Innovative heat pump solutions: the SunHorizon Technology Packages

FEDERICA FULIGNI
RINA Consulting S.p.A.
Genova – Italy
federica.fuligni@rina.org

SERENA SCOTTON
EHPA,
Brussels, Belgium
serena.scotton@ehpa.org

DAVID CHEZE
Univ Grenoble Alpes,
CEA, Grenoble, France
david.cheze@cea.fr

ANDREA FRAZZICA
ITAE / CNR, Messina, Italy
andrea.frazzica@itae.cnr.it

ANDREA GABALDÓN
CARTIF, Boecillo, Spain
andgab@cartif.es

GIUSEPPE DINO
ITAE / CNR,
Messina, Italy
giuseppe.dino@itae.cnr.it.

Heat Pump (HP) and solar appliances are socially well accepted Renewable Energy based energy systems. The SunHorizon project demonstrates TRL7 innovative HP solutions (thermal compression, adsorption, reversible) coupled with solar technologies (thermal, photovoltaic, hybrid) to provide heating and cooling to residential and tertiary buildings with lower emissions and energy bills.

Keywords: Heat pump solutions; solar driven heat pumps, EU Project, renovation, buildings.

Context

The analysis on the European HP market showed a constant increasing trend. However, two barriers are identified, the initial investment cost and the price difference between electricity and natural gas.

Furthermore, the solar market analysis identifies solar technologies as a growing market within the EU, both for electricity generation and thermal energy. In this case, the main barriers consist in the lack of access to subsidies and the fact that the EU legislation on Energy Performance of Buildings (EPBD) just covers new buildings, which is a minority of the total building stock.

As stated in EU Strategy on H&C (2016), *"large-scale demonstration projects of energy-efficient and low/zero-carbon technologies are needed to help reduce technical and market barriers by providing robust data to evaluate their performance in each market segment"* [1]. SunHorizon project wants to reach this goal and is a breakthrough demonstration-to-market project with 21 partners and 8 demos in Europe.

The project focuses on *"reducing system costs and improving performance as well as optimising existing technologies for H&C applications and for some of the most promising market segments"* [2]. Its technologies are properly managed by a

cloud based functional monitoring platform with services such as demand prediction, proactive and predictive maintenance tools, or a hybrid advance controller, supported by a *smart user interface*; the services will help on maximizing solar exploitation and give inputs to the manufacturer for the design and installation.

The project team is industry-driven, including 12 industrial partners, 5 top level Research and Technology Organisations (RTOs) and 4 associations. The 8 demo sites cover a wide range of European climate conditions, different energy markets and end-users, going from single houses to apartment blocks, public buildings, swimming pool and sport centre.

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SunHorizon technologies

5 different technology combinations, known as Technology Packages (TP), are supplied to the demo sites, combining the technologies listed below. One of the main goals of SunHorizon is to introduce technology innovations to be firstly validated at laboratory scale and, finally, on real demo-site applications. For each technology provider, the main innovations include:

- **BoostHEAT (BH)** provides a gas-driven HP consisting of one or more thermal compressors in parallel, fed by a low-NOx burner, and using CO_2 as working fluid. BH has improved within the project the compressor operation, the production chain and the software architecture
- **Fahrenheit (FAHR)** is a hybrid unit connecting in parallel a thermally driven adsorption chiller, using water (R718) as refrigerant and a vapour compression. FAHR has improved its technology by adding a new absorber to achieve an efficiency increase up to 40%, new heat exchangers and an improved coating process of the adsorbers
- **BDR Thermea group** provides two types of reversible HP: brine-water and air-water. Within the project, BDR has improved and optimized the control hardware and software allowing a higher reliability and efficiency improvement
- **TVP Solar** provides High Vacuum Flat Plate Solar Thermal technology, able to achieve extremely high delivering temperature, with the highest efficiency certified by the international standard Solar KeyMark. TVP has improved their absorber material, exit ports design and improvement of safety design and controls.
- **The DualSun (DS)** solar panel is an advanced hybrid solar (PV-T) technology that produces simultaneously electricity (photovoltaic) and hot water (solar thermal). The design of the panels has been improved by reducing thickness and weight, obtaining a faster and more reliable connection between panels and improving both electrical and thermal performance;
- **Ratiotherm** storage, delivering optimal solutions to achieve highly stratified storages, to maximise the integration among different sources and consumers. The stratification device of the tank has been adapted to expected flow rates and temperature levels.

Descriptions of each TP are described in the following.

Figure 1. Individual technologies included in SunHorizon project, and relative energy needs covered.

Technology package 1 (TP1)
TP1 consists in a parallel integration of TVP solar collectors to cover most of the heating demand (space heating and domestic hot water) and BH to cover non-solar periods. Via the stratification system the solar heat use is maximized. TP1 is applied in an apartment building in Berlin (Germany) and in a Sport centre in Verviers (Belgium).

