eurac research

Modelling results on New Generation Solar Cooling systems

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INTRODUCTION

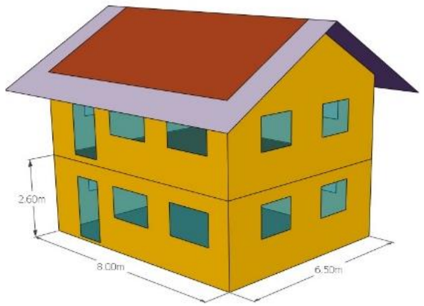
4 examples of new generation solar cooling systems:

- Building description and solar cooling plant layout;
- Working modes and characteristics of system components;
- Operational modes and system size variants, and results.

CASE 1

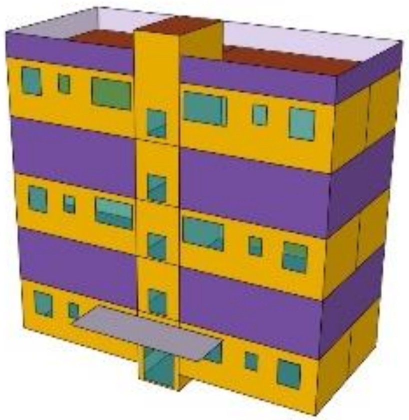
Building description

Reference Single Family House - SFH



Number of floors	2
Living area per floor	50 m²
Yearly heating demand	45 kWh/(m²y)

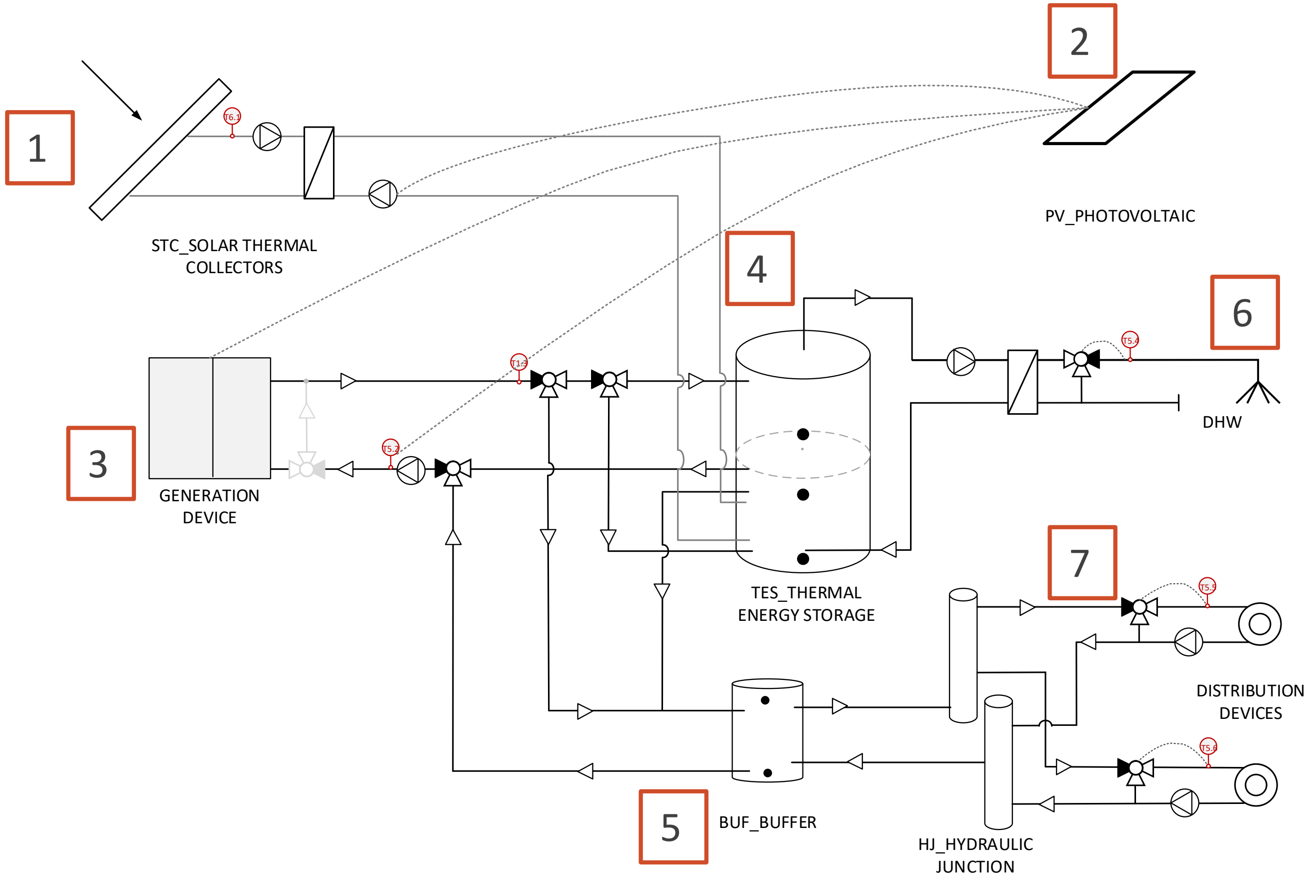
Reference Small Multi Family House - sMFH



Number of floors	5
Living area per dwelling	50 m²
Number dwelling per floor	2
Yearly heating demand	45 kWh/(m²y)

CASE 1

Solar cooling plant layout

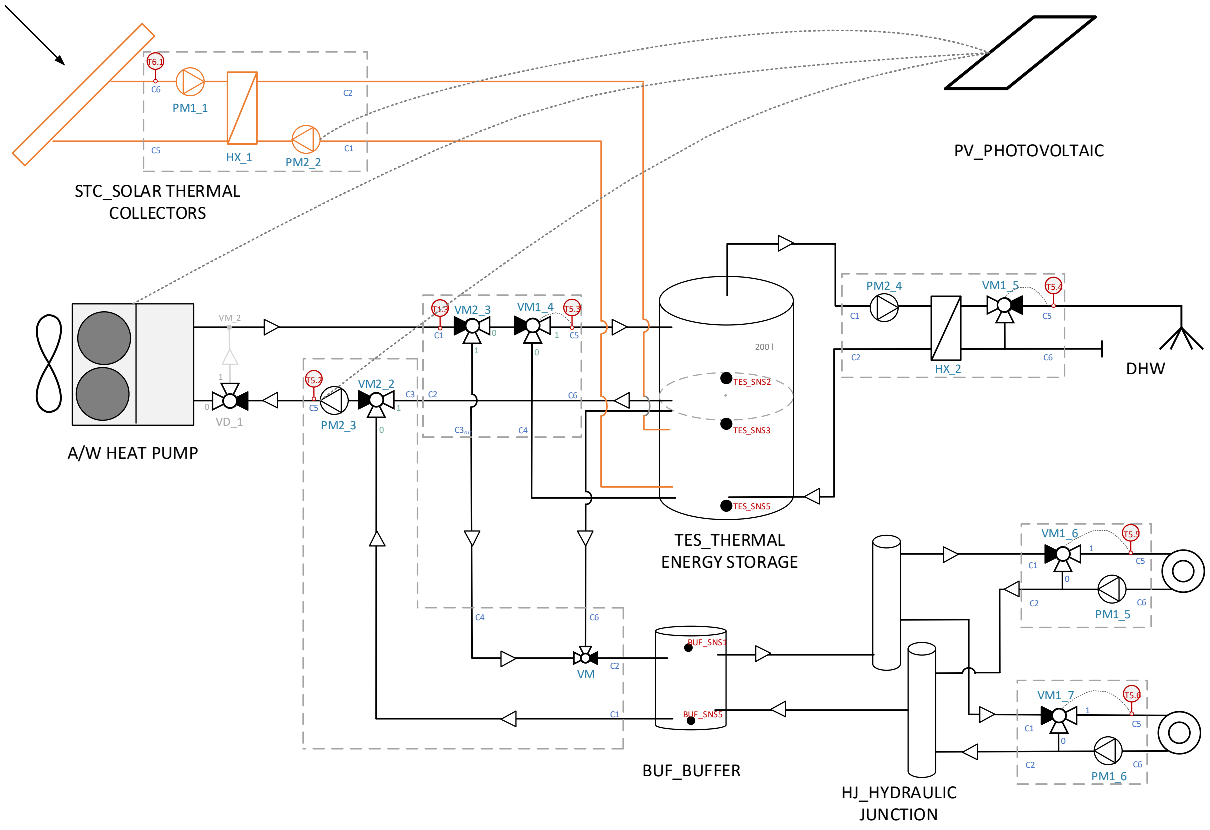


- Use of **solar thermal energy** for DHW production and space heating
- Use of **PV energy** for the HVAC system electricity consumption

1. Solar thermal collectors
2. PV panels
3. Air-to-water heat pump
4. Storage tank
5. Buffer
6. DHW distribution circuit
7. H&C Distribution circuit

