SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Existing PVT systems and solutions

IEA SHC TASK 60 | PVT SYSTEMS

Existing PVT systems and solutions

SHC Task 60/Report A1

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IEA Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency. Its mission is *"To enhance collective knowledge and application of solar heating and cooling through international collaboration to reach the goal set in the vision of solar thermal energy meeting 50% of low temperature heating and cooling demand by 2050."*

The members of the IEA SHC collaborate on projects (referred to as Tasks) in the field of research, development, demonstration (RD&D), and test methods for solar thermal energy and solar buildings.

Research topics and the associated Tasks in parenthesis include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54)
- Solar Cooling (Tasks 25, 38, 48, 53)
- Solar Heat for Industrial or Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58)

In addition to our Task work, other activities of the IEA SHC include our:

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- Solar Heat Worldwide annual statics report
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1 Introduction

Throughout the world, many new technologies and projects are currently being undertaken to assist in the reduction of fossil fuel consumption. While the focus has been in the electrical and transport sector, significant progress has been made in the combined realm of renewable electricity and heat production based on photovoltaic thermal collectors (PVT).

In several European countries the PVT market is picking up speed. The possible applications for PVT-collectors are very varied and range from e.g. swimming pool heating to solar heat for industrial processes. Many of the already installed PVT systems are small in nature, but are able to satisfy a huge fraction of the overall onsite thermal and electrical energy demand, and serve as a good demonstration of the potential fuel savings.

A good, though not all encompassing, survey of currently operating PVT plants has been conducted. Within this survey, 22.920 PVT-systems were identified. A Global market overview and a sample of installed PVT systems with various PVT-collector types are exhibited in the following chapters, spanning most of the relevant PVT applications. These case studies include a general description of the solar installation, the overall heat supply concept and integration scheme, and other pertinent information to provide a deeper understanding of the subtleties of such projects.

2 Global market overview

2.1 Market overview – PVT manufacturer

This report takes a look at the PVT market worldwide with a special focus on Europe. The market for Photovoltaic-Thermal (PVT) systems and the number of PVT module producers is growing. A market survey which was conducted in the framework of the IEA-SHC Task 60 PVT Systems[1] represents 26 PVT collector manufacturers und PVT-system suppliers in 11 countries (Figure 1). The large majority of manufacturers focus on liquid PVT-collectors (48% uncovered flat plate collectors, 28% covered flat plate collectors, 4% vacuum tube collectors), 12% produce air collectors and 8% concentrating collectors.

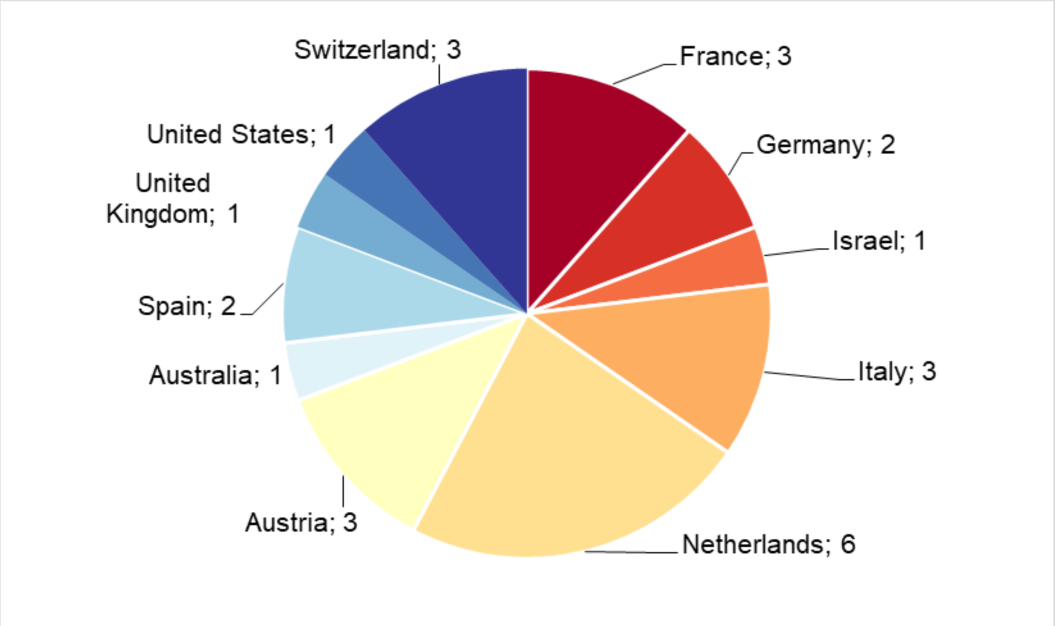

Figure 1: PVT-manufacturers by country

1 http://task60.iea-shc.org/

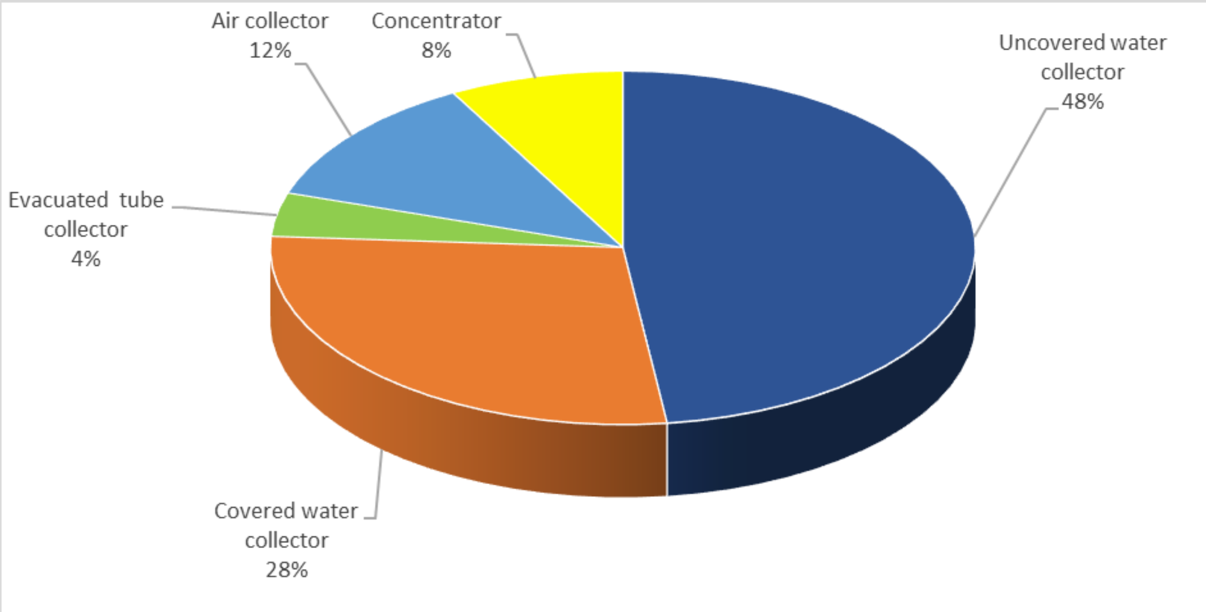

Figure 2: Distribution of PVT-manufacturer by collector type

2.2 Total installed area and capacity of PVT-collectors

Technical benchmark figures for PVT-collectors from the 26 PVT-manufacturers were collected from the comprehensive market survey. In Figure 3 the specific solar thermal power output in Wth/m² gross area highlighted in blue boxes is depicted for the different collector types (a blue diamond equals the average value). The nominal PV power in Wpeak/m² gross area is shown as green bars (a green diamond equals the average value). To derive the thermal and electrical capacity from the area of installed PVT-collectors, the average values of each collector type were used.

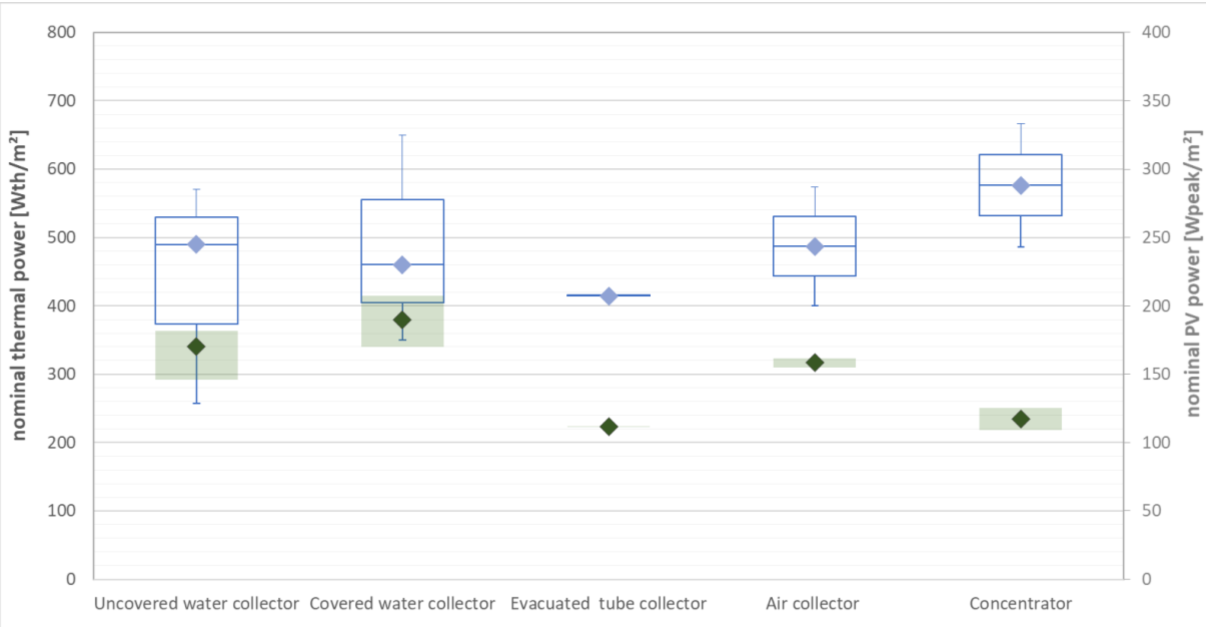

Figure 3: Thermal and electrical nominal power of PVT-collectors of a 26 manufacturers survey

By the end of the year 2018 a cumulated PVT collector area of 1.075.247 m² was manufactured according to IEA SHC Task 60 estimation. Considering the trading (export and import) of PVT collectors between the countries, Table 1 shows the installed collector area (assuming that all collectors produced were installed) in 2018 in total numbers by type of collector. In the European Market, France is the market leader with installed collector area of approximately 442.504 m² followed by Germany with 109.380 m². In Italy, Netherlands and Switzerland collector areas in the range of 5.000 to 15.000 m² are installed. In the remaining countries collector areas smaller than 5.000 m² were reported. Out of Europe the main PVT-manufacturer in Israel counted a cumulated manufactured collector area of 575.000 m² by the end of 2018 with a high export to Korea, China and Germany.

Table 1: Total installed PVT collector area worldwide

Country	Water Collectors [m²]			Air Collectors [m²]	Concentrators [m²]	TOTAL [m²]
	uncovered	covered	evacuated tube			
Australia	0	0	0	8	0	8
Austria	300	573	0	0	0	873
Belgium	524	0	0	290	15	829
Chile	0	0	0	0	10	10
China	133.721	25	0	0	171	133.916
Denmark	73	0	0	0	0	73
Egypt	0	0	0	0	21	21
France	9.204	0	0	433.300	0	442.504
Germany	107.927	1.232	0	87	135	109.380
India	0	4	0	0	240	244
Israel	53.488	0	0	0	0	53.488
Italy	9.038	6.400	0	0	0	15.438
Korea	280.814	0	0	0	0	280.814
Luxembourg	635	0	0	145	0	780
Maldive	0	0	0	0	21	21
Netherlands	5.588	7.579	0	0	1.773	14.940
Norway	200	0	0	0	0	200
Pakistan	0	4	0	0	0	4
Paraguey	0	0	0	0	51	51
South Africa	0	0	0	0	750	750
Spain	0	3.334	0	0	0	3.334
Sri Lanka	0	0	0	0	31	31
Switzerland	6.846	0	0	2.030	0	8.876
United Kingdom	15	0	38	348	0	400
United States	4.800	0	0	0	0	4.800
Others	162	3.300	0	0	0	3.462
TOTAL	613.334	22.449	38	436.208	3.218	1.075.247

The following figure show the installed collector area and the distribution of installed PVT-technology per country in the year 2018 in Europe.

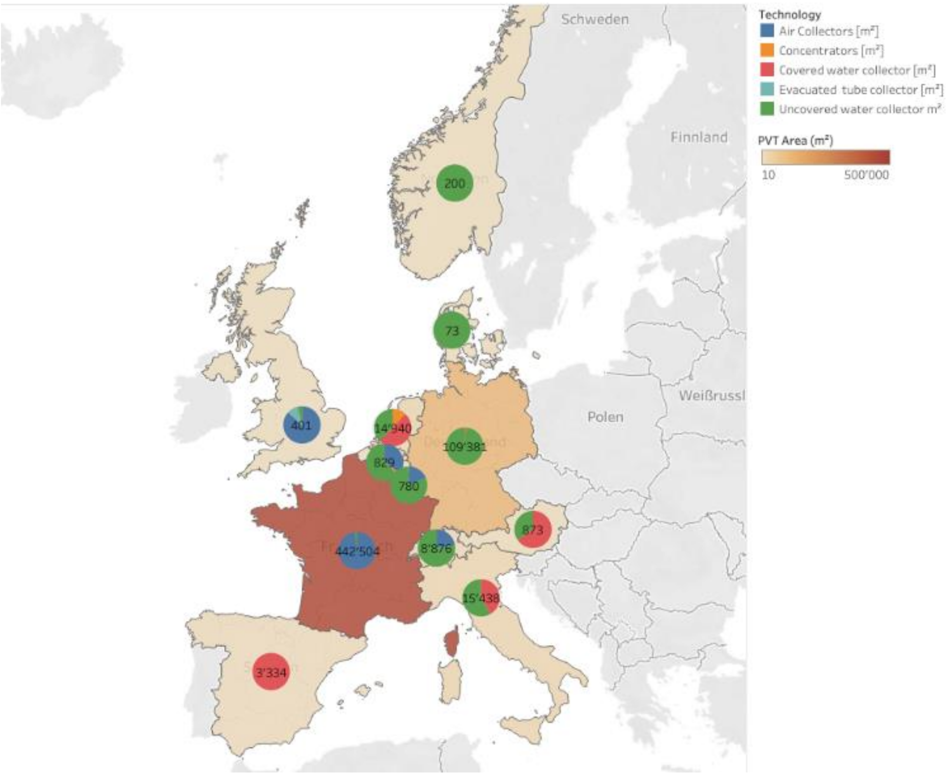

Figure 4: Installed collector area and PVT-technology in Europe in 2018

By the end of 2018, a total thermal capacity of PVT modules of 524.2 MW_{th} and a nominal PV power of 178.2 MW_{peak} were installed worldwide. The total installed capacity in operation was divided into uncovered water collectors: 298.1 MW_{th} and 103.6 MW_{peak}, covered water collectors: 10.3 MW_{th} and 4.3 MW_{peak}, evacuated tube collectors: 0.02 MW_{th} and 0.04 MW_{peak}, air collectors: 212.5 MW_{th} and 69.1 MW_{peak} and concentrators: 1.9 MW_{th} and 0.4 MW_{peak}.

Table 2: Total installed thermal and electrical capacity in 2018.

Country	Water Collectors						Air Collectors		Concentrators		TOTAL	
	uncovered		covered		evacuated tube							
	[kWth]	[kWpeak]	[kWth]	[kWpeak]	[kWth]	[kWpeak]	[kWth]	[kWpeak]	[kWth]	[kWpeak]	[kWth]	[kWpeak]
Australia	0	0	0	0	0	0	4	1	0	0	4	1
Austria	147	51	264	109	0	0	0	0	0	0	411	160
Belgium	257	89	0	0	0	0	141	46	9	2	406	137
Chile	0	0	0	0	0	0	0	0	6	1	6	1
China	65.523	22.775	12	5	0	0	0	0	98	20	65.633	22.800
Denmark	36	12	0	0	0	0	0	0	0	0	36	12
Egypt	0	0	0	0	0	0	0	0	12	2	12	2
France	4.510	1.568	0	0	0	0	211.060	68.609	0	0	215.570	70.176
Germany	52.884	18.382	567	234	0	0	42	14	78	16	53.571	18.646
India	0	0	2	1	0	0	0	0	139	28	140	29
Israel	26.209	9.110	0	0	0	0	0	0	0	0	26.209	9.110
Italy	4.429	1.539	2.944	1.215	0	0	0	0	0	0	7.373	2.755
Korea	137.599	47.828	0	0	0	0	0	0	0	0	137.599	47.828
Luxembourg	311	108	0	0	0	0	71	23	0	0	382	131
Maldive	0	0	0	0	0	0	0	0	12	2	12	2
Netherlands	2.738	952	3.486	1.439	0	0	0	0	1.022	208	7.247	2.599
Norway	98	34	0	0	0	0	0	0	0	0	98	34
Pakistan	0	0	2	1	0	0	0	0	0	0	2	1
Paraguey	0	0	0	0	0	0	0	0	30	6	30	6
South Africa	0	0	0	0	0	0	0	0	433	88	433	88
Spain	0	0	1.534	633	0	0	0	0	0	0	1.534	633
Sri Lanka	0	0	0	0	0	0	0	0	18	4	18	4
Switzerland	3.354	1.166	0	0	0	0	989	321	0	0	4.343	1.487
United Kingdom	7	2	0	0	16	4	170	55	0	0	192	62
United States	2.352	818	0	0	0	0	0	0	0	0	2.352	818
Others	79	28	1.518	627	0	0	0	0	0	0	1.597	654
TOTAL	298.182	103.645	10.327	4.263	16	4	212.477	69.069	1.855	377	525.208	178.177

With a global share of 57 % of the installed thermal capacity, uncovered water collectors were the dominating PVT-technology produced, followed by air collectors with 41 % and covered water collectors with 2 %. Evacuated tube collectors and concentrators play only a minor role in the total numbers (Figure 5).

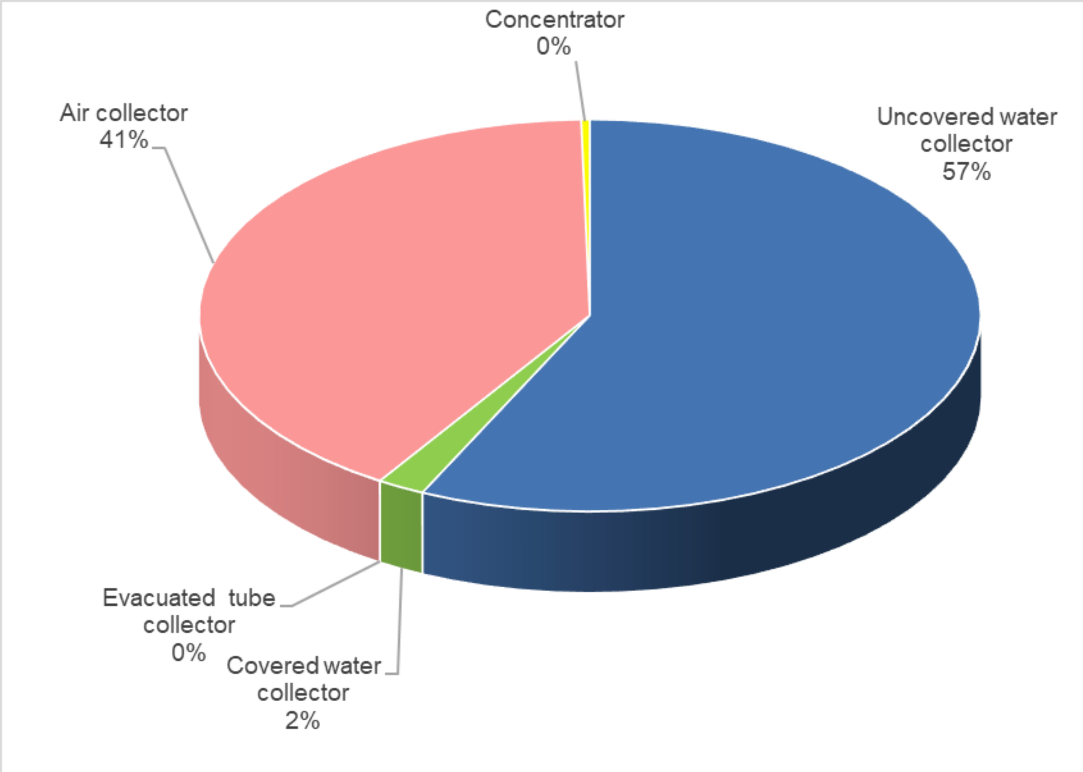

Figure 5: Distribution of the total installed thermal capacity in operation by collector type in 2018

2.3 Distribution by type of application

A number of promising projects have been implemented in the last couple of years ranging from small-scale plants to very large systems with 21 MW_{th} in Israel[2] capacity. The application in Table 3 shows that the majority of the accumulated systems which have been installed by the end of 2018 are in the application solar air (pre)heating/cooling for buildings followed by the application domestic hot water systems for single family houses.

Table 3 PVT-plants installed by the end of 2018. (Source: IEA SHC Task 60 survey, AEE INTEC)

PVT-Applications	Number of installations [#]	Total collector area [m²]
Swimming pool heating	82	8.360
Domestic hot water systems SFH	1.662	34.561
Large domestic hot water systems	165	20.851
Solar combi systems for SFH	633	17.758
Large solar combi systems	201	39.684
Solar air systems	20.121	441.674
Solar district heating systems	6	10.081
Solar heat for industrial applications	33	8.049
Not classifiable		494.229
TOTAL		1.075.247

2 www.millenniumsolar.com

As Figure 6 shows, the solar air systems dominate the market. More than 22.900 systems with totalling approximately 1.075.247 m² are documented. A collector area of 494.229 m² cannot be classified. In a global context, this breakdown is mainly driven by the dominance of the French market were almost all of the manufactured PVT collectors were air collectors. Nevertheless, apart from the solar air systems the uncovered PVT collectors are the most common technology. By the end of 2018, 2.169 systems of uncovered PVT collectors corresponding to a gross area of 613.334 m² were in operation. Out of these systems, 75 % were used for domestic hot water preparation in single and multifamily houses, hotels, hospitals, etc. Around 21 % of the systems supply electricity for the household together with heat for domestic hot water and space heating (combi systems). The remaining systems accounted for around 4 % and delivered energy to other applications such as industrial processes, district heating networks, swimming pool, etc. Covered PVT collectors are mainly used in combi systems.

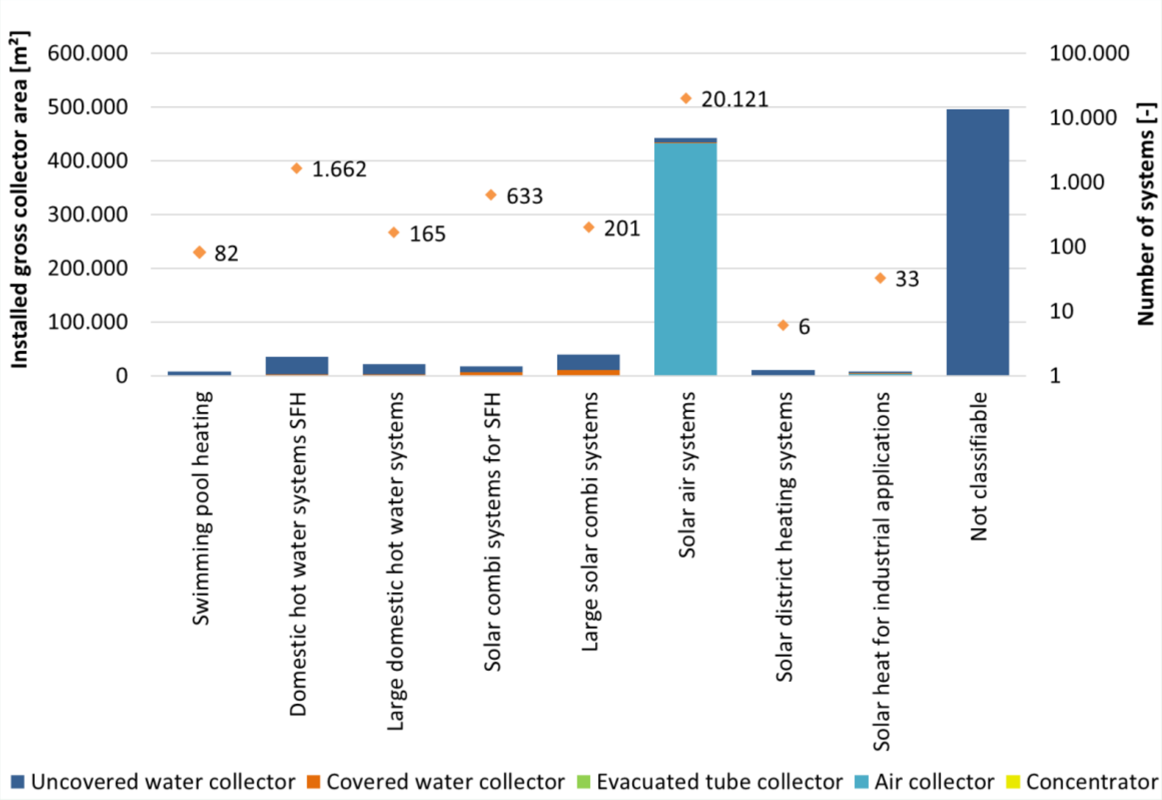

Figure 6: Global PVT-system plants in operation by type of application, type of collector and by collector area by end of 2018.

3 PVT Systems in operation

A sample of PVT-system projects from the global static are exhibited in the following chapters, spanning the applications swimming pool heating, solar combi systems for single family house (SFH), domestic hot water for single family house, domestic hot water for multifamily house, solar heat for industrial processes.

These case studies include a general description of the solar installation, the overall heat supply concept and integration scheme, and other pertinent information to provide a deeper understanding of the subtleties of such projects. Through this knowledge, such projects can be replicated in other regions to rapidly advance the future of PVT systems and reduce fossil fuel consumption and carbon emissions.

Table 4: Case Studies

Chapter	Project name	PVT-manufacturer	Type of PVT-collector	Collector area	Application
3.1	ECOMESH 1	EndeF	Covered water collector	30 m²	DHW for MFH
3.2	ECOMESH 2	EndeF	Covered water collector	10 m²	Solar combi system for SFH
3.3	ECOMESH 3	EndeF	Covered water collector	148 m²	DHW for hotel
3.4	ECOMESH 4	EndeF	Covered water collector	46 m²	DHW and water pool supply for Civil firefighters building
3.5	SYTA Truck Washing	Abora Solar	Covered water collector	264 m²	Heat water for process
3.6	Hotel Resort Iberostar Buganvilles	Abora Solar	Covered water collector	200 m²	DHW & swimming pool for Hotel
3.7	Sant Cugat's Sports Center	Abora Solar	Covered water collector	264 m²	DHW & swimming pool for Sports Center
3.8	Multi Dwelling Azud	Abora Solar	Covered water collector	55m²	DHW for MFH
3.9	Ambérieu-en-Bugey	DualSun	Uncovered water collector	6.4 m²	DHW for SFH
3.10	Saint-Genis-les-Ollières	DualSun	Uncovered water collector	9.6 m²	DHW for SFH
3.11	Sète	DualSun	Uncovered water collector	300 m²	DHW and pool preheating
3.12	Perpignan	DualSun	Uncovered water collector	300 m²	DHW and pool preheating
3.13	NVZ-Freiburg	Solvis	Covered water collector	48 m²	DHW for administrative center
3.14	Lintharea	Meyer Burger	Uncovered water collector	292 m²	Preheating of groundwater before used in heat pump
3.15	FVE - ATLAS O.C. s.r.o.	Fototherm	Uncovered water collector	188 m²	DHW, regeneration of boreholes, source for heat pump
3.16	SINGLE-FAMILY HOUSE IN SUELLO (LECCO)	Solink	Uncovered water collector	26 m²	Combi System (DHW, space heating, cooling) for SFH
3.17	P&D plant "Oberfeld"	Meyer Burger	Uncovered water collector	1320 m²	Combi System for MFH
3.18	Multi-Family house SOTCHA	Caotec	Uncovered water collector	130 m²	Combi System for MFH
3.19	Multi-Family house SENTMATT	Solator	Uncovered water collector	423 m²	Combi System for MFH

3.20	SINGLE-FAMILY HOUSE IN WETTSWIL AM ALBIS	Meyer Burger	Uncovered water collector	46 m²	Borehole regeneration and pool heating
3.21	FOOTBALL CLUB HOUSE IN STENLOESE	RACELL	Uncovered water collector	165m²	Combi System in a sports club
3.22	Consolar SOLINK heating system	Solink	Uncovered water collector	40 m²	Solar combi system for SFH
3.23	GSE AIR'SYSTEM	GSE	Air collector	24 m²	Space heating system for SFH
3.24	Domestic Pilot and Demonstration (P&D)	Sunovate	Air collector	8 m ²	Combi System for SFH
3.25	Active Office	Naked Energy	Vacuum tube collector	27 m²	Combi System for office building
3.26	Henri Willig cheese factory	Solarus	Concentrator	226 m²	Cheese production process
3.27	SOcool Office	SunOyster	Concentrator	34.2 m²	Heating and cooling a office building
3.28	Pilot PVT plant - University of Catania	Dualsun	Uncovered water collector	3.3 m²	DHW for SFH (simulated)
3.29	Pilot PVT plant- University of Denmark	Racell Technologies	Uncovered water collector	3.1 m²	DHW preparation and source for heat pump
3.30	Pilot PVT plant – UCEEB CTU	UCEEB CTU	Covered water collector	3,12 m2	DHW preparation

3.1 ECOMESH

3.1.1 Introduction and description

EndeF completed the installation and set into service of a hybrid solar system that supplies sanitary hot water individually for multi-family house and electricity for the common consumptions of the building including a charging system for electric vehicles. The project was within the framework of EU projects (LIFE) “NEW HOUSING SOLUTIONS 4OLD (LIFE10 ENV / ES / 439),” Innovative Technologies for an Efficient Use of Energy Resources and Housing Rehabilitation, promoted by the municipal association Zaragoza Vivienda.

Figure 7: View of the roof-mounting PVT installation in the urban centre of Zaragoza.

3.1.2 Solar installations

A total of 18 covered PVT collectors were installed in the roof of the building. The PVT model installed was the ECOMESH model, developed and manufactured by EndeF, covering a total solar surface of 29.7 m_2 and 4.14 kWp electrical output. Solar field was oriented to south (0º) and an inclination of 25º, corresponding to the roof tilt.