Technology package 2 (TP2):
TP2 has DS PVT panels which thermal output assists the BH evaporator and covers preheating of demand, enhancing the HP performance. Furthermore, the electricity needs are covered with the photovoltaic output. TP2 is applied in an apartment building in Nurnberg (Germany), two single-family houses in Riga (Latvia) and in a swimming pool centre in Verviers (Belgium).

Technology package 3 (TP3):
TP3 has TVP collectors to cover the heating demand in winter, while in summer the solar output drives the adsorption chiller from Fahrenheit to meet the space cooling needs. TP3 is applied to a tertiary building in Sant Cugat, replacing the constant speed HP currently installed, which is electrically- driven.

Technology package 4 (TP4)
Similarly, with TP2, two variants of TP4 are proposed in Madrid and Piera demo sites relying on reversible HP from BDR, dual production of solar heat and electricity, versatile thermal storage. In Madrid, 9-apartments building, the COP of the BDR brine/water HP benefits from both thermal and electricity outputs of the DS hybrid PVT panels while air/water HP is used as back up. The electricity production covers the HP's consumption and the dwellings demand. In Piera residential building, BDR solar thermal panels reduces the DHW request on the reversible air/water BDR HP while it can be activated to store BDR photovoltaic panels electricity either as heat or cold in the thermal storage, thus maximising the electricity self-consumption.

Technology package 5 (TP5):
TP5 is composed by TVP solar collectors, RT high stratification storage tank, FAHR hybrid chiller and the BH thermal HP. The hot water

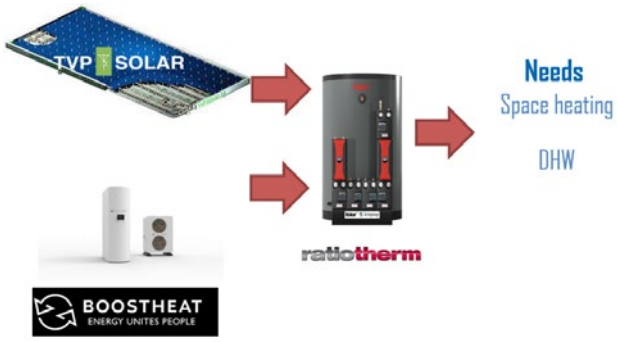

Figure 2. Technology package 1 presentation.

Figure 3. Technology package 2 presentation.

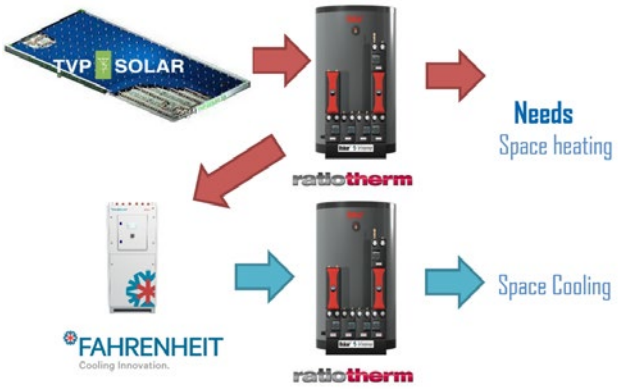

Figure 4. Technology package 3 presentation.

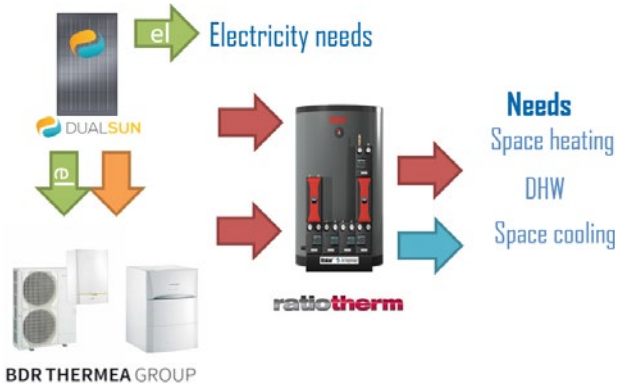

Figure 5. Technology package 4 (BDR+ DS).

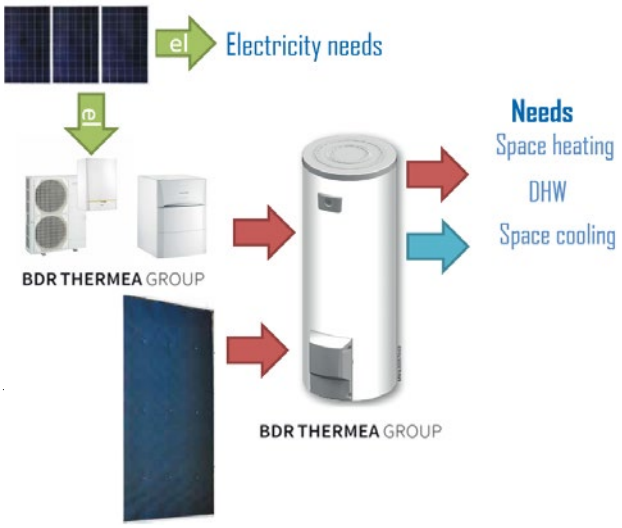

Figure 6. Technology package 4 presentation (BDR only).

