Performance Analysis of Hybrid Ground Source Heat Pump and PVT System for Nordic Climate

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ChiNOZEN Project

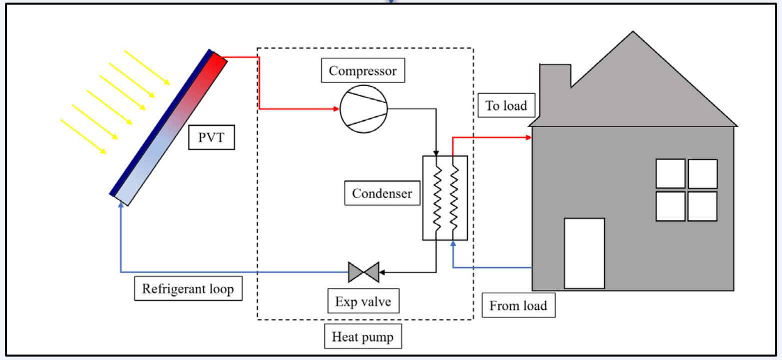
- A collaboration between the universities and research institutions from China, Norway for achieving Zero Energy Neighborhood (ChiNOZEN)
- Funded by Ministry of Science and Technology (MOST) in China and Research Council of Norway (RCN)
- Five work packages aim to investigate "Key technologies and demonstration of combined cooling, heating and power generation for low-carbon neighborhoods/buildings with clean energy"
- The current project is a part of WP1 entitled "Performance of grid-connected photovoltaic technologies (PVT) with Thermal Energy Storage (TES)"

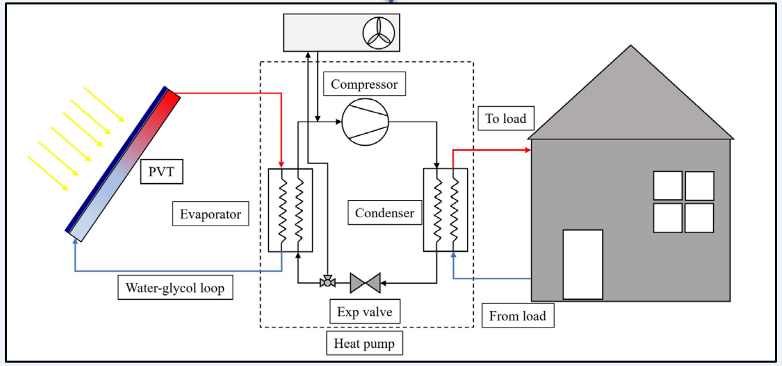
Outline/Agenda

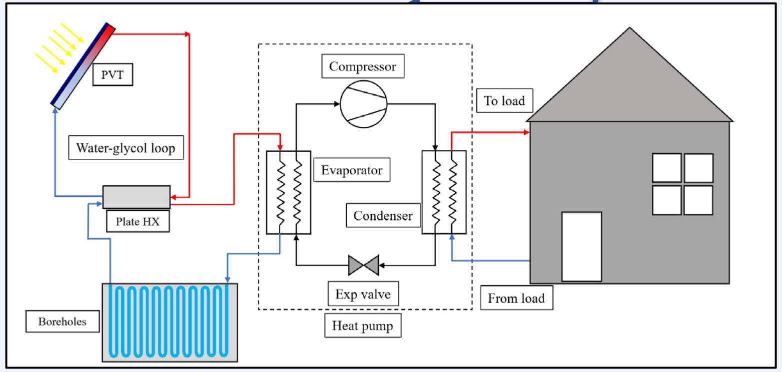
- Introduction
- The most efficient configuration for Scandinavia
- System layout, GSHP vs GSHP+PVT
- Results and discussion
- Concluding remarks

SAHP configurations

- PV/T-SAHP systems
  - DX system
    - Single source (Solar)
    - Dual source (Solar+Air)
  - IDX system
    - Single source (Solar)
    - Dual source (Solar+Air)
    - Dual source (Solar+Ground)

