



H2020-LC-SC3-2018-RES
EUROPEAN COMMISSION
Innovation and Networks Executive Agency
Grant agreement no. 818329



Sun coupled innovative Heat pumps
D6.7 – SunHorizon Guidelines for TPs installation,
operation and control:
Lessons learnt from demonstration

Due date of deliverable: **30/09/2023**

Actual submission date: **30/09/2023**

Organisation name of lead contractor for this deliverable: CEA

Participants: CARTIF, RINA-C, CNR ITAE, RTU, FAHR, CW, VEO, TVP, RATIO, BDR, EMVS, DS, AJSCV, SE, IES

Dissemination Level		
PU	Public	X
CO	Confidential	

Project Contractual Details

Project Title	Sun coupled innovative Heat pumps
Project Acronym	SunHorizon
Grant Agreement No.	818329
Project Start Date	01-10-2018
Project End Date	30-09-2023
Duration	60 months
Supplementary notes: <i>This document will be available only to SunHorizon Consortium partners.</i>	

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Executive summary

The report D6.7 summarizes the conclusions and key lessons learned from SunHorizon demonstration activities in WP6. The project initially aimed to conduct 8 specific demonstration of building energy system renovation projects in parallel relying on four Technology Package (TP) concept, defined as solar and heat pump technology combination. 3 of them were successfully completed and operational as in Riga TP2 (individual house heating), Sant Cugat TP3 (tertiary building civic center heating/cooling), and TP4 (multifamily building heating/cooling), thanks to interactions of SunHorizon technology providers with local demo site leading team during the 5 years project's duration. On the other hand 5 demo cases were finally cancelled with varying degrees of progress at the time of cancellation, three demo cases in Nurnberg and Verviers were still in the engineering phase and two in Berlin and Piera in installation phase.

In addition to the main KPIs in the table below integrated over various period durations (cf. details about calculations in D6.6), a few highlights and conclusion are drawn for the 3 demo cases that reached the end of the project :

- In Riga Sunisi demo case, TP2 is supplying space heating and DHW to a residential house in Nordic climate. The solar heat and electricity from Dualsun PVT hybrid panels are managed by RATIO controls and thermal storage to lower the required import of energy from the grid to power the heat pump ensuring flexible heat supply to the dwelling. Whenever the initial installation in Winter 2021 of Boosheat CO2 heat pump with gas fired thermal compressor revealed strong limitations after one year operation, it was then successfully replaced shortly before the end of the project by BDR hybrid heat pump, commissioned and already ran during the first month of the heating season in October 2023. Thanks to continuous effort of the demo partners led by RTU in monitoring, fixing issues and optimizing the TP2 installation settings for 22 months, RER above 41% from solar heat and electricity allows to reach 22% GHG savings and 45% PENren savings, considering an extra gas consumption due to Boosheat malfunction over the whole period. Nonetheless it doesn't allow to achieve effective cost bill reduction since the effect was exacerbated by the gas and electricity price surge of 2–4 times compared to the baseline 2019 prices bills.
- In Sant Cugat, TP3 is relying on solar heat supply from TVP high vacuum solar thermal panels through RATIO thermal storage and controls to space heating loop, complemented by existing reversible heat pump. The installation is switched manually in cooling mode so that solar heat is driving FAHR hybrid chiller to achieve efficient renewable solar cooling, complemented by existing reversible heat pump in cooling mode. Despite regular communication of demo partners led by AJSCV and VEO since the installation was completed in Spring 2022, a devious issue around the internet router prevented reliable remote access to TP3's controllers, notably to TVP controller, which prevent to detect and to fix quickly issues around solar loop and energy monitoring also around the cooling operation in summer period. In July 2023, solar loop issues were fixed and installation is running properly since then but still no enough reliable energy monitoring data to calculate reliably KPIs. From the demonstration experience Sant Cugat partners are now drawing the conclusion that for large, public, demonstration case with existing Building Management System, specific effort and budget is still required to develop a SunHorizon TP3 BMS enabling remote access and maintenance either fully autonomous or fully integrated in existing system.
- In Madrid, TP4 is supplying space heating and DHW to a residential multiapartment building in Madrid mediterranean climate. The solar heat and electricity from Dualsun PVT hybrid panels are managed by AJSCV controls and thermal storage to lower the required import of energy from the grid to power the BDR heat pumps ensuring flexible heat supply to the dwellings. During Spring 2022 the administrative agreements around electrical grid connection and electricity selling contracts for public bodies in Spain were finalized and allowed to finalize the HP electrical installation and TP4 system running in September 2022 to supply the dwellings. Thanks to continuous effort of the demo partners led by AJSCV in monitoring, fixing issues and optimizing the TP4 installation settings, high RER around 57% from solar heat and electricity allows to reach 63% GHG savings, 67% electricity self-consumption and about 30% bills reduction during the period running from January 2023.

KPI	Sant Cugat #3	Madrid #4	Riga Imanta #8.1	Riga Sunisi #8.2
Monitoring period	06/2023 to 10/2023	01/2023 to 10/2023	11/2022 to 10/2023	01/2022 to 10/2023
CAPEX	457633 €	317501€	133757€	132085€
CBR	60 €/day	783.5€ 29.8%	11.29€	-401.11€ -12.97%
CSAT	-	-	-	-
GHG savings	-42.45 kgCO ₂ eq	8205.8kgCO ₂ eq 62.7%	98%	1458.57kgCO ₂ eq 22.22%
HCI	0.06 °C	0.0°C	-	14.7°C·h [2022] 9.6°C·h [2023]
CCI	-	1.95°C	-	2.3°C·h [2022] 1.1°C·h [2023]
LCOH	-	-	-	-
OPEX	2288.17 €	1587.54€	300€	300€
PESnren (absolute) And relative:	-30363.26 kWh	38977.2kWh 58.6%	47%	21711.56kWh 45.24%
RER	11.75%	56.98%	18%	46.58%
SCR	-	67.09%	42%	41.61%
SPB₁	10-*	8.8*	-	-

In addition, D6.5 report also reminds the technical and administrative difficulties encountered and their impact on the project's progress and outcomes.

The cancellation of some demo cases was primarily due to a combination of administrative and technical challenges that could not be resolved within the project's defined timeframe and budget. The main reasons include:

- A devastating flood disaster that destroyed a project's site.
- Integration of the project into a separate renovation workplan of the municipality, leading to logistical and administrative complications.
- Seasonal and roof structure limitations for solar panel installations.
- Increased costs after the COVID-19 pandemic and the Ukrainian conflict.
- Challenges related to the availability of installers and components.
- The unexpected withdrawal of BoostHeat.
- Strict depreciation rules for heat pumps in Berlin.

Throughout the project, several significant challenges were encountered, including:

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

- Involvement of multiple subsystems manufacturers without proper whole new system engineering coordination, especially in managing the detailed interactions of subsystems in both the engineering and operational phases, particularly in the realm of controls.
- Budgetary constraints that impeded the smooth execution of the project.
- Delays in obtaining monitoring results, which hindered efforts to optimize the installations' performance.

Following the conclusion of the COVID-19 crisis in 2021, despite constant communication with the European Commission regarding iterative fall-back scenarios for Berlin and both Verviers demo sites none of them were successfully selected mainly for insoluble timing aspects. Notably, there was no suitable replacement identified for the Verviers swimming pool, large tertiary building case, which held promise for the coupling of solar PVT in series with the evaporator of heat pump technology. Similarly, no alternative case was carried on until achievement for the Verviers Sport Center, large tertiary building case as well, where highly efficient TVP solar thermal technology was originally planned to be implemented in parallel to heat pump heat supply.

In addition to the results gained from the on-site demonstration in the 3 demo cases above, technical knowledge arose also for TP1, TP2, TP4 in single family context through simulated performance (TP1, TP2, TP3, TP4) from Eurosun 2020 conference article, HPC conference 2022 article and Experimental test results in INES, from ISES SWC 2021 conference article. It draws the attention on several items at the design stage and in controls:

- For TP2, the outdoor air unit backup foreseen to secure the demo in the eventuality of low efficiency when low solar resource, which actually increased complexity of the hydraulics and caused installation and control issues
- For TP2, TP4, the layout with solar thermal circuit from PVT in series with standard HP evaporator requires increased complexity (buffer, tempering valve and control) and may cause lower real performance compared to theoretical one until optimal settings of the whole installation is achieved
- TP3: complex interactions issues between thermal storage, control, absorption chiller, existing H/C plant; solar field size suits solar heating demand but exceeds solar cooling demand during summer

Briefly the main technical challenge rising from the situation of multiple partners developing separate subsystem is turning into communication challenge.

From technical perspective about technology combination of solar hybrid electrical and thermal panels with heat pumps, the SunHorizon experience is fostering the integration of solar energies to be driven by heat pump developers: through development of ad-hoc solar heat integration schematics, covering as optional features existing Heating and Cooling generator circuit (boilers) and integration of control and connectivity aspects. These measures are likely to reduce the design, installation, operation and maintenance costs.

This report provides a comprehensive understanding of the challenges and complexities that the 3 remaining demo sites overcame and that led to the cancellation of other demonstration projects. The lessons learned from this experience will be valuable for future endeavours in the field of solar and heat pump energy systems for building heating and cooling and technology demonstrations.

1 Introduction

1.1 Objectives

The D6.7 report is the last report for overall WP6, SunHorizon technologies Demonstration at TRL7, the original objectives of which are:

- deploy and run the SunHorizon technologies in demo sites.
- monitor the performance,
- elaborate guidelines for successful future replication of the TPs and control schemes.

The Figure 1 is reminding the original plans of the various solar and heat pump technologies integration in the 8 demo sites across Europe.

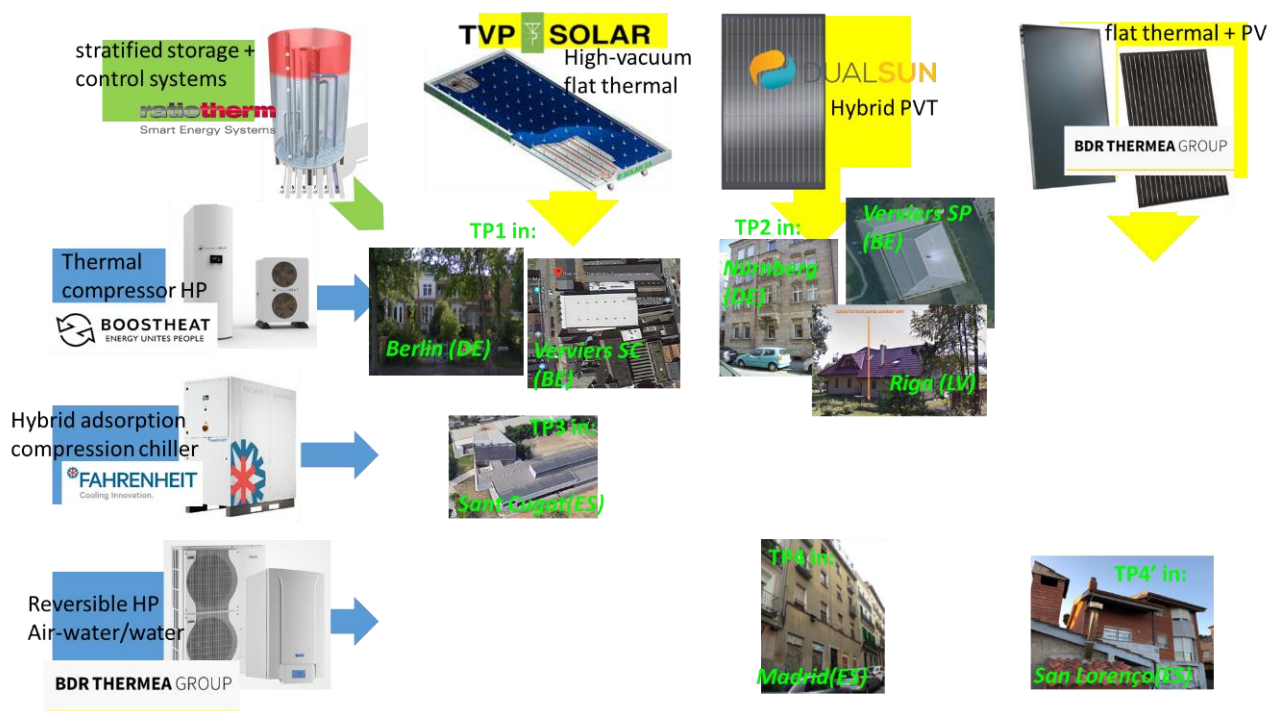


Figure 1 Overview of the original demonstration project

In addition to hardware heating and cooling technologies developed in WP3, the SunHorizon demonstration WP6 is aiming to integrate WP4 and WP5 software and hardware monitoring tools in the variety of demo sites, as illustrated in Table 1. It emphasizes the variety of the situations against which the single SunHorizon technologies need to be specified after core functionalities development in WP3, WP4 and WP5. In particular, technology providers and demo site leaders have to communicate seamlessly to synchronize technologies' readiness development from technology providers' perspective with the installation work schedule of the parallel demo sites.

Following this overall technology integration plan in demo site, we have been developing a table to clarify the relevant roles and names of each SunHorizon partner in the demo sites, thus supporting the communication between the partners. This is a living document according to real project's life, illustrated in Table 2 as March 2022 update.

Table 1 Overview of the original integration plans of SunHorizon technologies from WP3, WP4 and WP5 into the WP6 demonstration sites

	1- BERLIN	2- NURNBERG	3- SANT-CUGAT	4- MADRID	5- PIERA	6- VERVIERE RS-SC	7- VERVIERE RS-SP	8a- SUNISI	8b- IMANTA
TVP Th-panels	X		X			X			
DS PVT panels		X		X			X	X	X
BH BH20 connect	X	X				X	X	X	X
BDR HP Th-panels storage hydraulics control				HP	X				
FAHR Hybrid chiller			X			(?)			
RATIO Storage hydraulics controls	X	X	X	X		X	X	X	X
SE Meters,sensors,local comm,db server	X	X	X	X	X	X	X	X	X
CW App UI	X	X	X	X	X	X	X	X	X
IES Db server iSCAN, KPIs tool	X	X	X	X	X	X	X	X	X
CARTIF Control, KPIs tool	KPIs tool	KPIs tool	X	KPIs tool	KPIs tool	KPIs tool	KPIs tool	X	KPIs tool
CEA MPC control virtual			(X)					X	
RINA / CARTIF Design Maintenance tool	x	X	x	x	x	x	x	x	x

To follow the whole demonstration, a generic demo site demonstration project was originally developed as the sequence of tasks T6.1 to T6.5, illustrated in Figure 2 . In order to catch the singularity of each demonstration site's project , with specific subtasks' aims, timeplans and challenges to address, we update continuously the demo progress tracker, presented in Table 3, as March 2022 update.

Since the project's start in October 2018, the covid crisis in 2019-2021 period, the catastrophic floods in summer 2021 in Belgium and the Ukrainian war since February 2022, deeply upset the pending SunHorizon partners and demonstration activities in the 8 demo sites, and led to request project's amendments to manage the consequences of these major force issues, with one-year extension of the WP6 tasks as shown in Figure 3. The multiple difficulties met by the two Belgium demo sites led finally to the cancellation of both of them, to the withdrawal of GRE LIEGE partner as these demo sites' leader and to the introduction of Cluj Napoca demo site team to develop a demonstration fall-back scenario. As the covid crisis significantly affected the BDR Group activities, internal re-prioritization of the projects and financial policy of demonstrator led to give up the BDR Spanish demo site in December 2021. In addition, the global energy market change since 2018 also led to the withdrawal of BoostHeat partner from the consortium lately in October 2022, BoostHeat which was holding a key role both as innovative CO₂ gas fired thermal compression heat pump technology provider in 3 demo sites, and as demo site's leader in 2 demo sites.

The following section 1.2 summarises the chain of difficulties and events that led to significantly re-orient the demonstration activities in #8-Riga Sunisi and Imanta, or, unfortunately, to give up definitely any further activities for Berlin#1, Nurnberg#2, Piera#4, Verviers's Sport Center#6 and Swimming Pool#7, and Cluj Napoca#6 (# referring to the original demo site's identifier).

The conclusion of the WP6 demonstration process comes with T6.5 which summarizes for the 3 remaining demo sites the whole demonstration and conclusions from all materials, analysis of monitoring data compared to previous estimations and experience collection during the whole demonstration process, from design and engineering phase until the end of the monitoring period. Especially it collects the lessons learnt from all partners involved in demo sites, both from technology providers and technology hosts perspectives, presented in parallel in this report.

Table 2 Participants' roles in the various demo sites, March 2022

March 2022	demo 1	demo 2	demo 3	demo 4	demo 5 cancellation	demo 6	demo 7 cancellation	demo 8
Participants roles	Berlin	Nurnberg	Sant Cugat	Madrid	San Lorenzo replaced by Piera	Verviers SC replaced by Cluj-Napoca	Verviers SP	2 separate houses: Sunisi (8.2) – Imanta(8.1)
resp in Sunhorizon	Replaced by RATIO, BH	BH	VEO	VEO	BDR	TUCN	GRE	RTU
owner	-	-	AJSCV	EMVS	-	TUCN	-	-
relevant local technical team	Replaced by RATIO, BH	BH	-	-	-	TUCN	-	-
general support analysis, simulation, control	CEA	CEA	CNR ITAE / CARTIF / RINA	CARTIF	CEA	CARTIF	CARTIF	RINA / CARTIF
Supervision, support methodology, KPIs	RINA	RINA	RINA / CARTIF	RINA / CARTIF	RINA	RINA	RINA	RINA / CARTIF
SOLAR supply/integration	RATIO	DS	TVP	DS	BDR	TVP	RINA	DS
HP supply/integration	BH	BH	FAHR	BDR	BDR	BH	BH	BH
TES supply/integration	RATIO	RATIO	RATIO	RATIO	BDR	RATIO	RATIO	RATIO
MON supply/integration	SE , IES	SE , IES	SE , IES	SE , IES	SE , IES	SE , IES	SE , IES	SE , IES
UI supply/integration	CW	CW	CW	CW	CW	CW	CW	CW

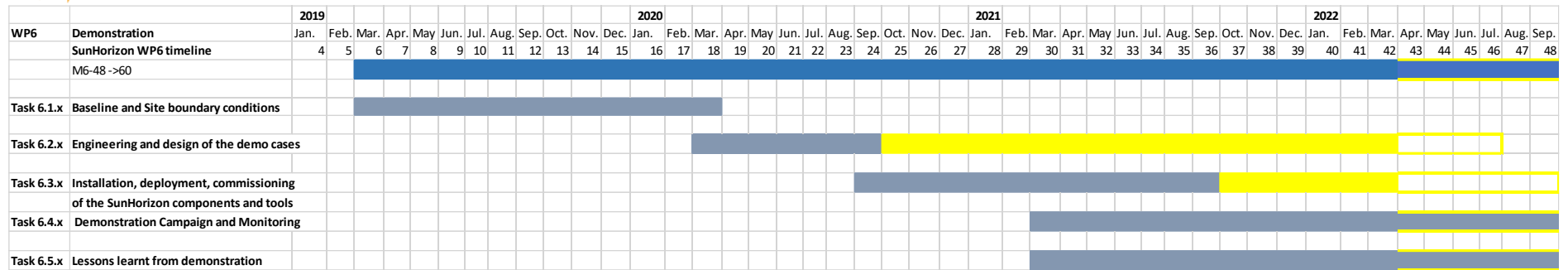


Figure 2 Original demonstration time plan ending in M48 = September 2022

Table 3 Demonstration progress tracker in March 2022

24/03/2023	overall demo progress	56%	32%	83%	78%	46%	18%	36%	80%	84%	56%
Demonstration Tasks	description	#1-Berlin mitigation	#2-Nürnberg cancelled	#3-SantCugat	#4-Madrid	#5-Pieter cancelled	#6-Cluj-Napoca repl. VerviersSC mitigation	#7-VerviersSP	#8-Rigalmenta mitigation	#9-RigaSunisi mitigation	all
16.2.x	Engineering , contract & installation timeplan	96%	29%	100%	100%	100%	100%	90%	100%	100%	91%
finder procedure	looking for possible installers with description of work	100%	100%	100%	100%	100%	100%	100%	100%	100%	
final detailed design & budget	installing companies selection and final technical design vs budget agreements (owner+installers+SH partners)	100%	100%	100%	100%	100%	80%	100%	100%	100%	
	civil work integration (roof, technical room...)	100%	100%	100%	100%	100%	90%	100%	100%	100%	
	hydraulic, gas	100%	100%	100%	100%	100%	90%	100%	100%	100%	
	electricity	100%	100%	100%	100%	100%	90%	100%	100%	100%	
	high-level communication (TP control + TP&building monitoring)	75%	100%	100%	100%	100%	90%	100%	100%	100%	
reports writing	D6.2	100%	100%	100%	100%	100%	100%	100%	100%	100%	
16.3.x	Installation, deployment, commissioning of the SunHorizon components and tools	62%	32%	94%	99%	32%	0%	30%	100%	96%	59%
Physical components ordering, delivery & storage											
	TVP			100%			0%				
	DS		25%		95%		100%	100%	100%	100%	
	RATIO	100%	100%	100%			0%	100%	100%	100%	
	BH	50%	100%				0%	100%	100%	100%	
	BDR			100%	100%						
	FAHR			100%							
	SE	100%	100%	100%	100%	100%	100%	100%	100%	100%	
	other	0%	100%	100%	100%		0%	100%	100%	100%	
software tool delivery											
	IES	0%	100%	80%	100%	100%	0%	100%	100%	100%	
	CW	50%	100%	100%	100%	100%	0%	100%	100%	100%	
	SE	100%	100%	100%	100%	100%	0%	100%	100%	100%	
	CARTIF		100%							100%	
installation (TP components + nter & building - connections + monitoring TP+building)											
	civil work building integration (roof, technical room...)	100%	100%	100%	100%	100%	0%	100%	100%	100%	
	hydraulic, gas	100%	100%	100%	100%	100%	0%	100%	100%	90%	
	electricity	100%	100%	100%	100%	100%	0%	100%	100%	100%	
	communication	50%	100%	90%	100%	100%	0%	100%	100%	100%	
	detailed installation timeplan update	10%	100%	100%	100%	100%	0%	100%	100%	100%	
Commissioning											
	hardware settings	80%	100%	100%	100%	100%	0%	100%	100%	70%	
	TP control settings	80%	100%	100%	100%	100%	0%	100%	100%	80%	
	monitoring and high-level communication settings	0%	100%	50%	100%	100%	0%	100%	100%	80%	
reports writing											
	contents collection and overall management										
	D6.3.1	100%	100%	100%	100%	100%	0%	100%	100%	100%	
	D6.3. final	28%	32%	71%	95%	58%	0%	31%	100%	100%	
16.4.x	Operation TPs, monitoring, data collection	25%	31%	74%	25%	31%	0%	31%	38%	78%	37%
	set channels in the corresponding tools (SE, IES, CW) - can only be done when hardware is commissioned	25%	25%	90%	25%	25%	0%	25%	90%	90%	
	collect data	0%	100%	100%	0%	100%	0%	100%	0%	100%	
	include data collection progress every month in the reports	0%	100%	80%	0%	100%	0%	100%	0%	100%	
reports writing											
	contents collection and overall management										
	D6.4	100%	100%	100%	100%	100%	0%	100%	100%	100%	
	D6.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	
	D6.6	0%	0%	0%	0%	0%	0%	0%	0%	0%	
16.5.x	Lessons learnt	0%	10%	8%	0%	4%	0%	4%	4%	4%	3%
	Data analysis	0%	25%	15%	0%	0%	0%	0%	0%	0%	
	Experience collection	0%	15%	15%	0%	15%	0%	15%	15%	15%	
reports writing											
	contents collection and overall management	0%	0%	0%	0%	0%	0%	0%	0%	0%	
	D6.7	0%	0%	0%	0%	0%	0%	0%	0%	0%	

		2022												2024											
WP6	Demonstration	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	SunHorizon WP6 timeline	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61		
	M6-48 ->60																								
Task 6.1.x	Baseline and Site boundary conditions																								
Task 6.2.x	Engineering and design of the demo cases																								
Task 6.3.x	Installation, deployment, commissioning of the SunHorizon components and tools																								
Task 6.4.x	Demonstration Campaign and Monitoring																								
Task 6.5.x	Lessons learnt from demonstration																								