3.1.3 Heat supply concept and integration of PVT collectors

The heat supply system is graphically explained in Figure 8. Solar field is proposed to cover the energy needs derived from DHW dwellings and electricity for general uses, including a charging system for electric vehicles located on the same building.

PVT panels were connected in parallel to provide hot water to the storage tank located in the lower plant of the building. Since the DHW supply in Spain is set in 60ºC, an external device is located to guarantee the water temperature, consisting of a gas boiler located on the same room. Electrical circuit were installed following the requirements depicted in the local normative (RD 900/2015 or current at that time) and under self-consumption regime, which means that it counted with the grid as a back-up system for the moments of no PVT electrical production.

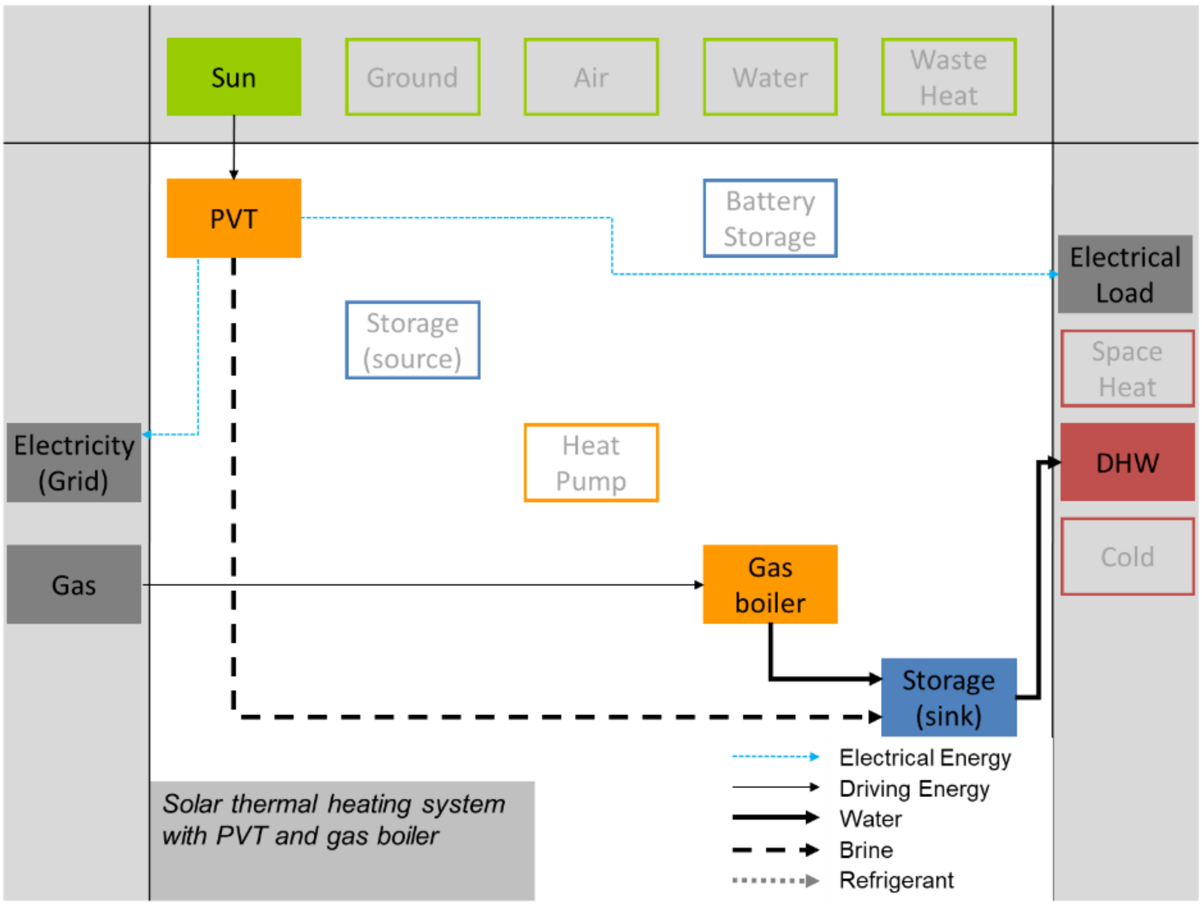

Figure 8: Visualisation of the PVT field for multi-family DHW.

3.1.4 Fact sheet

General Information		
Project name	[-]	ECOMESH
Country	[-]	Spain
City	[-]	Zaragoza
Year of operation start	[mm/yyyy]	05/2015

PVT system owner(s) (%)	[-]	ENDEF ENGINEERING SL (100%)
PVT system operators(s)	[-]	ENDEF ENGINEERING SL
PVT system developer	[-]	ENDEF ENGINEERING SL
Application	[-]	DHW

PLANT CONFIGURATION	_	
Panel model	[-]	ECOMESH PVT-2
PVT-Collector provider	[-]	ENDEF ENGINEERING SL
Category	[-]	PVT liquid collector
Type	[-]	Covered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	25
# of modules		18
Installed collector area (gross)	[m²]	29,7
Installed collector area (aperture)	[m²]	28,08
Total energy output PVT-collector (Etotal)	[kW]	23164
Seasonal Performance Factor (System) SPFsys	[-]	

Thermal Parameters		
Solar thermal energy used for	[-]	DHW for multi-family house
Heat demand	[kWh/a]	25610
Temperature range (application)	[°C]	60ºC
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	2000
Solar thermal energy to system (Qsol)	[kWh/a]	18004
Heat generator energy (Qaux)	[kWh/a]	7606
Solar fraction(Qsol/(Qsol+Qaux))	[%]	70.3%

Electrical Parameters	_	
Module type	[-]	Polycrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17%
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	5160
Type of inverter	[-]	Solivia
AC capacity per inverter	[kW]	5
# of inverter	[-]	1
Inverter provider	[-]	Delta Energy Systems
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	

Self-Consumption fraction	[%]	

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	32985
PVT-collector loop (excl. VAT)	[€]	16583
Solar thermal energy storage (excl. VAT)	[€]	5038
Inverter (excl. VAT)	[€]	1860
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	
Specific investment cost	[€/m²]	
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	Gas
Cost for fuel replaced	[€/MWhfuel]	30.11
Local feed-in tariff	[€/MWhelectricity]	117.8

Sources		
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Phone	[-]	34976365811
Homepage	[-]	http://endef.com/

3.2 ECOMESH 2

3.2.1 Introduction and description

EndeF designed and carried out the installation of a 6 ECOMESH hybrid solar panels on the roof of a single-family house located in Zaragoza (Spain) to provide DHW and electricity for family energy needs. The solar installation also complements a biomass boiler to supply hot water for the underfloor heating, activated only during winter months.

Figure 9: View of the 6-PVT solar installation in single family house.

3.2.2 Solar installations

Solar installation was composed by 6 ECOMESH PVT panels, with a total solar surface of 10 m_2 and 1.38 kWp of electrical output. PVT collectors were installed on the roof, with a tilt of 65º and faced to south (0º). Installation was completed with thermal storage tank with a volume of 2000 l and 3 micro-inverters of 0.5 kW.

3.2.3 Heat supply concept and integration of PVT collectors

The heat supply system is graphically explained in Figure 10. Solar field is proposed to cover the energy needs derived from DHW dwellings and electricity for general uses, as well as to give support to the biomass boiler for the space heating, consisting on radiant floor.

PVT panels were connected in parallel to provide hot water to the storage tank located in the lower plant of the building. Since the DHW supply in Spain is set in 60ºC, an external device is located to guarantee the water temperature, consisting of a gas boiler located on the same room. Electrical circuit were installed following the requirements depicted in the local normative (RD 900/2015 or current at that time) and under self-consumption regime, which means that it counted with the grid as a back-up system for the moments of no PVT electrical production.

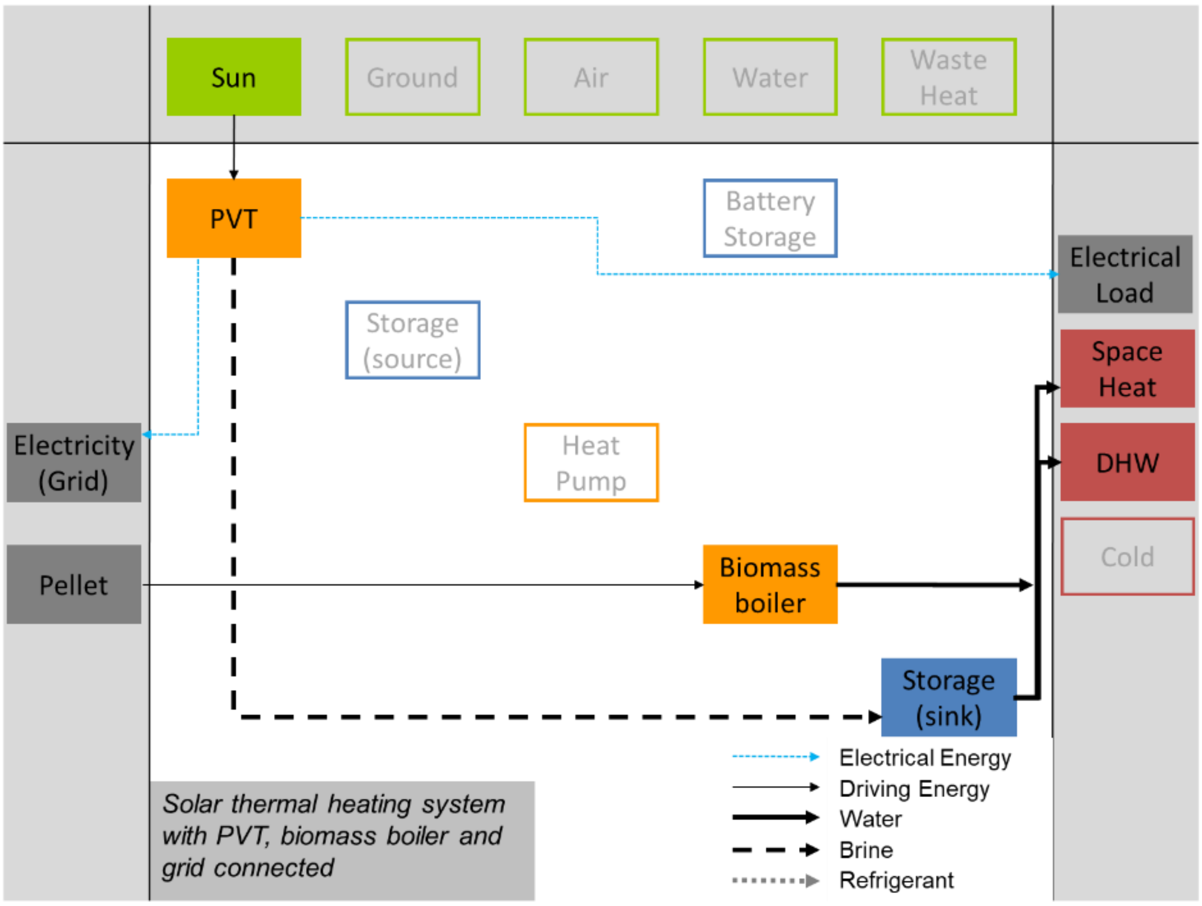

Figure 10: Schematic visualisation of the PVT field in single family house.

3.2.4 Fact sheet

General Information	_	
Project name	[-]	ECOMESH
Country	[-]	Spain
City	[-]	Zaragoza
Year of operation start	[mm/yyyy]	08/2014
PVT system owner(s) (%)	[-]	ENDEF ENGINEERING SL (100%)
PVT system operators(s)	[-]	ENDEF ENGINEERING SL
PVT system developer	[-]	ENDEF ENGINEERING SL
Application	[-]	DHW + radiant floor

PLANT CONFIGURATION	_	
Panel model	[-]	ECOMESH PVT-2
PVT-Collector provider	[-]	ENDEF ENGINEERING SL
Category	[-]	PVT liquid collector
Type	[-]	Covered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	65

# of modules		6
Installed collector area (gross)	[m²]	10
Installed collector area (aperture)	[m²]	9.36
Total energy output PVT-collector (Etotal)	[kW]	8812
Seasonal Performance Factor (System) SPFsys	[-]	

Thermal Parameters	_	
Solar thermal energy used for	[-]	DHW + radiant floor for single-family house
Heat demand	[kWh/a]	
Temperature range (application)	[°C]	45 - 60
Back-up system	[-]	Unknown
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	1500
Solar thermal energy to system (Qsol)	[kWh/a]	7165.5
Heat generator energy (Qaux)	[kWh/a]	
Solar fraction(Qsol/(Qsol+Qaux))	[%]	

Electrical Parameters	_	
Module type	[-]	Polycrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17%
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	1647.3
Type of inverter	[-]	
AC capacity per inverter	[kW]	0.5
# of inverter	[-]	3
Inverter provider	[-]	
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	
Self-Consumption fraction	[%]	

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	
PVT-collector loop (excl. VAT)	[€]	
Solar thermal energy storage (excl. VAT)	[€]	
Inverter (excl. VAT)	[€]	
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	
Specific investment cost	[€/m²]	
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	gas
Cost for fuel replaced	[€/MWhfuel]	30.11

Local feed-in tariff	[€/MWhelectricity]	117.8

Sources	_	
Author	[-]	ENDEF ENGINEERING SL
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3.3 ECOMESH 3

3.3.1 Introduction and description

Installation of 90 ECOMESH hybrid solar panels able to generate electricity and heat simultaneously. Those panels we installed for the preheating of domestic hot water (DHW) and for self-consumption of electricity without injection to the public electricity grid. Its location is a luxury resort in Ibiza (Balearic Islands, Spain).

Figure 11: View of the PVT solar installation on the roof of a luxury hotel in Ibiza.

3.3.2 Solar installations

Solar installation was composed by 90 ECOMESH PVT panels, with a total solar surface of 147.6 m^2 and 21.6 kWp of electrical output. PVT collectors were installed on the roof, with a tilt of 20º and faced to south (0º) and a storage volume of 9.000 l. The inverter device had a capacity of 20 kW.

3.3.3 Heat supply concept and integration of PVT collectors

The heat supply system is graphically explained in Figure 12. Solar field is proposed to cover the energy needs derived from DHW dwellings and electricity for general uses in a luxury hotel.

PVT panels were connected in parallel to provide hot water to the storage tank. Since the DHW supply in Spain is set in 60ºC, an external device is located to guarantee the water temperature, consisting of a gas boiler. Electrical circuit were installed following the requirements depicted in the local normative (RD 900/2015 or current at that time) and under self-consumption regime, which means that it counted with the grid as a back-up system for the moments of no PVT electrical production.

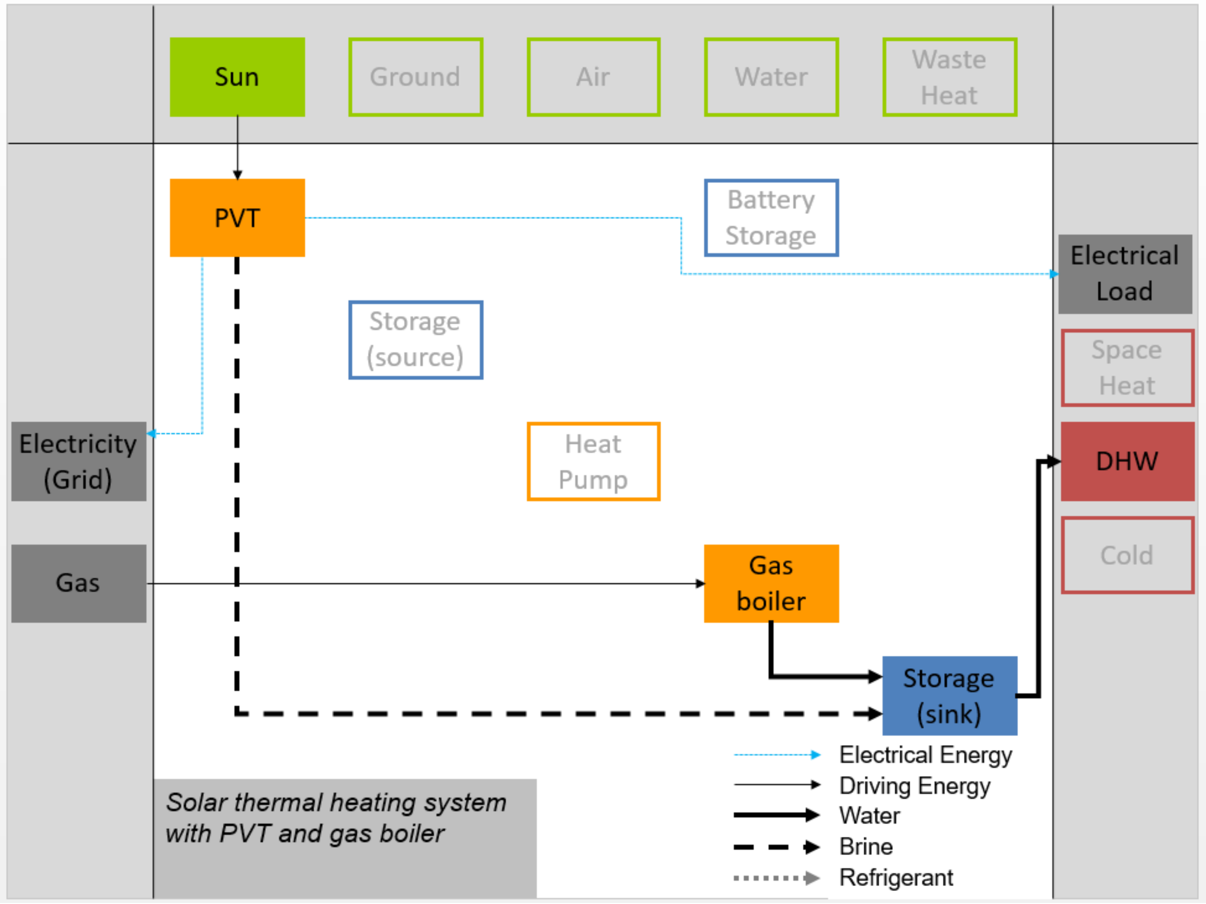

Figure 12: Schematic visualisation of the PVT field in hotel.

3.3.4 Fact sheet

General Information	_	
Project name	[-]	ECOMESH
Country	[-]	Spain
City	[-]	Ibiza
Year of operation start	[mm/yyyy]	02/2017
PVT system owner(s) (%)	[-]	ENDEF ENGINEERING SL (100%)
PVT system operators(s)	[-]	ENDEF ENGINEERING SL
PVT system developer	[-]	ENDEF ENGINEERING SL
Application	[-]	DHW

PLANT CONFIGURATION	_	
Panel model	[-]	ECOMESH PVT-2
PVT-Collector provider	[-]	ENDEF ENGINEERING SL
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0

Tilt angle [hor. = 0°; vert. = 90°]	[°]	20
# of modules		90
Installed collector area (gross)	[m²]	147.6
Installed collector area (aperture)	[m²]	140.4
Total energy output PVT-collector (Etotal)	[kW]	197100
Seasonal Performance Factor (System) SPFsys	[-]	

Thermal Parameters	_	
Solar thermal energy used for	[-]	DHW for Hotel
Heat demand	[kWh/a]	691489
Temperature range (application)	[°C]	60
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	9000
Solar thermal energy to system (Qsol)	[kWh/a]	162500
Heat generator energy (Qaux)	[kWh/a]	528989
Solar fraction(Qsol/(Qsol+Qaux))	[%]	23.50%

Electrical Parameters	_	
Module type	[-]	Polycrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17%
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	34600
Type of inverter	[-]	
AC capacity per inverter	[kW]	20
# of inverter	[-]	1
Inverter provider	[-]	
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	
Self-Consumption fraction	[%]	

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	
PVT-collector loop (excl. VAT)	[€]	49500 (only collectors)
Solar thermal energy storage (excl. VAT)	[€]	
Inverter (excl. VAT)	[€]	
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	
Specific investment cost	[€/m²]	
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	fuel
Cost for fuel replaced	[€/MWhfuel]	36,05

Local feed-in tariff	[€/MWhelectricity]	117.8

Sources	_	
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3.4 ECOMESH 4

3.4.1 Introduction and description

This solar hybrid installation took place on the roof of the fire station No.1 of Zaragoza (Spain) to face the high sanitary hot water consumption required by this building, resulting from the DHW needs and several swimming pools. With this installation, Zaragoza has become the first Spanish city where this hybrid technology has been installed on a public building.

Figure 13: View of the PVT field in firefighters building.

3.4.2 Solar installations

Solar installation was composed by 28 ECOMESH PVT panels, with a total solar surface of 46.2 m² and 6.72 kWp of electrical output. PVT collectors were installed on the roof, with a tilt of 45º and faced to south (0º). Installation was competed with thermal storage volume 3.000 l, distributed in two tanks, and a Fronius SYMO inverter of 8.2 kW of capacity.

3.4.3 Heat supply concept and integration of PVT collectors

The heat supply system is graphically explained in Figure 14. Solar field is proposed to cover the energy needs derived from DHW dwellings and electricity for general uses in a firefighters building, whose main heat consumption comes from the use of a swimming pool with high daily hot water consumption.

PVT panels were connected in parallel to provide hot water to the storage tank, where hot water was extracted at different levels to obtain different temperatures. Hot water at maximum temperature was extracted for DHW purposes, with extra supply coming from the gas boiler when needed to reach the required 60ºC. Hot water used for swimming pool was extracted at medium level of the tank, to be provided at 30ºC.

Electrical circuit were installed following the requirements depicted in the local normative (RD 900/2015 or current at that time) and under self-consumption regime, with grid connexion as a back-up system for the moments of no PVT electrical production. An additional PV solar field is planned to be installed next to the existing PVT field, to increase the electricity capacity of the solar roof installation, but its fulfilment is still under project stage.

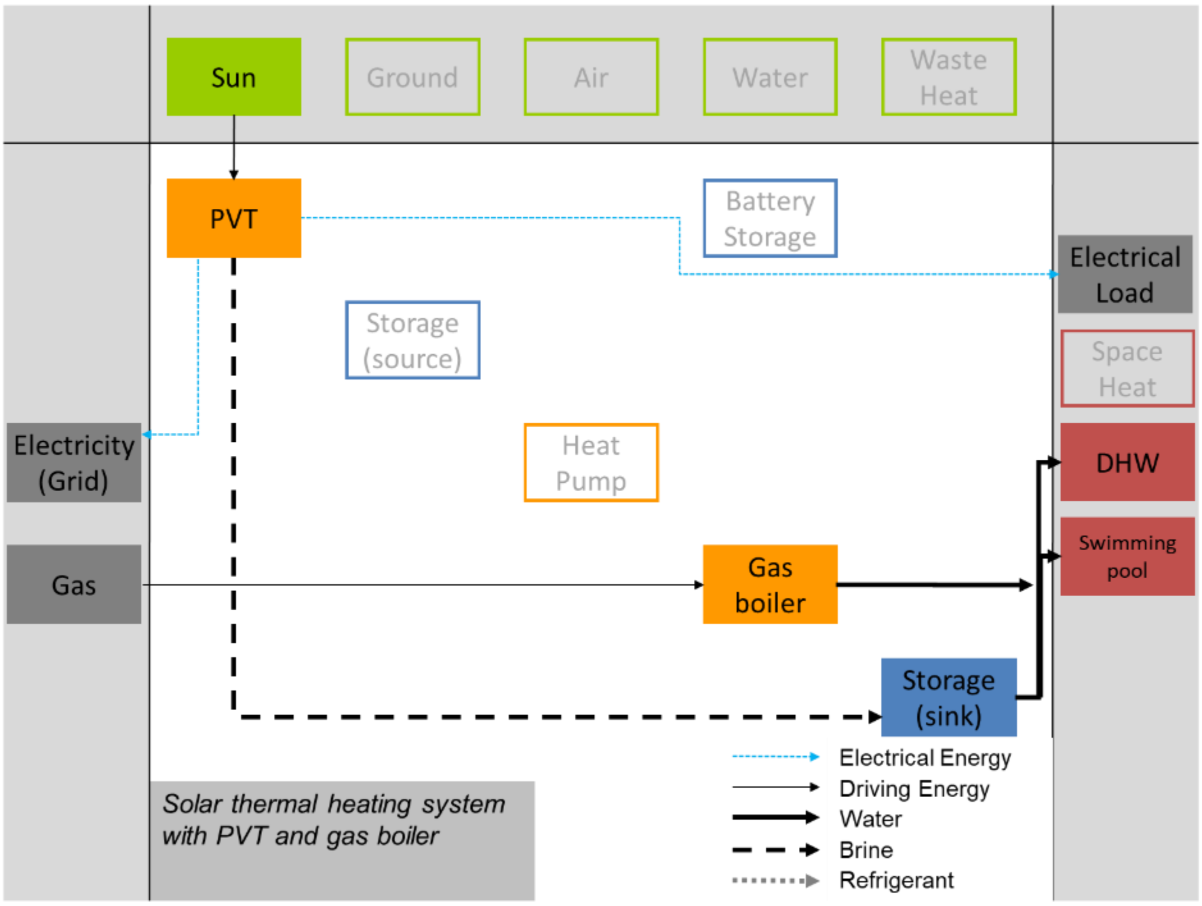

Figure 14: Schematic visualisation of the PVT field in firefighters building.

3.4.4 Fact sheet

General Information	_	
Project name	[-]	ECOMESH
Country	[-]	Spain
City	[-]	Zaragoza
Year of operation start	[mm/yyyy]	01/2018
PVT system owner(s) (%)	[-]	ENDEF ENGINEERING SL (100%)
PVT system operators(s)	[-]	ENDEF ENGINEERING SL
PVT system developer	[-]	ENDEF ENGINEERING SL
Application	[-]	DHW + pool suply

PLANT CONFIGURATION	_	
Panel model	[-]	ECOMESH PVT-2
PVT-Collector provider	[-]	ENDEF ENGINEERING SL
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No

System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	45
# of modules		28
Installed collector area (gross)	[m²]	46.2
Installed collector area (aperture)	[m²]	43.68
Total energy output PVT-collector (Etotal)	[kW]	35067
Seasonal Performance Factor (System) SPFsys	[-]	

Thermal Parameters	_	
Solar thermal energy used for	[-]	DHW for Civil Firefightes Building+ water pool supply
Heat demand	[kWh/a]	38559,1
Temperature range (application)	[°C]	25-60
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	3000
Solar thermal energy to system (Qsol)	[kWh/a]	25449
Heat generator energy (Qaux)	[kWh/a]	13110
Solar fraction(Qsol/(Qsol+Qaux))	[%]	66.00%

Electrical Parameters	_	
Module type	[-]	Polycrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17%
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	9618
Type of inverter	[-]	SYMO 8.2-3-M
AC capacity per inverter	[kW]	8.2
# of inverter	[-]	1
Inverter provider	[-]	FRONIUS
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	
Self-Consumption fraction	[%]	

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	41990
PVT-collector loop (excl. VAT)	[€]	37811
Solar thermal energy storage (excl. VAT)	[€]	4812
Inverter (excl. VAT)	[€]	1918
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	
Specific investment cost	[€/m²]	
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	

Fuel replaced	[-]	gas
Cost for fuel replaced	[€/MWhfuel]	30.11
Local feed-in tariff	[€/MWhelectricity]	117.8

Sources	_	
Author	[-]	ENDEF ENGINEERING SL
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Homepage	[-]	http://endef.com/

3.5 SYTA Truck Washing

3.5.1 Introduction and description

The installation is done in an existing truck tank laundry. The consumption of hot water in this industry is huge, depending on the exact process they use water between 40 and 60ºC.

The existing facility consists of biomass and diesel boilers that heat water that is stored in tanks.

The motivation of the owner to perform a PVT installation was profitability, and therefore the economic savings in his business.

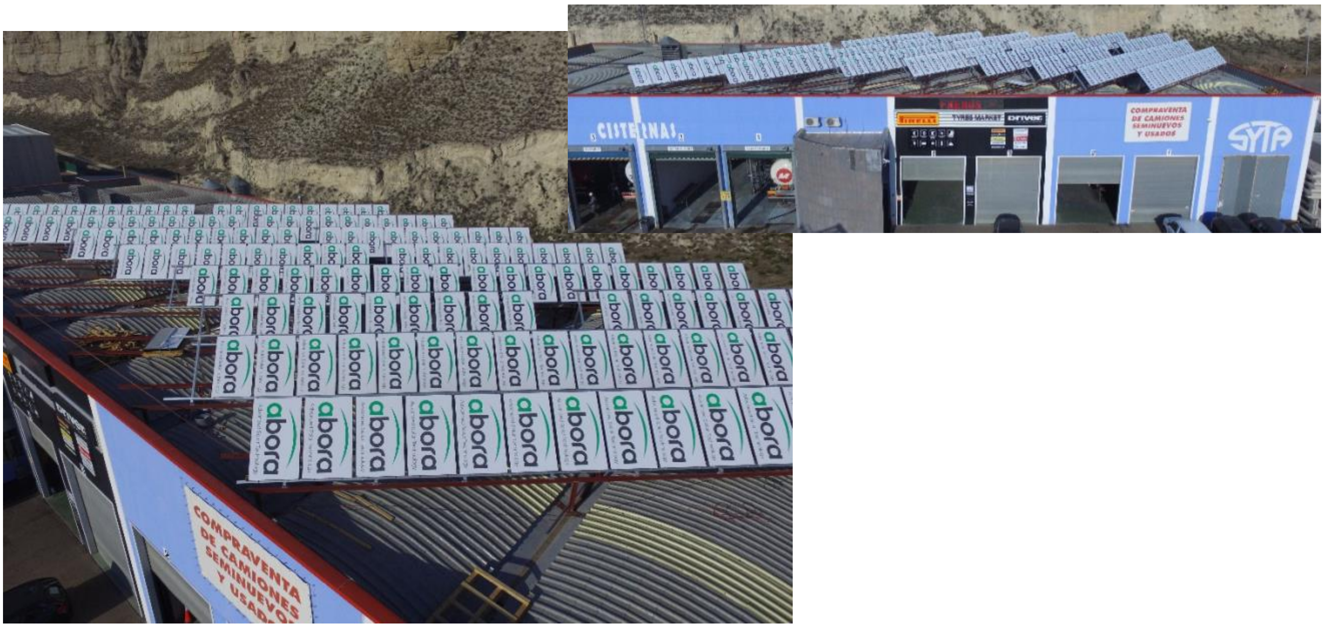

Figure 15: SYTA installation

3.5.2 Solar installations

At the beginning of 2019, 160 panels (aH60 from Abora Solar) were installed on an industrial vaulted roof. (total collector area, 264 m2; 41,6 kWp electrical output). The modules are oriented to the south (0 °) with an inclination angle of 35 °.

3.5.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure below. The existent system consisted of two boilers: biomass and oil. The boilers heat the tank storage, the heated water is used to wash the tanker trucks. The building is like a garage without space heating. Annex to the garage there is a small office with its own heating system.