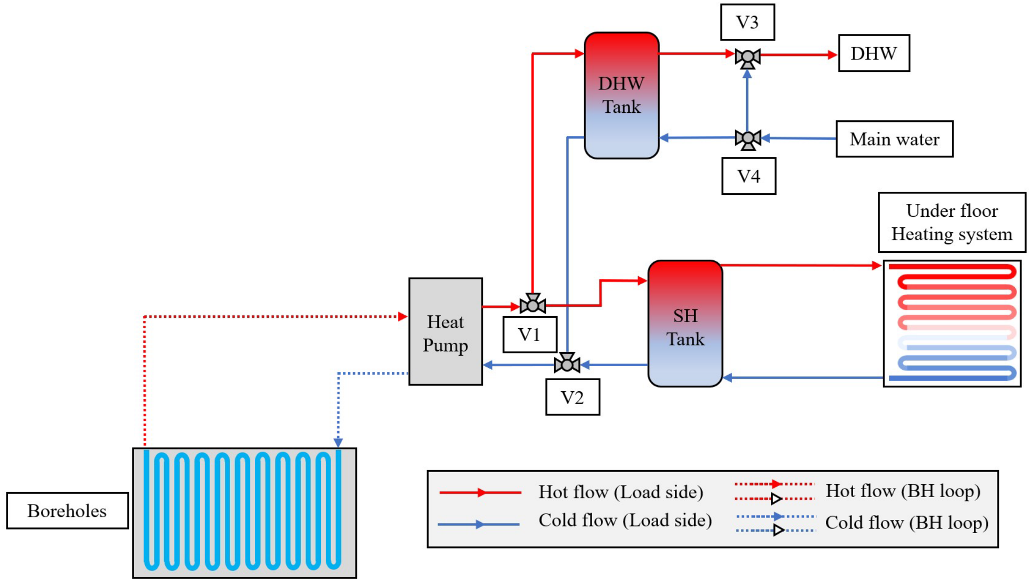


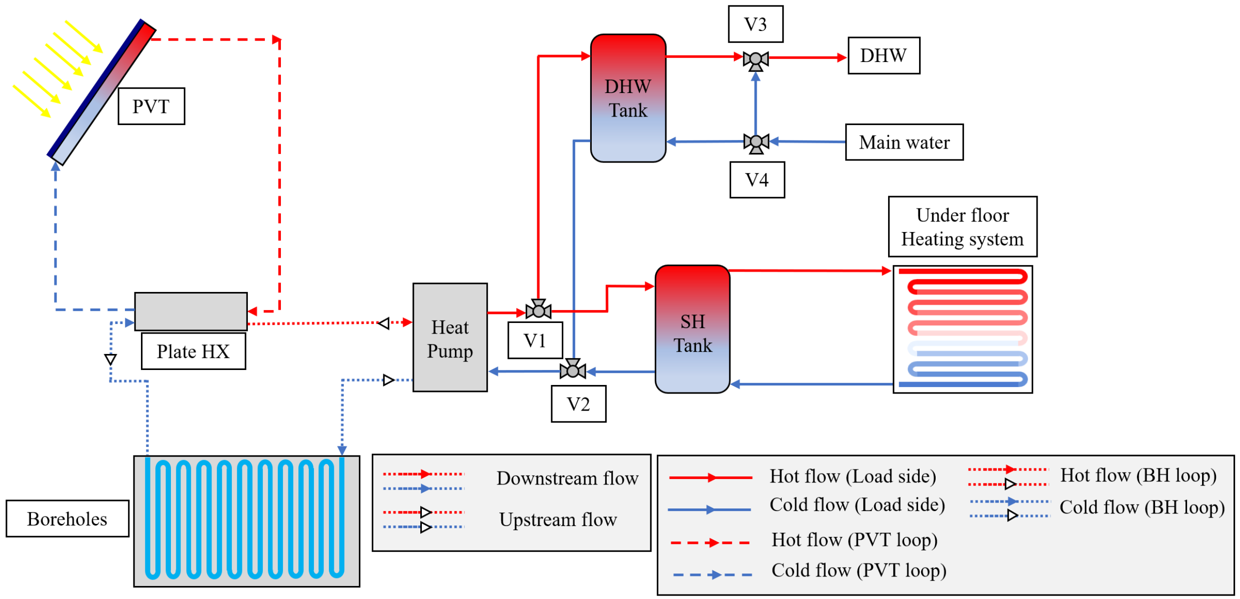




Comparing a standard GSHP to GSHP + PVT

- The system is simulated using <u>TRNSYS</u> over <u>50 years</u>





➢ The baseline is GSHP system with net heat extraction from the ground

➢ PVT combined GSHP system leads to

1. Boosting the HP inlet in the evaporator side
2. Regenerating the extracted heat from the ground

Building characteristics

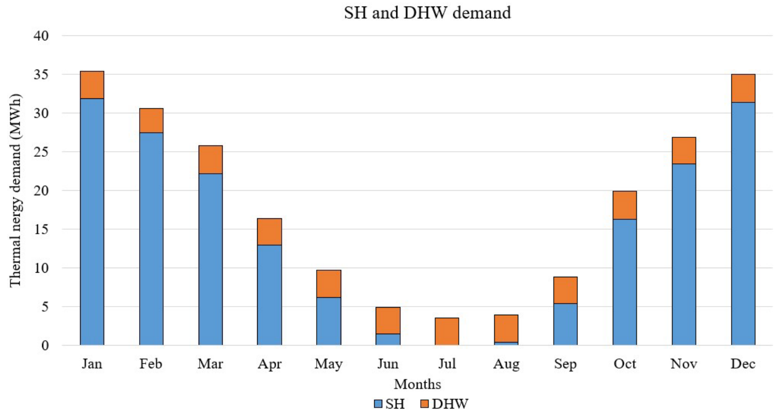
- Typical apartment block in Norway
- Generation 5, from 1991 to 2000