Figure 3 Overview of the original and final WP6 Demonstration timeline

1.2 6 Interrupted demo sites from the beginning of the project

1.2.1 Berlin demo site #1

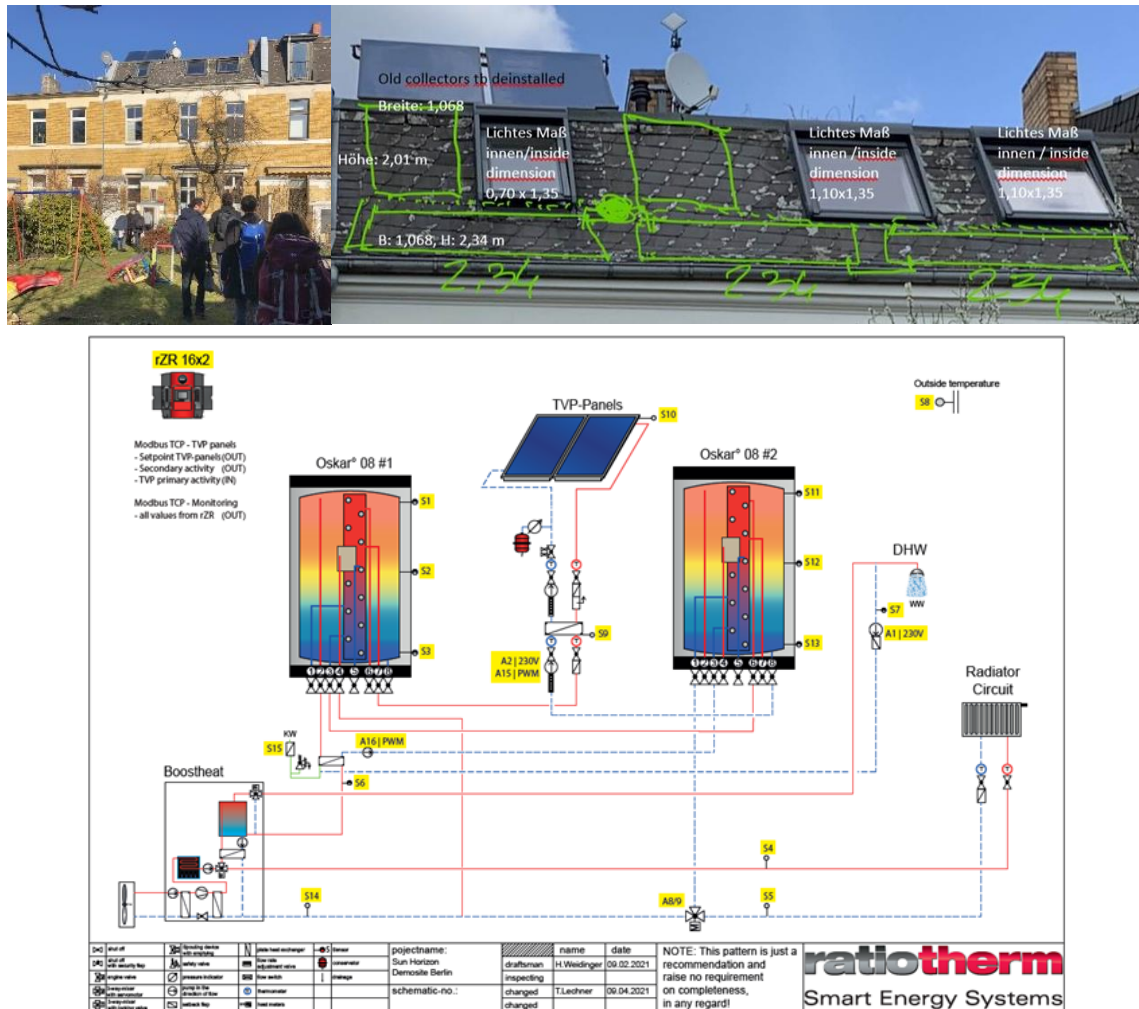


Figure 4 Overview of building, solar thermal panels existing roof integration and TP1 hydraulic diagram

BoostHeat is demo site leader of the Berlin demo case illustrated in Figure 4, in contact with single owner of 2 Apartments building 240 m² living area, with 7 people actually living in the building during the foreseen installation of TP1: TVP solar thermal panels, BoostHeat HP unit and Ratiotherm thermal storage and overall heating controller, SE sensors, CW user feedback app, IES idashboard.

The performance of this TP1 in Berlin was investigated since the beginning of the project, as simulation results in T2.4 report (CEA et al. 2020) and article (Chèze et al. 2020), as experimental test results in article (Chèze and Leconte 2021). H4plan engineering company was hired by BoostHeat to manage the details of TP1 integration in the building. Since BoostHeat can only manage BH unit technical details and SunHorizon project communication.

The engineering study required a roof structure engineering study to be performed regarding TVP panels integration requirements, especially regarding wind and snow loads, regulations compliance. It ended up with heavy mechanical load to set on the lateral walls since the wood frame roof and roof tightness can't sustain it. The proposed solution was relying on heavy steel beam structure which exhibited high costs for supporting infrastructure, transport to Berlin, lifting crane, scaffolding. secured components storage waiting for installation is required while no suitable (space, volume, accessibility)

areas in or around the building): It ended up with cancellation of TVP panels deployment and decision to replace it with Ratiotherm flat plate solar thermal panels replacement without heavy roof reinforcement and associated costs:

Indeed in May 2021, TVP withdrew from its role of solar thermal technology for the specific demo site. This was a decision jointly taken by the parties involved as a result of the initial engineering of the solar thermal installation on the rooftop of the building, the acquisition of offers for the reinforcement of the rooftop and the assessment of alternative solutions for the installation of the solar thermal panels. Unfortunately and despite the efforts made it became clear that the cost of the substructure for the installation of TVP's High Vacuum Flat Panels (HVFPs) (in the horizontal or the sloping part of the roof) is much higher compared to the installation of other type of solar thermal collectors in the sloping part of the roof. The latter (sloping roof) was the solution strongly preferred by the owner of the Berlin's site. A short overview of the steps followed up to this decision is given below:

- During the requirements and design stage of Berlin's demo site the size of the solar field has been repeatedly reduced to ultimately reach 4 collectors (equivalent to 8m²).
- Based on this, TVP in collaboration with the involved partners and the owner of the house has engineered the solar system and support structure of our panels according to the mutually agreed solution of installing the collectors on the horizontal part of the rooftop.
- However, local regulatory requirements have imposed a quite expensive metallic substructure with the respective techno-economic offer collected by the local partners amounts to around 26K€. This extra cost rendered the installation of the panels unfeasible.
- The option of placing TVP's collectors on the inclined part of the roof has been excluded as it would add technical complexity in the installation of the solar system, without reducing the cost of the substructure. This is because, despite other types of collectors, HVFPs require a free space of 40-50cm between the back of the collector and the surface of the roof on all sides of the collector. Therefore, they cannot be directly mounted onto the roof (and thus substantially reduce the cost of the substructure).

As lessons learnt from TVP perspectives, regulatory requirements differ based on the location (and country) and in combination with the building typology and roof structure can play a critical role on the economic and technical feasibility of the installation of the solar thermal system. Furthermore, solar thermal panels that are designed for large-scale applications may add further limitations that affect the economic feasibility of the whole system.

After TVP panels withdrawal from Berlin demo case, BH and RATIO inquired about local companies availability and costs to perform the installation of every TP1 components , solar, heat pump, storage, control, monitoring etc.. The covid crisis period made this research very uncertain, multiple delays revealing the difficulty to get quotations fitting in the demo site budget and availability of the installers in German heating/cooling installation market, showing components shortage and inflation costs, it finally ended up with selection E7 installer, trustful since was already in business with RATIO by other customers.

BoostHeat managed to achieve partial installation of TP1 system in Berlin demo building until July 2022, supplying heat for space heating and DHW from Ratiotherm's flat plate solar thermal panels complemented by auxiliary gas burner of BoostHeat unit since the installation of CO₂ heat pump of the BH unit was postponed then suspended: The evolution of the European building heating market is no more favourable to gas fired appliance after Ukrainian war in 2022 and led to BoostHeat to change the scope of the company in October 2022, and stopped producing gas driven heat pump. The demo site installation activities stopped and BoostHeat withdrew from the consortium officially with an Amendment in August 2023.

The SunHorizon app by CW was not deployed on this site.

1.2.2 Nurnberg demo site #2

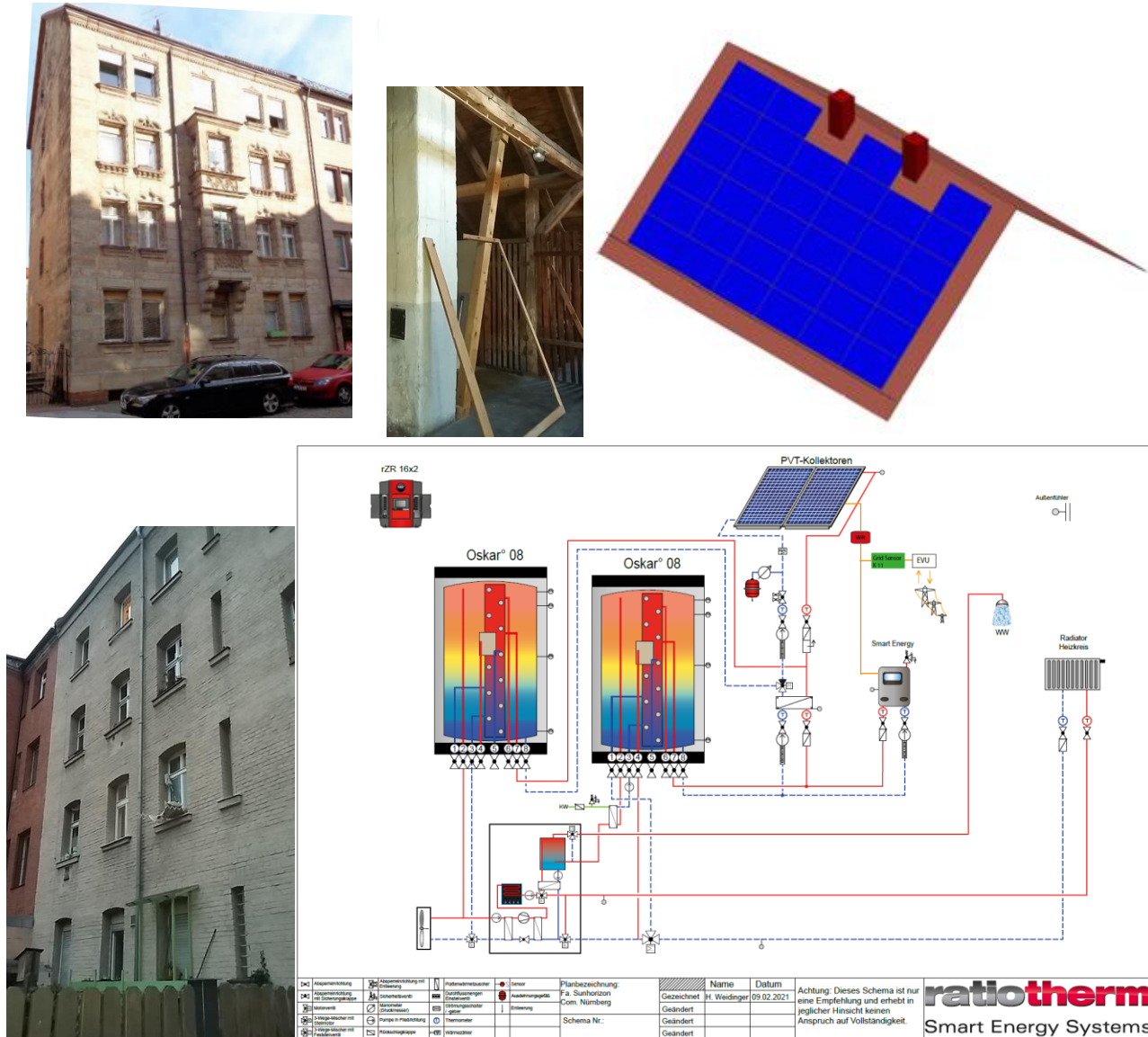


Figure 5 Streetview of the building façade, roof structure to be reinforced to support PVT panels, PVT panels layout on existing roof, view from the co-owned backyard of the rear façade to host the gas chimney, TP2 hydraulic layout

BoostHeat is demo site leader of the Nurnberg demo case illustrated in Figure 5, in contact with the 5 apartment's owner in historical building, 330 m² living area and 13 people living in.

The BH aim is the integration of TP2 concept (cf. Simulation results in T2.4 report (CEA et al. 2020) and article (Chèze et al. 2020)): Dualsun PVT panels, BoostHeat HP unit and Ratiotherm thermal storage and overall heating controller, SE sensors, CW user feedback app, IES idashboard.

BH mutualized engineering phase for Nurnberg demo case with Berlin demo case, thus selecting H4PLAN engineering company to lead the integration details of every TP2 components (solar, heat pump, storage, control, monitoring) into building. During this engineering phase until the beginning of installation phase, BoostHeat encountered lot of decision issues considering multiple owners of the building, with several temporary agreements then retractations, as the overall german energy market was deeply impacted by covid crisis then Ukranian war.

Only 3 apartments agree to take part to the demonstration which require to install central heating distribution to replace the existing separate heating systems; several issues around finding pathways from technical room to roof for gas exhaust, electrical wires and hydraulic tubes, in parallel of pathways through the apartment floors for central heat distribution of the apartments that participate to the demonstration; unexpected risk and piping-drilling costs because of incorrect historical drawings with ghost blind room in the basement .

Roof Works required unexpected engineering and installation cost for roof reinforcement to support the PVT panels

An external chimney needs to be installed, the on-site neighbour and co-owner from the backyard needs to accept that

On top of the previous difficulties, Boosheat also managed the same general difficulties in Germany at that time as for Berlin regarding the installer availability, increased cost compared to original budgets, secured temporary storage of components before installation issues. The TP2 installation was actually scheduled after Berlin demo site with the same installer therefore it never happens because of BoostHeat company withdrawn (with Amendment in August 2023) as previously mentioned.

The SunHorizon CW app was not deployed on this site.

1.2.3 San Lorenzo and Piera demo site #5

BDR is demo site leader of the San Lorenzo => Piera #4 demo case near Barcelona in Spain with the aim to integrate BDR 100% TP4 concept illustrated in Figure 6.: co-installed BDR PV and ST panels on the roof, reversible split ASHP with hot/cold water buffer tank inline with the thermalized water distribution to radiators and fan coils in single family building, 110m² living area. TP4 is aiming at aesthetic co-integration of PV and ST panels on the same frame, looking as uniform solar roof, and at PV electricity self-consumption maximisation for user's economical benefits.

Preliminary studies were performed on San Lorenzo demo case (nearby Barcelona and current Piera site) whose owner has withdrawn at M23 from the project : preliminary design and integration studies were performed again for Piera site, as replacement demo case. Simulation results in T2.4 report (CEA et al. 2020) and article (Chèze et al. 2020), test results in article (Chèze and Leconte 2021)

The system, comprising the air to water heat pump, the thermal collectors, the PV and the thermal storage for heating/cooling and domestic hot water, was designed for the house of Piera to cover the thermal needs with the optimal OPEX and CAPEX. The main difficulties was the adaptation of the emitters to include the cooling, and the adaptation of the system for the existing high temperature radiators by keeping in place the existing oil boiler as a backup for the worst climatic conditions.



TP4 - PIERA Demosite

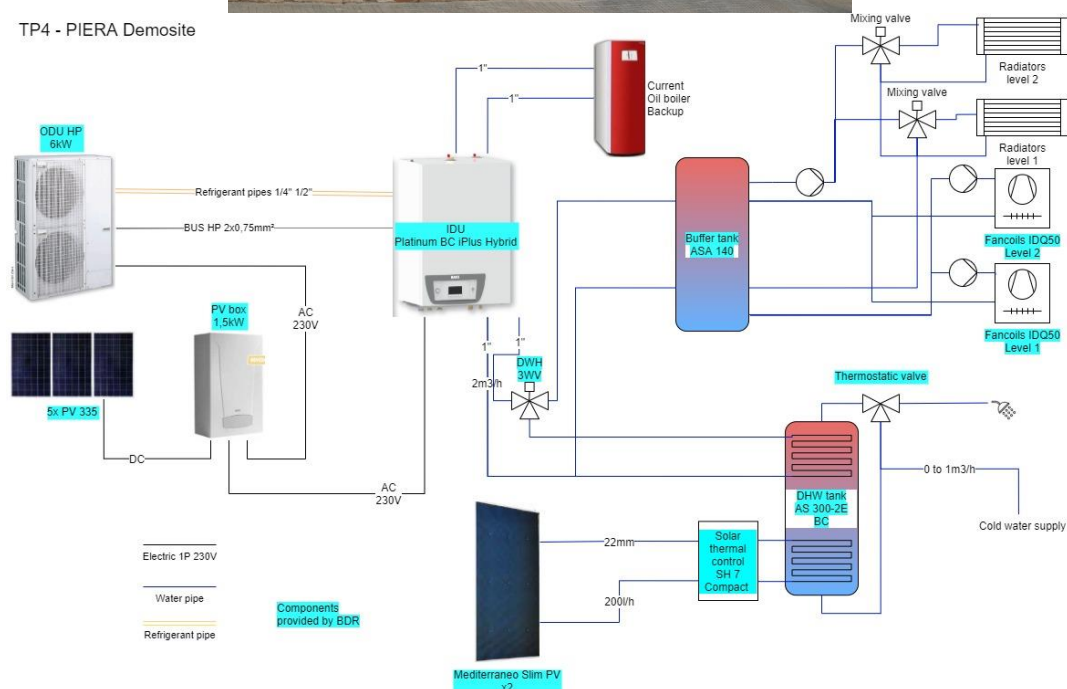


Figure 6 Overview of the building and TP4 integration in heating and cooling circuit

The engineering plan defined the roles of the installer, the technology provider and the monitoring equipment provider. The installer provides a quote in line with the expectations end of May 2021. All appliances and monitoring are available end of July 2021 near the demo site of Piera, in the warehouse of Baxi in Barcelona.

The demo site agreement work was stopped in August 2021 due to a new BDR internal field trial policy.

The new internal field trial policy enter in force end of August 2021. The main constraints are at the end of the demonstration period, with two options : the site will be returned to the original state, or, the user may purchase a commercially available equipment with a discounted price.

At the end of November 2021, BDR internal discussions conclude on the mandatory application of the policy for every demosite candidate.

The conditions was exposed to the demo site owner of Piera, he refused. BDR and consortium partners tried to find a new demo site but no candidate accepted the conditions.

The 30th of November, BDR Thermea was not able to install the products according to the new internal policy which led to the end of the demo site 5 and the on-site demonstration of this TP4 concept was cancelled. This demo site has been withdraw with an Amendment in XXXXX

The SunHorizon app was not deployed on this site.

1.2.4 Verviers SC demo site #6

GRE LIEGE was demo site leader of the Verviers Sport Center in Belgium to integrate TP1 concept : TVP solar thermal , BoostHeat thermal compression heat pump and Ratiotherm thermal storage and overall controls in the Building, illustrated in Figure 7.

Sports Centre demo in Verviers (BE) 250_{SH} / 9.8_{DHW} MWh demand :

- A TVP field of 220 m² on roof (standard tilt) A volume of RT tank of 10m³.
- 2 x 20kW BoostHeat HP $F_{sav,GHG} = 26\%$
- Energy Wasted through drycooler: electricity: 0.17 MWh thermal:48.7 MWh

The subcontracted company had to take into account this and study if it is feasible to install eventually FAHR unit to use the excess of heat in summer on solar thermal driven cooling purpose.

Simulation results in T2.4 report (CEA et al. 2020) : Demo-site 6 consists of a sports complex from 2006 located in Verviers (VSC, from now on) with four gyms, where basketball, table tennis, fencing and martial arts can be practiced. The current energy system consists of gas boilers to cover all energy needs. The SunHorizon intervention aimed at partially meeting the space heating demand and totally the DHW demand, allowing the system to reduce the gas consumption and improve the energy performance of the building. The electricity consumption of the building is out of the scope of the project.

The stability report providing the reassurance for the safe installation of the solar thermal panels on the rooftop of the building was delivered in spring 2019. The detailed engineering of the solar system was completed in January 2021. In parallel, the demo site partner - Groupement De Redeploiement Economique Du Pays De Liege (GRE) – has launched the tender procedure for the EPC services and received two initial offers in spring 2021. Both offers were much higher than the estimated budget, with the lowest exceeding the estimate by 43% (380K€ compared to 265K€). This offer has been scrutinised and a negotiation with the respective bidder has started to understand if there was and to which extent room for a reduction in the offer (e.g. by identifying potential overestimations in the required labour). Unfortunately, in July 2021 a major flood severely damaged the building, which was removed from the demonstration campaign of SunHorizon.

The clarification of the scope of work for each partner and contractor involved in the demo site took some time, along with the elaboration of the tender specifications. The fact that no engineering expertise was available on the demo site partner has added extra difficulties in the process. Also, and more importantly, the bidders for the EPC services were not familiar with the installation of solar thermal panels and for this reason they have over-estimated the required resources (most probably so that they can be on the safe side). The installation guide available from the technology provider has helped on acquaint them with the process but additional support appeared to be essential. However, no bidder was made available for an exchange with the solar thermal technology provider (i.e. TVP)

The appointment of an engineer as project manager (local coordinator) from the side of the demo site partner could help facilitate communication with the solar thermal technology provider (i.e. TVP) and the completion of the tender procedure. Availability of suitable audio-visual training material for the installation of the solar system can be valuable for contractors and technical personnel that are not familiar with (large-scale) solar thermal installations.



