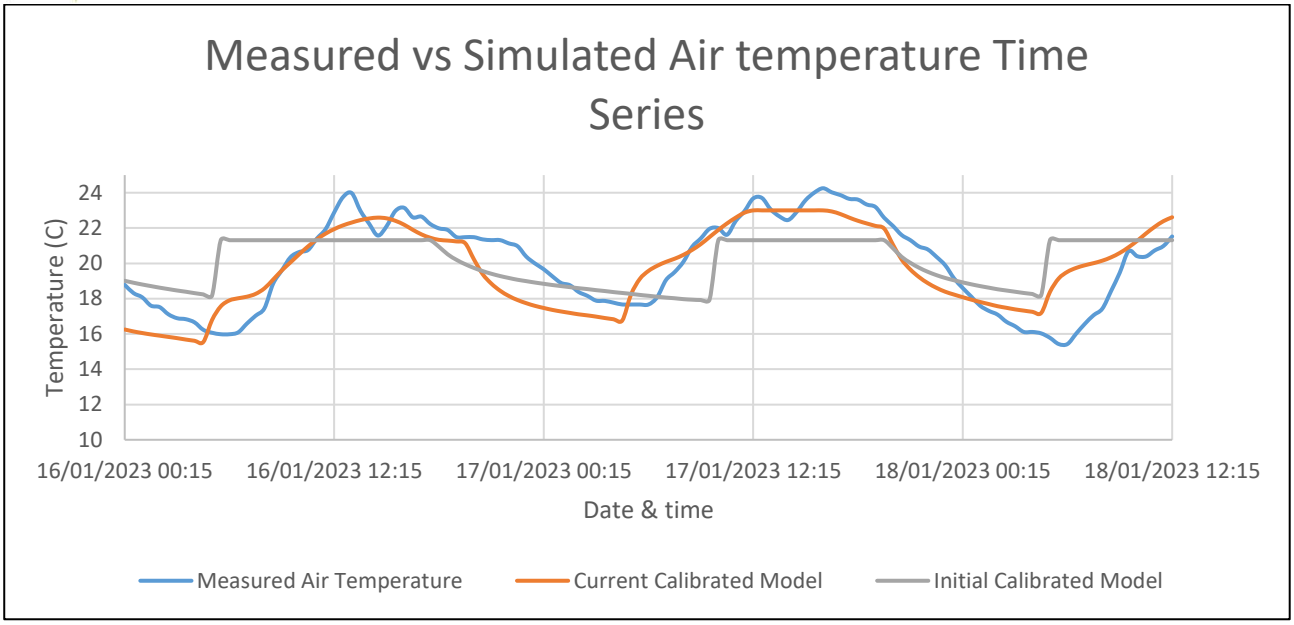


Figure 42: Air Temperature calibration result for example of the "Dance and movement room - Aula de expression"

The model was calibrated and the results are seen below:

Model Output

Space	Name	Air temperature	CO_2 concentration	Relative humidity
SS000000	Assembly hall events rooms	Yes	Yes	Yes
CV000000	Civic centre direction office	Yes	Yes	Yes
DN000000	Dance and movement room 2	Yes	Yes	Yes
DN000002	Dance and movement room	Yes	Yes	Yes
XH000000	Exhibition room	Yes	Yes	Yes
LC000000	Local entities and collective room	Yes	Yes	Yes
MS000000	Music classroom 1	Yes	Yes	Yes
MS000001	Music classroom 2	Yes	Yes	Yes
WR000002	Warehouse	Yes	Yes	Yes
WR000000	Workshop classroom	Yes	Yes	Yes

VE Model with Optimal Parameters:

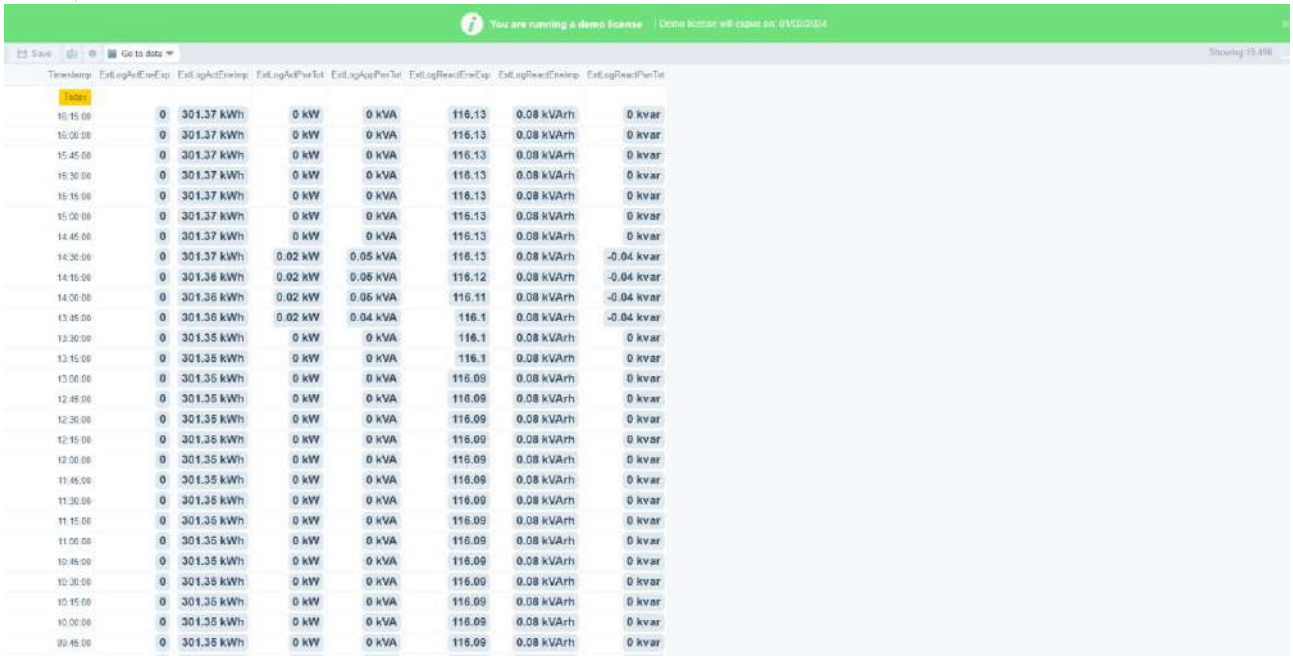
- Heating and cooling setpoints have been set using summer and winter profiles
- Equipment sensible gain has an average input value for the year
- Lighting sensible gain has been set using a modulating dimming profile to account for summer and winter variation
- Occupancy sensible and latent gains have been set using an average value for the year

4.2 Simulation module integration and automated simulation

The building energy model simulation module for Sant Cugat was integrated and automated to run every night at 11pm, and return Heating Sensible Load and Air Temperature results that are consumed by the hybrid controller via iSCAN-API. Steps 3, 4, 5, 9 were integrated and fully automated:

- **Step 3:** Sensor/Meter Data – [Automated] Integration between field level equipment and Smart Connector via MQTT connection. This is a standard practice by Schneider Electric (performed in WP4)

Figure 43: User Interface of Enterprise Server where all the data collected from Riga Sunisi demo site can be accessed



Timestamp	ExtLogActEnerExp	ExtLogActEnerImp	ExtLogActPwrTot	ExtLogAppPwrTot	ExtLogReactEnerExp	ExtLogReactEnerImp	ExtLogReactPwrTot
Today							
16:15:00	0	301.37 kWh	0 kW	0 kVA	116.13	0.08 kVArh	0 kvar
16:00:00	0	301.37 kWh	0 kW	0 kVA	116.13	0.08 kVArh	0 kvar
15:45:00	0	301.37 kWh	0 kW	0 kVA	116.13	0.08 kVArh	0 kvar
15:30:00	0	301.37 kWh	0 kW	0 kVA	116.13	0.08 kVArh	0 kvar
15:15:00	0	301.37 kWh	0 kW	0 kVA	116.13	0.08 kVArh	0 kvar
15:00:00	0	301.37 kWh	0 kW	0 kVA	116.13	0.08 kVArh	0 kvar
14:45:00	0	301.37 kWh	0 kW	0 kVA	116.13	0.08 kVArh	0 kvar
14:30:00	0	301.37 kWh	0.02 kW	0.05 kVA	116.13	0.08 kVArh	-0.04 kvar
14:15:00	0	301.36 kWh	0.02 kW	0.05 kVA	116.12	0.08 kVArh	-0.04 kvar
14:00:00	0	301.36 kWh	0.02 kW	0.05 kVA	116.11	0.08 kVArh	-0.04 kvar
13:45:00	0	301.36 kWh	0.02 kW	0.04 kVA	116.1	0.08 kVArh	-0.04 kvar
13:30:00	0	301.35 kWh	0 kW	0 kVA	116.1	0.08 kVArh	0 kvar
13:15:00	0	301.35 kWh	0 kW	0 kVA	116.1	0.08 kVArh	0 kvar
13:00:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
12:45:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
12:30:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
12:15:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
12:00:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
11:45:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
11:30:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
11:15:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
11:00:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
10:45:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
10:30:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
10:15:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
10:00:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar
09:45:00	0	301.35 kWh	0 kW	0 kVA	116.09	0.08 kVArh	0 kvar

Figure 44: User Interface of Enterprise Server where all the data collected from Riga Sunisi demo site can be accessed

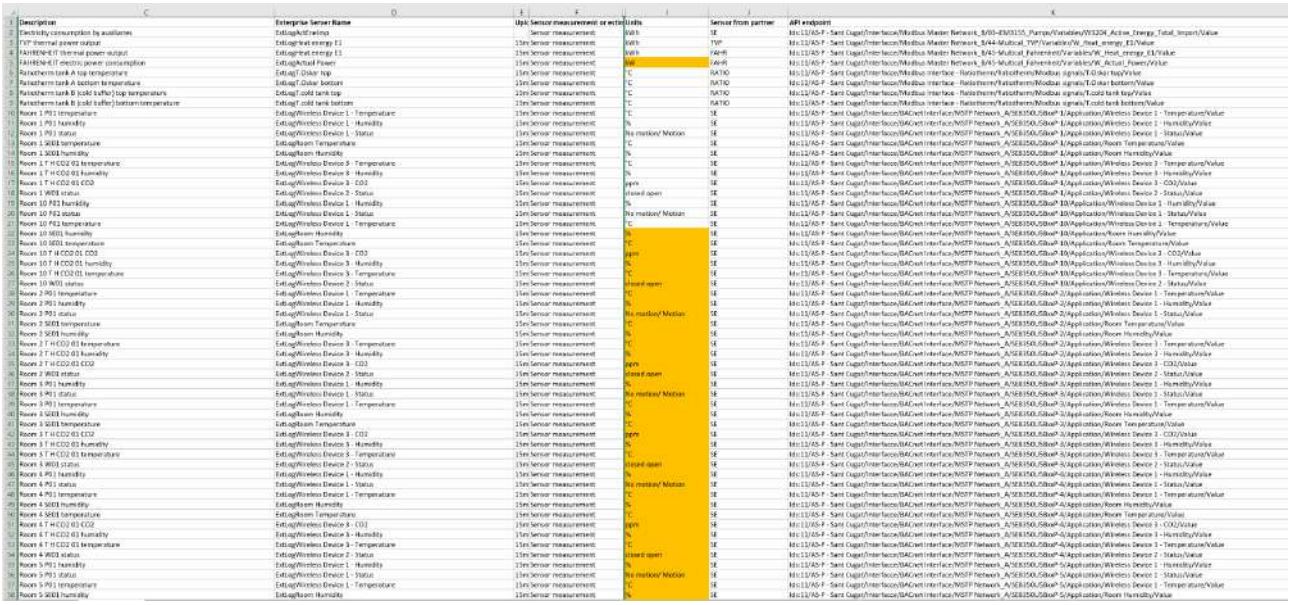
The portal to access the Riga Sunisi data is found below. The login details can be provided upon request.

https://185.168.27.5/

Step 4: Sensor/Meter Data – [Automated] Integration between Smart Connector and iSCAN via REST API. A new web hook has been developed to allow the integration. (performed in WP4). Variables from the technology packages were integrated during WP5 activities.

Access: https://iscan-research.iesve.com/building-visualise/SUNHORIZON/MiraSol (The login details can be provided upon request)

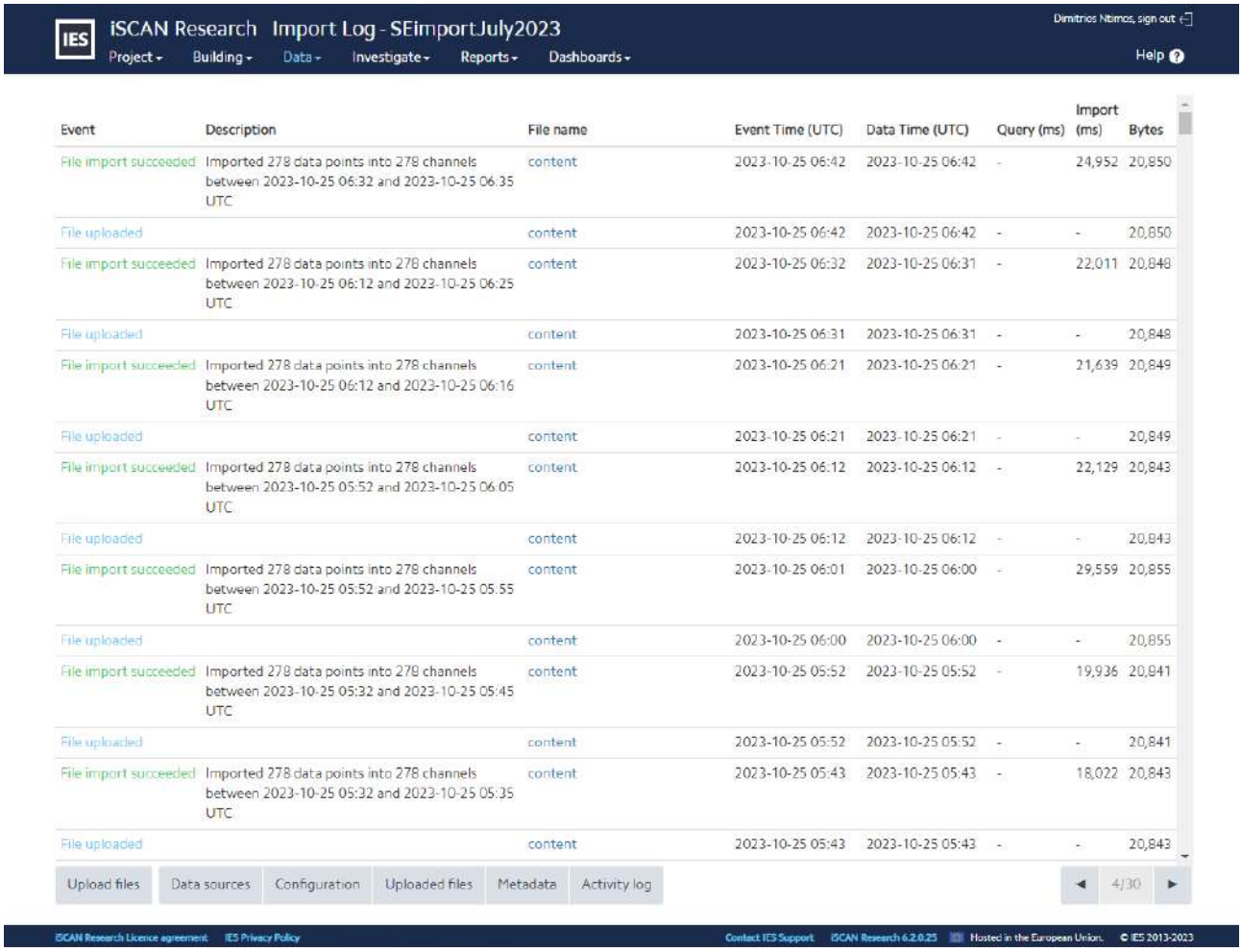
A data dictionary was created with API endpoint and corresponding iSCAN channel names, used to develop the automated data import



	Description	Enterprise Server Name	Upk	Sensor measurement or setpo	Units	Server from partner	API endpoint
2	Electricity consumption by auxiliaries	ExtLogActEnerImp		Sensor measurement	kWh	SE	http://11/AS-P - Saint Gobain/Interface/Modbus Master Network_B/00-IEM3155_Pumps/Variables/W3204_Active_Energy_Total_Import/Value
3	TVP thermal power output	ExtLogHeatenergyE1		15m Sensor measurement	kWh	TVP	http://11/AS-P - Saint Gobain/Interface/Modbus Master Network_B/44-Multical_TVP/Variables/W_Heat_energy_E1/Value
4	FAHRENHEIT thermal power output	ExtLogHeatenergyE1		15m Sensor measurement	kWh	FAHR	http://11/AS-P - Saint Gobain/Interface/Modbus Master Network_B/41-Multical_Fahrenheit/Variables/W_Heat_energy_E1/Value
5	FAHRENHEIT electric power consumption	ExtLogActual Power		15m Sensor measurement	kW	FAHR	http://11/AS-P - Saint Gobain/Interface/Modbus Master Network_B/41-Multical_Fahrenheit/Variables/W_Actual_Power/Value
6	Ratiotherm tank A top temperature	ExtLogT Disker top		15m Sensor measurement	°C	RATIO	http://11/AS-P - Saint Gobain/Interface/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T-Diskr top/Value
7	Ratiotherm tank A bottom temperature	ExtLogT Disker bottom		15m Sensor measurement	°C	RATIO	http://11/AS-P - Saint Gobain/Interface/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T-Diskr bottom/Value
8	Ratiotherm tank B (cold buffer) top temperature	ExtLogT cold tank top		15m Sensor measurement	°C	RATIO	http://11/AS-P - Saint Gobain/Interface/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T-cold tank top/Value
9	Ratiotherm tank B (cold buffer) bottom temperature	ExtLogT cold tank bottom		15m Sensor measurement	°C	RATIO	http://11/AS-P - Saint Gobain/Interface/Modbus Interface - Ratiotherm/Ratiotherm/Modbus signals/T-cold tank bottom/Value
10	Room 1 P01 temperature	ExtLogWireless Device 1 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Wireless Device 1 - Temperature/Value
11	Room 1 P01 humidity	ExtLogWireless Device 1 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Wireless Device 1 - Humidity/Value
12	Room 1 P01 status	ExtLogWireless Device 1 - Status		15m Sensor measurement	No motion/ Motion	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Wireless Device 1 - Status/Value
13	Room 1 S001 temperature	ExtLogRoom Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Room Temperature/Value
14	Room 1 S001 humidity	ExtLogRoom Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Room Humidity/Value
15	Room 1 T HCO2 01 temperature	ExtLogWireless Device 3 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Wireless Device 3 - Temperature/Value
16	Room 1 T HCO2 01 humidity	ExtLogWireless Device 3 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Wireless Device 3 - Humidity/Value
17	Room 1 T HCO2 01 CO2	ExtLogWireless Device 3 - CO2		15m Sensor measurement	ppm	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Wireless Device 3 - CO2/Value
18	Room 1 W01 status	ExtLogWireless Device 2 - Status		15m Sensor measurement	closed/ open	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#1/Application/Wireless Device 2 - Status/Value
19	Room 10 P02 humidity	ExtLogWireless Device 1 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Wireless Device 1 - Humidity/Value
20	Room 10 P02 status	ExtLogWireless Device 1 - Status		15m Sensor measurement	No motion/ Motion	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Wireless Device 1 - Status/Value
21	Room 10 P02 temperature	ExtLogWireless Device 1 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Wireless Device 1 - Temperature/Value
22	Room 10 S001 humidity	ExtLogRoom Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Room Humidity/Value
23	Room 10 S001 temperature	ExtLogRoom Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Room Temperature/Value
24	Room 10 T HCO2 01 CO2	ExtLogWireless Device 3 - CO2		15m Sensor measurement	ppm	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Wireless Device 3 - CO2/Value
25	Room 10 T HCO2 01 humidity	ExtLogWireless Device 3 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Wireless Device 3 - Humidity/Value
26	Room 10 T HCO2 01 temperature	ExtLogWireless Device 3 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Wireless Device 3 - Temperature/Value
27	Room 10 W01 status	ExtLogWireless Device 2 - Status		15m Sensor measurement	closed/ open	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#10/Application/Wireless Device 2 - Status/Value
28	Room 2 P01 temperature	ExtLogWireless Device 1 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Wireless Device 1 - Temperature/Value
29	Room 2 P01 humidity	ExtLogWireless Device 1 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Wireless Device 1 - Humidity/Value
30	Room 2 P01 status	ExtLogWireless Device 1 - Status		15m Sensor measurement	No motion/ Motion	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Wireless Device 1 - Status/Value
31	Room 2 S001 temperature	ExtLogRoom Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Room Temperature/Value
32	Room 2 S001 humidity	ExtLogRoom Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Room Humidity/Value
33	Room 2 T HCO2 01 temperature	ExtLogWireless Device 3 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Wireless Device 3 - Temperature/Value
34	Room 2 T HCO2 01 humidity	ExtLogWireless Device 3 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Wireless Device 3 - Humidity/Value
35	Room 2 T HCO2 01 CO2	ExtLogWireless Device 3 - CO2		15m Sensor measurement	ppm	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Wireless Device 3 - CO2/Value
36	Room 2 W01 status	ExtLogWireless Device 2 - Status		15m Sensor measurement	closed/ open	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#2/Application/Wireless Device 2 - Status/Value
37	Room 3 P01 humidity	ExtLogWireless Device 1 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Wireless Device 1 - Humidity/Value
38	Room 3 P01 status	ExtLogWireless Device 1 - Status		15m Sensor measurement	No motion/ Motion	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Wireless Device 1 - Status/Value
39	Room 3 P01 temperature	ExtLogWireless Device 1 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Wireless Device 1 - Temperature/Value
40	Room 3 S001 humidity	ExtLogRoom Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Room Humidity/Value
41	Room 3 S001 temperature	ExtLogRoom Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Room Temperature/Value
42	Room 3 T HCO2 01 CO2	ExtLogWireless Device 3 - CO2		15m Sensor measurement	ppm	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Wireless Device 3 - CO2/Value
43	Room 3 T HCO2 01 humidity	ExtLogWireless Device 3 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Wireless Device 3 - Humidity/Value
44	Room 3 T HCO2 01 temperature	ExtLogWireless Device 3 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Wireless Device 3 - Temperature/Value
45	Room 4 W01 status	ExtLogWireless Device 2 - Status		15m Sensor measurement	closed/ open	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#3/Application/Wireless Device 2 - Status/Value
46	Room 4 P01 humidity	ExtLogWireless Device 1 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Wireless Device 1 - Humidity/Value
47	Room 4 P01 status	ExtLogWireless Device 1 - Status		15m Sensor measurement	No motion/ Motion	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Wireless Device 1 - Status/Value
48	Room 4 P01 temperature	ExtLogWireless Device 1 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Wireless Device 1 - Temperature/Value
49	Room 4 S001 humidity	ExtLogRoom Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Room Humidity/Value
50	Room 4 S001 temperature	ExtLogRoom Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Room Temperature/Value
51	Room 4 T HCO2 03 CO2	ExtLogWireless Device 3 - CO2		15m Sensor measurement	ppm	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Wireless Device 3 - CO2/Value
52	Room 4 T HCO2 03 humidity	ExtLogWireless Device 3 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Wireless Device 3 - Humidity/Value
53	Room 4 T HCO2 03 temperature	ExtLogWireless Device 3 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Wireless Device 3 - Temperature/Value
54	Room 4 W01 status	ExtLogWireless Device 2 - Status		15m Sensor measurement	closed/ open	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#4/Application/Wireless Device 2 - Status/Value
55	Room 5 P01 humidity	ExtLogWireless Device 1 - Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#5/Application/Wireless Device 1 - Humidity/Value
56	Room 5 P01 status	ExtLogWireless Device 1 - Status		15m Sensor measurement	No motion/ Motion	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#5/Application/Wireless Device 1 - Status/Value
57	Room 5 P01 temperature	ExtLogWireless Device 1 - Temperature		15m Sensor measurement	°C	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#5/Application/Wireless Device 1 - Temperature/Value
58	Room 5 S001 humidity	ExtLogRoom Humidity		15m Sensor measurement	%	SE	http://11/AS-P - Saint Gobain/Interface/BACnet Interface/WSFP Network_A/SE3500_Office#5/Application/Room Humidity/Value

Figure 45: Riga Sunisi House data dictionary and API endpoints to achieve ES-iSCAN integration

Using the web hook and the REST API endpoints the automated data import was achieved. The screenshot below demonstrates a sample of automated data imports from Enterprise Server to iSCAN every 10 minutes for 154 variables collected from sensors/meters in Riga Sunisi House.



Event	Description	File name	Event Time (UTC)	Data Time (UTC)	Query (ms)	Import (ms)	Bytes
File import succeeded	Imported 278 data points into 278 channels between 2023-10-25 06:32 and 2023-10-25 06:35 UTC	content	2023-10-25 06:42	2023-10-25 06:42	-	24,952	20,850
File uploaded		content	2023-10-25 06:42	2023-10-25 06:42	-	-	20,850
File import succeeded	Imported 278 data points into 278 channels between 2023-10-25 06:12 and 2023-10-25 06:25 UTC	content	2023-10-25 06:32	2023-10-25 06:31	-	22,011	20,848
File uploaded		content	2023-10-25 06:31	2023-10-25 06:31	-	-	20,848
File import succeeded	Imported 278 data points into 278 channels between 2023-10-25 06:12 and 2023-10-25 06:16 UTC	content	2023-10-25 06:21	2023-10-25 06:21	-	21,639	20,849
File uploaded		content	2023-10-25 06:21	2023-10-25 06:21	-	-	20,849
File import succeeded	Imported 278 data points into 278 channels between 2023-10-25 05:52 and 2023-10-25 06:05 UTC	content	2023-10-25 06:12	2023-10-25 06:12	-	22,129	20,843
File uploaded		content	2023-10-25 06:12	2023-10-25 06:12	-	-	20,843
File import succeeded	Imported 278 data points into 278 channels between 2023-10-25 05:52 and 2023-10-25 05:55 UTC	content	2023-10-25 06:01	2023-10-25 06:00	-	29,559	20,855
File uploaded		content	2023-10-25 06:00	2023-10-25 06:00	-	-	20,855
File import succeeded	Imported 278 data points into 278 channels between 2023-10-25 05:32 and 2023-10-25 05:45 UTC	content	2023-10-25 05:52	2023-10-25 05:52	-	19,936	20,841
File uploaded		content	2023-10-25 05:52	2023-10-25 05:52	-	-	20,841
File import succeeded	Imported 278 data points into 278 channels between 2023-10-25 05:32 and 2023-10-25 05:35 UTC	content	2023-10-25 05:43	2023-10-25 05:43	-	18,022	20,843
File uploaded		content	2023-10-25 05:43	2023-10-25 05:43	-	-	20,843

Figure 46: Automated data import from Enterprise Server to iSCAN every 10 minutes for 154 variables collected from sensors/meters in Riga Sunisi House

In iSCAN all the data can be analysed, visualised, and used in simulation. Additionally, weather data and weather forecasts for Sant Cugat was activated (existing feature of iSCAN software).