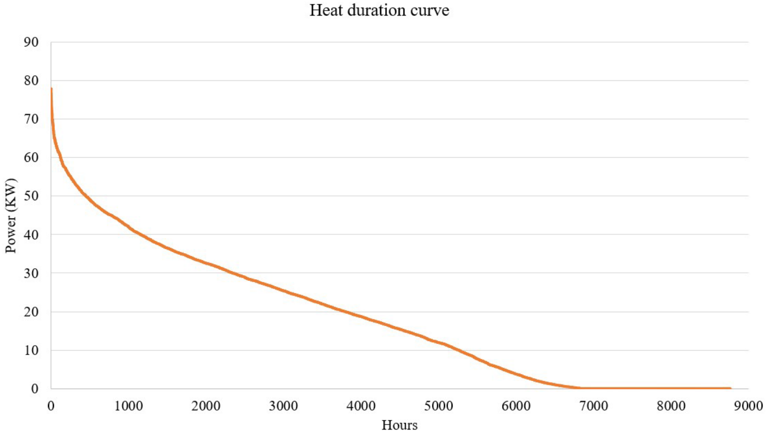
- Number of floors: 4
- Number of dwellings: 24
- Total reference area: 1656 m^2

- Setpoints for room temperature: 20-22 °C
- Setpoint for DHW: 55 °C
- No cooling required

AB.05	Aldersklasse 5	NO.N.AB.05.Gen		
	Bygningstype klassifisering (TABULA kode)			
	Land	NO	Norge	Norway
	Region	N	Uspesifisert	National
	Størrelsesklasse	AB	Boligblokk	Apartment block
	Aldersklasse	5	1991…2000	
	Tilleggskategori	Gen	Grunntype	Generic
Referanseareal 1656 m^2; Antall fulle etasjer 4; Antall leiligheter 24	NTNU SINTEF		TABULA EPISCOPE	

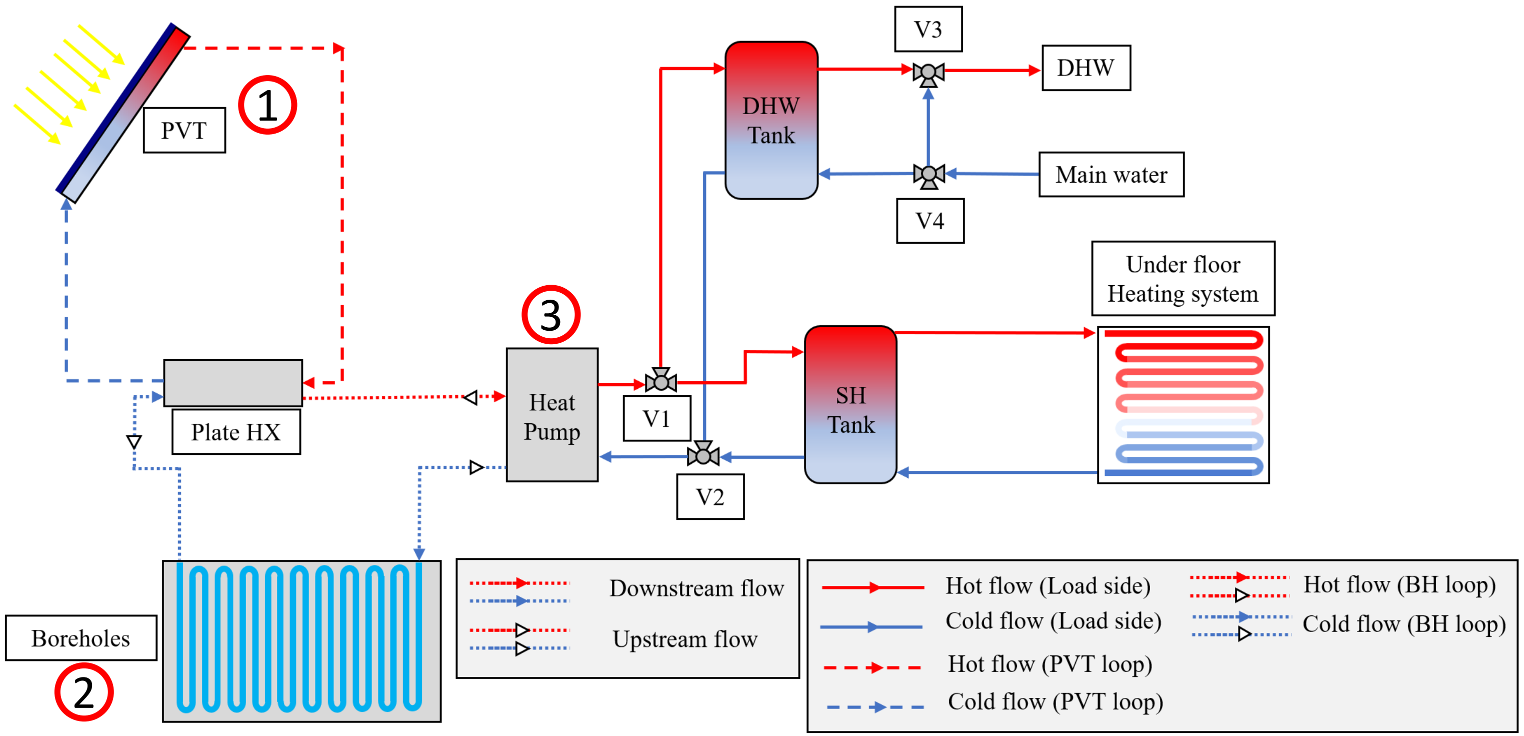
Variant 1 - Eksempelbygning i nå tilstand				
KONSTRUKSJON	U-verdi W/(m²K)	INSTALLASJONER		
TAK: Betongdekke, 180mm min. ull Flatt tak mot det fri	0,20	OPPVARMING: El-varme	[-]	1,32
YTTERVEG: Bindingsverk i tre, 150mm min. ull, 50mm kuldebrobrytere	0,29	VARMTVANN: Fyrkjel, el	[-]	2,19
		Primærenergifaktor samlet [-]		1,42
VINDUER: TEK87 vindu	2,40	VENTILASJON Avtrekk ventilasjonssystem	$\eta_{ve, rec}$ [%]	0
GULV: Betonggulv, 120mm min. ull Gulv mot uoppvarmet kjeller	0,27	SOLCELLER Ikke relevant	[kW_p] -	-