TP 1 - Verviers Sport Centre

hydraulic diagram

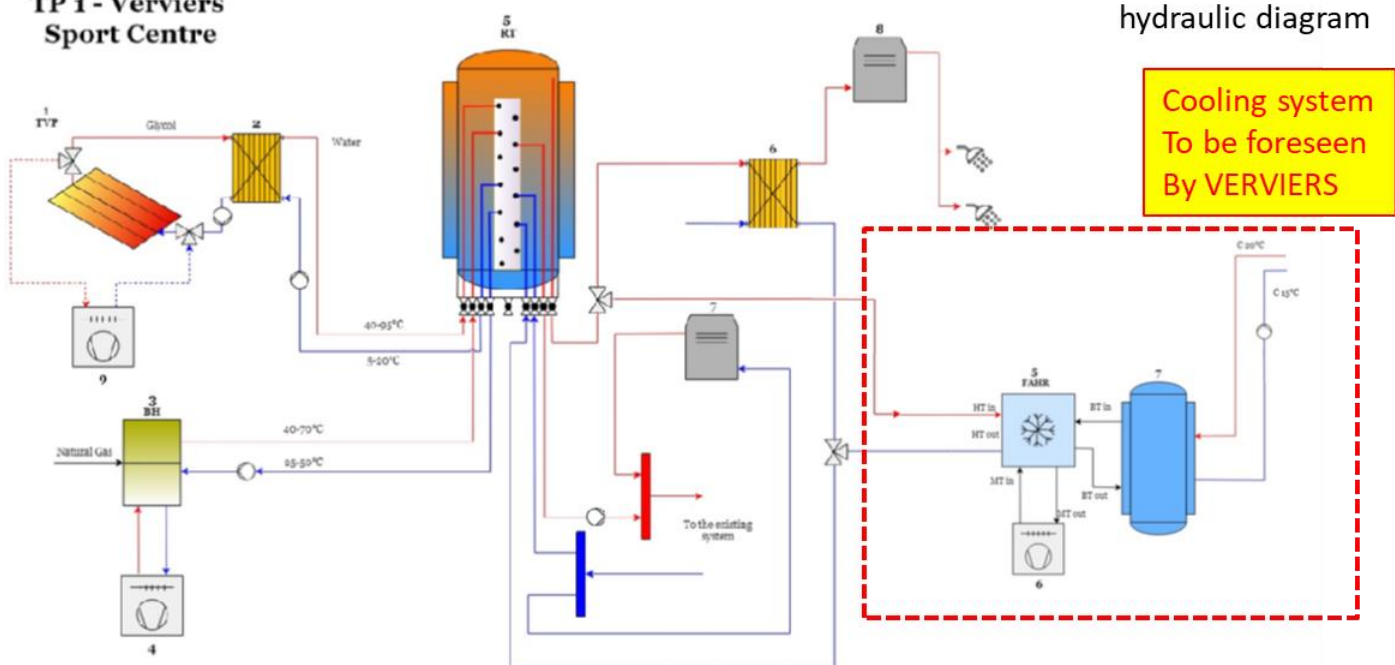


Figure 7 Overview of Verviers SC demo case and TP1 integration

Main difficulties met by GRE LIEGE :

- Include technical engineering studies and installers work supervision in the tender procedure, on top of the installation work
- Synchronize SunHorizon project workplan with
 - o long term, public administration and procurement procedures,
 - o parallel renovation and maintenance works relying on other administrative departments, engineering company and architects
- Significant effort has been required to push some companies to answer the tendering process since the budget envelope for engineering installation of the whole Sunhorizon topic was not attractive enough, limitation amplified by covid crisis and further evolution of the market, as in most of the European countries
- tendering had to be repeated because no answer, accumulated huge delays

At M39 December 2021 meeting :

- Publication of the specifications in February 2021
 - During the electronic opening of the offers = no offer
 - GRE used a facilitated procedure and contacted more than 8 companies of the GRE network
 - No company was interested in working for the SunHorizon project
- After negotiations, two companies finally agreed to submit an offer (end of May 2021)
 - It was already too late compared to the schedule set at the GA in March 2021
 - The offer of the company D-Fi was > 1 million €
 - The offer of the company Balteau was not reliable / not precise enough
- GRE LIEGE worked extensively with technical partners to specify the Balteau offer (before flood)
 - organization of call between the technical partners and the project manager of Balteau
 - GRE asked the technical partners to cost their installation
 - Solved technical problem with TVP: stability of the roof
 - The technical partners precisely determined what was provided by their company or what should be in the offer
 - Thanks to the work of the technical partners, we have drastically reduced the amounts of the two offers (Balteau and D-fi)

While GRE LIEGE had advanced very well with the technical partners to refine the offers, the hall has been destroyed by the floods (July 2021)

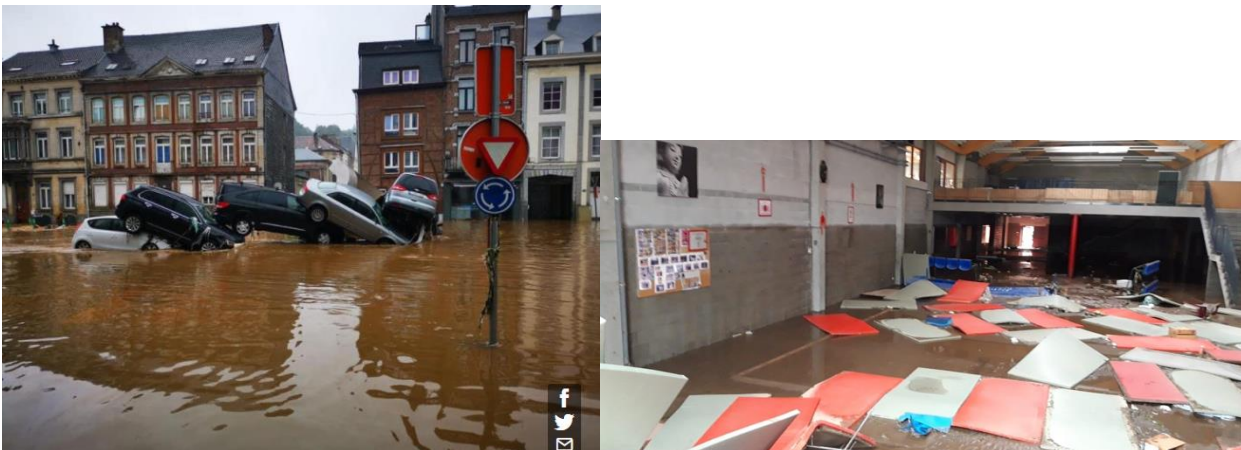


Figure 8 View of street just behind the Albert Moray hall and inside the Sport Center

Based on this catastrophic situation, the biggest natural disaster in Belgium for 100 years, it has been decided to withdraw the Moray Hall from the SunHorizon project (formalised with an Amendment in May 2022).

The SunHorizon CW app was not deployed on this site.

1.2.5 Cluj-Napoca demo site #6

After the final decision at the end of January 2022 to cancel the #7VerviersSP and considering the previously cancelled #6VerviersSC in summer 2021, the remaining budget linked to these demo cases was released to investigate fall-back scenario to achieve TP1 installation in large building scale.

For this purpose, the Technical University of Cluj Napoca (TUCN) offered a demo site in Cluj Napoca, Romania: an existing student dormitory, hosting around 1850 students. The dormitory is used all year long; and uses a Building Energy Management System (BEMS) to monitor its electricity use. In May 2022 EU approved the Amendment to the Grant Agreement and TUCN became an official SunHorizon partner with the Cluj-Napoca demo site starting from May 2022.

Type of building: Residential building (1977; envelope insulation); Available roof: 48 x 24 m² in the restaurant next to dormitory(close to boiler house)

Demonstration action: TP1, Parallel integration:

Existing: Gas boilers and DHW tanks

SunHorizon TP1:

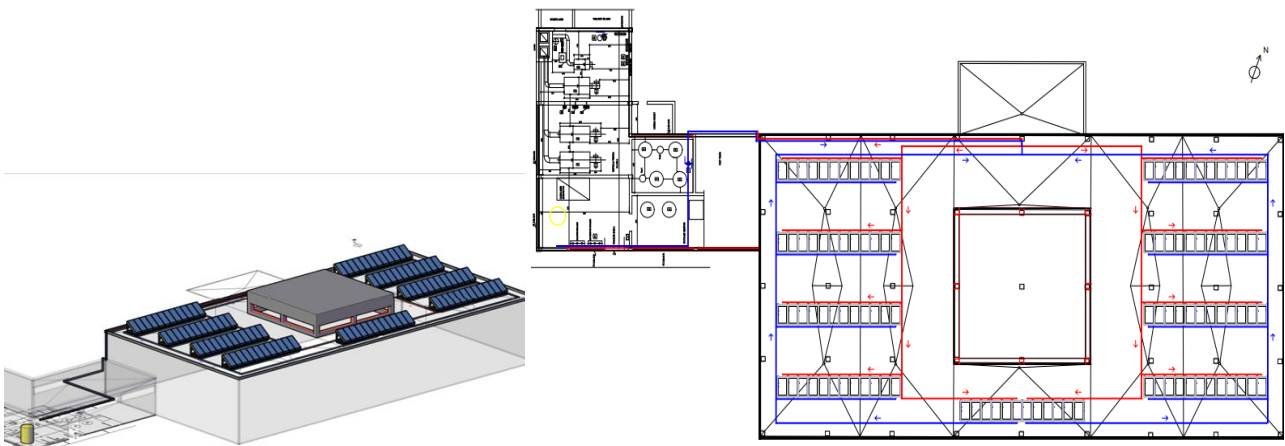
- 220 m², 132 kW, Solar Thermal System provided by TVP
- 2x20 kW Thermal compression Heat Pump provided by BoostHeat
- 10000 liters Storage Tank provided by Ratiotherm

With the financial problems regarding BoostHeat the technical solution of the Cluj-Napoca pilot site was redesigned in October 2022 to replace these units by BDR HP similar capacities. TUCN had to cancel and relaunch the procurement process for the subcontracting EPC services and to update accordingly the workplan, shifting again the . The ClujNapoca demo case's mitigation plans following BoostHeat failure in November 2022 were officially rejected by Project Officers in April 2023 since the second request for extension of the project by 6-months to include relevant monitoring data of the TP1 in TUCN was not acceptable regarding EC criteria.

The Technical University of Cluj Napoca (TUCN) joined officially the SunHorizon consortium on 26/04/2022 as a replacement for Verviers demo sites (see next paragraph). Unfortunately, the timetable for the demo site deployment has been interrupted due to the withdrawal of BoostHeat (one of the SunHorizon's technology providers) within autumn 2022. TUCN had to cancel and relaunch the procurement process for the subcontracting EPC services. Despite the fact that a replacement for the BoostHeat HP technology has been found and all partners' involved in the demonstration expressed their commitment, the EC decided to cancel the demo site.

There is a sequence of events and/or delays that as a whole have contributed to the cancelation of the Romanian demo site. At first, the decision for the withdrawal of Verviers' demo sites has been prolonged with no evidence of real progress and despite repetitive delays from the respective user partner. In parallel, a major flood event (summer 2021) caused major damages to one of the demo sites, which was then cancelled. A second delay has been experienced between the confirmation of the feasibility of the Romanian demo site (autumn 2021) and the official signature of the respective amendment on the Grant Agreement (end of April 2022). A third misfortune was the withdrawal of one of the key technology providers (i.e. BoostHeat) during the evaluation stage of the tender procedure launched by TUCN (autumn 2022). A fourth cause of the cancelation may have been the misconception that the EC would approve an additional 6-month extension of the project duration (on top of the 12 month extension already approved). The latter created a sense of safety, which turned into complacency, and that was abruptly ended as soon as the rejection was communicated to the partners (03/2023).

Some decisions could have been taken much earlier (e.g. withdrawal of the Verviers demo-sites, official entry of Cluj Napoca, etc.) and thus the Romanian demo-site would have sufficient time to be deployed without the need of the additional extension. The public procurement procedures in Europe may be relaxed and relieved from unnecessary bureaucracy to allow some flexibility, especially with respect to innovation-related procurement.



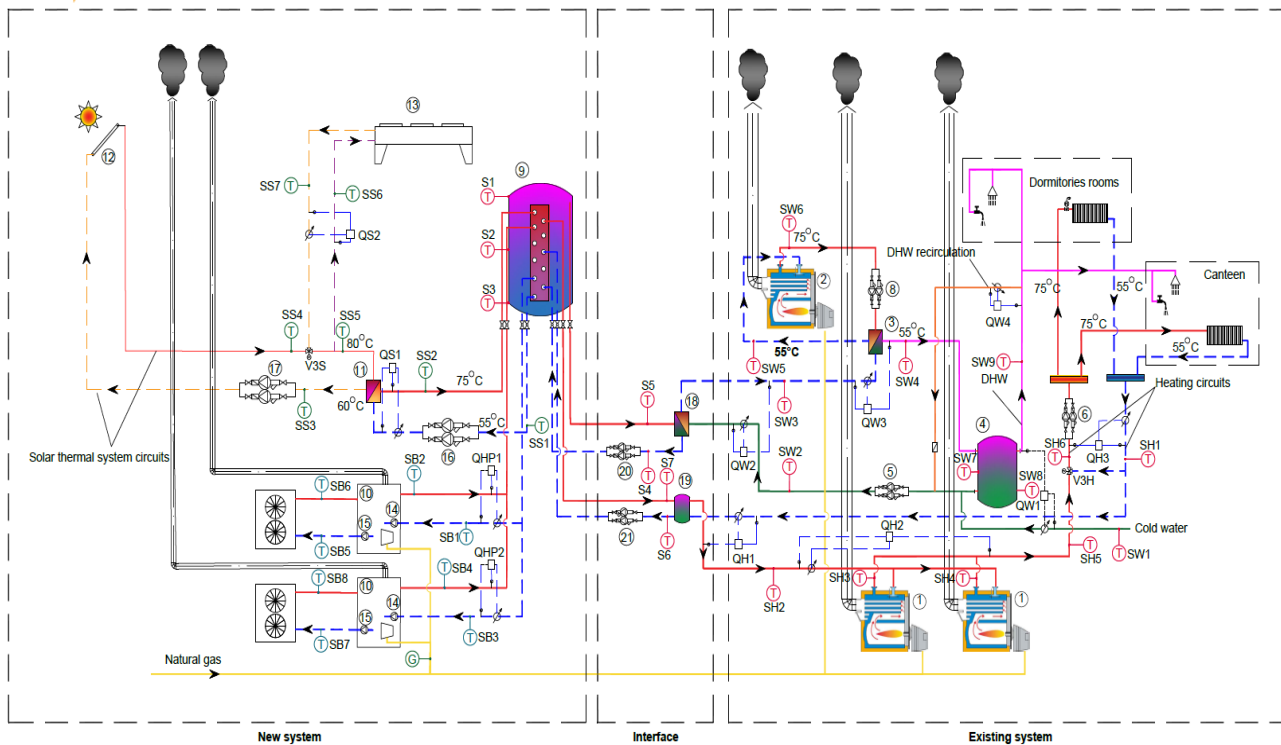
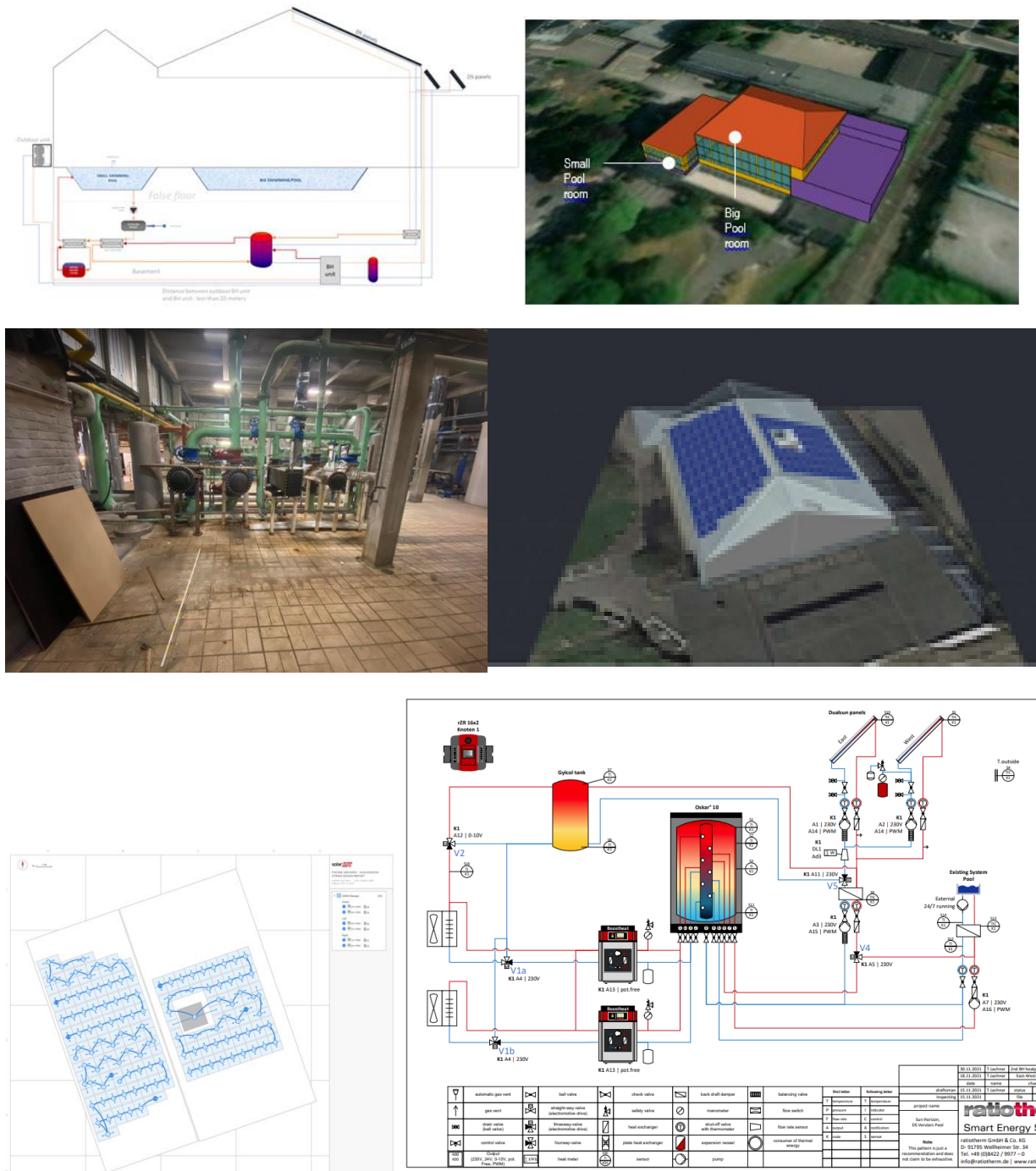


Figure 9 ClujNapoca demo case: buildings overview, TVP roof implementation for TP1 and boiler room relationship, original TP1 integration principles, analysis of possible areas for additional PVT for eventual extension to TP2

The SunHorizon app was not deployed on this site.

1.2.6 Verviers SP demo site #7



Second round : only two offers from D-Fi and Balteau , for all SunHorizon installation work in both Verviers SC and SP: much too expensive and lack of follow-up → no more contact with them.

3 times whole SunHorizon project re-scheduling since 2019: because of pool's public access road renovation, pool building renovation changes, unexpected asbestos in certain roofs in Nov. 2021 which is leading to decision status to-date, illustrated in Figure 10 :

- The location originally determined in 2019 for the SunHorizon indoor units (RATIO and BH components), is taken for the pool renovation project by architects from 2021. GRE is in discussion with architects to move the pulsion group machine and refine the SunHorizon technology space requirements.
- Detailed SunHorizon schematic and controls updated by Ratiotherm
- PVT panels roof layout, piping and wiring by Dualsun

In November 2021 starting again discussions with E7 local company (already present for other SunHorizon demonstration sites in Berlin and Nurnberg). GRE LIEGE learned from Synergis (demo site manager) that the pool water was empty until 01/11/2021. Originally it was mid-May 2021. So GRE postponed again the timeplan waiting for E7 eventual answer to the tender by January 2022. As no answer received in February 2022, the ultimate decision to cancel the #7Verviers SP demo site is made by GRE Liege, also leaving consortium and remaining budget especially for ClujNapoca #6 replacement. The demo #7 has been officially withdrawn with an Amendment in May 2022.

Main difficulties in engineering phase:

- Include technical engineering studies and installers work supervision in tendering , not only installation work
- Synchronize SunHorizon project workplan with
 - o long term, public administration and quotation requests procedures,
 - o parallel renovation and maintenance works relying on other administrative departments, engineering company and architects
- lot of effort to push some companies to answer the tendering process since the budget envelope for engineering installation of the whole Sunhorizon topic was not attractive enough, limitation amplified by covid crisis and further evolution of the market, as in most of the European countries
- tendering had to be repeated because no answer, accumulated huge delays

The SunHorizon app was not deployed on this site.

2 Active demo sites

2.1 Sant Cugat demo site #3 AJSCV

2.1.1 TP3 overview VEO

The objective for Sant Cugat, as part of the Sunhorizon project is to demonstrate the viability of the technology package (TP) number 3, based on the following demonstration action: the solar thermal system (based on the High Vacuum Flat Panels (HVFPs) of TVP) drives the thermal compressor of FAHR chiller with increased efficiency to provide 50kW cooling capacity with existing 93 kW chiller on the existing cooling distribution.

Table 4 Technology package 3

SunHorizon TP	Solar-HP concept	integration	Description
TP3 TVP+FAHR	Solar thermal-driven HP for cooling	HP	TVP for space heating + DHW in winter + activation of the thermal compressor of the adsorption chiller (FAHR)

Specifically, for the installation in Sant Cugat, the following sizing of the component was foreseen:

Table 5 Component sizing for Sant Cugat demo site

Component	Size
TVP High Vacuum Flat Panels (HVFPs)	200 m ²
FAHR chiller	40 kW sorption 60 kW compression
RT tank	10'000 L
RATIO Cold buffer	2'000 L

2.1.2 Building integration engineering phase

2.1.2.1 Building integration engineering by VEO and AJSCV

The overall layout of the system has changed a little bit compared to the preliminary design:

- The solar thermal field dimension changed from 200 m² to 192 m² (98 panels)
- The existing equipment was included and integrated in the scheme since the current air conditioner was not well differentiated in the original scheme and two fan coils from the theater dressing rooms did not appear.
- A new 3-way valves of the heat pump bypass was adapted to the needs.
- The installation of an exchanger in the heat stage was included to reduce the inlet temperature of the existing hot water heat pump.

As RT tank had to be positioned in the courtyard (outside) a structural study has been conducted resulting in the need to reinforce the courtyard where the tank is positioned. The data provided by the geotechnical study determines that the working tension of the ground for direct foundations supported on stratum A is 1.00 kg / cm² and with a K30 ballast of 2.20 kg / cm³. In order to carry out this action, the surface of the corresponding existing floor was demolished and a 20cm reinforced concrete floor is executed.

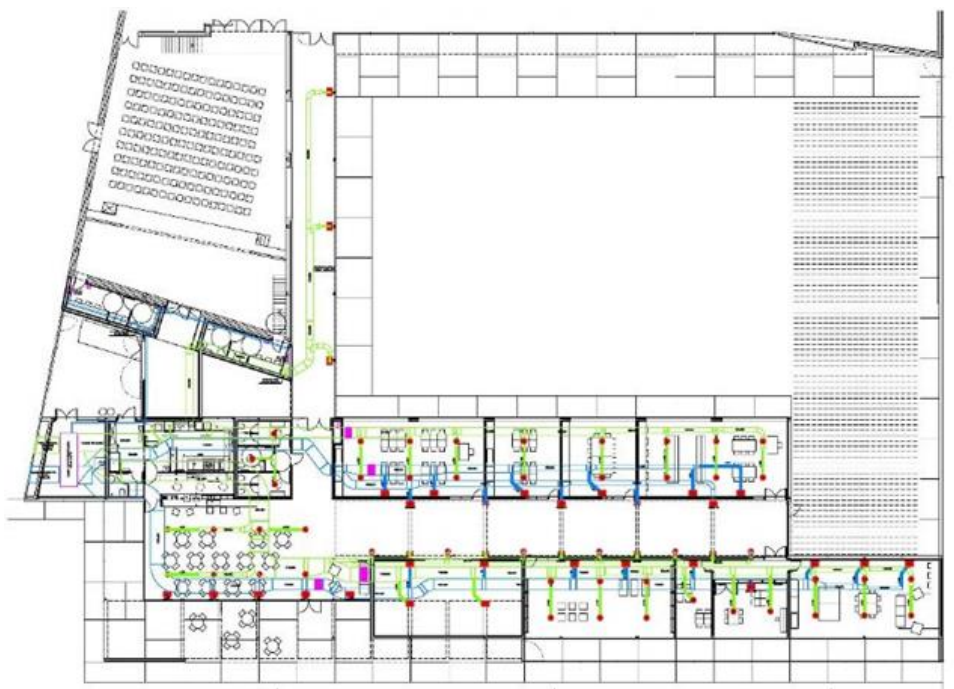
In parallel, the structural calculation made by AJSCV shows that the TVP solar field can be installed on the roof of the demo site. Roof loads in the building project:

- Own load: 60 kg/m²
- Permanent loads: 100 kg/m²
- Use/snow overload: 50kg/m²

TOTAL: 210 kg/m²

Static load of new solar collectors: 55 kg/m² and static load of new dry cooler: 92,34 kg/m².

The project must be registered with the competent administration (Ajuntament de St Cugat) to obtain the execution permit. The documentation was registered the 14th of May 21 and the permit was obtained the 15th of June 21. Likewise, a health and safety study was carried out by a competent technician and evaluation during the project execution.



2.1.2.2 Engineering of the solar thermal system based on High Vacuum Flat Panels (HVFP) by TVP

The following specific challenges and lessons learnt have been identified during the engineering phase:

- Tailored technical solutions for mounting the panels' support structure onto the rooftop were needed (due to the limitations in space availability, the solar panels had to be installed in parts of the roof, which had different structure/ stability specs). The same applied to the thermal block (pump, valves, expansion vessel, sensors, flowmeter), which has been adapted to the demo site special needs (for a lighter structure installed in the rooftop). In this respect, TVP has gained valuable knowledge on rooftop installations that will be applied in new solar thermal systems.
- Local/ national regulatory requirements (e.g. construction permissions, procurement requirements) should be clarified early enough to ensure that they are taken into consideration during the engineering stage and that the respective procedures are completed on time.
- It is essential to ensure that the engineering is not limited to each technology separately but also takes into consideration integration issues, as well as applies a global approach to monitoring and control of the technology package as a whole. A single partner/ expert (integrator) should ideally be responsible for the engineering at technology package level.