CASE 1

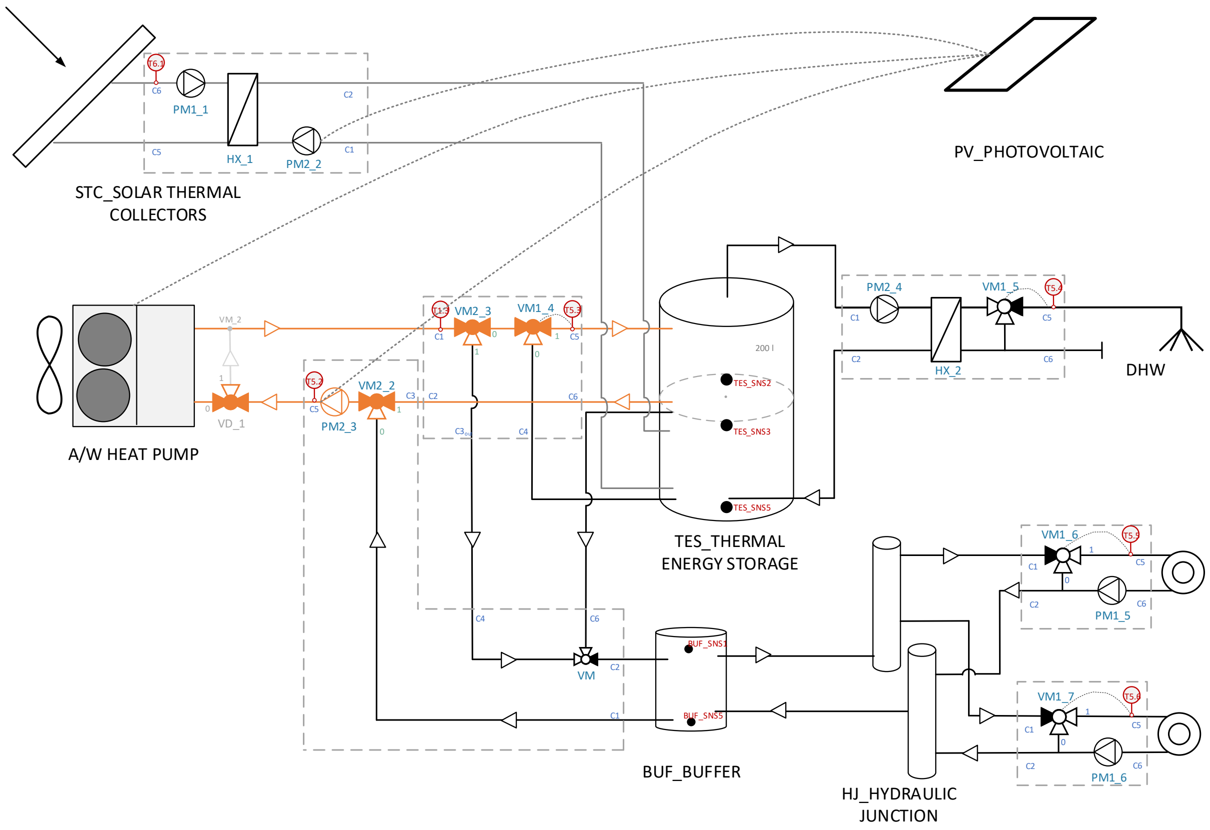
Working conditions



TES charging by solar energy

CASE 1

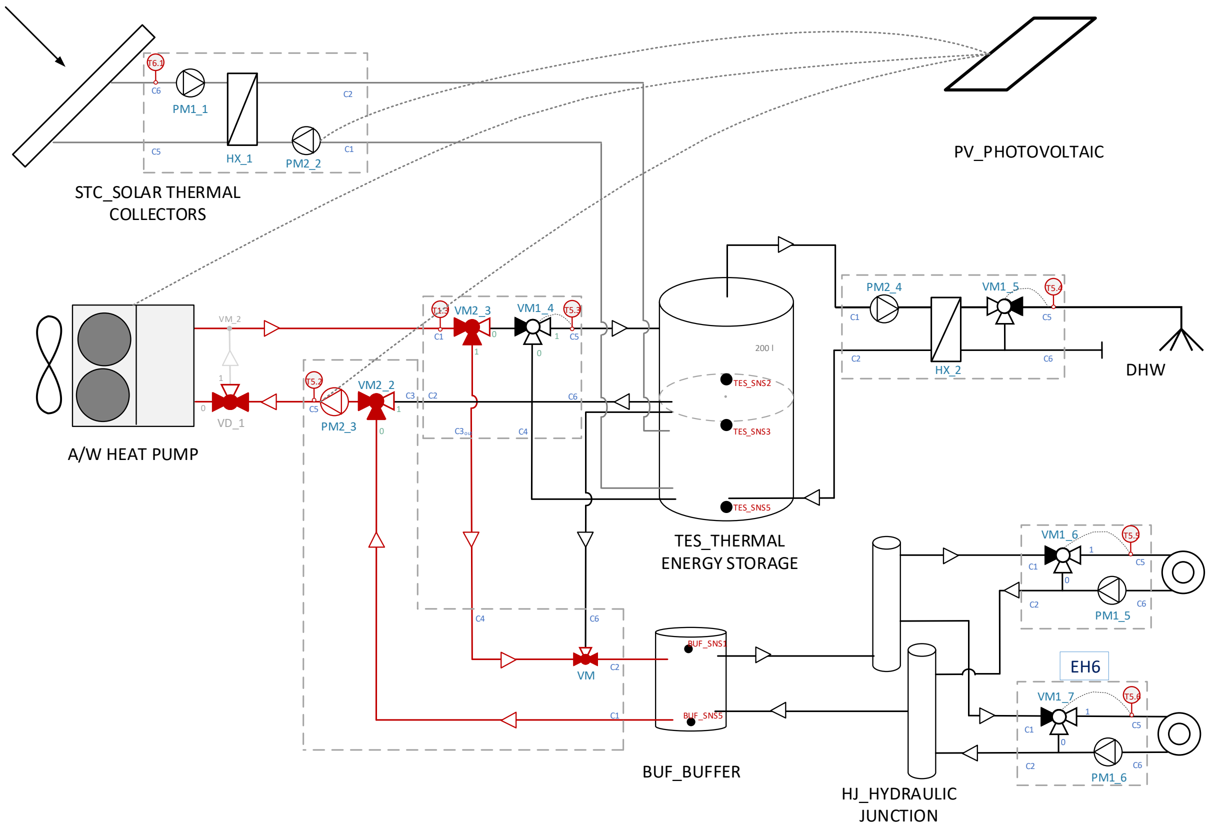
Working conditions



TES charging by heat pump

CASE 1

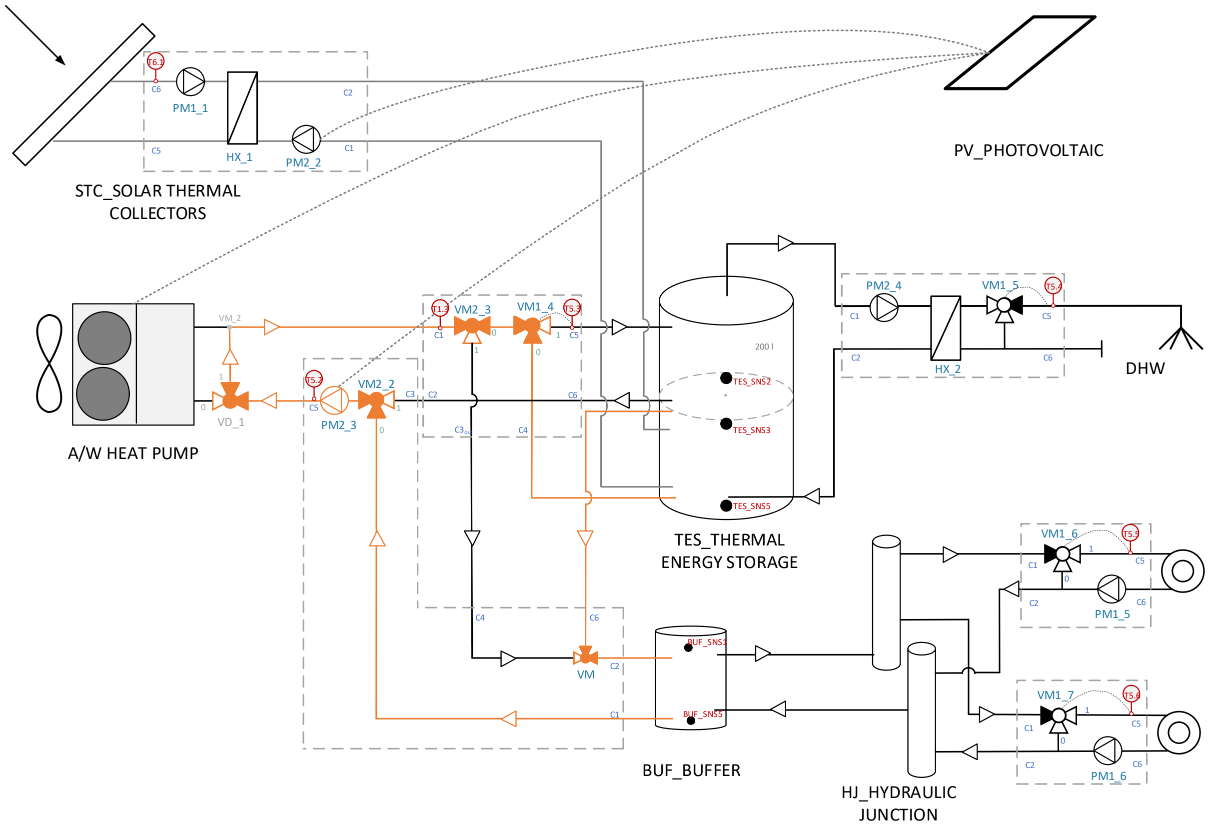
Working conditions



Buffer charging by heat pump

CASE 1

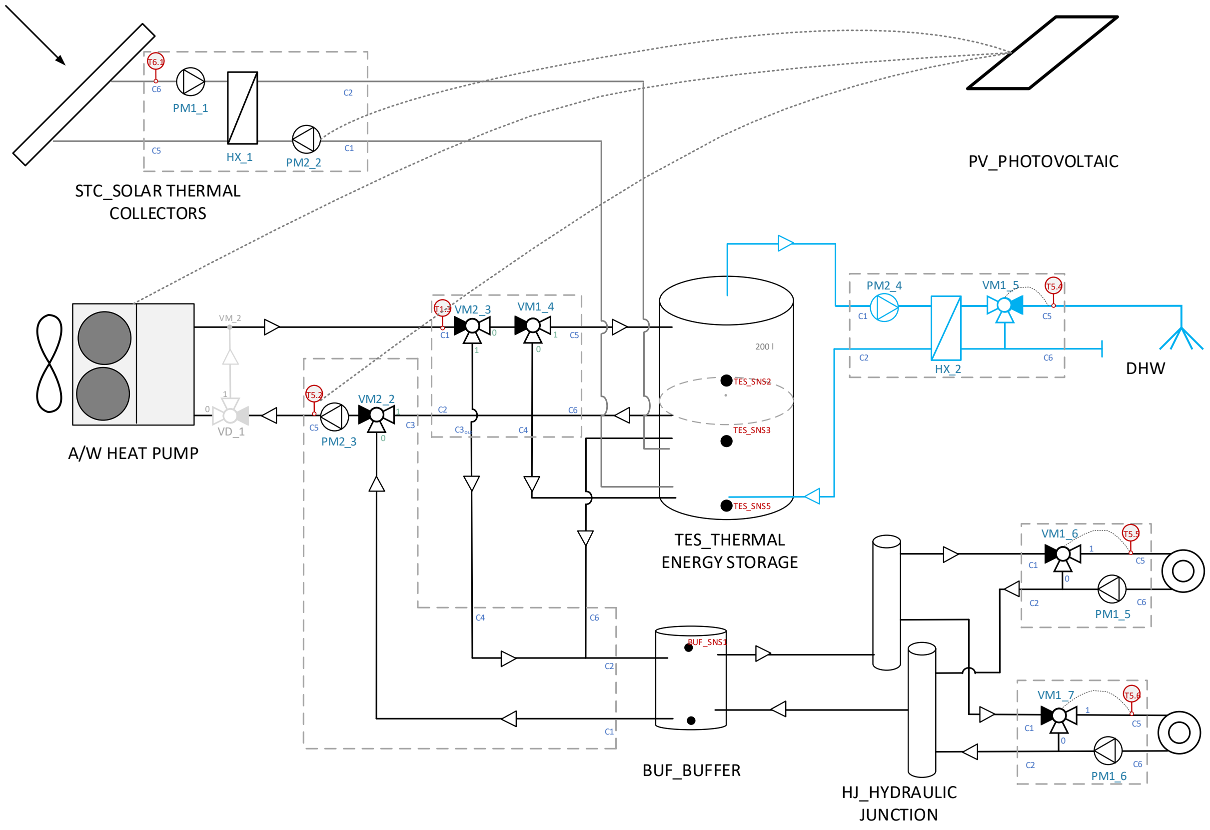
Working conditions



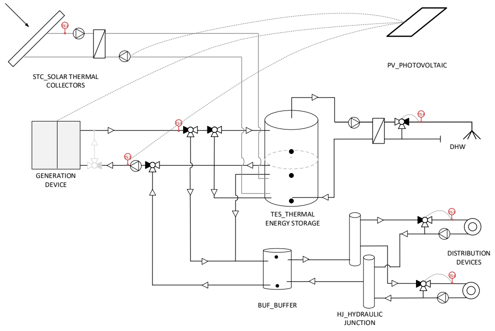
Buffer charging by solar energy

CASE 1

Working conditions



DHW distribution



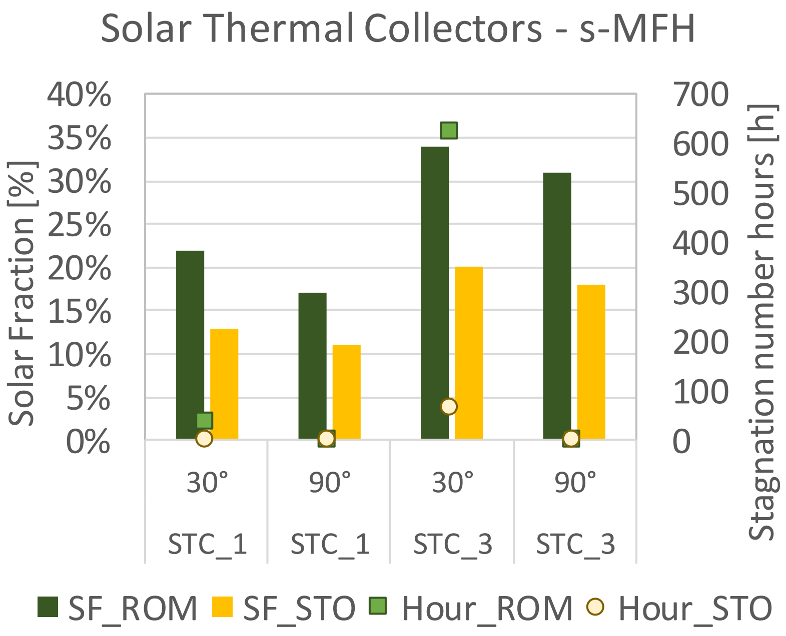
RESULTS – CASE 1

ST and PV performance with varying field size and tilt angle

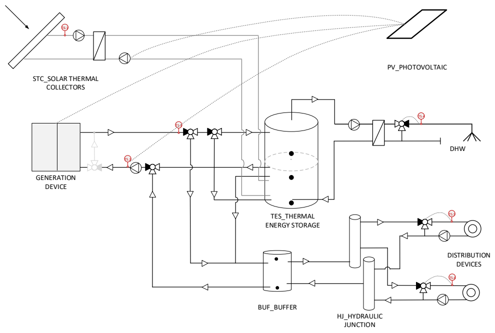
	Solar Thermal	
	Unit	s-MFH
STC_1	m^2	18.4
STC_2	m^2	27.6
STC_3	m^2	36.8