System layout description

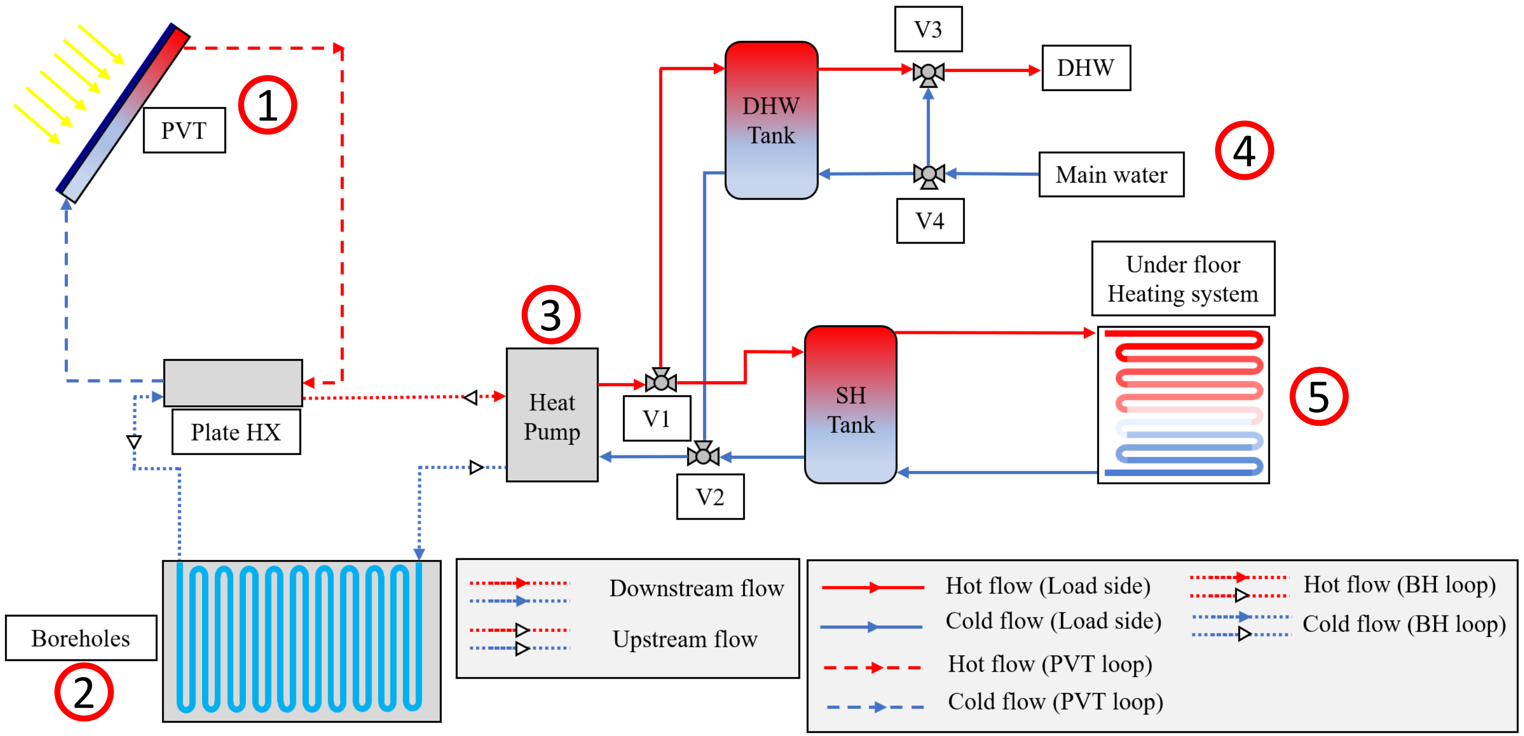
1. PVT loop
   - Designed as a function of HP power, 1 PVT per KW of HP
   - Cut in/off temperatures: 6 and 1 °C
   - Boosting the HP inlet in the evaporator side
   - Regenerating the extracted heat from the ground
2. BH loop
   - Baseline is a BH filed with 12 BHs, 200 m depth, 20 m spacing
   - Designed to provide approximately 70% of the heat for HP
3. HP
   - Covers both SH and DHW production
   - The priority of providing heat is by DHW
   - Designed to cover 90% of building heat energy demand
   - Designed to cover 65% of peak power of the building