2.1.2.3 Thermal storage and controls RATIO

The biggest challenge was to fulfill all specifications regarding the needed volume (10T Liter) of the tank to fit into the available room. The hydraulic connection needed an adjustment for a better integration and benefit hydraulic consumer.

2.1.2.4 Hybrid chiller FAHR

The hybrid chiller performance could be improved on different levels:

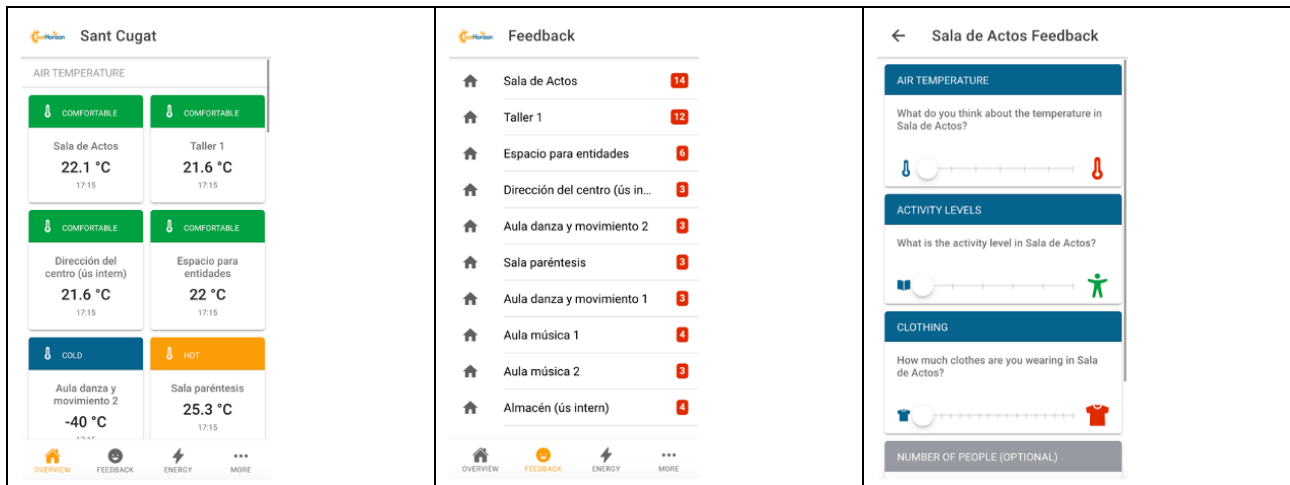
- Valuable engineering knowledge was obtained in a re-design of the adsorption module. Improved adsorber and evaporator heat exchanger designs were employed, resulting in more compact adsorption modules with improved thermal and mechanical stability. D3.3 (#16, sec. 2.4)
- The parallel connection of the adsorption and compression heat rejection circuits turned out to be more feasible compared to the initially planned serial/cascaded connection.
- R134a was replaced by R290 (lower GWP), which required re-design of the compression unit. The efficiency of the compression unit was improved by using a frequency inverter. D7.5 (#49, p. 12)

Furthermore, adaptations to the internal control software of the hybrid chiller had to be made to improve performance and to enable compatibility with the top-level system control.

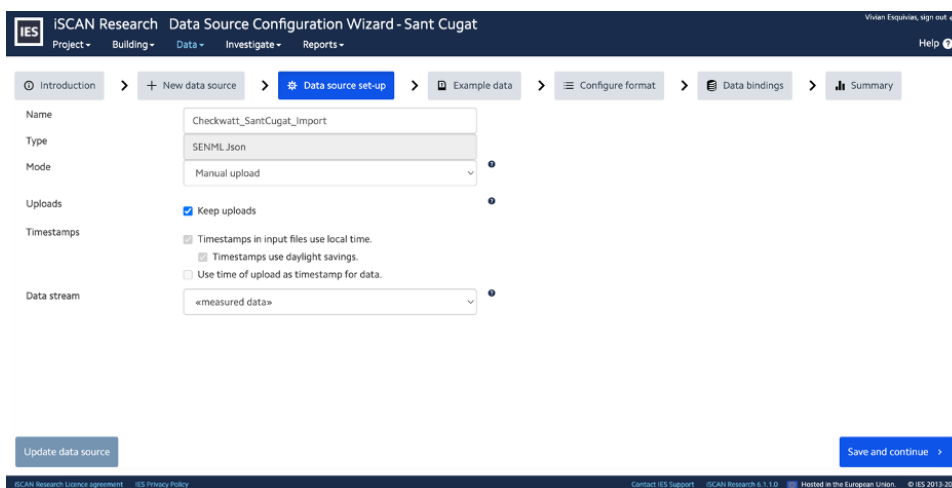
2.1.2.5 User app CW

The building integration of the SunHorizon app was mainly the integration and synchronization with the ISCAN system. The hardest part was to find the correct rooms/sensors and their ids to retrieve data and show in the app. But once this was sorted out, the integration went smoothly. Another lesson learned was that we made the right decision when we

decided to make the app easily configurable and modular. Since the Sant Cugat demo is different from the Riga demo (which was the first demo the app was integrated with), in terms of the type of building (public) and the end-users (building managers) many parts needed configuration. This part went quite smoothly as well.



SunHorizon app, Sant Cugat



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

2.1.2.6 Monitoring sensors and platform SE

Performed activities:

- Viewing documents regarding the project about room controllers, power meters and water meters.
- Choosing the devices to be installed according to the needs.
- Elaboration of the wiring drawing for the chosen devices.
- Elaboration of the video instruction for the Wi-Fi sensors pairing.

Encountered challenges:

- Haven't received the complete project documentation.
- Having internet on the Schneider Router to enable the VPN: since the building is a public structure has been very difficult to have internet on the router to enable the communication with the Schneider server.
- In most of the meetings there weren't the right person that should've handled the issue encountered.

Lessons learnt:

- It is important to receive the whole documentation of a project even if it is not necessary for the assigned task.
- When a meeting is scheduled for a specific task the person that oversees that task should attend to it and, if they can't, the meeting should be rescheduled, since most of the time is pointless to talk to someone that knows every aspect of the project superficially and not specifically.

2.1.2.7 Monitoring platform IES

During the engineering phase the activities performed in the demo site of Sant Cugat included the specification of the software architecture to achieve smooth integration of the Enterprise Server and iSCAN software. This process is described in detail in Deliverable 4.4. A webhook that pulls the data from Enterprise Server and uploads to iSCAN every 15 minutes was configured and developed by IES, using the REST API endpoints provided by Schneider Electric. Then, using the iSCAN API, the rest of the tools were enabled and integrated such as the proactive/predictive maintenance, hybrid controller. Furthermore, during the integration engineering phase, a test server was set up by Schneider Electric to enable the testing and configuration of the integration before the actual installation of the pre-monitoring sensors.

Specific challenges faced and resolved included:

- Data Incompatibility – the two software programs using different data formats or structures
- Synchronisation issues - The 15-minute data transfer interval lead to synchronization problems, resulting in data gaps or overlaps
- Security and Privacy Concerns - Integrating two systems introduces potential vulnerabilities, so ensured data security and privacy with password protection and SSL certificates
- Error Handling - Handling errors and exceptions during data transmission is essential to maintain system reliability
- Scalability - The integration was designed to accommodate future scalability requirements as the building's IoT network grows
- Performance Optimization - Data transfer and processing should be optimized to avoid delays and improve system performance
- Technical support – provided to software developers using APIs and new tools
- User requirements specification - the end-users of the demo sites were consulted early in the process to provide their feedback about the platform user experience and appearance

Lessons learned included:

- Early Planning - Proper planning, scoping, and understanding the systems' capabilities are essential before starting the integration process
- Collaborative Approach - Encourage close collaboration between the development teams of software programs to identify potential challenges beforehand
- Prototyping and Testing - Create prototypes and conduct thorough testing during the integration to identify and address issues early in the process
- Continuous Improvement - Continuously review the integration process and identify areas for improvement to optimize efficiency
- Error Handling and data gaps – The data gaps that are recorded in iSCAN side need a streamlined investigation in both sides (IES and SE side), there is no automated error handling mechanism, other than notifications for data gaps that are set up in both sides

Data dictionaries creation issues – a 3rd party (CARTIF) created the nomenclature and data dictionaries and this caused issues with integration timelines and synchronisation. The way the platform is set up, it depends a lot on a spreadsheet which is “translating” the names of the monitoring variables from the Enterprise Server to iSCAN channels

2.1.3 Installation and commissioning phase

2.1.3.1 Installation and commissioning by VEO

The reception of the equipment and the starting date of the installation suffered some delays. Prior to the start of the installation and as a result of the study on the need to carry out structural reinforcement in the courtyard where the thermal tank will be installed, the reinforcement was carried out during in May 2021 by Ajuntament de Sant Cugat. The works consists of the replacement of the existing floor by a new floor with sufficient structural capacity: the existing floor has been demolished and a 20cm reinforced concrete floor has been executed.

Regarding the potential reinforcement of the roof, the initial studies were done in 2020 but due the new location of the solar field (using elevated areas) a new study has been carried out by Ajuntament de Sant Cugat. The result has been that the rooftop and the new area to locate the solar panels would support the total weight.

The installation officially started the 17th of June 2021 with the execution of the concrete supports for the solar field. The starting date was affected by the permit obtention, submitted by the city council. Right after this, the TVP panels were installed by VEO with the support of TVP. During the works, it has been reviewing the panels distribution since the provided roof layout was wrong.

Most of the equipment has delay their delivery on site:

- Solar panels (provided by TVP): The solar panels have been delivered on W20 (20th of May 2021) with 1,5-month delay over the initial planning. The solar field was completed installed and connected in August 2021.
- Thermal tanks (provided by Ratiotherm): The equipment (two tanks) were delivered on W16 (21st of April 2021) with 1-month delay over the initial planning.
- Heat pumps (provided by Fahrenheit): The heat pump production has suffered delay on the production. The equipment (re coolers) has been delivered on W26 (14th of June 2021) with 2,5-month delay over the initial planning.

The equipment was delivered on site according to the planning (Tanks (Ratiotherm), Solar thermal field (TVP) and Heat pumps (Fahrenheit), from May to December 2021. The technical room and the interconnections with the re coolers and the current system were performed without major incidents as well as the installation of the FAHR chillers, the interconnection to the existing system and the deployment of the monitoring system.

The commissioning works took place on January 2022 and right after the installation the consortium start working on the iScan visualization to collect data.





2.1.3.2 Installation & Commissioning of the HVFP-based solar thermal system TVP

The following specific challenges and lessons learnt have been identified during the installation & commissioning phase

- The fact that a local engineering partner (i.e. Veolia) was available and had the overall responsibility for the installation and commissioning of the overall system has proved valuable for TVP (by e.g. relieving the company from investing additional human resources for the installation). TVP role was focused on the shipment of the components of the solar thermal system, the training of the local labour on the installation of the system, their supervision and finally to the actual commissioning of the solar thermal system.
- The above arrangement has the potential to work optimally for both the technology provider (i.e. TVP), the local engineering partner (i.e. Veolia) and the demo site partner (i.e. Municipality of StCugat) because it: (i) uses efficiently local human resources & expertise; (ii) transfers know how (on solar thermal systems) to local companies; (iii) sets the foundations for operation & maintenance support services in the future (by the same local partner); and, (iv) paves the way for potential future collaboration in commercial solar thermal projects between the technology provider and the local engineering partner.
- However, a number of improvements have been identified: (a) A more systemic approach on the training of local installers should be adopted by producing and making available additional and well organised audio-visual training material (language issues should be addressed, as well as both remote and onsite training modes), and standardised check lists and list of required tools for task completion; (b) A procedure facilitating communication between technical personnel of all involved actors for trouble-shooting and fine tuning (especially regarding the operational integration of the Technology Package) can help in improving efficiency and avoid unnecessary delays.

2.1.3.3 Thermal storage and controls RATIO

Ratiotherm developed the hydraulic schematic for the integration of the solar panels and adsorption chiller. The tank has about 10.000l. Therefore it was necessary to reinforce the floor and a crane was necessary to unload the truck.

2.1.3.4 Hybrid chiller FAHR

During physical local installation no severe issues occurred but for the commissioning only in the 3rd visit high temperature driving heat was available. Therefore, Fahrenheits support had to visit San Cugat 3 times which delayed the commissioning. From this experience it is highly advisable to

- Demo-side owners need to have qualified personal available
- So personal qualification is mandatory already for the installation
- Unless documents for the preparation of installation and commissioning were provided, critical assessment of sufficient preparations have to be done before support visits

2.1.3.5 User app CW

The biggest challenge was to find the best way to distribute the app. Since we did not have contact with the end-users directly, we needed to involve the demo site representatives and make sure they had all information they needed, such as instructions on how the app works, how to register/login etc., so that they can pass the information to the end-user. This was solved by arranging an online meeting where we (CW) could do a walkthrough of the app, during this meeting we also found some more features that needed to be configured in the app for this demo site (ex. Multi-language support).

2.1.3.6 Monitoring sensors and platform SE

Performed activities:

- System integration of installed devices and third-party systems such as Ratiotherm, BoostHeat, etc.

Challenges encountered:

- Sometimes the on-site installer wired some Modbus devices in an incorrect way despite the electrical schemes provided, and we had to schedule a call to make all the possible tests to find the communication problem or go on-site ourselves to make it right.

Lessons learnt:

Before making any modifications, the on-site installer should ask the correct party if the modification is correct

2.1.3.7 Monitoring platform IES

The installation and commissioning of the monitoring platform for Sant Cugat demo site was conducted under WP4 activities, and described in detail in D4.5. The key challenges and lessons learned during the process are listed below:

Challenges:

- Data Integration and Mapping - Integrating data from different sources and mapping them to specific KPIs for the dashboard requires careful planning and attention to detail
- Network Connectivity - Establishing a reliable network infrastructure to support data transmission between devices and the central system can be challenging, especially in large buildings
- Data Validation and Quality Assurance - Implementing measures to validate data accuracy and quality during commissioning is crucial for generating meaningful KPIs on the dashboard
- User Acceptance Testing - Conducting thorough user acceptance testing to ensure the KPI dashboard meets the needs and expectations of end-users
- Interoperability Testing – Verifying interoperability between different software components and devices to avoid potential communication issues
- Customization Options: Provide customization features on the dashboard to allow end-users to tailor the information presented to their specific requirements.

Lessons Learned:

- Pre-Installation Assessment - Conduct a thorough assessment of the building's infrastructure and existing systems to identify potential integration challenges early on
- Collaboration and Communication - Foster strong communication and collaboration between the installation team, stakeholders, and end-users to ensure everyone is aligned on project objectives
- Prototyping and Pilot Testing - Conduct small-scale pilot tests to validate the feasibility and effectiveness of the KPI dashboard design and user interfaces
- Scalability Considerations - Design the KPI dashboard and IoT system with scalability in mind to accommodate future expansion and replication

2.1.4 Operation and monitoring Phase

2.1.4.1 Operation and monitoring AJSCV

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

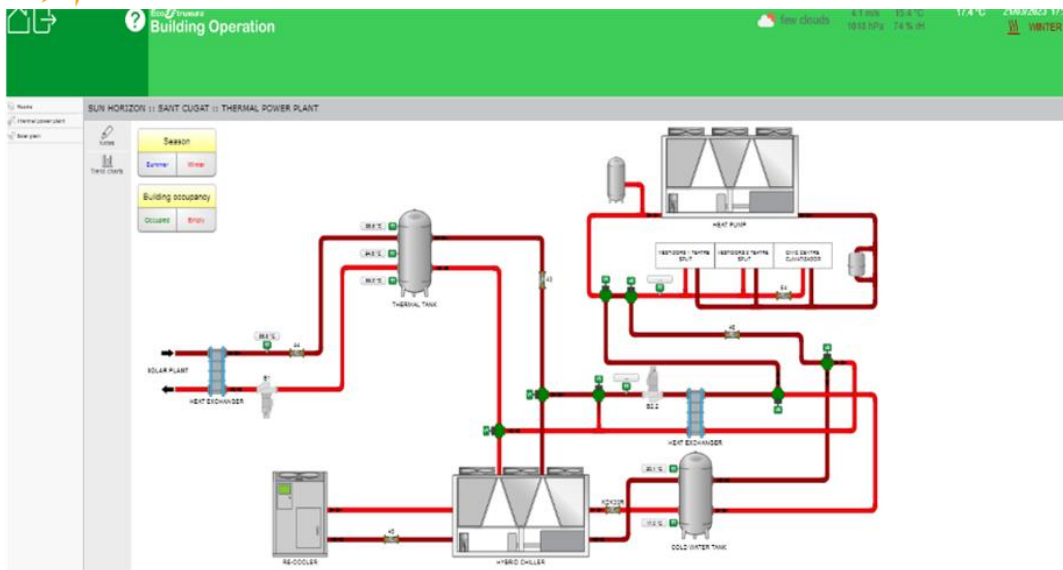
Next steps: validation of hybrid controller in Sant Cugat, predictive maintenance tool and submission of D5.7 (IES).

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

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

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

Only at the Sant Cugat demo site is the TVP not working and no maintenance has been carried out in recent weeks.



2.1.4.2 Operation and monitoring of the HVFP-based solar thermal system TVP

The following specific challenges and lessons learnt have been identified during the operation & monitoring phase

- The effective monitoring of the solar thermal system operation is not feasible with unstable or no internet connection. The operation of the HVFP-based systems is fully automatic; however, remote monitoring from TVP personnel is essential for fine tuning purposes and/or troubleshooting of alarms (e.g. caused by power interruptions, component malfunctions, etc.). Unfortunately, interruptions in the internet connection have been rather frequent in the case of StCugat demo site. As a result, TVP personnel did not receive information about alarms triggered and subsequently could not identify and perform remedial actions. Based on the above experience, it is highly recommended that the internet infrastructure is selected so that it is compatible with the individual requirements of the different systems (e.g. solar thermal, HP, storage tank), as well as the operation of the Technology Package as a whole.
- Leakages in the panel connections have been experienced and ultimately a new type of gasket has been supplied and the old gaskets replaced.
- Local engineering & technical capabilities have helped in remote troubleshooting, while they facilitated transfer of knowledge and the development of experience on solar thermal system operation locally.

2.1.4.3 Thermal storage and controls RATIO

The current operation works temporary. The final validation is planned till end of August 2023.

2.1.4.4 Hybrid chiller FAHR

Monitoring the hybrid chiller demo unit via cloud data showed no major issues that had to be addressed. In a period from Sept. to Oct. 2022 heat from solar field powered the adsorption part of the hybrid chiller resulting in a cooling power output of around 12-17 kW. The operating conditions especially for the driving heat circuit were in the expected range.

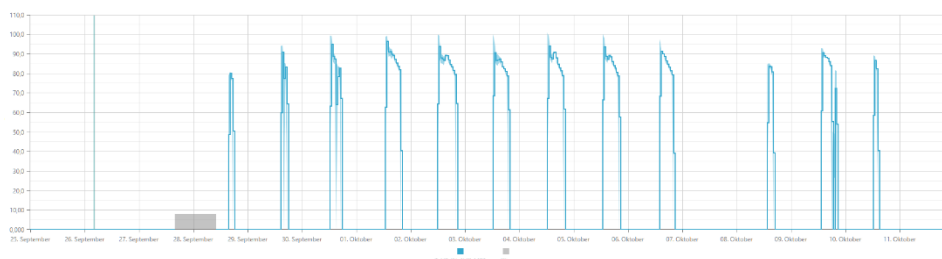


Figure: high temperature (HT) input from solar field in working period 2022.

A comparison of the evaluated data with the alternative Fahrenheit silica gel technology shows, that zeolite as adsorbent was the right choice regarding both cooling power and thermal efficiency. At the local ambient/back cooling temperatures of up to 32°C, driving solar heat at 77-95°C and selected cooling temperatures of 10-12°C a silicagel based chiller would have only provided around 5 kW of cooling.

From Oct. 2022 to Sept. 2023 only the compression part of the hybrid chiller was running as the adsorption chiller was not feed with heat from the solar field. The latest data on adsorption performance starting middle of Sept. 2023 are still in evaluation. The data collection will be continued after end of the project.

2.1.4.5 User app CW

One of the biggest challenges with the SunHorizon app was to find a way to make sure that the app was used by the end users. This was an issue that we identified early in the project and tried to find solutions for, such as making the app appealing enough in terms of usability and design, but another big part of making sure that the app was used lay in the distribution plan. The app is now available for download from App Store and Google play, the demo site managers have been instructed on how the app works so they can pass it through to the end-users.

2.1.4.6 Monitoring sensors and platform SE

Performed activities:

- Modification of the navigation graphic pages and dashboard to fit the site needs.
- Regular check for devices' status.

Challenges encountered:

- API functionality: the usual way of transmitting the data didn't work and we had to adjust our software to fit the needs.
- Offline devices: some devices have been offline for a short period of time since some wiring modifications have been made on-site without letting us know.

Lessons learnt:

- Every modification regarding the monitoring system should always be advised to every party involved before making it.

2.1.4.7 Monitoring platform IES

During the operational and monitoring phase, the key challenges and lessons learned are:

Challenges:

- Connectivity Issues - Unforeseen connectivity problems between the integrated systems can lead to data gaps and impact the accuracy of the dashboard
- End-User Training - Educating end-users on how to interpret and utilize the dashboard effectively requires thorough training and ongoing support
- User Engagement - Foster user engagement and promote the dashboard's value by regularly communicating its benefits and successes.

Lessons Learnt

- Continuous Data Validation - Implementing automated data validation and verification mechanisms to maintain data integrity and accuracy on the dashboard
- User Feedback and Iterative Improvement - Gather feedback from end-users and iterate on the dashboard design to enhance usability and meet their evolving needs

2.1.5 Performance analysis from monitoring data CNR

The obtained results, summarized in D6.6, showed some lacks in terms of data availability and overall performance. A share of renewable of about 12% was obtained in the monitoring period. This is related to the limited data collection performed due to malfunctioning of the system during the summer monitoring period.

On the other hand, the performance of the hybrid chiller was in line with the expected values, similar to the measured data point in the lab, showing reliable operation even in the demo site.

2.1.6 Conclusion AJSCV

Final overall conclusion about experience of demonstration in Sant Cugat, main outcomes.

DESIGN PHASE:

The implementation of this demonstration building has been a great challenge, mainly due to the need to integrate the SUNHORIZON project in a space where there is constant occupation, without affecting the normal service of the center

Therefore, when preparing proposals for innovation projects, the importance of providing resources and budget to hire local design teams that can translate the initial idea and designs of the R&D project must be considered to the reality and regulations of each country.

Along these lines, in this type of collaborative innovation projects between the project partners and the local partner, it is very important that the partners who provide the equipment and those who are in charge of the preliminary project support the 'local team of architects during the design phase. to develop the engineering project.

In the design phase the BMS was not taken into account and therefore it was a key factor that has caused us to have difficulty today. In the design phase, many things are taken into account, but most importantly, the company that will not manage or its maintenance is considered.

PHASE OF THE TENDER PROCESS:

Usually the owners of the demos that are public companies must follow very structured procedures at the time of contracting, so it is necessary to foresee in the general planning of the project an affordable time slot, for the internal preparation of the documents of recruitment, tender processing, etc. award of contracts, etc.

As this is a project with considerable technical complexity, it is important to define the technical requirements of the specifications very well, since the main contractor must have proven skills and experience in the work to be carried out, especially in terms of control and monitoring of facilities.

MONITORING AND CONTROL SYSTEM

Once the installation was put into operation, and after a year of operation, we were able to verify the great importance of the monitoring and control system. It is the key to success in this type of project. If you can't measure you can't make sure the system is working properly, and worst of all, you can't know where to act to improve system performance.

Only with access to the data can the operation of the system be evaluated, and it gives the opportunity to make continuous improvements, achieving higher levels of comfort and energy savings of the system, optimizing maintenance, etc.