Figure 47: iSCAN User Interface where all data from Riga Sunisi House can be visualised and shared via iSCAN API

Step 9 :Simulation Data from the calibrated model to iSCAN - The calibrated building energy data is programmed to execute simulations daily at 11.50 pm. The model is having as an input the weather forecasts of the next day, and returns as output to iSCAN the space conditioning energy demand and environmental variables, such as Air Temperature for the next 2 days.

Prerequisites and steps to deploy an automatic calibrated model simulation and return results to iSCAN:

1. Obtain APR and APS files and upload to iSCAN
2. Create/Get Token and create Scenarios in iSCAN. Download Weather files.
3. Create channels at building and room levels.
4. Set up the automated simulation and return results to iSCAN using a Python Script

Figure 48: Uploading APS file and ASP file to iSCAN

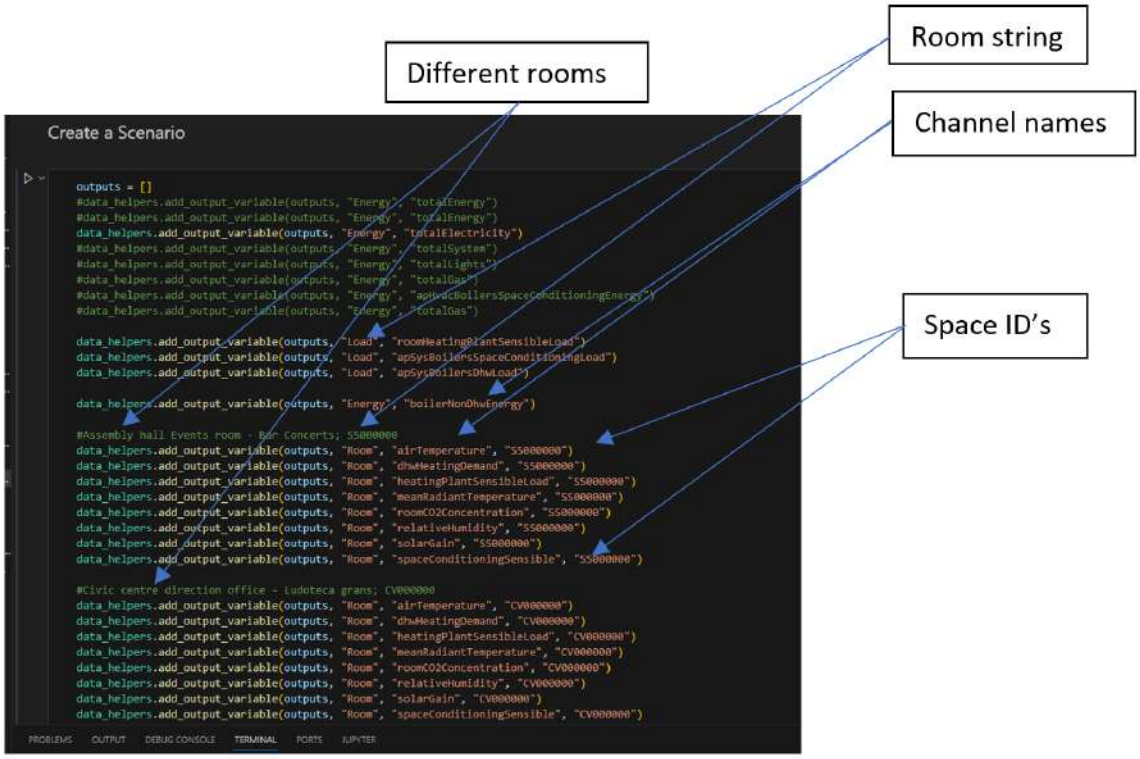


Figure 49: Setting up the automated decoupled apache simulation using a script

The process was deployed for Sant Cugat demo site in 7th August 2023 and is running automatically until the time of finalising this report.

Below is a screenshot of iSCAN showing the heating plant sensible loads calculated for all rooms in Sant Cugat demo site using the building energy model of the building by the simulation module.

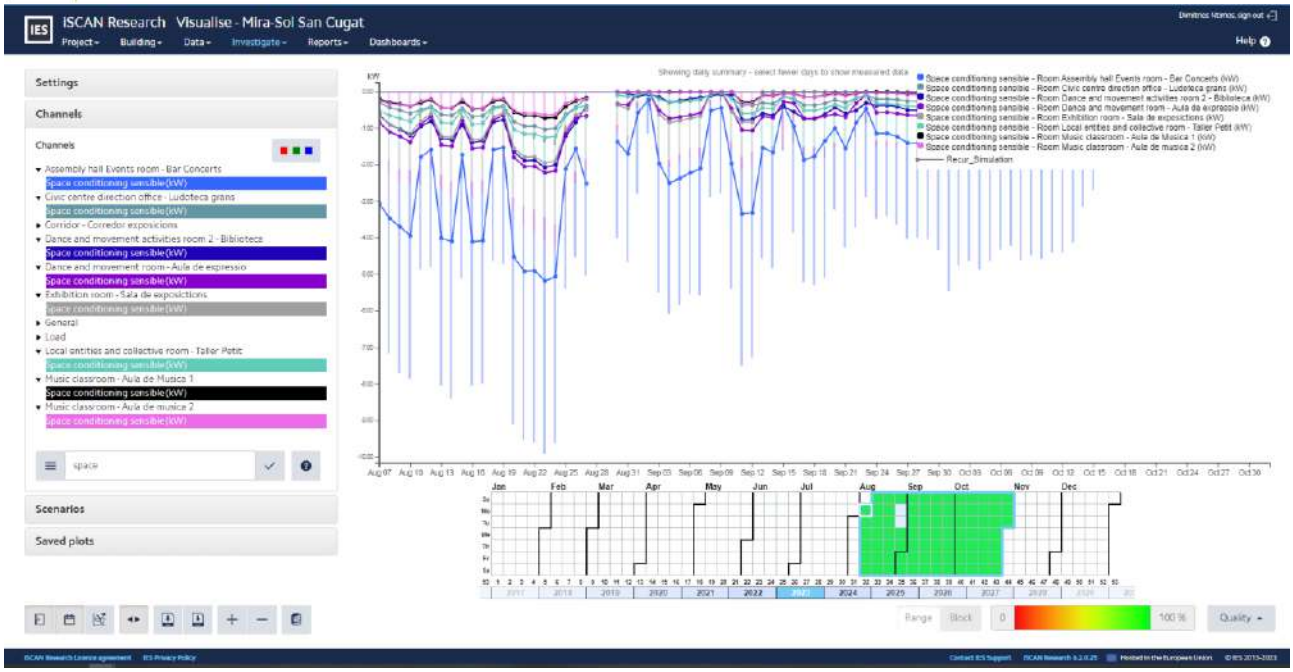


Figure 50: Heating plant sensible load (kW) calculated daily for all rooms in Riga Sunisi demo using the calibrated building energy model and displayed in iSCAN

Step 7,8: Re-calibration The new algorithm to check if the model needs recalibration is scheduled to run every day and compare the measured against the simulated data and return to iSCAN the calibration metric. Then, the model, if needed, is recalibrated using the latest data collected from the building's sensors and meters and recorded in iSCAN. The module was deployed in Sant Cugat demo site iSCAN project in September 2023. The model can calculated all the suggested calibration metrics in CIBSE methodology and return email alert if a metric is below the suggested threshold. Then, the energy modeller knows that the accuracy of the model is less that required to predict future conditions.

The screenshot below shows a sample of the calibration metrics automatically calculated for "hall Events room". The tool is capable of calculating daily, weekly, monthly or total calibration metrics automatically and return results to iSCAN.

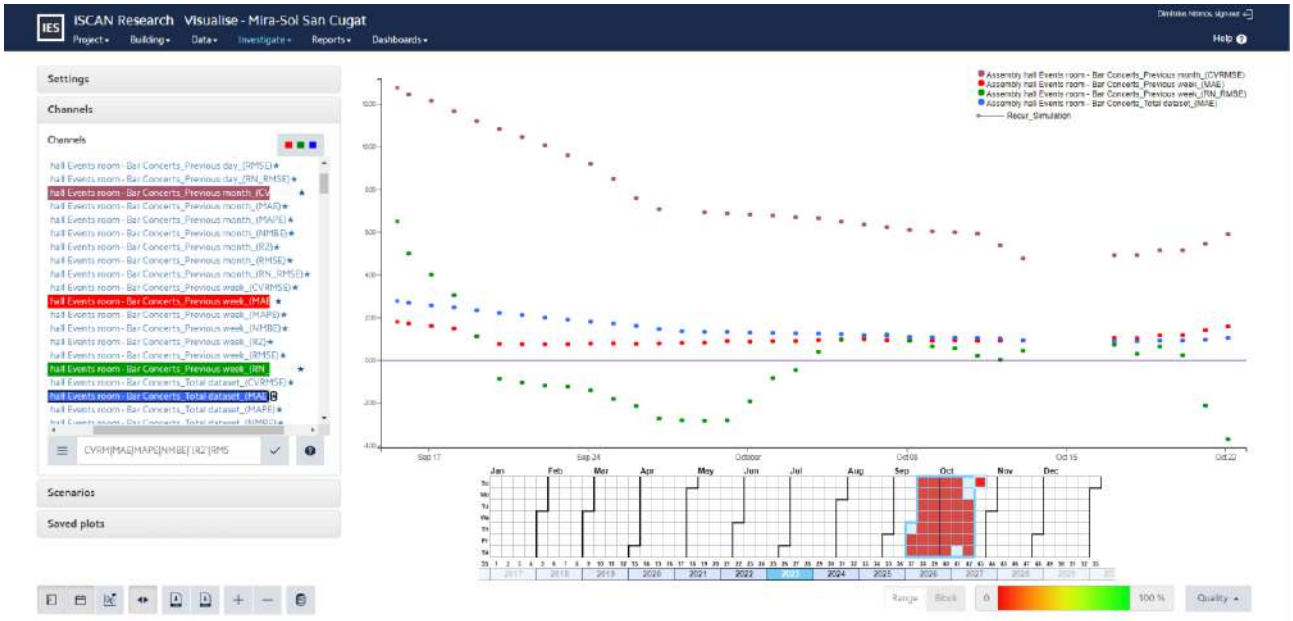


Figure 51: Sant Cugat Model – sample of calibration metrics automated calculation

Finally, all the real and simulated data are available to access in real time using the iSCAN-API, where documentation can be found below. It is used by CARTIF to download simulated data to hybrid controller and KPI modules.

https://iscan-research.iesve.com/api-reference

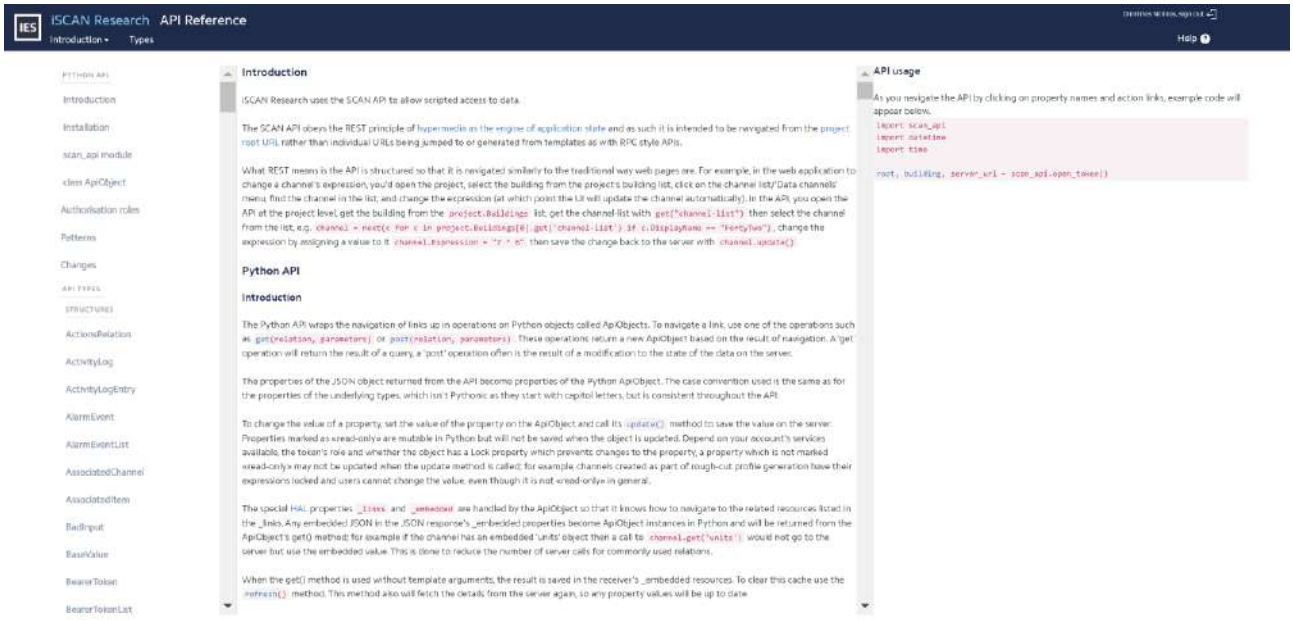


Figure 52: Screenshot of the iSCAN API reference page

4.3 Feedback APP-ISCAN integration

The SunHorizon app for the Sant Cugat site was configured to work for a public building where the end-users are the building managers. The purpose of the app was the same as previously mentioned, both to visualize real-time indoor climate and send feedback about the indoor climate by room.

The integration steps were the same as previously mentioned for the Sunisi site (see section 2.3), only difference is the new references to rooms, sensors and feedback data-import (see image below) for this specific site. To summarize, the app retrieves data from ISCAN (ex. App overview, see image below) using a token for authentication through the App API. The endpoints including the reference for a room or sensor were manually configured and stored in the App database. The integration was tested using the Import log in ISCAN (see last image in this section).

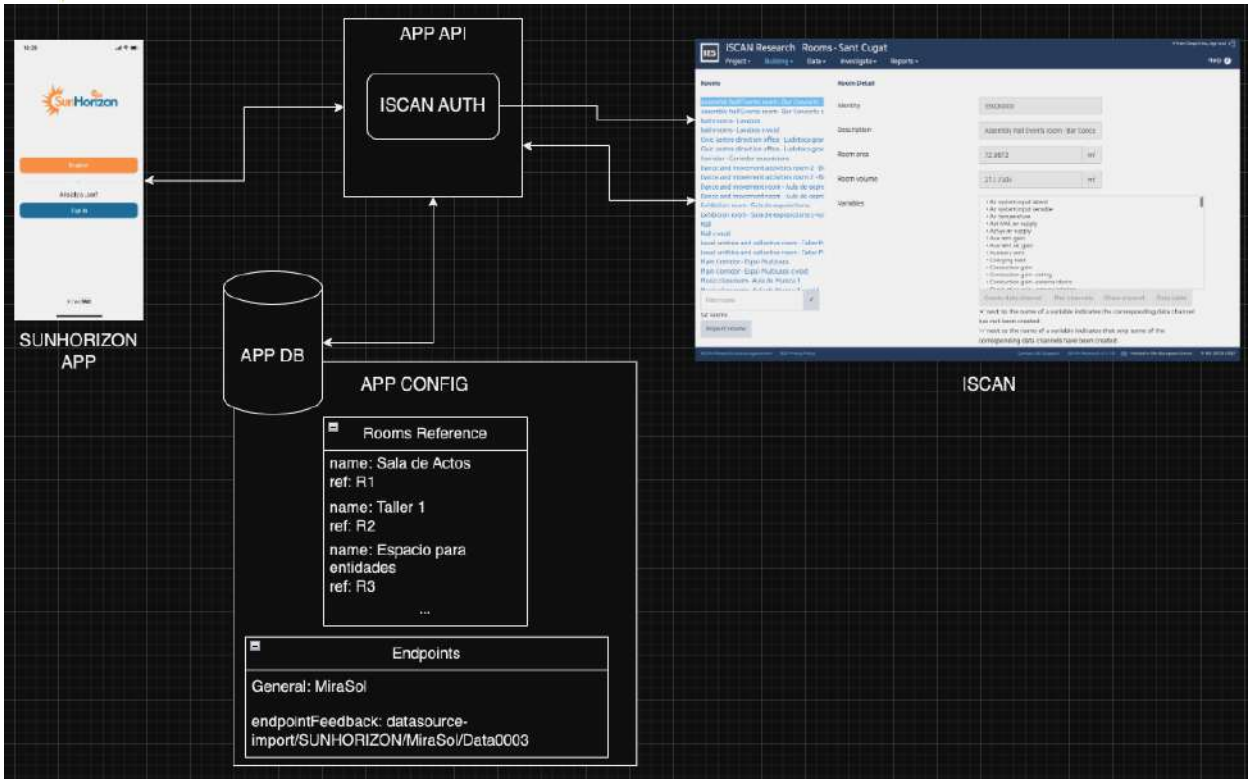


Figure 53: App – ISCAN integration overview

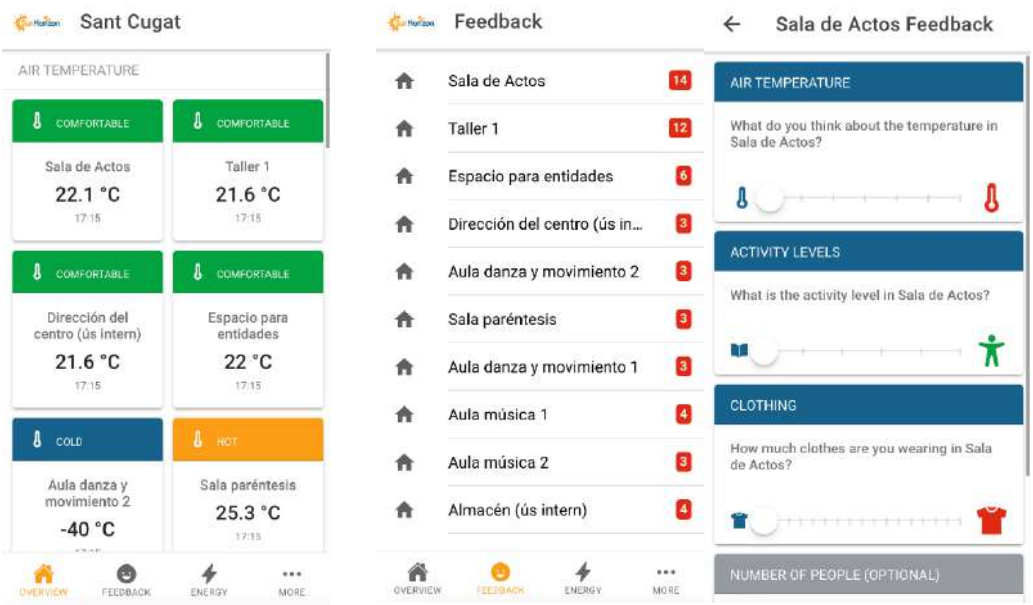


Figure 54: SunHorizon feedback app

Step 14: Comfort Vote from iSCAN to ML model [Automated] - The comfort votes from the occupants are transmitted from iSCAN to the Comfort prediction model, and is used to enhance the accuracy of the model predicting the comfort sensation.

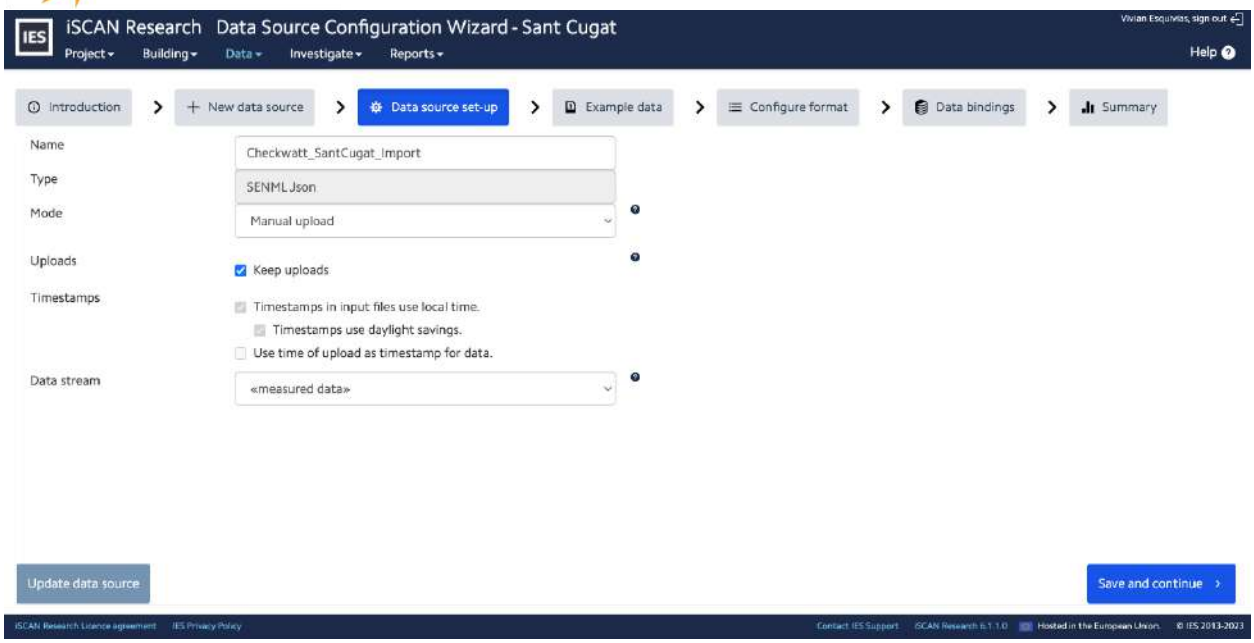
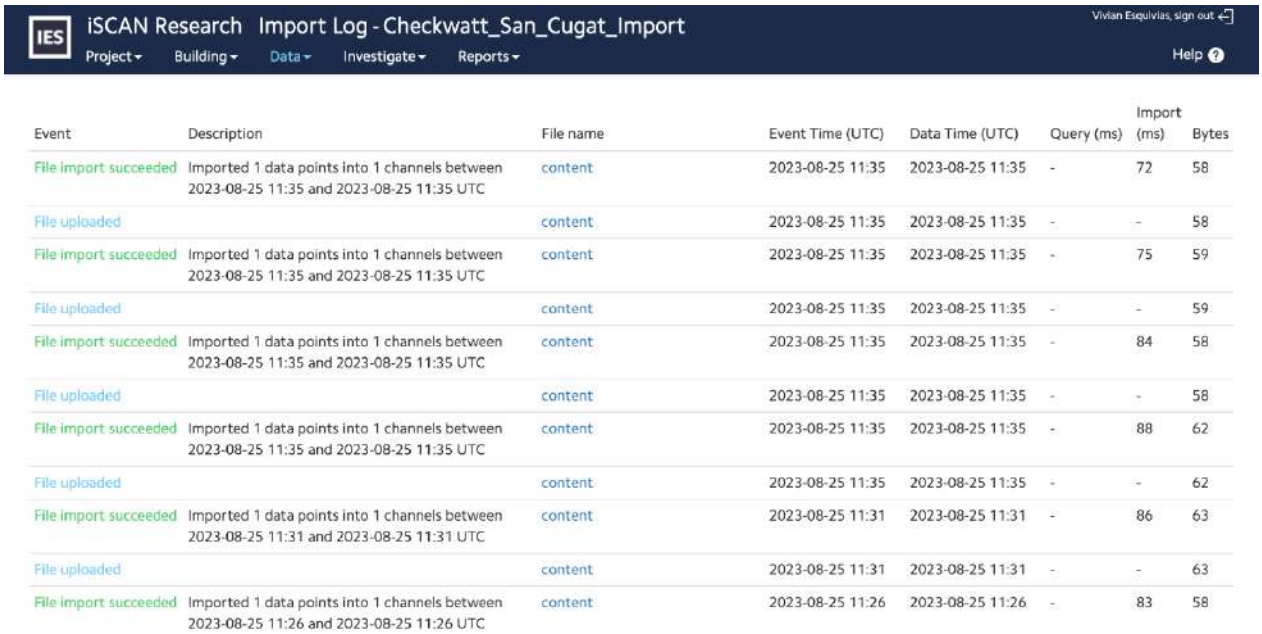


Figure 55: Data-import configuration in ISCAN for feedback from app for Sant Cugat



Event	Description	File name	Event Time (UTC)	Data Time (UTC)	Query (ms)	Import (ms)	Bytes
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:35 and 2023-08-25 11:35 UTC	content	2023-08-25 11:35	2023-08-25 11:35	-	72	58
File uploaded		content	2023-08-25 11:35	2023-08-25 11:35	-	-	58
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:35 and 2023-08-25 11:35 UTC	content	2023-08-25 11:35	2023-08-25 11:35	-	75	59
File uploaded		content	2023-08-25 11:35	2023-08-25 11:35	-	-	59
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:35 and 2023-08-25 11:35 UTC	content	2023-08-25 11:35	2023-08-25 11:35	-	84	58
File uploaded		content	2023-08-25 11:35	2023-08-25 11:35	-	-	58
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:35 and 2023-08-25 11:35 UTC	content	2023-08-25 11:35	2023-08-25 11:35	-	88	62
File uploaded		content	2023-08-25 11:35	2023-08-25 11:35	-	-	62
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:31 and 2023-08-25 11:31 UTC	content	2023-08-25 11:31	2023-08-25 11:31	-	86	63
File uploaded		content	2023-08-25 11:31	2023-08-25 11:31	-	-	63
File import succeeded	Imported 1 data points into 1 channels between 2023-08-25 11:26 and 2023-08-25 11:26 UTC	content	2023-08-25 11:26	2023-08-25 11:26	-	83	58

Figure 56: Import log in ISCAN showing a list of feedback data sent from the SunHorizon app for Riga SuniSant Cugat site.

4.4 Predictive Maintenance APP-ISCAN integration (CAR)

Following the same structure of the section 3.4, and taking into account the two modules that the predictive maintenance tool is composed. In case of Sant Cugat demonstrator, the following KPIs and PIs have been predicted by the predictive tool in order to surveillance, fault detection and fault prediction from these indicators.