ROM – Rome

STO - Stockholm



*Solar Fraction and stagnation hours referred to the total heating production (**space heating + DHW**)*



RESULTS – CASE 1

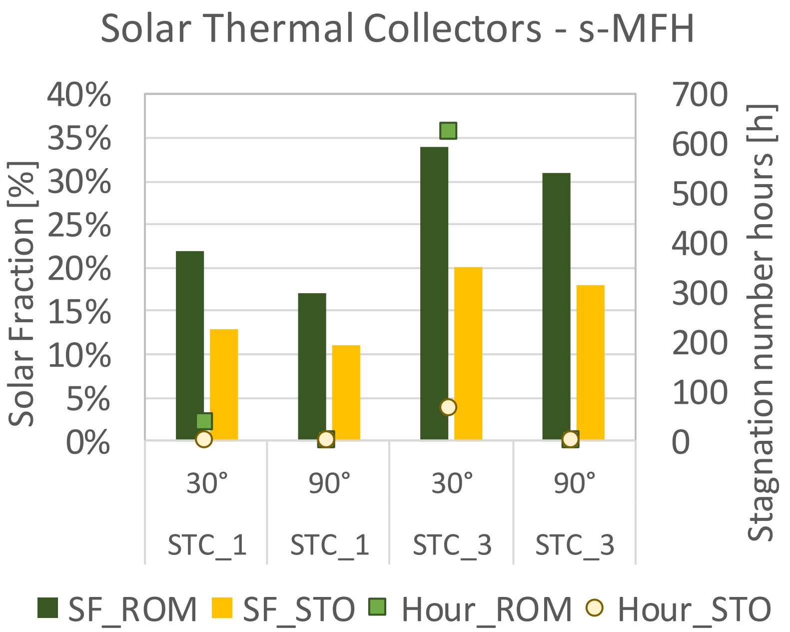
ST and PV performance with varying field size and tilt angle

	Solar Thermal	
	Unit	s-MFH
STC_1	m^2	18.4
STC_2	m^2	27.6
STC_3	m^2	36.8

	Photovoltaic	
	Unit	s-MFH
PV_1	kWp	3
PV_2	kWp	4
PV_3	kWp	5

ROM – Rome

STO - Stockholm



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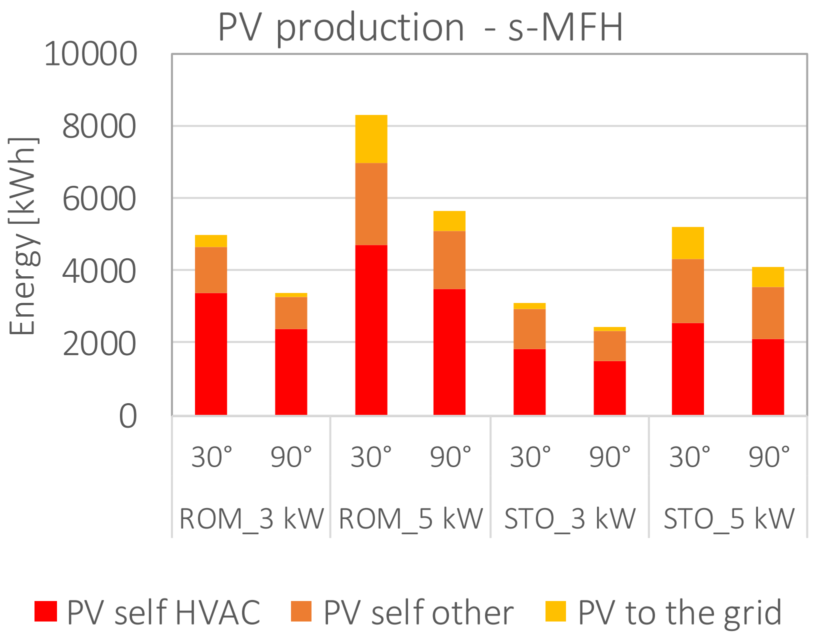
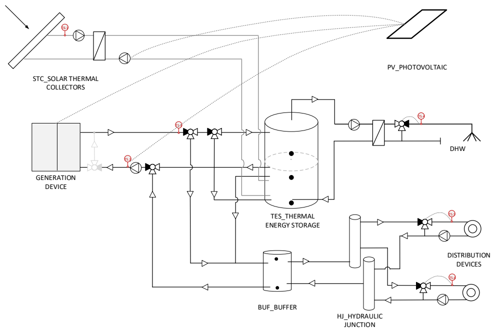
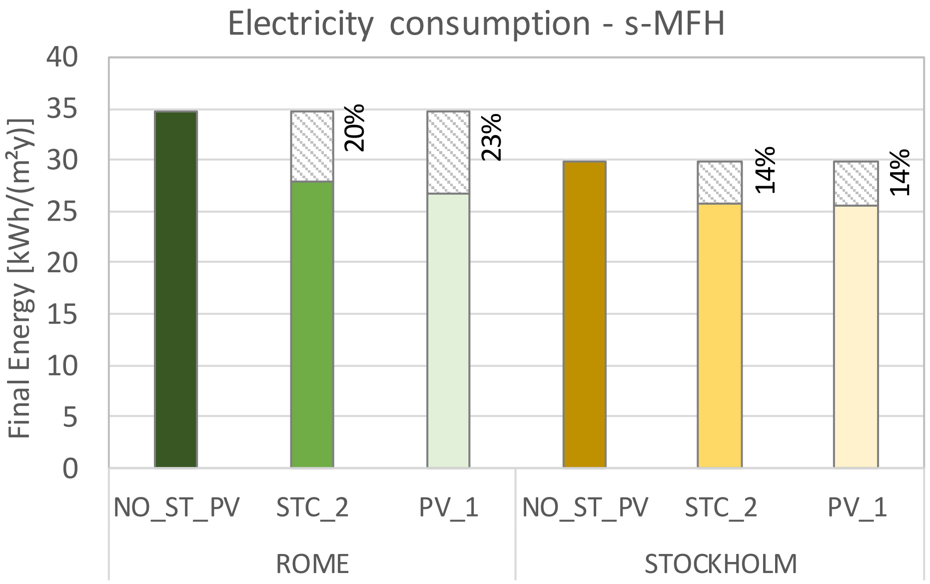


***PV production and self-consumption** for two different fields size and panel slope*



RESULTS – CASE 1

ST and PV performance for different sizes and slopes



*Comparison of similar field areas of STC (**27 m²**) or PV (**24 m²**) in terms of electric energy savings for DHW, heating and cooling uses*

ROM – Rome *STO – Stockholm*

- Slightly higher energy savings in **Southern climates** due to higher cooling loads
- Same energy savings for a solar thermal (STC) or photovoltaic (PV) field in **Northern climates**

CASE 2

Building description

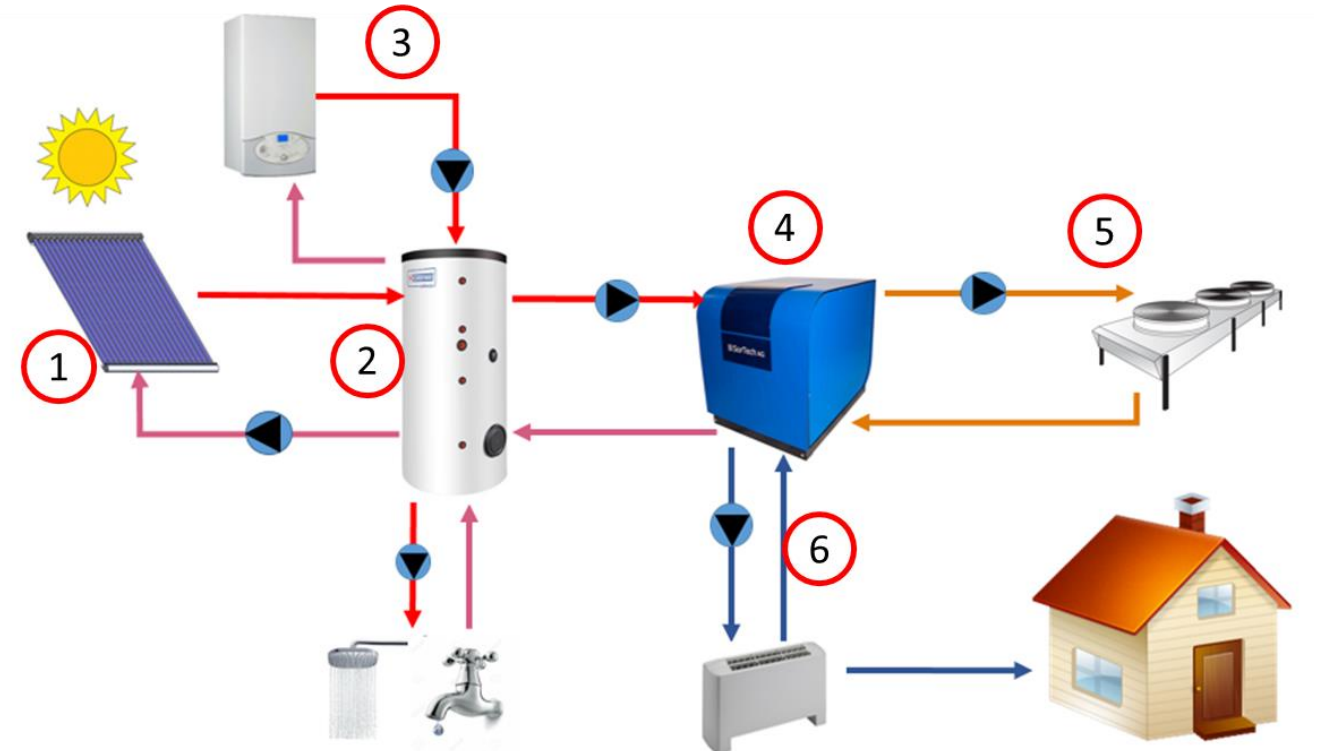
Wooden Residential Building (WRB)

Number of floors	2
Living area per floor	130 m²

Athens (EL)
Almeria (ES)
Barcellona (ES)
Larnaca (CY)
Luca (MT)
Marseille (FR)
Messina (IT)
Freiburg (DE)
Stuttgart (DE)

CASE 2

Solar cooling plant layout

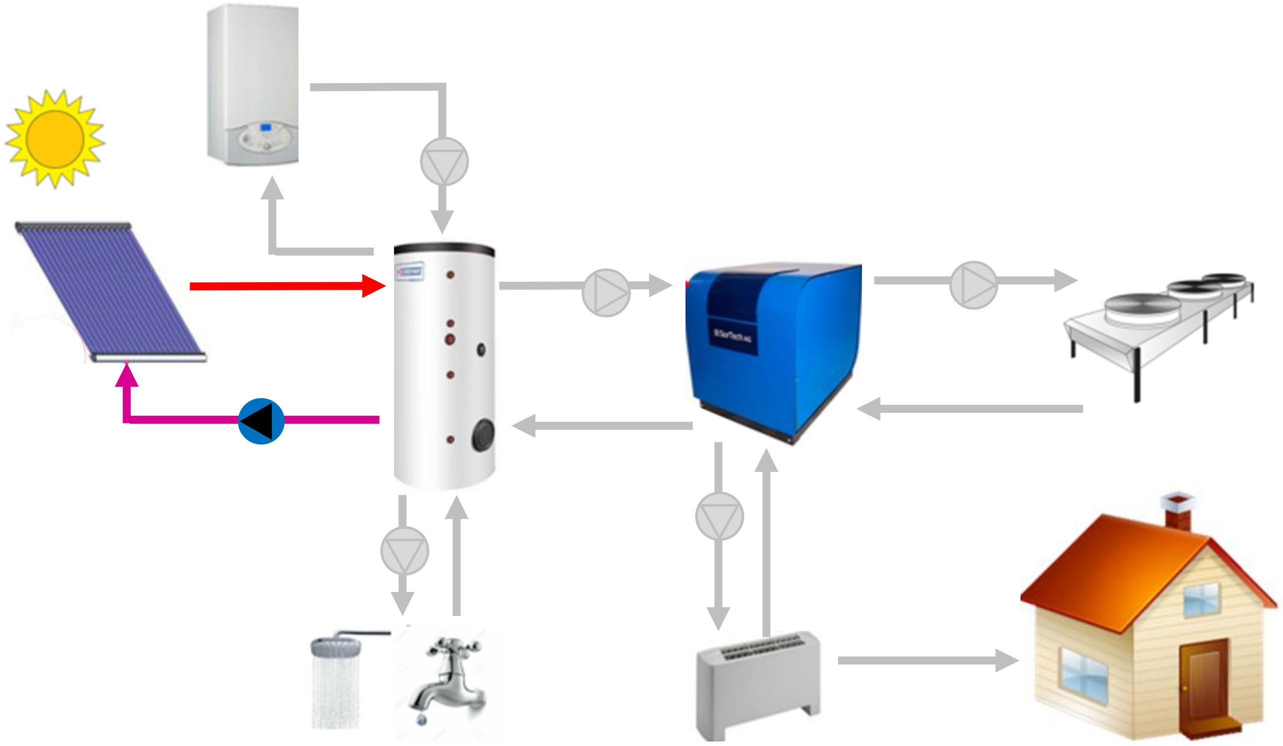


- **Adsorption chiller** for space cooling;
- **Solar collectors** (CPC) for heating and DHW demands
- **Heat rejection** through dry-cooler.