To this day we still have problems with remote monitoring of the installation, so many hours are spent on careful monitoring

In conclusion, we can say that all the implemented systems are very innovative, but the monitoring of the system and therefore the actual monitoring has failed. Better design must be planned and everyone involved in the design phase

2.2 Madrid demo site #4 EMVS

2.2.1 TP4 overview VEO

The objective for Sant Madrid, as part of the Sunhorizon project is to demonstrate the viability of the technology package (TP4) number action, based on the following demonstration action: reversible HP (BDR) for space H&C + DHW; output from solar PV-T (DS), PV-T (DS) electricity production for electric appliances:

Table 6 Technology package 4

SunHorizon TP	Solar-HP concept	integration	Description
TP4 DS + BDR + RT	Parallel Integration		Reversible HP (BDR) for space H&C + DHW; output from solar PV-T (DS), PV-T (DS) electricity production for electric appliances

Specifically, for the installation in Madrid, the following sizing of the component is foreseen:

Table 7 Component sizing for Madrid demo site

Component	Size
DS panels	50 m ²
BDR HP	27 kW A-W HP 9 kW W-W HP
RT tank	1000 L and 1300L

2.2.2 Building integration engineering phase

2.2.2.1 Building integration engineering by EMVS and VEO

In 2017, an unfavorable Technical Building Inspection report was carried out in the building requiring immediate reparation of several technical aspects. For this reason, the EMVS promoted a retrofitting project consisting mainly in improving the envelope (insulation, facade, windows, roof), the structure and the accessibility (ground floor, elevator, etc.)

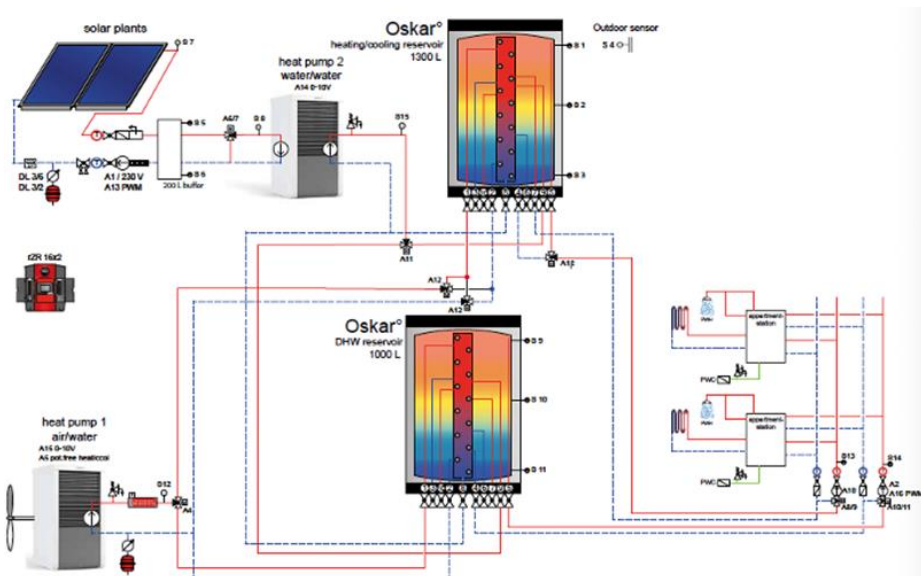
In 2018, the building was selected as a Demonstrator for the SUNHORIZON European Project. The intervention would warrantee the renovation of the HVAC systems, which go from being individual to centralized, and the integration of renewal energy systems.

At this moment a great challenge arises, which was to integrate SUNHORIZON project into an ongoing Renovation Project that was already in motion, with the less impact in terms of cost, timing and affection to the tenants. A great effort was done to achieve this, resulting in the necessity to split Sun Horizon intervention in two phases:

A first phase, including both the installation of the HVAC equipment inside the dwellings, as well as the hydraulic vertical distribution. It was carried out in parallel to the Passive renovation. And a second phase, which included the installation of the Sun Horizon equipment, solar field, hydraulic, electrical and control system and commissioning.



The final sizing of Madrid demo consist of 50 m² DualSun PVT panels on the roof, 1.0SC/SH / 1.3DHW m³ Ratiotherm tank, reversible HP 9BW/27AW kW BDR Thermea obtaining GHG savings of 70% and a primary energy savings of 76%.



In **Madrid** demo, a number of design and installation aspects had to be approved before starting the installation:

- Obtain the installation license from the public administration. This activity requests an executive project with a detailed description of the activities, plans and execution budget to approve the SunHorizon installation.
- Tender procedure to subcontract the installation works. This activity was performed by EMVS between June and July 2021. The contractor was Umavial (the same company that performed the first phase of the renovation works).
- EMVS had to request the electric legalization process with the electric company to modify the existing electric connection (three phase, increase of Power up to 34kW, etc) and the Legalization of PV system.

- The verification process of the monitoring points and communications was done including the definition of the monitoring variables to be imported by IESCAN and the validation of the methodology to access to the monitoring data by SCHNEIDER.

2.2.2.2 Hybrid PVT collector DS

It is strongly recommended to have an energy design office which concentrates the expertise of the entire hydraulic system to define the coupling most suited to the building. The absence of a design office aimed at optimizing the system complicated the progress of the project and should not be generalized. The consortium had not planned generic pre-study tools for future buildings and case-by-case specifications will have to be produced.

The coupling of PVT panels on the HP evaporator is an innovative aspect of the project, redundant production systems led to an overlapping of controls and a more complex system, which had initially been sub-optimized for the benefit of production rescue, but was recalibrated as the project progressed. Demonstration of the effectiveness of the PVT HP coupling should make it possible to simplify the system for future installations by implementing a refined system.

2.2.2.3 Thermal storage and controls RATIO

The limited space and small doors was a challenge for designing the tank. Moreover the sizes of the connection has to fit the estimated flows. We provided the control strategy how to implement the brain heat pump and combine them with the air/water heat pump.

2.2.2.4 Hybrid solar assisted HP BDR

Specific challenges and lessons learnt from SunHorizon technology providers during the engineering phase

- a. Sizing of the Water to Water Heat Pump (WWHP) vs size of the PVT field : working the night during winter, or not. The sizing of the WWHP was done on the minimum cold source temperature during the coldest night of the heating season.
- b. The water from the PVT can overpass the maximum temperature accepted by the WWHP. A mitigation valve need to be installed to limit the temperature of the water going to the evaporator of the WWHP.
- c. The PVT panels have big pressure losses and don't accept big pressure. In consequence, the water flow allowed for the PVT panels is lower than the water flow required for the WWHP. A decoupling tank need to be installed between the panels and the WWHP. This decoupling tank is oversized to act as a thermal storage for the heated water from the panels.
- d. The Air to Water Heat Pump (AWHP) power is chosen to cover the thermal needs, including the WWHP.

2.2.2.5 Monitoring sensors and platform SE

Specific challenges and lessons learnt from SunHorizon technology providers during the engineering phase

Performed activities:

- Viewing documents regarding the project about room controllers, power meters and water meters.
- Choosing with on-site personnel which was the best way to connect the two systems together since this site has had an integrated BMS already installed.

No specific challenges encountered, except for the choosing of the list of variables collecting by the existing system to be sent to SH platform.

2.2.2.6 Monitoring platform IES

In this phase the architecture and the whole process designed for Riga Sunisi and Sant Cugat site was replicated without any significant challenges other than the ones seen in 2.2.7.

2.2.3 Installation and commissioning phase

2.2.3.1 Installation and commissioning

The reception of the equipment and the starting date of the installation has suffered some delays since generalized material supply delays. Additionally, the project had to deal with contractor issues due to lack of experience and knowledge in executing high complexity systems, specially associated to hydraulics and communication and controls.

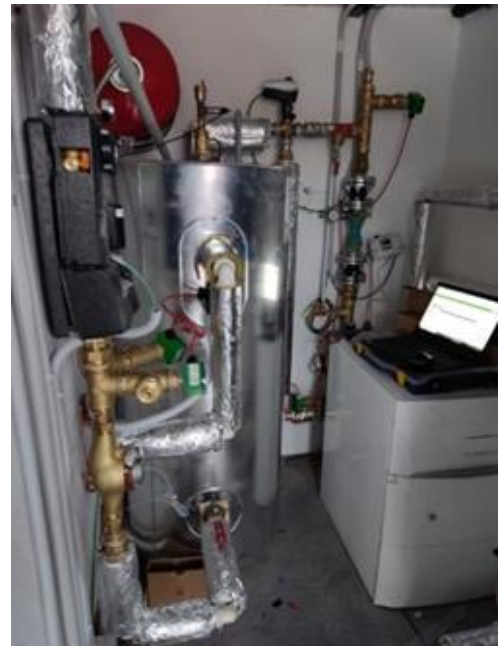
The execution works were divided into phases: Phase I of the renovation works and The Phase II includes the SunHorizon equipment connection to the pre-installation.

Phase I of the renovation works finished in February 2021: all dwelling renovation, installation of the distribution heating/cooling and DHW pipes, and heat meters at dwelling level were properly executed.

The Phase II includes the SunHorizon equipment connection to the pre-installation (Hydraulics, Electrics and Controls) and commissioning with different activities:

- Validation of Control Strategy and Architecture from Subcontracted Control Company (EMVS) October 2020 – March 2021
- Definition and Elaboration of the PROJECT for the 2nd Phase (VEOLIA) Submitted in 01/03/21
- Project review, preparation of the Tender and Launch Tender March 2021 – June 2021
- Contract Installation Company (EMVS) June 2021 –July 2021
 - Main Contractor: Umavial (Same Company that perform the First Phase of the Renovation)
 - Three Months to perform the Works + One year of monitoring and optimization by the Control Company
- Start of procedures with Electric Company (EMVS) May 2021
 - SunHorizon system required to modify existing electric connection (Three Phase, Increase of Power, etc).
- Final Definition and Shipment of Equipment (RT, DS, BDR, SCHE)
- Renovation works (Main Contractor): Done between July 2021 and April 2022, including the Civil Works, the Hydraulics, Electricity and Communication and Controls.
- Commissioning (Main Contractor): Done in September 2022
- PV Commissioning (Main Contractor): Done in October 2022

The installation and commissioning suffered many delays associated to the shipment of the new solar panels, and the insulation of the tanks. In the first shipment of the solar panels (end of July 2021) the model of solar panels were not correct, and a replacement was needed. During the second shipment (14th September 2021) arrived the correct model of solar panels but one of them was broken.



2.2.3.2 Hybrid PVT collector DS

It is important for the PVT collectors that the installer is trained in DualSun products, and particularly in the hydraulic pressure constraints, which are specific. For the PVT manufacturer, it is not possible to generalize the approach of going

on site for commissioning, but DualSun has created support courses for installers to help them carry out qualitative installations .

In any case, given that the products are well known in France, but still little known in the rest of Europe, contact between DualSun and the installation company is essential before the works, even if - and maybe especially if - the person in charge of the project is not the installer (engineering office, project management assistance), both to train the installers in the product installation procedures, but also to reassure them of the simplicity and the robustness of an installation following the rules. To avoid them to over-cost their service because of a product ignorance, and thus maintain a good economic balance of the project.

In future versions, we are planning to launch also PVT modules with aluminium materials heat exchanger (instead of polymeric heat exchanger) for HP coupling systems to propose a more expensive PVT alternative, but that reduce the risk of misuse of the product by installers.

2.2.3.3 Thermal storage and controls RATIO

For the demo site in Madrid was no special challenge to fulfill the specifications.

2.2.3.4 Hybrid solar assisted HP BDR

Some recommendations for the water to water heat pump integrated with the PVT panels :

- Decouple the water flow from the PVT panels to the heat pump with a decoupling tank, the reasons are :
 - o The water flow required by the heat pump can be higher than the water flow accepted by the PVT panels.
 - o The decoupling tank is a heat reserve to manage the power difference between the heat provided by the PVT panels and the heat absorbed by the heat pump
- Design the glycoled circuit up to -15°C to increase the working time with the heat pump

For both heat pumps, water to water and air to water, in case of installation with two way valves on the heat delivery side, we preconize a decoupling tank just after the heat pump to avoid water flow blocking, with the consequence of securing the heat pump and an alarm.

Installation and commissioning of the heat pumps need to be done by following the manuals and the installation rules.

2.2.3.5 Monitoring sensors and platform SE

Performed activities:

- Integration of the Madrid' system through Modbus TCP/IP communication. The collected data come from the existing local BMS and we implemented and tested the data sending from it to the SH platform.

No specific challenges encountered.

2.2.3.6 Monitoring platform IES

In this phase the configuration and commissioning process was replicated for Madrid site without any significant challenges other than the ones as seen in 2.3.7.

2.2.4 Operation and monitoring phase

2.2.4.1 Operation and monitoring by EMVS

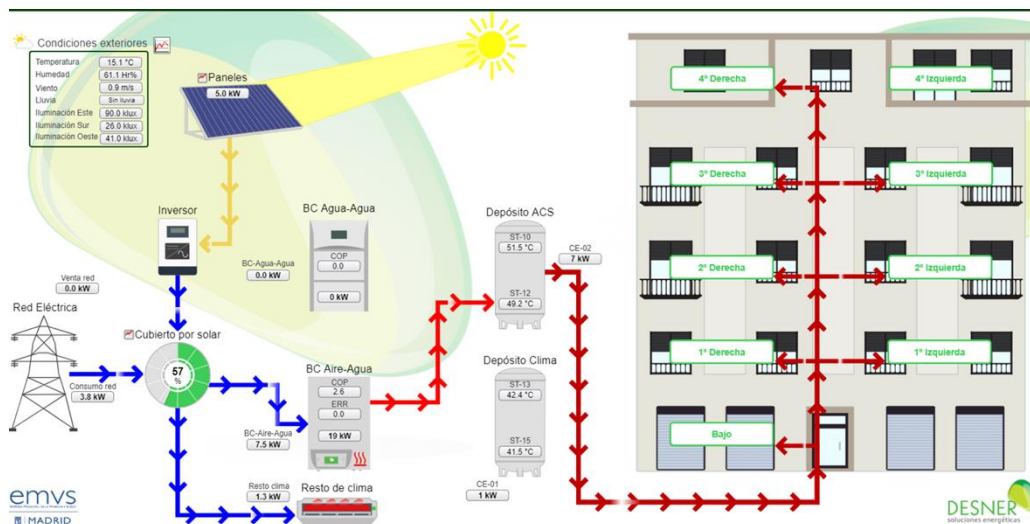
In November 2022, the operational tests of the system were completed and it was commissioned the air-water heat pump. Therefore, the space heating and the DHW system was put into operation starting the energy supply inside the dwellings. In December 2022, it was finished the legalization of the PV system and all the administrative procedures and contracting with the Electric Company. So, we were able to connect the PV inverter and start the energy production and the self-consumption.

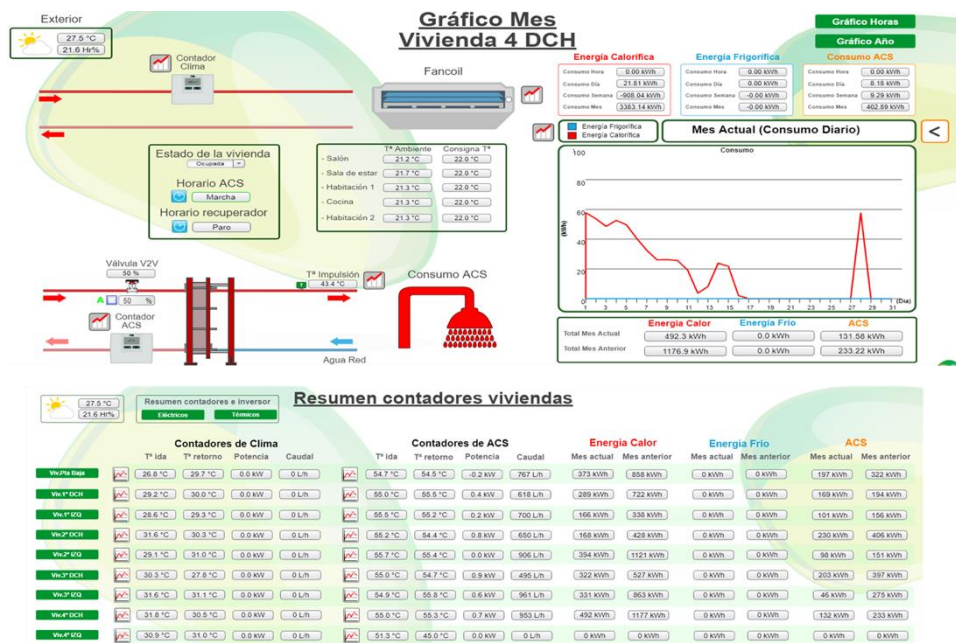
It was needed several months, until February 2023, to finalize the commissioning of the water-water heat pump. The unit had some blocking issues that made the operation impossible. It was required the support of BDR and the Spanish technical service of BAXI, that visit the building many times onsite to solve the issue

Due to the dilation of the flexible piping of the PVT solar panels, we had some leakages in May 2023 that force use to stop the water-water heat pump, only supplying DHW with the air-water heat pump

During these months it has been made some modifications and updates in the control strategy to increase the performance and the energy savings of the system:

- Set Operation schedules for the Heat Pumps, Hydraulic pumps, etc.
- Supply temperature Setpoint for heating established by Exterior Temperature Curve
- Delay the entry of electrical back up for heating and DHW
- Maximize the use of PV generation to increase Setpoints (Thermal Storage)
- Priorize the operation of the W/W heat pump vs the A/W heat pump.
- W-W heat Pump utilization 24h for DHW preparation during Summer time.
- Variable Pump Speed in relation with the demand





2.2.4.2 Hybrid solar assisted HP BDR

The operation monitoring helped us to check and finetune the controls of the heat pumps.

- The electrical backup control was adjusted to work less.
- The WWHP work in safety with a cold source below 35°C, the mixing valve work efficiently.
- The buffer tank between the PVT panels and the WWHP could be more efficient with a bigger size.
- In summer mode, the AWHP is dedicated to cooling, and the WWHP to domestic hot water.

A conservative low operating temperature on the cold source of the WWHP will protect the circuit in case of decrease of the concentration of glycol in the water, but will limit the working range of the WWHP with an impact on the yearly efficiency of the system.

To work efficiently on the long term, an annual maintenance of the system is highly recommended, there is a non-representative list of points to control :

- Control the water pressure
- Control the water quality
- Clean the filters
- Control the electrical connections
- For the Split AWHP, control refrigerant leaks
- Control the glycol concentration

2.2.4.3 Monitoring sensors and platform SE

Performed activities:

- Modification of the navigation graphic pages and dashboard to fit the site needs.
- Regular check for devices' status.

Challenges encountered:

- API functionality: the usual way of transmitting the data didn't work and we had to adjust our software to fit the needs.
- The electrical energy Modbus registers were too small to contain the value, so we asked to the on-site system integrator to change the register type to 32-bit, and we did the same on our side.

Lessons learnt:

- It is better to set the registers type to 32-bit or even 64-bit when electrical energy is involved to avoid reading issues.

2.2.4.4 Monitoring platform IES

In this phase the operation and monitoring was smooth for Madrid site without any significant challenges other than the ones as seen in 2.4.7

2.2.5 Performance analysis from monitoring data CARTIF

Monitoring started in January 2023, since then data has been collecting without many issues; the integration of data on the IES dashboards started in March 2023 and the integration of the KPIs formulas around April or May 2023, but this integration process has included a continuous refining and fine-tuning of both platform, data channels and formulas. The monthly results presented in the figure below have been calculated and updated with data obtained from Schneider platform since January 2023 until October 2023.²

Madrid 2023	GHG savings [kg CO2]	PE_nren savings [kWh]	Customer Bills Reduction [€]	Renewable Ratio [%]	Self-cons. Ratio [%]	Mean temp. [°C]	Heating comfort [°C-h]	Cooling comfort [°C-h]
1	-34.6	-1251.5	-9.3	34.1%	95.4%	0.0	0.0	0.0
2	-35.8	-860.0	-237.7	26.4%	91.0%	21.8	0.0	0.0
3	795.0	3739.9	18.6	53.3%	56.7%	21.5	0.0	0.0
4	1307.0	6641.9	191.5	90.4%	46.8%	22.1	0.0	0.0
5	1443.4	7385.0	207.5	93.5%	35.3%	20.0	0.0	0.0
6	1266.8	6415.8	172.6	80.3%	48.6%	22.1	0.0	0.1
7	722.1	3329.8	87.5	41.5%	88.5%	26.4	0.0	0.6
8	688.4	3140.5	62.8	40.7%	87.8%	26.5	0.0	1.2
9	1134.3	5670.8	148.4	63.5%	56.8%	24.2	0.0	0.0
10	979.2	4775.2	141.6	46.1%	64.0%	23.5	0.0	0.0
Total	8205.8	38977.2	783.5	56.98%	67.09%	23.3	0.0	2.0

Figure 11:Madrid: Monthly KPIs [January to October 2023]

Even though there is not a complete year of data there are in fact savings and performance figures that meet the defined SunHorizon project's threshold, which are included within the table below for the whole monitoring period. Some negative figures appear for January and February, due to an increase in the electric consumption, triggered by a new favourable tariff that led to an increase in the user's thermal demand. Regarding renewable energy ratio the obtained results are directly related to onsite electricity generation, obtaining maximum values greater than 90%, and minimum values in January and February when the thermal demand was higher and the operation not optimised so it resulted in higher imported electricity from the grid. Madrid demosite self-consumption shows high ratios with an average of 67%, maximum of 95% and minimum of 35%. Finally, the indoor comfort has been calculated for the average building temperature and there have been cooling discomfort (indoor temperature higher than 25°C) during the warmer months of summer, coincident with a heat wave in Spain; there were no heating discomfort (indoor temperature lower than 18°C) registered for the monitoring period.

² More detailed figures have been included into the Sunhorizon's deliverable D6.6 Final Report on SunHorizon monitoring activities.

The table below includes the calculated savings on GHG emissions non-renewable primary energy and energy bills, expressed as absolute and relative values from the defined baseline data, and showing no deviation from threshold.

Table 8: Madrid: Monthly KPIs [January to October 2023]

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

2.2.6 Conclusion EMVS

Regarding **DESIGN PHASE**, the implementation of this demo building has been a great challenge, mainly due to the necessity to integrate SUNHORIZON project into an ongoing Renovation Project that was already in motion, and also due to the difficulties that comes with rehabilitation projects, where there is not much room for maneuver.

For this reason, the design phase has been crucial in this of project. Investing a high number of resources during this phase translates into a considerable reduction in unforeseen events during the construction phase that could lead into delays, cost increases, etc.

Therefore, when drafting innovation project proposals, it must be considered the importance to foresee resources and budget to hire local design teams that can translate the initial idea and designs of the R&D project to the reality and regulations of each country.

In this line, in this type of collaborative innovation project between the project partners and the local partner, it is very important that the partners who provide equipment and those who are in charge of the preliminary design support the local team of architects during the design phase to develop the engineering project.

Regarding the **BIDDING PROCESS PHASE**, normally the owners of the demos that are public companies must follow very structured procedures at the time of contracting, so it is necessary to foresee in the general planning of the project an affordable time slot, for the internal preparation of contracting documents, process bidding, awarding of contracts, etc.

Being a project with considerable technical complexity, it is important to define very well the technical requirements of the bid specifications, since the main contractor must have proven skills and experience in the work to be carried out, especially in relation to control. and facility monitoring.

Regarding the **MONITORING AND CONTROL SYSTEM**, once the installation was commissioned, and after one year of operation, we could verify the great importance of the monitoring and control system. It is the Key to success in this type

of projects. If you cannot measure you cannot ensure that the system is working properly, and worst of all, you cannot know where to act to improve the performance of the system.

Only with access to the data, it is possible to evaluate how the system is working, and gives the opportunity to make continuous improvements, achieving higher levels of comfort and energy savings of the system, optimizing the maintenance, etc.

Thanks to the monitoring we could prove Great results in coupling Heat Pump technologies with PV renewable systems, that was one of the main objectives of the project. It allows us the Possibility to adapt consumption and generation curves. When there is excess of Renewable generation, storage it as thermal energy and use it when there is no PV production.