Table 16: KPIs and PIs for the predictive tool in Sant Cugat

Code	REF	Description	Unit	Sampling time
K.RERsy-3-15m	EN02	Renewable Energy Ratio	% or ratio	15 min
K.HCIsy-3-15m	COM01	Heating Comfort Index	% or ratio	15 min
K.CCIsy-9-15m	COM02	Cooling Comfort Index	% or ratio	15 min
P.EFTtv-3	TVP01	TVP instantaneous thermal efficiency	% or ratio	15 min
P.FSOtv-3	TVP02	TVP solar Thermal Fraction	% or ratio	15 min
P.EERfa-3-mon	FAHR01	Fahrenheit seasonal electric EER (cooling)	% or ratio	Month
P.SPFfa-3-mon	FAHR02	Fahrenheit seasonal Performance Factor	% or ratio	Month
P.RATdt-3	RT01	Ratiotherm tank stratification efficiency	°C	15 min

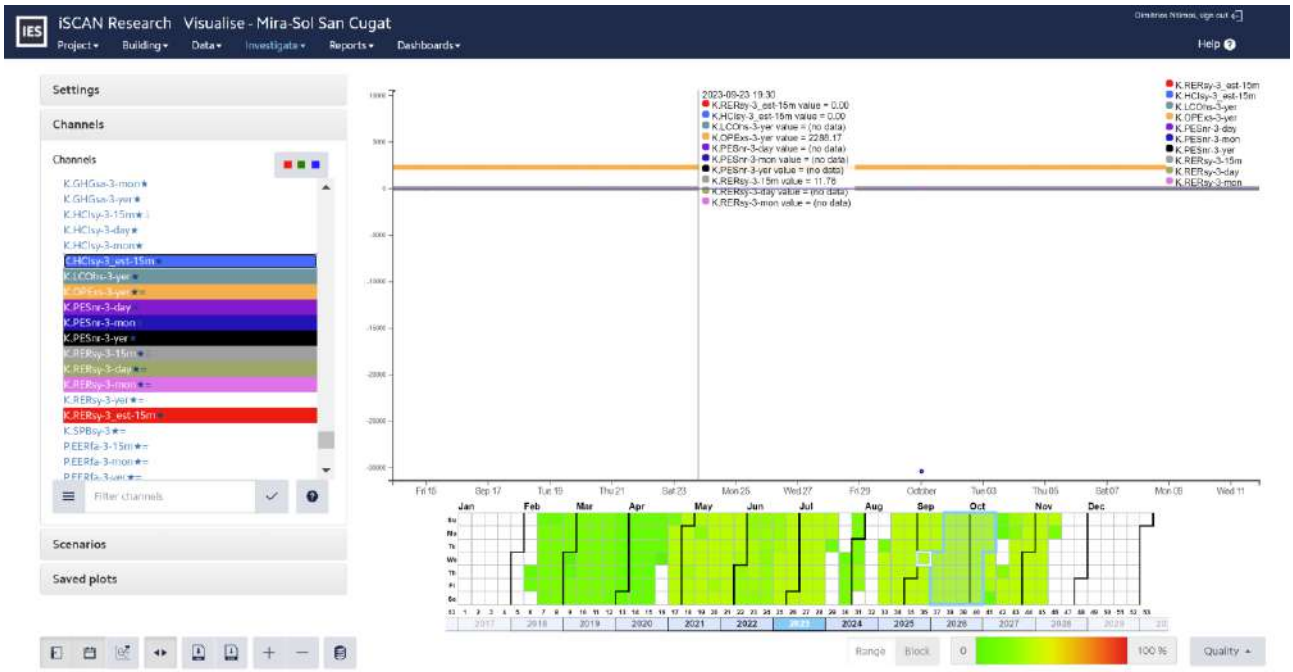


Figure 57: Sample of KPIs and PIs integrated with iSCAN for Sant Cugat demo site

Furthermore, in order to calculate the KPIs and PIs the following indicators are needed.

Table 17: Indicators used by the predictive tool in Sant Cugat

Code	Description	Unit	KPI/ PI for whose calculation is used
I.QFEfu-3	Final gas demand (post-retrofit)	kWh	EN02
I.EFEsy-3	Final electricity demand (post-retrofit)	kWh	EN02
I.PENnp-3	Non-renewable primary energy (post-retrofit)	kWh	EN02
I.PENre-3	Renewable primary energy	kWh	EN02
I.PENto-3	Final primary energy	kWh	EN02
I.HALlr-3-Tem1	Assembly hall/ events room temperature sensor 1	°C	COM01, COM02
I.HALlr-3-Tem1	Assembly hall/ events room temperature sensor 2	°C	COM01, COM02
I.HALlr-3-Tem3	Assembly hall/ events room temperature sensor 3	°C	COM01, COM02
I.WORkr-3-Tem1	Workshop classroom temperature 1	°C	COM01, COM02
I.WORkr-3-Tem2	Workshop classroom temperature 2	°C	COM01, COM02
I.WORkr-3-Tem3	Workshop classroom temperature 3	°C	COM01, COM02
I.COLlr-3-Tem1	Local entities and collectives room temperature 1	°C	COM01, COM02

I.COLlr-3-Tem2	Local entities and collectives room temperature 2	°C	COM01, COM02
I.COLlr-3-Tem3	Local entities and collectives room temperature 3	°C	COM01, COM02
I.OFFcr-3-Tem1	Civic center direction office temperature 1	°C	COM01, COM02
I.OFFcr-3-Tem2	Civic center direction office temperature 2	°C	COM01, COM02
I.OFFcr-3-Tem3	Civic center direction office temperature 3	°C	COM01, COM02
I.DANr2-3-Tem1	Dance and movement activities room 2 temperature 1	°C	COM01, COM02
I.DANr2-3-Tem2	Dance and movement activities room 2 temperature 2	°C	COM01, COM02
I.DANr2-3-Tem3	Dance and movement activities room 2 temperature 3	°C	COM01, COM02
I.EXHir-3-Tem1	Exhibition room temperature 1	°C	COM01, COM02
I.EXHir-3-Tem2	Exhibition room temperature 2	°C	COM01, COM02
I.EXHir-3-Tem3	Exhibition room temperature 3	°C	COM01, COM02
I.DANr1-3-Tem1	Dance and move activities room 1 temperature 1	°C	COM01, COM02
I.DANr1-3-Tem2	Dance and move activities room 2 temperature 2	°C	COM01, COM02
I.DANr1-3-Tem3	Dance and move activities room 3 temperature 3	°C	COM01, COM02
I.MUSr1-3-Tem1	Music classroom 1 temperature 1	°C	COM01, COM02
I.MUSr1-3-Tem2	Music classroom 1 temperature 2	°C	COM01, COM02
I.MUSr1-3-Tem3	Music classroom 1 temperature 3	°C	COM01, COM02
I.MUSr2-3-Tem1	Music classroom 2 temperature 1	°C	COM01, COM02
I.MUSr2-3-Tem2	Music classroom 2 temperature 2	°C	COM01, COM02
I.MUSr2-3-Tem3	Music classroom 2 temperature 3	°C	COM01, COM02
I.QFTvp-3	TVP thermal power output	W	TVP01, TVP02
I.SCUwe-3-Its1	Solar irradiation on the tilted surface	W/m2	TVP01
I.QUSex-3	Heat pump thermal power consumption	W	TVP02, FAHR02
I.QFFah-3	Fahrenheit thermal power output	W	FAHR01, FAHR02
I.EFFah-3	Fahrenheit electricity power consumption	W	FAHR01
I.STA01-3-tem1	Top ratiotherm tank temperature	°C	RT01
I.STA01-3-tem3	Bottom ratiotherm tank temperature	°C	RT01

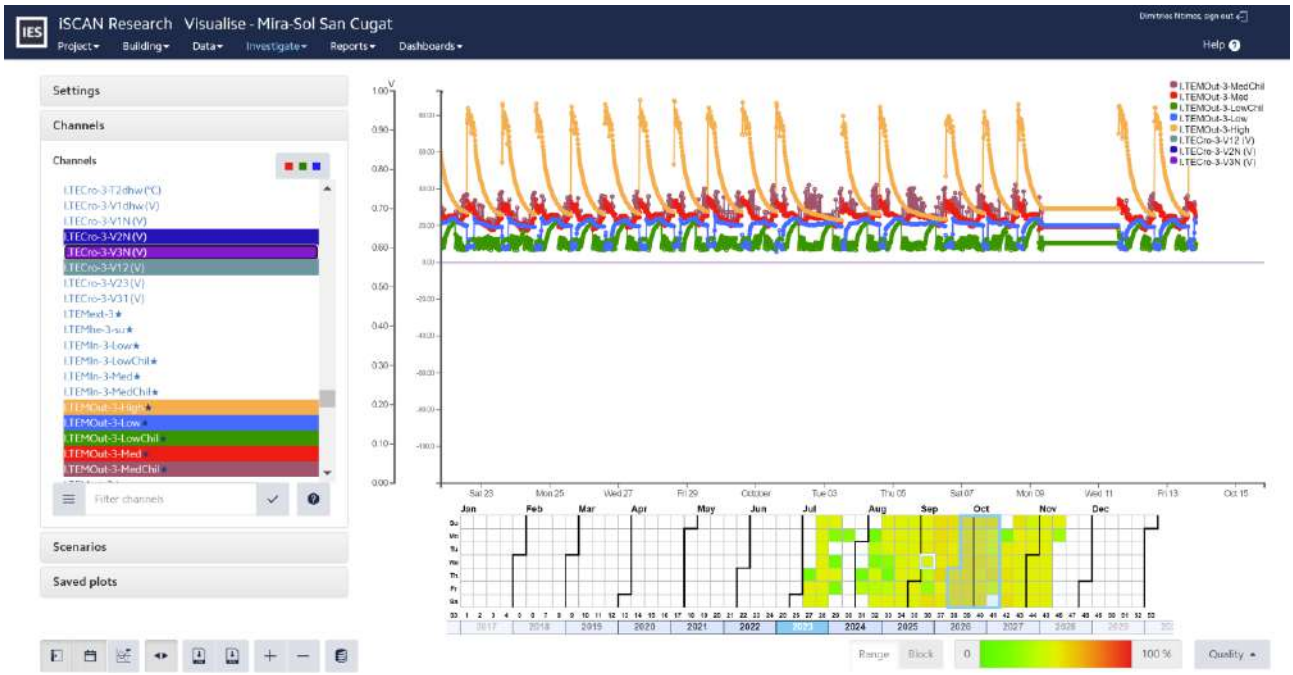


Figure 58: Sample of PIs integrated with iSCAN for Sant Cugat demo site

However, in the case of the predictive tool, it has not been able to validate it in the real demonstrator due to the lack of data. Since the tool would need at least one year to predict the trend of the KPIs and PIs with more accurate and more

realistic approach, some simulations have been carried out in order to try to validate the tool. The Figure 59 shows a predictive tool results simulation.

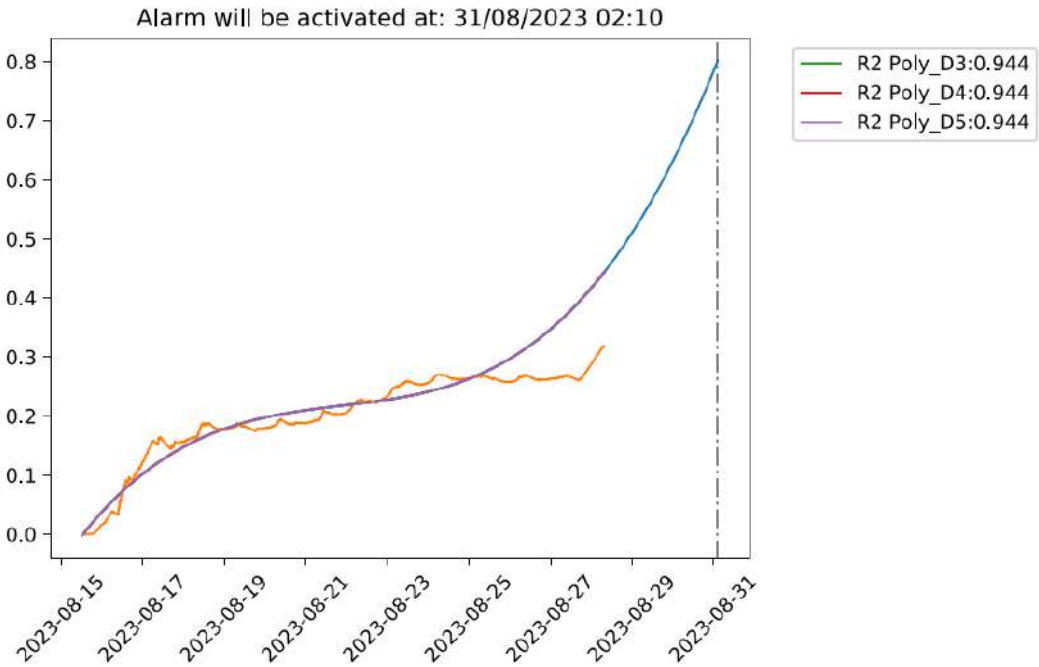


Figure 59: Predictive tool simulation in Sant Cugat

The simulation is composed by the real data (orange line) associated with the accumulative error, vertical discontiguous line (the time when the predictive tool consider that the alarm could be achieved) and the rest lines are associated with different polynomial regressions with 3, 4 and 5 degree and a lineal regression as well, which the tool disdained due to in this case was despicable. Therefore, the predictive tool, and as defined in the D5.6, has to decide when the real case would reach up until a 80% (vertical axis) of accumulated error which is considered a failure, in the simulation case the alarm is triggered at 02:10 on 31/08/2023. The result of the time in which the alarm could be triggered is a very short time due to the predictive tool needs to have a large amount of data to be able to understand, correlate and predict the trends of the proposed indicators. For this reason, the predictive tool could not be validated in a real case due to data availability.

4.5 Hybrid Controller integration with iSCAN and RATIO PLCs

4.5.1 Refinement of the model

As Riga Sunisi, in Sant Cugat some changes have been made which have had had on the configuration of the facilities of the demo-site during the development of T5.4. As reported in D5.5, the Figure 60 shows the system model, which is divided below:

- Heat generation subsystem based on solar collectors provided by TVP
- Solar thermal energy storage based on the stratification tank provided by RATIO
- Heat distribution circuit
- Cooling generation subsystem based on the hybrid chiller provided by FAHRENHEIT
- Existing system based on a heat pump and air handling units (AHU)

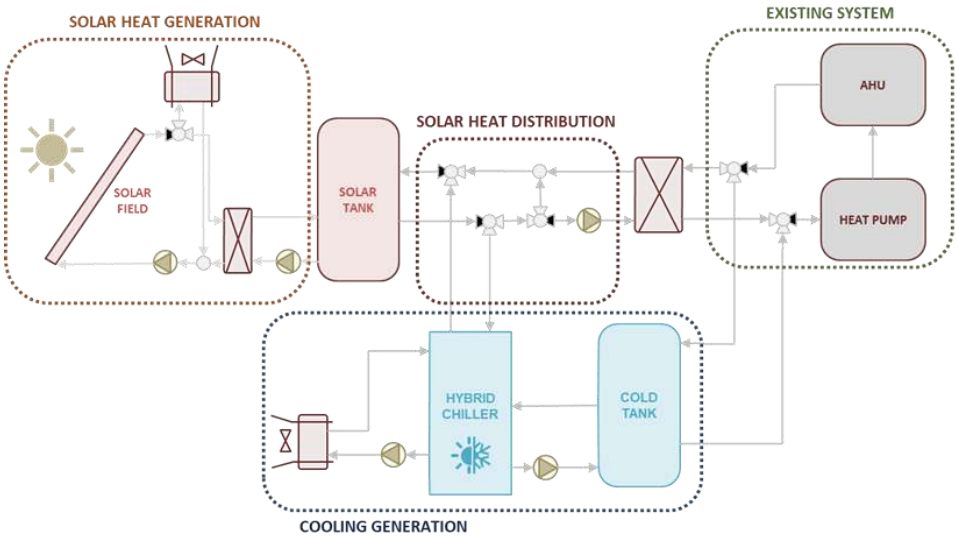


Figure 60: Sant Cugat system model

In the case of Sant Cugat, it has been divided in two operation system that depends on the current season (winter and summer). In winter season, solar energy is supplied to the air handling units (AHU) coming from a solar stratification tank while the use of an intermediate exchanger, in case that the Hybrid Chiller is turned off and the cold tank is not conditioned. The heat pump in the system is used to move the water through the secondary circuit. If the temperature of the water heated by the heat exchanger using solar energy falls below a predetermined threshold, the existing heat pump is responsible for increasing the inlet water temperature to meet that specified value (Figure 61).

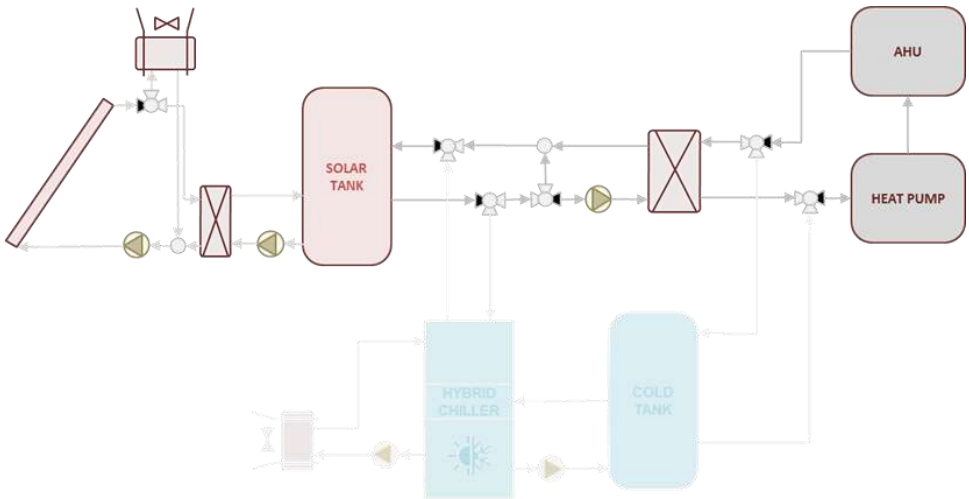


Figure 61: Sant Cugat system in winter period

Throughout the summer season, the use of the solar heat exchanger is turned off, as delineated in (Figure 62).Then the solar energy stored within the solar tank is harnessed by the hybrid chiller to generate cold, which is subsequently distributed to the Air Handling Unit (AHU). The existing heat pump facilitates the transfer of water from the cold storage tank to the AHU. Furthermore, in situations where the temperature within the cold storage tank exceeds a predefined threshold, the existing heat pump takes over the responsibility of reducing the inlet water temperature to align with the specified value.

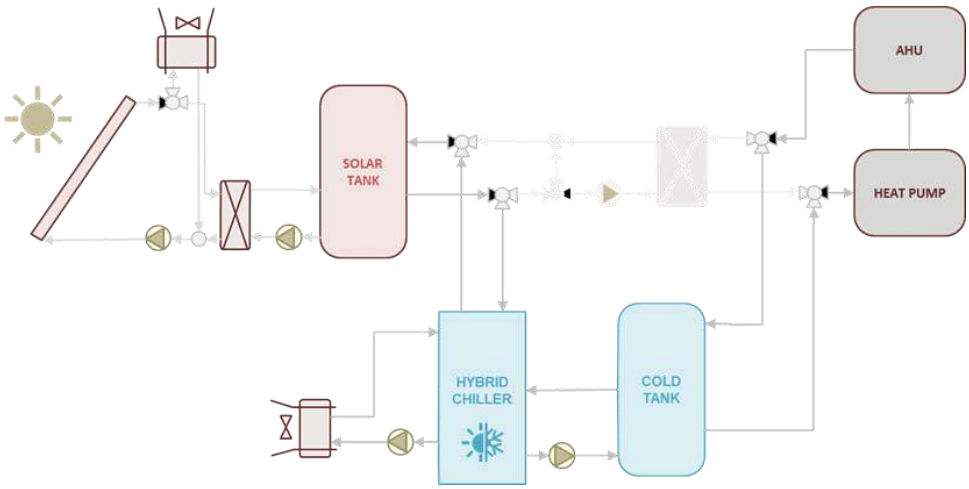


Figure 62: Sant Cugat system in summer period

The complete model of the facility has been split into two different models, developed both with TRNSYS, each designed for seasonal deployment (winter or summer). The winter (Figure 63) model provides heating for the building, while the summer model (Figure 64) provides cooling solutions.

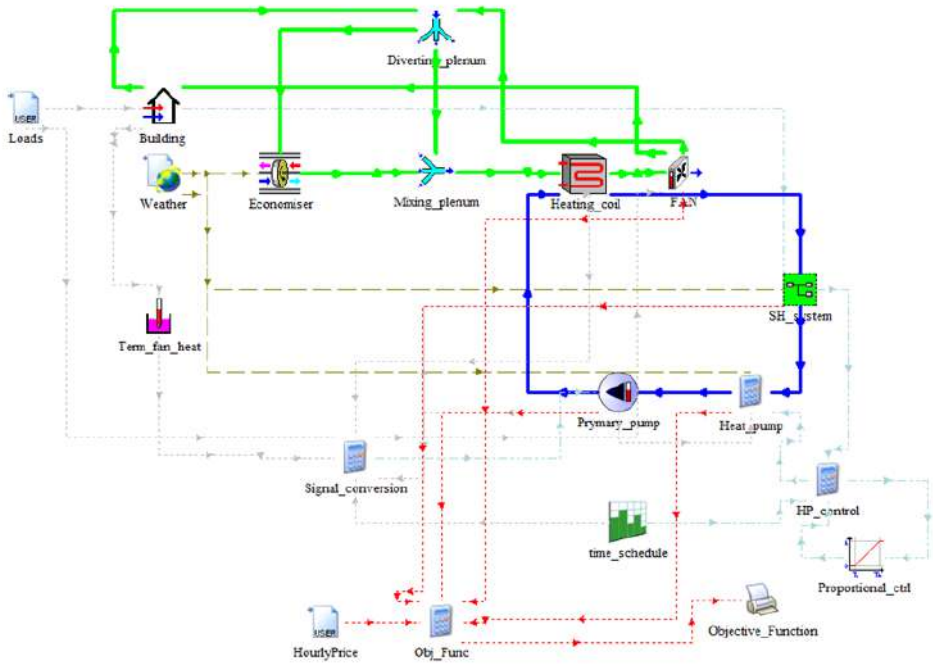


Figure 63: Sant Cugat TRNSYS model in winter period

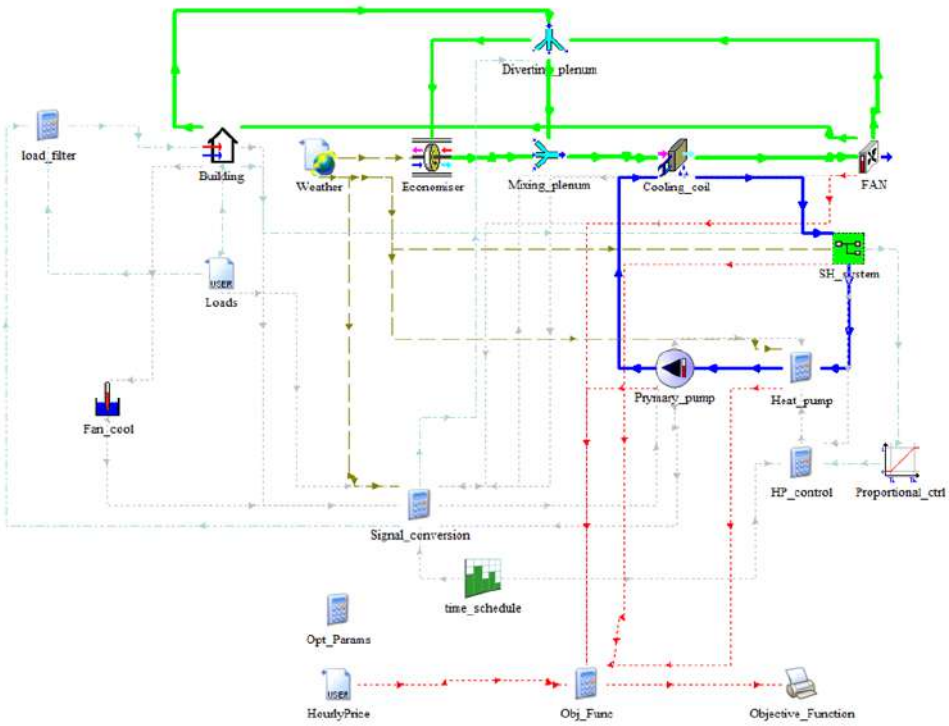


Figure 64: Sant Cugat TRNSYS model in summer period

The models are further divided into several segments according to the diagrams of the existing facility provided by the owners of the demo-site, which described the existing infrastructure as well as the proposed configuration for the SunHorizon system implementation. The air conditioning circuit interacts with a building model to emulate indoor environmental conditions such as; weather and rooms temperature, or relative humidity, which are obtained from iSCAN platform, are based on the equilibrium between thermal loads and conditioned air supplied and extracted. The predicted loads and conditioned air are introduced in the TRNSYS models based on text file.

4.5.2 Control strategy

The control strategy employed at the Sant Cugat demonstration site relies on low-level algorithms. Nevertheless, the hybrid controller introduces adjustments to multiple setpoints within the low-level control framework to optimise the system's performance and enhance specific metrics, such as the self-consumption ratio. To provide a comprehensive understanding of the hybrid controller operation, it is discussed in the los-level control strategies

The primary objective of the overall system is to maintain the building's temperature within predefined comfort limits during specified time periods, regulated by a time-scheduling mechanism. This involves continuous temperature monitoring and comparison to a setpoint, including a hysteresis cycle. This control mechanism operates like a thermostat. It becomes active during the winter season when the building temperature falls below the setpoint and during the summer season when the building temperature exceeds the setpoint. Beyond the scheduled hours, this control mechanism remains inactive, allowing the building temperature to remain unregulated.

The air conditioning system employs a control strategy that revolving around the activation of the main fan of the ventilation system when the building temperature is actively controlled, as indicated by the aforementioned thermostat. When the building temperature is not actively controlled, such as during unscheduled hours, the fan remains deactivated.The solar primary circuit, utilized throughout both winter and summer seasons, incorporates distinct control loops. Initially, the circuit's flow rate is adjusted to attain specific temperature setpoints at the outlet of the solar collectors while considering

operational constraints related to maximum and minimum flow rates. Subsequently, a safety control mechanism is activated if the temperature from the collectors reaches 99°C, a measure taken to prevent the generation of vapor within the pipes, which could pose a threat to the system's integrity. During the activation of the safety system, the water is directed through an air cooler to reduce its temperature to safe levels. Finally, the pump for the secondary solar circuit is activated when two conditions are met: the outlet water temperature from the panels exceeds the temperature at the lower section of the RATIO tank, and the temperature at the upper part of the tank falls below 95°C.