For the integration of the solar system was installed a primary water tank of 6000 litres which is heated with the 160 collectors. The outlet of the tank is connected to the inlet of the existing tank storage. When the temperature of that existing tank is lower than setpoint the boiler heats it.

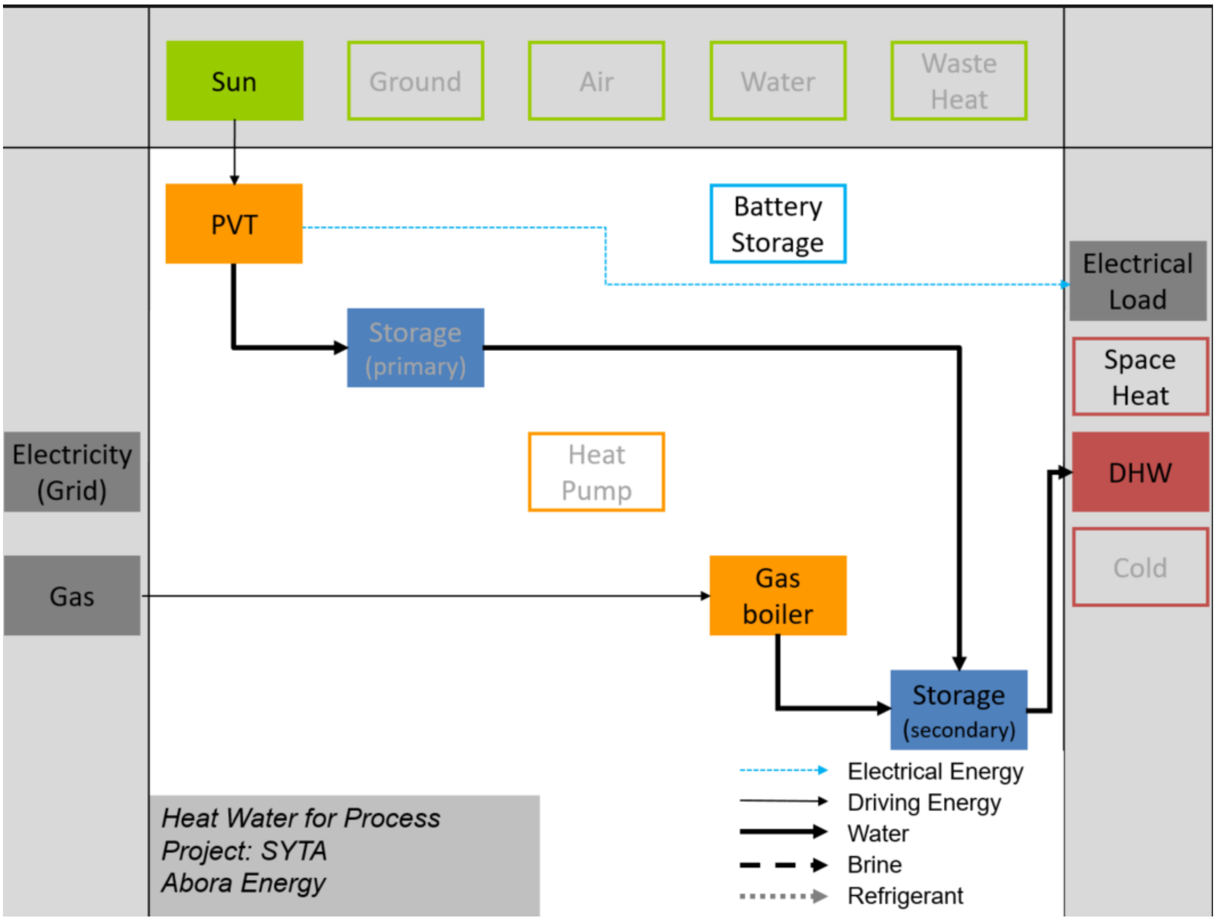

Figure 16: Visualisation of the PVT system "SYTA".

3.5.4 Fact sheet

General Information		
Project name	[-]	SYTA Truck Washing
Country	[-]	Spain
City	[-]	Alfajarin (ZGZ)
Year of operation start	[mm/yyyy]	03/2019
PVT system owner(s) (%)	[-]	Company SYTA
PVT system operators(s)	[-]	Company SYTA
PVT system developer	[-]	Ingeniería Torne
Application	[-]	Heat water for process & selfconsumption electricity

PLANT CONFIGURATION		
Panel model	[-]	aH60
PVT-Collector provider	[-]	Abora Solar
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol Mixture

Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	40
# of modules	[-]	160
Installed collector area (gross)	[m²]	264
Installed collector area (aperture)	[m²]	252,6
Total energy output PVT-collector (E_{total})	[kWh]	291.978
Seasonal Performance Factor (System) SPF_{sys}	[-]	

Thermal Parameters		
Solar thermal energy used for	[-]	Heat water for process
Heat demand	[kWh/a]	664.462
Temperature range (application)	[°C]	40-60
Back-up system	[-]	oil boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	6.000
Solar thermal energy to system (Qsol)	[kWh/a]	235.166
Heat generator energy (Qaux)	[kWh/a]	429.296
Solar fraction(Qsol/(Qsol+Qaux))	[%]	35

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	55.934
Type of inverter	[-]	MPPT-Self consumption
AC capacity per inverter	[kW]	21
# of inverter	[-]	2
Inverter provider	[-]	Growatt
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrial storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	30
Self-Consumption fraction	[%]	100

Economic Parameters		
Total investment cost (excl. VAT)	[€]	164.170
PVT-collektor loop (excl. VAT)	[€]	119.776
Solar thermal energy storage (excl. VAT)	[€]	7.980
Inverter (excl. VAT)	[€]	5.746
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	30.668
Specific investment cost	[€/m²]	621
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	oil
Cost for fuel replaced	[€/MWhfuel]	85
Local feed-in tariff	[€/MWhelectricity]	90

Sources		
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3.6 Hotel Resort Iberostar Buganvilles

3.6.1 Introduction and description

The installation is done in an existing 4 stars Hotel in Tenerife (Canary Islands). The motivation to deploy it was the rentability for the business, because of the huge non-seasonal consumption of domestic heat water. The hotel has 1006 seats. The heat existing system to produce DHW is propane gas boilers.

Figure 17:View of PVT in the flat roofs of Hotel Iberostar Buganvilles

August 2019, 102 panels (aH72 from Abora Solar) were installed on the flat roofs at different levels. (total collector area, 200 m2; 30,6 kWp electrical output). The modules are oriented to the south (0 °) with an inclination angle of 45 °.

3.6.2 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 4. The existent system consisted of a propane gas boiler. The boiler kept DHW tanks warm.

For the integration of the solar system were installed a primary water tanks with a total volume of 10000 litres which are heated with the 102 collectors. The outlet of the tank is connected to the inlet of the existing tank storage. When the temperature of that existing tanks is lower than set point the boiler heats them.

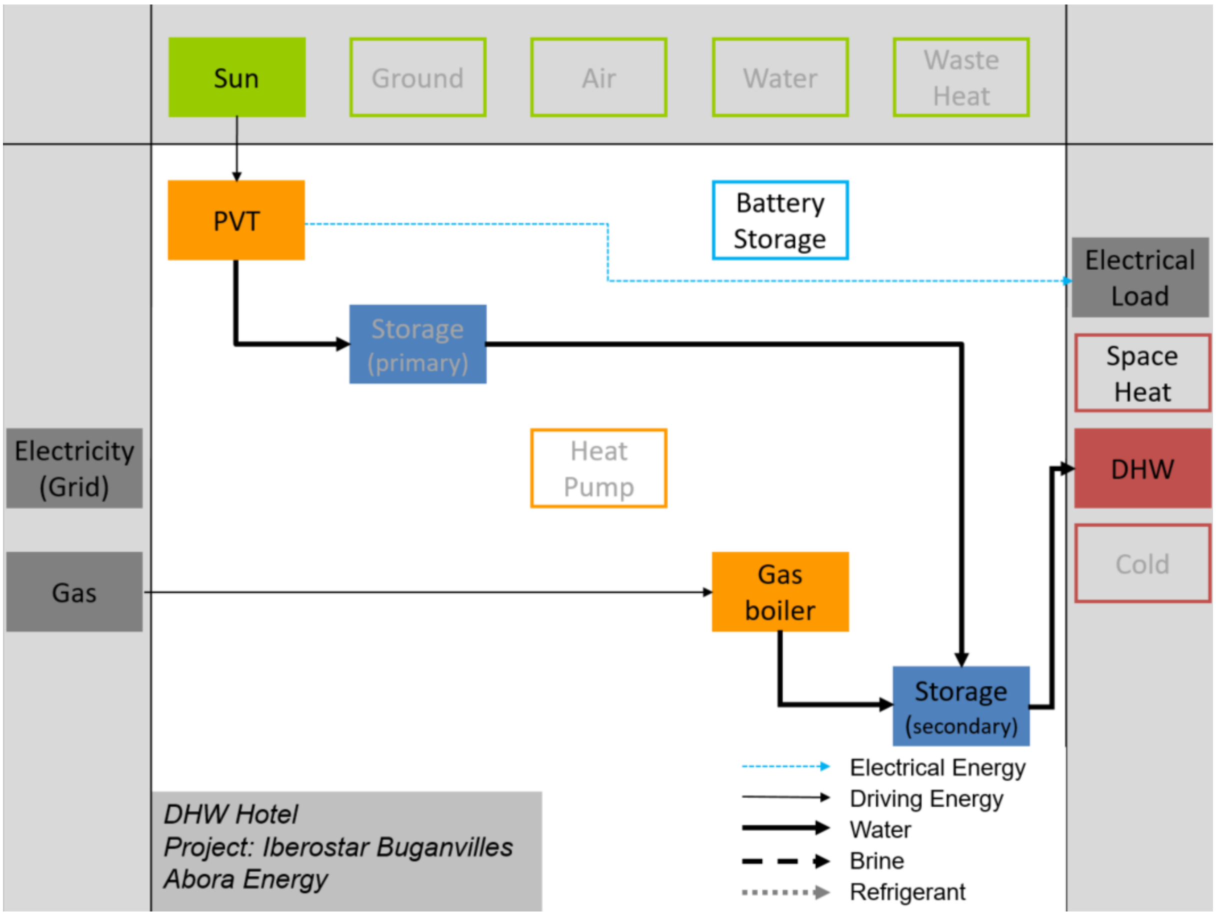

Figure 18: Visualisation of the PVT system "Hotel Iberostar Buganvilles".

3.6.3 Fact sheet

General Information		
Project name	[-]	Iberostar Hotel Buganvilles
Country	[-]	Spain
City	[-]	Tenerife
Year of operation start	[mm/yyyy]	08/2019
PVT system owner(s) (%)	[-]	Iberostar Hotels
PVT system operators(s)	[-]	Iberostar Buganvilles
PVT system developer	[-]	Ingeniería Insiteca
Application	[-]	DHW & selfconsumption electricity

PLANT CONFIGURATION		
Panel model	[-]	aH72
PVT-Collector provider	[-]	Abora solar
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water

Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	45
# of modules	[-]	102
Installed collector area (gross)	[m²]	199,92
Installed collector area (aperture)	[m²]	191,76
Total energy output PVT-collector (E_{total})	[kWh]	230.729
Seasonal Performance Factor (System) SPF_{sys}	[-]	

Thermal Parameters		
Solar thermal energy used for	[-]	DHW
Heat demand	[kWh/a]	881.901
Temperature range (application)	[°C]	40-70
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	10.000
Solar thermal energy to system (Qsol)	[kWh/a]	190.259
Heat generator energy (Qaux)	[kWh/a]	691.642
Solar fraction(Qsol/(Qsol+Qaux))	[%]	22

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	40.470
Type of inverter	[-]	MPPT-Self consumption
AC capacity per inverter	[kW]	15
# of inverter	[-]	2
Inverter provider	[-]	Fronius
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrial storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	17
Self-Consumption fraction	[%]	100

Economic Parameters		
Total investment cost (excl. VAT)	[€]	132.383
PVT-collektor loop (excl. VAT)	[€]	88.265
Solar thermal energy storage (excl. VAT)	[€]	13.639
Inverter (excl. VAT)	[€]	5.124
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	25.355
Specific investment cost	[€/m²]	662
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	gas
Cost for fuel replaced	[€/MWhfuel]	66
Local feed-in tariff	[€/MWhelectricity]	104

Sources		
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3.7 Sant Cugat's Sports Center

3.7.1 Introduction and description

This installation is a pilot facility of the European Project "Chess-Setup": https://www.chess-setup.net/sant-cugat.

There are multiple heat circuits in the sports center for: each of the pools, the different shower areas and the spaces heating. All powered with several natural gas boilers.

Figure 19: View of the PVT collectors "Sant Cugat's Sports Center".

3.7.2 Solar installations

The proposed system will perfectly match the energy needs of a sport centre, as it will be designed to provide heat at peak times (week-end) thanks to its inertia.

The system will also supply the domestic hot water to an existing athletic tracks attached to the sport centre. In this way, the implementation will constitute a retrofitting solution.

3.7.3 Heat supply concept and integration of PVT collectors

The heat supply system is represented in simplified form in Figure 7. The existing natural gas boiler systems have been maintained. And for some of the heat circuits, thermal energy storage tank (TES) of 160 m3 volume, 160 PVT, a heat pump (Water-water) and a buffer tank were incorporated.

The circuit allows the energy stored in the TES to go directly to heating consumption circuits if the temperature is very high, or in more usual way it works with the heat pump.

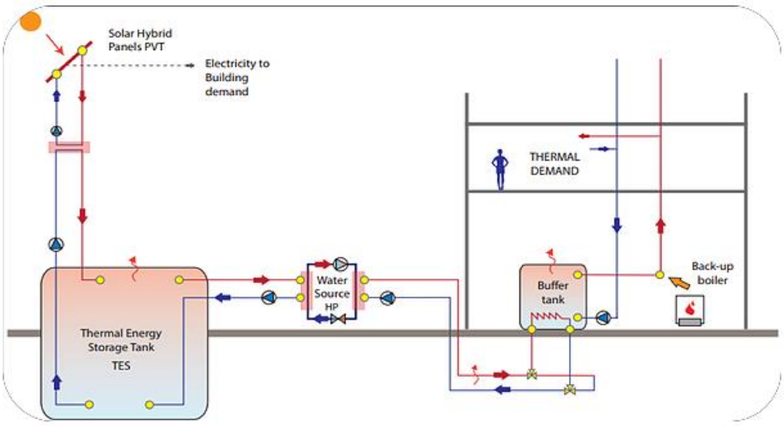

Figure 20: System Design (source Chess-Setup).

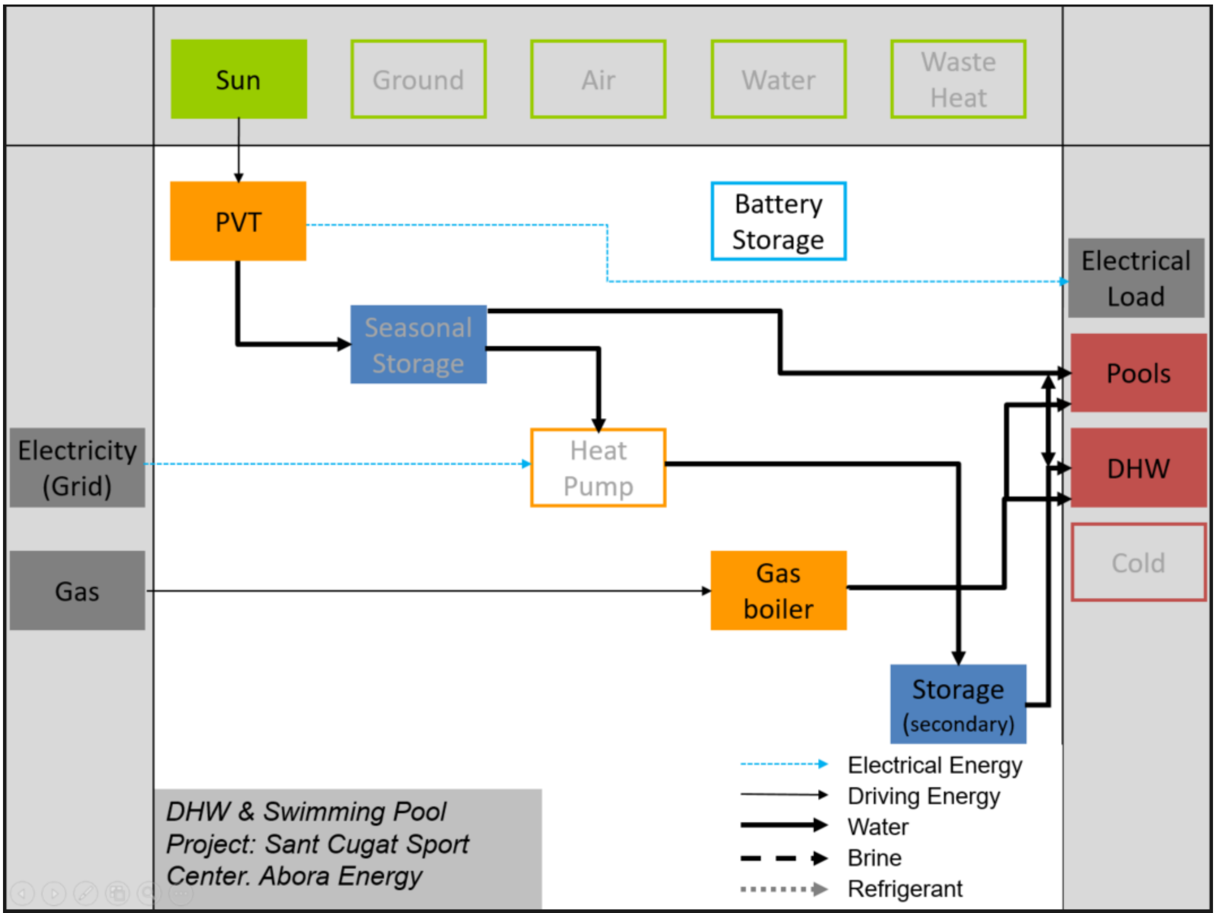

Figure 21: Visualisation of the PVT system "Sant Cugat's Sports Center".

3.7.4 Fact sheet

General Information		
Project name	[-]	Sant Cugat's Sport Center
Country	[-]	Spain
City	[-]	Sant Cugat (BCN)
Year of operation start	[mm/yyyy]	05/2019
PVT system owner(s) (%)	[-]	Ajuntament Sant Cugat
PVT system operators(s)	[-]	Eurofitness
PVT system developer	[-]	BCN Ecología
Application	[-]	Electricity for self-consumption & heating of swimming pools & DHW (shower)

PLANT CONFIGURATION		
Panel model	[-]	aH60
PVT-Collector provider	[-]	Abora Solar
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol Mixture

Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	25
Tilt angle [hor. = 0°; vert. = 90°]	[°]	25
# of modules	[-]	160
Installed collector area (gross)	[m²]	264
Installed collector area (aperture)	[m²]	252,6
Total energy output PVT-collector (E_{total})	[kWh]	284.035
Seasonal Performance Factor (System) SPF_{sys}	[-]	

Thermal Parameters		
Solar thermal energy used for	[-]	DHW & swimming pool
Heat demand	[kWh/a]	1.117.115
Temperature range (application)	[°C]	30-70
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Long term
Storage Volume	[L]	160.000
Solar thermal energy to system (Qsol)	[kWh/a]	230.363
Heat generator energy (Qaux)	[kWh/a]	886.752
Solar fraction(Qsol/(Qsol+Qaux))	[%]	21

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	53.672
Type of inverter	[-]	MPPT-Self consumption
AC capacity per inverter	[kW]	20
# of inverter	[-]	2
Inverter provider	[-]	Ingeteam
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrial storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	26
Self-Consumption fraction	[%]	100

Economic Parameters		
Total investment cost (excl. VAT)	[€]	232.078
PVT-collektor loop (excl. VAT)	[€]	126.234
Solar thermal energy storage (excl. VAT)	[€]	60.210
Inverter (excl. VAT)	[€]	6.824
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	38.810
Specific investment cost	[€/m²]	879
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	gas
Cost for fuel replaced	[€/MWhfuel]	60
Local feed-in tariff	[€/MWhelectricity]	89

Sources		
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3.8 Multi Dwelling Azud

3.8.1 Introduction and description

This installation was mounted in a new multi dwelling building of new construction. In Spain is mandatory include for new buildings renewables energy to reduce CO_2 at least of the DHW demand.

The building consists of 42 apartments with a forecast of 210 people and an outdoor pool.

Figure 22: View of the PVT panels “Multi dwelling Azud”.

3.8.2 Solar installations

This installation was completed in February 2019. 28 aH72 panels of Abora Solar were mounted on its flat roof. The machine room is also on the roof. The total area of collectors is 55 m2 with 8.4 kWp electrical output. The modules are oriented to the south-west (-20 °) with an inclination angle of 45 °.

3.8.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 9. The auxiliary system consisted of a natural gas boiler. The PVT's collectors heat the primary tank with a volume of 3000 litres.

The outlet of the primary tank is connected to the inlet of the auxiliary tank storage. When the temperature of that auxiliary tank is lower than set point the boiler heats them.

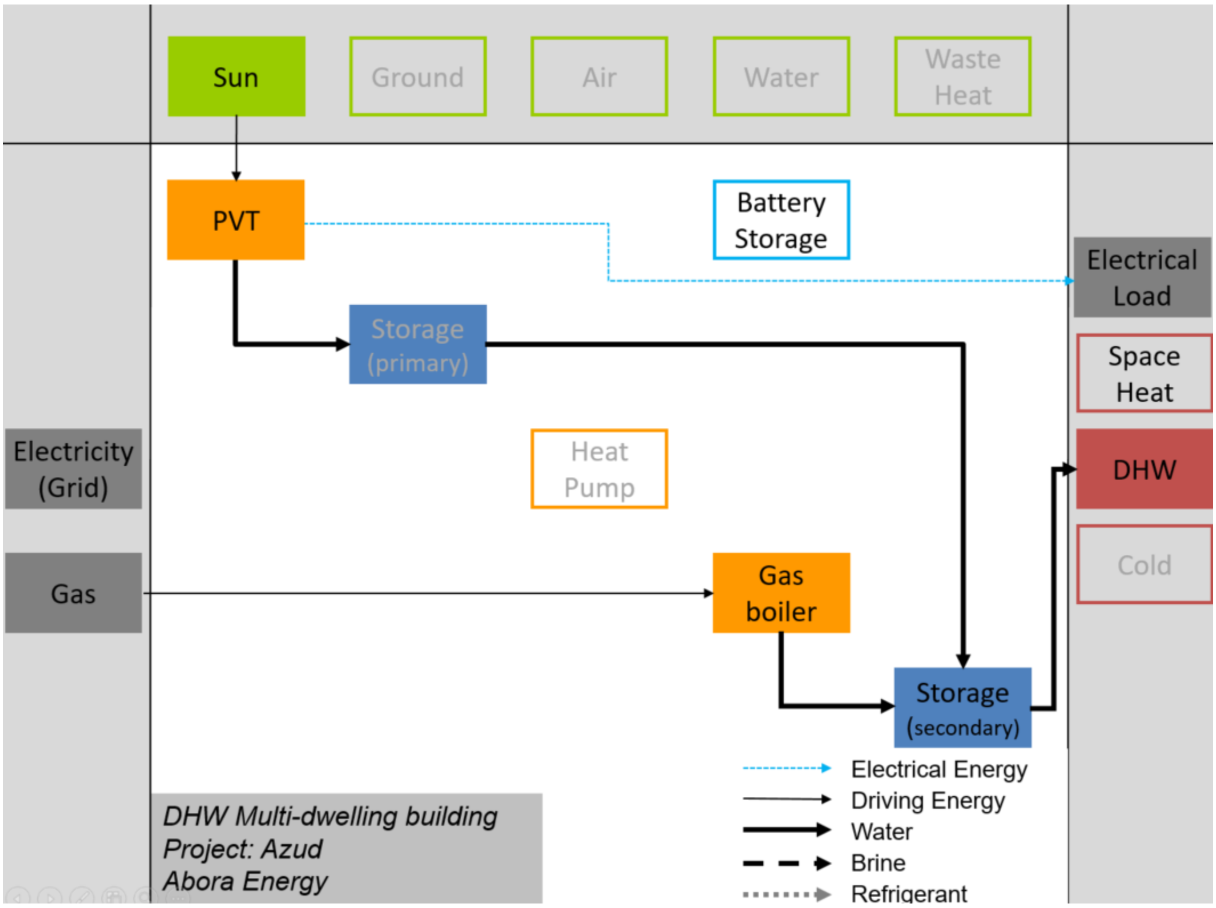

Figure 23: Visualisation of the PVT system "Multi dwelling Azud".

3.8.4 Fact sheet

General Information		
Project name	[-]	Multi Dwelling Azud
Country	[-]	Spain
City	[-]	Zaragoza
Year of operation start	[mm/yyyy]	02/2019
PVT system owner(s) (%)	[-]	Private owners
PVT system operators(s)	[-]	Private owners
PVT system developer	[-]	Oscar Del Castillo
Application	[-]	DHW & selfconsumption electricity

PLANT CONFIGURATION		
Panel model	[-]	aH72
PVT-Collector provider	[-]	Abora Solar
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol Mixture

Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	-20
Tilt angle [hor. = 0°; vert. = 90°]	[°]	45
# of modules	[-]	28
Installed collector area (gross)	[m²]	54,88
Installed collector area (aperture)	[m²]	52,64
Total energy output PVT-collector (E_{total})	[kWh]	61.565
Seasonal Performance Factor (System) SPF_{sys}	[-]	

Thermal Parameters		
Solar thermal energy used for	[-]	DHW
Heat demand	[kWh/a]	99.133
Temperature range (application)	[°C]	40-60
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	3.000
Solar thermal energy to system (Qsol)	[kWh/a]	49.137
Heat generator energy (Qaux)	[kWh/a]	49.996
Solar fraction(Qsol/(Qsol+Qaux))	[%]	50

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	12.428
Type of inverter	[-]	MPPT-Self consumption
AC capacity per inverter	[kW]	8,5
# of inverter	[-]	1
Inverter provider	[-]	Kostal
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrial storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	60
Self-Consumption fraction	[%]	100

Economic Parameters		
Total investment cost (excl. VAT)	[€]	38.664
PVT-collektor loop (excl. VAT)	[€]	21.456
Solar thermal energy storage (excl. VAT)	[€]	3.990
Inverter (excl. VAT)	[€]	2.015
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	11.203
Specific investment cost	[€/m²]	704
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	gas
Cost for fuel replaced	[€/MWhfuel]	69
Local feed-in tariff	[€/MWhelectricity]	140

Sources		
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3.9 Ambérieu-en-Bugey

3.9.1 Introduction and description

https://dualsun.com/fr/realisations/amberieu-fr-4pvt

The object concerned a PVT DHW preheating in a single-family. It was installed in 2013.

Figure 24: View of the PVT system on the roof of the single-family house in Ambérieu.

3.9.2 Solar installations

4 PVT collectors (DualSun 250Wp) were installed on the tilted roof of the building (total collector area, 6.4 m²; 1.0 kWp electrical output). The modules are oriented to the southwest (40°) with an inclination angle of 20°.

3.9.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 25. It is preheating a tank before an instant gas boiler.

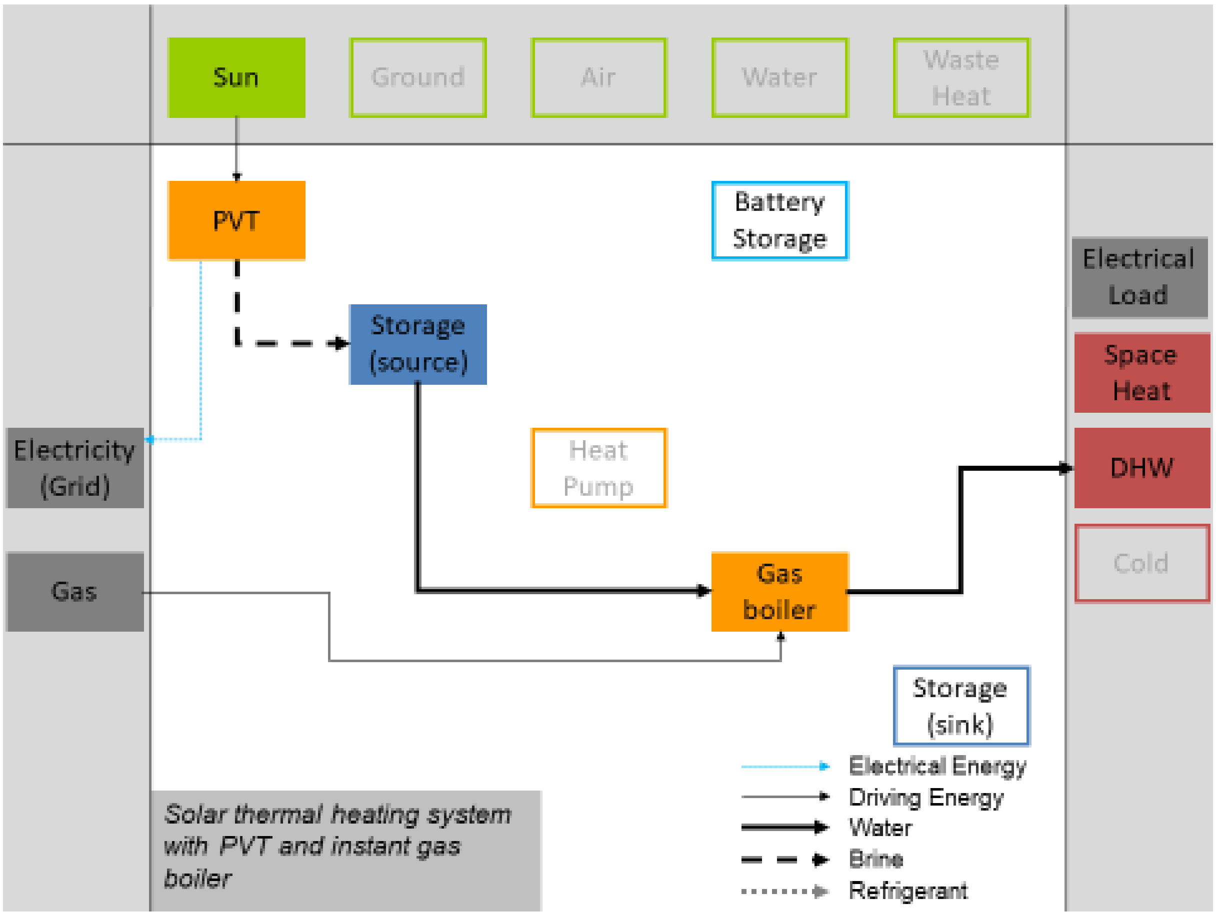

Figure 25: Visualisation of the PVT system "Amberieu".