Also we could test the Use of Water-Water Heat Pumps technology for retrofitting. Normally this technology is used for geothermal purposes, requiring to build high wells. Coupling this technology with Hybrid panels (PV-T) allows to recover the thermal energy from the panels to improve the performance of those heat pumps, reaching COP of 5-6.

With the improvements that we have implemented during this first year of operation we estimate around a 70% of primary energy consumption reduction with respect the initial state before renovation. In conclusion, we would be in a position to affirm that the project has been a success, it will be given continuous monitoring because we believe that there is potential for improvement, and that it has a high potential for replicability in building rehabilitation projects.

2.3 Riga demo site #8 RTU

Riga demo comprises two single-family residential houses located in Riga city (Imanta neighbourhood) and its vicinity (Sunīši village). Both houses, built in 2010s, have two floors; their heated area is 235 m² (Imanta) and 144 m² (Sunīši). Before SunHorizon, space heating and DHW preparation was provided by a tankless gas boiler in each house (28 kW and 24 kW capacity in Imanta and Sunīši, respectively). Hence, to benefit from the existing connection to the gas distribution grid, both houses were equipped with SunHorizon **TP2 initially** consisting of BoostHeat gas-based thermal compression **heat pump** (featuring an outdoor unit with a dry cooler and an indoor unit with a thermodynamic heat pump unit and a condensing gas boiler) along with DualSun **PVT panels**, Ratiotherm **glycol storage** tank, **stratified storage** tank and a smart **electrical heater** (the heater can consume surplus PV electricity and store its heated water into the Oskar tank).



Figure 12 Imanta demo site



Figure 13 Sunīši demo site



The TP2 was first installed in Riga demo in late 2021 and was operational with its original components and configuration until August/September 2023³ when the BH heat pump was replaced by a **heat pump** provided by **BDR**. The replacement was necessary since BH decided to discontinue their business activities related to further heat pump development and, accordingly, withdrew as a partner from SunHorizon consortium. BH decision was at least partly related to the energy crisis and the subsequent lack of support for natural gas based heat sources in the EU. Moreover, the BH units initially installed in Riga demo were merely prototypes lacking CE certificates and thus could not be used in the long-term due to legal considerations and, additionally, due to discontinued after-sales technical support from BH. Hence, even before the issues of BH company, they had already planned to replace both prototypes by CE-certified equipment (produced either by BH

³ Until mid-September in Imanta and beginning of August 2023 in Sunisi when the BH machine permanently failed there. Until installation of BDR equipment in Sunisi, the household employed their old gas boiler in the main house for DHW production.

or available on market otherwise) at the conclusion of project. Eventually, the replacement of the BH heat pump became inevitable and imperative after their withdrawal from SunHorizon.

After BH broke the news on their withdrawal from the SunHorizon consortium in November 2022, the consortium prepared a mitigation plan for the affected demo sites in December 2022. For Riga demo, it involved decommissioning BH heat pump and replacing it with a BDR heat pump along with a backup condensing gas boiler from BDR. The mitigation plan foresaw full integration of BDR equipment within the existing TP2 with as little interventions as technically possible, benefitting from all the already installed components. Straightforward modification of TP2 controls was possible thanks to the highly adaptable Ratiotherm Central controller (PLC) installed with the TP2. Final approval from the PO to start the onsite activities for the BH replacement in Riga was received in June 2023. Replacement in both Riga demo houses was completed in September 2023, hence continuing SunHorizon TP2 operation albeit with the BDR heat pump instead of BH and slightly modified TP2 configuration. Consequently, the final **TP2** demonstrated in Riga consists of BDR water/water **heat pump** (without an outdoor unit but connected to the glycol storage tank), backup condensing **gas boiler** from BDR, DualSun **PVT panels**, Ratiotherm **glycol storage** tank, **stratified storage** tank and a smart **electrical heater**. Within the modified TP2 the key concept remains the same as originally: connecting solar heat to the evaporator of the HP which is supplying the heat to the user, and the overall system is still a solar-assisted hybrid heat pump which consumes electricity and gas. Additionally, with the modified TP2 reliance on fossil gas has been further reduced compared to the TP2 with BH as the BDR HP consumes only electricity and the gas boiler is meant only for backup during cold spells or unexpected outages of the HP.

2.3.1 TP2 overview RTU

Before SunHorizon, the following heat sources were used in **Imanta**: a conventional tankless gas boiler (no water storage tank) for space heating and DHW preparation, electric underfloor heating in bathrooms and an occasionally used wood fireplace in the living room. Space heating from the gas boiler is distributed through radiators. Within SunHorizon scope, the TP2 configuration was developed so as to provide **space heating** and **DHW** (i.e. replace the existing gas boiler) as well as produce **electricity** for all household needs (incl. the TP2 electricity consumption).

In **Suniši**, there was also a conventional tankless gas boiler (no water storage tank) for space heating and DHW preparation. However, space heating is distributed both by radiators on the upper floor and underfloor heating on the ground floor. There is an additional heat pump in the main house employed for cooling during summer which is out of scope for SunHorizon purposes. Hence, the new **TP2** is supposed to provide **space heating** and **DHW** by replacing the existing gas boiler as well as produce **electricity** for the household.

As concerns electricity generation by the PVT panels, **net metering** can be applied for households with up to 11.1 kW capacity of renewable microgeneration in Latvia whereby the surplus generation not consumed instantly by the household can be fed into the distribution grid and then repurchased for a discounted price (i.e. the grid tariff only). The surplus electricity can thus be “stored” into the grid and accumulated during the most productive months of the year, but it needs to be consumed until the end of net metering period (up to a year) to get the discount. The net metering period lasts from March until February next year, hence the calculation of the energy “stored” restarts from zero in March. It must be noted that some legislative aspects concerning net metering regulation in Latvia have changed during the course of the SunHorizon project to facilitate integration of distributed renewables (so mostly for the benefit of the end-user). This deliverable reflects the current regulation applied to both Riga demo sites. When planning new projects involving microgeneration from renewables, one should always double-check the applicable up-to-date legislation.

2.3.2 Building integration engineering phase

2.3.2.1 Building integration engineering RTU

2.3.2.2 Initial TP2 with BH heat pump

Engineering of TP2 for Riga demo site was carried out in several steps. First, **high-level design of TP2** was developed and detailed dynamic TRNSYS simulations were performed by the modelling partners within WP2 whereby parametric

analysis and comparison of different design options was carried out. This allowed the consortium to select the optimum configuration and sizing of components and served as the basis for the technical specification for the local installer which was then subcontracted by RTU through a public tender. The high-level design was completed in January 2021 and, based on simulation outcome, the same TP2 configuration (Figure 15) and similar sizing (Table 9) was selected both for Imanta and Suniši. The only slight difference in sizing is the amount of solar panels due to space restrictions (52.8 m² in Imanta vs 49.5 m² in Suniši). Afterwards, the installer was responsible for development of a **detailed TP2 design** for Riga demo considering the local peculiarities and specifics of each house, and they also carried out all the required **permitting** procedures. During the whole period of engineering until completing the installation, RTU organised remote bi-weekly demo group meetings involving all the technology providers and other supporting partners.

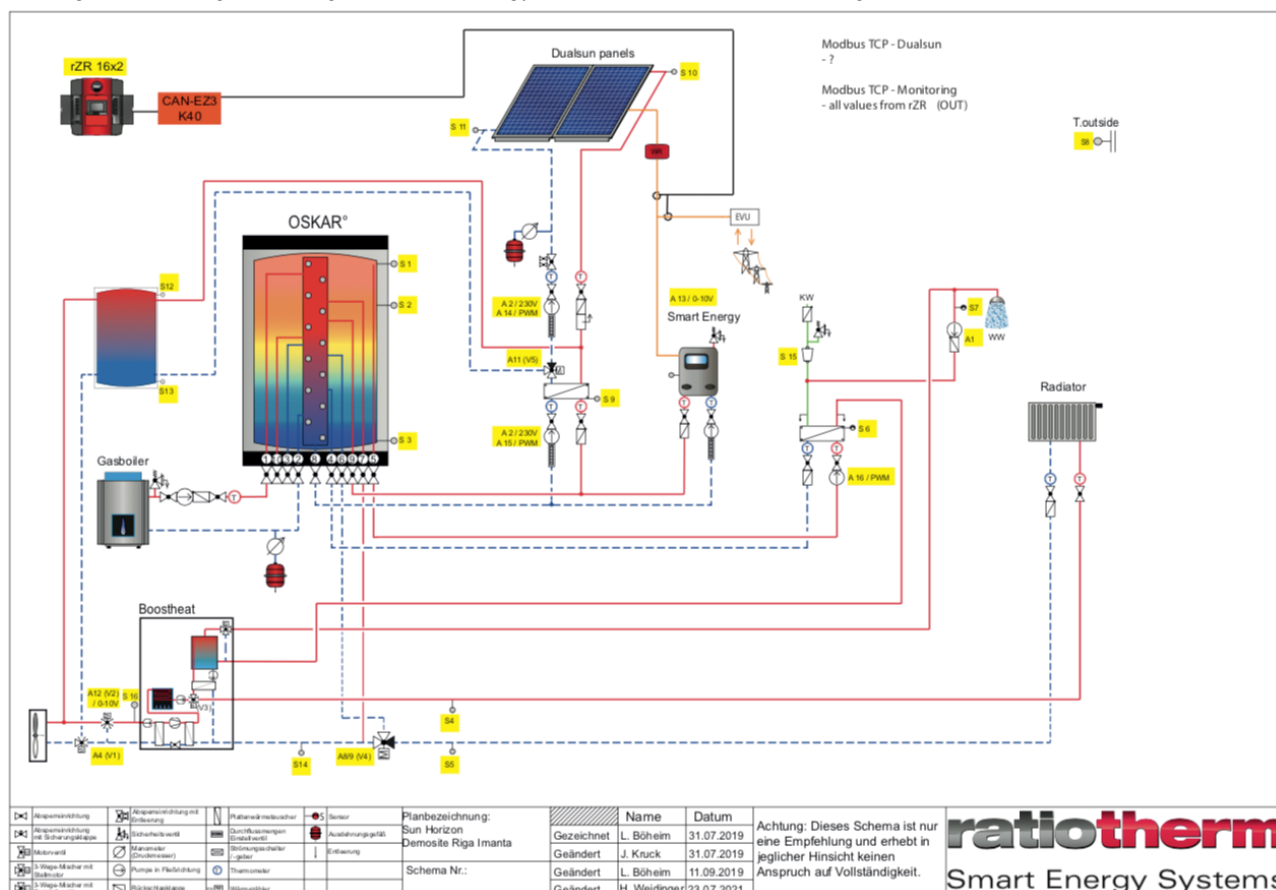


Figure 14. Initial TP2 configuration for Imanta demo site with BH heat pump, in operation since 2021 until August 2023

Table 9 Initial component sizing in Riga demo site

Component	Size in Imanta	Size in Suniši
DS PVT Panels	52.8 m ² (10.24 kWp)	49.5 m ² (9.6 kWp)
BH Heat pump	20 kW	20 kW
RATIO Oskar tank	1300 L	1300 L
RATIO glycol tank	200 L	200 L

The installer was selected through a “design & construct” **public tender** considering the innovative nature of SunHorizon technologies and the TP2 as a whole. Indeed, since the deployment of TP2 is technically challenging compared to standard heating systems used in Latvia, it is reasonable to have the same contractor in charge of the detailed design of the system, installation and commissioning in both Riga demo houses. Since some of the SunHorizon TP2 innovative technologies

are not commercially available on the Latvian market, in order to select an installer with the relevant competence, a number of qualification requirements were included in the tender such as previous experience with installation of solar thermal or hybrid PVT collectors, heat pumps and gas boilers as well as availability of qualified professionals in heating system design and installation, electrical installation and microgenerator connection to the distribution grid etc. From around ten potential installers initially approached by RTU, only one company submitted their offer, which, after assessment of their application and receipt of a few clarifications required by the procurement committee, was declared satisfactory and in line with the SunHorizon budget for this activity. The selected contractor started their work on demo deployment in June 2021 with a deadline to complete the commissioning of TP2 by end of September 2021, in line with the project schedule and taking into account the expected delivery time of equipment from SunHorizon technology providers.

2.3.2.3 Final TP2 with BDR heat pump

To replace the BH heat pump, a hybrid setup with two separate units from BDR was selected:

- Water/water heat pump, manufactured by BDR Thermea in France. Model: GSHP 9 TR-E (9 kW nominal heating capacity, fixed speed compressor), SCOP = 181% in average conditions. The source side temperature range is – 15...+35°C to supply up to 60°C on the heating side.
- Backup condensing gas boiler MCR 24/28 MI (24 kW).

The new water/water heat pump is connected to the glycol tank and Oskar tank, while the condensing gas boiler is connected to Oskar tank ensuring the temperature level on top of the tank is achieved, complementing the HP's temperature level and capacity. This concept is close to the initial TP2 with solar-assisted heat pump on the evaporator side. The new design (Figure 15) is largely based on the initial TP2 installation, including the equipment form RATIO and DS commissioned previously, and reuses major components and pipework already installed in the demo during 2021, incl. control and monitoring system, underground pipelines for gas, electricity and heat transfer etc. Thus, the upgrade was straightforward and could be done in a short time compared to the initial TP2 deployment. RATIO was able to easily adapt the control system to integrate the new equipment accordingly.

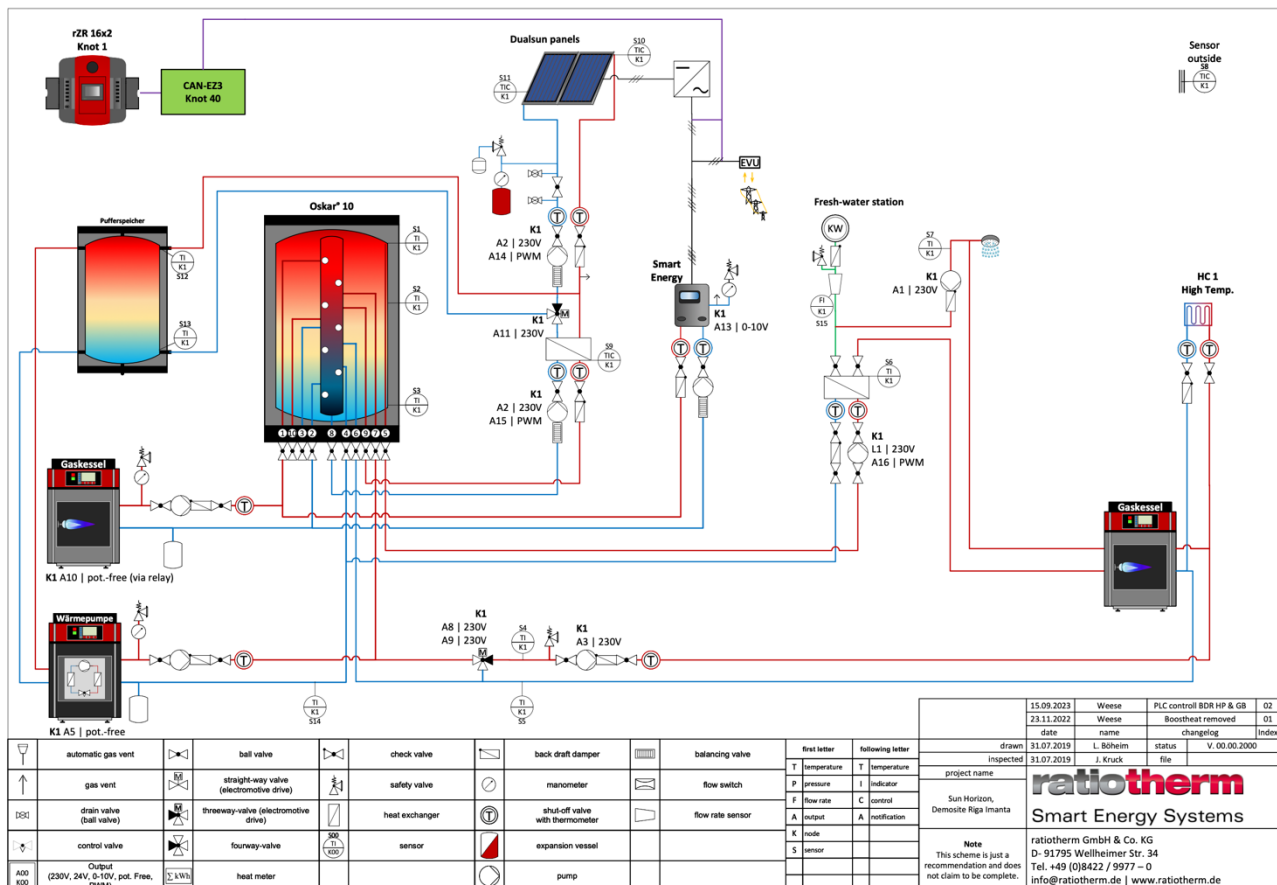


Figure 15. Final TP2 configuration for Imanta demo site with BDR heat pump, in operation since September 2023

As a result, similar serial integration of solar heat from DS panels is achieved with BDR HP through the glycol tank connection (without the need of an outdoor unit). Electricity produced by the PVT panels can be self-consumed by the heat pump and the household and converted into heat by the existing RATIO Smart Energy electric heater. The surplus can be fed into the grid via net metering. Gas connection is still used by the condensing boiler as a backup source for space heating and DHW supply during peak demand.

Table 10 Final component sizing in Riga demo site

Component	Size in Imanta	Size in Suniši
DS PVT Panels	52.8 m ² (10.24 kWp)	49.5 m ² (9.6 kWp)
BDR Heat pump	9 kW	9 kW
BDR Gas boiler	24 kW	24 kW
RATIO Oskar tank	1300 L	1300 L
RATIO glycol tank	200 L	200 L

The modified technology package, where BH is replaced by the BDR hybrid heat pump, is still considered as TP2 since the key concept remains the same: connecting solar heat to the evaporator of the HP which is supplying the heat to the user. Upgrade with the electric heat pump from BDR allows further reduction of gas consumption and GHG emissions during the most part of the year, while the backup gas boiler benefits from the already existing gas connection and will efficiently cover the peak heating demand during cold spells. Moreover, the BDR heat pump has an overall higher seasonal efficiency (180% vs BH's 130%). In addition to that, previously DHW production was possible only by the BH gas boiler (which therefore needed to operate the whole summer), whereas the BDR heat pump is indeed able to produce also the DHW. The HP will be able to consume electricity produced by the PVT panels, contributing to increased PV electricity self-consumption and further reduction of end-user bills. Consequently, dependence on gas as the primary source is significantly reduced, meanwhile ensuring reliable heat production throughout the year by the hybrid setup and avoiding the need to oversize the HP.

2.3.2.4 Hybrid PVT collector DS

Specific challenges and lessons learnt during the engineering phase:

- There were some challenges concerning the PVT mounting frame (selection, supply shortages...) requiring quite lengthy process and communication between DS and RTU to agree on all the technical details and find a suitable mounting frame for each specific site, since DS were responsible for supplying the mounting frame and thus needed to act as an intermediary between the frame producers and demo manager.
- Selection process and delivery of the heat carrier: DS was in charge of supplying it but could only offer a concentrated one; since the installer would not be able to dilute it, it was decided to purchase the heat carrier from a local supplier. At some point during the engineering phase, the residents in Imanta were extremely concerned about the supposed dangerousness of the glycol heat carrier and even wanted to withdraw from the project because of this. Eventually, after detailed clarifications from RTU explaining that the heat carrier is based on the safe propylene glycol (instead of ethylene-based glycol), the demo owners accepted it.
- Detailed design for PVT integration (hydraulic layout and electric layout) was initially developed by DS. However, eventually a slightly different solution for the hydraulics was implemented as suggested by the installer, based on the Tichelmann loop to facilitate the balancing. The installer then also fine-tuned the design based on DS feedback.
- The installer also selected pre-insulated pipes for PVT panels based on DS specification and considering their feedback. An important aspect, which facilitated pipe selection, was the 80 °C stagnation temperature of DS Spring panels. This allowed using multilayer composite pipes which are common for DHW and heating/cooling applications. However, it was challenging to find insulated pipes with UV protection, therefore it was decided to install additional UV-resistant conduit.

2.3.2.5 Thermal storage and controls RATIO

For the demo sites in Riga (Sunīši/Imanta) was no special challenge to fulfill the specifications.

Briefly:

- For both demo owners, it was impossible to fit the storage tanks into their existing boiler rooms, which are rather small and initially designed only for a wall-hung gas boiler. While the heat pump also takes more place compared to the old boiler, the storage tanks were the major limiting factor. Therefore, in Imanta the TP2 technologies were installed in the garage (next to the previous boiler room) with much more space available. In Sunīši, a dedicated annex was constructed for the TP2 equipment (incl. PVT panels on the roof) next to the existing garage.
- RATIO developed the complete integrated TP2 diagram based on the outcomes of simulations within WP2 and as a basis for the local installer.
- A custom control program was elaborated by RATIO and implemented within the PLC. It also included some specific control rules for the operation of the Smart Energy electric heater considering the net metering in Latvia, which is quite different from the standard solution of RATIO for the German market and is based on different logics to take into account the total annual surplus production of the PVT panels.
- Though initially it was planned to use a 400 L tank for the cold glycol storage, eventually RATIO switched to 200 L to be able to ensure diffusion-proof insulation.
- RATIO documentation (installation manuals) was not fully available in English from the beginning. However, RATIO prepared it just before the installation phase.

2.3.2.6 Hybrid solar assisted HP BDR

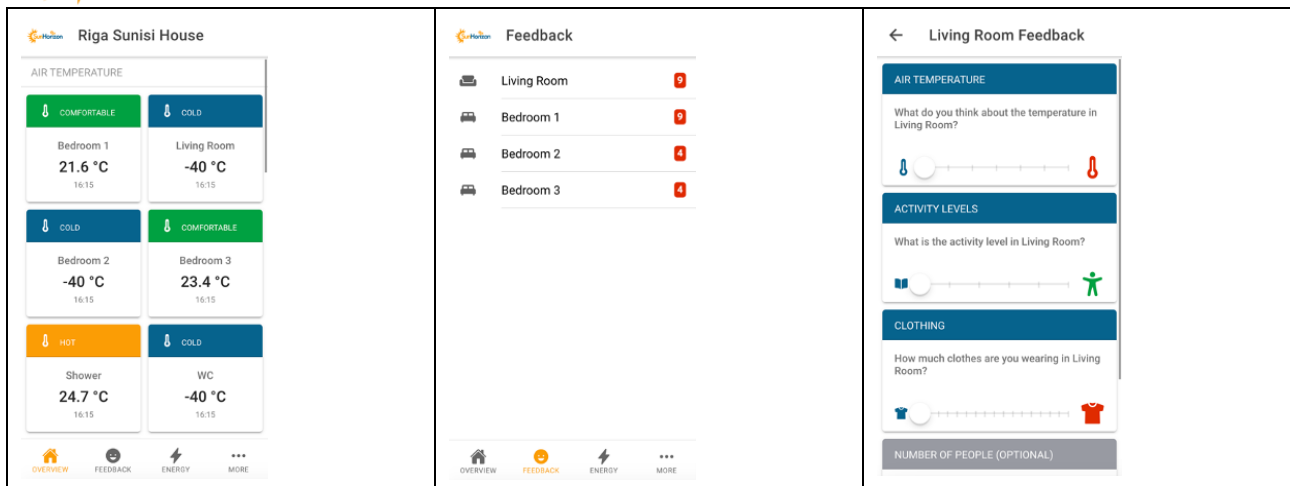
Brief outlook of HP control in late replacement of previous Boosheat HP:

- Control logic: heat pump and gas boiler supplying fixed temperature to the Oskar tank.
- Gas boiler usage logic: boiler turned on if there has been continuous heat demand for 2 hours. With the current diagram, impossible to implement a more sophisticated algorithm. To alleviate this, the gas boiler temperature setting is lower than that of the heat pump so that eventually the HP is operated more.