During the winter season, the regulation of the temperature supplied to the heating coil within the air conditioning system takes place through a dual mechanism. Primarily, the SunHorizon system plays the role in supplying energy from the RATIO tank, which works in tandem with a three-way diverter valve to achieve a specified temperature setpoint in the outlet water of the secondary circuit of the second heat exchanger. However, if this temperature deviates by 5 °C below the designated set point, an existing heat pump is activated at a predetermined power level, which depends on the magnitude of the deviation between the water temperature and the established set point.

During the summer season, the control system exhibits distinct characteristics, the main focus is on the cooling coil supplied with water from a cold buffer integrated into the SunHorizon system. The temperature of this water is meticulously regulated to attain a specific temperature setpoint. If the temperature of the cold buffer exceeds this predetermined setpoint, the existing heat pump is initiated at a predetermined power rate, determined by the deviation between the water temperature and the setpoint. This parameter is calculated through a proportional controller, the behaviour of which is depicted in Figure 65. The power rate of the evaporator is computed using the same equation employed during the winter season.

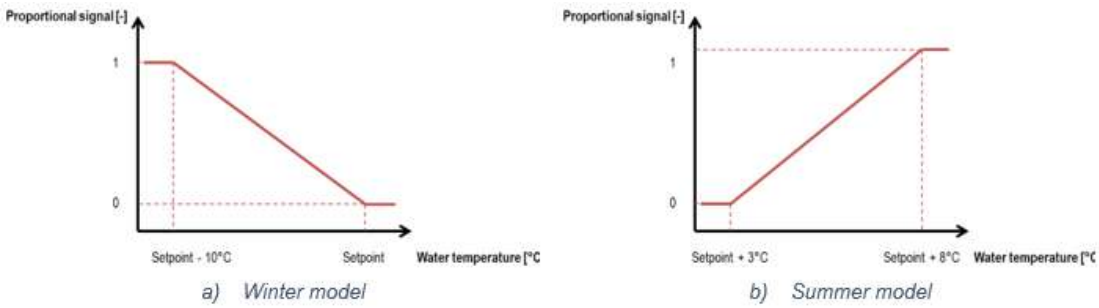


Figure 65: Proportional control used in winter model of Sant Cugat demo site

Once the low-level control strategies have been established, the SunHorizon hybrid controller is designed with the primary objective of optimising various setpoints discussed above, with the ultimate goal of minimising specific objective functions. These objective functions include:

- Minimization of energy use. The energy use is calculated as the sum of all the energy consumptions of the main equipment (existing heat pump, hybrid chiller, ventilation fan) and auxiliary devices (pumps, air coolers, etc.).

- Minimization of operation cost, calculated as the energy consumption multiplied by the electricity price since electricity is the only power source present in this demo site.

- Minimization of green-house-gases emissions, calculated as the energy consumption multiplied by the electricity primary energy conversion

SunHorizon hybrid controller optimization will be launch only minimizing operation cost. In Table 18, the setpoints to be changed to optimize the objective functions are summarized indicating the range within their value must be, depending on the technical specifications of each device

Table 18: Control set points to optimise in Sant Cugat

Setpoint	Season	
	Winter	*Summer*
Indoor temperature of the building [°C]	20-23	21-24
Solar collector outlet temperature [°C]	20-80	80-95
Heating coil inlet temperature [°C]	30-50	NA
Cold buffer tank temperature [°C]	NA	5-15

4.6 Self-Learning Modules integration with iSCAN

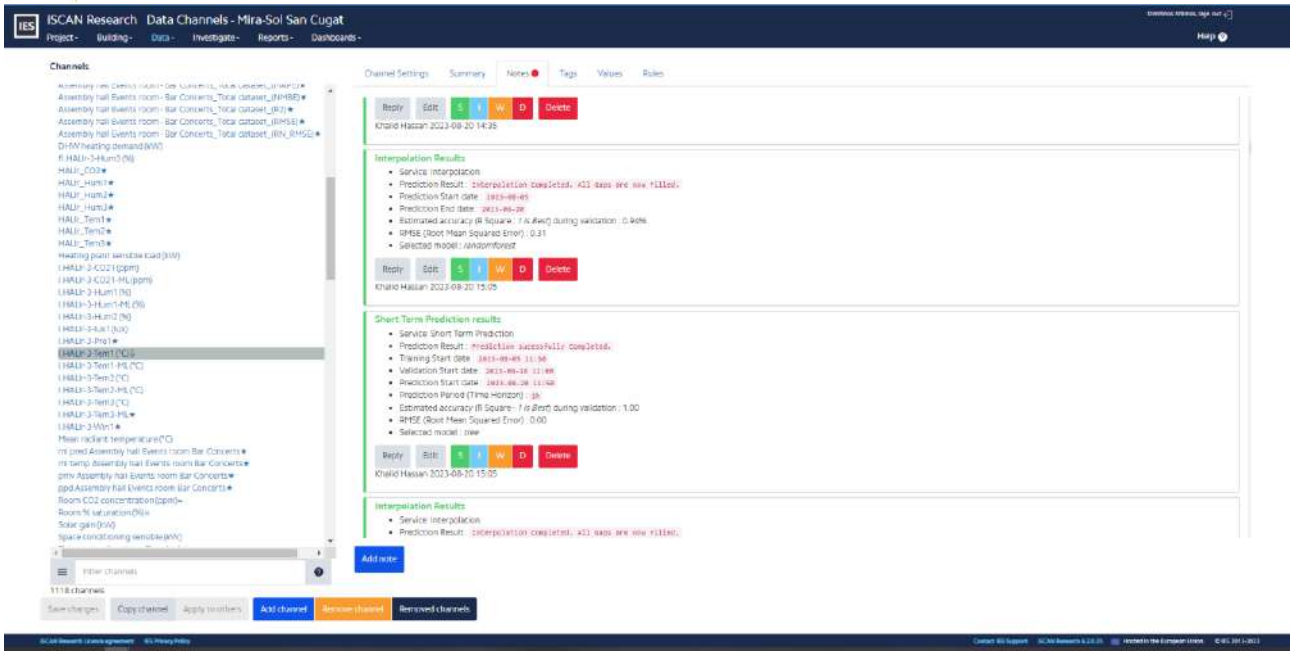
The following steps in the workflow were integrated for Sant Cugat demo site:

Step 15: Sensor/Meter data and simulated data from iSCAN to ML models [Automated] – The Sensor/Meter data and simulated data are transmitted to the machine learning models and used for forecasting of the short term future conditions of the building, to allow comfort predictions in step 14 and other functionalities such as filling data gaps.

Step 16: Fill data gaps self-learning forecasts to iSCAN [Automated] – Whenever required, iSCAN is integrated with a module to fill in the gaps in data using machine learning

Step 17: Short term predictions self-learning forecasts to iSCAN [Automated] – Scheduled to be executed every 30 minutes, the Short term predictions self-learning tool transmitting forecasts for the next 30 minutes to iSCAN

In the screenshot below, a sample of results of filling data gaps and short term future predictions are shown, which are automatically send to iSCAN after the data gap filling and interpolation jobs. Each time whenever required, the self-learning modules are downloading data from iSCAN, perform data gap filling and short term prediction job with the most appropriate machine leaning model, and return results as long as metrics such as estimated accuracy (R^2) and Root Mean Squared Error (RMSE). Finally, if the result of self-learning job is positive, the item in iSCAN is coloured Green, if Moderate it is coloured Orange, if not accurate it is coloured Red.



Interpolation Results

- Service: Interpolation
- Prediction Result : `Interpolation Completed. All Gaps are now Filled.`
- Prediction Start date : `2023-08-05`
- Prediction End date : `2023-08-20`
- Estimated accuracy (R Square : *1 is Best*) during validation : 0.94%
- RMSE (Root Mean Squared Error) : 0.31
- Selected model : *randomforest*

Reply Edit S I W D Delete

Khalid Hassan 2023-08-20 15:05

Short Term Prediction results

- Service: Short Term Prediction
- Prediction Result : `Prediction sucessfully Completed.`
- Training Start date : `2023-08-05 11:50`
- Validation Start date : `2023-08-18 12:00`
- Prediction Start date : `2023-08-20 11:50`
- Prediction Period (Time Horizon) : `1h`
- Estimated accuracy (R Square - *1 is Best*) during validation : 1.00
- RMSE (Root Mean Squared Error) : 0.00
- Selected model : *tree*

Reply Edit S I W D Delete

Khalid Hassan 2023-08-20 15:05

Figure 66: Self-learning modules in Sant Cugat model, screenshots from iSCAN

Step 18: Thermal comfort predictions self-learning forecasts to iSCAN [Automated] – Scheduled to be executed every 30 minutes, the comfort forecasting tool transmitting forecasts for the next 30 minutes to iSCAN

In the screenshot below, the yellow vertical line shows present, while from the line to the left is the past, and to the right is the future. The thermal comfort self-learning module is programmed to predict thermal comfort of the Sant Cugat rooms using the votes of the occupants via the feedback app, the sensor measurements and a database of thermal comfort sensation votes.

The thermal comfort module calculates the following:

- Adaptive comfort
- PMV (-3 to 3)
- PPD (0-100%)
- ML PMV prediction based on occupant votes (-3 to 3 integers only)

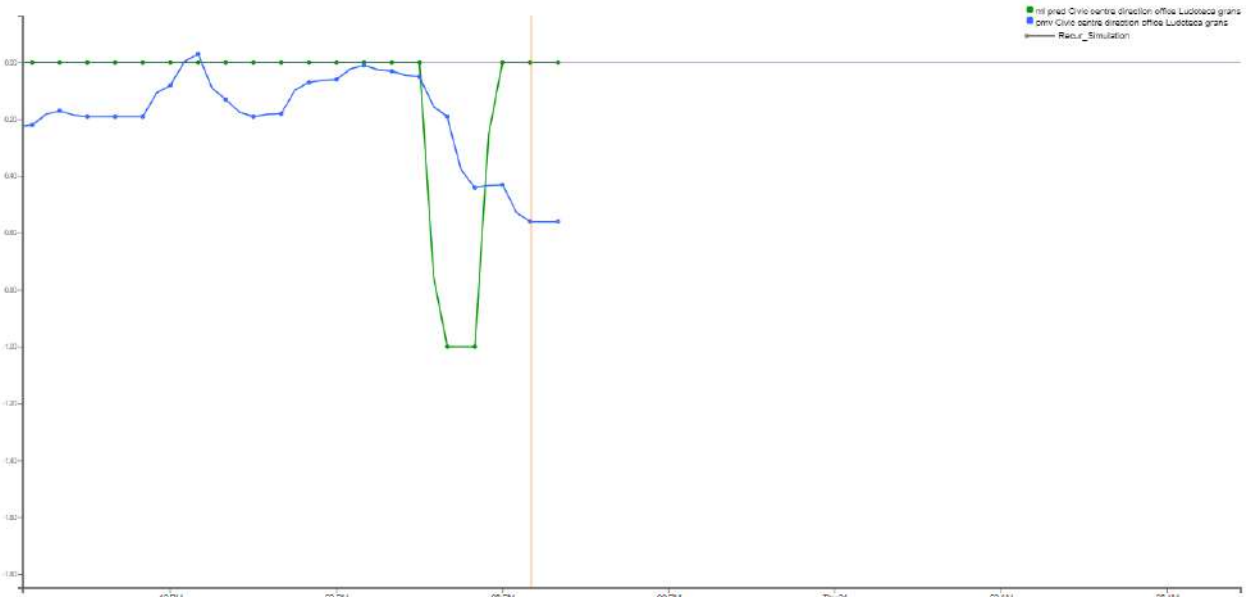


Figure 67: Self-learning prediction of thermal comfort in 2 rooms in Sant Cugat model, Screenshot from iSCAN

4.7 Dashboard integration and hand over to demo sites

The following integrations where fully achieved and automated (follow-up work from WP4), to allow the full deployment of the Monitoring Platform (dashboard) to allow demonstration and KPI calculation in WP6:

3. Sensor/Meter Data – [Automated] Integration between field level equipment and Smart Connector via MQTT connection. This is a standard practice by Schneider Electric (performed in WP4)

4. Sensor/Meter Data – [Automated] Integration between Smart Connector and iSCAN via REST API. A new web hook has been developed to allow the integration. (performed in WP4)

19. Real data from sensors and meters are posted to the hybrid control and proactive/predictive maintenance modules using iSCAN-API to enable control and KPIs calculations

21. KPIs from proactive/predictive maintenance modules to iSCAN [Automated] – Scheduled periodically to transmit the KPIs to iSCAN once calculated

28. Sensor/Meter data from iSCAN to dashboard [Automated] – Data selected by demo site leaders are transmitted from iSCAN to the dashboard every 15 minutes and plotted in selected visualisations by demo site leaders

30.Fault detection and KPIs from iSCAN to dashboard [Automated] – Fault detection such as data gaps, and the KPIs of the project are integrated with iSCAN and displayed in the dashboard

31.32. Sensor Meter Data, KPIs and alerts displayed to the end user to enable:

a.Monitoring of energy and indoor environmental quality

b. Decision making based on minimising energy use and maximising comfort

c.Encourage the necessary maintenance required in building devices

d.Deploy optimised setpoints if needed

The dashboard can be accessed at: KPIs | Sunhorizon-Sancugat2023

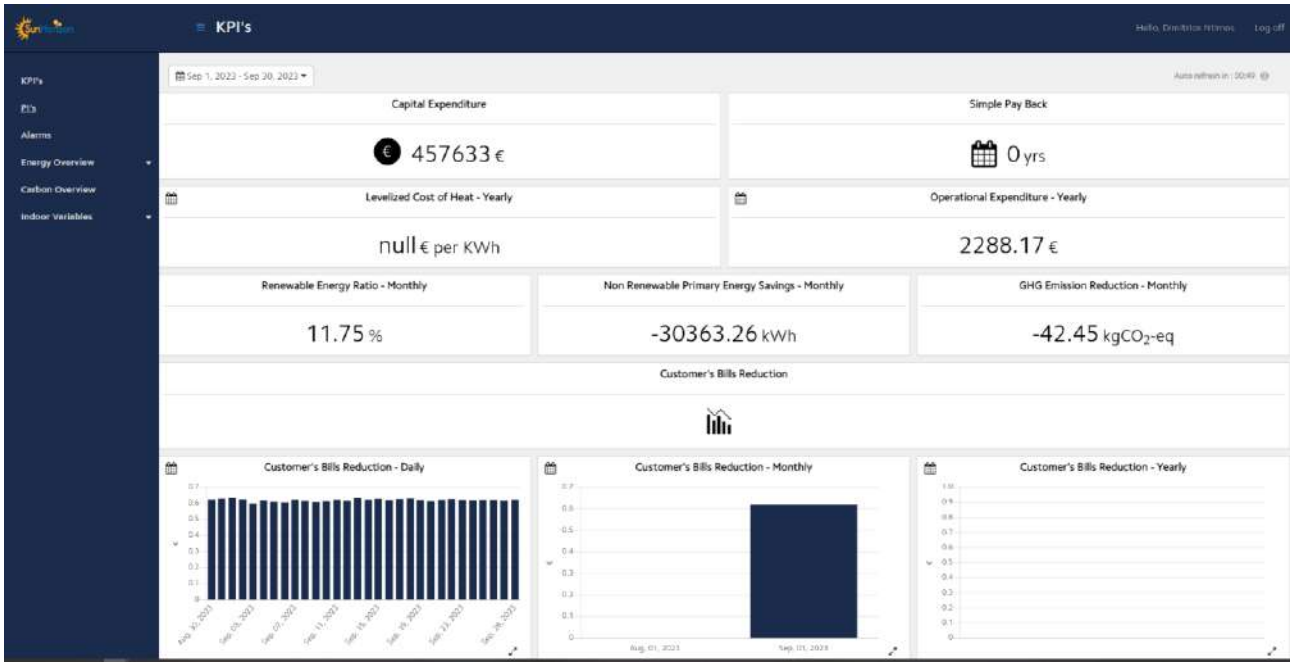


Figure 68: KPIs page, screenshot from dashboard of the Sant Cugat dashboard in the SunHorizon monitoring platform

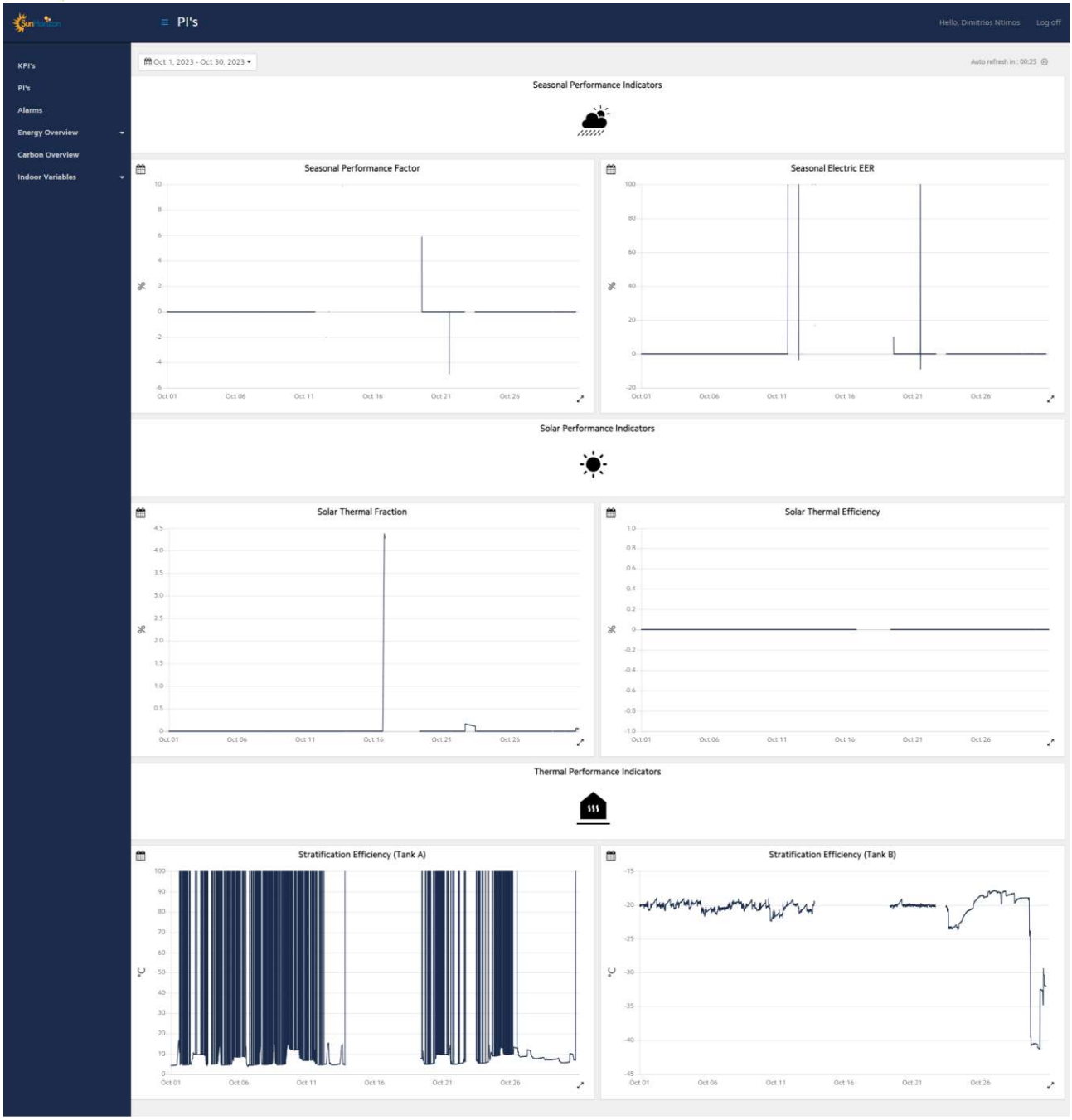


Figure 69: PIs page, screenshot from dashboard of the Sant Cugat dashboard in the SunHorizon monitoring platform

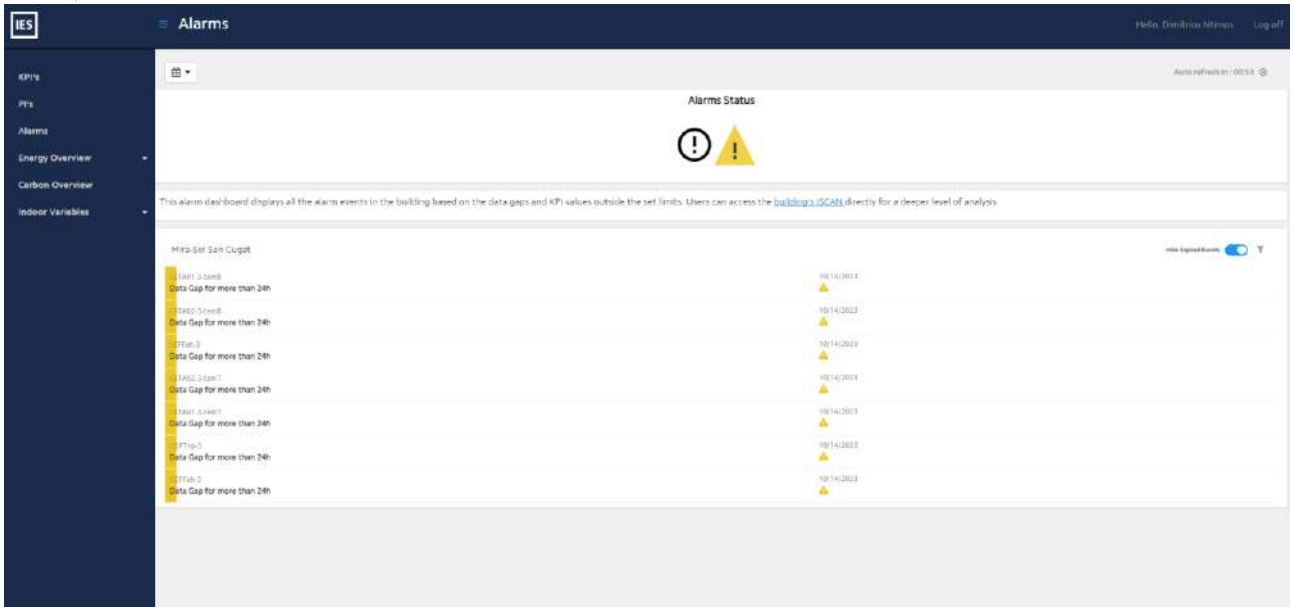


Figure 70:Alerts page, screenshot from dashboard of the Sant Cugat dashboard in the SunHorizon monitoring platform

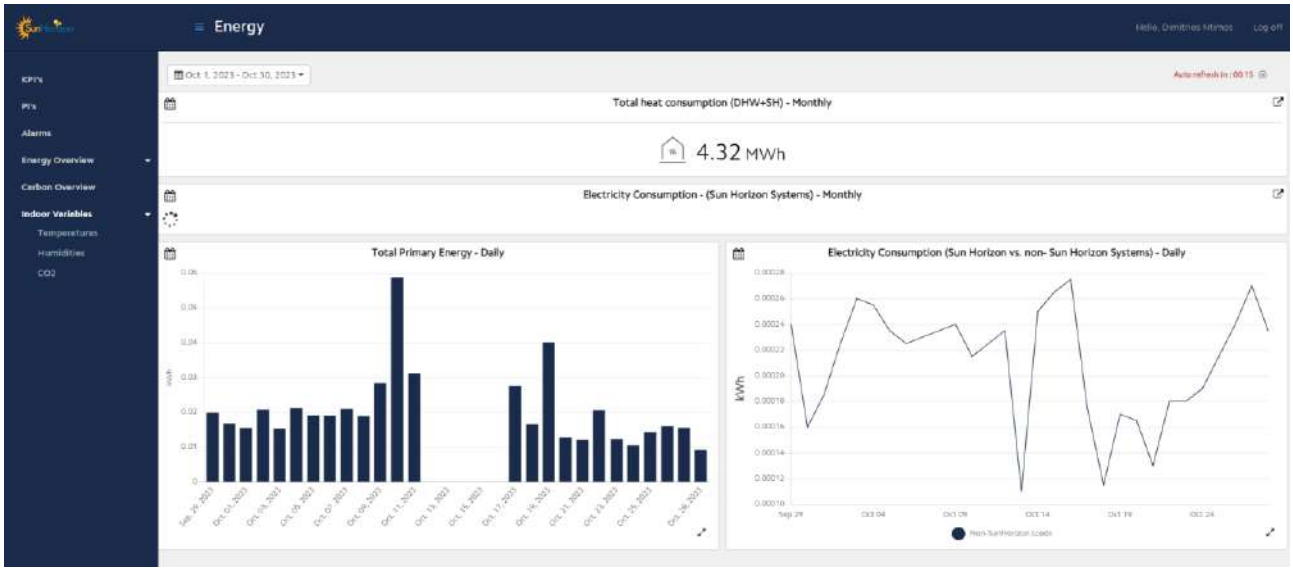


Figure 71: Energy Overview page, screenshot from dashboard of the Sant Cugat dashboard in the SunHorizon monitoring platform

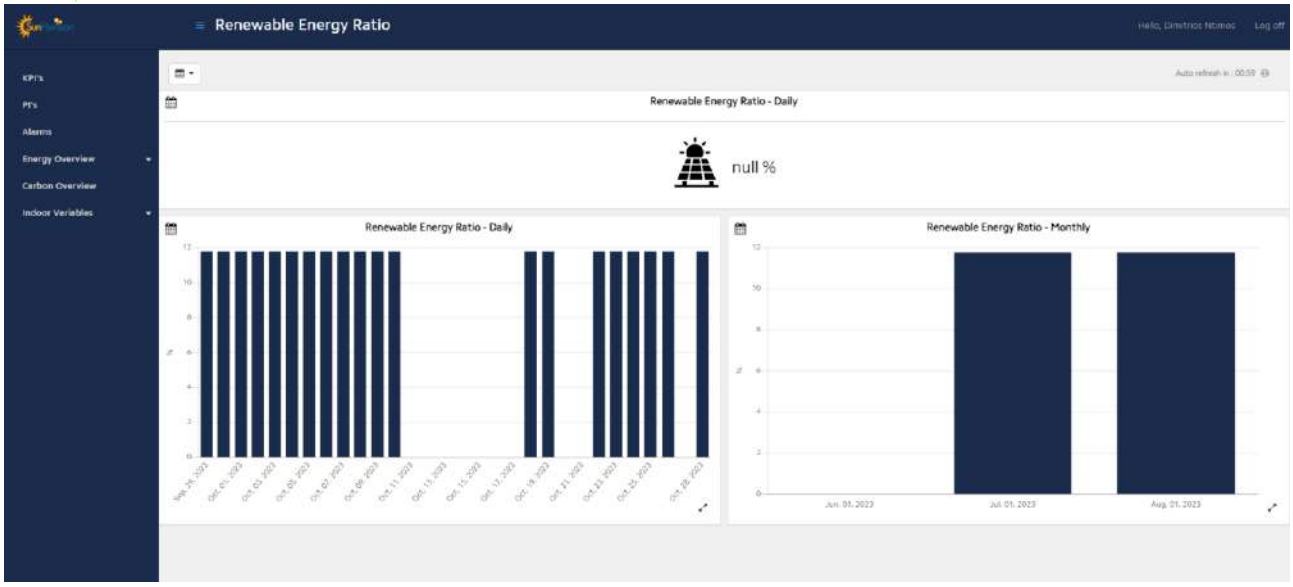


Figure 72: Renewable energy page, screenshot from dashboard of the Sant Cugat dashboard in the SunHorizon monitoring platform