1. Compound Parabolic Collectors (CPC)
2. Storage tank – 1000 l
3. Electric Heater
4. Adsorption chiller – 10 kW
5. Dry cooler
6. Fan coil

CASE 2

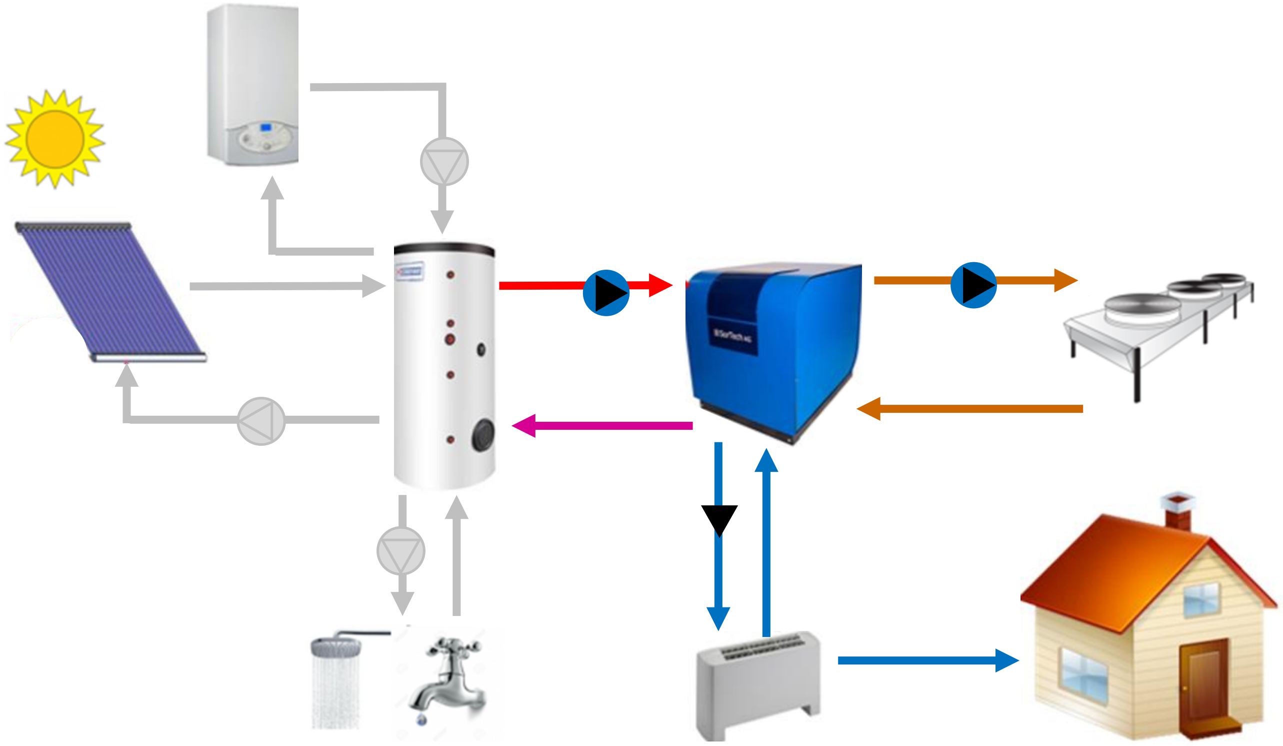
Working conditions



Running the solar system

CASE 2

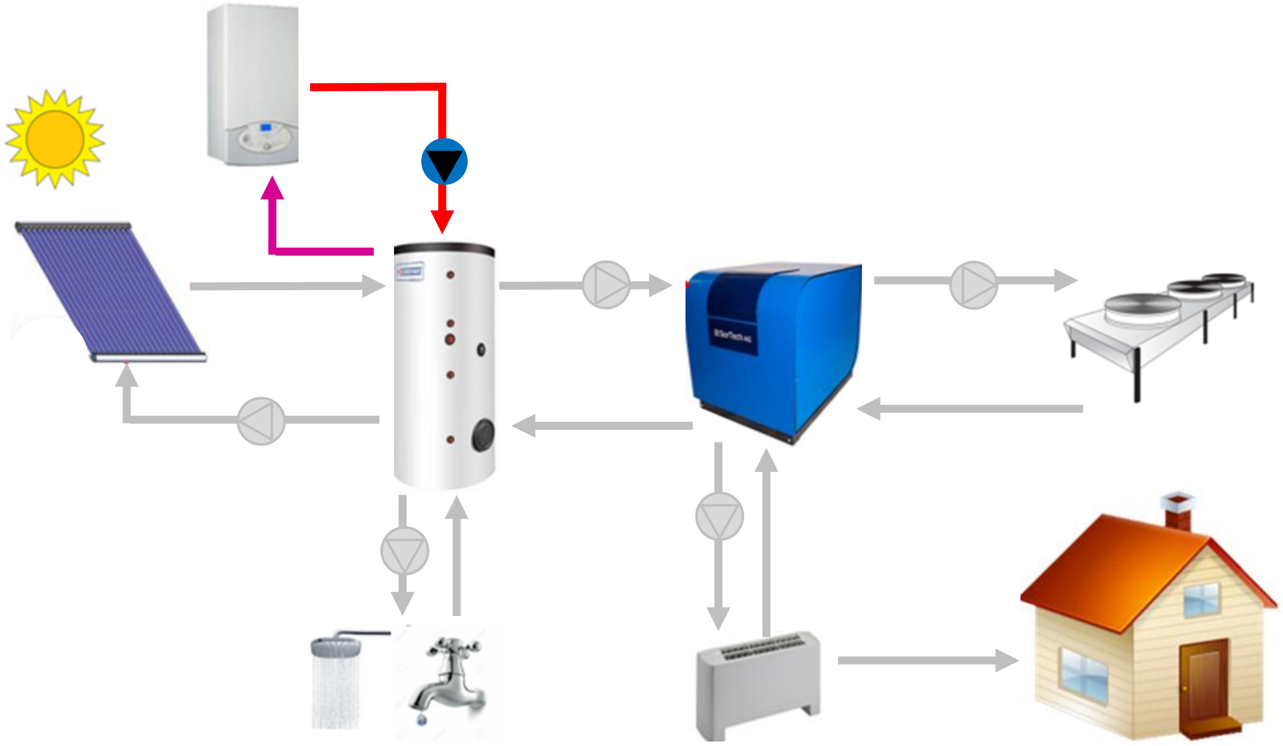
Working conditions



Space cooling mode

CASE 2

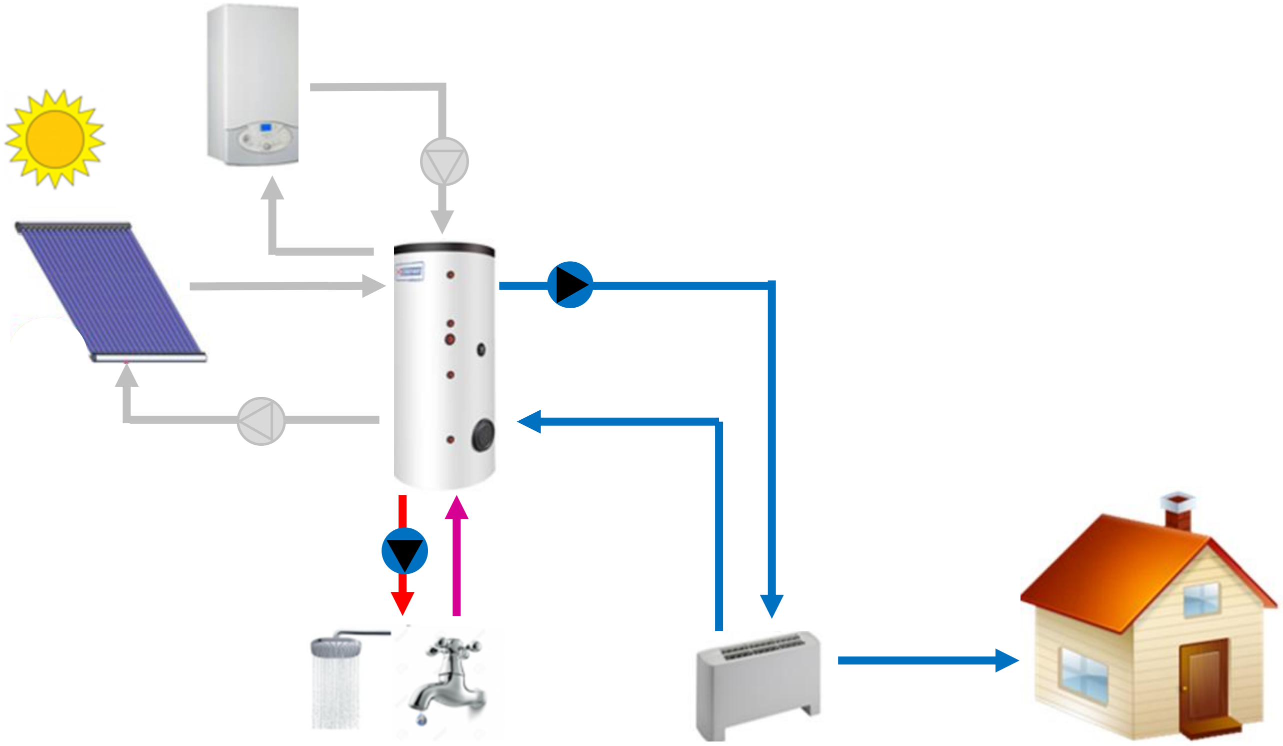
Working conditions



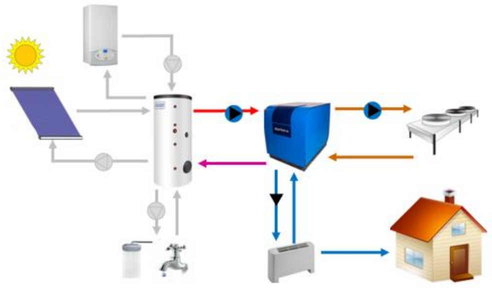
Running the back-up heater

CASE 2

Working conditions



Domestic Hot Water and space heating

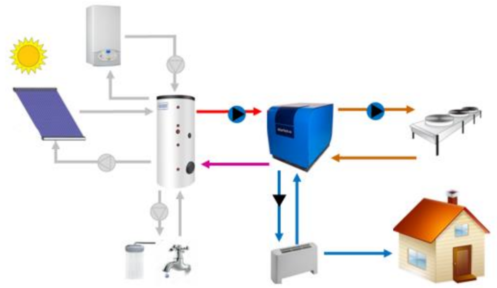


RESULTS – CASE 2

Absorption chiller in different climates

	# solar collectors	SPF heating [-]	SPF cooling [-]	SF total [%]	PER total [-]
Freiburg	6	6.7	5.2	51%	1.2
Stuttgart	6	9.5	7.9	56%	1.3
Marseille	6	11.6	9.6	92%	1.9
Messina	8	14.8	12.3	67%	2
Luca	8	14.3	13.0	66%	2
Athens	8	10.4	10.9	69%	2.4
Barcelona	8	12.9	11.7	73%	2.4
Almeria	8	10.7	11.8	66%	1.9
Larnaca	10	11.9	12.7	63%	2.1

- The highest SF is in Marseille where heating and cooling demands are similar;