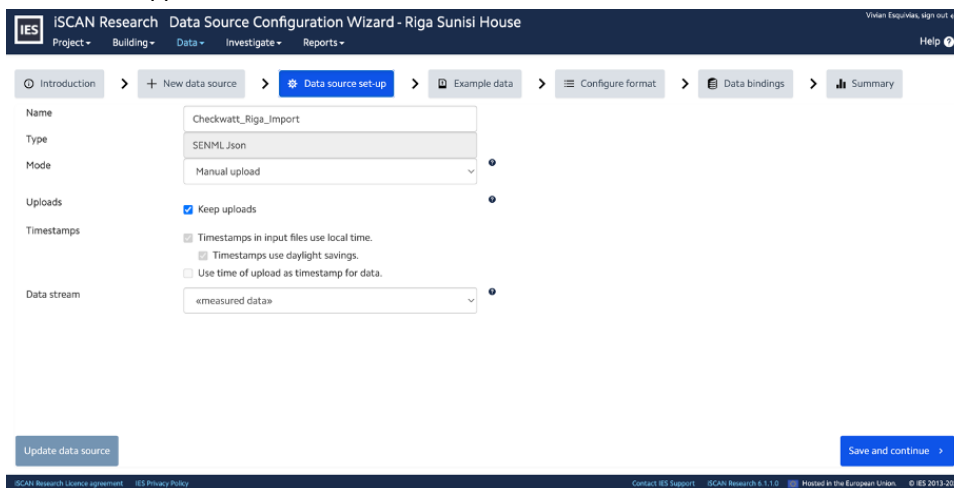
The water-to-water heat pump power design is linked to the PVT field size, the heating need of the house, and the temperature of design. The heat pump alone cannot provide the heating power required by the house during the night of the coldest day. So, the gas boiler power is designed to cover the heating power needed during the coldest day.

2.3.2.7 User app CW

Riga was the first demo site that we integrated the SunHorizon app on. The biggest challenge was, as mentioned previously, to find the correct references to the rooms and sensors that the app needed to retrieve data from through the ISCAN system. The second challenge was to configure the communication from the app to the ISCAN system, this consisted of feedback information entered by the user through the app ex. *The temperature in Room X is too high*. We needed to determine a set of values for each environmental factor (temperature, humidity etc.) but once we had this in place everything worked as expected.



SunHorizon app, Sunisi



ISCAN Research Data Source Configuration Wizard - Riga Sunisi House

Project - Building - Data - Investigate - Reports -

Introduction > + New data source > **Data source set-up** > Example data > Configure format > Data bindings > Summary

Name: Checkwatt_Riga_Import

Type: SENML Json

Mode: Manual upload

Uploads: ☒ Keep uploads

Timestamps: ☐ Timestamps in input files use local time. ☐ Timestamps use daylight savings. ☐ Use time of upload as timestamp for data.

Data stream: «measured data»

Update data source Save and continue

ISCAN Research Licence agreement IES Privacy Policy Contact IES Support ISCAn Research 6.1.1.0 Hosted in the European Union © IES 2013-2023

Data-import configuration in ISCAN for feedback from app for Sunisi

2.3.2.8 Monitoring sensors and platform SE

Performed activities:

- Viewing documents regarding the project about room controllers, power meters and water meters.
- Choosing the devices to be installed according to the needs.
- Elaboration of the wiring drawing for the chosen devices.
- Elaboration of the video instruction for the Wi-Fi sensors pairing.

Encountered challenges:

- Haven't received the complete project documentation.
- Mixed fluid water meter: has been difficult to retrieve the correct information about the glycol percentage for every different water meter that should've been provided by us.

Lessons learnt:

It is important to receive the whole documentation of a project even if it is not necessary for the assigned task.

2.3.2.9 Monitoring platform IES

See 2.2.7

2.3.2.10 Initial TP2 with BH heat pump

To prepare for the installation, the first activities of installer were to develop a **detailed design** of the new heating system for both houses and prepare the documentation for required by the gas distribution system operator (DSO) (for gas piping) and municipality (for placement of the PVT field on ground in Imanta). The design phase was delayed by 1–2 months. As explained by the contractor, the main reason for this was the complexity of the project since not only the TP2 as a package but also its individual components were unfamiliar to the installer before this project, requiring a lot of effort for studying the technical documentation and clarifying the additional technical questions with technology providers and other SunHorizon partners involved in simulation and testing of TP2. Additionally, design of the new gas piping was more time-consuming due to the complexity (especially in Sunīši). Furthermore, the selected installer being a small company, they were not flexible when occasional shortage of staff arose (due to vacation period, sick leave of personnel, parallel ongoing projects etc.).

Installation of SunHorizon technologies was performed in a number of rounds over several months subject to the delivery of components from SunHorizon technology providers and completion of design and permitting processes. The contractor started with installation of **RATIO** equipment in **Imanta** in July 2021, which also facilitated completion of the detailed design since the installer was able to study the physical components, not only the documentation. Equipment from RATIO for Sunīši was delivered in August after its testing at CEA was completed; however, one of the delivered components, Smart Energy electrical heater, was damaged during the testing at CEA and was replaced by RATIO in October. While delivery of RATIO equipment was slightly delayed, mostly due its longer testing, it did not have significant impact on demo deployment activities.

However, the delivery of TP2 components from DS (PVT panels, mounting system, inverter and a number of additional accessories and materials) and BH (heat pump and accessories) was delayed by at least one month and subsequently was delivered to the demo sites at the end of September (BH) and end of October 2021 (DS). Installation of **BH** in Imanta was completed in October 2021 with onsite participation of BH engineers who assisted in configuring and commissioning of their machine. For testing purposes, a temporary gas supply connection was used.

Installation of **DS** panels both in Imanta and Sunīši was completed in November, after their delivery at the end of October. Similarly, the last components from RATIO were installed in October, except the controls and electrical wiring which took much longer than expected and was fully commissioned in December with remote assistance of RATIO. To successfully install the controls, several rounds of consultations with RATIO were required due to the complex wiring and lack of prior experience of the installer with RATIO equipment.

In order to start full operation of TP2, it was necessary to establish **permanent gas supply to the BH**. This, in turn, required disconnecting the old gas boiler from the gas grid by the gas distribution system operator as both units cannot be connected at the same time due to capacity restrictions of the gas connection. The permanent gas supply was established and BH **commissioning completed** on 20 December 2021, and since then BH along with the other TP2 components was covering all of the space heating and DHW demand in Imanta until replacement with BDR in August 2023.

As concerns the demo deployment in Sunīši, the **final commissioning** of BH took place on 5 April 2022, where also a BH engineer took part onsite. The main reason of the delays by the installer was the long permitting process for the new gas connection which was much more complex than in Imanta demo both from the technical and legal point of view. Installation of underground gas pipeline was required (more than 40 m length) in order to connect the new SunHorizon boiler room to the gas grid, requiring approvals both from the gas operator and municipality. After several iterations and improvements required by the gas DSO, the final approval was acquired at the end of March. Hence, the full operation of TP2 was started in April 2022, even though the TP2 components had been installed by November 2021. Nevertheless, electricity production from the DS PVT panels has been ongoing in Sunīši since January 2022.

Summary of the main reasons for the **delays and challenges** experienced during demo installation and commissioning:

- In May 2021, when the tender was announced, the expected delivery time of equipment from BH was end of August and from DS – mid-August. This was used by the installer to plan the installation timeline. Eventually, the **delivery** of DS was delayed until end of October and BH until end of September. Additional challenges arose due to colder

weather during the installation in October compared to August/September when it was scheduled initially, as a result of which there was less time allowed for outages or testing of the equipment (since the house needs to be heated) and less days suitable for the various installation activities outside. This was mitigated by using the existing gas boiler before completing the commissioning of TP2.

- Initially it was expected by the installer to approve and **commission the new gas pipelines** within two weeks after their installation. However, it took several months due to more complicated approval procedure which the installer hadn't sufficiently considered beforehand. In Imanta, it was not possible to employ the simplified approval procedure because of BH being located in a different room than the existing gas boiler. However, in Sunīši the approval was much more complicated as it needed to be performed both by the gas DSO and the municipality (due to the buried pipeline) and, additionally, the gas meter needed to be relocated to a different spot.
- The final approval for the **gas connection** in Sunīši was acquired by the installer at the end of March 2022. The main reason for delays was the slow approval process with the gas distribution operator (Gaso AS) who needed to be involved in several steps during the whole gas piping construction process (design stage, construction permit, construction documentation approval, onsite inspection etc.). Due to the limited human resources of Gaso in the specific region, there is usually long waiting time for the inspection. This was further aggravated by their partially remote work during pandemic, considering that Latvia underwent the largest infection wave during the whole pandemic in autumn/winter of 2021/2022. Additionally, some employees of the installer also got infected or needed to be quarantined. Consequently, a number of challenges and delays accumulated during the construction of the buried gas pipeline and the permitting process. Since the final construction work of the buried pipeline was delayed until the winter months, heavy snowfalls made it even more difficult. Eventually, several visits from the gas operator were required to inspect and approve the new installation as they asked the gas connection constructors to improve or correct a number of aspects.
- BH fitter travelled from France to Latvia around mid-October for commissioning of the heat pump in Imanta. BH then trained the local installer so they could manage the installation of BH in Sunīši independently and, in addition to that, perform the necessary maintenance tasks in the future. Since the new gas connection was not in place yet when the BH fitter came to Imanta, the full commissioning of BH (and TP2 as a whole) took place afterwards (in December 2021) with only **remote assistance** from the technology providers. This introduced some additional technical challenges during the commissioning. Nevertheless, all the technology providers have full visibility of the real-time data from their equipment, since the main components are going to be connected to the internet and SunHorizon cloud platform, so this facilitated successful commissioning with remote assistance of technology providers.
- Finally, BH engineer visited the Sunīši demo in the beginning of April 2022 too for the commissioning of BH. During commissioning, a local certified CO₂ refrigerant technician also took part as BH technicians had observed during the remote monitoring that there had been a leakage of the **CO₂ refrigerant** and refilling was necessary, even though BH had not been operating before. Furthermore, it was concluded that regular refilling of the refrigerant would be also required annually.
- During BH visit in April 2022, the **thermodynamic (heat pump) unit** of BH machine in Imanta was also replaced. BH sent a replacement unit as the previous one had demonstrated deteriorated behavior according to their remote monitoring results.



Figure 16. Initial TP2 installed in Imanta



Figure 17. PVT panels installed on the ground in Imanta



Figure 18. Initial TP2 installed in Sunīši



Figure 19. PVT panels installed on the roof in Sunīši and BH outdoor unit

2.3.2.11 Final TP2 with BDR heat pump

Preparatory phase

While the TP2 diagram enabling integration of the BDR equipment (Figure 15) was developed in November/December 2022 along with the mitigation plan, the technical implementation did not start until informal approval from the EC in the end of May 2023 when the technical demo group was able to finalise the technical details, e.g.:

- It was decided to not install a heat exchanger (HX) between the heat pump and the PVT glycol loop as it would decrease the overall TP2 efficiency. Compared to the BH, the high variation of glycol pressure is not a problem for the BDR heat pump. While the HX might increase the circulator pump lifetime, this pump's cost is not so high. Moreover, an additional HX would increase the effort and cost of installation and make any future maintenance and troubleshooting more difficult.
- RATIO confirmed they can adapt the controls of the upgraded TP2 rather easily and quickly. Compared to the previous configuration, RATIO is now in charge of controlling all the DHW and space heating provision.

- SE confirmed they would be able to integrate into their monitoring system the existing gas meter and heat meter from BH in order to continue monitoring the TP2 without the need to purchase any new meters. Any changes to the existing meter configuration would be kept at minimum so as to limit the impact on other partners' systems and data flows.

After the formal approval from the EC in mid-June 2023, RTU proceeded with the technical specification and legal paperwork to subcontract the installer. The equipment from technology providers was delivered in June (BDR) and July (RATIO). The previous installer was unavailable to do the upgrade due to their other ongoing projects; hence, a new installer was sought after. In contrast to the first installation phase, it was possible to select the installer based on price quotes instead of a public procurement procedure due to less cost of work and because of the urgency. Still, only one qualified installer submitted a valid proposal out of more than 10 companies with whom the full technical specification was shared. Due to the summer vacation period, the related paperwork was finalized by the RTU Procurement department and Legal department in August 2023. Furthermore, the installer postponed the start of work several times until September due to their other contractual commitments.

Installation and commissioning

Installation onsite was started on 13 September 2023 with decommissioning of BH in Imanta, followed by installation and commissioning of the BDR gas boiler and the heat pump. The BH unit in Sunīši demo was decommissioned on 20 September 2023. However, even before that (since 3 August 2023) BH was not operating in Sunīši and had stopped providing heat after an electricity outage when it became impossible to turn the machine on at all. BoostHeat was unable to provide any technical support as they did not have the personnel nor the remote monitoring in place anymore, hence from August until September, Sunīši demo site was using the old gas boiler (not integrated within TP2) for DHW production.

Soon after BH decommissioning, the thermal needs were already covered by the BDR equipment. However, several challenges were faced and needed to be solved, mainly related to the TP2 control, therefore the final commissioning incl. full control of the integrated TP2 with RATIO PLC took place on 28 and 29 September 2023 in Sunīši and Imanta, respectively. Some fine-tuning of the controls was still necessary during the next days based on the first observations of the upgraded TP2 operation, and the final corrections of the PLC program were implemented by RATIO on 4 and 6 October 2023 in Imanta and Sunīši, respectively. Hence, during the 2–3 weeks when the TP2 upgrade took place, some inefficiencies in TP2 operation could be noticeable.

Main challenges experienced during BDR equipment installation and commissioning:

- During decommissioning of the BH HP, it was found that the electricity supply to the different TP2 components was implemented via BH. This required additional rewiring to ensure electricity supply also after BH decommissioning.
- RTU needed to perform the electrical and control installation by itself as the installer had not provided an electrician to work onsite. It was challenging as only the standard installation manual for BDR equipment was available and there were no SunHorizon-specific installation instructions shared before on wiring of the controls to the BDR HP and gas boiler (e.g. which ports to use), thus all the clarifications were requested on a case-by-case basis which delayed the implementation.
- As before the installation the main control aspects were mostly discussed between RATIO and BDR and the complete control strategy was shared by RATIO shortly before the commissioning, only during the onsite work it turned out that the initial control strategy developed did not include the BDR gas boiler and also the heat circulating pump, which were new features to be controlled by RATIO after installation of the BDR HP. Once identified, this could be easily solved by RATIO. For the gas boiler, an additional relay was installed to enable integration with the PLC employing the remaining ports available.
- During the installation, it was found that the heat circulator pump package delivered by RATIO did not include the connection cable. As the pump is not a standard one sold in Latvia, the delivery time for the cable from the supplier would be ~3 weeks. To solve this, RTU made a DIY connection cable that could fulfil the same function.
- Difficulties of SE to read the monitored data from the new BH meters due to incomplete documentation from BH as well as delays in reconfiguring the existing meters leading to data gaps and delaying integration of the monitoring variables in the tools for KPI assessment developed by other involved partners.
- After commissioning of the BDR heat pump, it regularly provided non-critical error messages in Sunīši. To solve this, after onsite inspection BDR decided to send a replacement PCB with upgraded software.

- There were issues with internet connection of RATIO PLC in Suniši: while the internet worked fine for other components, RATIO were often unable to connect remotely to their PLC. To solve this, RATIO sent a new component for replacement (CMI module).



Figure 20. Final TP2 installed in Imanta (left) and Suniši (right)

Lessons learnt during demo deployment [RTU]

Technology providers should be highly involved in defining the scope of **simulations**, parameters to be tested and configuration as well as analysing the results. If the configuration needs to be changed due to modifications of a single technology, it can be time consuming to agree on that with all the technology package (TP) providers and to rerun the simulations. Simulations should be strongly supported by a partner responsible for devising TP **control strategy** and implementing an integrated control of TP. Moreover, end-user feedback and needs need to be considered properly.

For a technology package comprised of components from different equipment manufacturers, it is necessary to thoroughly discuss and decide on their integrated **control strategy** during the design stage as early as possible. This process should also involve gathering end-user feedback to consider their comfort requirements and other preferences. The control strategy should be adapted to the local specifics of the demo site, including legislation.

Already at early design stage, preliminary **placement of technologies** should be planned and shared / agreed on with potential demo participants / residents. It should be based on feedback from all involved partners to correctly consider the required space, safety distances and user needs. Important to do so early to avoid causing concerns to the residents at a later stage as the TP occupies a lot of space compared e.g. to a standard gas boiler.

Ideally, all parties undertaking **technical tasks** should be directly and actively involved in the project (preferably as project partners). Each partner should be represented by a knowledgeable technical expert. When **subcontracting** is required, it is vital to anticipate extra time and resources for the subcontractor to enable detailed information exchange / training if necessary etc. with the project partners (technology providers) due to the innovative nature of technologies and the TP. Deviations (increase) of budget due to unexpected circumstances should be also planned for.

Before the official launch of a **public tender**, it is vital to perform a thorough market research by preliminarily engaging the potential installers (or similar parties) and obtaining their feedback on the scope and cost of work as early as possible. Given the complicated nature of the project and fixed/limited budget of a tender, the final costs for the installer remain uncertain at the stage of tendering. Hence, they risk incurring losses and consequently there is very little interest from the installers or their quoted cost can be extremely high.

The installation of an innovative technology package is highly facilitated by its previous **testing in lab conditions**. The findings obtained during the testing should be shared and discussed with all technology providers and local installers at the demo sites.

The installer should receive hands-on training from technology providers and/or providers should preferably participate in **installation** or **commissioning**. There should be continuous communication (e.g. regular meetings with **all** parties) between the installer and all the technology providers throughout the whole process from the detailed design to commissioning so as ensure the best result possible, which is especially challenging when the technology providers are located in different countries and the installers haven't had any prior experience with the specific technologies. Preferably, some face-to-face meeting should also be held.

The communication on technical aspects should be properly documented using suitable IT and project management tools to serve as a **single reference point** enabling quick catch up whenever needed and smooth learning when a new person joins the project.

It is crucial to provide to the **demo participants / end-users** comprehensive information on the project, technologies and the installation process in a user-friendly way. The information should be available in their language of choice in written form at the very beginning of the project as well as Q&A sessions can be organised if needed. The written form allows the candidates to make informed choice on their participation in the demo and refer to it at any later stage as well as share it with their family members and other relevant persons. It should cover all aspects important to the end-user on the operation of innovative technologies, expected interventions in their home, safety, reliability and environment related aspects, user comfort etc. Preparing such an information leaflet can be time-consuming, but otherwise there is much larger risk of participant withdrawal during later stages of the project (i.e. as late as during the installation phase).

At a very early stage of the project there should be a common understanding and agreement between the project partners and demo participants on the **post-project ownership, operation, maintenance and warranty** of technologies. There should be clear division of the responsibilities and costs among the partners involved so that the demo participant does not need to suffer any losses and their comfort is ensured continuously.

With a project lasting several years, **significant changes** can happen during the project lifetime: e.g. legislation amendments, unexpected technological and financial challenges. The pandemics caused a lot of delays to some technology providers as the technical development was halted for several months, followed with increased cost or unavailability of some materials and staff shortages inducing further delays and challenges.

A project of this scale would benefit from an overall aligned process for the detailed engineering and installation process of technologies, especially if they are unfamiliar to the local installers, in order to save resources and avoid mistakes. There should be a partner in the project responsible for the **detailed engineering studies** of all demo sites.

2.3.2.12 Hybrid PVT collector DS

DS provided remote training of the installer beforehand and most of the technical questions were already addressed during the engineering phase. During installation, DS provided support when needed, e.g. on PVT panel mounting, optimizer attachment, temperature sensors.

2.3.2.13 Thermal storage and controls RATIO

- The correct mounting of the valves was critical. Besides this no special challenges have been faced.
- As the equipment was previously unknown to the local installer, during the installation phase RATIO continuously supported them. Some connection ports to Oskar were switched as suggested by the installer and agreed by RATIO due to space restrictions onsite. There was also a number of questions, e.g. on hydraulic connections (which ports to use, flow directions), valve control, positioning of the power meter and grid sensor for the Smart Energy electric heater etc. Namely, since the heater control strategy differs from the standard (German) operation mode, the positioning for the Latvian net metering purposes was also different from the RATIO manual.
- The initial installation and commissioning of the controls was the most challenging and required several iterations and clarifications from RATIO, incl. on the connection cables, integration with SE monitoring system etc. When the installation of controls completed, RATIO assisted in remote testing of all the connections, valves, pumps etc. which was very useful and allowed to correct a few errors before the full commissioning.
- When BH was replaced, after BDR commissioning, the control program was remotely updated by RATIO a few times based on RTU and BDR feedback and observations during operation. For example, the glycol tank was only heated when its temperature difference with the PVT collectors was less than 13 °C. This led to the glycol tank cooling down below 0 °C when heat pump was operating during the night in the beginning of October when it was much > 10 °C outside. The agreed solution implemented by RATIO was to start the solar pump when the PVT collectors are at least 5 °C warmer than the glycol tank top and stop when this difference decreases to 1 °C.
- Additionally, RATIO updated the software to include a manual switch feature for the electric heater (e.g. turn all the PV surplus electricity into heat during summer to avoid running the heat pump); manual summer heating mode feature to avoid running the heat circulator pump unnecessarily; additional screen and settings for the heating loop control etc.
- For the Smart Energy electric heater, based on PV electricity production and consumption analysis by RTU, it was found that with the electric BDR heat pump, generally, there won't be any surplus electricity because the electricity

consumption will be much higher than with the BH gas-driven heat pump. Thus, the custom control logic of the heater for the Latvian net metering system is not necessary anymore.

2.3.2.14 Hybrid solar assisted HP BDR

- During the installation, BDR provided continuous technical support to RTU on integration and connection of the heat pump and the gas boiler. There were a number of questions, especially on the controls, settings and communication with the RATIO PLC that were not clearly explained or hard to find in the standard manual.
- During commissioning and initial operation of the heat pump, several unexpected error messages came up, especially in Sunīši. To solve this, BDR decided to send a replacement PCB with updated software, covered by the warranty of the heat pump.

2.3.2.15 User app CW

As mentioned previously the biggest challenge with the SunHorizon app during this phase was to distribute it and make sure that the end users got everything they needed to use the app, as well as understanding why it was important for the project. During the app walkthrough meeting with demo representatives from Sant Cugat and Riga we received a lot of valuable feedback on the app which led to improvements and fixes.

2.3.2.16 Monitoring sensors and platform SE

SE developed and tested a solution for reading/writing data from/to the RATIO PLC. Furthermore, a custom solution was successfully developed in collaboration with BH for SE to be also able to read the data from the BH machine which was not planned for from the beginning. It was especially challenging and took some extra time and effort as SE and BH were using different sources of internet and could not be connected in a straightforward way compared to RATIO PLC.

2.3.2.17 Monitoring platform IES

See 2.3.7

2.3.3 Operation and monitoring phase

2.3.3.1 Operation and monitoring RTU

Since the initial commissioning of TP2 in two Riga demo sites, electricity and heat supply has been successfully provided by the new technology package, bringing a number of benefits to the end-users. For the PV production, both demo sites have benefitted from the net metering system currently in force in Latvia, whereby the surplus PV production can be fed to the distribution grid and “stored” there within a year-long period (from March until February next year). Within this period, the energy “stored” in the grid can be used by the household at a discounted price (by paying only the distribution tariff). If there is any remaining energy stored by the end of February, this amount is annulled, and net metering is restarted from zero in March. To address the challenges caused by a large amount of microgeneration, some amendments in legislation are expected. For example, new entrants won’t be able to join the net metering starting from 2024. Instead, they will be able to use the net billing system. However, the existing participants can continue using the net metering system until February 2029.

As concerns the thermal performance of TP2, savings have also been achieved compared to the previously used conventional gas boiler. However, during the whole demonstration period there have been many issues with the BH operation in the heat pump mode as a result of which BH was mostly operating as a condensing gas boiler (and even so

with different occasional errors). The technical issues were identified thanks to the preventive maintenance and real-time monitoring set up by BH; some alarms were also displayed on the BH screen. For example, “low pressure of glycol network” was a continuous issue as the BH HP and DS panels were in the same glycol circuit but had conflicting pressure requirements and behaviour. This issue became irrelevant after BH replacement as the situation is completely different with the BDR HP, which operates based on the flow, not pressure. Hence, after installation of the BDR HP, the PVT panel and HP coupling has been operating successfully without any problems, and the heat produced by the PVT is successfully stored in the glycol tank and used by the HP even in colder weather (e.g. Oct/Nov 2023).