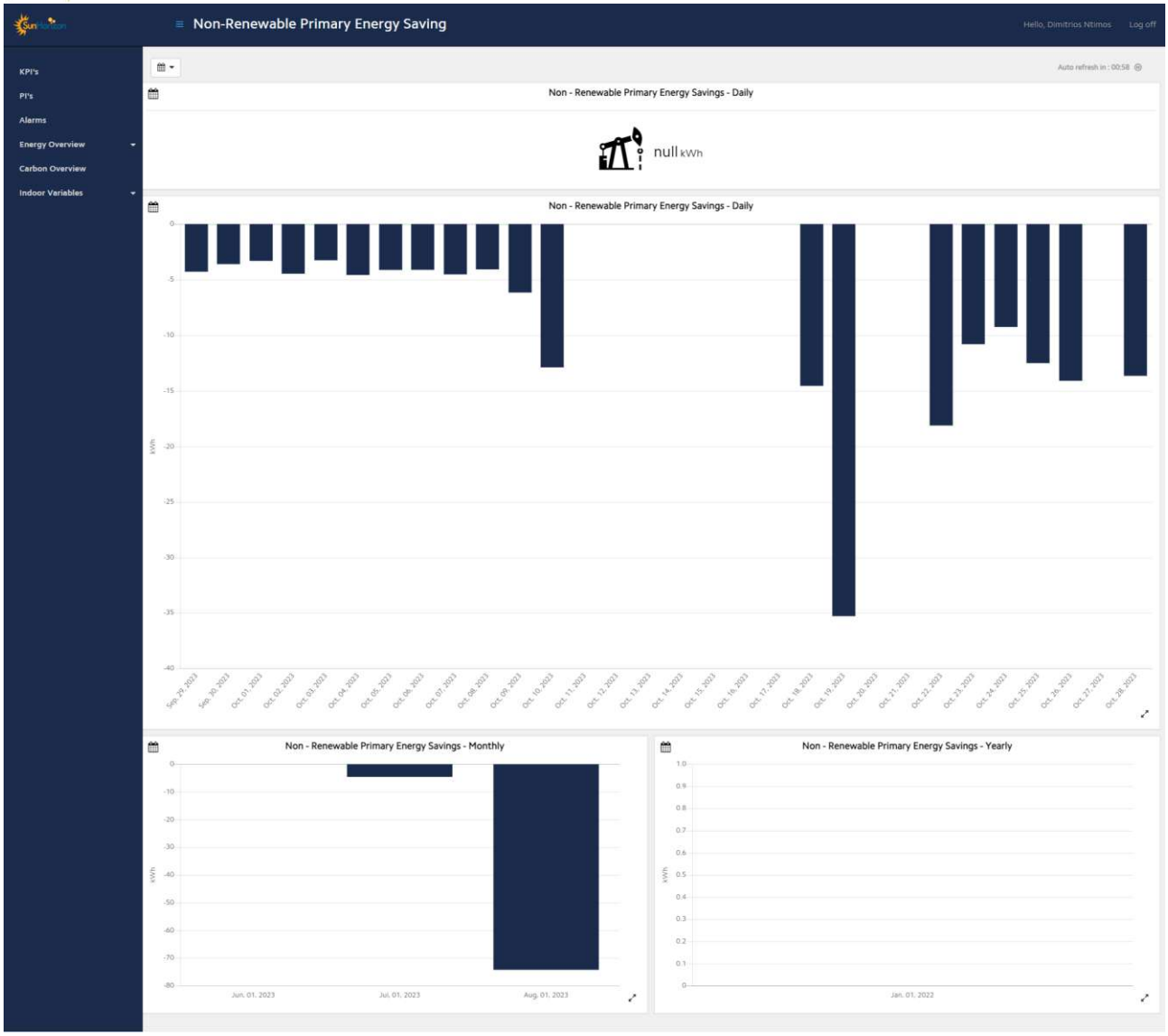


Figure 73: Non-renewable energy page, screenshot from dashboard of the Sant Cugat dashboard in the SunHorizon monitoring platform

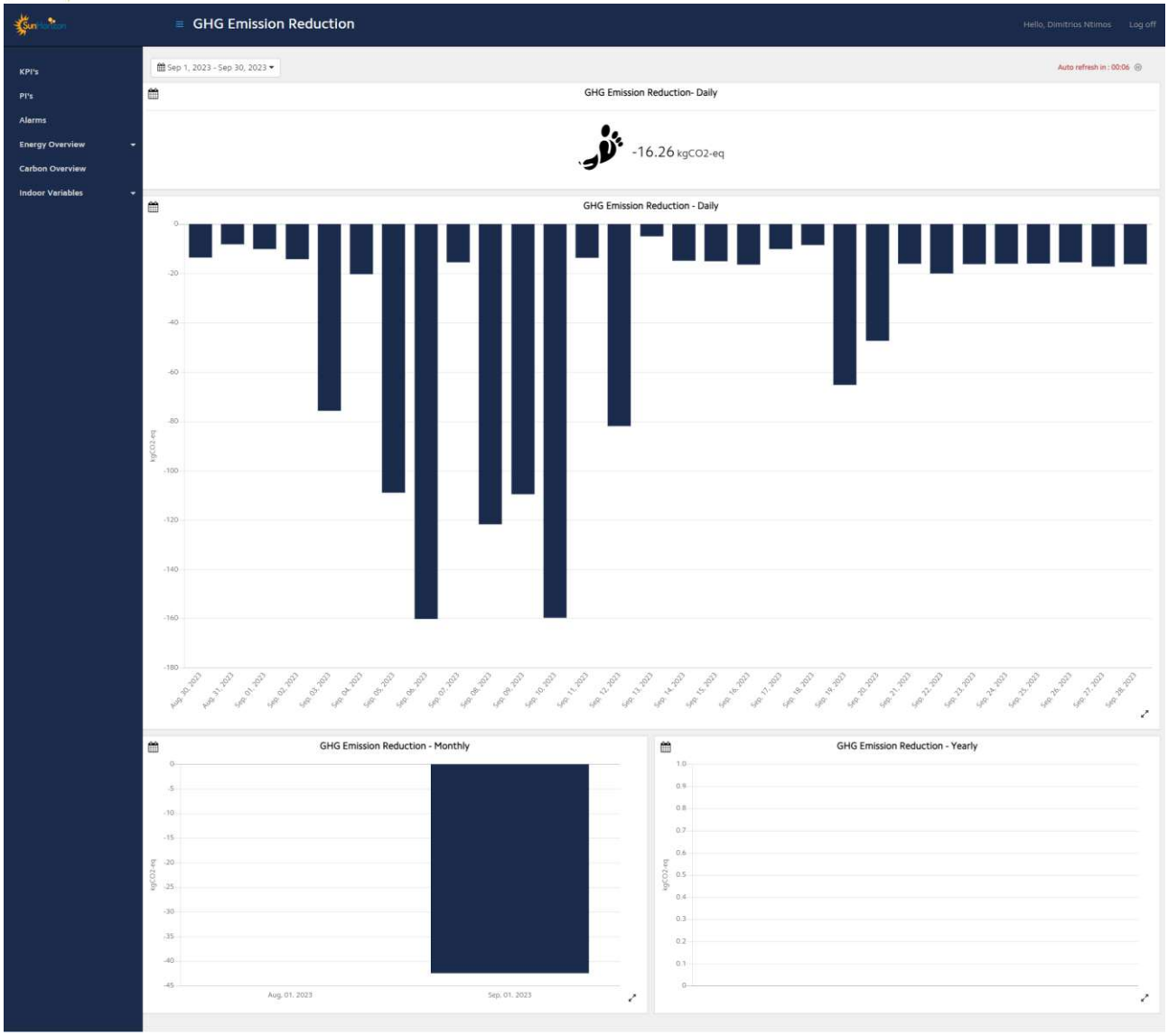


Figure 74: Carbon Overview page, screenshot from dashboard of the Sant Cugat dashboard in the SunHorizon monitoring platform

Figure 75: CO2 concentration in Sant Cugat Rooms in September 2023, screenshot from dashboard of the SunHorizon monitoring platform (similar pages for Air Temperature and Relative Humidity

5 Control modules validation in Sant Cugat

5.1 Simulation module validation

The following validation tests performed to ensure, robustness, reliability and accuracy of the simulation.

The module is automated and uploading data to iSCAN since they day it was activated in 3rd of August 2023 without any disruption.

At the time of finalising this report, there was no data gap recorded, since the ones seen in the iSCAN screenshot below were necessary deactivations to upload a new improved calibrated model to the module. The screenshot below shows the data gaps in the upload of simulated air temperature from the building simulation module.

Figure 76: no data gaps in the simulation module during the period of automated running

To ensure accuracy of the module, results were compared against desktop simulation results and found identical.

There was also improvement of the calibrated energy model to bridge the gap between actual measured data and simulated data (see next paragraph). Finally, the re-calibration check module was compared against manual calculation of metrics and results were found identical.

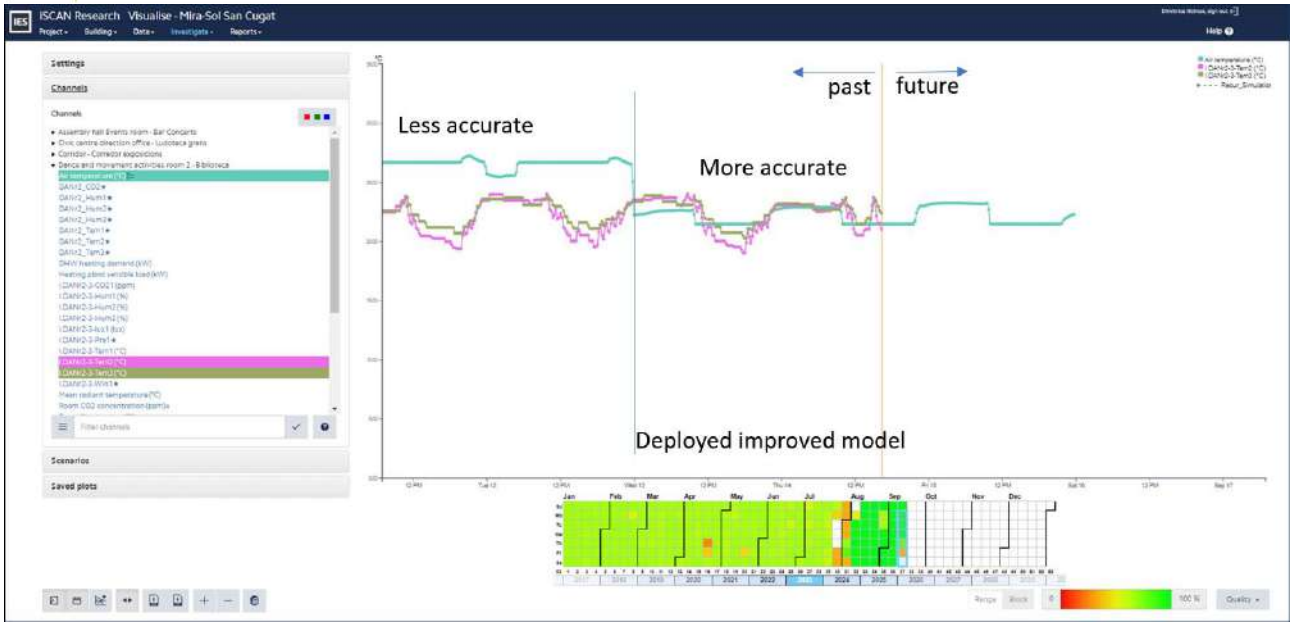


Figure 77: Simulated vs Measured air temperature in Dance and movement activities room in Sant Cugat demo site

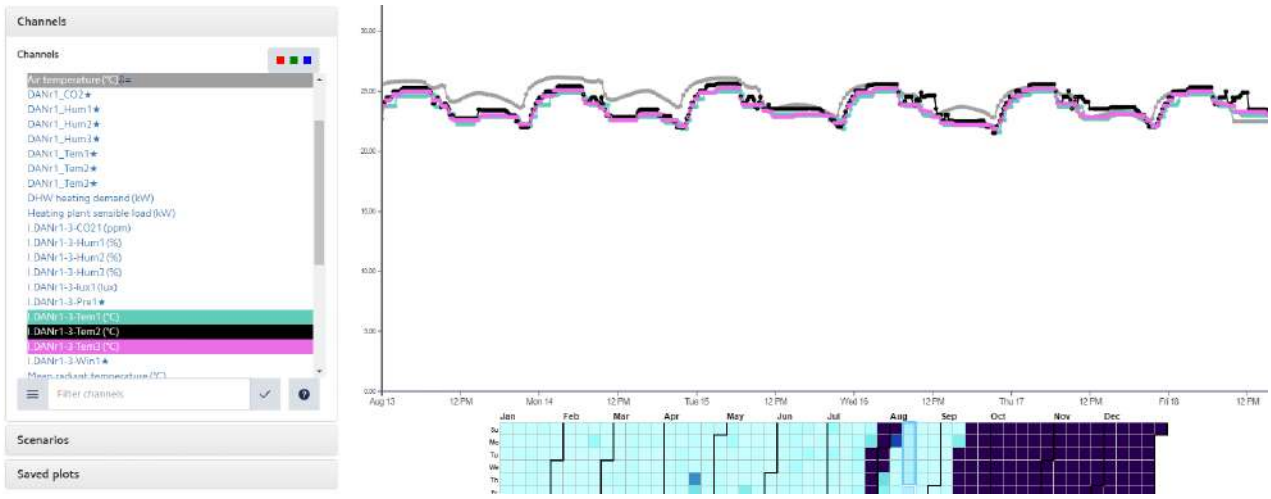


Figure 78: Simulated vs Measured air temperature in Dance and movement activities room in Sant Cugat demo site

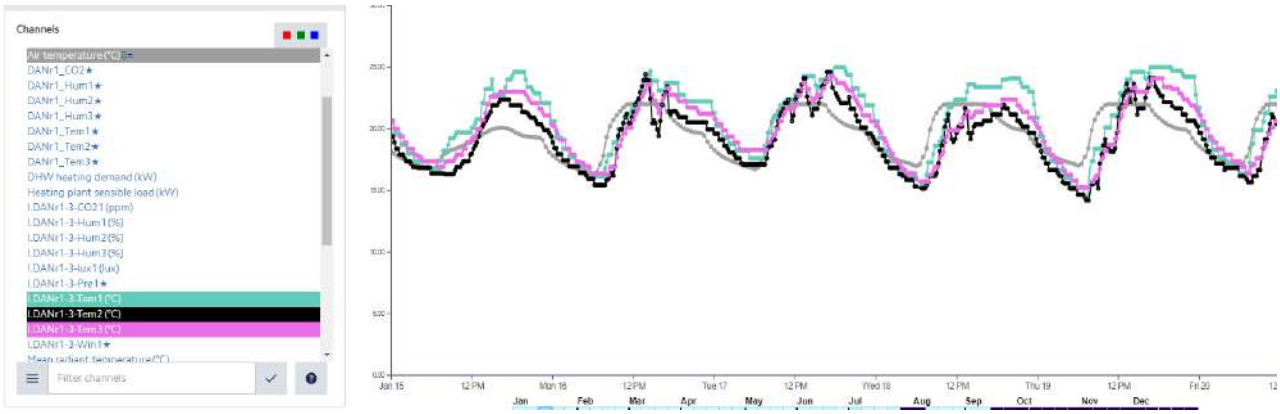


Figure 79: Simulated vs Measured air temperature in Dance and movement activities room in Sant Cugat demo site

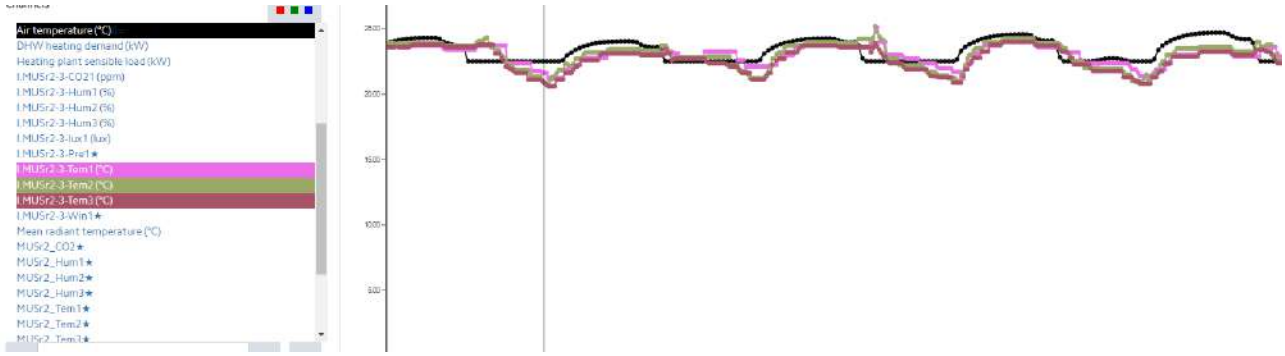


Figure 80: Simulated vs Measured air temperature in Music classroom in Sant Cugat demo site

5.1.1.1 2nd calibration

After the validation study and data collection throughout January and July 2023 the calibration of the Sant Cugat model was found inaccurate and had to be recalibrated. A new weather file for the year 2022 was used.

The model was re-calibrated for air temperature using a semi-automated calibration procedure developed by IES, mainly funded by the EU funded R&D project iBECOME[8], which is more systematic, efficient and consistent than the manual, trial and error, approach to calibration more frequently used in the industry. The automated calibration was based on a Genetic algorithm, each iteration (generation) a set of simulations (population) is created, through a competition between the different subjects of the population, the algorithm selects the ones that fit best with the objective, and then generates a new population for the next generation with the best subjects and new random ones. The calibration was based on the hourly air temperature time series obtained from sensors in 10 rooms.

Due to the ideal system used with infinite or oversized heating and cooling capacities, any combination of internal gains and air exchanges in the calibration algorithm, could produce a close match with the measured data, alongside the heating or cooling load from the ideal system. Therefore, the internal gains and air exchanges were calibrated using measured data from a period without heating or cooling between mid-April 2023 to mid-May 2023. These calibrations consisted of populations of 256 simulations and 128 generations. The results of the statistical indices RMSE & MAE of the calibrations for each room are shown in Table [].

Subsequently, the heating and cooling setpoints used by the system were calibrated using measured air temperature data from January 2023 and July 2023. These calibrations consisted of populations of 128 simulations and 64 generations. The results of the statistical indices RMSE & MAE for each room are shown in Table [] and Table[].

The results of the statistical indices of the calibrations for each of the rooms are summarized in Table 19, Table 20, Table 21.

Table 19: Calibration metrics for April-May 2023 period

Room	RMSE	MAE
Assembly hall	3.30	2.86
Dance room	2.11	1.67
Dance room 2	2.71	2.31
Direction office	2.81	2.50
Exhibition room	2.30	1.82

[8] https://cordis.europa.eu/project/id/894617

Local entities - Taller Petit	2.52	2.22
Music classrooms 1	2.15	1.84
Music classrooms 2	1.86	1.51
Warehouse	2.26	1.80
Workshop classroom	1.59	1.24

Table 20: Calibration metrics for January 2023

Room	RMSE	MAE
Assembly hall	3.85	3.22
Dance room	2.70	2.12
Dance room 2	2.67	2.01
Direction office	2.76	2.32
Exhibition room	2.37	1.83
Local entities - Taller Petit	1.93	1.46
Music classrooms 1	2.73	2.32
Music classrooms 2	2.68	2.32
Warehouse	3.35	2.78
Workshop classroom	1.71	1.31

Table 21: Calibration metrics for July 2023

Room	RMSE	MAE
Assembly hall	1.23	1.02
Dance room	1.15	0.83
Dance room 2	1.34	1.09
Direction office	1.35	1.13
Exhibition room	2.12	1.90
Local entities - Taller Petit	1.15	0.94
Music classrooms 1	1.64	1.41
Music classrooms 2	2.56	1.64
Warehouse	1.49	1.26
Workshop classroom	1.11	0.92

Errors for the above tables are in the range of 2 °C, which is acceptable according to CIBSE TM63: 2020. Humidity control has been set between 20% and 80 % to match sensor data.

Energy calibrations were not performed due to lack of availability and clarity on energy meter data and not required for the hybrid controller.

Internal Gains and Occupancy

lighting gains were initially set at 5 W/m^2 for all room, for the re-calibration, the lighting gains of each room was individually calibrated, with the results shown in the table below.

Table 22: Lighting gains

Room	Power density / Total power (W/m^2)
Assembly hall	5.3
Dance room	7.4
Dance room 2	6.1
Direction office	7.0
Exhibition room	5.3
Local entities - Taller Petit	3.0
Music classrooms 1	3.6
Music classrooms 2	6.8
Warehouse	4.0
Workshop classroom	5.5

Occupancy sensible and latent heat gains per person were considered as per ASHRAE Fundamentals Handbook values depending on the type of room, while the number of occupants for each room was an input of the calibration algorithm. The range for the search space for each room was bound by the data from the occupancy survey.

Table 23: Occupancy

Room	Number of occupants
Assembly hall	50.8
Dance room	9.2
Dance room 2	6.3
Direction office	1.8
Exhibition room	9.6
Local entities - Taller Petit	3.9
Music classrooms 1	3.0

Music classrooms 2	2.9
Warehouse	19.0
Workshop classroom	6.8

Air exchanges

The initial values for mechanical ventilation were calculated based on ASHRAE guidelines Ventilation for Acceptable Indoor Air Quality ANSI/ASHRAE Standard 62.1 for the evaluation of both occupancy and ventilation rates required for the spaces in the buildings.

Air exchanges in the form of natural and mechanical ventilation rates were considered individually for each room, mechanical ventilation was considered to operate between 7:00 to 23:00, while natural ventilation schedules were obtained from window sensor data. Most room had windows constantly open or constantly closed, with the exception of the Assembly hall which was closed during winter and was then changed to open mid-March.

The values for natural ventilation are very low despite window sensors indicating open windows.

Values for mechanical ventilation were consistently calibrated by the algorithm at the lower end of the search space range, this might indicate the values are actually lower than the calibrated ones, however, they were kept at a reasonable value below the ASHRAE standards they were initially set for.

Table 24: Ventilation rates

Room	Mechanical ventilation rate (ACH)	Natural ventilation rate (ACH)
Assembly hall	2.74	0.14
Dance room	1.65	0.19
Dance room 2	1.52	0.06
Direction office	1.02	0.16
Exhibition room	2.26	0.02
Local entities - Taller Petit	1.60	-
Music classrooms 1	1.73	-
Music classrooms 2	1.77	-
Warehouse	2.77	0.04
Workshop classroom	1.66	0.02

Building Envelope

No changes were made to the U values from the initial model.

Table 25: Baseline Building constructions

Surface Description	U-Value (W/m². K)	G-value

Roof	0.33	-
External Wall	0.25	-
External Windows	1.9	0.4
Internal Ceiling/Floor	3.85	-
Internal Partition	1.05	-
Door	2.20	-
Exposed Floor	0.22	-

Set-points

Heating and cooling setpoints were calibrated using air temperature data for January and July respectively. The setpoints were considered the same for the all the rooms, heating setpoint was set at 19.5 °C, and the cooling setpoint at 25.3 °C.

System Schedules

System schedules were changed to better match available heat meter data. Figure below shows the overlaid reading of all the days in January 2023 with a dotted line of the mean values, indicating a heating schedule between 7:00 and 23:00. Figure shows the same for July 2023 indicating a cooling schedule between 6:00 and 22:00.