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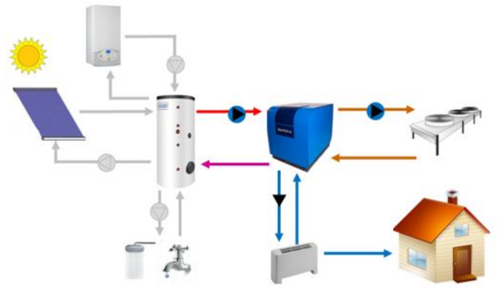
- The highest SF is in Marseille where heating and cooling demands are similar;
- Northern climates have low SF due to small collector size and high heating demand;



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- The highest SF is in Marseille where heating and cooling demands are similar;
- Northern climates have low SF due to small collector size and high heating demand;
- Although Northern climates are not the best application for adsorption chillers, all the cases have PER (Primary Energy Ratio) > 1 and Solar Fraction > 60%

CASE 3

Building description

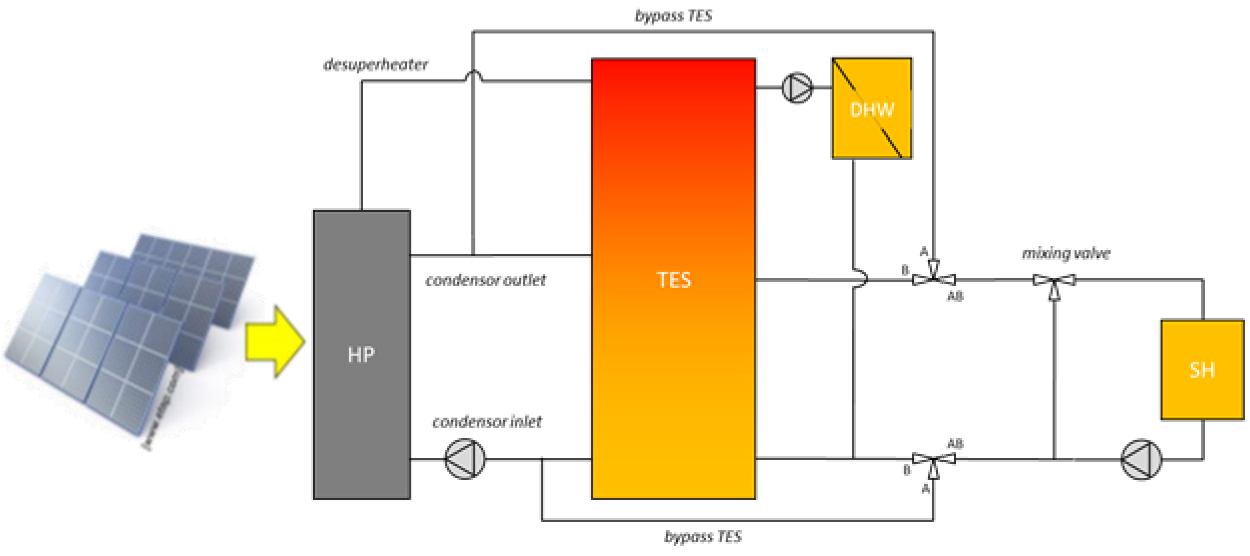
TheBat Building (Task 44)

Number of floors	2
Living area per floor	70 m^2
Yearly heating demand	45 $kWh/(m^2y)$

Location: Innsbruck (Austria)

CASE 3

Solar cooling plant layout



Use of PV for covering the heat pump consumption:

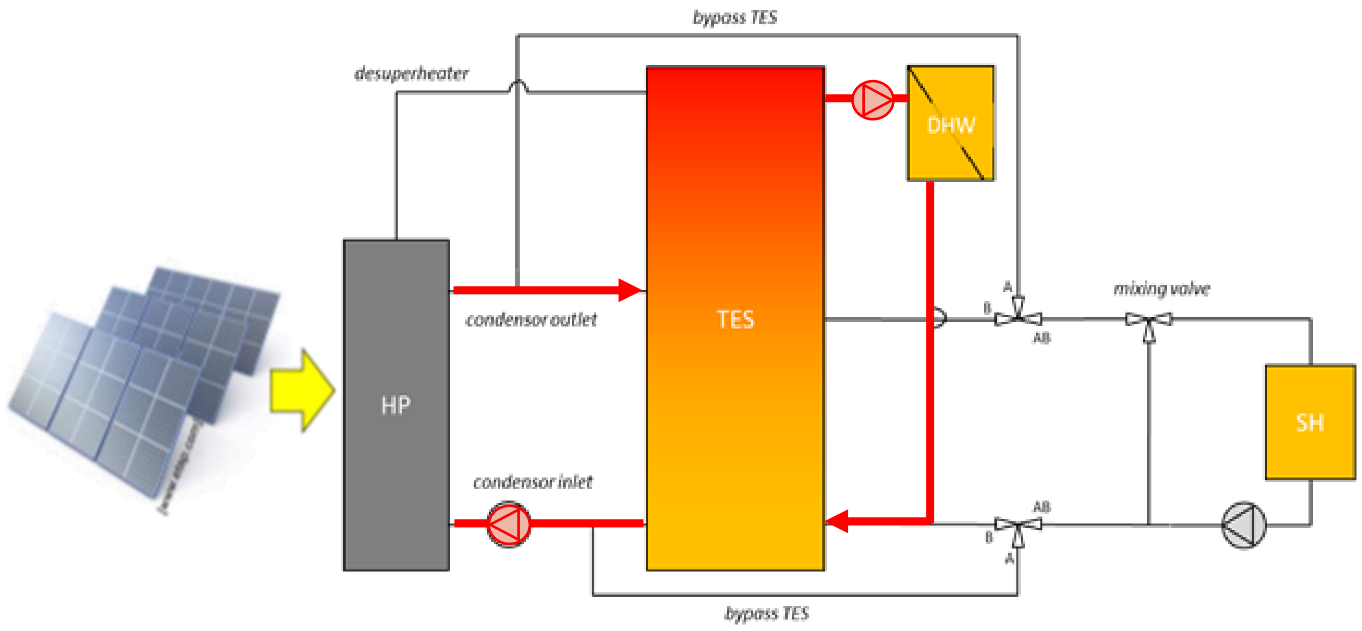
1. SELF consumption;
2. Overheating the TES;
3. Overheating the TABS;
4. Overheating TES and TABS.

1. PV PV panels – 20 m² - 40 m²
2. HP Heat pump – 10 kW
3. DHW Domestic Hot Water
4. SH Space heating
5. TES Thermal Energy Storage
6. TABS Thermal Activated Building Structure