3.9.4 Fact sheet

General Information		
Project name	[-]	Amberieu
Country	[-]	FR
City	[-]	Amberieu-En-Bugey
Year of operation start	[mm/yyyy]	2012
PVT system owner(s) (%)	[-]	the owner is the resident
PVT system operators(s)	[-]	owner
PVT system developer	[-]	installer
Application	[-]	single-family house

PLANT CONFIGURATION		
Panel model	[-]	DualSun Wave 250Wp
PVT-Collector provider	[-]	DualSun
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture

Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	-40°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	20
# of modules	[-]	4
Installed collector area (gross)	[m²]	6.4
Installed collector area (aperture)	[m²]	-
Total energy output PVT-collector (Etotal)	[kW]	
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	DHW preheating
Heat demand	[kWh/a]	500
Temperature range (application)	[°C]	45
Back-up system	[-]	Gas boiler
Solar thermal energy storage type	[-]	Tank
Storage Volume	[L]	200
Solar thermal energy to system (Qsol)	[kWh/a]	300
Heat generator energy (Qaux)	[kWh/a]	200
Solar fraction(Qsol/(Qsol+Qaux))	[%]	60%

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.4
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	1000 (AC = post inverter)
Type of inverter	[-]	Micro-inverter
AC capacity per inverter	[kW]	M215
# of inverter	[-]	4
Inverter provider	[-]	Enphase
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	Unknown
Self-Consumption fraction	[%]	Unknown

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	6700
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	-

Specific investment cost	[€/m²]	1050
Calculated solar thermal system life time	[a]	25
Subsidy, € or % of total investment costs	[€/%]	1000
Fuel replaced	[-]	Gas, Elec
Cost for fuel replaced	[€/MWhfuel]	80, 160
Local feed-in tariff	[€/MWhelectricity]	60 (only for surplus from self-consumption)

Sources		
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3.10 Saint-Genis-les-Ollières

3.10.1 Introduction and description

https://dualsun.com/en/realisations/genis-fr-2013-6pvt-6pv-en/

The object concerned a PVT DHW preheating in a single-family. It was installed in 2012.

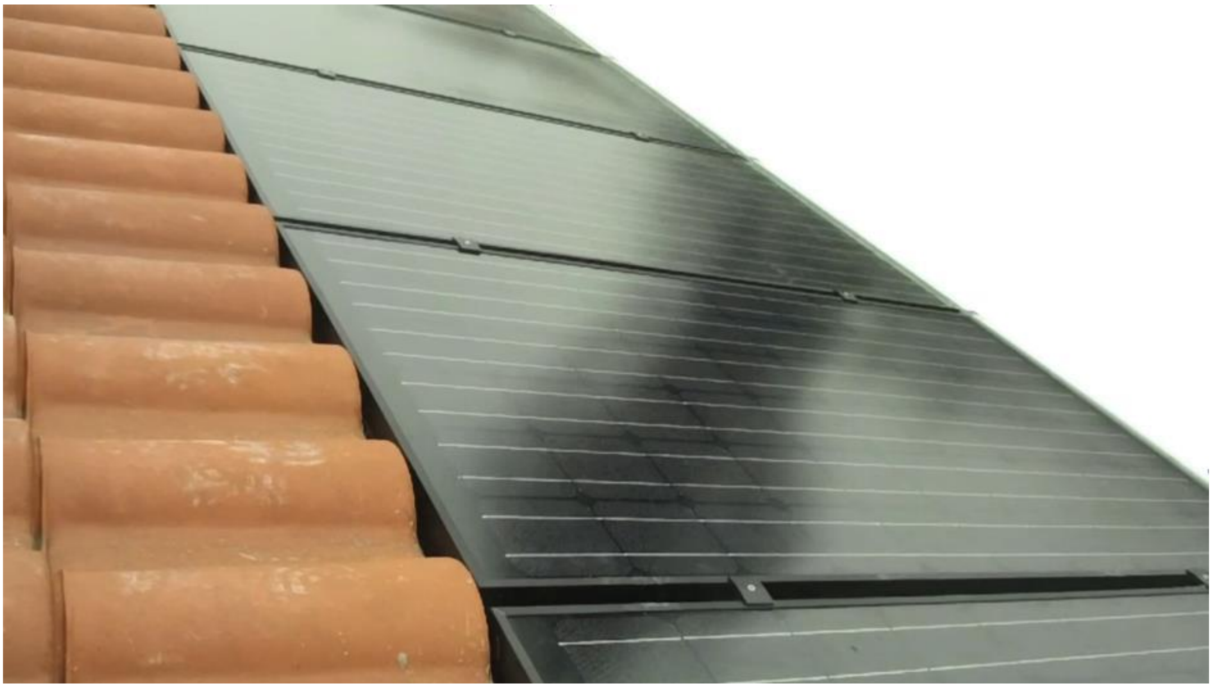

Figure 26: View of the PVT system on the roof of the single-family house in St Genis

3.10.2 Solar installations

6 PVT collectors (DualSun 250Wp) were installed on the tilted roof of the building (total collector area, 9.6 m^2; 1.5 kWp electrical output). The modules are oriented to the south (5°) with an inclination angle of 30°.

3.10.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 27. It is preheating a tank before an instant gas boiler.

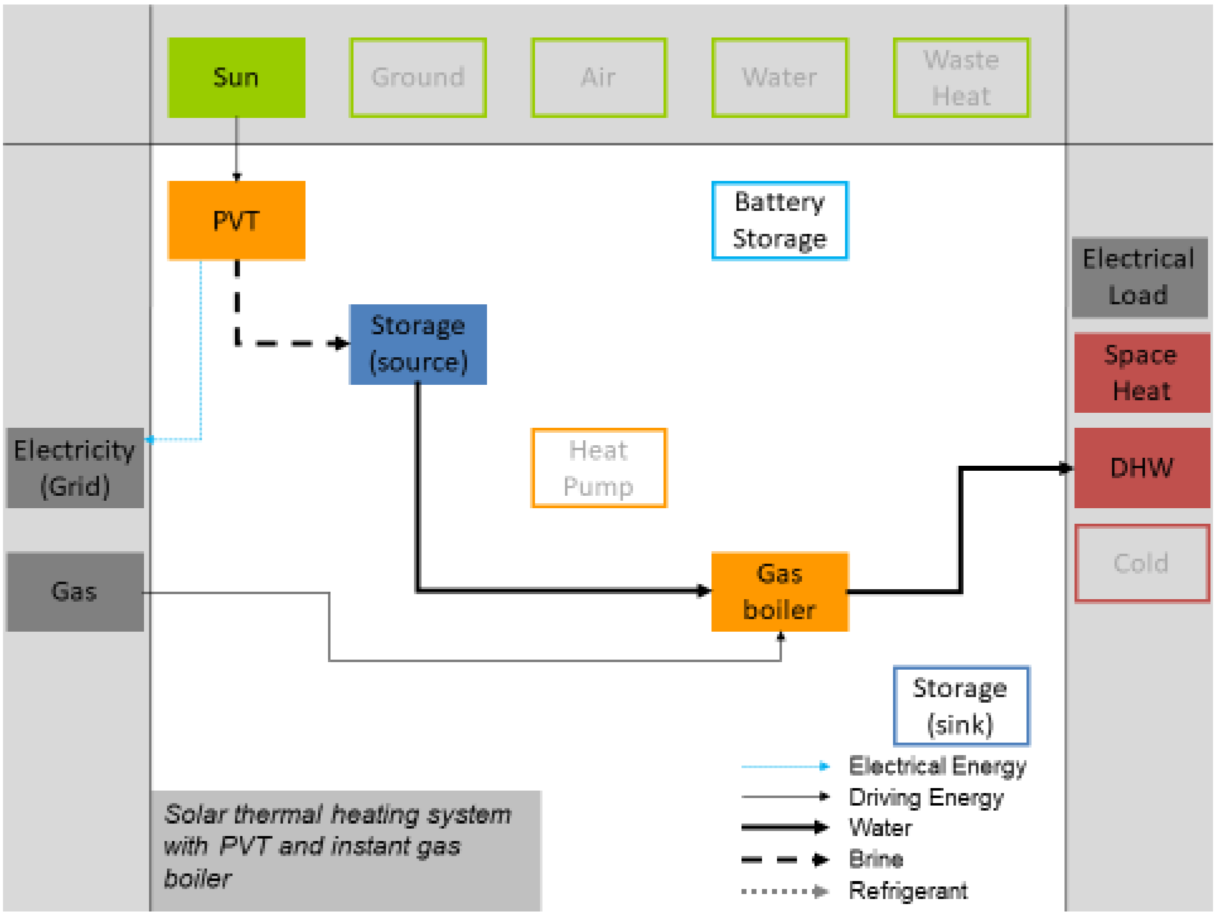

Figure 27: Visualisation of the PVT system "St Genis".

3.10.4 Fact sheet

General Information		
Project name	[-]	St Genis
Country	[-]	FR
City	[-]	Saint-Genis-Les-Ollieres
Year of operation start	[mm/yyyy]	2012
PVT system owner(s) (%)	[-]	the owner is the resident
PVT system operators(s)	[-]	owner
PVT system developer	[-]	installer
Application	[-]	single-family house

PLANT CONFIGURATION		
Panel model	[-]	DualSun Wave 250Wp
PVT-Collector provider	[-]	DualSun
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	in-roof mounted
Tracking	[-]	No

System Orientation [E = +90°; S = 0°; W = -90°]	[°]	5°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	30
# of modules	[-]	6
Installed collector area (gross)	[m²]	9.6
Installed collector area (aperture)	[m²]	-
Total energy output PVT-collector (Etotal)	[kW]	
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	DHW preheating
Heat demand	[kWh/a]	700
Temperature range (application)	[°C]	45
Back-up system	[-]	Gas boiler
Solar thermal energy storage type	[-]	Tank
Storage Volume	[L]	300
Solar thermal energy to system (Qsol)	[kWh/a]	410
Heat generator energy (Qaux)	[kWh/a]	290
Solar fraction(Qsol/(Qsol+Qaux))	[%]	59%

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15,4
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	1150 (AC = post inverter)
Type of inverter	[-]	Micro-inverter
AC capacity per inverter	[kW]	M215
# of inverter	[-]	6
Inverter provider	[-]	Enphase
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	Unknown
Self-Consumption fraction	[%]	Unknown

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	10000
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	-
Specific investment cost	[€/m²]	1050
Calculated solar thermal system life time	[a]	25

Subsidy, € or % of total investment costs	[€/%]	1500
Fuel replaced	[-]	Gas, Elec
Cost for fuel replaced	[€/MWhfuel]	80, 160
Local feed-in tariff	[€/MWhelectricity]	60 (only for surplus from self-consumption)

Sources		
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3.11 Sète

3.11.1 Introduction and description

https://dualsun.com/en/realisations/sete-fr-2016-180pvt-en/

The object concerned a PVT municipal indoor swimming pool installation for the preheating of the pools and the showers. It was installed in 2016.

Figure 28: View of the PVT canopy for the municipal swimming pool in Sète

3.11.2 Solar installations

180 PVT collectors (DualSun 250Wp) were installed on the tilted roof of the building (total collector area, 300.0 m^2; 45 kWp electrical output). The modules are oriented to the southeast (20°) with an inclination angle of 10°.

3.11.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 29. It is preheating a tank before an internal network with a heat pump and a gas additional boilers trough serial heat exchangers.

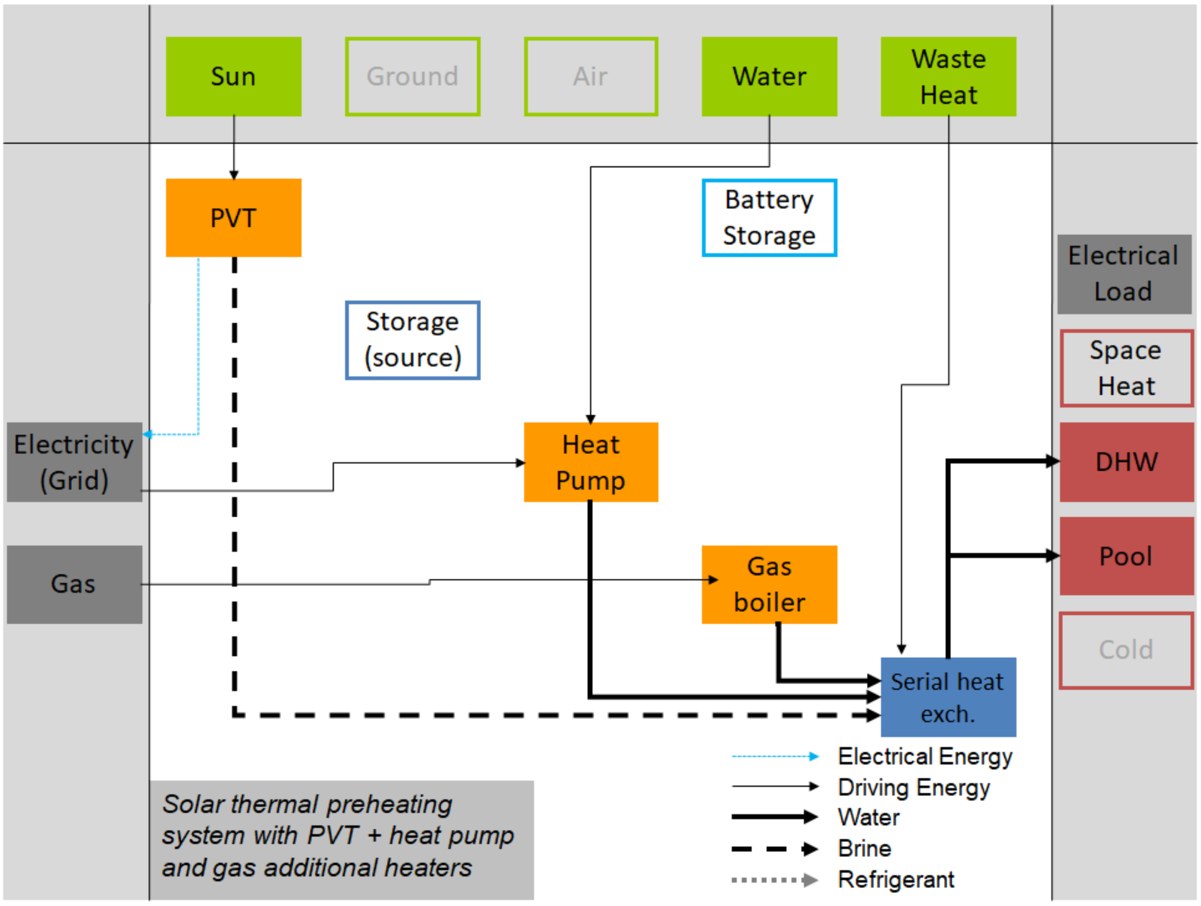

Figure 29: Visualisation of the PVT system "Sète".

3.11.4 Fact sheet

General Information		
Project name	[-]	Sete
Country	[-]	FR
City	[-]	Sete
Year of operation start	[mm/yyyy]	2016
PVT system owner(s) (%)	[-]	Dalkia
PVT system operators(s)	[-]	Dalkia
PVT system developer	[-]	Dalkia
Application	[-]	Municipal swimming pool

PLANT CONFIGURATION		
Panel model	[-]	DualSun Wave 250Wp
PVT-Collector provider	[-]	DualSun
Category	[-]	PVT liquid collector
Type	[-]	Uncovered
Working Fluid	[-]	Water/Glycol Mixture

Kind of installation	[-]	Canopy
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	20°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	10
# of modules	[-]	180
Installed collector area (gross)	[m²]	300
Installed collector area (aperture)	[m²]	-
Total energy output PVT-collector (Etotal)	[kW]	
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	DHW and pool preheating
Heat demand	[kWh/a]	1 180 835
Temperature range (application)	[°C]	30
Back-up system	[-]	HeatPump and Gas boilers
Solar thermal energy storage type	[-]	-
Storage Volume	[L]	-
Solar thermal energy to system (Qsol)	[kWh/a]	82100
Heat generator energy (Qaux)	[kWh/a]	1 098 735
Solar fraction(Qsol/(Qsol+Qaux))	[%]	7%

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.4
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	59115 (AC = post inverter)
Type of inverter	[-]	Unknown
AC capacity per inverter	[kW]	Unknown
# of inverter	[-]	Unknown
Inverter provider	[-]	Unknown
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	Unknown
Self-Consumption fraction	[%]	Unknown

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	350 000
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	-

Specific investment cost	[€/m²]	1170
Calculated solar thermal system life time	[a]	25
Subsidy, € or % of total investment costs	[€/%]	175 000
Fuel replaced	[-]	Gas, Elec
Cost for fuel replaced	[€/MWhfuel]	Unknown
Local feed-in tariff	[€/MWhelectricity]	131

Sources		
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3.12 Perpignan

3.12.1 Introduction and description

The object concerned a PVT municipal indoor swimming pool installation for the preheating of the pools and the showers. It was installed in 2016.

Figure 30: View of the PVT canopy for the municipal swimming pool in Perpignan

3.12.2 Solar installations

180 PVT collectors (DualSun 250Wp) were installed on the tilted roof of the building (total collector area, 300.0 m^2; 45 kWp electrical output). The modules are oriented to the south (0°) with an inclination angle of 10°.

3.12.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 31. It is preheating a tank before an internal network with a gas additional boiler trough serial heat exchangers.

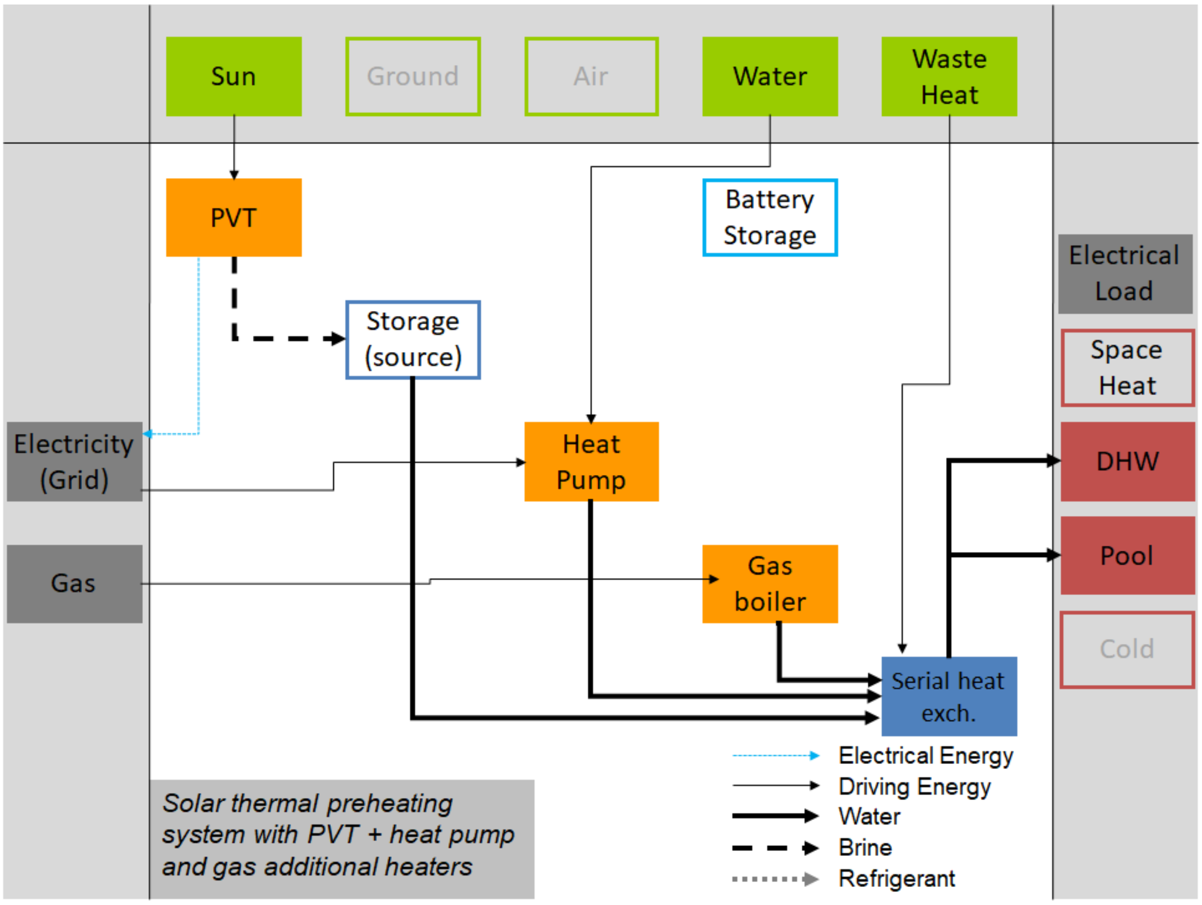

Figure 31: Visualisation of the PVT system "Sète".

3.12.4 Fact sheet

General Information		
Project name	[-]	Perpignan
Country	[-]	FR
City	[-]	Perpignan
Year of operation start	[mm/yyyy]	2016
PVT system owner(s) (%)	[-]	Dalkia
PVT system operators(s)	[-]	Dalkia
PVT system developer	[-]	Dalkia
Application	[-]	Municipal swimming pool

PLANT CONFIGURATION		
Panel model	[-]	DualSun Wave 250Wp
PVT-Collector provider	[-]	DualSun
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	Canopy
Tracking	[-]	No

System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	10
# of modules	[-]	180
Installed collector area (gross)	[m²]	300
Installed collector area (aperture)	[m²]	-
Total energy output PVT-collector (Etotal)	[kW]	
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	DHW and pool preheating
Heat demand	[kWh/a]	1 140 520
Temperature range (application)	[°C]	30
Back-up system	[-]	Gas boiler
Solar thermal energy storage type	[-]	-
Storage Volume	[L]	-
Solar thermal energy to system (Qsol)	[kWh/a]	119 870
Heat generator energy (Qaux)	[kWh/a]	1 020 650
Solar fraction(Qsol/(Qsol+Qaux))	[%]	12%

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.4
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	63 940 (AC = post inverter)
Type of inverter	[-]	Unknown
AC capacity per inverter	[kW]	Unknown
# of inverter	[-]	Unknown
Inverter provider	[-]	Unknown
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	Unknown
Self-Consumption fraction	[%]	Unknown

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	350 000
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	-
Specific investment cost	[€/m²]	1170
Calculated solar thermal system life time	[a]	25

Subsidy, € or % of total investment costs	[€/%]	175 000
Fuel replaced	[-]	Gas
Cost for fuel replaced	[€/MWhfuel]	Unknown
Local feed-in tariff	[€/MWhelectricity]	131

Sources		
Author	[-]	Laetitia Brottier
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3.13 NVZ-Freiburg

3.13.1 Introduction and description

The new administrative center (Neues Verwaltungszentrum: NVZ) of the city of Freiburg (D) has been designed and built with the objective of a plus-energy balance. The NVZ has been commissioned and handed-over to the city in summer 2017. With a net floor area of 22.650 m², it is to date one of the largest designed and built plus-energy building in Europe. To achieve a positive primary energy balance, the thermal characteristics of the building envelope correspond to a passive building standard, the building services have a high energy efficiency and onsite energy is generated by a large photovoltaic-plant (PV), composed of photovoltaics panels on the building roof and facades, combined with photovoltaic-thermal combined collectors (PVT). The central component of the heat generation is a ground-water coupled heat pump system supplying thermal activated concrete slabs, heating ceilings and air handling units (AHUs). Cooling is ensured over a geothermal well.


Figure 32: View of the new town hall with façade-integrated PV modules (© Stadt Freiburg) and the PVT collector array on the roof (© Manuel Lämmle).

3.13.2 Solar installations

Onsite power is generated here by a photovoltaic plant composed of monocrystalline solar panels with a total peak power of 682 kWp installed on the roof (461 kWp) and in the facade (221 kWp). Each solar module is equipped with a Maximum Power Point tracker, which continuously controls the point of the current-voltage characteristic curve at which the solar module provides the highest performance. A compound of 22 inverters converts the direct current of the solar modules into alternating current and feeds it into the building or in the public electricity grid accordingly to the current load of the building.

The heat demand for drinking hot water is mainly required for the canteen. Glazed hybrid photovoltaic-thermal solar collectors (PVT) with a gross collector area of 52 m² provide low- temperature heat and cover 29 % of the drinking hot water demand. PVT collectors potentially resolve the conflict between the application of photovoltaic or solar thermal systems on limited roof areas. While PVT collectors have a slightly lower electrical yield per square meter than PV modules, they simultaneously generate heat on the same surface area and thus achieve higher specific primary energy yields. Originally, conventional solar thermal collectors with an area of 29 m² were planned with a designed solar fraction of 15 % or an annual thermal output of 22 MWh/a. The PVT collector array was designed to achieve the same solar fraction. To compensate for their lower thermal efficiency, the aperture area of the PVT collector array amounts to 48 m². Thus, the substitution of the solar thermal collectors with glazed PVT collectors is planned to increase the electrical output of 180% on the given area, while maintaining the same thermal output

3.13.3 Heat supply concept and integration of PVT collectors

The building heat generation is realized by a combination of two ground-water coupled heat pumps with a total thermal power of 200 kW that supply thermal activated concrete slabs (TABS), radiant ceilings and radiators in the oces as well as ventilation air-handling units with heat recovery system, heating and cooling coils. A gas boiler operates as back-up to cover peak loads in periods of high heat demand.

The PVT system operates independently from the low temperature heat supply to the building and is only connected to the storages for the hot water supply of the kitchen, toilets and offices. As can be seen in the square view, the PVT collectors provide the heat to storage tanks, with a gas boiler as back-up. The electricity is used to cover the electrical load of the building. Excess electricity feeds back to the grid.

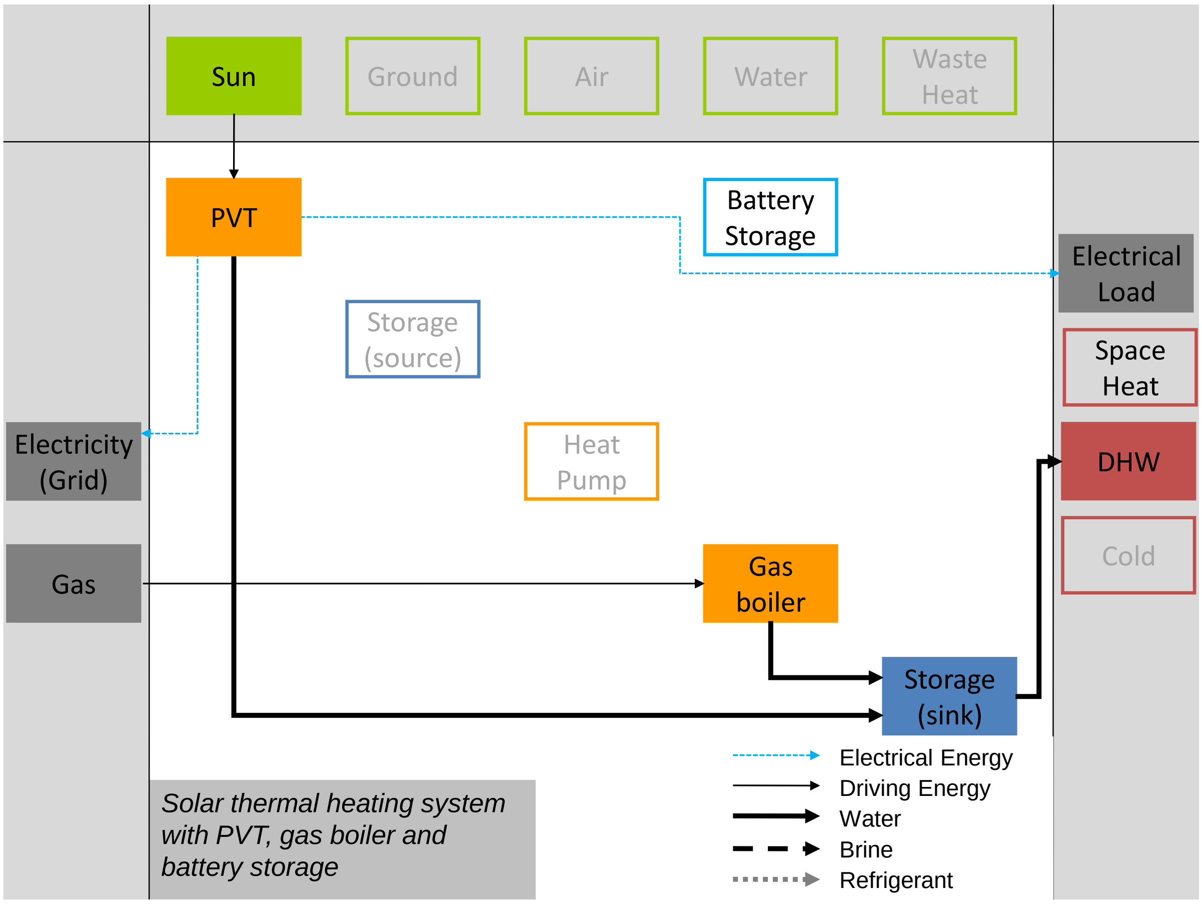

Figure 33: Square view of the PVT system for domestic hot water supply.

3.13.4 Fact sheet

The NVZ-Freiburg undergoes a detailed monitoring of the overall building performance. A more detailed analysis of the overall energetic building performance is published by Rehault (2019)3.
For the design of the PVT system an annual hot water demand of 145 MWh/a was assumed by the planners. The PVT system was designed to cover 15 % of the heat demand and deliver 22 MWh_{th}/a. In contrast to the design assumptions, the measured heat demand amounted to 24 MWh/a only, or 17 % of the originally assumed heat demand. Due to the much lower demand, the PVT collector array is dimensioned too large relative to the given heat demand. As consequence, the temperatures in the collectors are higher and thus the specific thermal output per collector is lower than the originally expected numbers.
Nonetheless, the solar thermal fraction of the PVT system amounts to 29.6 %, and is thus double as high as the originally expected solar fraction.

The electrical output of the PVT array meets the expected performance.

General Information	-	System 1
Project name	[-]	NVZ-Freiburg
Country	[-]	Germany

3 Nicolas Réhault, Peter Engelmann, Manuel Lämmle, Leo Munzinger (2019): New town hallin Freiburg (D): concept,performance and energy balance after the first year of monitoring of a large net plus-energy building. Proceedings of the 1st Nordic Conference on Zero Emission and Plus Energy Buildings.