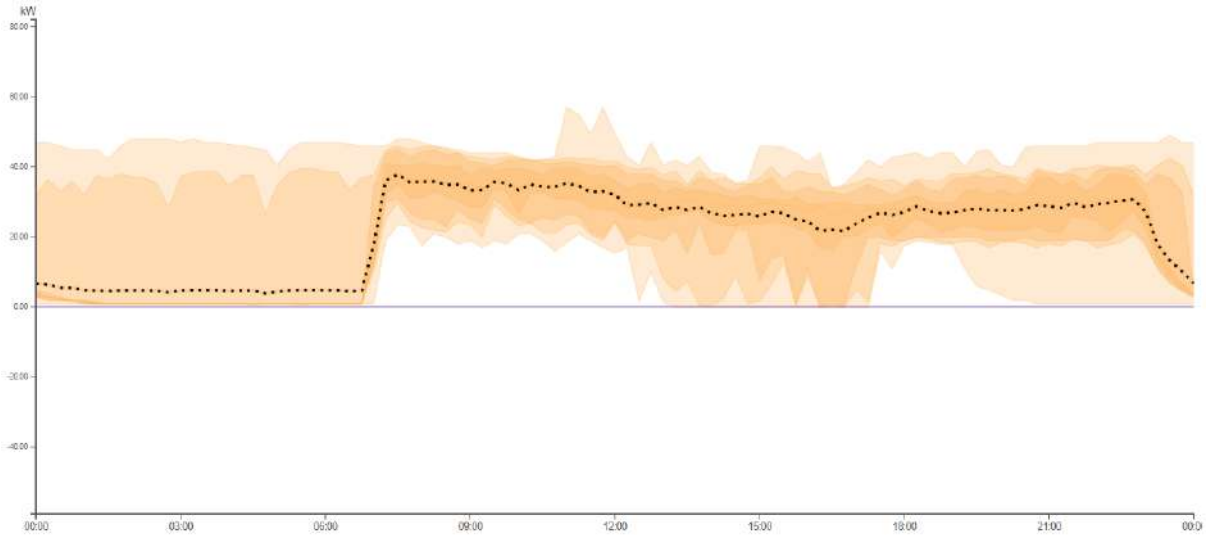


Figure 81: Heat meter data January 2023

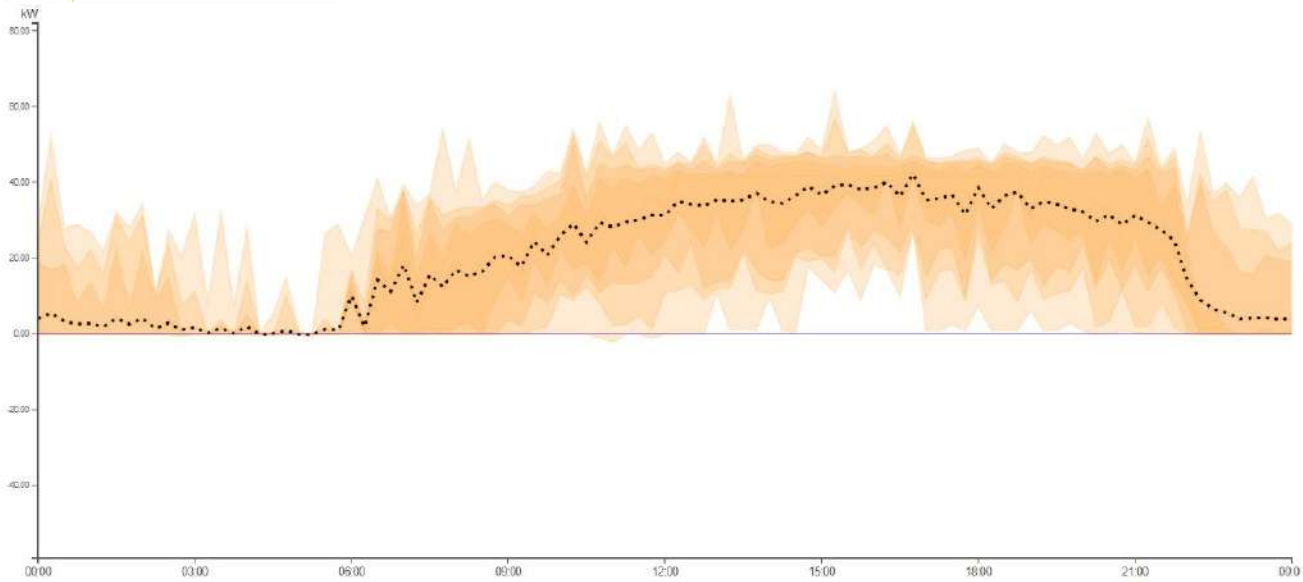


Figure 82: Heat meter data July 2023

Figure below shows overlaid data for July for the example of the assembly room measured air temperature (red) plotted against the dry bulb temperature outside (blue). The cooling operating hours can be noted from the chart. The apparent cooling setpoint from the plot seems to be lower than the calibrated value, this is because the calibrated value is the same across all rooms, while the plot is only for the assembly room. It can also be noted that the temperature of the building is higher than the outside temperature at night time, this provides an opportunity to open some windows and introduce some natural ventilation to cool down the building overnight, minimizing the load on the cooling system. The example of only one room is shown below for simplicity, but all other rooms with available data have similar plots (with slightly varying apparent cooling setpoints).

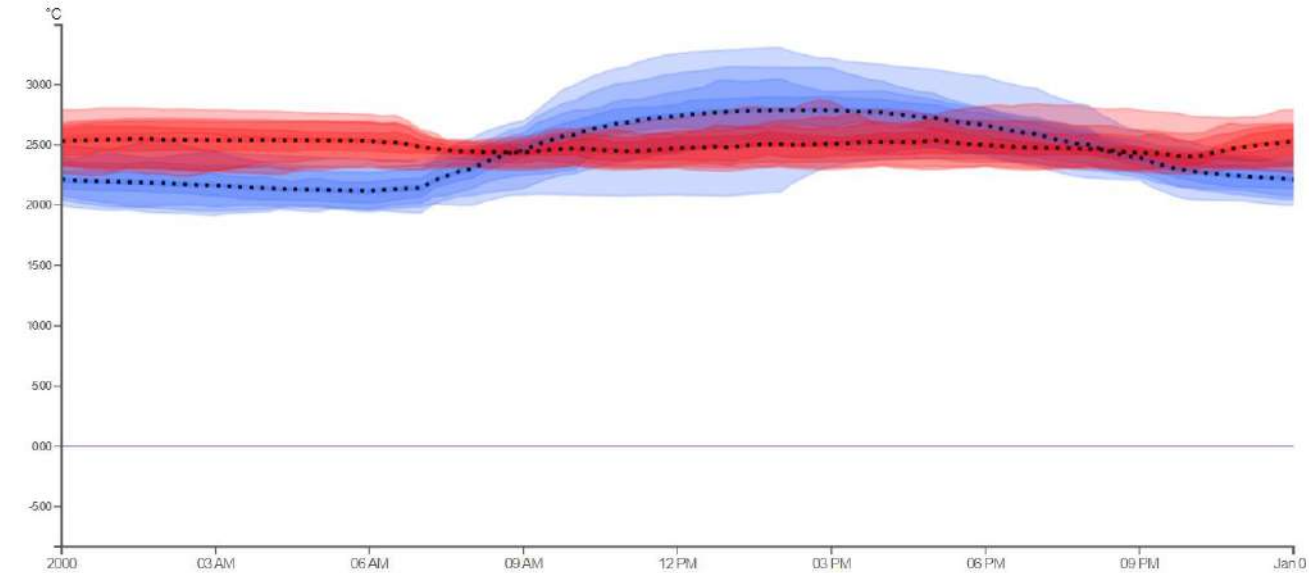


Figure 83: assembly room measured air temperature (red) plotted against the dry bulb temperature outside (blue)

Heating season was set between mid-November to mid-April, while cooling season was set between mid-May to mid-October. With no data beyond July 2023 as of the writing of this report, the end of the cooling season time period is speculative.

Figure below shows the overlaid heat meter data from mid-April to mid-May 2023 (period used for internal gains calibration), showing no significant use of the system during that period.

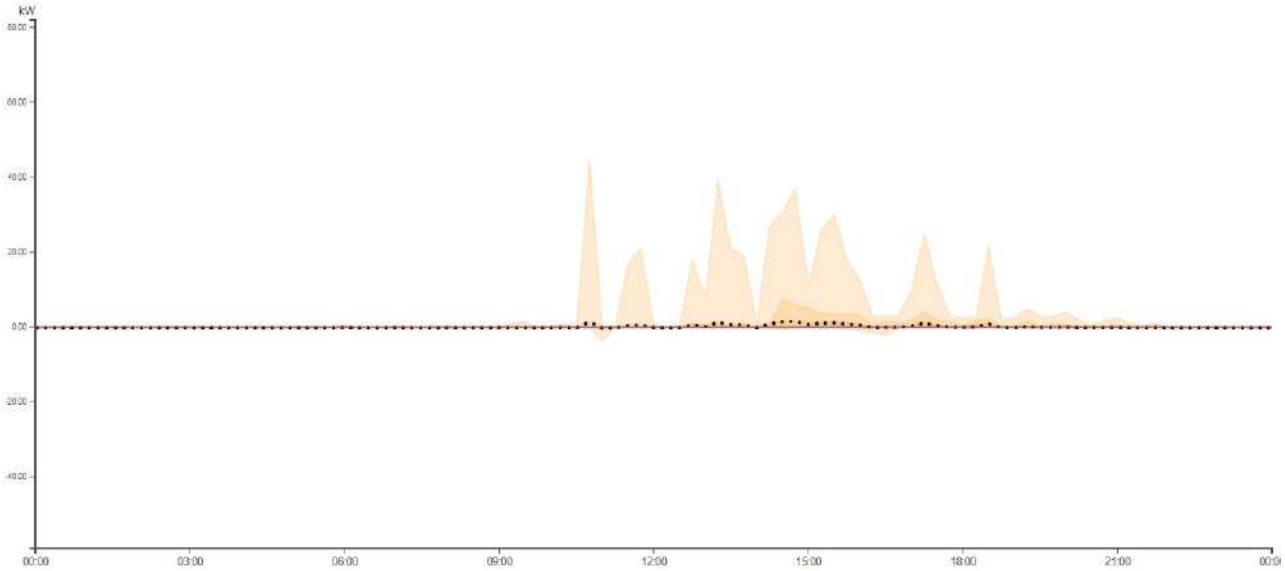


Figure 84: Heat meter data April-May 2023

Internal gains & occupancy schedules were obtained from presence detector data, Table 26 summarises the occupancy schedules for all the rooms. Weekends have been left unoccupied in the model due to low occupancy levels from sensor data.

Table 26: Occupancy schedules

Room	Start time	Break	End time
Assembly hall	7:00	-	17:00
Dance room	8:00	-	17:00
Dance room 2*	9:00	15:00 – 18:00	23:00
Direction office	9:00	-	15:00
Exhibition room	9:00	15:00 – 16:00	22:00
Local entities - Taller Petit	10:00	-	15:00
Music classrooms 1**	9:00	13:00 – 16:00	21:00
Music classrooms 2**	17:00	-	23:00
Warehouse	8:00	-	16:00
Workshop classroom	9:00	15:00 – 16:00	22:00

** Only winter occupied*

*** unoccupied summer*

Figure 85 shows an overlay of presence detector data for the period from January to August for the example of the workshop room,

It should be noted that the number of occupants is not represented on the y-axis, it is a discrete value of either 4 for no occupancy detected or 5 for detection of occupants.

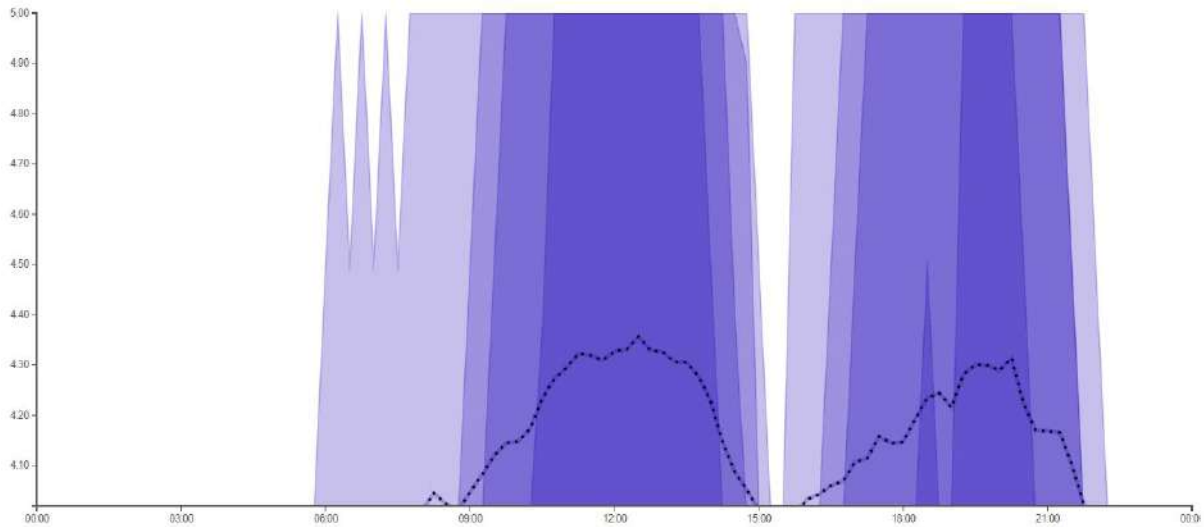


Figure 85: Presence detector data workshop room January – August 2023

5.2 Enterprise Server-ISCAN connection validation

The enterprise server-iscan connection was validated for the integrations performed as part of WP5 and checked for data gaps in the automated data integration.

Data gap means that there is an integration error between Enterprise Server and iSCAN. The table below and screenshot show the percentage and hours of data gaps recorded in iSCAN throughout 2021-2022 and 2023, where the connections are established for the 4 demo sites:

Table 27: Data gaps in all demo sites since 2021

	Sant Cugat	Riga Sunisi	Riga Imanta	Madrid
% of data gap in 2021	0.85%	23.33%		
Hours of data gap in 2021	52/ 6240h	2044/8760h		
% of data gap in 2022	0.16%	1.33%		
Hours of data gap in 2022	14/8760h	117/8760h		
% of data gap in 2023	0.41%	13.56%	23%	20.14%
Hours of data gap in 2023	27/6552h	889/6552h	860/3744h	1107/5496h
% of data gap in September 2023	0%	9.48%	2.35%	6.75%

Hours of data gap in September 2023	0%	69/720h	17h / 720h	48.5/720h

As seen in the table above, the most stable connection was established for Sant Cugat demo site. The percentage data gaps are lower than 1% at all times, and in the final control validation month the gap 0%.

In Riga Sunisi, the most robust connection was during 2022 with 1.33% of time with connection failure, and less than 10% in September 2023. In Riga Imanta, the improvement between 2023 and the last month of the project is remarkable, going down from 23% to 2.35% of integration failure. Finally, data disconnection in Madrid for 2023 is 20.14%, while dropped to 6.75% in September 2023.

Alarms are set up to warn users with an email whenever there is a data gap more than 24h long.

Figure 86: Alarm library in Madrid demo site

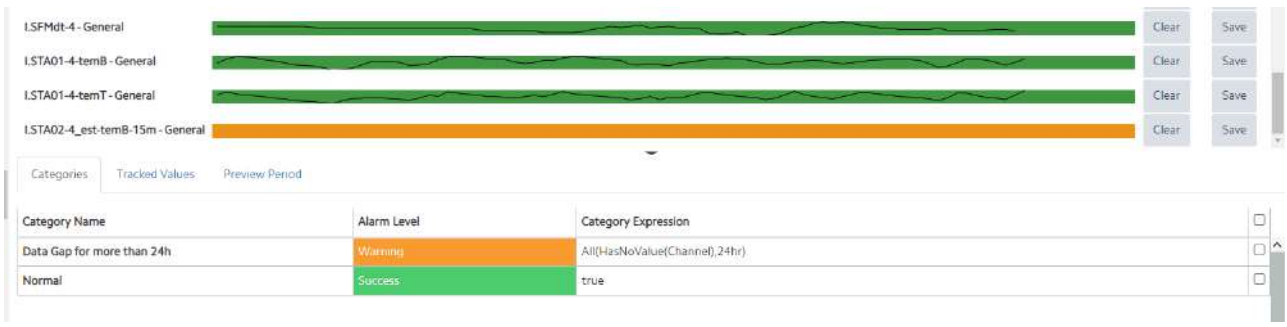


Figure 87: Data gap alarm in Madrid demo site

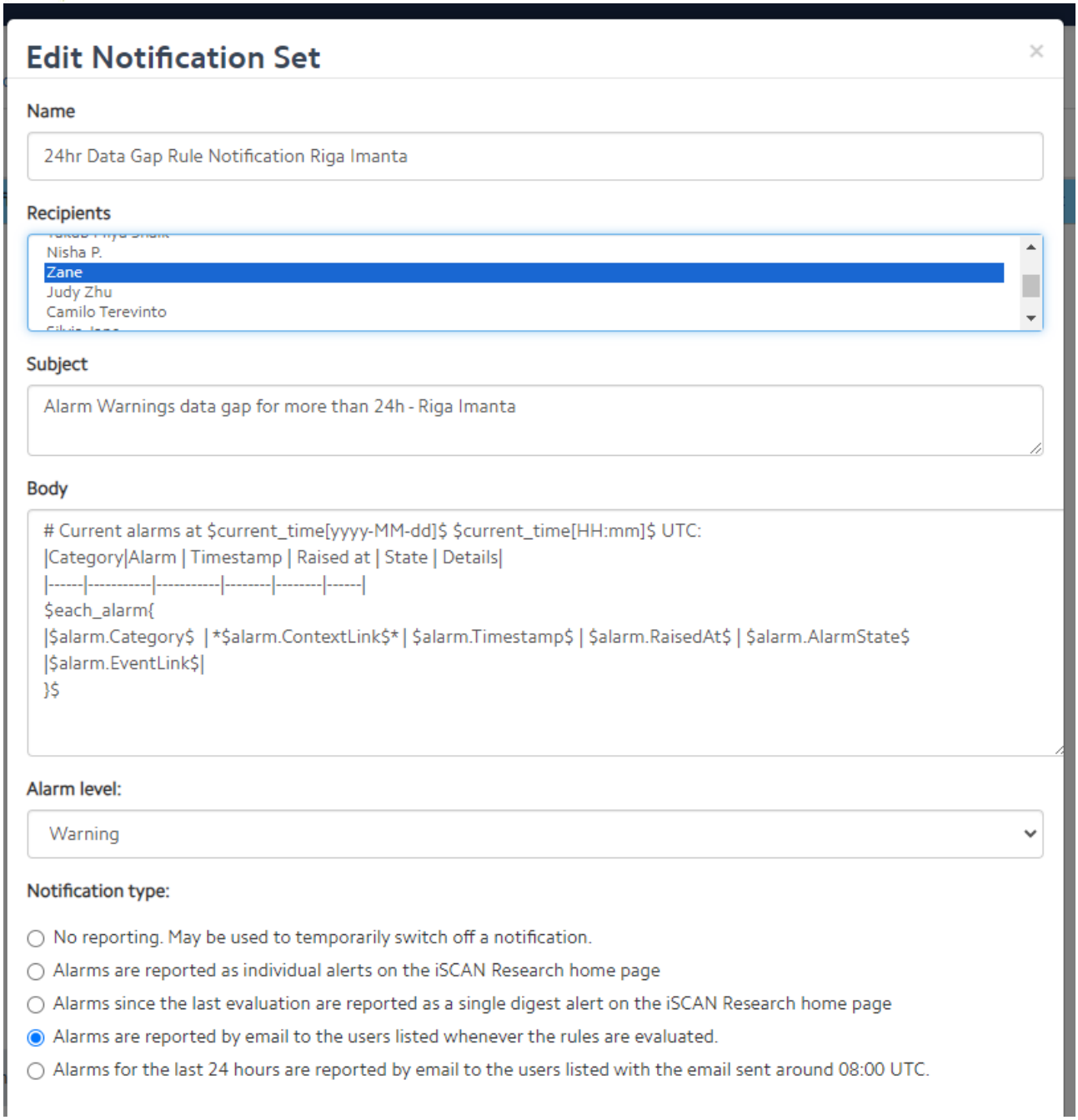


Figure 88: Email notification triggered by alarm in Madrid demo site

5.3 Feedback APP-ISCAN connection validation

The image below shows a feedback messages way from app to ISCAN

- Step 1 - App: Selecting the Feedback view in the app (assuming the user is logged in)
- Step 2 - App: Selecting a room in Sant Cugat, in this case *Taller 1*
- Step 3 - App: Send feedback on temperature,
- Step 4 - App: Verification that feedback message was sent
- Step 5 - ISCAN: Selecting import log for *Checkwatt_San_Cugat_Import* in ISCAN portal
- Step 6 – ISCAN: Downloading the latest message

- Step 7 – ISCAN: View message, *bt* shows the timestamp in Unix format, *v* shows the temperature value in a numeric format (-3 = too cold, 0 = comfortable, 3 = too hot) and *n* is a reference to the room this feedback was made from, in our case *Taller 1*.

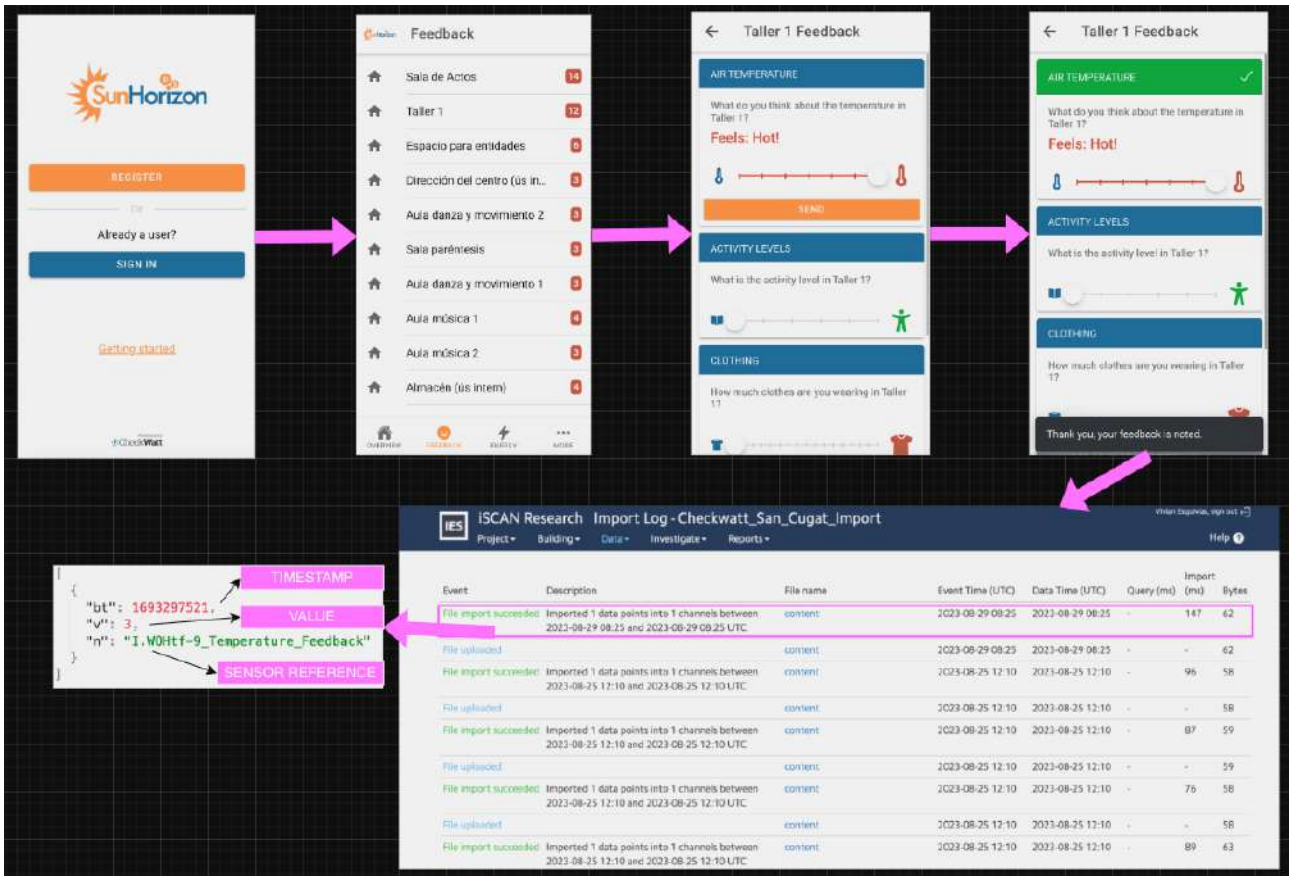


Figure 89: Feedback messages sent to ISCAN from the SunHorizon app.

The app has unfortunately not been used as much as we hoped, the image below shows the number of feedback messages sent from the app to ISCAN and there are 2 time periods that stand out *Dec 2021 – Feb 2022* and *Oct 2022 – Nov 2022*. Mars 2023 are mainly test-messages made during the integration of Sant Cugat.

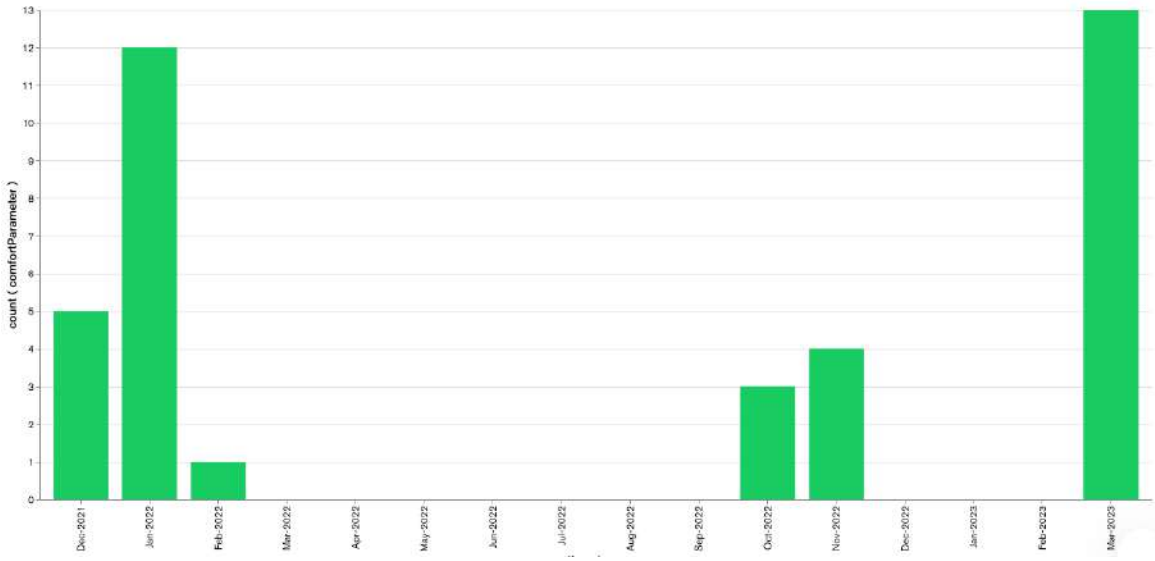


Figure 90: Number of feedback messages sent to ISCAN from the app

5.4 Self-Learning Modules validation

The data gap and short term prediction module was tested and validated 267 times in Sant Cugat for temperature sensor I.HALlr-3-Tem1. Returned success (accurate prediction) 266 times, and warning 1 time.

Figure 91: The warning received in short term prediction for I.HALlr-3-Tem1 I.HALlr-3-Tem1 sensor

The comfort forecast tool was validated for room civic centre direction office in Mirasol Sunhorizon project for the previous day, current day and the next 30 minutes (this way we overwrite the forecast with actual data from the sensor), capturing temperature from "I.OFFcr-3-Tem1", taking into account short term prediction from above and assuming the following:

- Mean radiant temperature = I.OFFcr-3-Tem1
- Air speed 0.1 m/s
- Metabolic rate: 1.1
- Clothing insulation 0.5

Limitation: the self-learning model only calculates integers

PMV calculation was compared against Self learning comfort calculation for a dataset of 1430 points. In 721 occasions the two models agree in the comfort calculation. Also, there is discrepancy comparing against the free CBE tool[9], as seen in the screenshots below.