CASE 3

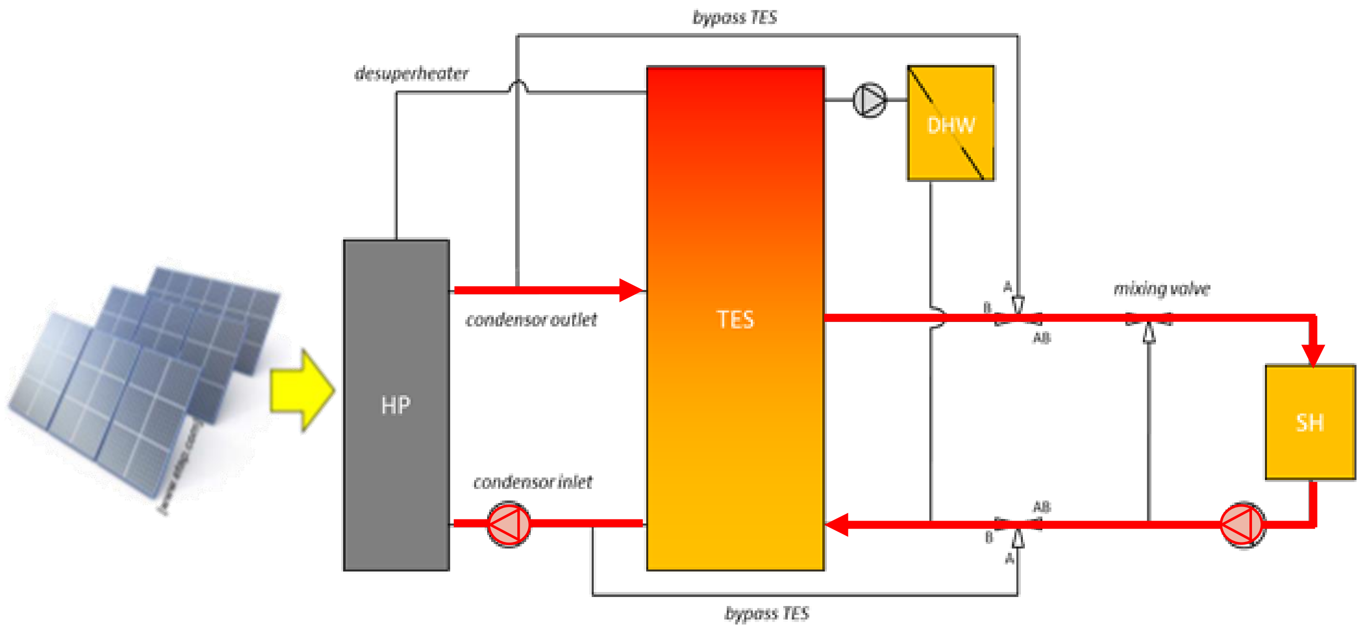
Working conditions

TES charging for DHW uses



CASE 3

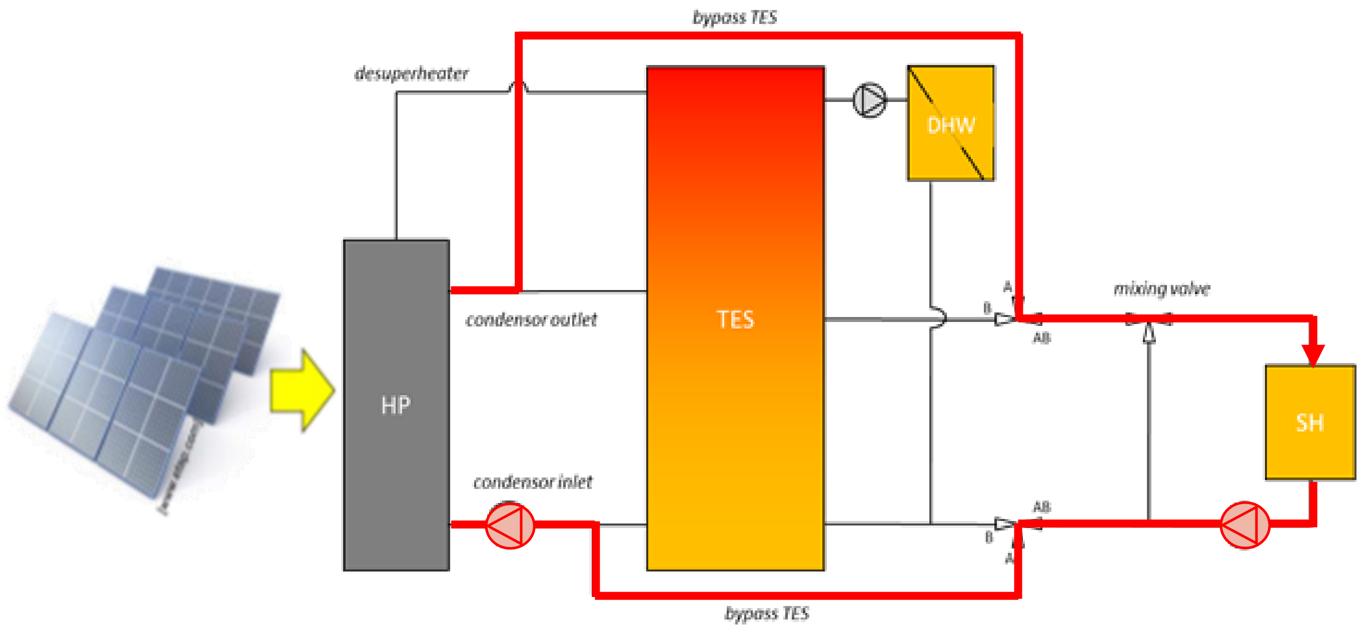
Working conditions



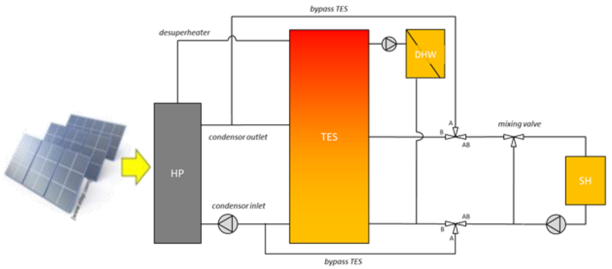
TES charging for space heating use

CASE 3

Working conditions

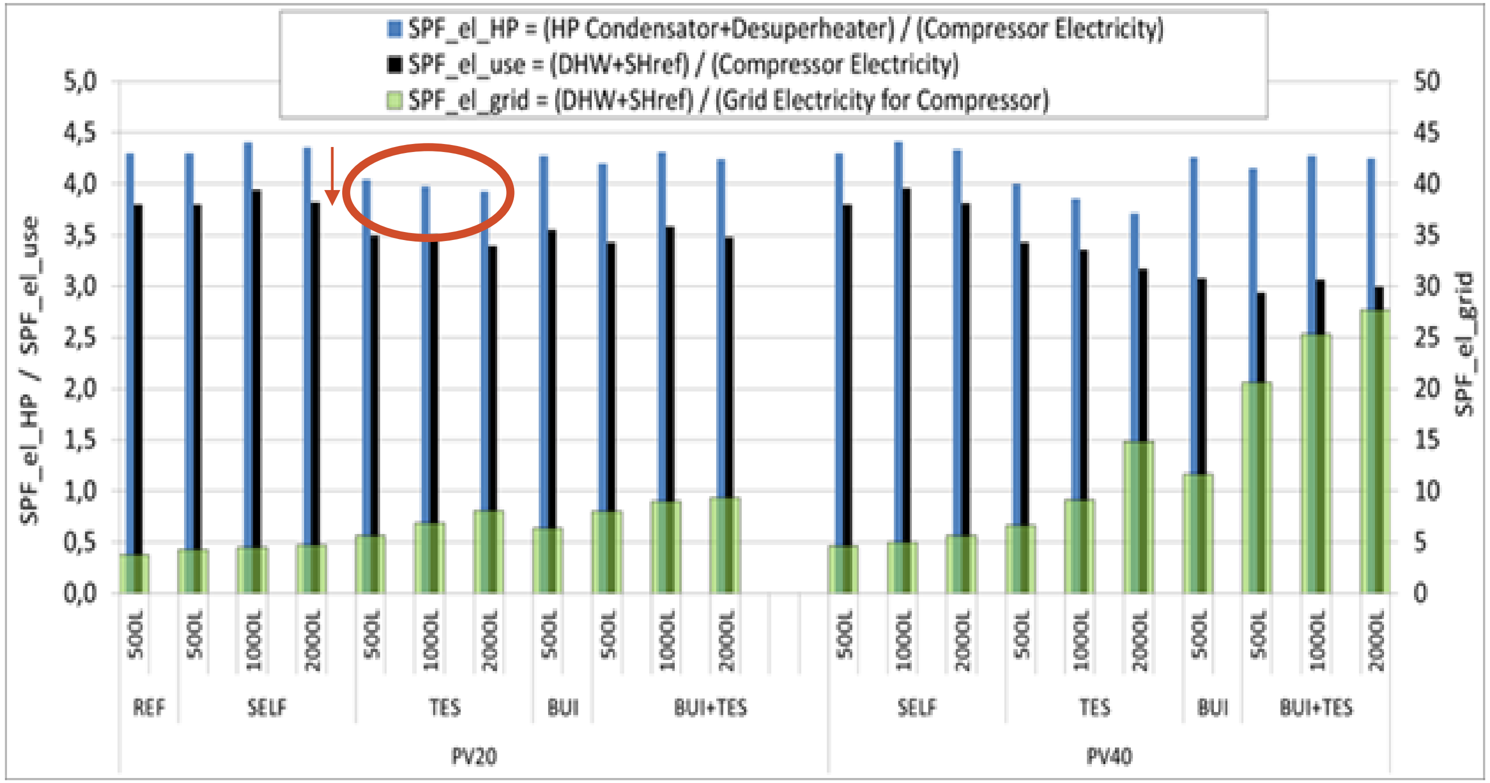


Direct space heating from the heat pump

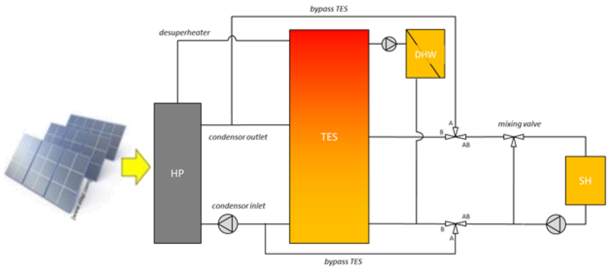


RESULTS – CASE 3

SPF and HP performance at different working conditions

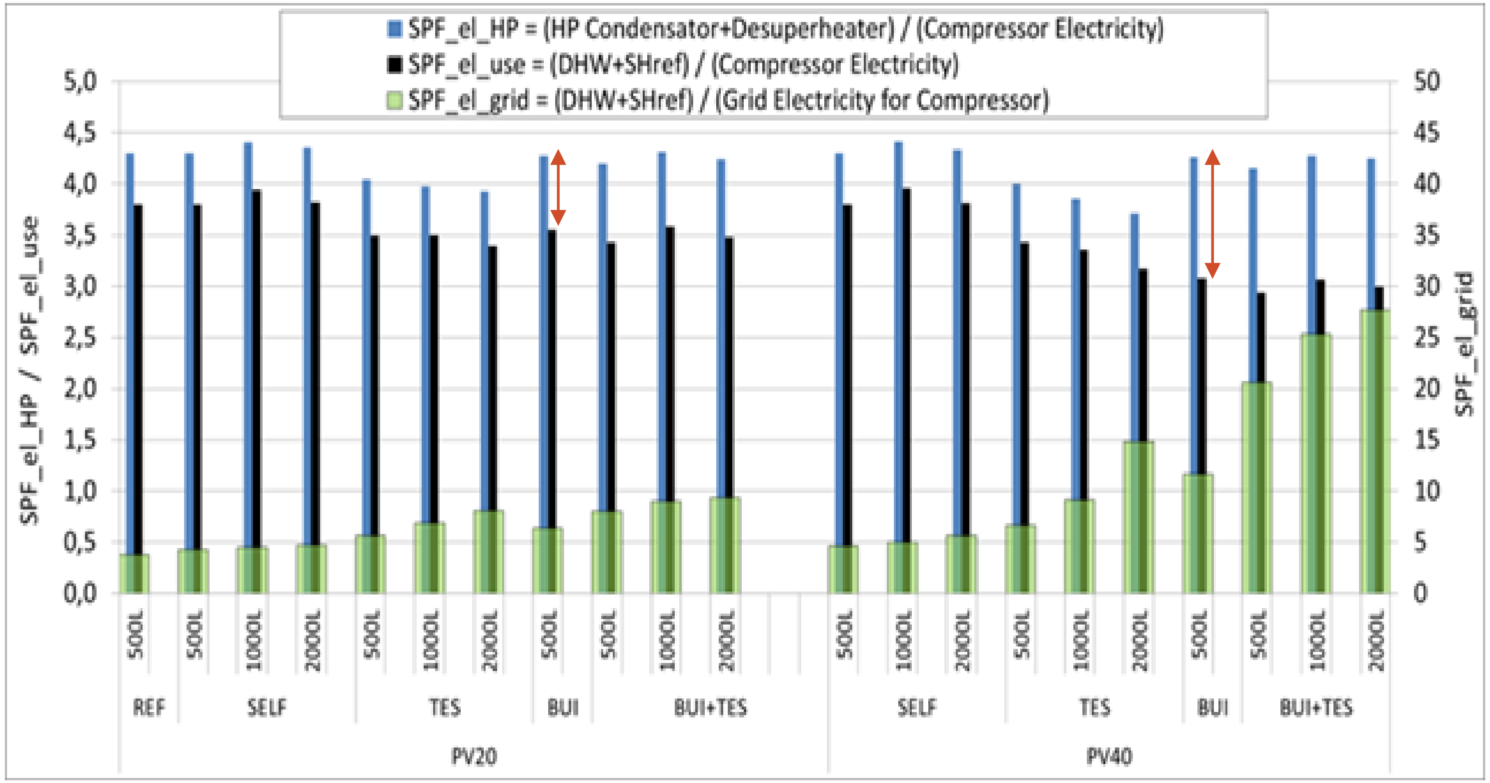


- The strategy of overheating the TES reduces the HP performance ($SPF_{el,HP}$) because of the higher working temperatures;



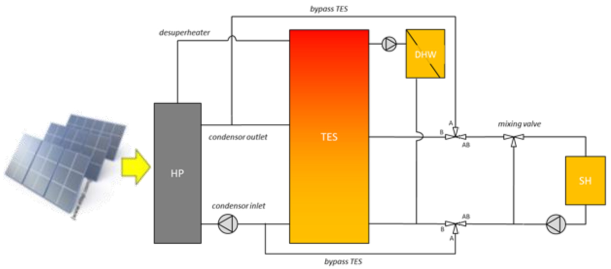
RESULTS – CASE 3

SPF and HP performance at different working conditions

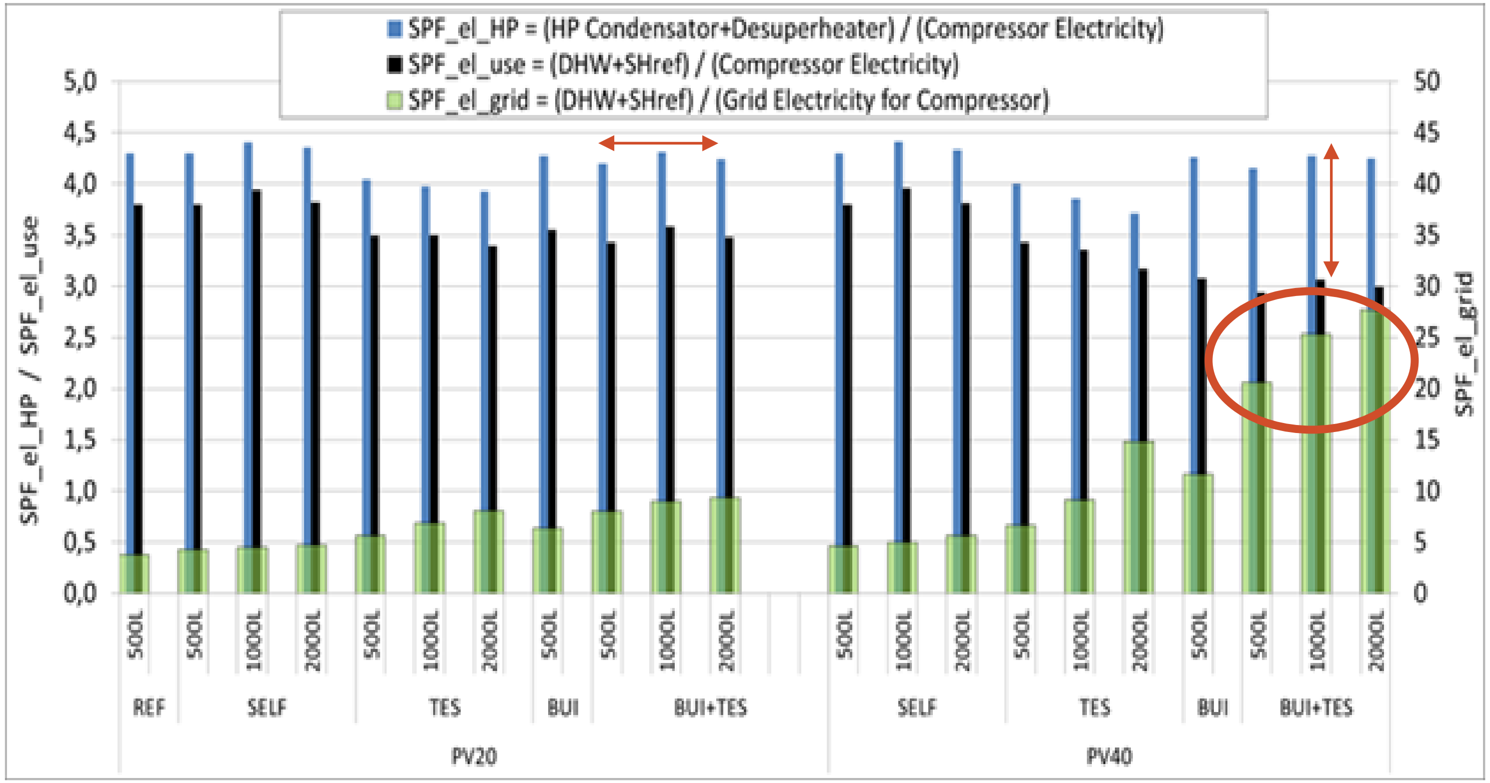


- The strategy of overheating the TES reduces the HP performance ($SPF_{el,HP}$) because of the higher working temperatures;
- Overheating the BUI and the TES+BUI increases the thermal losses;