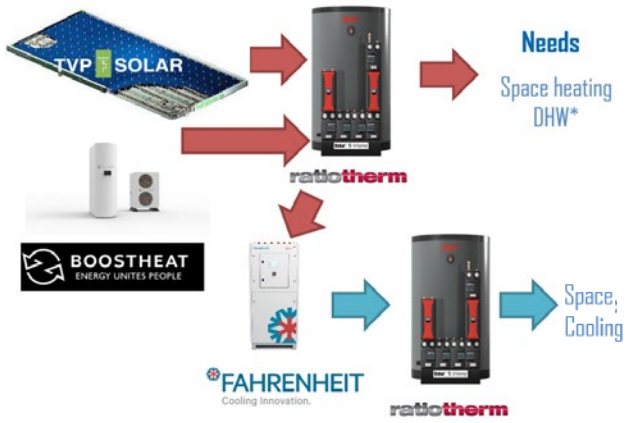

Figure 7. Technology package 5 presentation.

produced by TVP is stored in the high stratification RT tank, providing high temperature to the adsorption input and for DHW and space heating. The chilled water produced by FAHR hybrid chiller is stored in a smaller tank and then delivered to the space cooling system. During winter the pre-heated water by TVP is delivered to the BH unit that, if necessary, heats it up to cover the space heating and DHW demand.

Expected impacts

The technical partners of the project (CEA, CARTIF, CNR/ITAE and RINA) estimated the building energy demand of the 8 Demonstrators (9 buildings in total) using TRNSYS software, calibrated on theirs monthly gas and electricity bills. The existing and future scenario were compared in terms of non-renewable primary energy savings, costs and greenhouse gas emission savings, and the electricity self-consumption ratio. From the results, it is estimated that SunHorizon technology packages will allow to achieve 33-70% GHG emissions savings and 30-85% operation costs savings in the different demo sites. *TP1 to TP4 will be demonstrated in different demo sites, while TP5 will be only tested in simulation, in 3 locations and 2 types of buildings (tertiary and apartment building).*

The detailed performance of each technology package is shown in **Table 1**.

Table 1. *Technology package performance.*

SunHorizon TP		Solar-HP integration concept	Results from simulations
TP1	TVP + BH	Parallel integration	In **Berlin**: 43% of primary energy savings, and 37% of costs savings for the user In **Verviers**: ~30% of primary energy and costs savings.
TP2	DS + BH	Mixed solar-assisted/ parallel integration	In **Nurnberg**: ~ 33% of primary energy and costs savings, 80% of electrical self-consumption ratio (SCR). In **Verviers**: ~25% of primary energy and costs savings. 95.1% of SCR In **Riga**: ~37% of primary energy and costs savings. 43% of SCR
TP3	TVP + FAHR	Solar-driven HP for cooling	In **Sant Cugat**: ~35% of primary energy and costs savings
TP4	BDR	Mixed solar-assisted/ parallel integration	In **Madrid**: ~76% of primary energy and 84% of costs savings, and 37% of SCR In **Piera**: ~59% of primary energy and 53% of costs savings, and 47% of SCR
TP5	TVP + BH + FAHR	Mixed solar-driven/ parallel integration	For tertiary building the primary energy saving ranges from 19% to 57% depending on the location. For the multifamily residence building the primary energy saving ranges from 33% to 41%

Take-Aways

SunHorizon project is a pre-industrial project with high TRL that combines different type of heat pump with solar technologies that will help to meet the H&C demand with lower emissions, energy bills and fossil fuel dependency. The main take-aways from the project are:

- It is possible to enhance the performance of PVT panels (DS), when coupled with brine-water HP;
- Compared to other flat plate panels, the approx. 30% higher thermal efficiency of TVP panels allows either for reducing the solar field area or for achieving higher amount of non-renewable energy savings;
- 33–70% GHG emissions savings and 30-85% operation costs savings can be achieved, when we compare the performance of SunHorizon with a gas boiler system and an air conditioner;
- Without policy support it is difficult for the technology packages to be applied in the refurbishment of existing buildings.

If you want to know more about the project and follow up, visit the SunHorizon website: https://www.sunhorizon-project.eu/. ■

References

[1] European Commission (2016). Overview of support activities and projects of the European Union on energy efficiency and renewable energy in the heating and cooling sector.

[2] SunHorizon project https://www.sunhorizon-project.eu/.