City	[-]	Freiburg
Year of operation start	[mm/yyyy]	07.2017
PVT system owner(s) (%)	[-]	Stadt Freiburg (100%)
PVT system operators(s)	[-]	Stadt Freiburg
PVT system developer	[-]	Solvis
Application	[-]	Water preheating for kitchen and toilets

PLANT CONFIGURATION		
Panel model	[-]	non-commercial
PVT-Collector provider	[-]	Solvis
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	-30° - 30°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	30°
# of modules	[-]	22
Installed collector area (gross)	[m²]	51.7
Installed collector area (aperture)	[m²]	48.0
Total energy output PVT-collector (Etotal)	[kW]	6.8
Seasonal Performance Factor (System) SPFsys	[-]	-

Thermal Parameters		
Solar thermal energy used for	[-]	Water preheating for kitchen and toilets
Heat demand	[kWh/a]	24000
Temperature range (application)	[°C]	15 - 65°C
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	1960
Solar thermal energy to system (Qsol)	[kWh/a]	7329
Heat generator energy (Qaux)	[kWh/a]	17000
Solar fraction(Qsol/(Qsol+Qaux))	[%]	29%

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.8
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	5926
Type of inverter	[-]	Three-phase inverter
AC capacity per inverter	[kW]	-
# of inverter	[-]	1 inverter for PVT array
Inverter provider	[-]	SolarEdge
Electrical storage type	[-]	None

Storage integrated in AC/DC side	[-]	-
Storage capacity (electrial storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	100 %, on a net annual basis (including PV on roof and facade)
Self-Consumption fraction	[%]	83 % (including PV on roof and facade)

Sources		
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3.14 Lintharea (sports centre, pool, hotel, restaurant) NÄFELS

3.14.1 Introduction and description

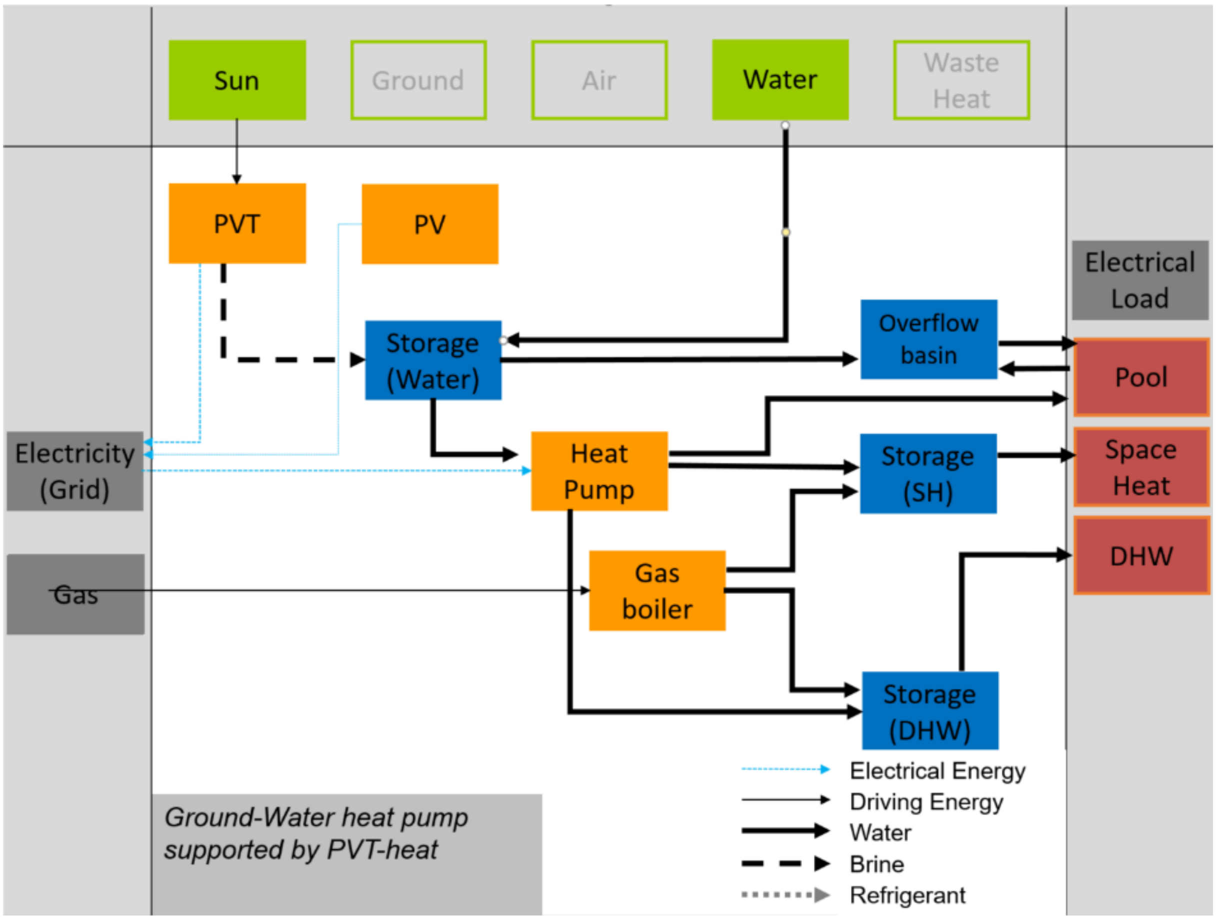
The linth-arena sgu is a sports and meeting centre with swimming pool, fitness rooms, restaurant and hotel. The heating system is based on a ground water heat pump and a gas boiler for peak load coverage. a PVT is coupled with a groundwater heat pump. The PVT heat integrated in the system to pre-heat the groundwater and, therefore, improving the seasonal performance factor (SPF) of the System.

3.14.2 Solar installations

On the roof of the Lintharena there are 178 PVT-Panels (MeyerBurger, 270/900) plus 699 PV-Panels (Typ Sky, 270 Wp). The total electrical output of the plant is 236.79 kWp (PV and PVT). The modules are oriented to the southeast (-18°) with an inclination angle of 10°.

3.14.3 Heat supply concept and integration of PVT collectors

The PVT – heat is used for pre-heating the groundwater storage. Heat is transferred from the ground water storage directly to the heat pump and to the overflow basins of the pools. The heat pump generates heat for pools, space heating and domestic hot water. The heat pump is supported by a gas boiler for the coverage of peak loads.



3.14.4 Fact sheet

General Information		
Project name	[-]	Lintharena SGU PVT plant
Country	[-]	Switzerland
City	[-]	Näfels
Year of operation start	[mm/yyyy]	04.2015
PVT system owner(s) (%)	[-]	Energieallianz Glarus-Linth
PVT system operators(s)	[-]	Energieallianz Glarus-Linth & ZHAW
PVT system developer	[-]	ZHAW, Meyer Burger AG
Application	[-]	pre-heating of ground water for heat pumps

PLANT CONFIGURATION		
Panel model	[-]	Hybrid 270Wp/900W
PVT-Collector provider	[-]	Meyer Burger
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture

Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	24
Tilt angle [hor. = 0°; vert. = 90°]	[°]	10
# of modules	[-]	178
Installed collector area (gross)	[m²]	292
Installed collector area (aperture)	[m²]	269
Total energy output PVT-collector (E_{total})	[kWh]	359.500
Seasonal Performance Factor (System) SPF_{sys}	[-]	not known (no use of produced electricity in the building)

Thermal Parameters		
Solar thermal energy used for	[-]	preheating of groundwater before used in heat pump
Heat demand	[kWh/a]	2.717.000
Temperature range (application)	[°C]	source: 8-13°C
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	cold storage up to 17'500l
Solar thermal energy to system (Qsol)	[kWh/a]	129.000
Heat generator energy (Qaux)	[kWh/a]	2.717.000
Solar fraction(Qsol/(Qsol+Qaux))	[%]	0

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	16,5
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	56015,35
Type of inverter	[-]	Fronius Symo
AC capacity per inverter	[kW]	2*15 & 1*17.5 kVA
# of inverter	[-]	3
Inverter provider	[-]	Fronius
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	0
Self-Consumption fraction	[%]	0

Economic Parameters		
Total investment cost (excl. VAT)	[€]	256.193
PVT-collector loop (excl. VAT)	[€]	102.390
Solar thermal energy storage (excl. VAT)	[€]	42.413
Inverter (excl. VAT)	[€]	
Electrical storage (excl. VAT)	[€]	0
others (excl. VAT)	[€]	111.390
Specific investment cost	[€/m²]	877
Calculated solar thermal system life time	[a]	25
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	electricity
Cost for fuel replaced	[€/MWhfuel]	
Local feed-in tariff	[€/MWhelectricity]	165

Sources		
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3.15 FVE - ATLAS O.C. s.r.o.

3.15.1 Introduction and description

The energy system for multi-family house located in Czech Republic was built in 2014. The system consists of ground source heat pump coupled with unglazed PVT collectors.

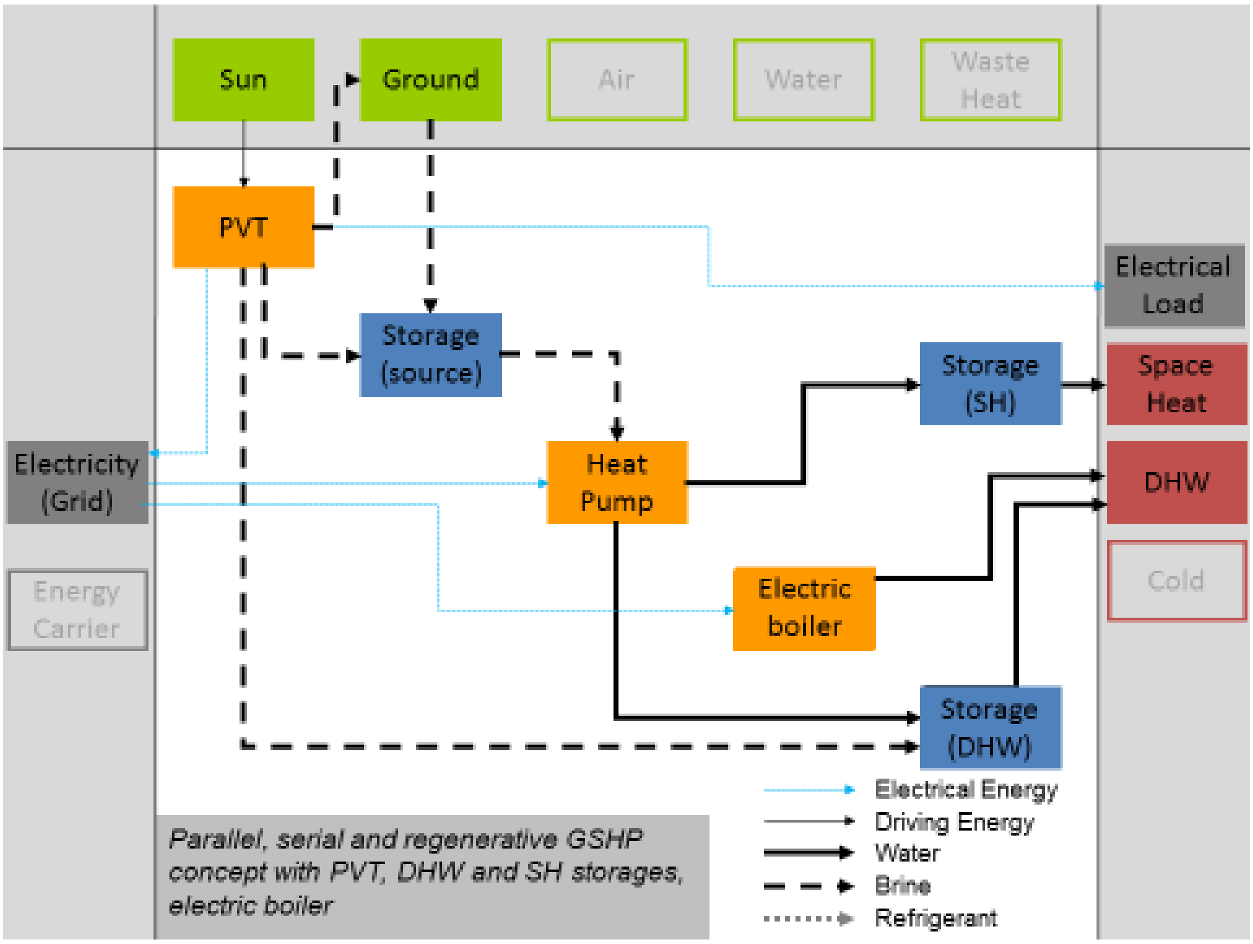
Figure 34: PVT system on the roof of the multi-family house (left) and technical room with ground source heat pump and storages (right)

3.15.2 Solar installations

Solar installation consists of 119 PVT collectors (Fototherm) installed on the roof of the building (total collector area, 188 m^2; 29.8 kW_p electrical output). Aperture area of one PVT collector is 1.58 m^2. The PVT collectors are oriented to the southwest (20°) with an inclination angle of 17°.

3.15.3 Heat supply concept and integration of PVT collectors

The PVT collector field operates in three modes based on priority of heat utilization. Heat from PVT collectors is primary used for DHW preparation (500 l), secondary is the heat used for storage (300 l) before heat pump. If both requirements are fulfilled the heat from PVT collectors is used for regeneration of boreholes.



3.15.4 Fact sheet

General Information		
Project name	[-]	FVE - ATLAS O.C. s.r.o.
Country	[-]	Czech republic
City	[-]	Prerov
Year of operation start	[mm/yyyy]	01/2014
PVT system owner(s) (%)	[-]	ATLAS O.C. s.r.o.
PVT system operators(s)	[-]	ATLAS O.C. s.r.o.
PVT system developer	[-]	ATLAS O.C. s.r.o.
Application	[-]	Multi-family house

PLANT CONFIGURATION	

Panel model	[-]	FT250AL
PVT-Collector provider	[-]	Fototherm
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	17°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	20°
# of modules	[-]	119
Installed collector area (gross)	[m²]	188
Installed collector area (aperture)	[m²]	188
Total energy output PVT-collector (E_{total})	[kWh]	52598 (2017)
Seasonal Performance Factor (System) SPF_{sys}	[-]	-

Thermal Parameters	-	
Solar thermal energy used for	[-]	DHW, regeneration of boreholes, source for heat pump
Heat demand	[kWh/a]	-
Temperature range (application)	[°C]	-5 to 50°C
Back-up system	[-]	brine/water heat pump
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	boreholes, DHW storage 500 l, source storage 300 l
Solar thermal energy to system (Qsol)	[kWh/a]	22085 (2017)
Heat generator energy (Qaux)	[kWh/a]	-

Electrical Parameters	-	
Module type	[-]	Polycrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.2
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	30 513 (2017)
Type of inverter	[-]	-
AC capacity per inverter	[kW]	-
# of inverter	[-]	-
Inverter provider	[-]	-
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-

Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	-
Self-Consumption fraction	[%]	-

Sources	-	
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3.16 Single-family house SUELLO (LECCO)

3.16.1 Introduction and description

The object concerned is a new single-family house which includes a PVT system, installed in 2016. The heating and cooling plant includes a reversible heat pump, two storage tanks, 16 PVT modules and two ground heat exchangers. Moreover, a 16 PV modules plant is installed on the house roof.

Figure 35: View of the PVT system on the roof of the single-family house in Suello (Lecco).

3.16.2 Solar installations

16 PVT collectors (Solink HBK250850) were installed on the pitched roof of the building (total collector area, 26.08 m^2; 4 kWp electrical output). The modules are oriented to the south with an inclination angle of 35°. In addition, a PV system with the same orientation comprising 16 modules of the same type, though without heat absorbers, was installed (26.08 m^2; 4 kWp).

3.16.3 Heat supply concept and integration of PVT collectors

The heating and cooling supply system is depicted in simplified form in Figure 36. It is based on a reversible heat pump coupled with the PVT plant or a geothermal heat exchanger (depending on the season). In the summer, during the day the building is cooled through the reversible heat pump, which is electrically driven by the PVT and PV plants, while the condenser is connected to one geothermal heat exchanger (total surface of about 20.24 m^2). During the day, PVT modules are cooled by another twin geothermal heat exchanger, while during night the PVT is used to cool down the cold water storage. In the winter, the heat produced by PVT is used on the evaporator side of the heat pump.

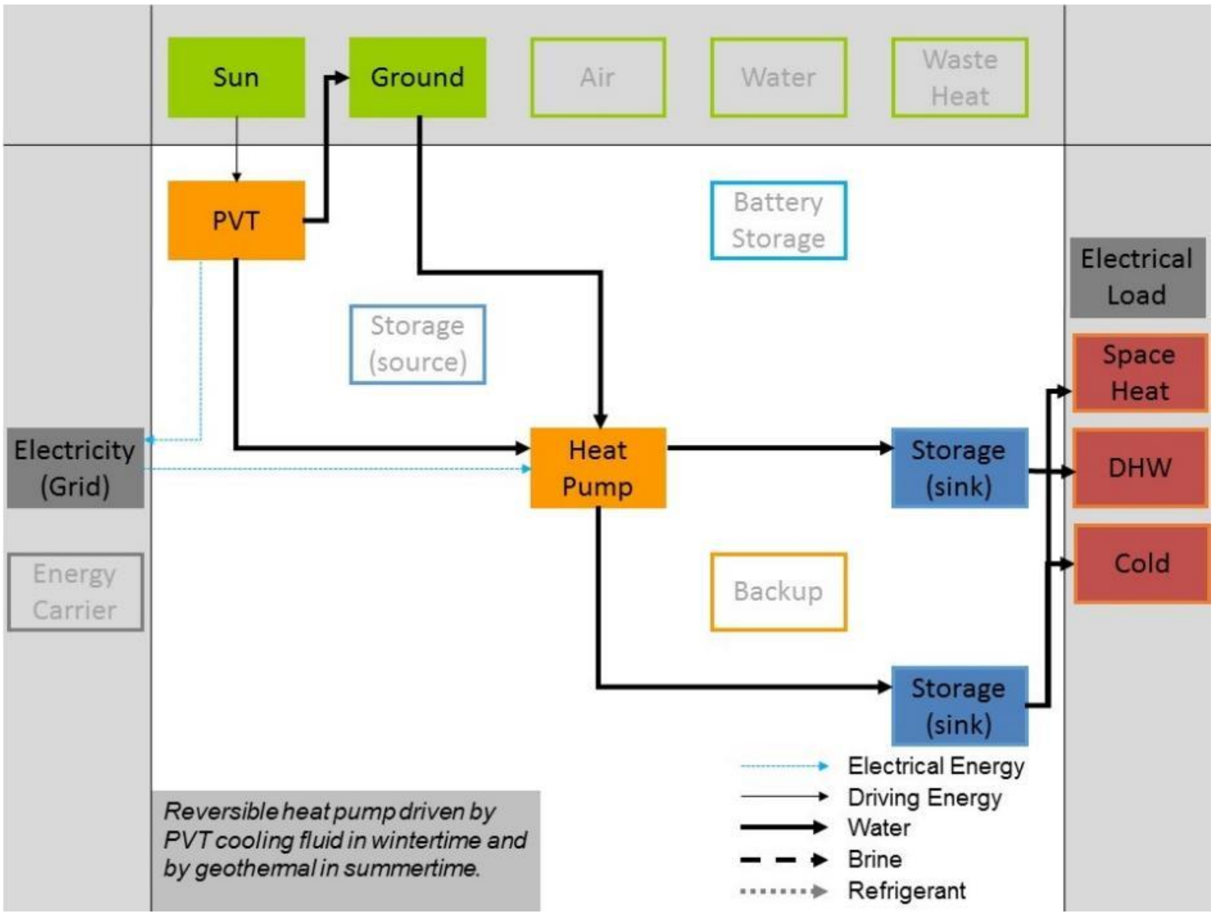

Figure 36: Visualisation of the PVT system "Suello".

3.16.4 Fact sheet

General Information		
Project name	[-]	PVT Suello
Country	[-]	Italy
City	[-]	26
Year of operation start	[mm/yyyy]	05/2016
PVT system owner(s) (%)	[-]	Private
PVT system operators(s)	[-]	Solink
PVT system developer	[-]	Solink
Application	[-]	Integration with ground source heat pump

PLANT CONFIGURATION		
Panel model	[-]	HBK250850
PVT-Collector provider	[-]	Solink
Category	[-]	PVT liquid collector
Type	[-]	Unglazed
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	Roof or façade integration

Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	35°
# of modules	[-]	16
Installed collector area (gross)	[m²]	26.08
Installed collector area (aperture)	[m²]	23.20
Total energy output PVT-collector (Etotal)	[kW]	21520
Seasonal Performance Factor (System) SPFsys	[-]	2

Thermal Parameters		
Solar thermal energy used for	[-]	Increase heat pump COP
Heat demand	[kWh/a]	11750
Temperature range (application)	[°C]	0-20
Back-up system	[-]	water/water heat pump
Solar thermal energy storage type	[-]	Ground
Storage Volume	[L]	NA
Solar thermal energy to system (Qsol)	[kWh/a]	18345
Heat generator energy (Qaux)	[kWh/a]	42840
Solar fraction(Qsol/(Qsol+Qaux))	[%]	30%

Electrical Parameters		
Module type	[-]	Polycrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.35
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	5200
Type of inverter	[-]	3Phase
AC capacity per inverter	[kW]	8.5
# of inverter	[-]	1
Inverter provider	[-]	ABB
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	50
Self-Consumption fraction	[%]	50

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	39000
PVT-collector loop (excl. VAT)	[€]	6400
Solar thermal energy storage (excl. VAT)	[€]	8500
Inverter (excl. VAT)	[€]	2000
Electrical storage (excl. VAT)	[€]	0
others (excl. VAT)	[€]	22100
Specific investment cost	[€/m²]	1495

Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	0
Fuel replaced	[-]	Electricity
Cost for fuel replaced	[€/MWhfuel]	22
Local feed-in tariff	[€/MWhelectricity]	22

Sources		
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3.17 Multi-family house OBERFELD

3.17.1 Introduction and description

The object Oberfeld is a multi-family house it's a sustainable and car-free settlement in Ostermundigen near Bern. The construction project is according to Minergie-P-ECO standard. The whole settlement consists of the three buildings A, B and C. Each of the three buildings has its own separate heating system consisting of heat pump, geothermal field and PVT solar system.

Figure 37 : View of the building B (background) in front part of the PVT system on the roof of building C

3.17.2 Solar installation

The entire PVT system is distributed over the different roofs of the buildings. It consists total 799 PVT collectors and has a total area more than 1300 m2. With this system size the borehole field should be 100% regenerated. The aim of this P&D project is to gain experience on the earth temperatures with full regeneration over several years. The PVT collectors are the Meyer Burger Hybrid type 240/90 they are installed flat (0° inclination angle) to maximize the collector area on the roof.

3.17.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 38. As mentioned each building has his own heating system. The solar heat is used to regenerate the boreholes. A simultaneous operation of regeneration and heat pump use is possible. In this case the heat pumps benefit from higher fluid temperatures during regeneration operation. If so the solar heat is used as direct source for the heat pumps. Even though the PVT fluid temperature is damped first by the borehole field. The maximum temperature allowed to entry the boreholes field is 30°C. It turned out this being also the achieved temperature by the PVT filed at sunny summer days for this particular system.

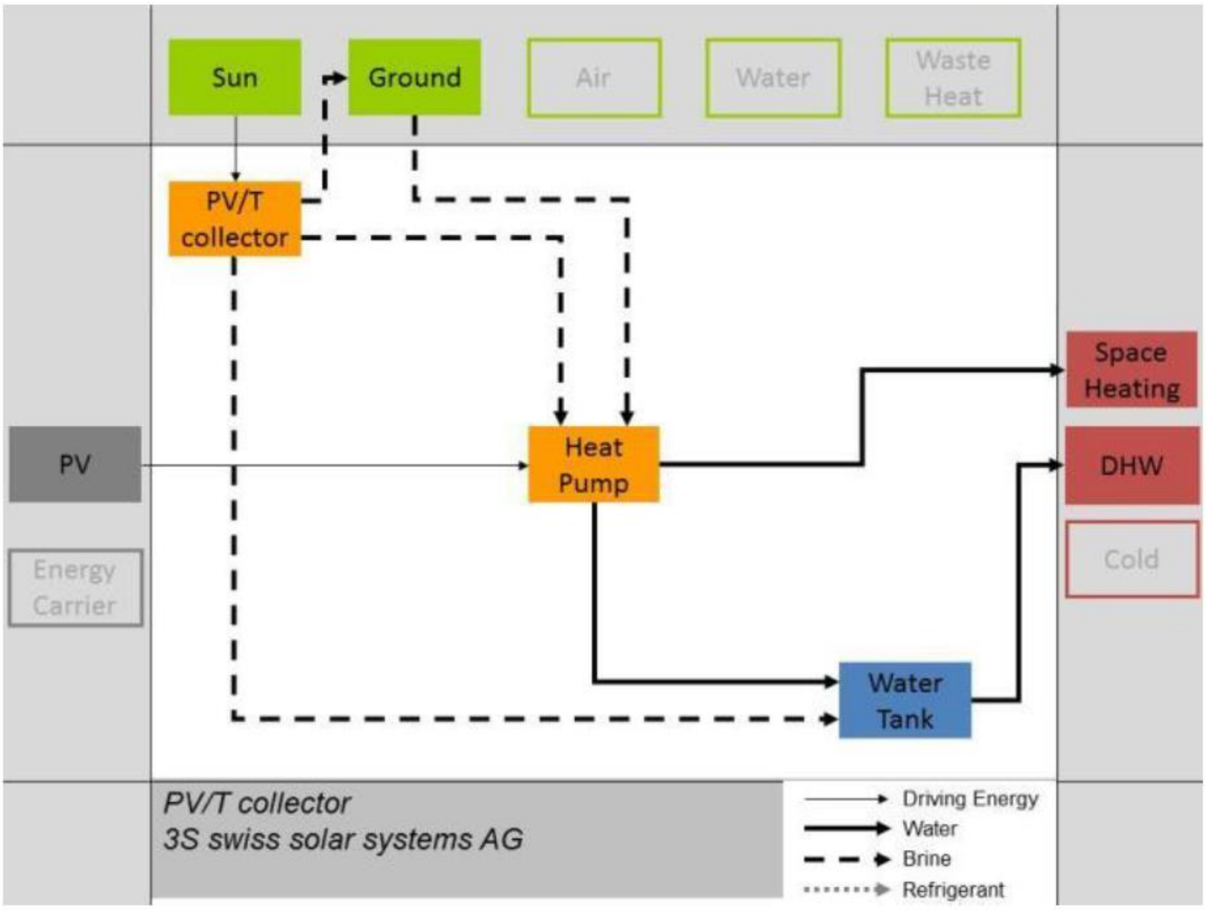

Figure 38 : Visualisation of the PVT system "Oberfeld"

3.17.4 Fact sheet

General Information		
Project name	[-]	P&D plant "Wohnbaugenossenschaft Oberfeld"
Country	[-]	CH
City	[-]	Ostermundigen
Year of operation start	[mm/yyyy]	2014-2019
PVT system owner(s) (%)	[-]	Contractor (utility company)
PVT system operators(s)	[-]	Contractor
PVT system developer	[-]	Contractor, PVT manufacturer, research institute
Application	[-]	building complex (3 MFH, in total 100 apartments)

PLANT CONFIGURATION		
Panel model	[-]	Meyer Burger Hybdrid 260/900
PVT-Collector provider	[-]	Meyer Burger AG
Category	[-]	PVT liquid collector
Type	[-]	uncovered

Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
		flat roof
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	
Tilt angle [hor. = 0°; vert. = 90°]	[°]	0
# of modules	[-]	799 (Haus B: 379)
Installed collector area (gross)	[m²]	1320 (Haus B: 622)
Installed collector area (aperture)	[m²]	1320 (Haus B: 622)
Total energy output PVT-collector (Etotal)	[kW]	
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters	_	
Solar thermal energy used for	[-]	borehole regeneration, direct heat source of heat pump
Heat demand	[kWh/a]	436'000
Temperature range (application)	[°C]	corresponding to applications, borehole regeneration maximum inlet temperature 30 °C
Back-up system	[-]	water/water heat pump
Solar thermal energy storage type	[-]	Ground
Storage Volume	[L]	28 boreholes 200 m each
Solar thermal energy to system (Qsol)	[kWh/a]	Haus B: 187000-205000
Heat generator energy (Qaux)	[kWh/a]	220000
Solar fraction(Qsol/(Qsol+Qaux))	[%]	not meaningful for case of borehole regeneration and solar heat as source of heat pump
Borehole regeneration rate		

Electrical Parameters	_	
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.9
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	unknown
Type of inverter	[-]	unknown
AC capacity per inverter	[kW]	-
# of inverter	[-]	Haus B: 7
Inverter provider	[-]	Solarmax
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	

Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	unknown
Self-Consumption fraction	[%]	unknown

Sources	_	
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3.18 Multi-family house SOTCHA

3.18.1 Introduction and description

One of the first residential complexes in the region of the Alps based on the Minergie-A standard has been constructed in Scuol (GR). In this complex, which forms an integral part of the new "Monolith" residential district, three heating systems based on different solar installations were realised in three identical apartment houses. Buildings A, B and C are structurally identical, have the same orientation and each comprise eight apartments. A detailed monitoring system was installed that will permit a comparison between the three systems. The mountain location poses special challenges due to the low outside temperatures, but thanks to the high level of solar irradiation it also offers advantages for qualifying for the demanding Minergie-A label.

3.18.2 Solar installation

The other properties of the three heat supply systems are as follows:

House A: PV system (130 m^2; 21.8 kWp electricity) with electrical storage facility (28 kWh). This building without regeneration of the ground source serves as the reference system.

House B: In-roof PVT system developed by Caotec (130 m^2; 21.8 kWp electricity) with uncovered rearinsulated PVT collectors. In addition to ground source regeneration via a brine buffer storage unit, the solar heat can also be used as a direct source for the heat pump and for direct hot water preheating.

House C: Solar thermal installation (40 m^2) with "Alpsun Indach" roof-integrated flat-plate collectors from Caotec. The remainder of the surface of this roof was covered with PV modules (90 m^2). The solar heat is primarily used for providing hot water, with heating support as second priority and borehole regeneration via a brine buffer storage unit as third priority.

The type of PV modules installed on buildings A and C is Capillary G/G 280W from Sunage. All the solar installations have a southern orientation.

3.18.3 Heat supply concept and integration of PVT collectors

All three buildings have a power adjustable brine/water heat pump (30 kW heating capacity) that is connected to an individual geothermal borehole field (five boreholes with a depth of 170 meters). Solar heat can be uses direct (preheating DHW), heating up brine storage (direct source for hp) and regenerating boreholes. The capacity of each brine storage unit is 1,000 liters. The capacity of the buffer storage tank for hot water and space heating into which the solar heat is fed, is 2,000 liters.