RESULTS – CASE 3



SPF and HP performance at different working conditions

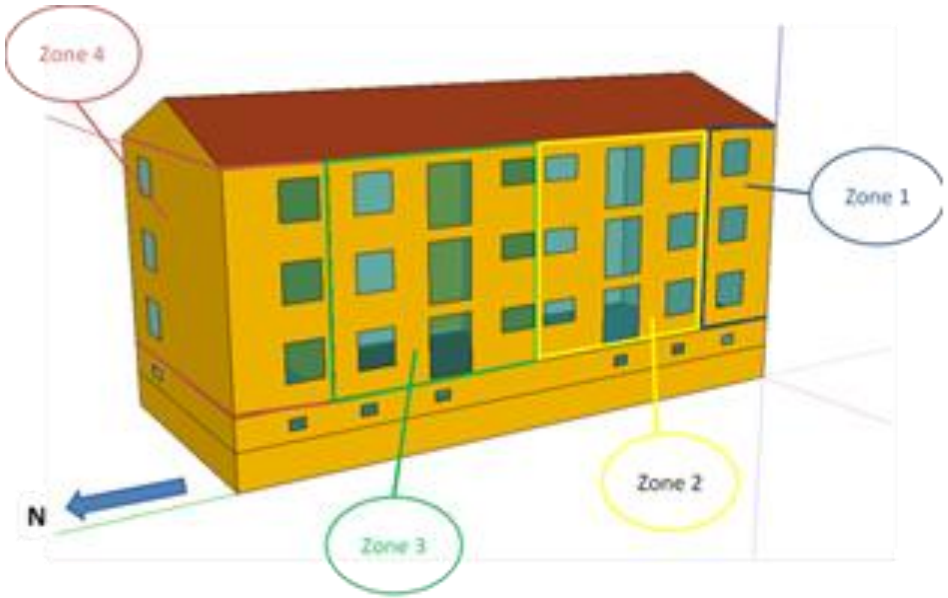


- The strategy of overheating the TES reduces the HP performance ($SPF_{el,HP}$) because of the higher working temperatures;
- Overheating the BUI and the TES+BUI increases the thermal losses;
- Bigger PV field area and storage capacity reduce the used energy from the grid, but increase energy losses;
- Bigger storages do not significantly improve the system performance.

CASE 4

Building description

Multi-family house HVACviaFaçade

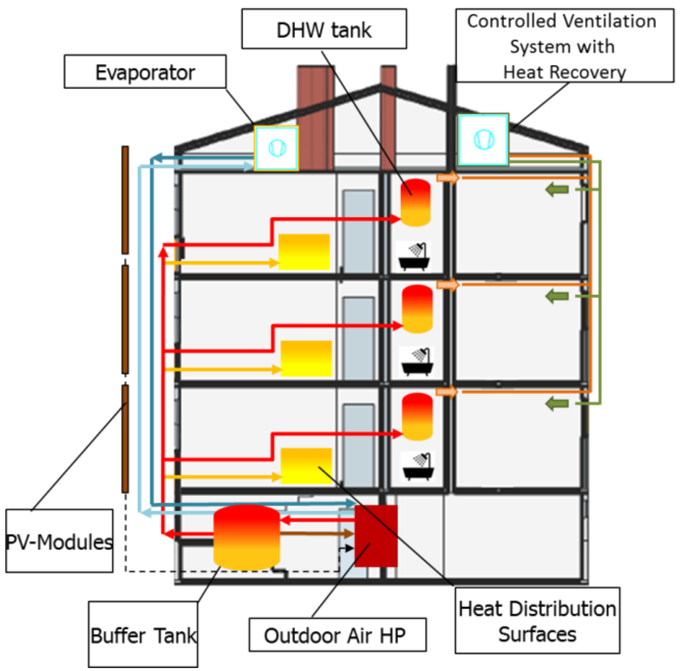


Number of floors	3
Living area per dwelling	50.3 m² (average)
Dwellings per floor	4
Yearly heating demand	15 kWh/(m²y) – BUI 15
Yearly heating demand	30 kWh/(m²y) – BUI 30

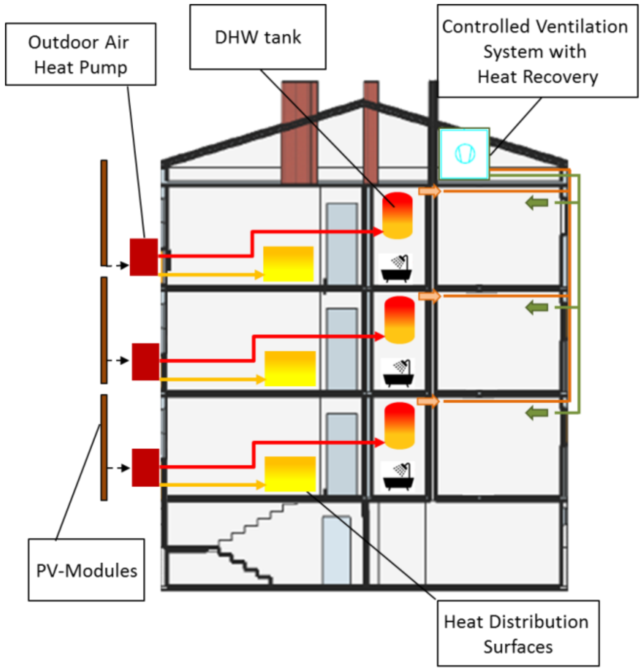
Location: Graz (Austria)

CASE 4

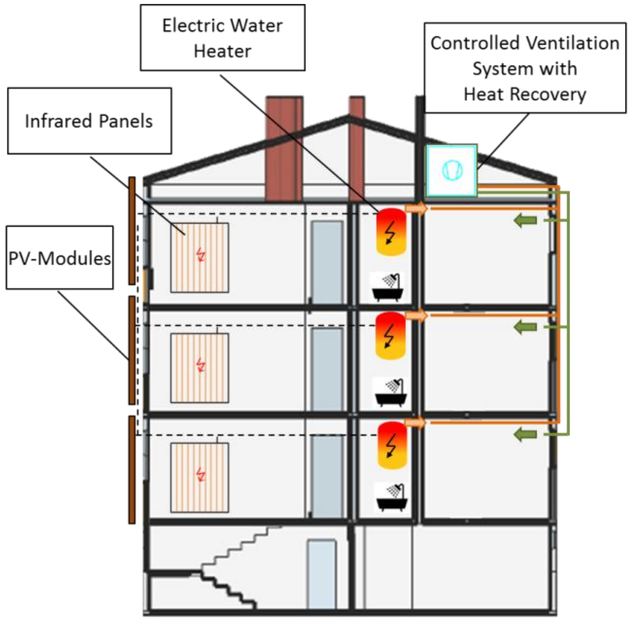
Layout description



Central outdoor air heat pump



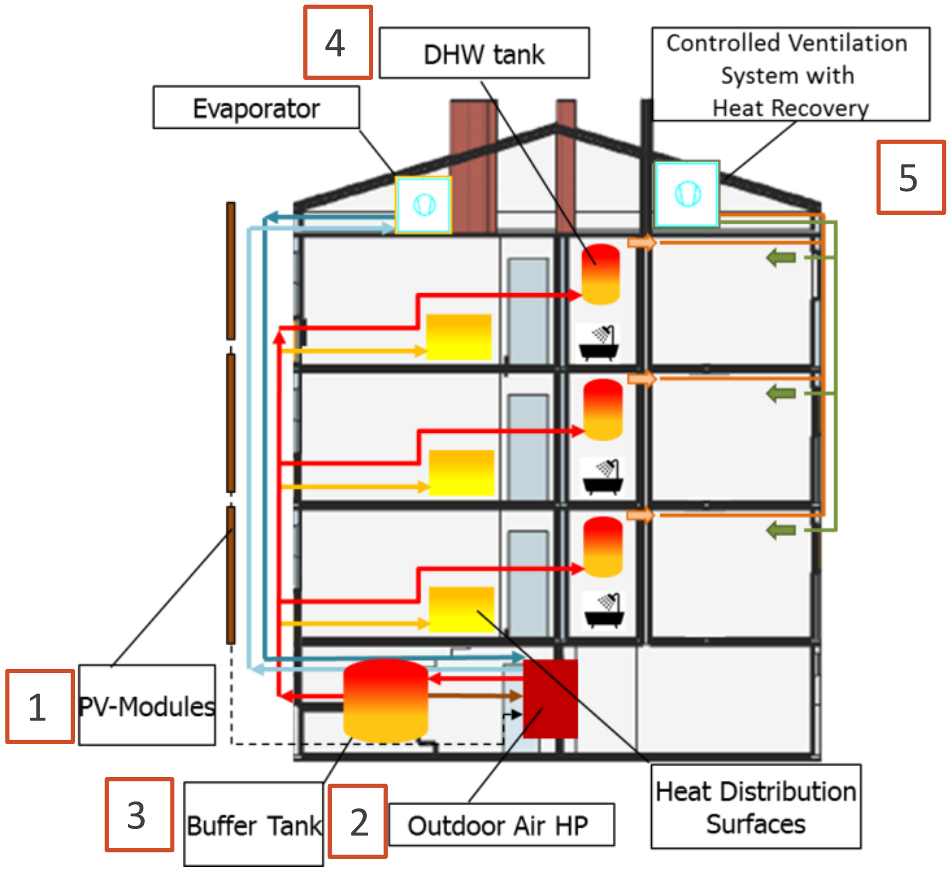
Decentralized outdoor air heat pump



Direct electric heating

CASE 4 - 1

Layout description and working conditions



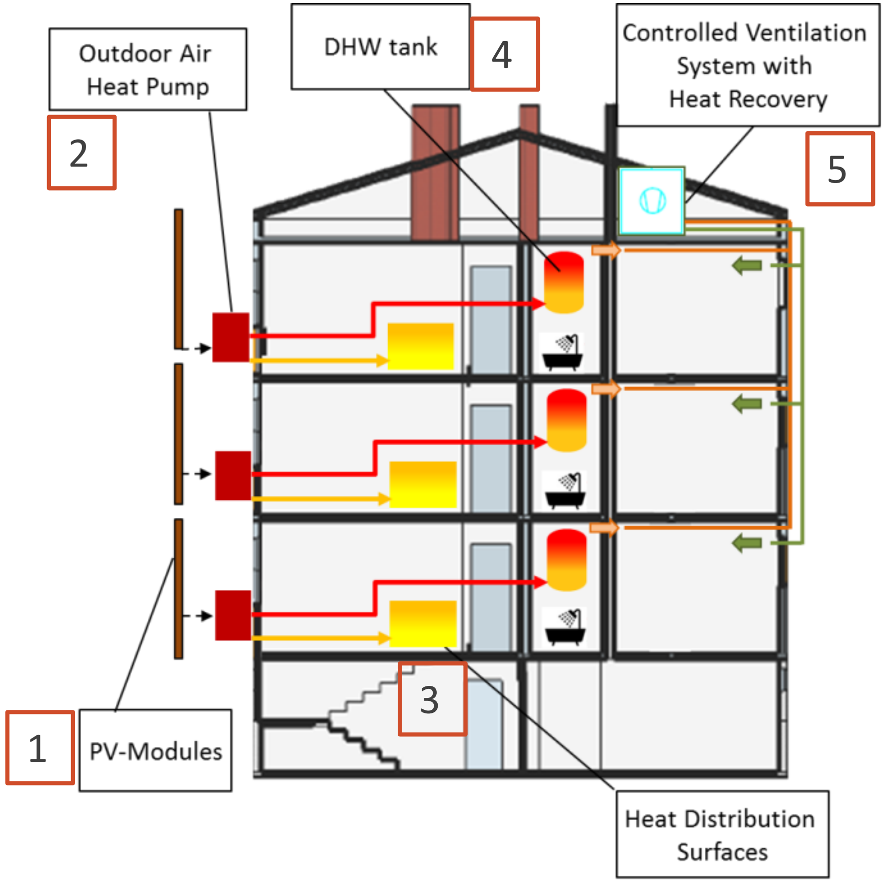
Central outdoor air heat pump

- Maximize PV production for the **centralized heat pump** electric consumption;
- Use of **decentralized storages for DHW** uses;
- Use of **two set temperatures** for the tanks.