System layout description

4. DHW production
   - Specific energy demand: 25 kWh/m^2.year
   - Setpoint temperature: 55 ^{o}C

5. SH
   - Specific energy demand: 107 kWh/m^2.year
   - Provided by floor heating with supply temperature 30 – 40 ^{o}C
   - Direct electric heater is used as peak load system when the HP cannot cover the total SH energy demand



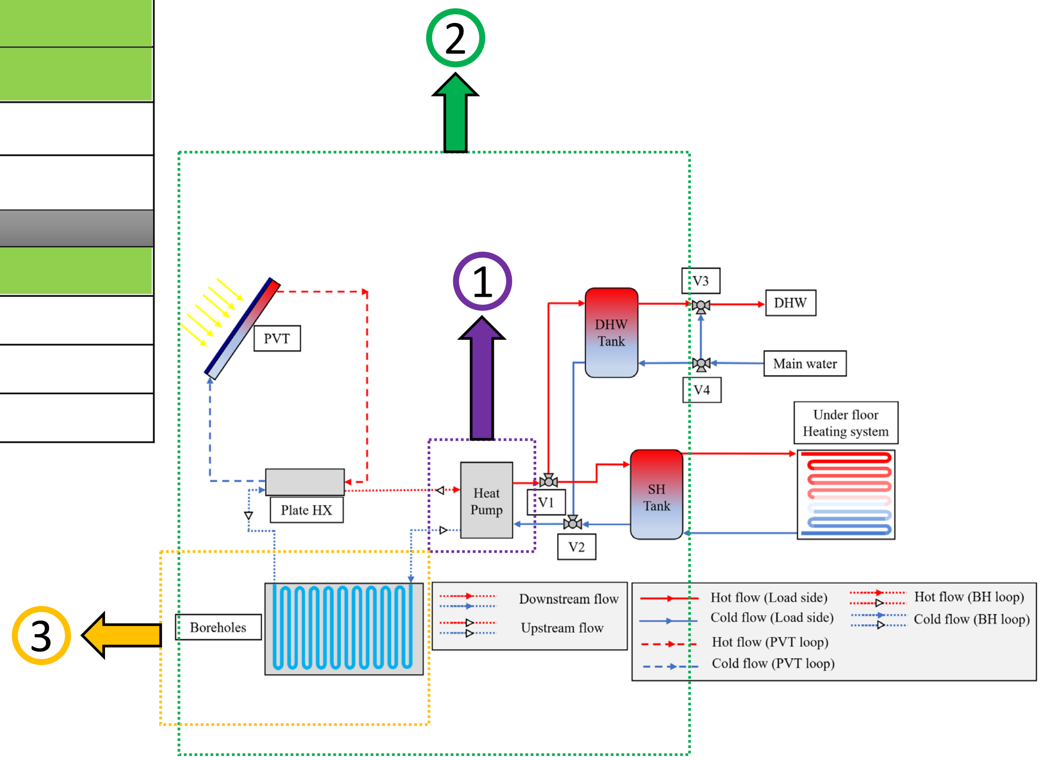
Key Performance Indicators (KPIs)

1. $SPF_1^{(HP)}$
   - Coefficient of Performance (SCOP) of the HP

2. $SPF_4^{(Total)}$
   - Performance indicator of the whole system
   - Self consumption of PVT panels is not considered
   - Energy import/export from/to grid is not considered

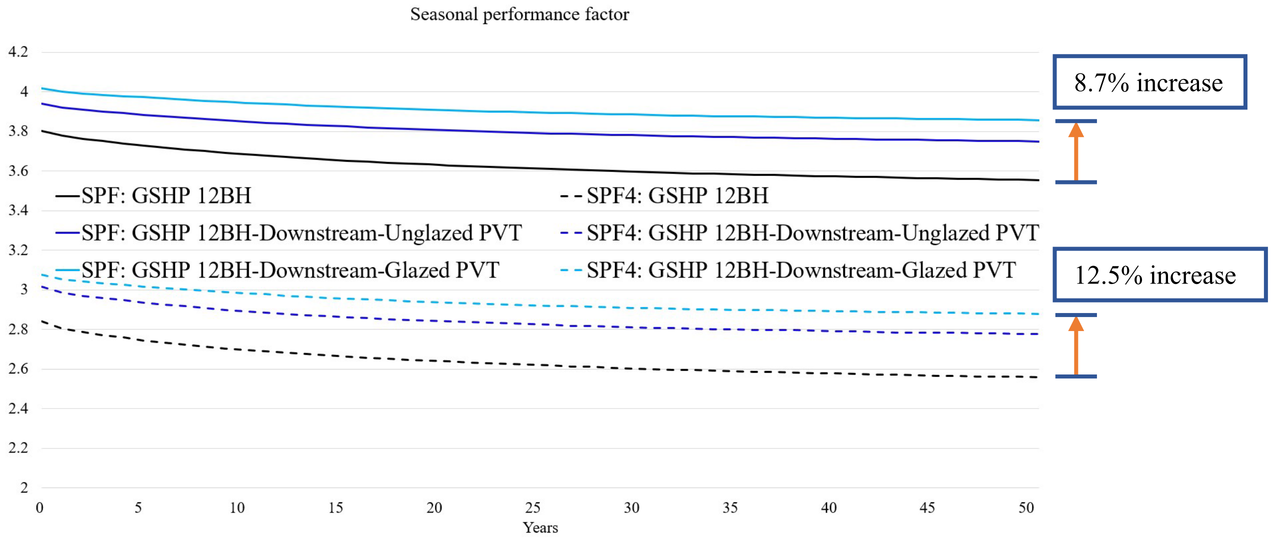
3. Ave BH Temp
   - Monthly values of inlet and outlet flow temperature is used
   - Soil temperature is not presented in this project