[9] https://comfort.cbe.berkeley.edu/

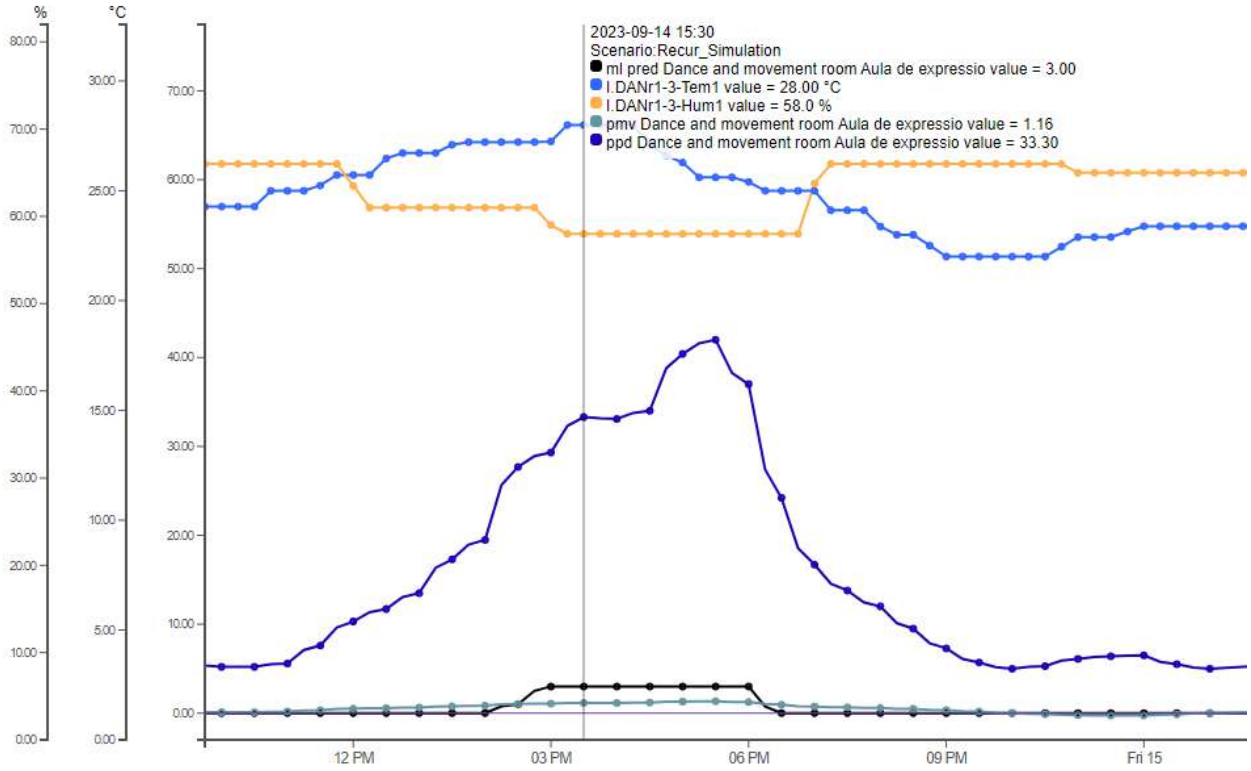


Figure 92: Dance and movement room – comparison of comfort calculation between Self Learning (black) against PMV (green), also display of temperature (blue), humidity (yellow) and PPD(purple)

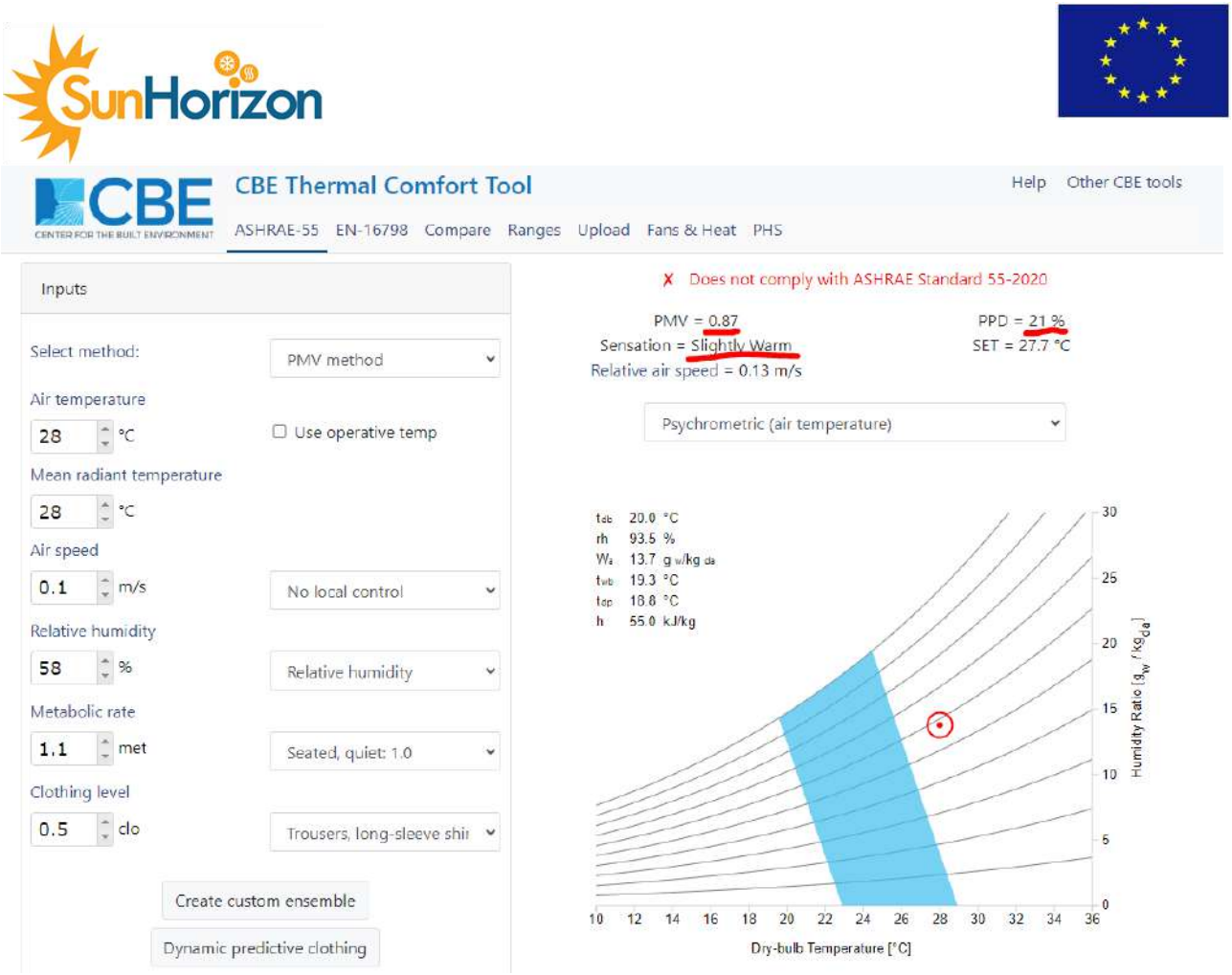


Figure 93: Calculation of Figure 92 conditions in CBE tool

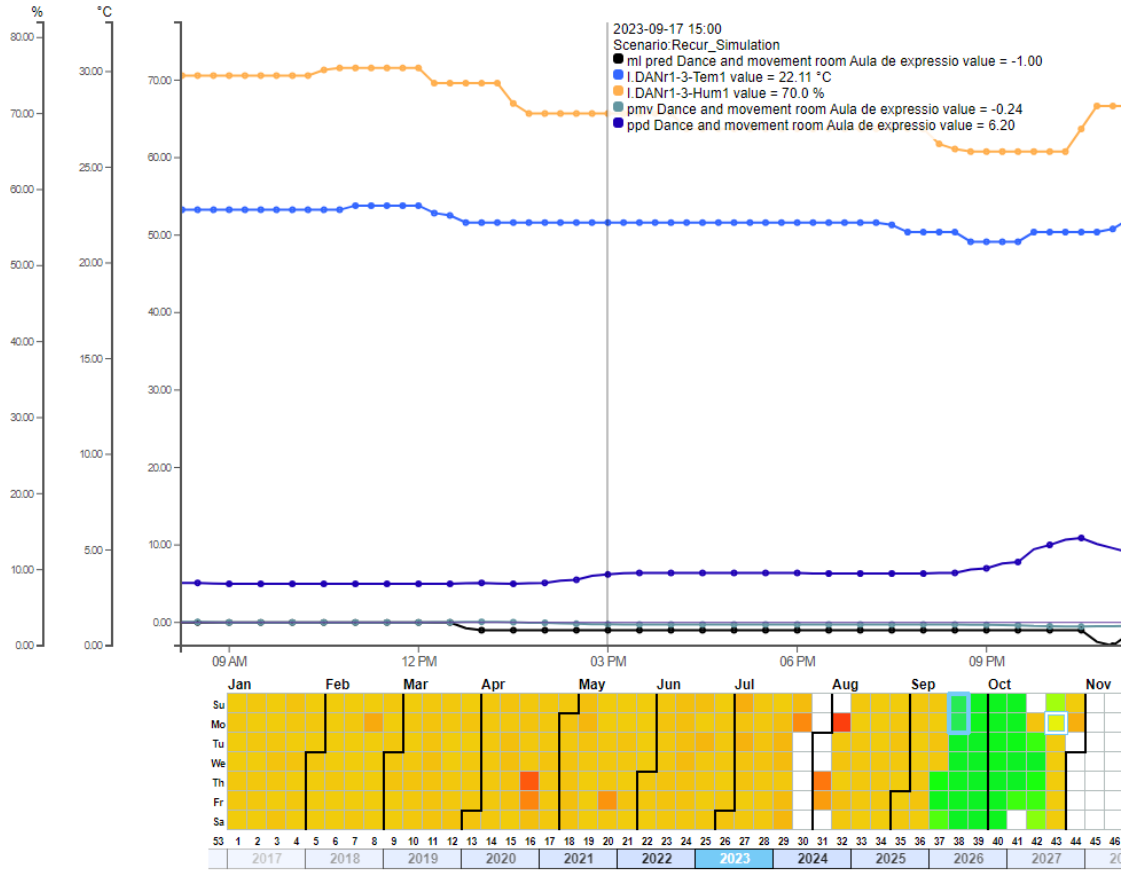


Figure 94: Dance and movement room – comparison of comfort calculation between Self Learning (black) against PMV (green), also display of temperature (blue), humidity (yellow) and PPD(purple)

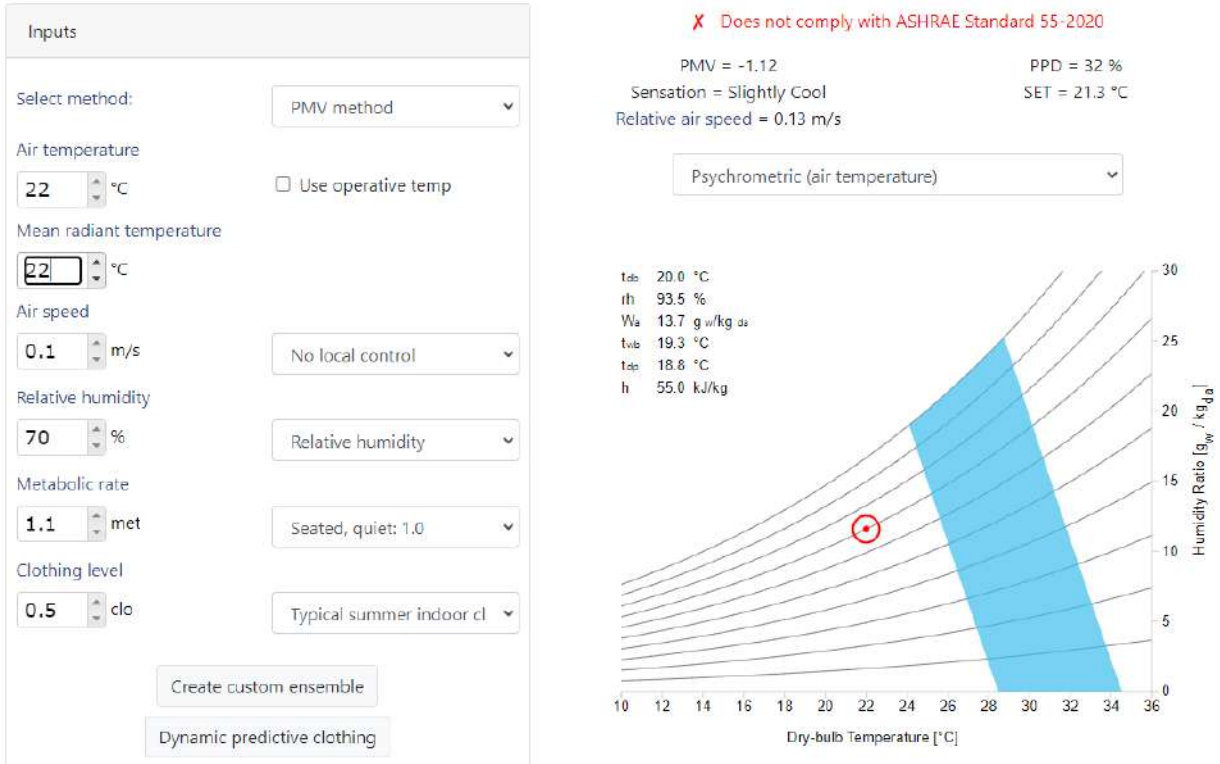


Figure 95: Calculation of Figure 94conditions in CBE tool

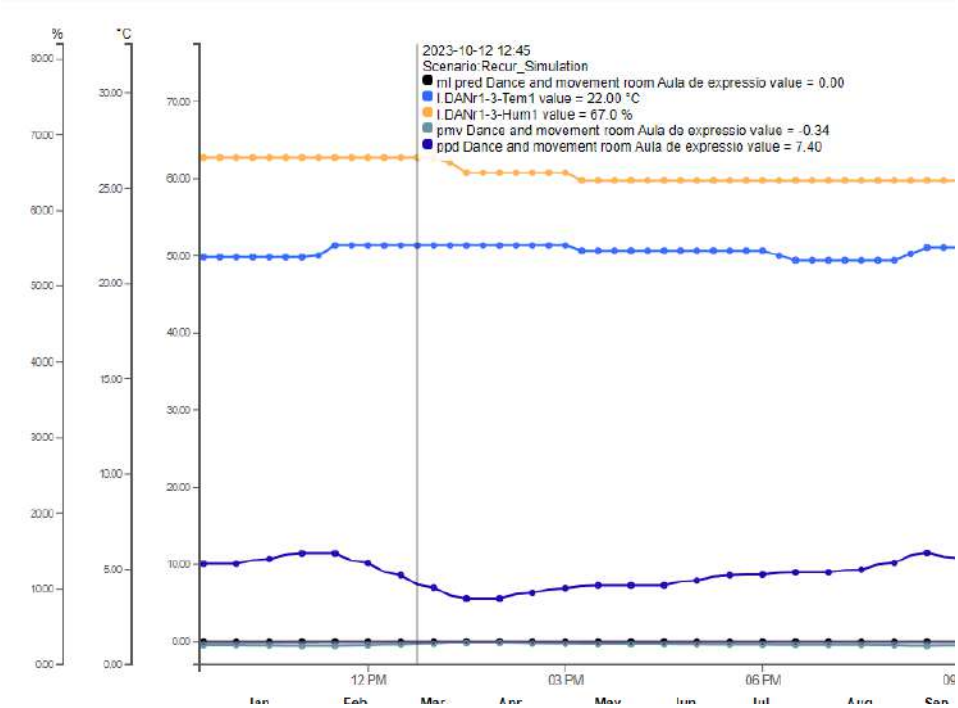


Figure 96: Dance and movement room – comparison of comfort calculation between Self Learning (black) against PMV (green), also display of temperature (blue), humidity (yellow) and PPD(purple)

5.5 Validation and demonstration of hybrid controller strategies in a real case(CAR)

Since it was discussed in section 4.5, the hybrid controller has been validated in Sant Cugat demo-site under the controller rules displayed and commented in section 4.5.2. The hybrid controller has to find out the best control strategy in order to satisfy the objective function implemented, which in this case is related with the minimisation of the cost system, for the next 24 hours with an hourly time step.

The strategy achieved by the hybrid controller has to be uploaded to iSCAN platform, which show the evolution of these variables displayed in Figure 97, and also integrated in the Schneider platform in order to get a faster response between the hybrid controller hosted on a cloud server, Table 11, and the PLC located in the real demonstrator. The control variables, which in case of Sant Cugat are set-points to introduce in the local PLC, to be calculated by the hybrid controller are; the TVP collector outlet temperature setpoint (I.SPTtvp-3), the supply temperature to the building (I.SPTex-3) through the exchanger control,), and depends on the season could be the FAHR cold tank temperature setpoint (I.SPTct-3) in summer or the return temperature setpoint for SH system (I.SPTdiv-3). Finally, the *Watchdog* binary variable (I.EHCwd-3) indicates whether the hybrid controller is running on the actual demonstrator (1) or whether the hybrid controller is off (0). The Figure 97 shows the evolution of these variables in a real case from the iSCAN platform.

Figure 97: Hybrid controller variables in a real scenario

The red line is the current time, 21/09/23 at 2023, and it divides two sections in the graph: the past results in the left and the future strategy in the right side. As can be seen in the figure, the past sections show results with a lowest variation in comparation with the future sections, it is due to the future predictions are under uncertainty and the closer it is to the current instant the more accurate and acceptable the calculated strategy would be. However, although the hybrid controller reported a worst results in the past due to it gave a quickly response and remarkable variation between two time steps, which could lead to failure of the real equipment, the hybrid controller working with real data reported a more realistic response as the Figure 98 shows, where the variations in the setpoint are not as pronounced as in the past.

Figure 98: Hybrid controller results comparation

In order to do the hybrid controller validation and compare it with the local controller to obtain a result about the control strategy followed by each controller, only October 2023 was acceptable and available to do it. October was considered to do the validation due to the data availability and quality in the demonstrator, where some actions are reported in D6.7 and D6.5. Then to compare both controllers, and taking into account some IES updates carried out in the middle of the October (Figure 99), only 13 days were used to compare both but with the following figures the system is compared in its entirety. The beginning of the month the hybrid controller was working, while at the end of the month it switched to the local PLC.

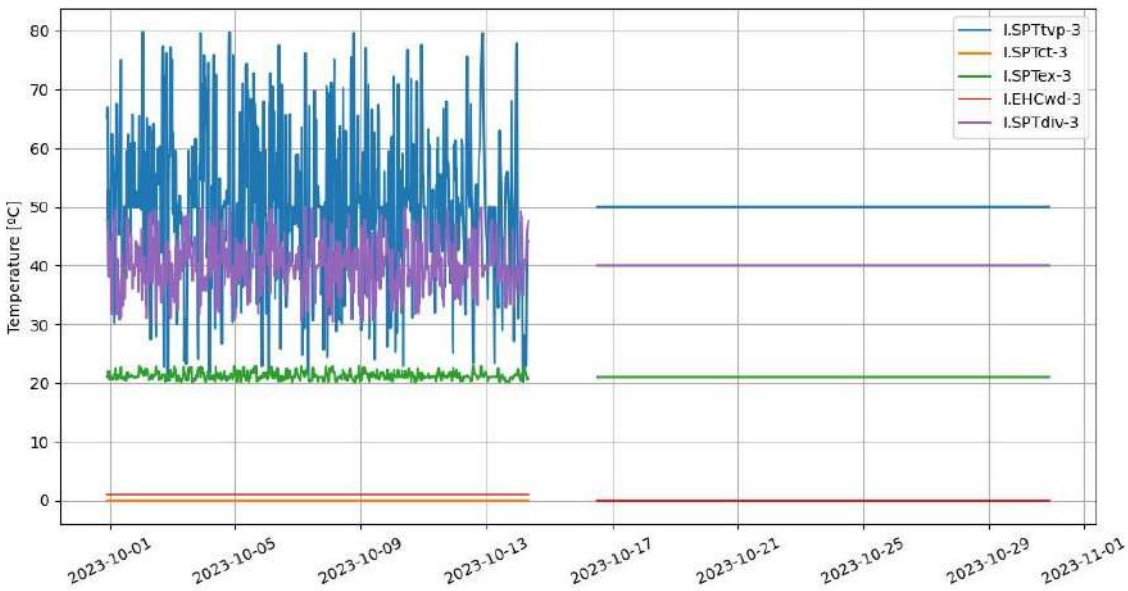


Figure 99: Hybrid controller responses in October

The validation has been done under two perspectives: The costs related to the system and the use of the technologies integrated in the current demonstrator. To cover the system costs validation, the comparation between different channels about the system costs are done, such as: K.CBRsy-3, I.CELbs-3 and I.CELpr-3, where their equations and definitions are discussed in D2.4.

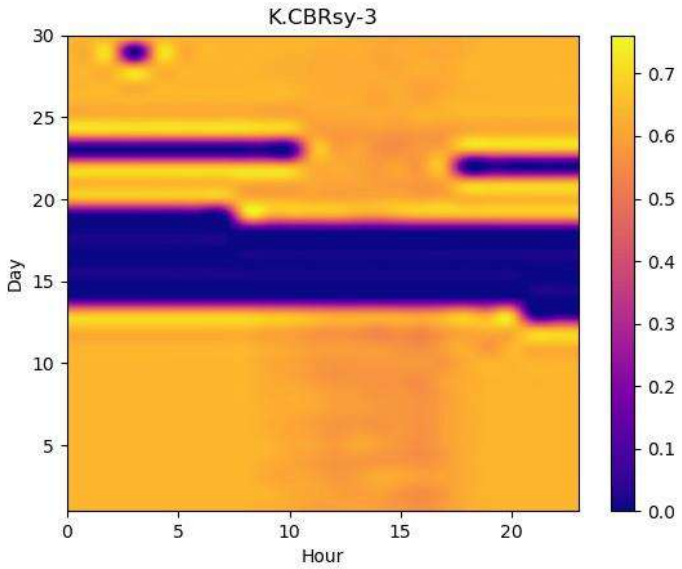


Figure 100: Costumer's bills reduction in October

The Figure 100, which is a heatmap graph, represents the costumer's bill reduction (K.CBRsy-3) during the month of October, where it can be seen that in the midday hours there is a smaller reduction of the bill due to electricity costs. The vertical axis is the day, the horizontal is the month and the intersection of both is the value of the bill reduction associated with a colour legend represented in the right side of the figure. Although the purple colour could be considered, these values are gaps found in the month due to software updates and unforeseen failures during the real test. The Figure 101 represent the electricity cost of the system (I.CELpr-3) where in the beginning of the month, where the hybrid controlled was operating, there was more electricity cost than in the final, where the local PLC worked.

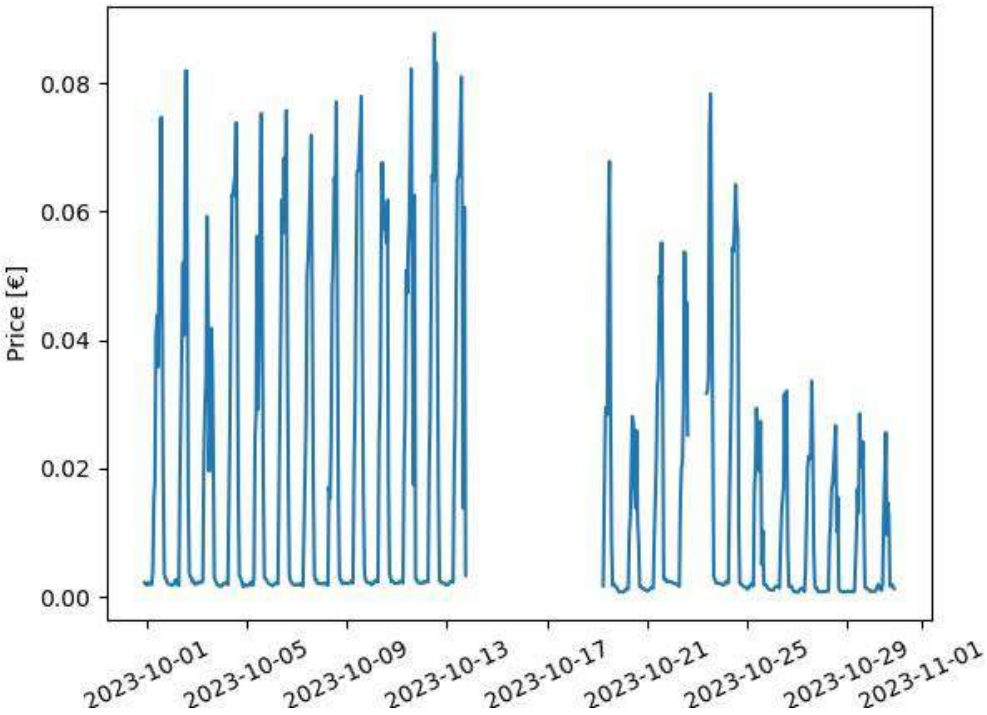


Figure 101: Electricity costs by the system in October

However, these electricity price can be affected by other factors such as the spot price. The Figure 102 shows a comparation between the spot price (€/Mwh) in blue colour and the electricity costs indicator (I.CELpr-3) discussed above in green. Unfortunately, the electricity price was more expensive at the beginning of the month than at the end of the month, thus affecting the validation of the controller. To do a better validation, at least one year of validation would be necessary to avoid these scenarios and to obtain a fair balance.

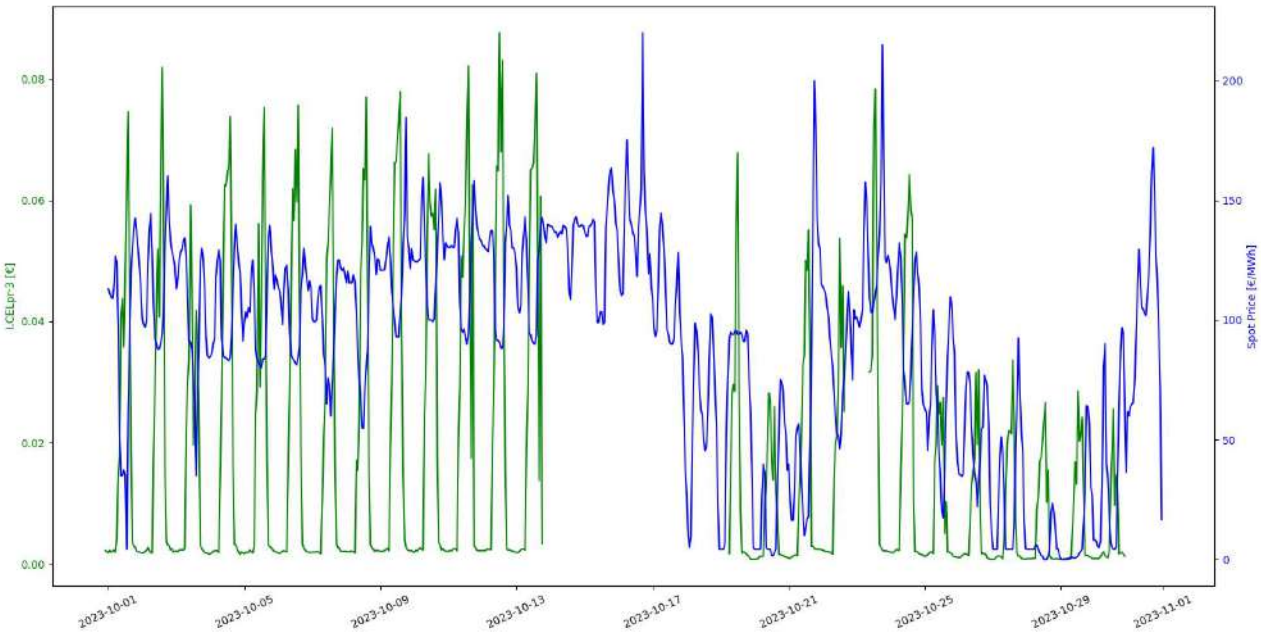


Figure 102: Electricity costs vs Spot price

On the other hand, and focusing on the use of the renewables technologies in the demonstrator, the indicators selected to the validation are: the TVP thermal power output (I.QFTvp-3), the building mean temperature (I.BUMdt-3) and the Ratiotherm tank stratification (P.RATdt-A-3-15m). The Figure 103 shows the I.QFTvp-3.