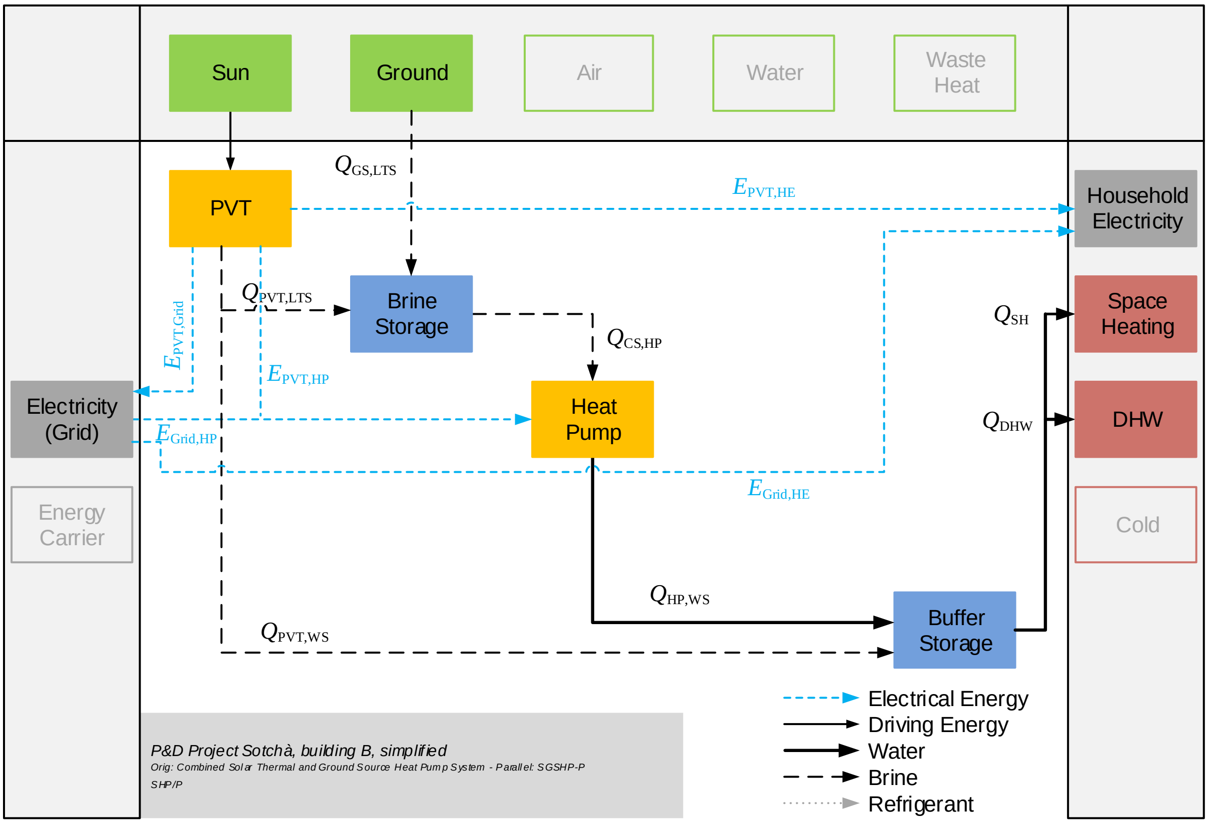

Figure 39: square view sotcha

3.18.4 Fact sheet

General Information	_	
Project name	[-]	P&D Project "Sotchà"
Country	[-]	CH
City	[-]	Scuol
Year of operation start	[mm/yyyy]	2015
PVT system owner(s) (%)	[-]	real estate company
PVT system operators(s)	[-]	installer
PVT system developer	[-]	installer, research institute
Application	[-]	building complex (1 MFH, 8 appartments)

PLANT CONFIGURATION	_	
Panel model	[-]	Caotec Ibrido
PVT-Collector provider	[-]	Caotec

Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	roof or facade integration
		slanted roof
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	45
# of modules	[-]	78
Installed collector area (gross)	[m²]	130
Installed collector area (aperture)	[m²]	130
Total energy output PVT-collector (Etotal)	[kW]	
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters	-	
Solar thermal energy used for	[-]	borehole regeneration, direct heat source of heat pump, heat into low-temperature storage tank (brine) source of heat pump, heat into hot water storage tank, heat into space heating storage tank
Heat demand	[kWh/a]	48000
Temperature range (application)	[°C]	corresponding to applications, borehole regeneration maximum inlet temperature ~20 °C
Back-up system	[-]	brine/water heat pump
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	2000
Solar thermal energy to system (Qsol)	[kWh/a]	17000
Heat generator energy (Qaux)	[kWh/a]	52000
Solar fraction(Qsol/(Qsol+Qaux))	[%]	
Borehole regeneration rate		

Electrical Parameters	-	
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17.1
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	not known yet
Type of inverter	[-]	unknown
AC capacity per inverter	[kW]	20
# of inverter	[-]	1
Inverter provider	[-]	SMA
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	

Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	unknown
Self-Consumption fraction	[%]	unknown

Sources	_	
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3.19 Multi-family house SENTMATT

3.19.1 Introduction and description

The construction project in Obfelden consists of 3 buildings and a total of 119 apartments. The energy reference area total is 12'900 m_2. The heat requirement (including hot water) is 648 MWh/a. In addition, the central energy system supplies an energetically refurbished older building too.

3.19.2 Solar installation

The collector area of the system consists of 70% PVT collectors and 30% of selective, uncovered solar collectors. The entire PVT system is distributed over the three roofs of the buildings. It consists total 258 PVT collectors and has a total area of 423 m_2.

3.19.3 Heat supply concept and integration of PVT collectors

The heat pump draws geothermal energy from a large probe field, consisting of 27 conventional geothermal probes. Each is 270m deep the total length of the probes is 7290 m. The probes are filled with water and the calculated reference power during operation is 260 kW.

The system consists two heat pumps connected in series. The first one is an Ammonia (NH_3) heat pump which receives the heat from the ground probe field and supplies the heat to a technical storage (temperature range 20-30 ° floor heating). The second heat pump is a carbon dioxide (CO_2). This has as a source of technical storage and then gives the heat on the temperature level of 60 ° C to a large cubic storage. The cubic storage is then for DHW and space heating (radiator heating) for the renovated building.

3.19.4 Fact sheet

General Information	_	
Project name	[-]	P&D Project "Sentmatt"
Country	[-]	CH
City	[-]	Obfelden
Year of operation start	[mm/yyyy]	2017
PVT system owner(s) (%)	[-]	real estate company
PVT system operators(s)	[-]	real estate company
PVT system developer	[-]	real estate company, installer
Application	[-]	building complex (4 MFH, in total 141 appartments)

PLANT CONFIGURATION	_	
Panel model	[-]	solator® PV+THERM AUFDACH

PVT-Collector provider	[-]	Solator
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
		flat roof
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	10
# of modules	[-]	258
Installed collector area (gross)	[m²]	423
Installed collector area (aperture)	[m²]	423
Total energy output PVT-collector (Etotal)	[kW]	
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters	_	
Solar thermal energy used for	[-]	borehole regeneration, direct heat source of heat pump, heat into hot water storage tank
Heat demand	[kWh/a]	not known yet
Temperature range (application)	[°C]	corresponding to applications, borehole regeneration maximum inlet temperature ~40 °C
Back-up system	[-]	water/water heat pump
Solar thermal energy storage type	[-]	Ground
Storage Volume	[L]	27 boreholes 270 m each
Solar thermal energy to system (Qsol)	[kWh/a]	not known yet
Heat generator energy (Qaux)	[kWh/a]	not known yet
Solar fraction(Qsol/(Qsol+Qaux))	[%]	not meaningful for case of borehole regeneration and solar heat as source of heat pump

Electrical Parameters	_	
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17.1
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	not known yet
Type of inverter	[-]	unknown
AC capacity per inverter	[kW]	-
# of inverter	[-]	-
Inverter provider	[-]	-
Electrical storage type	[-]	None

Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	unknown
Self-Consumption fraction	[%]	unknown

Sources	_	
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3.20 Single-family house in WETTSWIL AM ALBIS

3.20.1 Introduction and description

The object concerned is a single-family house with a heated outdoor swimming pool, where an existing heat supply system based on a heat pump coupled with a ground source was expanded in 2012 by adding a PVT system. The reason for the integration of the PVT system was an observed cooling of the boreholes.

Figure 40: View of the PVT system on the roof of the single-family house in Wettswil.

3.20.2 Solar installations

28 PVT collectors (Meyer Burger Hybrid 240/900) were installed on the flat roof of the building (total collector area, 45.9 m^2; 6.7 kWp electrical output). The modules are oriented to the southeast (30°) with an inclination angle of 10°. In addition, a PV system with the same orientation comprising 10 modules of the same type, though without heat absorbers, was installed (16.4 m^2; 2.4 kWp).

3.20.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 41. It is based on a heat pump coupled with three geothermal boreholes, each with a length of 150 metres. In the summer, the building is cooled through free cooling via the geothermal probes, which are thus partially regenerated. The building also has a wine cellar cooling system, some of the waste heat from which is used for heating up water, while the remainder is fed into the boreholes.

For the integration of the solar system the boreholes were hydraulically separated. Only two of them are regenerated via the PVT collectors, and the third is used for free cooling. This means that both functions can be used simultaneously. When heat is drawn by the heat pump, all three boreholes are used in parallel. The solar heat can be used for heating the swimming pool in addition to the regeneration of the ground source. The installed hydraulics would also allow for use of the solar heat as a direct source for the heat pump. This operation mode, however, is not planned.

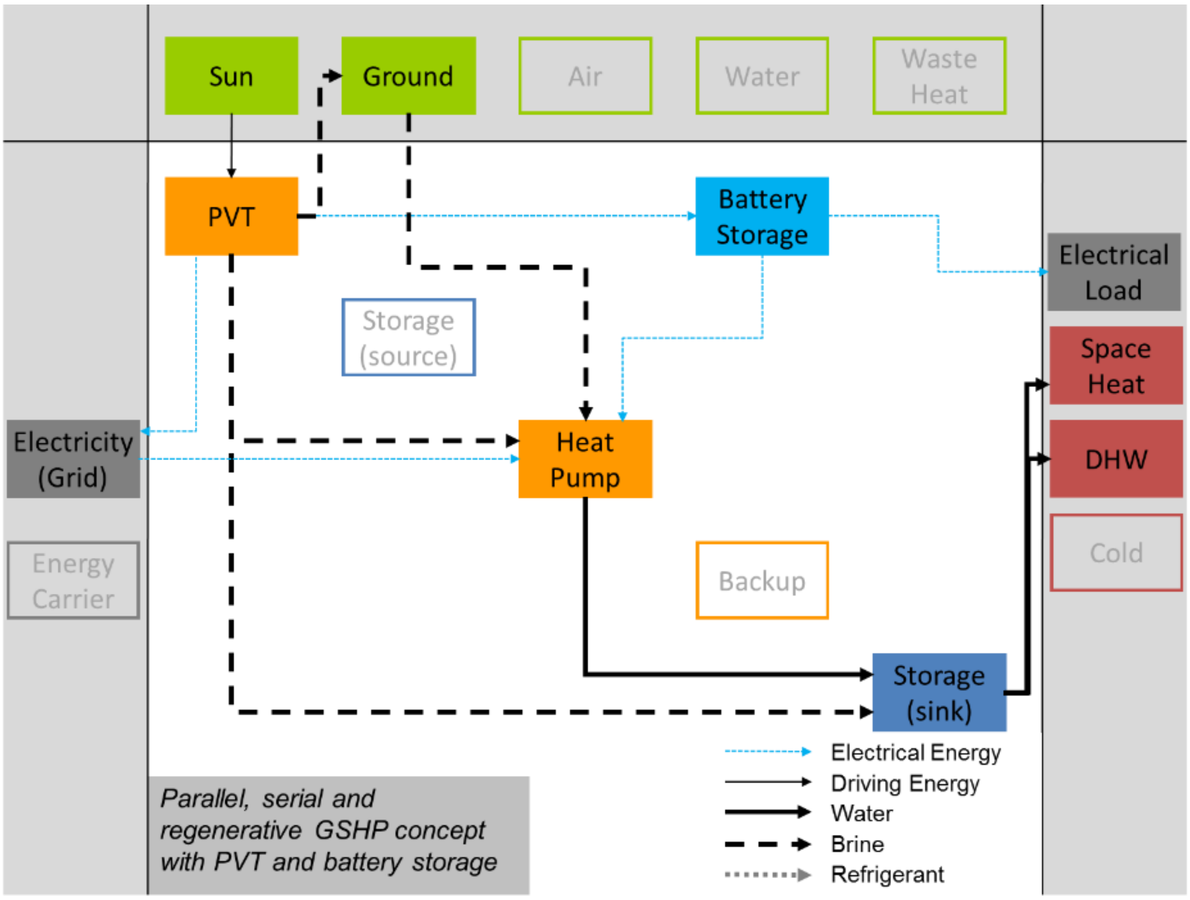

Figure 41: Visualisation of the PVT system “Wettswil”.

3.20.4 Fact sheet

General Information		
Project name	[-]	Pilot and Demonstration (P&D) plant "Wettswil am Albis"
Country	[-]	CH
City	[-]	Wettswil am Albis
Year of operation start	[mm/yyyy]	2013
PVT system owner(s) (%)	[-]	the owner is the resident
PVT system operators(s)	[-]	owner / installer
PVT system developer	[-]	installer, PVT manufacturer, research institute
Application	[-]	single-family house, energy reference area (ERA)

PLANT CONFIGURATION		
Panel model	[-]	Meyer Burger Hybdrid 240/900
PVT-Collector provider	[-]	Meyer Burger AG
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted

Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	30
Tilt angle [hor. = 0°; vert. = 90°]	[°]	10
# of modules	[-]	28
Installed collector area (gross)	[m²]	45,9
Installed collector area (aperture)	[m²]	45,9
Total energy output PVT-collector (Etotal)	[kW]	17800
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	borehole regeneration, pool heating
Heat demand	[kWh/a]	not known
Temperature range (application)	[°C]	corresponding to applications
Back-up system	[-]	brine/water heat pump
Solar thermal energy storage type	[-]	Ground
Storage Volume	[L]	3 boreholes 150 m each
Solar thermal energy to system (Qsol)	[kWh/a]	12300
Heat generator energy (Qaux)	[kWh/a]	46400 heat pump to system
Solar fraction(Qsol/(Qsol+Qaux))	[%]	-

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	14,6
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	5500
Type of inverter	[-]	transformerless
AC capacity per inverter	[kW]	-
# of inverter	[-]	4
Inverter provider	[-]	Solarmax
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	unknown
Self-Consumption fraction	[%]	unknown

Sources		
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3.21 Football club house in STENLOESE

3.21.1 Introduction and description

The case described is added to a football club house from the 1970'ties which originally was heated by electricity. In 2014 the electric radiators were replaced by a low temperature radiator central heating system as first step of a R&D project aiming at integrating a self-bearing waterproof PVT roof on the building. To supply heat a 25 kW ground source heat pump was installed.

Figure 42: View of the BIPVT system integrated in the roof of the football club house in Stenloese

3.21.2 Solar installations

24 PVT collectors (Racell SE1100-220 Hercules iTM) were installed as a new roof of the building (total collector area, 165 m2; 24.6 kWp electrical output). The modules are oriented to the south with an inclination angle of 25°. In addition, a PV system with the opposite orientation (North) comprising 24 modules of the same type and visually exactly the same looks, though without heat absorbers, was installed (165 m2; 24.6 kWp).

3.21.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in a simplified form in Figure 43. It is based on a heat pump coupled with 1500 m horizontal pipes. The heat is delivered to the 850 l buffertank in 2 different levels – low- and mid temperatures normally up to 55°C - and high temperature from the super heater part up to 65°C. the buffertank supplies high temp. heat to the DHW tank and to the central heating system by 25-55°C.

The PVT delivers heat to the buffertank through an integrated heating coil. On warm summerdays the buffertank is heated up to more than 60°C. In cooler periods with lower PVT temperatures the heat can be supplied to the ground source pipes to be stored there and used later by the heat pump.

The energy supply of heating and electricity exceeds by far the energy consumption of the building. However, the reason and concept of combining both horizontal geothermal pipes and PVT is that the ground pipes will function both as the supply connection for other buildings in the area and also function as storage when there is excess energy. This concept makes the energy supply to several buildings very flexible and smart control for heating, cooling and electricity can be implemented.

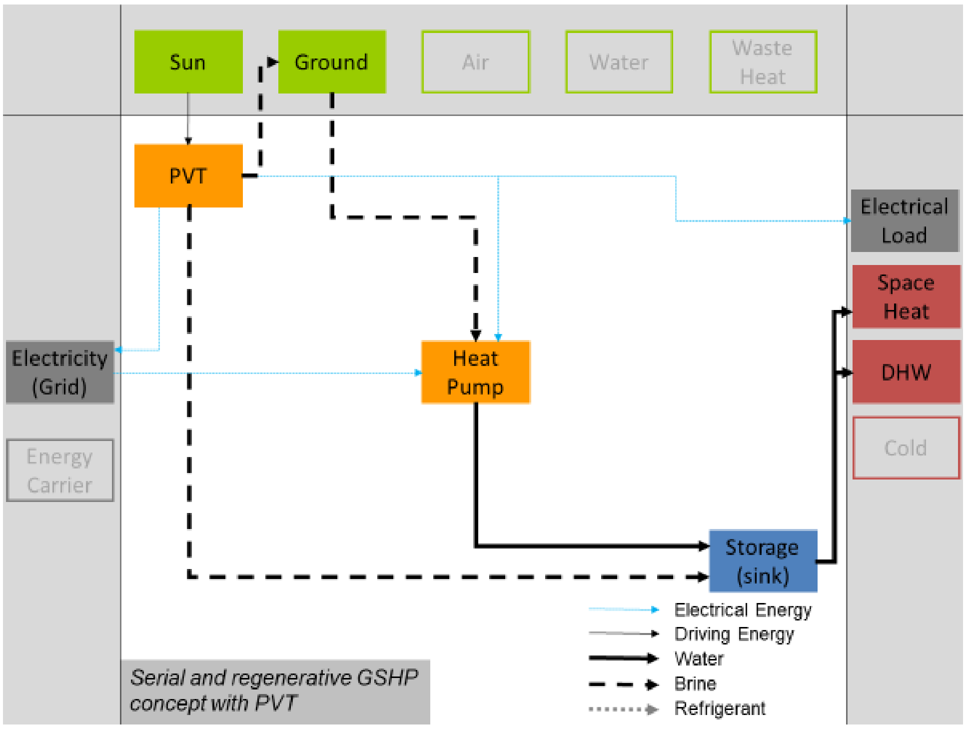

Figure 43: Visualisation of the PVT system "Stenloese".

3.21.4 Fact sheet

General Information		***System 1***
Project name	[-]	Stenløse Footballclub
Country	[-]	Denmark
City	[-]	Egedal
Year of operation start	[mm/yyyy]	11-2017
PVT system owner(s) (%)	[-]	Egedal Municipality
PVT system operators(s)	[-]	Egedal Municipality
PVT system developer	[-]	EUDP + Racell + Ramboll
Application	[-]	DHW + roomheating

PLANT CONFIGURATION		
Panel model	[-]	SE1100-220 Hercules iTM
PVT-Collector provider	[-]	RACELL
Category	[-]	PVT liquid collector
Type	[-]	uncovered

Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	roof or facade integration
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	S
Tilt angle [hor. = 0°; vert. = 90°]	[°]	25
# of modules	[-]	24
Installed collector area (gross)	[m²]	165
Installed collector area (aperture)	[m²]	154
Total energy output PVT-collector (E_{total})	[kWh]	36835
Seasonal Performance Factor (System) SPF_{sys}	[-]	5,1

Thermal Parameters		
Solar thermal energy used for	[-]	DHW + roomheating in a sports club
Heat demand	[kWh/a]	50000
Temperature range (application)	[°C]	25 - 60
Back-up system	[-]	brine/water heat pump
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	950
Solar thermal energy to system (Qsol)	[kWh/a]	12000
Heat generator energy (Qaux)	[kWh/a]	50000
Solar fraction(Qsol/(Qsol+Qaux))	[%]	19

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	18,1
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	27200
Type of inverter	[-]	3 phase , Symo
AC capacity per inverter	[kW]	8,2
# of inverter	[-]	3
Inverter provider	[-]	Fronius
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrial storage)	[kWh]	None
Storage provider	[-]	None
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	24
Self-Consumption fraction	[%]	52

Economic Parameters	

Total investment cost (excl. VAT)	[€]	135000
PVT-collektor loop (excl. VAT)	[€]	88000
Solar thermal energy storage (excl. VAT)	[€]	10000
Inverter (excl. VAT)	[€]	3750
Electrical storage (excl. VAT)	[€]	0
others (excl. VAT)	[€]	18000
Specific investment cost	[€/m²]	1498
Calculated solar thermal system life time	[a]	25
Subsidy, € or % of total investment costs	[€/%]	60%
Fuel replaced	[-]	electricity
Cost for fuel replaced	[€/MWhfuel]	200
Local feed-in tariff	[€/MWhelectricity]	0

Sources		
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3.22 Consolar SOLINK heating system in single-family house near Stuttgart, Germany

3.22.1 Introduction and description

The single family house in the greater area of Stuttgart, Germany, has been completely renovated and equipped with a PVT driven heat pump system to provide the space heating and hot water demand. The heating system is running since April 2018, though the house has been uninhabitated until now. The hot water part of the buffer store has regularly been heated but without any draw-off yet. The system is monitored within the SOLINK project, funded by “Deutsche Bundesstiftung Umwelt”.

Figure 44: View of the PVT field on the single family house in winter.

3.22.2 Solar installations

Solar installation was composed by 20 SOLINK PVT collectors, with a total solar surface of 39.6 m2 and 6.8 kWp of electrical output. PVT collectors were installed on the roof, with a tilt of 26º and faced approximately to south (10º towards east). Hydraulics include a 300 l ice store on the source side of the heat pump (7 kW at B0/W35) and a 1000 l buffer store for combined hot water preparation and space heating. On the electrical side, a SMA Sunny Tripower inverter is installed.

3.22.3 Heat supply concept and integration of PVT collectors

The heat supply system is graphically explained in Figure 14Figure 12. The PVT collector field delivers solar and ambient heat at a low temperature level to the ice store and the serial connected heat pump. Electrically the heat pump is driven to a certain degree directly by the output of the PVT collectors, otherwise electrical energy is taken from the grid. The 1000 l water store is recharged by the heat pump according to the hot water and space heating demand. During sunny days the water store may be charged directly by the thermal output of the PVT collector. An electrical resistance heater is installed in the water store as backup heating system to guarantee coverage of the heat demand also in rare cases with extremely low ambient temperatures and low solar radiation in winter (heat pump inlet source temperature below -15 °C).

A smart energy management system will be added to the system to maximize the electrical self consumption of the heat pump system, using intelligent thermal load management via the available buffer storage.

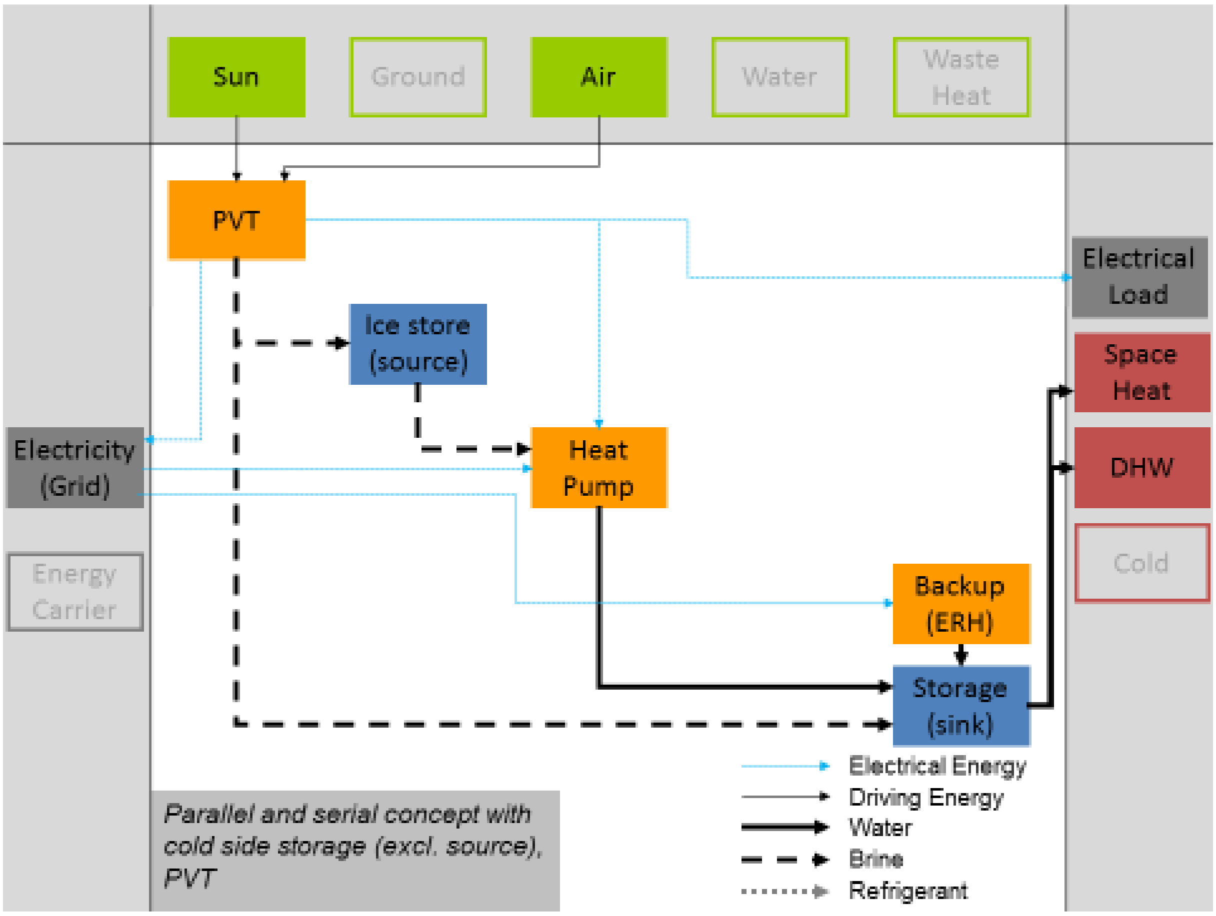

Figure 45: Schematic visualisation of the PVT heat pump system.

3.22.4 Fact sheet

General Information	_	
Project name	[-]	Consolar SOLINK, SFH Korb
Country	[-]	Germany
City	[-]	Stuttgart
Year of operation start	[mm/yyyy]	02/2018
PVT system owner(s) (%)	[-]	Kienle
PVT system operators(s)	[-]	Ruoff Energietechnik GmbH
PVT system developer	[-]	Consolar GmbH
Application	[-]	SH + DHW

PLANT CONFIGURATION		
Panel model	[-]	Consolar SOLINK
PVT-Collector provider	[-]	Consolar GmbH
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	10
Tilt angle [hor. = 0°; vert. = 90°]	[°]	26
# of modules		20
Installed collector area (gross)	[m²]	39,4
Installed collector area (aperture)	[m²]	38,2
Total energy output PVT-collector (Etotal)	[kWh]	14380
Seasonal Performance Factor (System) SPFsys	[-]	4,7

Thermal Parameters		
Solar thermal energy used for	[-]	SH + DHW @ 50°C (no tapping)
Heat demand	[kWh/a]	13580
Temperature range (application)	[°C]	25-50
Back-up system	[-]	electric resistance heater
Solar thermal energy storage type	[-]	ice store + Water - Short term
Storage Volume	[L]	300 + 1000
Solar thermal energy to system (Qsol)	[kWh/a]	6250
Heat generator energy (Qaux)	[kWh/a]	
Solar fraction(Qsol/(Qsol+Qaux))	[%]	

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	17,5%
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	8130 (AC)
Type of inverter	[-]	SMA Sunny Tripower
AC capacity per inverter	[kW]	
# of inverter	[-]	1
Inverter provider	[-]	SMA
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrial storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	16
Self-Consumption fraction	[%]	8

Economic Parameters		

Total investment cost (excl. VAT)	[€]	26,884
PVT-collector loop (excl. VAT)	[€]	14,642
Solar thermal energy storage (excl. VAT)	[€]	Inc. Inverter
Inverter (excl. VAT)	[€]	12,242
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	-
Specific investment cost	[€/m²]	672
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	7000
Fuel replaced	[-]	Oil
Cost for fuel replaced	[€/MWhfuel]	70
Local feed-in tariff	[€/MWhelectricity]	290

Sources	_	
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3.23 GSE AIR'SYSTEM

3.23.1 Introduction and description

The aim of this project is providing a heating supplement to a residential home by recovering the warm air created naturally through the greenhouse effect under photovoltaic solar panels integrated into the roof.

As a result, we are also optimizing the production of electricity from photovoltaic panels in order to make the customer as autonomous as possible in terms of energy.

Figure 46: View of the PVT air system on the roof.

3.23.2 Solar installations

The installation consists of 14 photovoltaic panels of BenQ brand with a power of 295 Wp per panel for a total power of 4.13 Wp. The photovoltaic field represents 23.8 m². It is oriented southeast (45°) and inclines 30°. The electricity produced by the photovoltaic panels is exploited by 14 micro-inverters (1 per panel) of the Enphase brand and partially stored in a 1.2 kW battery of the same brand. To these panels is added the GSE AIR'SYSTEM connected with a sheath behind each panel to the photovoltaic field.

3.23.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 47.

The system consists of a box containing a fan and a bypass. It is connected to the photovoltaic field with one 75 mm diameter aspiration pipe under each panel. During the day in winter, when the sun hits the panels, the heat builds up under them naturally by greenhouse effect. Thanks to this box and a temperature sensor placed under the panels, we take this air under the panels when the temperature below is sufficiently high, and we blow it through ducts of insufflation in the house of the customer to cover up to 30 % of its heating needs.

During the summer, the bypass closes the house side and opens to a roof hat to allow us to blow the warm air outward. In this way, the system ventilates the photovoltaic panels to improve their electric production up to 10%.

Solar photovoltaic panels have been integrated in the roof instead of tiles with our integration system GSE IN-ROOF System. These produce electricity that is fed back into the customer's network via an intelligent energy management system. This electricity will be stored in a 1.2kW battery if it is not self-consumed by the customer. It will be returned when the customer needs it, at night for example when the panels do not produce.