	1. System Performance Factor (SPF:)	
1	$SPF_1^{(HP)} = \frac{Q_{HP}}{E_{HP}}$	
2	$SPF_4^{(Total)} = \frac{Q_{SH} + Q_{DHW}}{E_{HP} + E_{Peak\ Load} + E_{Pumps}}$	
	$SPF_4^{(Grid)} = \frac{Q_{SH} + Q_{DHW}}{E_{Grid}}$	
	$SPF_4^{(Net)} = \frac{Q_{SH} + Q_{DHW}}{E_{Grid} - E_{Export}}$	
	2. BH temperature	
3	$Ave\ BH\ Temp = \frac{T_{In} + T_{Out}}{2}$	
	$Ave\ soil\ temp$	
	$Ave\ soil\ temp\ - Center$	
	$Ave\ soil\ temp\ - Edges$	



GSHP+PVT, downstream layout Glazed PVT vs Unglazed PVT

Comparing the downstream cases with the baseline

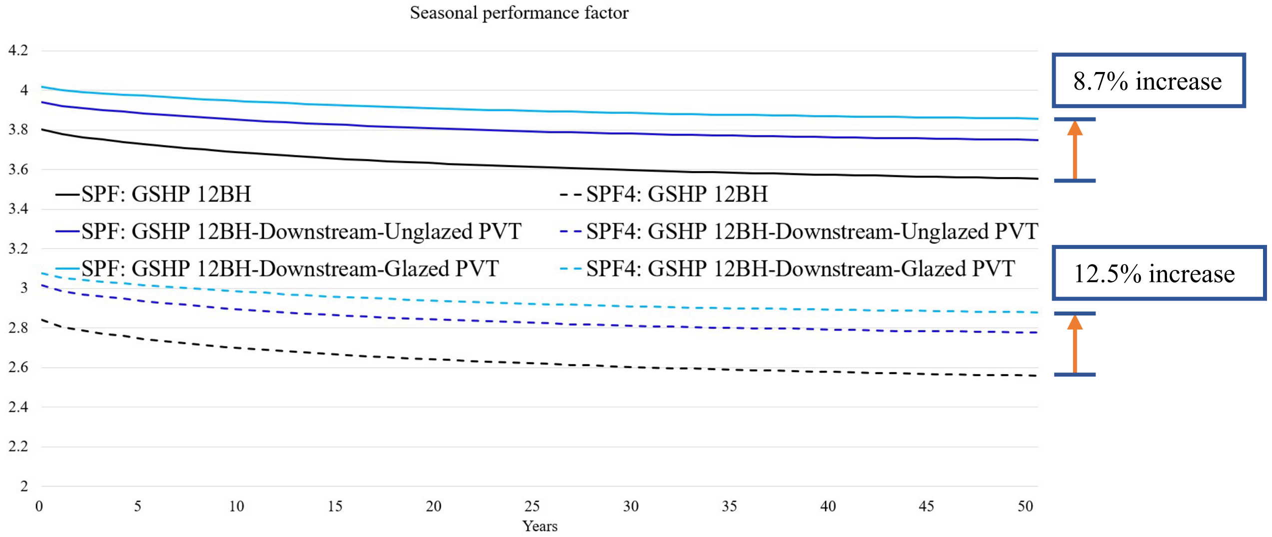


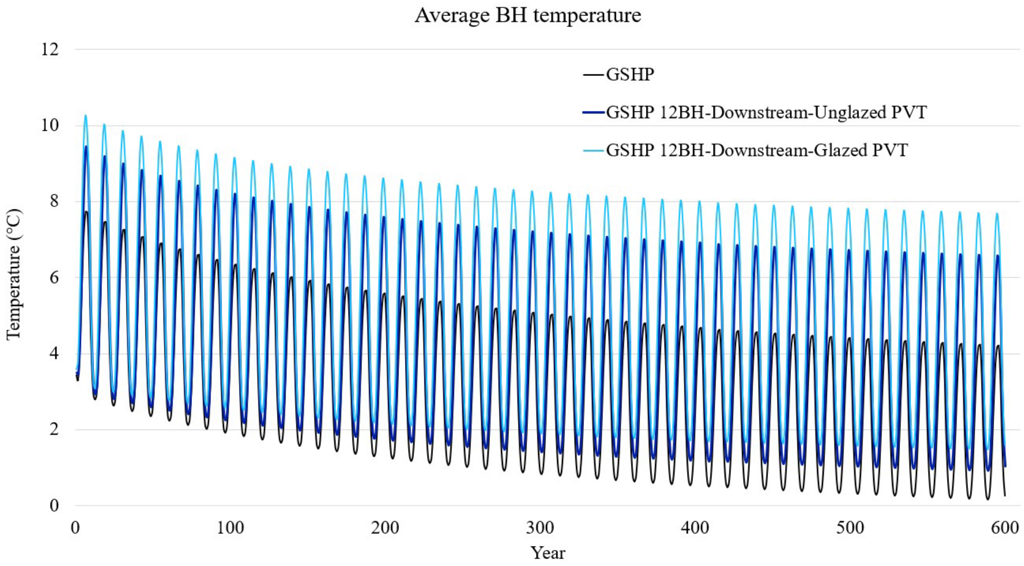
Parameter	Downstream Unglazed	Downstream Glazed
SPF enhancement of first year	3.6%	5.7%