1. PV panels 189 m² - 15.75 m²/dwelling
2. Heat pump 10 kW (BUI 15) – 20 kW (BUI 30)
3. Buffer Tank – 1500 l (BUI 15) – 2000 l (BUI 30)
4. DHW tank – 150 l/dwelling
5. Mechanical Ventilation with Heat Recovery

CASE 4 - 2

Layout description and working conditions



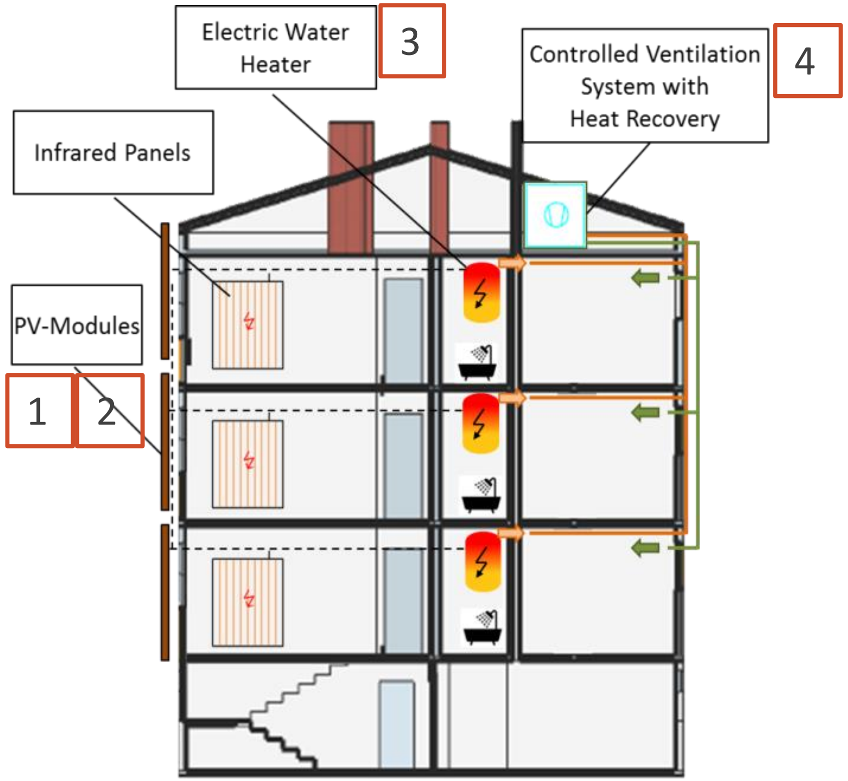
- Maximize PV production for the **decentralized heat pumps** consumption;
- Use of **decentralized storages for DHW** uses;
- Use of **two set temperatures** for the tanks.

1. PV panels 176 m² - 14.5 m²/dwelling
2. Heat pump 2 kW/dwelling
3. Direct space heating from the heat pump
4. DHW tank – 150 l/dwelling
5. Mechanical Ventilation with Heat Recovery

Decentralized outdoor air heat pump

CASE 4 - 3

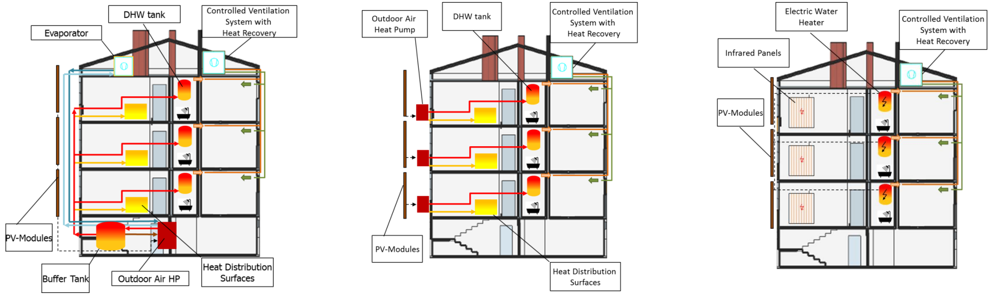
Layout description and working conditions



- Maximize **PV production** for self-use;
- Use of **two set temperatures** for the tank;
- Use of the **roof surface** for additional PV panels.

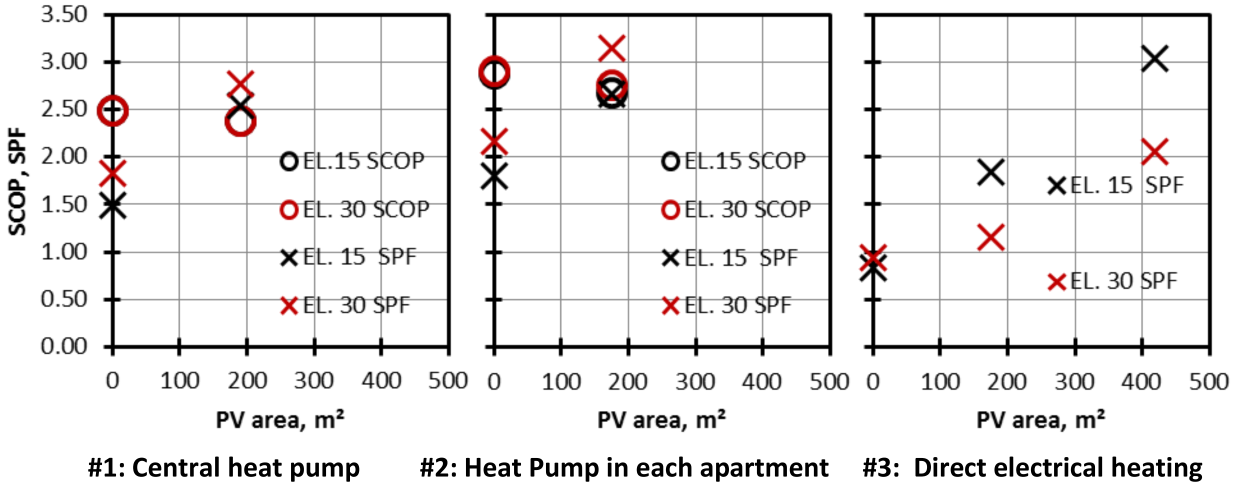
1. PV panels 1   176 m² - 14.5 m²/dwelling
2. PV panels 2   419 m² - 34.9 m²/dwelling
3. Electric heater 2.5 kW and 150 l
4. Mechanical Ventilation with Heat Recovery

Direct electric heating

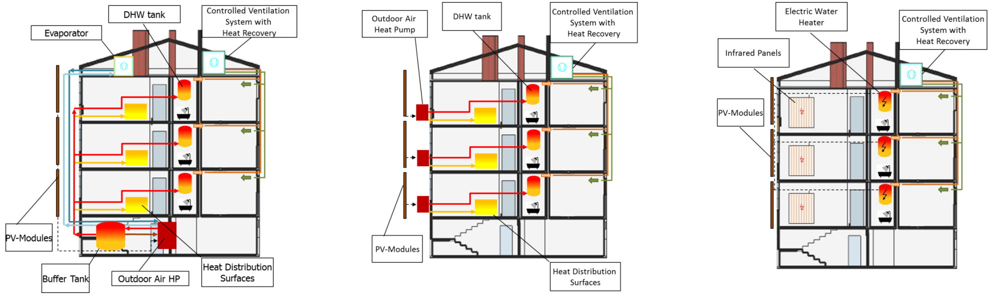


RESULTS – CASE 4

SPF and SCOP

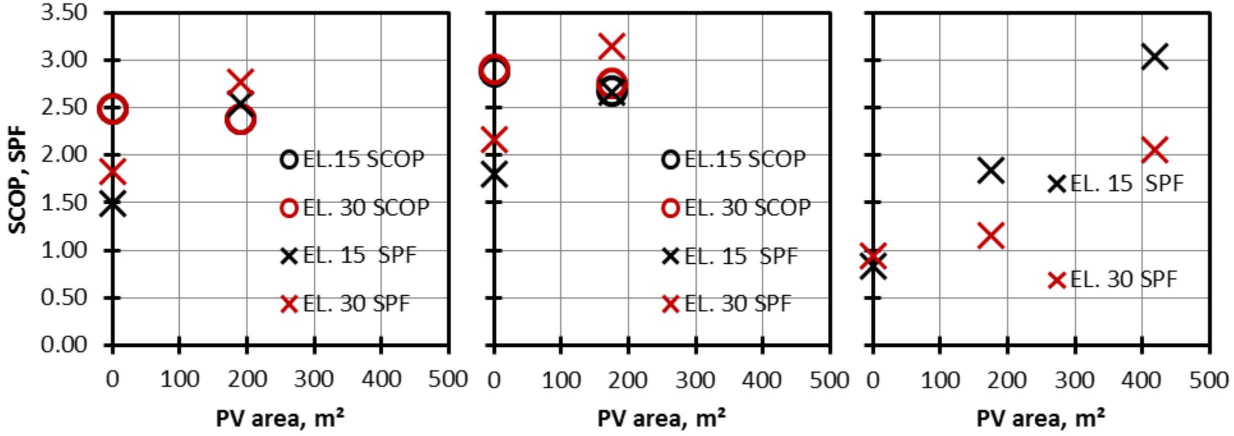


- SCOP is slightly lower in cases with a PV field due to the higher working temperatures
- The highest SPFs are encountered in the decentralized configuration;
- However, a low energy demanding building with a big PV field has a high SPF.

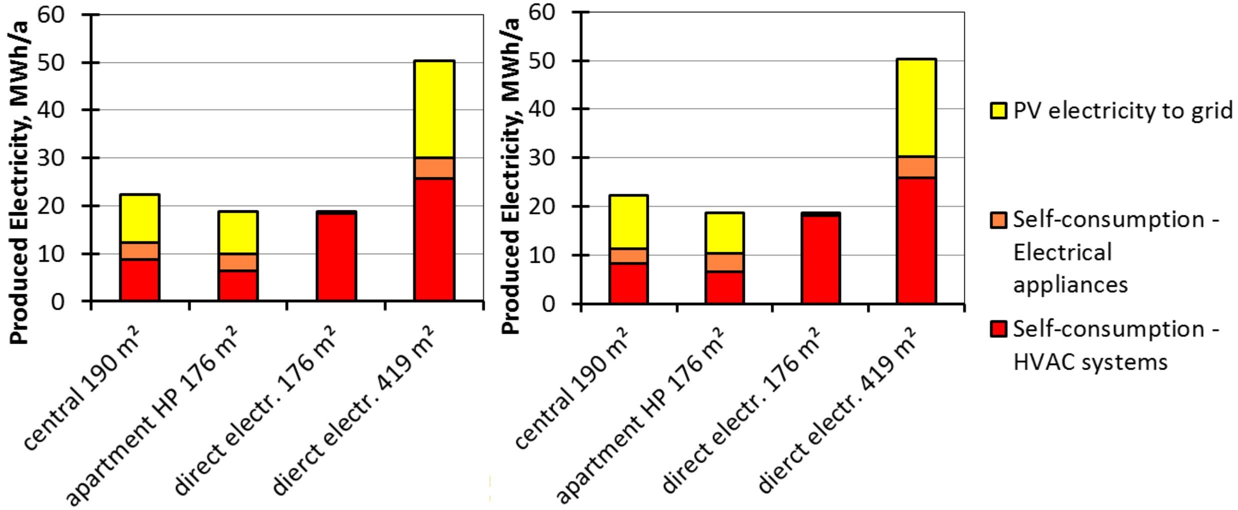


RESULTS – CASE 4

SPF and SCOP



#1: Central heat pump **#2: Heat Pump in each apartment** **#3: Direct electrical heating**



- SCOP is slightly lower in cases with a PV field due to the higher working temperatures
- The highest SPFs are encountered in the decentralized configuration;
- However, a low energy demanding building with a big PV field has a high SPF.

- Self-consumption accounts for one third to a half of the total production.
- The excess of electricity fed into the grid is high in all cases, with exception of the direct heating with small PV field

CONCLUSIONS

- Solar driven systems can assume different configurations, from the **PV coupled** to a heat pump for heating production to the **integration of solar thermal collectors** for decreasing thermal loads to the use of **sorption chillers** for the cooling loads;
- When designing a solar energy system, the solar field size is key, in fact bigger solar thermal fields can cause **stagnation problems** and in PV systems the **self-consumption** can be only a **small fraction of the produced energy** (20% to 30%);
- Solar technologies have good results in terms of solar fraction and SPF also in northern climates thanks to the longer winter season and the inclination of solar radiation in this period.
- The use of thermal storages can help to **maximize the use of solar energy** also in combination with PV systems.

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THANK YOU

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