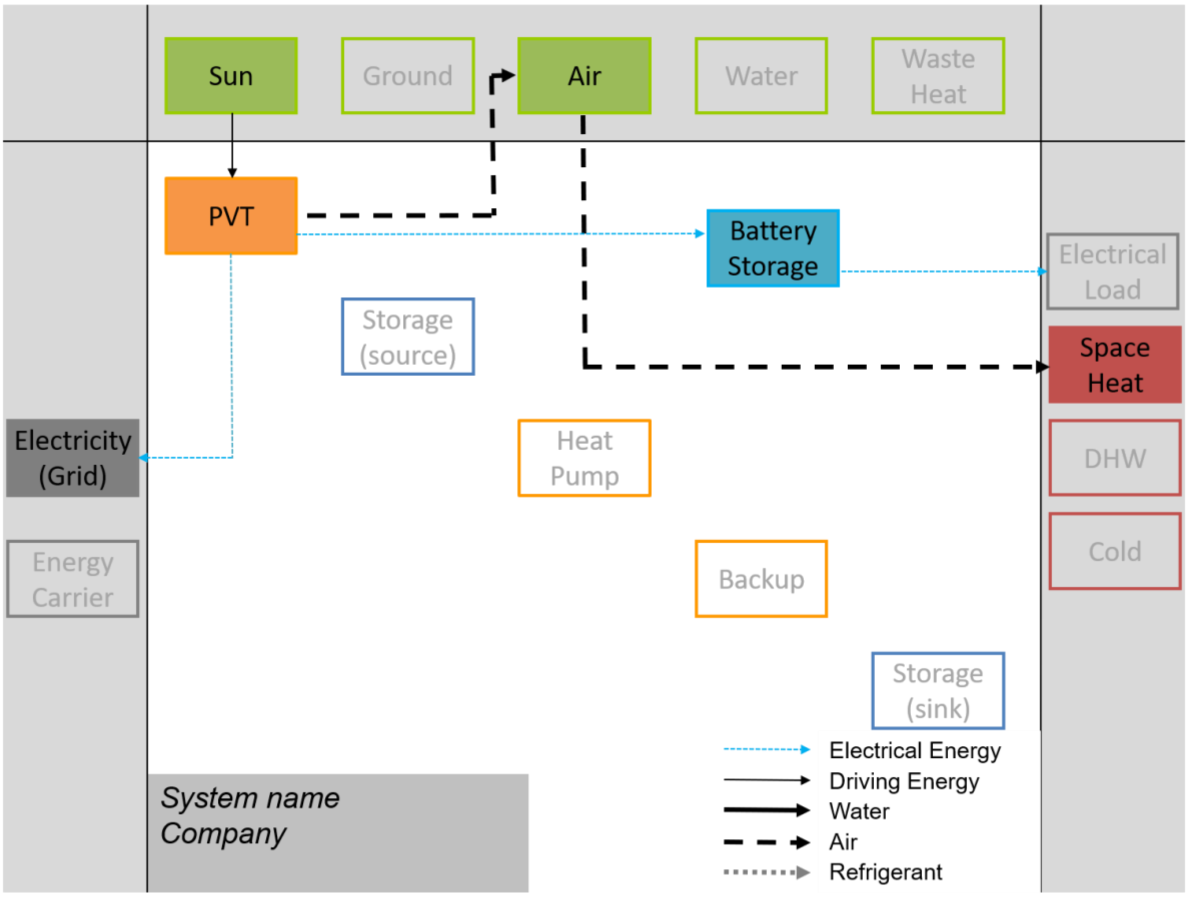

Figure 47: Visualisation of the PVT system "GSE AIR'SYSTEM".

3.23.4 Fact sheet

General Information		
Project name	[-]	GSE AIR'SYSTEM
Country	[-]	France
City	[-]	TRAINON
Year of operation start	[mm/yyyy]	09/2018
PVT system owner(s) (%)	[-]	The owner is the resident
PVT system operators(s)	[-]	Resident
PVT system developer	[-]	GSE INTEGRATION
Application	[-]	Single-family house

PLANT CONFIGURATION		
Panel model	[-]	BenQ 295w full black
PVT-Collector provider	[-]	BENQ
Category	[-]	Ventilated PV with heat recovery
Type	[-]	covered
Working Fluid	[-]	Air
Kind of installation	[-]	roof or facade integration
Tracking	[-]	Yes
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	SE = +45°
Tilt angle [hor. = 0°; vert. = 90°]	[°]	30°
# of modules	[-]	14
Installed collector area (gross)	[m²]	23,8
Installed collector area (aperture)	[m²]	22,8
Total energy output PVT-collector (Etotal)	[kW]	10800
Seasonal Performance Factor (System) SPFsys	[-]	4,7

Thermal Parameters		
Solar thermal energy used for	[-]	Air
Heat demand	[kWh/a]	12000
Temperature range (application)	[°C]	17 - 57°C
Back-up system	[-]	electrical heating element
Solar thermal energy storage type	[-]	none
Storage Volume	[L]	-
Solar thermal energy to system (Qsol)	[kWh/a]	6000
Heat generator energy (Qaux)	[kWh/a]	4500
Solar fraction(Qsol/(Qsol+Qaux))	[%]	43

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	295
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	4820
Type of inverter	[-]	Microinverter
AC capacity per inverter	[kW]	0,25
# of inverter	[-]	14
Inverter provider	[-]	Enphase
Electrical storage type	[-]	Battery (Lithium)
Storage integrated in AC/DC side	[-]	DC
Storage capacity (electrial storage)	[kWh]	1,2
Storage provider	[-]	Enphase
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	47
Self-Consumption fraction	[%]	70

Economic Parameters		
Total investment cost (excl. VAT)	[€]	14600
PVT-collektor loop (excl. VAT)	[€]	8600
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	1600
Electrical storage (excl. VAT)	[€]	1500
others (excl. VAT)	[€]	2900
Specific investment cost	[€/m²]	600
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	1200€ (8,2%)
Fuel replaced	[-]	
Cost for fuel replaced	[€/MWhfuel]	-
Local feed-in tariff	[€/MWhelectricity]	17

Sources		
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3.24 Single-family house in PERTH western Australia

3.24.1 Introduction and description

The object concerned is a single story freestanding family house. The house has incorporated a number of new features a part of the endeavour to decarbonise the energy supply and make more electrical capacity available for complete self-sustainability of the domestic load and future electric mobility solutions. Future planning includes provision for electric car charging and a battery energy storage system. A 3.5 kW rated Sunovate System was installed in 2018 to provide space heating during winter and electricity for water heating with a dedicated solar PV element. The Sunovate PVT system includes 6 x 190 W Conergy PV panels.

The house was originally fitted with an electric boosted 3 panel Solarhart 300L SHW, gas space heating and a ducted reverse cycle air conditioner. In late 2011 a 3.0 kW PV system was fitted which was upgraded to 5.0 kW together with the removal of the aged solar hot water. Water heating was replaced with a larger 315L dual element electric resistance storage unit. The gas heating was decommissioned and the gas utility service disconnected. The existing ducted air conditioning system (which failed) was replaced with a smaller split reverse cycle air conditioning system and the ducting modified and repurposed for integrating the PVT system.

Figure 48: View of the PVT system on the roof of the single story family house in Perth.

3.24.2 Solar installations

6 PVT collectors (Conergy 190M) were installed on the flat roof of the building (total collector area, 7.59 m2; 1.14 kWe electrical output). The modules are oriented to the northwest (45°) with an inclination angle of 22.5°. In addition, a PV system with the same orientation comprising 26 modules of the same type, though without heat absorbers, was installed (32.9 m2; 4.94 kWe).

3.24.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 49. It is based on a simple electric resistance hot water load for preheating the large 315L hot water storage tank and simple closed loop air flow circuit for winter space heating. Excess heat in summer is discharge directly to atmosphere in an open loop mode to increase PV performance.

Water heating services are backed up by the grid through a separate electric resistance heater on timer. Space heating serviced are backed up by grid connected split reverse cycle air-conditioner.

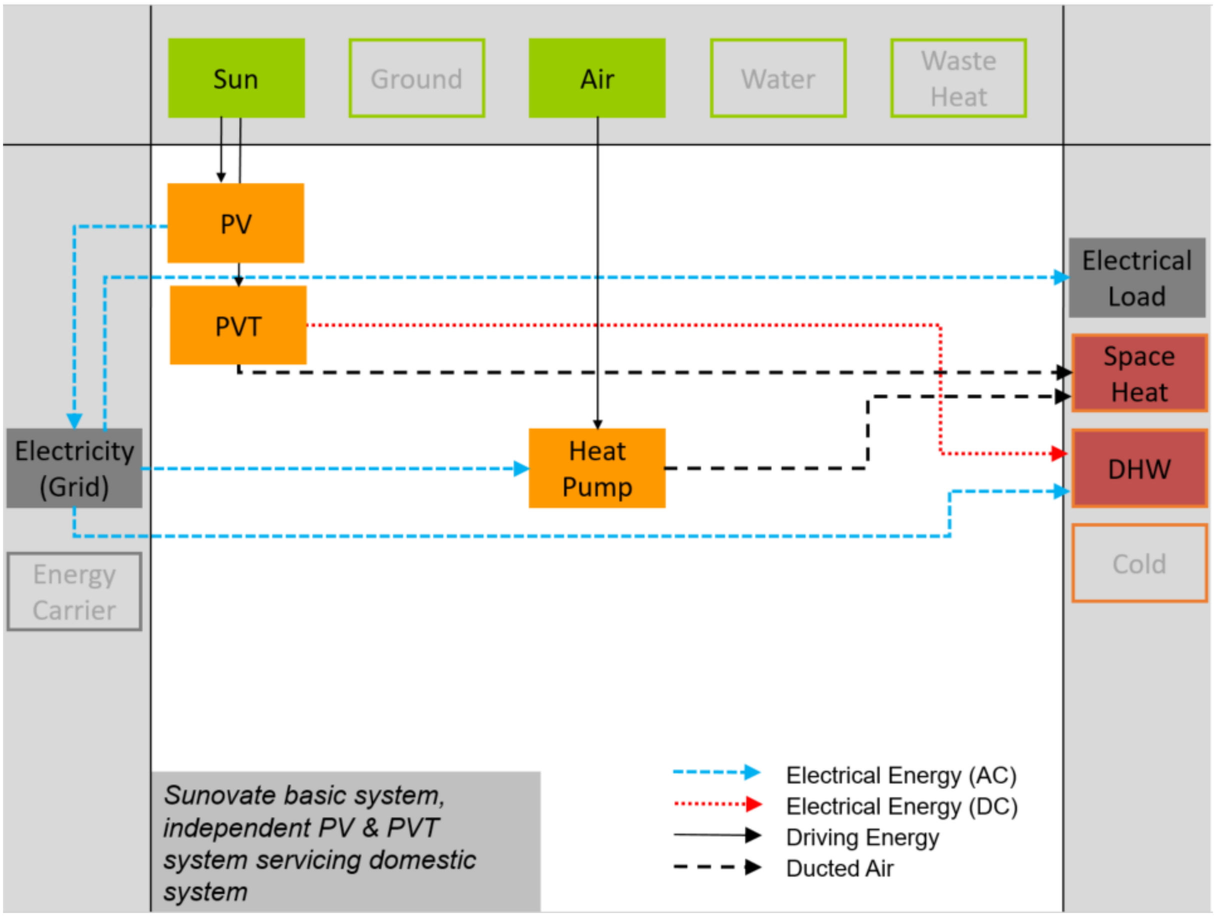

Figure 49: Visualisation of the Basic PVT system "South Perth - Domestic".

3.24.4 Fact sheet

General Information		
Project name	[-]	Sunovate Domestic Pilot and Demonstration (P&D) plant
Country	[-]	AU
City	[-]	South Perth Western Australia
Year of operation start	[mm/yyyy]	06/2018

PVT system owner(s) (%)	[-]	the owner is the resident
PVT system operators(s)	[-]	owner / installer
PVT system developer	[-]	Sunovate
Application	[-]	Single story -family house

PLANT CONFIGURATION		
Panel model	[-]	Conergy 190M
PVT-Collector provider	[-]	Sunovate Pty Ltd
Category	[-]	PVT air collector
Type	[-]	WISP
Working Fluid	[-]	Air
Kind of installation	[-]	on-roof frame mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	-45
Tilt angle [hor. = 0°; vert. = 90°]	[°]	22.5
# of modules	[-]	6
Installed collector area (gross)	[m²]	7,5
Installed collector area (aperture)	[m²]	7,2
Total energy output PVT-collector (Etotal)	[kW]	3,5
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	Hot water, space heating
Heat demand	[kWh/a]	not known
Temperature range (application)	[°C]	corresponding to applications
Back-up system	[-]	Grid connected electric resistance heater (hot water service) Grid Connected air sourced heat pump (space heating)
Solar thermal energy storage type	[-]	315L insulated domestic hot water tank. Building fabric for space heating
Storage Volume	[L]	315L insulated tank,
Solar thermal energy to system (Qsol)	[kWh/a]	not yet known
Heat generator energy (Qaux)	[kWh/a]	not yet known
Solar fraction(Qsol/(Qsol+Qaux))	[%]	-

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	14,7
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	4500
Type of inverter	[-]	DC Switched Direct Connect
AC capacity per inverter	[kW]	-
# of inverter	[-]	-
Inverter provider	[-]	-
Electrical storage type	[-]	-

Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	unknown
Self-Consumption fraction	[%]	unknown

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	-
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	-
Specific investment cost	[€/m²]	-
Calculated solar thermal system life time	[a]	-
Subsidy, € or % of total investment costs	[€/%]	-
Fuel replaced	[-]	-
Cost for fuel replaced	[€/MWhfuel]	-
Local feed-in tariff	[€/MWhelectricity]	-

Sources		
Author	[-]	Glen Ryan
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Homepage	[-]	www.sunovate.com.au

3.25 Office building (Specific)

3.25.1 Introduction and description

The Active Office at Swansea University is the UK's first energy-positive office building. The office employs an evacuated-tube PVT array on the south facing façade, a PV array on the roof, lithium ion batteries and an air source heat pump. The PVT array is shown in Figure 50.

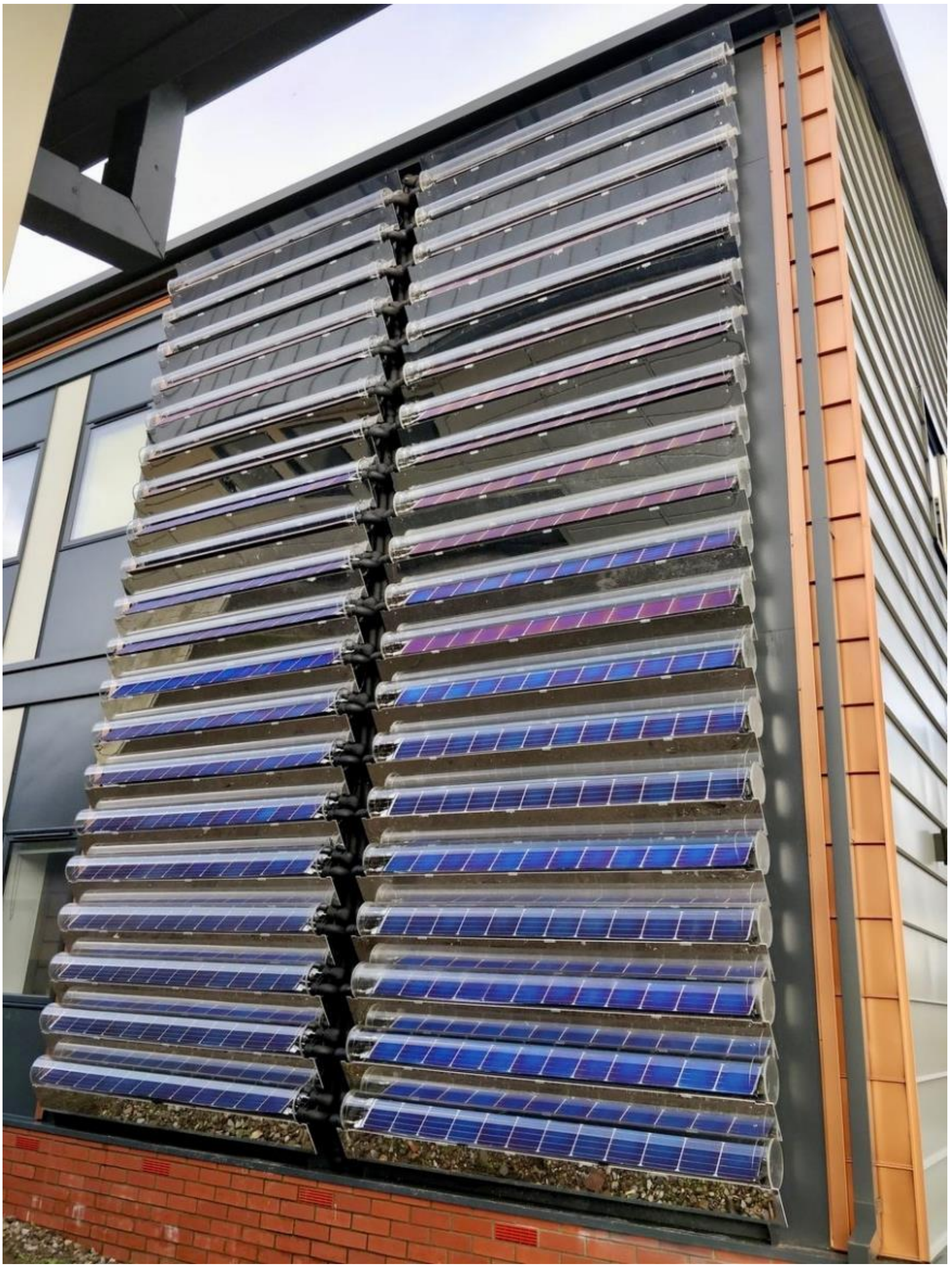

Figure 50: The evacuated tube PVT array (Virtu PVT by Naked Energy) on the south facing façade of the Active Office building at the University of Swansea.

3.25.2 Solar installations

40 PVT collectors (VirtuPVT by Naked Energy) were installed on the southern facing facade of the building (total aperture area, 16 m2; thermal output, 11 kWp; electrical output, 2.8 kWp). In addition, a 22kWp CIGS PV array was installed on the roof (not PVT).

3.25.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 51. Heat is supplied by both the PVT array and an air source heat pump in parallel.

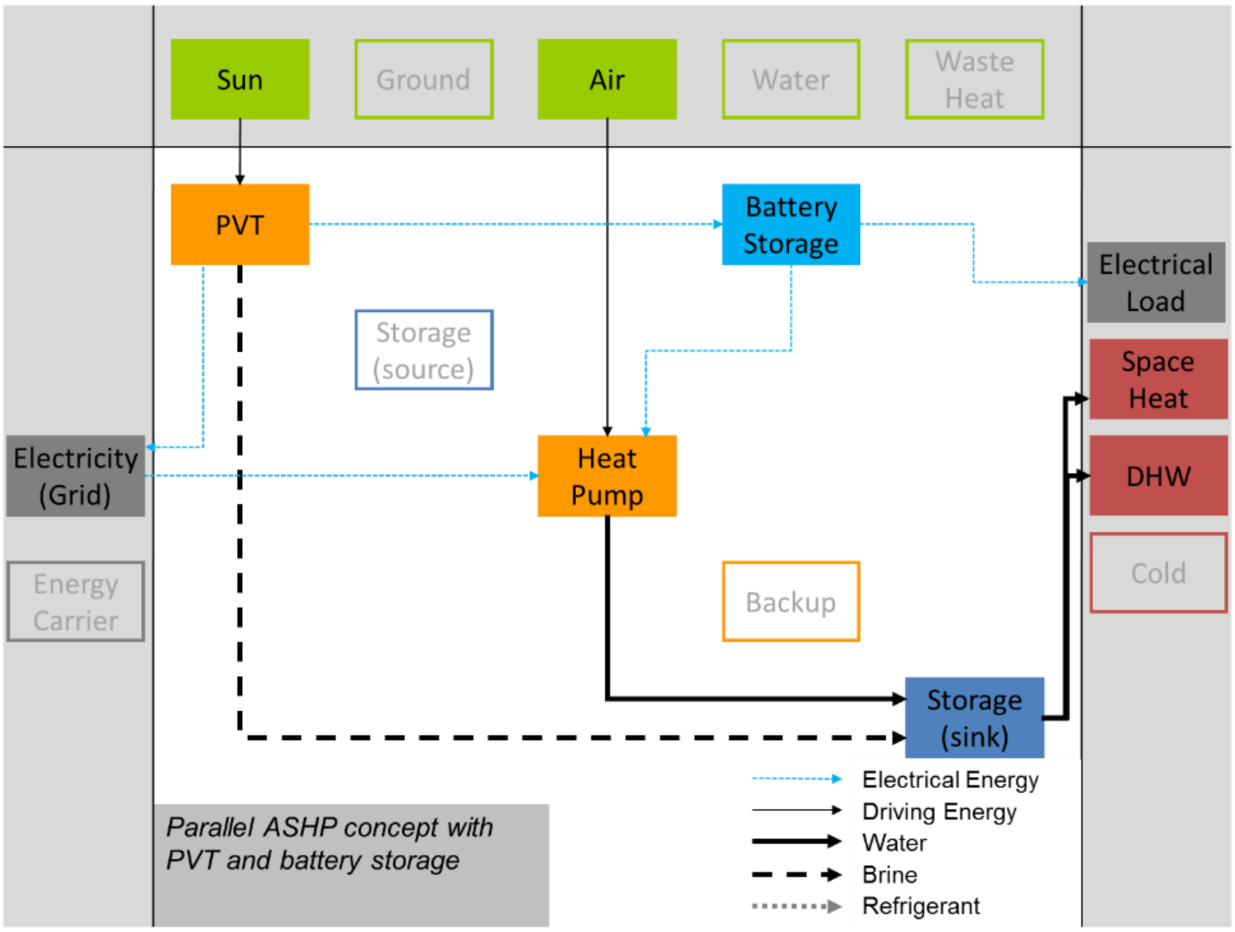

Figure 51: Visualisation of the PVT system at the Specific Active Office in Swansea, UK.

3.25.4 Fact sheet

General Information		
Project name	[-]	Active Office
Country	[-]	UK
City	[-]	Swansea
Year of operation start	[mm/yyyy]	2018
PVT system owner(s) (%)	[-]	University of Swansea
PVT system operators(s)	[-]	University of Swansea
PVT system developer	[-]	Naked Energy Ltd/Pursey and Bal/SPECIFIC
Application	[-]	Energy-positive office building

PLANT CONFIGURATION		
Panel model	[-]	VirtuPVT
PVT-Collector provider	[-]	Naked Energy Ltd
Category	[-]	PVT liquid collector
Type	[-]	Evacuated tube
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	facade mounted
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	35
# of modules	[-]	40
Installed collector area (gross)	[m²]	27
Installed collector area (aperture)	[m²]	16
Total energy output PVT-collector (Etotal)	[kW]	2.8
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	Space heating and DHW
Heat demand	[kWh/a]	not known
Temperature range (application)	[°C]	Up to 70C
Back-up system	[-]	Air source heat pump
Solar thermal energy storage type	[-]	Water tank
Storage Volume	[L]	2,000 litre
Solar thermal energy to system (Qsol)	[kWh/a]	5640
Heat generator energy (Qaux)	[kWh/a]	unknown
Solar fraction(Qsol/(Qsol+Qaux))	[%]	unknown

Electrical Parameters		
Module type	[-]	Monocrystalline, PERC
Module efficiency at STC (25°C; 1000W/m²)	[%]	16
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	2080
Type of inverter	[-]	Micro-inverter
AC capacity per inverter	[kW]	-
# of inverter	[-]	8
Inverter provider	[-]	Enphase
Electrical storage type	[-]	Li Ion Battery
Storage integrated in AC/DC side	[-]	DC
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	100
Self-Consumption fraction	[%]	100

Economic Parameters		
Total investment cost (excl. VAT)	[€]	-
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	-
Specific investment cost	[€/m²]	-
Calculated solar thermal system life time	[a]	-
Subsidy, € or % of total investment costs	[€/%]	-
Fuel replaced	[-]	-
Cost for fuel replaced	[€/MWhfuel]	-
Local feed-in tariff	[€/MWhelectricity]	-

Sources		
Author	[-]	Alexander Mellor
Company of Author	[-]	Naked Energy Ltd
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Phone	[-]	" +44 1293 541449 "
Homepage	[-]	https://www.nakedenergy.co.uk

3.26 Henri Willig cheese factory

3.26.1 Introduction and description

The object concerned is a food industry factory in Katwoude, the Netherlands. The system has been operational since July 2017, where it produces both heat and electricity to meet portion of their daily demand around 8 m^3 at 45 °C. Hot water is needed only 5 days a week on average for cheese producing equipment. The project was qualified for the SDE+ subsidy in the Netherlands on both heat and electricity generation.

Figure 52: View of the PVT system on the roof of Henri Willig cheese factory in Katwoude, the Netherlands.

3.26.2 Solar installations

88 low C-PVT collectors (Solarus PowerCollertor$_{TM}$) were installed on the flat roof of the building with a total collector area of 226.2 m_2, being divided in 22 kWp_{elect} and $110kWp_{th}$. The modules are oriented to the southeast (20°) with an inclination angle of 10°.

3.26.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 53. 110 kWp system pre-heats the tank up to 30 °C in winter and 75 °C in summer. An 8 m_3 hygienic tank is used in between the collectors and the inline gas boiler units to deliver heat. A mixing valve at the outlet of the tank ensures that water is delivered at temperatures around 45 °C. A 22 kWp electrical system with module level optimization is connected and the energy produced is consumed by the building. In 2018 the collectors have supplied close to 54 MWh of heat and 15 MWh of electricity.

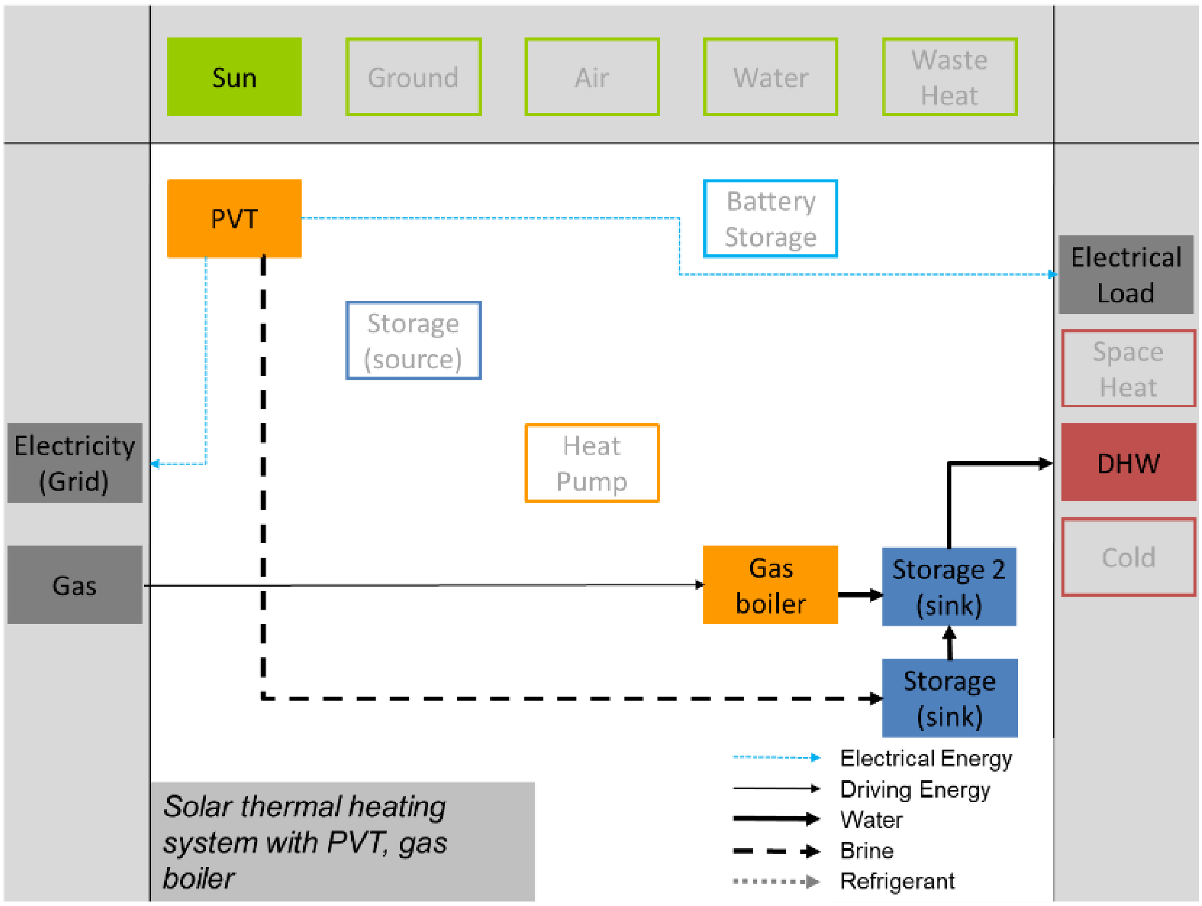

Figure 53: Visualisation of the C-PVT system 'Henri Willig cheese factory'.

3.26.4 Fact sheet

General Information	
Project name	Henri Willig cheese factory
Country	Netherlands
City	Katwoude
Year of operation start	July, 2017
PVT system owner(s) (%)	Henri Willig cheese factory (100%)
PVT system operators(s)	Henri Willig cheese factory
PVT system developer	SOLARUS
Application	Electricity for production and hot water for cleaning processes

PLANT CONFIGURATION		
Panel model	[-]	SOLARUS PowerCollector
PVT-Collector provider	[-]	SOLARUS
Category	[-]	C-PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol mixture
Kind of installation	[-]	on-roof mounted

Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	20
Tilt angle [hor. = 0°; vert. = 90°]	[°]	10
# of modules	[-]	88
Installed collector area (gross)	[m²]	226.16
Installed collector area (aperture)	[m²]	203.28
Total energy output PVT-collector (Etotal)	[kWh]	68539
Seasonal Performance Factor (System) SPFsys	[-]	unknown

Thermal Parameters		
Solar thermal energy used for	[-]	Cheese production process
Heat demand	[kWh/a]	NA
Temperature range (application)	[°C]	45°C
Back-up system	[-]	gas boiler
Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	8000
Solar thermal energy to system (Qsol)	[kWh/a]	53687 (at the HX)
Heat generator energy (Qaux)	[kWh/a]	Not available
Solar fraction(Qsol/(Qsol+Qaux))	[%]	Not available

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25 °C; 1000 W/m²)	[%]	9.73
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	14852 (AC side)
Type of inverter	[-]	2 string inverters
AC capacity per inverter	[kW]	12.5 and 10
# of inverter	[-]	2
Inverter provider	[-]	SolarEdge
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	NA
Self-Consumption fraction	[%]	100% AS the PV does not even meet their base load

Economic Parameters		
Total investment cost (excl. VAT)	[€]	NA
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	NA
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	NA

others (excl. VAT)	[€]	-
Specific investment cost	[€/m²]	NA
Calculated solar thermal system life time	[a]	25
Subsidy, € or % of total investment costs	[€/%]	SDE+ for 15 years
Fuel replaced	[-]	Electricity & gas
Cost for fuel replaced	[€/MWhfuel]	NA
Local feed-in tariff	[€/MWhelectricity]	NA

Sources		
Author	[-]	Diogo Cabral
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3.27 GreenTEC Campus in Enge-Sande

3.27.1 Introduction and description

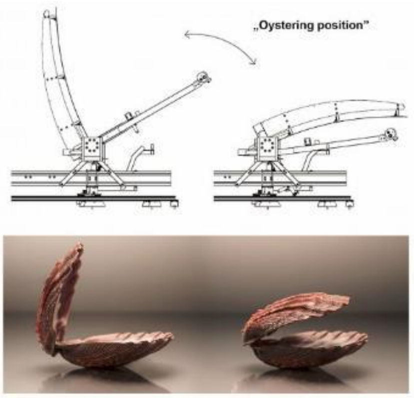
SunOyster Systems GmbH (SOS) develops the SunOyster, a concentrating solar technology for the co-generation of power and heat (CPVT). The primary concentration is by standard parabolic mirrors and the secondary concentration by tailor-made lenses, the SunOyster Crystals.