SPF enhancement of last year	5.6%	8.7%
SPF_4 enhancement of first year	5.7%	8.5%
SPF_4 enhancement of last year	8.7%	12.5%

- Performance enhancement is more significant in the last years compared to the first year
- Using Glazed PVT, more significant enhancement in SPF and SPF_4 can be achieved

GSHP+PVT, downstream layout
Glazed PVT vs Unglazed PVT

GSHP+PVT with downstream layout, Glazed vs Unglazed

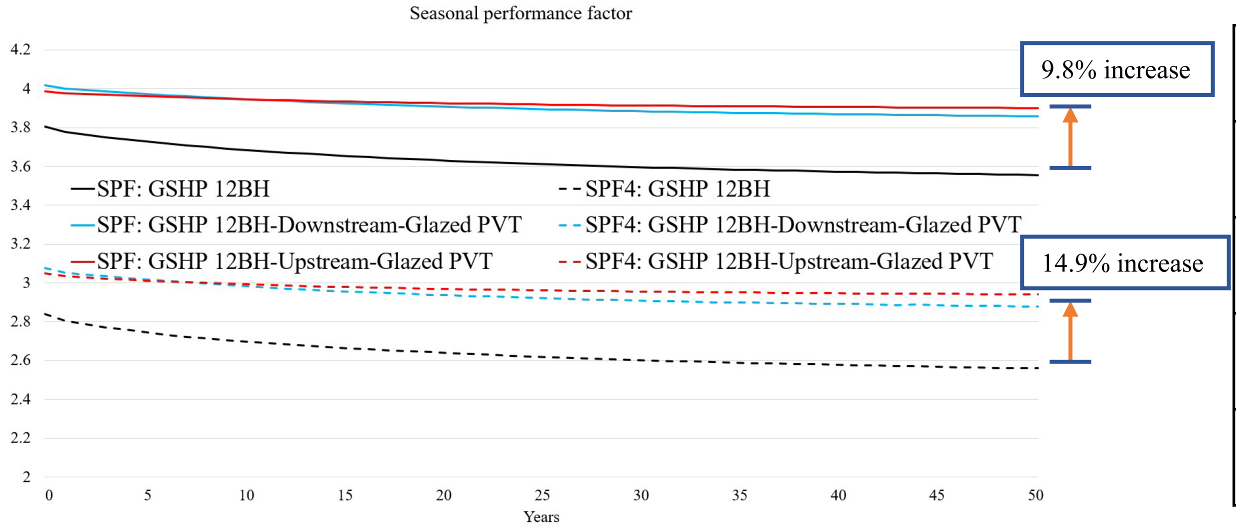




- Maintaining the ground temperature using PVT results in achieving more stable performance after some years of operation
- Glazed PVT collector can compensate the extracted energy from the ground better than unglazed PVT