Additionally, both BH machines experienced strange leaks of the CO₂ refrigerant. In Sunisi, refilling of the refrigerant was performed in April 2022 and subsequent annual top-up recommended by BH. Even so, a lack of refrigerant was observed already in November after operating the BH in the HP mode for ~2 weeks. In Imanta, the whole internal heat pump unit was replaced in April 2022 due to “deteriorated behaviour”. Nevertheless, in October a severe leak was identified by BH through the remote monitoring, which could not be fixed by refilling. Consequently, due to the missing/leaking refrigerant, the heat pump operation was impossible except for ~2 weeks in Sunisi, when the glycol tank was decoupled from the PVT panels for testing purposes.

Furthermore, end-users were discontent with the DHW temperature setting of BH: it was too high and impossible to adjust since summer 2022 (was user-selectable previously). The DHW tank top temperature was set to 65 °C; however, to save energy and gas, the users would have preferred a lower temperature, e.g. 50 °C, which would also allow to more rely on the solar heat during the summer. This also caused unnecessary overheating of the technical room, especially in Imanta. The issue has become irrelevant with installation of BDR equipment as their external heat losses are much less and hence much lower temperature has been achieved in the technical room. Additionally, the maximum temperature of Oskar tank has also been reduced to decrease the thermal losses in the whole technical room.

Regarding operation of the PVT thermal part, there have been one leakage of the PVT piping identified and solved both in Imanta and Sunisi demo site. In Imanta, a small leak in one of the glycol pipes behind the DS panels was found and fixed in September 2022. The reason remained unclear (might be caused by birds). In Sunisi, a leak was found and fixed in June 2023. This seemed like installer’s oversight because the respective DualQuickfit fitting had not been plugged in properly during the installation and subsequently had become loose after longer operation.

In Sunisi, the end-users have experienced unsatisfactory DHW recirculation. They strongly rely on it as the distance from the technical building to the main house is ~30 m. Due to poor recirculation, they need to wait for about 3 min in the morning before warm water becomes available in their tap. Eventually, when analysing the issue in more detail in October 2023, it was found that the circulator loop has not been connected correctly and hence did not properly circulate the hot water from the heat source. The installer who performed the TP2 upgrade with the BDR equipment was requested to fix the issue.

After commissioning of BDR equipment and launching the updated control program, space heating was challenging during the first weeks of operation. Namely, after commissioning both demo sites in the end of September, during the first weekend both houses were somewhat overheated due to unexpected space heating production (it was still warm outside, hence no heating required). With the new configuration, space heating is controlled by RATIO PLC employing the new heat circulating pump. Compared to the previous system, there is no central thermostat for the room temperature control. Instead, the residents need to manually adjust the thermostatic radiator valves (TRVs) and the thermostatic valve of the underfloor heating in Sunisi to adjust the temperature setpoint in each room. Therefore, it took some time to learn to use and control the new heating system. Moreover, several other settings were adjusted in the PLC with assistance of RATIO (e.g. heating curve setpoints, outside temperature limit for space heating etc.) and a forced summer mode feature was implemented to allow the end-user to turn off the space heating themselves.

2.3.3.2 Hybrid PVT collector DS

During PVT panel operation, large glycol pressure variations can be observed, which is normal for the specific type of PVT panels but was especially challenging for BH heat pump integration and hence also confusing for the local installer. Namely, extensive troubleshooting was carried out by the installer and RTU to try to increase the glycol pressure up to the minimum accepted for the BH. Additionally, BH found that they have an issue with a too high concentration (near 100%) of the heat carrier and asked the demo manager to dilute the heat carrier a few months after the installation. Consequently, concentration close to ~55% was achieved. Still, BH heat pump encountered other issues and was in fact never able to run in the heat pump mode despite the large number of efforts by BH and the demo manager.

Only when the BH was replaced with the BDR heat pump, it was possible to start testing the PVT panel and heat pump coupling in real-life. With the BDR heat pump in place, the system has been running fine and the BDR HP has no issues with the glycol pressure. BDR HP can efficiently use the heat stored in the glycol tank even during colder autumn weather.

2.3.3.3 Thermal storage and controls RATIO

No critical or special challenge to set up the operation and monitoring.

However, some improvements were required during operation:

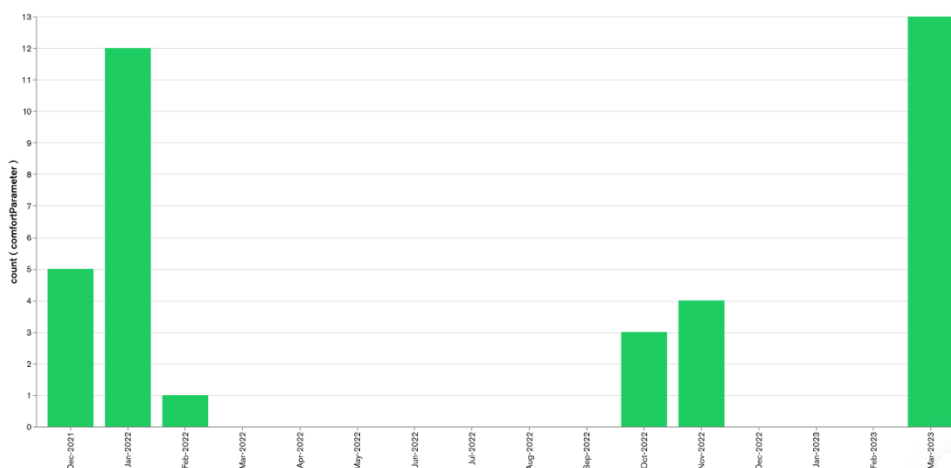
- Smart Energy control program did not work as expected, was corrected after BDR installation.
- During the initial TP2 operation incl. BH, it was observed that the primary solar pump was operating with a rate up to ~35% even when the PVT collector temperature significantly exceeded that of the storage tank. This was according to the implemented control strategy, whereby the solar pump was trying to reach 60 °C and thus was running with minimum speed if the temperature from the PVT collectors was lower. In order to improve the control program adaptation for the particular use case with the PVT panels, which usually provide a lower temperature, the strategy was eventually modified. With the new settings and the final TP2 configuration (incl. the BDR heat pump), the primary solar pump now usually operates at a rate of 100%, thus drawing as much heat as possible from the PVT field even at low temperatures and during the heating season.

2.3.3.4 Hybrid solar assisted HP BDR

The operation of BDR HP has allowed to verify onsite the control strategy of the TP2 and the SunHorizon-specific coupling between the HP and the PVT field via the glycol storage tank. The short operation time has not provided many lessons learned for now. However, the first weeks of BDR HP operation have been used to adjust some parameters of the heat pump based on the first observations as well as to fine-tune the overall TP2 control strategy. For example, based on tests and observations of the energy use onsite, the lowest HP source temperature was set to -10 °C by BDR in order to achieve a COP not lower than ~2 as otherwise it is more economically beneficial for the residents to use the gas boiler instead. This is based on the current ratio (~2) between the electricity and gas price and the setting can be adjusted in the future if needed. The coupling between the HP and the PVT panels has been validated onsite successfully and, together with the back-up gas boiler, the HP serves as a reliable heat source within the integrated TP2.

2.3.3.5 User app CW

The app worked quite well during this phase, we tested continuously. The challenge was, as mentioned, to get the end users to use the app more frequently. Unfortunately, the app has not been used as much as we hoped yet, 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.



Number of feedback messages sent to ISCAN from the app

2.3.3.6 Monitoring sensors and platform SE

Performed activities:

- Modification of the navigation graphic pages and dashboard to fit the site needs.
- Regular check for devices' status.

Challenges encountered:

- API functionality: the usual way of transmitting the data didn't work and we had to adjust our software to fit the needs.
- Offline devices in Riga Imanta: Schneider router is in the garage and the building's walls are thicker therefore the signal strength is weaker and a little unstable, even with the Wi-Fi repeaters provided.

Lessons learnt:

It is always better to consider of having a cabled connection between the router and the first access point in the building.

2.3.3.7 Monitoring platform IES

See 2.4.7

2.3.4 SUNISI Performance analysis from monitoring data CARTIF

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

Due to the issues previously defined the integration of data on the IES dashboards and the KPIs formulas had to wait until October 2023. For this reason, the formulas have been directly applied onto downloaded data from the Schneider platform, in order to extend the monthly KPI analysis period from January 2022 to October 2023 included in the below figure, that will reflect mostly the performance of the DualSun panels and BoostHeat as condensing gas boiler, there is not enough data to obtain monthly figures from new BDR heat pump.⁴

⁴ More detailed figures have been included into the Sunhorizon's deliverable *D6.6 Final Report on SunHorizon monitoring activities*.

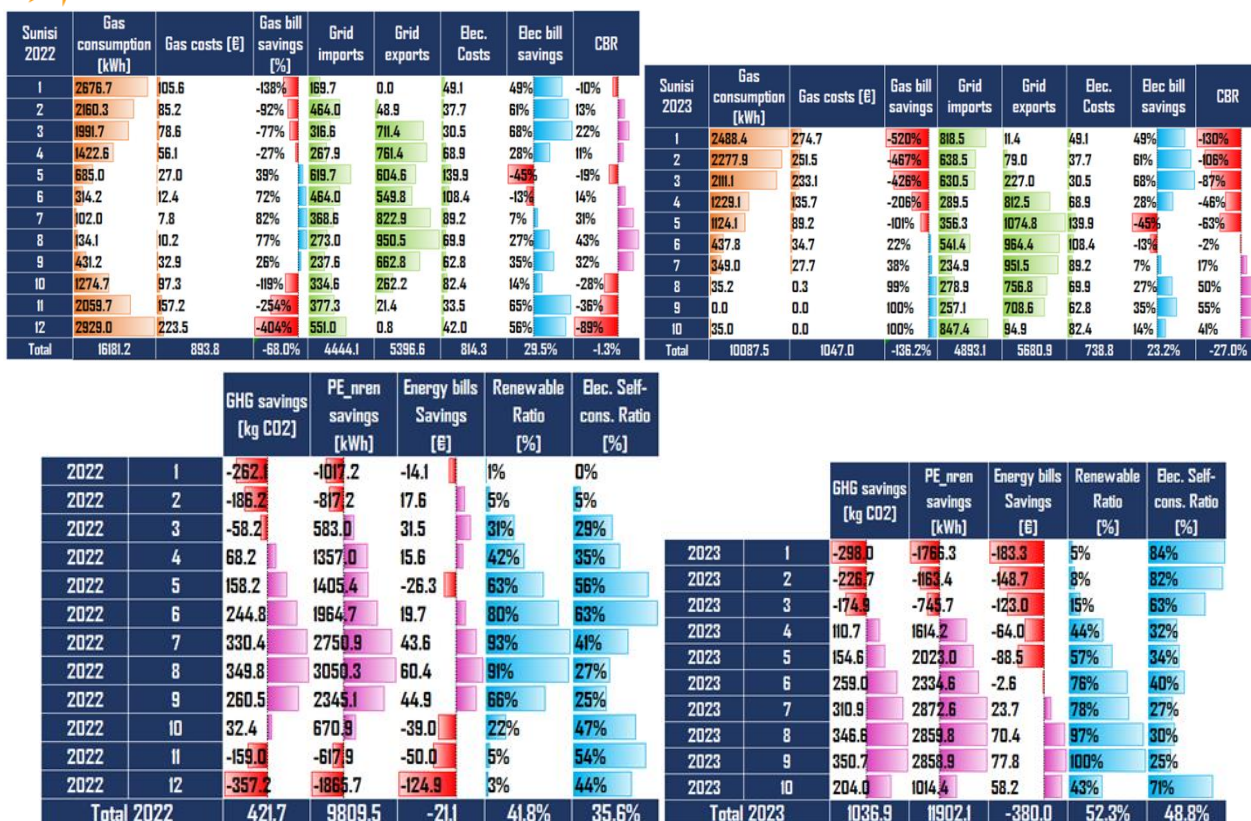


Figure 21: Riga_Sunisi: Monthly KPIs

These figures include monthly final energy consumption (electricity and gas) as well as its estimated savings comparing the measured data from the defined baseline on the internal deliverable D2.5, it can be appreciated that there were no savings on the gas bills and great savings on the electricity bills mainly due to exported electricity to the main grid, resulting in negative global economic savings. Due to small savings on the gas consumption, there are even some negative savings in terms of GHG emissions and non-renewable primary energy in winter months where the consumption was higher.

The updated figures on savings and performance have been included in the tables below, with yearly values for 2022 and the aggregated values from January to October 2023. It can be seen how due to various issues this TP did not meet the defined threshold, with mayor deviations mainly affected by the gas consumption and rise of electricity prices which reduces the possible savings on the electricity bills.

Table 11: Riga_Sunisi: Yearly KPIs for 2022

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

Table 12: Riga_Sunisi: Monthly KPIs for 2023 from January to October

KPI_2023	Name	Actual Value	Threshold	Deviation
GHG savings	Avoided GHG emissions	1.04 tons of CO ₂ eq; or 34.8%.	40 to 60%	Yes
PESnren	Non-renewable energy savings	11.9 MWh; or 54.6%	50 to 70%	No
CBR	Customer Bills Reduction	-380.0€; or -27%	Up to 60%	Yes
RER	Renewable Energy Ratio	52.3%	40 to 70%	No
SCR	Self-Consumption Ratio	48.8%	Up to 80%	No
HCI	Heating Comfort Index	9.60	7 to 15 °C·h	No major deviation
CCI	Cooling Comfort Index	1.06	7 to 15 °C·h	No

2.3.5 IMANTA Performance analysis from monitoring data RINA

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

The chosen period to be analysed is from November 2022 to October 2023 (in the deliverable D6.5 the period chosen was from February 2022 to October 2022). It is worth mentioning that BH unit was operational (only as condensing gas boiler) from April 2022 until September 2023 when it was replaced by a new BDR heat pump whose installation and integration within the TP was not finalised until mid-October 2023, so there are not enough data to obtain monthly indicators for this equipment.

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

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

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

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

Table 13: Riga_Imanta: Monthly KPIs from November 2022 to October 2023

KPI 2022-2023	Name	Actual Value	Threshold	Deviation
CAPEX	Capital Expenditure	133757€	-	-
CBR	Customer Bills Reduction	11.29 €	Up to 60%	No
GHG savings	Avoided GHG emissions	98%	40 to 60%	No
OPEX	Operation Expenditure	168.37 €	-	No
PESnren	Non-Renewable Energy Savings	47%	50 to 70%	No
RER	Renewable Energy Ratio	18%	40 to 70%	No
SCR	Self-Consumption Ratio	42%	Up to 80%	No

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

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

2.3.6 Conclusion RTU

The benefits of SunHorizon TP2 have been successfully verified during the demonstration in Riga, Latvia. While having the coldest climate conditions compared to the other SunHorizon demo sites, eventually this was also the only demonstration involving residential single-family buildings.

Implementation of the demonstration involved many stages, starting from the general demo needs analysis, simulations, detailed engineering up to the installation and commissioning. It was made possible thanks to the contribution of the consortium and expertise of the different partners involved despite the various challenges experienced throughout the project, including the consequences of pandemics and energy crisis, eventually leading to a withdrawal of a key technology provider and replacement of their equipment in the demo site after almost two years of operation. Nevertheless, it provided many invaluable learnings as detailed in the previous sections.

In addition to the expertise and great contribution from all the technology providers as elaborated previously, the role of RTU as a demo manager was vital to serve as an intermediary and a single point of contact for the demo owners/residents, technology providers and the subcontracted installer companies. RTU was in continuous communication throughout the demonstration with all the parties involved and also took active participation in some key technical tasks, for instance, to set up the monitoring system, communication and control of the individual components and the whole TP2 with guidance from all the technology providers. This has provided up to three years of monitoring data for KPI assessment (starting with the pre-monitoring in Sunīši demo since 2020 up to the operation of the TP2 as soon as it was commissioned, until the end of project and beyond).

3 Conclusion

The report D6.7 summarizes the conclusions and key lessons learned from SunHorizon demonstration activities in WP6. The project initially aimed to conduct 8 specific demonstration of building energy system renovation projects in parallel relying on four Technology Package (TP) concept, defined as solar and heat pump technology combination. 3 of them were successfully completed and operational as in Riga TP2 (individual house heating), Sant Cugat TP3 (tertiary building civic center heating/cooling), and TP4 (multifamily building heating/cooling), thanks to interactions of SunHorizon technology providers with local demo site leading team during the 5 years project's duration. On the other hand 5 demo cases were finally cancelled with varying degrees of progress at the time of cancellation, three demo cases in Nurnberg and Verviers were still in the engineering phase and two in Berlin and Piera in installation phase.

In addition to the main KPIs in the table below integrated over various period durations (cf. details about calculations in D6.6), a few highlights and conclusion are drawn for the 3 demo cases that reached the end of the project :

- In Riga Sunisi demo case, TP2 is supplying space heating and DHW to a residential house in Nordic climate. The solar heat and electricity from Dualsun PVT hybrid panels are managed by RATIO controls and thermal storage to lower the required import of energy from the grid to power the heat pump ensuring flexible heat supply to the dwelling. Whenever the initial installation in Winter 2021 of Boosheat CO2 heat pump with gas fired thermal compressor revealed strong limitations after one year operation, it was then successfully replaced shortly before the end of the project by BDR hybrid heat pump, commissioned and already ran during the first month of the heating season in October 2023. Thanks to continuous effort of the demo partners led by RTU in monitoring, fixing issues and optimizing the TP2 installation settings for 22 months, RER above 41% from solar heat and electricity allows to reach 22% GHG savings and 45% PENren savings, considering an extra gas consumption due to Boosheat malfunction over the whole period. Nonetheless it doesn't allow to achieve effective cost bill reduction since the effect was exacerbated by the gas and electricity price surge of 2–4 times compared to the baseline 2019 prices bills.
- In Sant Cugat, TP3 is relying on solar heat supply from TVP high vacuum solar thermal panels through RATIO thermal storage and controls to space heating loop, complemented by existing reversible heat pump. The installation is switched manually in cooling mode so that solar heat is driving FAHR hybrid chiller to achieve efficient renewable solar cooling, complemented by existing reversible heat pump in cooling mode. Despite regular communication of demo partners led by AJSCV and VEO since the installation was completed in Spring 2022, a devious issue around the internet router prevented reliable remote access to TP3's controllers, notably to TVP controller, which prevent to detect and to fix quickly issues around solar loop and energy monitoring also around the cooling operation in summer period. In July 2023, solar loop issues were fixed and installation is running properly since then but still no enough reliable energy monitoring data to calculate reliably KPIs. From the demonstration experience Sant Cugat partners are now drawing the conclusion that for large, public, demonstration case with existing Building Management System, specific effort and budget is still required to develop a SunHorizon TP3 BMS enabling remote access and maintenance either fully autonomous or fully integrated in existing system.
- In Madrid, TP4 is supplying space heating and DHW to a residential multi-apartment building in Madrid Mediterranean climate. The solar heat and electricity from Dualsun PVT hybrid panels are managed by AJSCV controls and thermal storage to lower the required import of energy from the grid to power the BDR heat pumps ensuring flexible heat supply to the dwellings. During Spring 2022 the administrative agreements around electrical grid connection and electricity selling contracts for public bodies in Spain were finalized and allowed to finalize the HP electrical installation and TP4 system running in September 2022 to supply the dwellings. Thanks to continuous effort of the demo partners led by AJSCV in monitoring, fixing issues and optimizing the TP4 installation settings, RER around 57% from solar heat and electricity allows to reach 63% GHG savings, 67% electricity self-consumption and about 30% bills reduction during the period running from January 2023.

KPI	Sant Cugat #3	Madrid #4	Riga Imanta #8.1	Riga Sunisi #8.2
Monitoring period	06/2023 to 10/2023	01/2023 to 10/2023	11/2022 to 10/2023	01/2022 to 10/2023
CAPEX	457633 €	317501€	133757€	132085€
CBR	60 €/day	783.5€ 29.8%	11.29€	-401.11€ -12.97%
CSAT	-	-	-	-
GHG savings	-42.45 kgCO ₂ eq	8205.8kgCO ₂ eq 62.7%	98%	1458.57kgCO ₂ eq 22.22%
HCI	0.06 °C	0.0°C	-	14.7°C·h [2022] 9.6°C·h [2023]
CCI	-	1.95°C	-	2.3°C·h [2022] 1.1°C·h [2023]
LCOH	-	-	-	-
OPEX	2288.17 €	1587.54€	300€	300€
PES _{nren} (absolute) And relative:	-30363.26 kWh	38977.2kWh 58.6%	47%	21711.56kWh 45.24%
RER	11.75%	56.98%	18%	46.58%
SCR	-	67.09%	42%	41.61%
SPB ₅	10-*	8.8*	-	-

In addition, D6.5 report also reminds the technical and administrative difficulties encountered and their impact on the project's progress and outcomes.

The cancellation of some demo cases was primarily due to a combination of administrative and technical challenges that could not be resolved within the project's defined timeframe and budget. The main reasons include:

- A devastating flood disaster that destroyed a project's site.
- Integration of the project into a separate renovation workplan of the municipality, leading to logistical and administrative complications.
- Seasonal and roof structure limitations for solar panel installations.
- Increased costs after the COVID-19 pandemic and the Ukrainian conflict.
- Challenges related to the availability of installers and components.
- The unexpected withdrawal of BoostHeat.
- Strict depreciation rules for heat pumps in Berlin.

Throughout the project, several significant challenges were encountered, including:

- Involvement of multiple subsystems manufacturers without proper whole new system engineering coordination, especially in managing the detailed interactions of subsystems in both the engineering and operational phases, particularly in the realm of controls.
- Budgetary constraints that impeded the smooth execution of the project.
- Delays in obtaining monitoring results, which hindered efforts to optimize the installations' performance.

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

Following the conclusion of the COVID-19 crisis in 2021, despite constant communication with the European Commission regarding iterative fallback scenarios for Berlin and both Verviers demo sites none of them were successfully selected mainly for insoluble timing aspects. Notably, there was no suitable replacement identified for the Verviers swimming pool, large tertiary building case, which held promise for the coupling of solar PVT in series with the evaporator of heat pump technology. Similarly, no alternative case was carried on until achievement for the Verviers Sport Center, large tertiary building case as well, where highly efficient TVP solar thermal technology was originally planned to be implemented in parallel to heat pump heat supply.

In addition to the results gained from the on-site demonstration in the 3 demo cases above, technical knowledges arose also for TP1, TP2, TP4 in single family context through simulated performance (TP1, TP2, TP3, TP4) from Eurosun 2020 conference article, HPC conference 2022 article and Experimental test results in INES, from ISES SWC 2021 conference article. It draws the attention on several items at the design stage and in controls:

- For TP2, the outdoor air unit backup foreseen to secure the demo in the eventuality of low efficiency when low solar resource, which actually increased complexity of the hydraulics and caused installation and control issues
- For TP2, TP4, the layout with solar thermal circuit from PVT in series with standard HP evaporator requires increased complexity (buffer, tempering valve and control) and may cause lower real performance compared to theoretical one until optimal settings of the whole installation is achieved
- TP3: complex interactions issues between thermal storage, control, absorption chiller, existing H/C plant; solar field size suits solar heating demand but exceeds solar cooling demand during summer

Briefly the main technical challenge rising from the situation of multiple partners developing separate subsystem is turning into communication challenge.

From technical perspective about technology combination of solar hybrid electrical and thermal panels with heat pumps, the SunHorizon experience is fostering the integration of solar energies to be driven by heat pump developers: through development of ad-hoc solar heat integration schematics, covering as optional features existing Heating and Cooling generator circuit (boilers) and integration of control and connectivity aspects. These measures are likely to reduce the design, installation, operation and maintenance costs.

This report provides a comprehensive understanding of the challenges and complexities that the 3 remaining demo sites overcame and that led to the cancellation of other demonstration cases. The lessons learned from this experience will be valuable for future endeavours in the field of solar and heat pump energy systems for building heating and cooling, and technology demonstrations.

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