The building is the office and factory for the SunOyster receiver production which was promoted under the SME instrument of the European Union. It is a former military building which is forming part of the GreenTEC Campus in Enge-Sande, Northern Frisia, 150 km North of Germany.

3.27.2 Solar installations

The solar installation consists of one SunOyster 16 hybrid pvplus.

The **SunOyster 16** consists of two parabolic mirrors of approx. 8 m² gross mirror surface which are tracking the sun bi-axially all day, concentrating the direct radiation on a focus line. In case of storm, the SunOyster closes into a secure flat position, the Oystering position, in which the machines survived already various heavy storm.



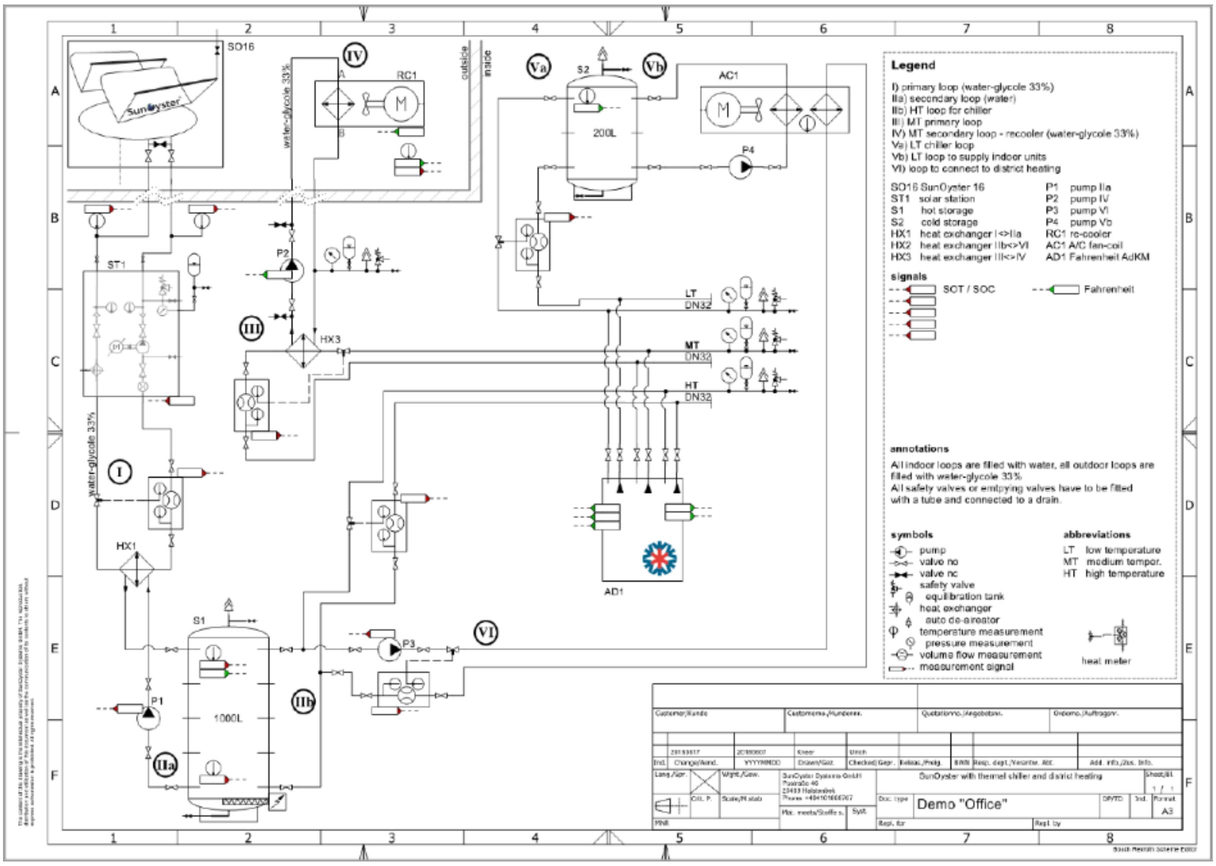
In the focus line, two **hybrid receivers** of the pre-series generate at the same time electricity and heat. The electric output is 3.2 kW p and the parallel thermal output 6 kW of heat. With some further optimization, the SunOyster 16 from serial production shall have 4.7 kW p and 7.5 kW thermal power.

In order to use the space most efficiently, the SunOyster mirrors of the version **pvplus** are surrounded by 12 PV modules which are tracking together with the SunOyster from East to West. However, their elevation is fixed. They contribute another 3.8 kW p to the total electric output.

Together, the SunOyster an pvplus shall generate at least the double total energy output in form of both electricity and heat of photovoltaics, reaching the best **surface efficiency** of solar technologies.

3.27.3 Heat supply concept and integration of PVT collectors

The heat of the SunOyster is supplied to a 1000 l buffer storage. From there, it can be used by a Fahrenheit ecoo thermal chiller, converting the heat into cold and storing cold water in a small 200 l cold water storage. The distribution of both heat and cold is via a fan coil. Below is a hydraulic scheme.



The installation looks as follows:

3.27.4 Fact sheet

General Information		
Project name	[-]	SOcool Office
Country	[-]	D
City	[-]	25917 Enge-Sande, Schleswig-Holstein (150 km North of Hamburg)
Year of operation start	[mm/yyyy]	07/2018
PVT system owner(s) (%)	[-]	SunOyster Systems (SOS)
PVT system operators(s)	[-]	SOS
PVT system developer	[-]	SOS
Application	[-]	Solar thermal cooling and heating of small office

PLANT CONFIGURATION		
Panel model	[-]	SunOyster 16 hybrid pvplus
PVT-Collector provider	[-]	SunOyster Systems
Category	[-]	CPVT liquid collector
Type	[-]	Concentrating
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	Ground-installation
Tracking	[-]	Yes, bi-axial
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	[-]
Tilt angle [hor. = 0°; vert. = 90°]	[°]	17° of pvplus
# of modules	[-]	2 receivers, 12 PV modules
Installed collector area (gross)	[m²]	15 for mirrors, 19.2 for PV
Installed collector area (aperture)	[m²]	34.2

Total energy output PVT-collector (Etotal)	[kWh]	Measurement not completed
Seasonal Performance Factor (System) SPFsys	[-]	Measurement not completed

Thermal Parameters		
Solar thermal energy used for	[-]	Solar thermal cooling or heating
Heat demand	[kWh/a]	Measurement not completed
Temperature range (application)	[°C]	60 for heating, >=70 for cooling
Back-up system	[-]	District heating, none for cooling
Solar thermal energy storage type	[-]	Steel tanks with water
Storage Volume	[L]	1000 l for heat, 200 l for cold
Solar thermal energy to system (Qsol)	[kWh/a]	Measurement not completed
Heat generator energy (Qaux)	[kWh/a]	Measurement not completed
Solar fraction(Qsol/(Qsol+Qaux))	[%]	Measurement not completed

Electrical Parameters		
Module type	[-]	SunOyster receivers
Module efficiency at STC (25°C; 1000W/m²)	[%]	21,3 pre-series, expected 30% series production
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	Measurement not completed
Type of inverter	[-]	transformerless
AC capacity per inverter	[kW]	3.6 and 4.2 kW
# of inverter	[-]	2
Inverter provider	[-]	ABB
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrical storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	Measurement not completed
Self-Consumption fraction	[%]	Measurement not completed

Sources		
Author	[-]	Dr. Carsten Corino
Company of Author	[-]	SOS
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Phone	[-]	0049 4101 8548181
Homepage	[-]	www.sunoyster.com

3.28 Pilot PVT plant Cittadella Universitaria

3.28.1 Introduction and description

The solar plant is installed in the "Cittadella Universitaria" (i.e. the campus of University of Catania), Catania, Italy (Lat.37.55N, Long.14.29E), on the terrace of building 13.

This is a pilot plant, which has the main scope to evaluate the performance of a PVT system under different operating conditions, as well as to compare the experimental data with the results carried out by numerical simulation on such PVT plant. The design of the PVT plant allows to analyze different electrical and hydraulic configurations (e.g., it is possible to have an electrical series connections and a parallel hydraulic connection). The thermal load can be modified to simulate different profiles of energy demands.

Figure 54: View of the PVT system at the University of Catania.

3.28.2 Solar installations

Two PV/T collectors (Dualsun wave 250/880) are installed on the flat roof of the building (total collector area, 3.32 m$_2$; 0.5 kWp electrical output). The modules are south oriented (azimuth angle = 0°) and the tilt angle is equal to 25° (the tilt angle can be changed manually).

3.28.3 Heat supply concept and integration of PVT collectors

The scheme of the hydronic section of the PVT plant is reported in Figure 38.

The position of the sensors for the monitoring of fluid temperatures and flow rates are also showed. .

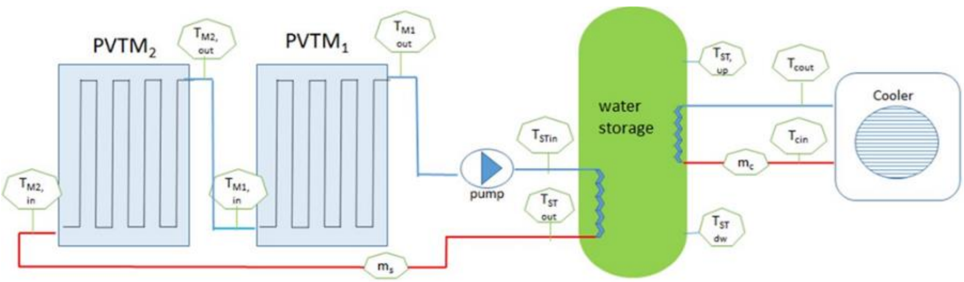

Figure 55: Scheme of the hydronic section of the PV/T plant with the measured variables

The main components of the plant are: two PV/T modules; a solar thermal tank (capacity 185 litre), a water pump, a dry cooler and the network tubes.
The dry cooler has the function to mimic the domestic hot water demand.
The measured variables are the temperatures of the fluid at the inlet and outlet of each PVT modules, namely $T_{Mi,in}$ and $T_{Mi,out}$, at the inlet and outlet of the thermal solar tank, $T_{ST,in}$ and $T_{ST,out}$, at the bottom and the top of the solar

tank, $T_{ST,dw}$ and $T_{ST,up}$, as well as the flowrate, m_S. Moreover, the temperatures, T_{Cout} and T_{Cin}, and cooling volumetric flowrate, m_C, are measured in the cooling circuit. In addition the temperatures in the back of the modules are measured ($T_{M1,b}$ and $T_{M2,b}$).

The designed PVT hydronic system allows the connection in series or in parallel of the two modules by means of partitioning valves.

The electric demand of the PVT is set by means of an electronic load used for the electrical characterization of the PVT modules (tracing of I-V and P-V curves).

3.28.4 Fact sheet

General Information		
Project name	[-]	Moses- Pilot PV/T plant
Country	[-]	Italy
City	[-]	Catania
Year of operation start	[mm/yyyy]	03/2017
PVT system owner(s) (%)	[-]	University of Catania
PVT system operators(s)	[-]	Moses-Lab
PVT system developer	[-]	Moses-Lab
Application	[-]	Research studies
PLANT CONFIGURATION		
Panel model	[-]	Wave
PVT-Collector provider	[-]	DualSun
Category	[-]	Unglazed liquid PVT collector
Type	[-]	uncovered
Working Fluid	[-]	Water
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No (manual variation of tilt angle)
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	25
# of modules	[-]	2
Installed collector area (gross)	[m²]	3.32
Installed collector area (aperture)	[m²]	3.16
Total energy output PVT-collector (Etotal)	[kWh]	2500
Seasonal Performance Factor (System) SPFsys	[-]	2.85

Thermal Parameters		
Solar thermal energy used for	[-]	DHW for single-family house (simulated)
Heat demand	[kWh/a]	2500
Temperature range (application)	[°C]	45
Back-up system	[-]	air/water heat pump

Solar thermal energy storage type	[-]	Water - Short term
Storage Volume	[L]	189
Solar thermal energy to system (Qsol)	[kWh/a]	1450
Heat generator energy (Qaux)	[kWh/a]	1050
Solar fraction(Qsol/(Qsol+Qaux))	[%]	58

Electrical Parameters	-	
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	15.4
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	1040
Type of inverter	[-]	
AC capacity per inverter	[kW]	
# of inverter	[-]	
Inverter provider	[-]	
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	
Storage capacity (electrical storage)	[kWh]	
Storage provider	[-]	
Grid connected	[-]	No
Degree of self-sufficiency	[%]	unknown
Self-Consumption fraction	[%]	unknown

Economic Parameters	-	
Total investment cost (excl. VAT)	[€]	10000
PVT-collector loop (excl. VAT)	[€]	3500
Solar thermal energy storage (excl. VAT)	[€]	1500
Inverter (excl. VAT)	[€]	
Electrical storage (excl. VAT)	[€]	
others (excl. VAT)	[€]	5000
Specific investment cost	[€/m²]	3125
Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	
Fuel replaced	[-]	electricity
Cost for fuel replaced	[€/MWhfuel]	250
Local feed-in tariff	[€/MWhelectricity]	

Sources	-	
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3.29 Pilot PVT plant - Demonstration of a PVT solar assisted heat pump system with buffer and DHW storage tanks.

3.29.1 Introduction and description

A demonstration system of a PVT solar assisted heat pump system was installed and operated at the Technical University of Denmark. In the system configuration, the uninsulated PVT collector operated both as solar thermal absorber during sunny periods and as an energy absorber by extracting heat from the ambient air during periods with no solar irradiance. A cold buffer storage tank, which was charged by the thermal absorber of the PVT collector, was used as the source for the heat pump.

Figure 56: View of the PVT collector on the test facility at DTU.

3.29.2 Solar installations

One uninsulated/WISC PVT collector with a total absorber gross collector area of 3.1 m^2 with the PV cells covering 2.58 m^2 of the panel was installed at the test facility. The PVT collector faced due south with a tilt of 45°. The PVT collector was installed with a distance of approximately 10 cm above the roof structure so that air could pass underneath it as well.

3.29.3 Heat supply concept and integration of PVT collectors

The thermal absorber of the PVT collector was connected in a solar collector loop to a heat exchanger spiral in the bottom of a 160 l DHW storage tank. The hydraulic loop was furthermore connected to a 200 l buffer storage tank. As the PVT collectors were uninsulated and could work as heat exchangers with the ambient, they could still extract low temperature heat from the ambient, when no solar radiation was available. Automated draw offs of hot water were made three times per day to simulate an actual installation in a house. 1.5 kWh of energy was tapped three times per day at 7, 12, 18 h. A Vølund F1155-6 heat pump was used to heat the DHW tank when the heat from the solar collectors was insufficient to maintain the required temperature level. This corresponds to approximately 1 m^2 PVT area per kW thermal power of the heat pump. This heat pump was designed to cover both a space heating and domestic hot water demand. In the present system, the system was only used for DHW. The heat pump was therefore oversized for the demonstration system presented. A cold buffer storage tank was used as the source for the cold side of the heat pump. The thermal absorber of the PVT panels could charge both tanks. The heat pump charged the DHW tank while extracting heat from the buffer storage tank when the temperature level of the DHW tank dropped below a set value.

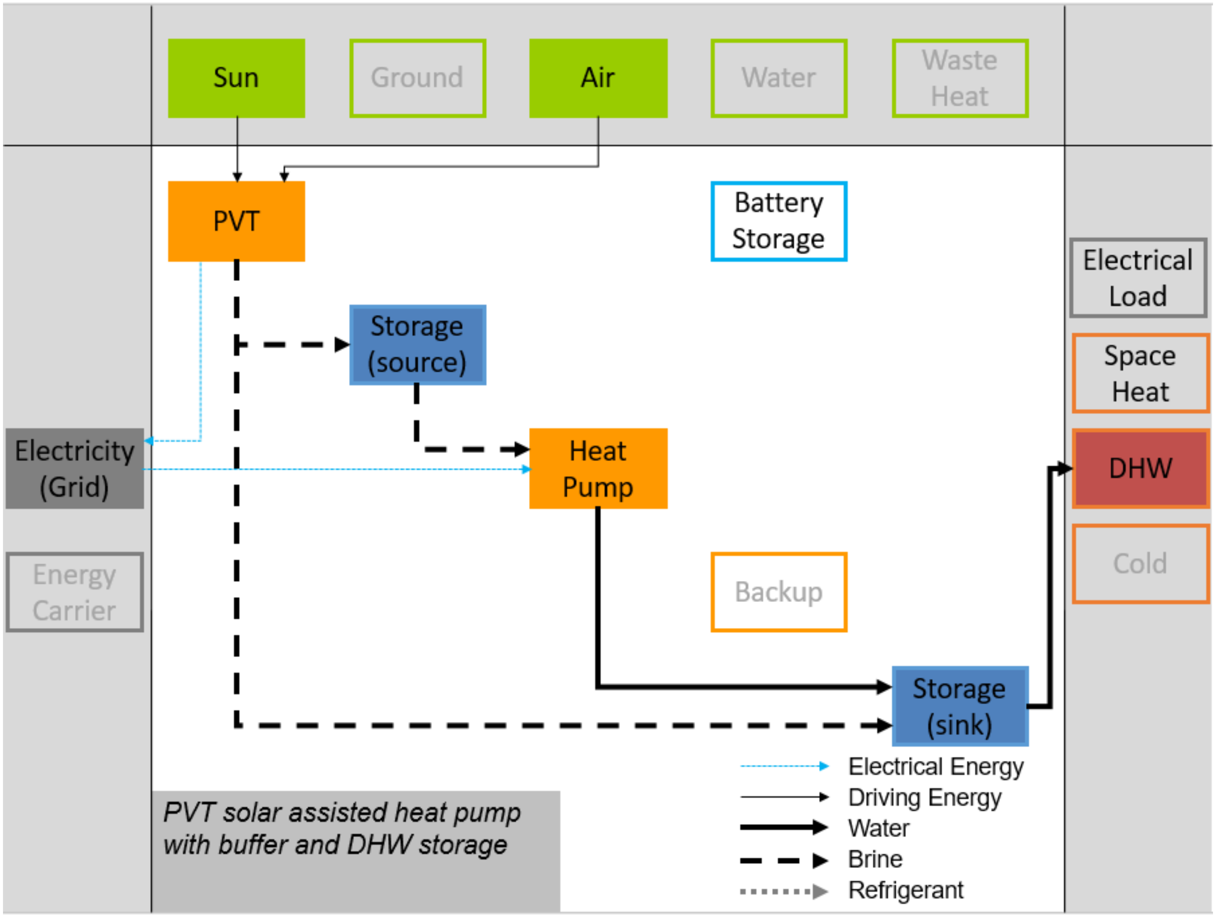

Figure 57: Visualisation of the PVT system.

3.29.4 Fact sheet

General Information		
Project name	[-]	PVT - 2 tank - HP laboratory test system
Country	[-]	Denmark
City	[-]	Kgs. Lyngby
Year of operation start	[mm/yyyy]	2016
PVT system owner(s) (%)	[-]	DTU
PVT system operators(s)	[-]	DTU
PVT system developer	[-]	DTU, Racell, COWI
Application	[-]	DHW supply

PLANT CONFIGURATION		
Panel model	[-]	Prototype
PVT-Collector provider	[-]	Racell Technologies
Category	[-]	PVT liquid collector
Type	[-]	uncovered
Working Fluid	[-]	Water/Glycol Mixture
Kind of installation	[-]	on-roof mounted
Tracking	[-]	No

System Orientation [E = +90°; S = 0°; W = -90°]	[°]	0
Tilt angle [hor. = 0°; vert. = 90°]	[°]	45
# of modules	[-]	1
Installed collector area (gross)	[m²]	3.14
Installed collector area (aperture)	[m²]	3.14
Total energy output PVT-collector (Etotal)	[kWh]	1710
Seasonal Performance Factor (System) SPFsys	[-]	1.83

Thermal Parameters		
Solar thermal energy used for	[-]	DHW preparation and source for heat pump
Heat demand	[kWh/a]	1642.5
Temperature range (application)	[°C]	-5 to 50
Back-up system	[-]	brine/water heat pump
Solar thermal energy storage type	[-]	Tanks
Storage Volume	[L]	Buffer storage 200L, DHW storage 160L
Solar thermal energy to system (Qsol)	[kWh/a]	1407
Heat generator energy (Qaux)	[kWh/a]	1481
Solar fraction(Qsol/(Qsol+Qaux))	[%]	48.7%

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	18.1
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	Not measured
Type of inverter	[-]	micro-inverter INV350-60
AC capacity per inverter	[kW]	0.24
# of inverter	[-]	1
Inverter provider	[-]	AEconversion
Electrical storage type	[-]	None
Storage integrated in AC/DC side	[-]	None
Storage capacity (electrical storage)	[kWh]	None
Storage provider	[-]	No
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	8.9%
Self-Consumption fraction	[%]	26.6%

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	research project - no realistic cost
PVT-collector loop (excl. VAT)	[€]	research project - no realistic cost
Solar thermal energy storage (excl. VAT)	[€]	research project - no realistic cost
Inverter (excl. VAT)	[€]	250
Electrical storage (excl. VAT)	[€]	-
others (excl. VAT)	[€]	research project - no realistic cost
Specific investment cost	[€/m²]	research project - no realistic cost

Calculated solar thermal system life time	[a]	20
Subsidy, € or % of total investment costs	[€/%]	-
Fuel replaced	[-]	Electricity
Cost for fuel replaced	[€/MWhfuel]	306
Local feed-in tariff	[€/MWhelectricity]	80/53

Sources		
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3.30 Pilot PVT plant - Covered PVT collectors integrated into façade module for DHW preparation

3.30.1 Introduction and description

Test cell for long-term testing of energy-active façade modules was built on the experimental area of the UCEEB CTU. One integrated PVT collector was with standard solar glass on the top of the PVT absorber and second collector has spectrally selective low-e coating on the top of the absorber. Integrated PVT collector for the administration building was constructed. The façade module consist of glazed PVT collector, window with triple glazing, and glass rasters. Glass rasters reflects beam radiation during summer months a during winter months rasters allow radiation entry to the indoor environment.

Figure 58: Two façade modules with integrated covered PVT collectors

3.30.2 Solar installations

Two different facade modules were installed on the south wall (azimuth -15°) of the test cell. Test cell is divided into two parts. First part is for necessary HVAC facilities, second part is testing room with controlled indoor temperature. Thermal energy from PVT collectors is stored in 160 l solar tank.

3.30.3 Heat supply concept and integration of PVT collectors

Solar PVT system is dedicated to the preparation of domestic hot water in 160 l solar tank. Conventional controller has been installed with the monitoring of the temperature difference and switching on and off the circulation pump of the system. Mass flow in the collector loop was set to 90 $l.h^{-1}$. Hot water load has been emulated. Every night was the solar tank discharged till the temperature in the top of the tank was 20 °C. Cooling unit above the roof is for cooling of 200 l cold water tank. This cooled water is used for cooling in the testing room and for controlled cooling of the solar tank. Second part of the test cell is isolated testing room where ambient temperature is controlled by the electric heater and air cooler. Both cooling power and heating power are measured. PVT collectors are connected with inverter and then the electrical energy is wasted in the grid.

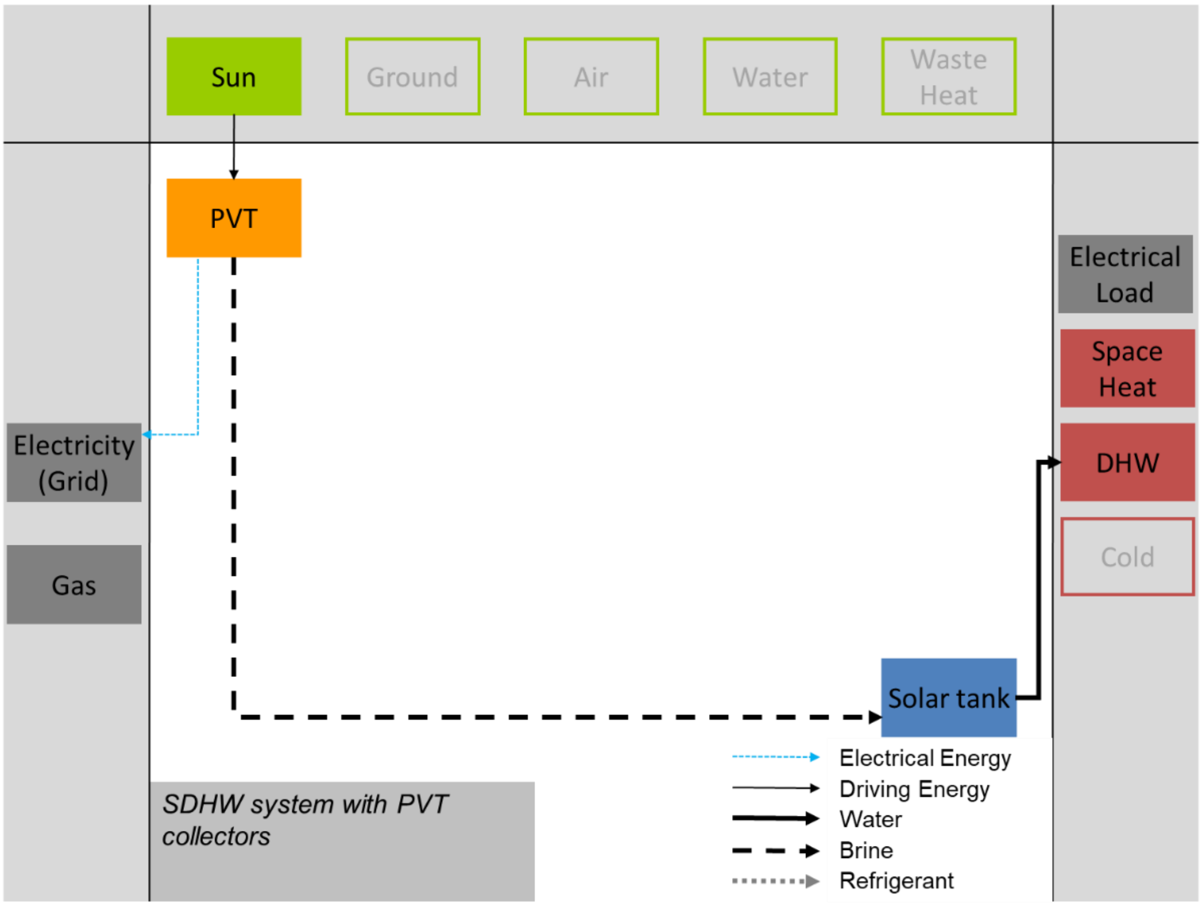

Figure 59: Visualisation of the PVT system.

3.30.4 Fact sheet

General Information		
Project name	[-]	Energy-active façade module
Country	[-]	Czech republic
City	[-]	Bustehrad
Year of operation start	[mm/yyyy]	2017
PVT system owner(s) (%)	[-]	UCEEB CTU
PVT system operators(s)	[-]	UCEEB CTU
PVT system developer	[-]	UCEEB CTU
Application	[-]	DHW preparation

PLANT CONFIGURATION		
Panel model	[-]	Prototype
PVT-Collector provider	[-]	UCEEB CTU
Category	[-]	PVT liquid collector
Type	[-]	covered
Working Fluid	[-]	Water/Glycol Mixture

Kind of installation	[-]	façade integration
Tracking	[-]	No
System Orientation [E = +90°; S = 0°; W = -90°]	[°]	15
Tilt angle [hor. = 0°; vert. = 90°]	[°]	90
# of modules	[-]	2
Installed collector area (gross)	[m²]	3.12
Installed collector area (aperture)	[m²]	2,8
Total energy output PVT-collector (Etotal)	[kWh]	394 (1.2019-7.2019) One PVT collector (1,557 m2)
Seasonal Performance Factor (System) SPFsys	[-]	-

Thermal Parameters		
Solar thermal energy used for	[-]	DHW preparation
Heat demand	[kWh/a]	-
Temperature range (application)	[°C]	10 to 80 °C (stagnation temperature 160 °C)
Back-up system	[-]	-
Solar thermal energy storage type	[-]	Water – Short term
Storage Volume	[L]	Solar tank 160L
Solar thermal energy to system (Qsol)	[kWh/a]	339 (1.2019-7.2019) One PVT collector (1,557 m2)
Heat generator energy (Qaux)	[kWh/a]	-
Solar fraction(Qsol/(Qsol+Qaux))	[%]	-

Electrical Parameters		
Module type	[-]	Monocrystalline
Module efficiency at STC (25°C; 1000W/m²)	[%]	8,8
Annual Yield Photovoltaics DC side (Epv)	[kWh/a]	55 (1.2019-7.2019) One PVT collector (1,557 m2)
Type of inverter	[-]	micro-inverter
AC capacity per inverter	[kW]	0.24
# of inverter	[-]	2
Inverter provider	[-]	GWL/POWER
Electrical storage type	[-]	-
Storage integrated in AC/DC side	[-]	-
Storage capacity (electrial storage)	[kWh]	-
Storage provider	[-]	-
Grid connected	[-]	Yes
Degree of self-sufficiency	[%]	-
Self-Consumption fraction	[%]	-

Economic Parameters	_	
Total investment cost (excl. VAT)	[€]	-
PVT-collector loop (excl. VAT)	[€]	-
Solar thermal energy storage (excl. VAT)	[€]	-
Inverter (excl. VAT)	[€]	-
Electrical storage (excl. VAT)	[€]	-

others (excl. VAT)	[€]	-
Specific investment cost	[€/m²]	-
Calculated solar thermal system life time	[a]	-
Subsidy, € or % of total investment costs	[€/%]	-
Fuel replaced	[-]	-
Cost for fuel replaced	[€/MWhfuel]	-
Local feed-in tariff	[€/MWhelectricity]	-

Sources		
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