GSHP+PVT, Glazed PVT Downstream vs Upstream layout

GSHP+PVT with glazed PVT, Upstream vs Downstream



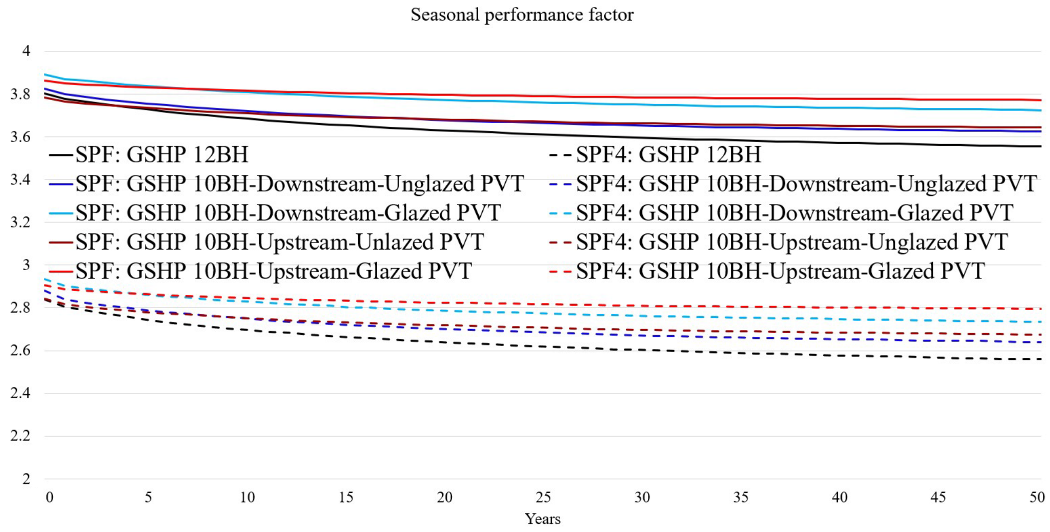
Parameter	Downstream Glazed	Upstream Glazed
SPF enhancement of first year	5.7%	4.9%
SPF enhancement of last year	8.7%	9.8%
SPF_4 enhancement of first year	8.5%	7.4%
SPF_4 enhancement of last year	12.5%	14.9%

- Upstream layout shows lower performance enhancement in the first years of operation
- Due to the better recharging the BHs using upstream layout, performance enhancement in the last years of operation is more significant

GSHP+PVT, reducing the BH field

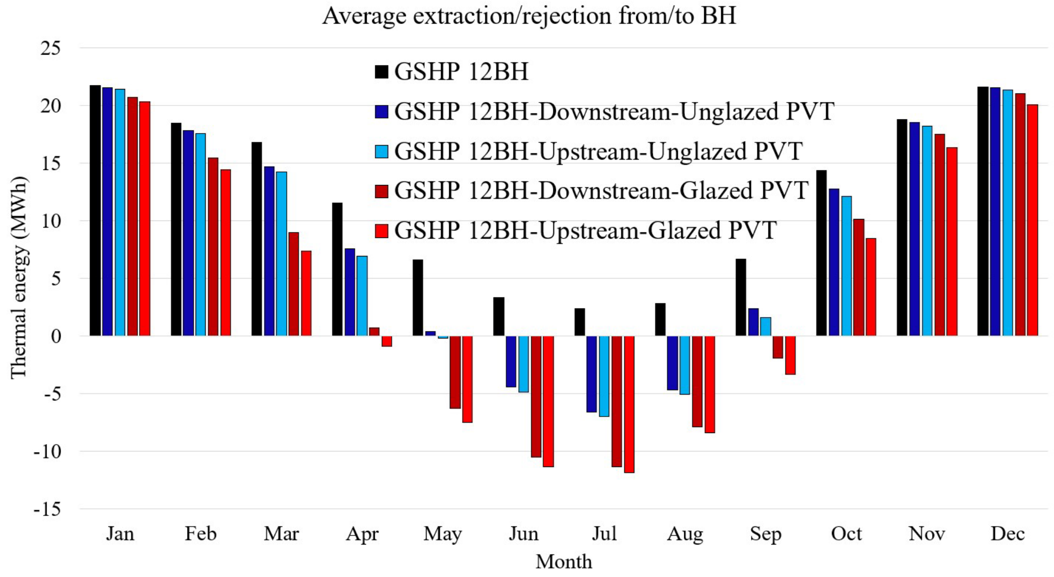
Comparing the cases with smaller BH filed to the baseline

- More than 15% reduction in total BH length can be achieved when the system is combined with PVT collectors
- Still higher performance factors can be achieved by comparing GSHP and GSHP+PVT with smaller BH field
- By reducing the BH filed by 15%, there is not a significant difference in performance factor of the systems of GSHP and GSHP+PVT with smaller BH field
- The difference is more significant for the last years of operation



Average heat extraction from the BH

Comparing the cases to the baseline



Case definition	Ground regeneration percentage
GSHP 12BH	-
GSHP 12BH-Downstream-Unglazed PVT	30.2%
GSHP 12BH-Upstream-Unglazed PVT	33.6%
GSHP 12BH-Downstream-Glazed PVT	61%
GSHP 12BH-Upstream-Glazed PVT	70%

- Up to 70% of the extracted heat can be injected to the ground using glazed PVT and upstream layout

Concluding remarks

- By using Glazed PVT, more significant enhancement in SPF and SPF_4 can be achieved, compared to unglazed PVT
- The heat injected to the ground is relatively higher in case of using glazed PVT collectors
- The yearly variation of SPF and SPF_4 is more stable than the other cases
- Due to the better recharging of the BHs using upstream layout, performance enhancement in the last years of operation is more significant, 14.9% increase in SPF_4 in case of using glazed PVT collectors
- Up to 70% of the extracted heat can be injected to the ground using glazed PVT and upstream layout
- Using GSHP+PVT system results in reducing the BH total length by 15% and at the same time, achieving higher SPF and SPF_4 6.2% and 8.4% for upstream-glazed case, respectively

THANK YOU