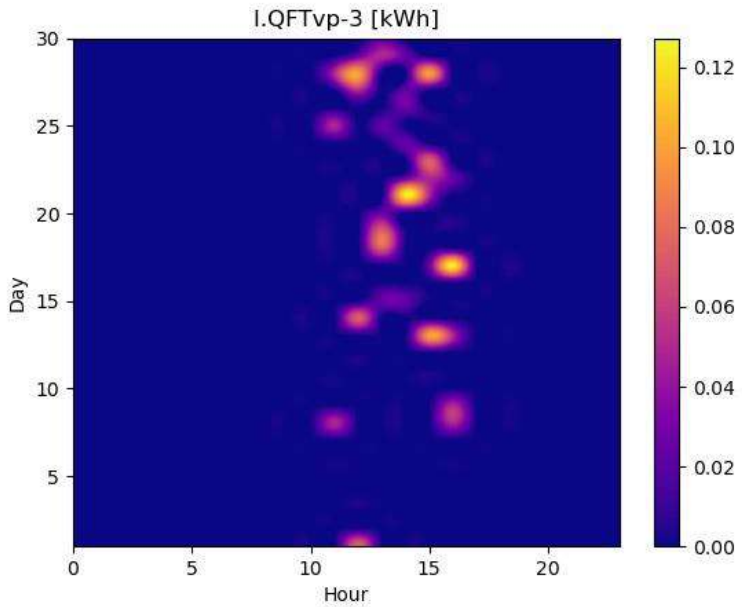


Figure 103: TVP thermal power output

The indicators show that, in October, the TVP generated significantly more thermal energy at the end of month than in at the beginning of the month according to the hybrid controller decisions. May could be due to the hybrid controller

decided to lower the TVP set point because the thermal tank was hot enough as can be seen in Figure 104 through the P.RATdt-A-3-15m indicator.

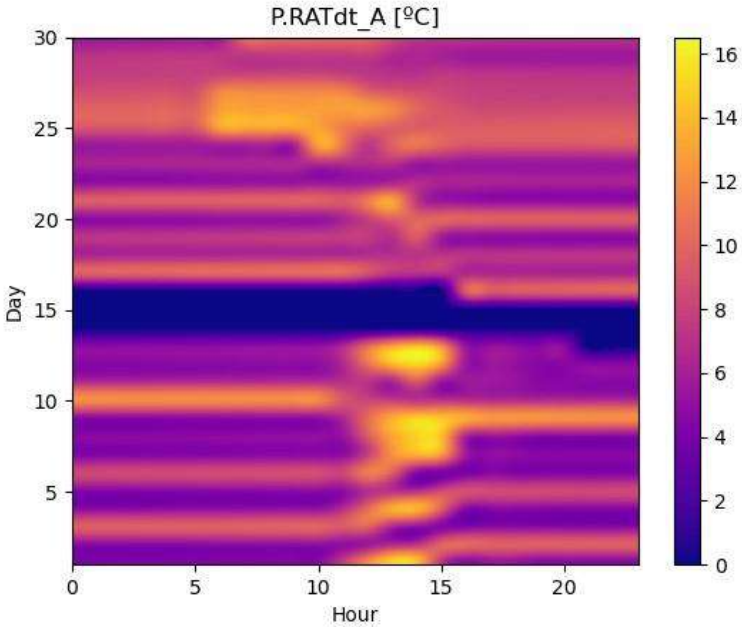


Figure 104: Ratiotherm tank A stratification efficiency

The hybrid controller has been decided centralised the tank heat during the midday hours in order to save energy and thus electricity cost, which is subject to the spot price. The hybrid controller also decided to store energy during the midday and expend it on the rest of the time because of the building temperature remains during that the time. However, the building temperature is more dynamically variable at the end of the month due to the local PLC decisions, as the Figure 105 shown.

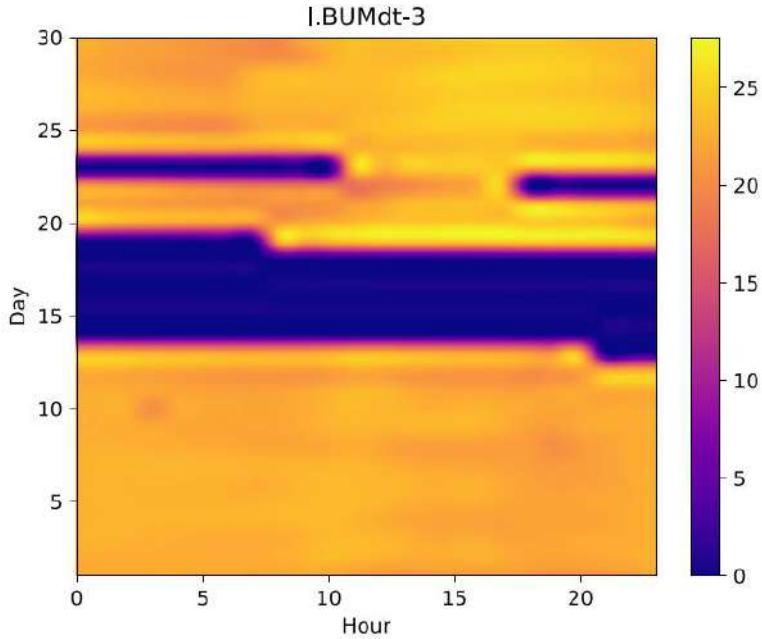


Figure 105: Building mean temperature

6 Dashboard integration for Type B demo sites

The following integrations where fully achieved and automated for the demo sites of Madrid and Imanta (follow-up work from WP4), to allow the full deployment of the Monitoring Platform (dashboard) to allow demonstration and KPI calculation in WP6:

3. Sensor/Meter Data – [Automated] Integration between field level equipment and Smart Connector via MQTT connection. This is a standard practice by Schneider Electric (performed in WP4)

4. Sensor/Meter Data – [Automated] Integration between Smart Connector and iSCAN via REST API. A new web hook has been developed to allow the integration. (performed in WP4)

19. Real data from sensors and meters are posted to the hybrid control and proactive/predictive maintenance modules using iSCAN-API to enable control and KPIs calculations

21. KPIs from proactive/predictive maintenance modules to iSCAN [Automated] – Scheduled periodically to transmit the KPIs to iSCAN once calculated

28. Sensor/Meter data from iSCAN to dashboard [Automated] – Data selected by demo site leaders are transmitted from iSCAN to the dashboard every 15 minutes and plotted in selected visualisations by demo site leaders

30.Fault detection and KPIs from iSCAN to dashboard [Automated] – Fault detection such as data gaps, and the KPIs of the project are integrated with iSCAN and displayed in the dashboard

31.32. Sensor Meter Data, KPIs and alerts displayed to the end user to enable:

a.Monitoring of energy and indoor environmental quality

b. Decision making based on minimising energy use and maximising comfort

c.Encourage the necessary maintenance required in building devices

d.Deploy optimised setpoints if needed

Below is the integration for Type B demo sites graphically depicted, with green colour the fully automated integrations to enable KPI calculations and dashboards for monitoring.

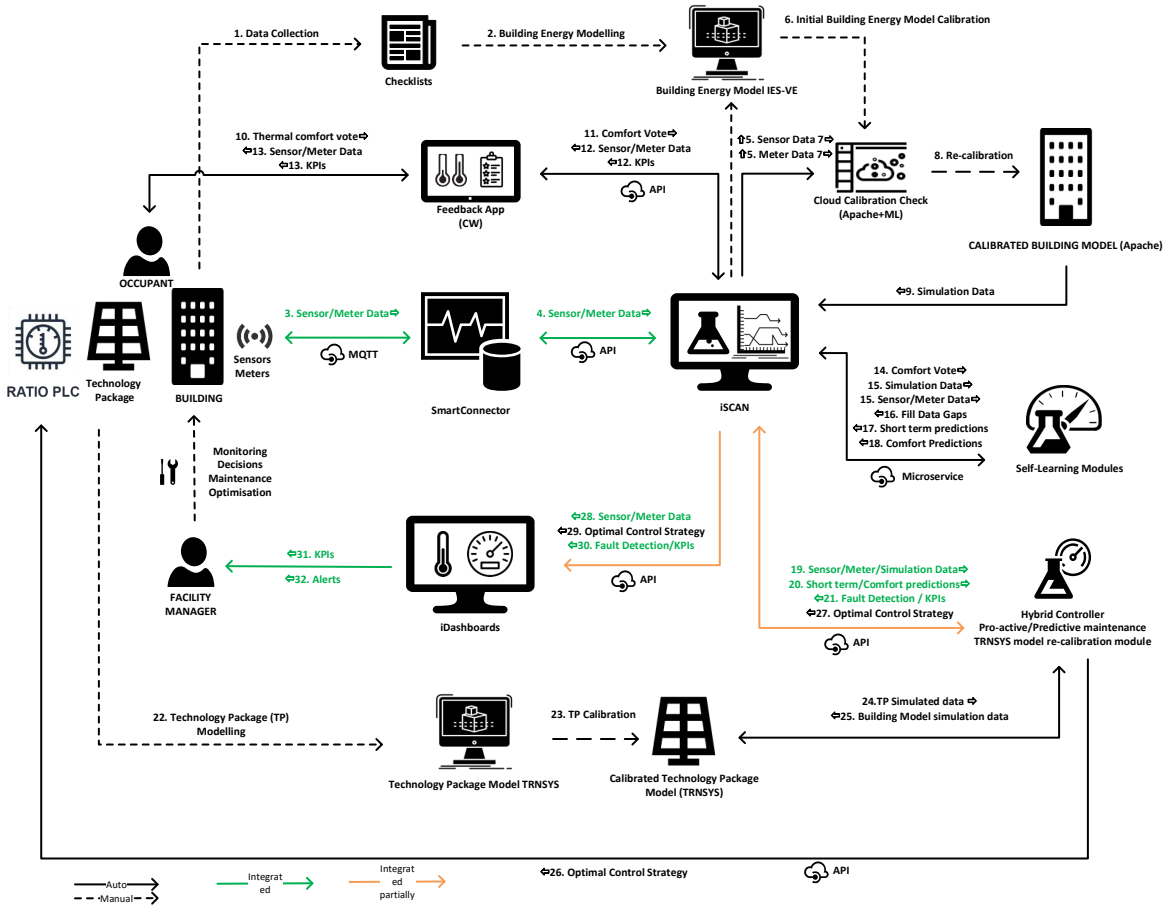
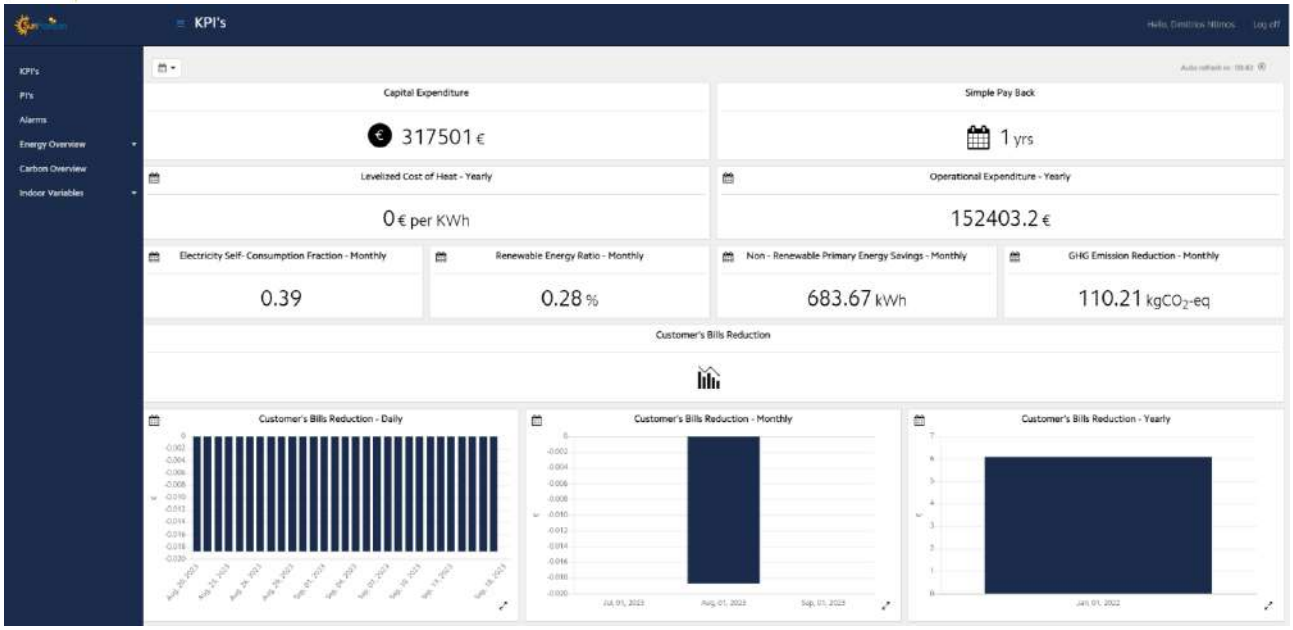
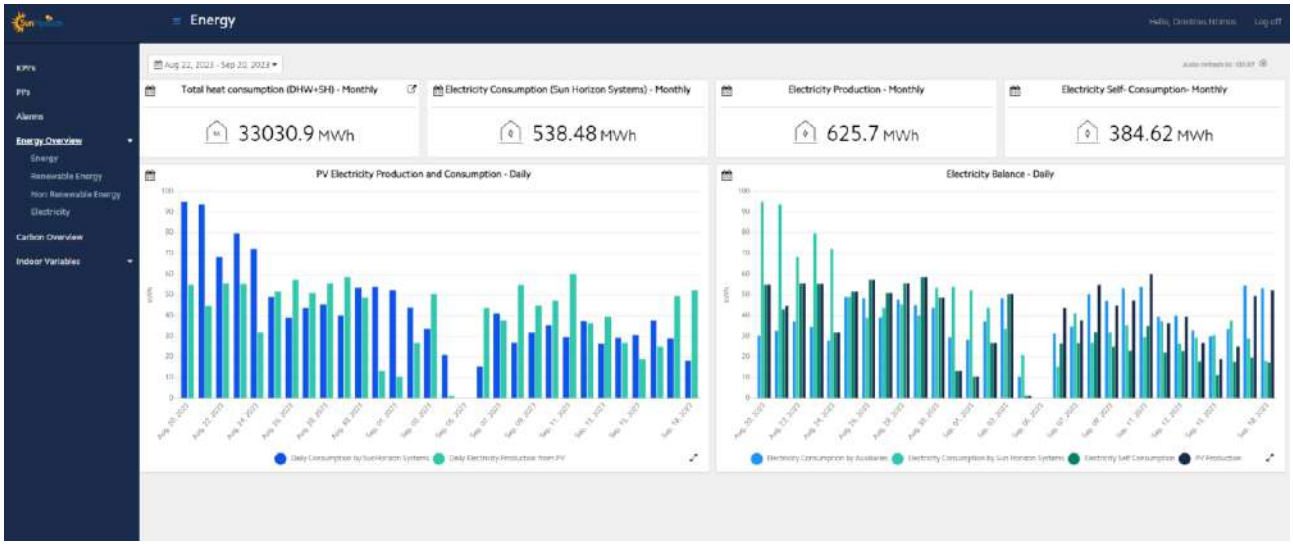


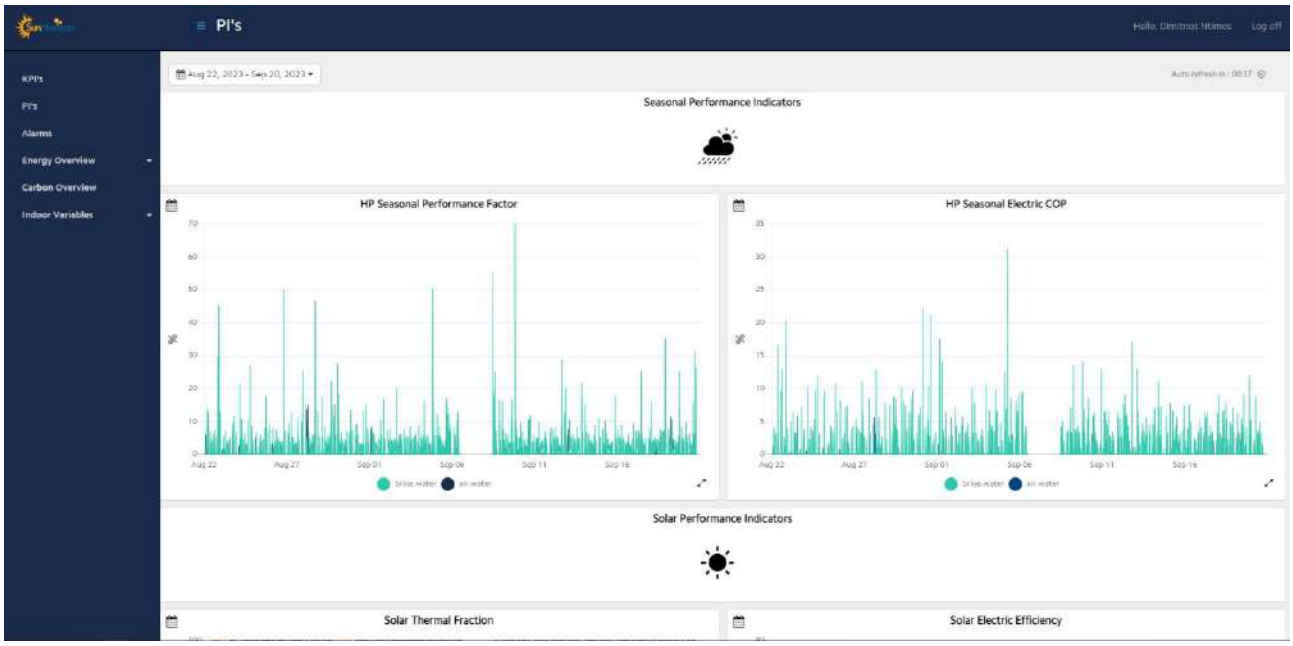
Figure 106: Fully automated Integration achieved in Type B demo sites

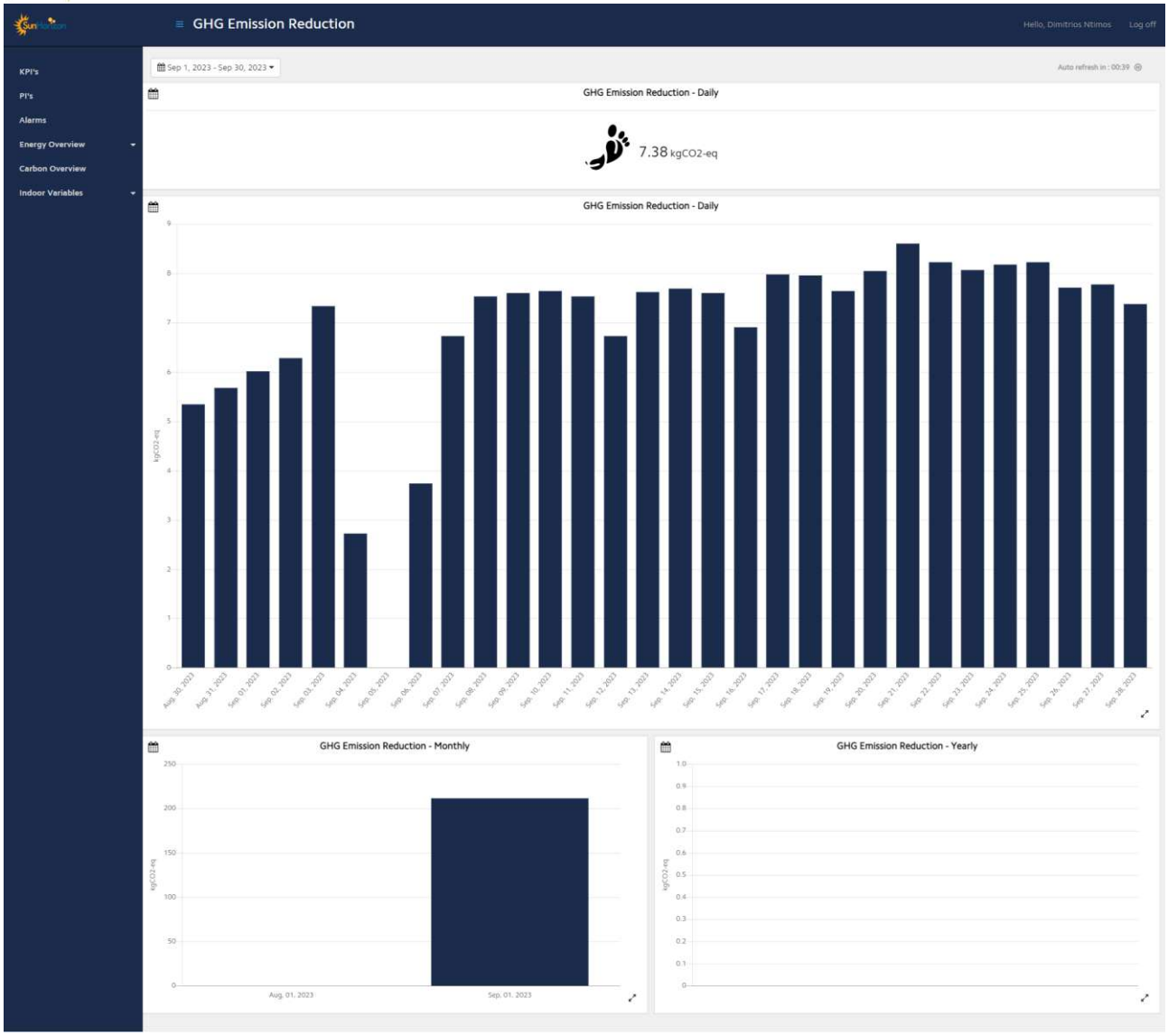
6.1 Dashboard for Madrid demo site

The dashboard for Madrid demo site can be accessed here (login details can be provided upon request): https://dashboards.iesve.com/dashboard/2858/KPIs/Sunhorizon-Madrid2023


KPI's
Capital Expenditure
317501 €
Simple Pay Back
1 yrs
Levelized Cost of Heat - Yearly
0 € per KWh
Operational Expenditure - Yearly
152403.2 €
Electricity Self- Consumption Fraction - Monthly
0.39
Renewable Energy Ratio - Monthly
0.28 %
Non - Renewable Primary Energy Savings - Monthly
683.67 kWh
GHG Emission Reduction - Monthly
110.21 kgCO2-eq
Customer's Bills Reduction
Customer's Bills Reduction - Daily
Customer's Bills Reduction - Monthly
Customer's Bills Reduction - Yearly


Energy
Total heat consumption (DHW+SH) - Monthly
33030.9 MWh
Electricity Consumption (Sun Horizon Systems) - Monthly
538.48 MWh
Electricity Production - Monthly
625.7 MWh
Electricity Self- Consumption- Monthly
384.62 MWh
PV Electricity Production and Consumption - Daily
Electricity Balance - Daily


PI's
Seasonal Performance Indicators
HP Seasonal Performance Factor
HP Seasonal Electric COP
Solar Performance Indicators
Solar Thermal Fraction
Solar Electric Efficiency


GHG Emission Reduction
Hello, Dimitrios Ntimos
Log off
KPI's
PI's
Alarms
Energy Overview
Carbon Overview
Indoor Variables
Sep 1, 2023 - Sep 30, 2023
Auto refresh in : 00:39
GHG Emission Reduction - Daily
7.38 kgCO2-eq
GHG Emission Reduction - Daily
kgCO2-eq
GHG Emission Reduction - Monthly
Aug. 01, 2023
Sep. 01, 2023
GHG Emission Reduction - Yearly


Temperatures
Hello, Dimitrios Ntimos
Log off
KPI's
PI's
Alarms
Energy Overview
Carbon Overview
Indoor Variables
Room Temperatures
°C
17/09/2023, 13:00
24.10
24.50
23.60
25.50
24.00
22.20
24.30
23.50
0.00
25.00
18.00
Sep 14
Sep 15
Sep 16
Sep 17
Sep 18
Sep 19
Sep 20
DW1
DW2
DW3
DW4
DW5
DW6
DW7
DW8
DW9
Maximum Temperature Comfort
Minimum Temperature Comfort

6.2 Dashboard for Riga Imanta demo site

The dashboard for Riga Imanta demo site can be accessed here (login details can be provided upon request): https://dashboards.iesve.com/dashboard/2879/KPIs/Sunhorizon-RigaImanta2023

7 Conclusions

This document described the activities performed to integrate and validate the control modules in Type A demo sites. All the workflow and modules were explained in detail. In Riga Sunisi, the baseline model was calibrated and then re-calibrated to allow best accuracy in simulation results. The model was executed periodically for a period to allow integration with the hybrid controller. All modules integrated with iSCAN and the dashboard was developed and shared with the local representatives. Similar integration was performed for the Sant Cugat demo site. However, due to shortcomings, the full validation of the controller was only possible in Sant Cugat demo site.

As the hybrid controller validation conclusions discussed in section 5.5, the hybrid controller has been possible to validate in a real demonstrator, Sant Cugat, and it presented some advantages related to the use of renewable technologies, which are followed by the control strategies computed by the hybrid controller, and their impacts in the building. However, and the related to economical results, one month was no enough to validate the controller. At least one year to make a fair comparation between the hybrid and local controller. As was discussed in Figure 102, at the October month, the electricity prices were more expensive than at the end of the month, affecting the electricity prices indicators and with it to the controllers comparison.