

Comparison of different heat sources to assist ground-source heat pump systems

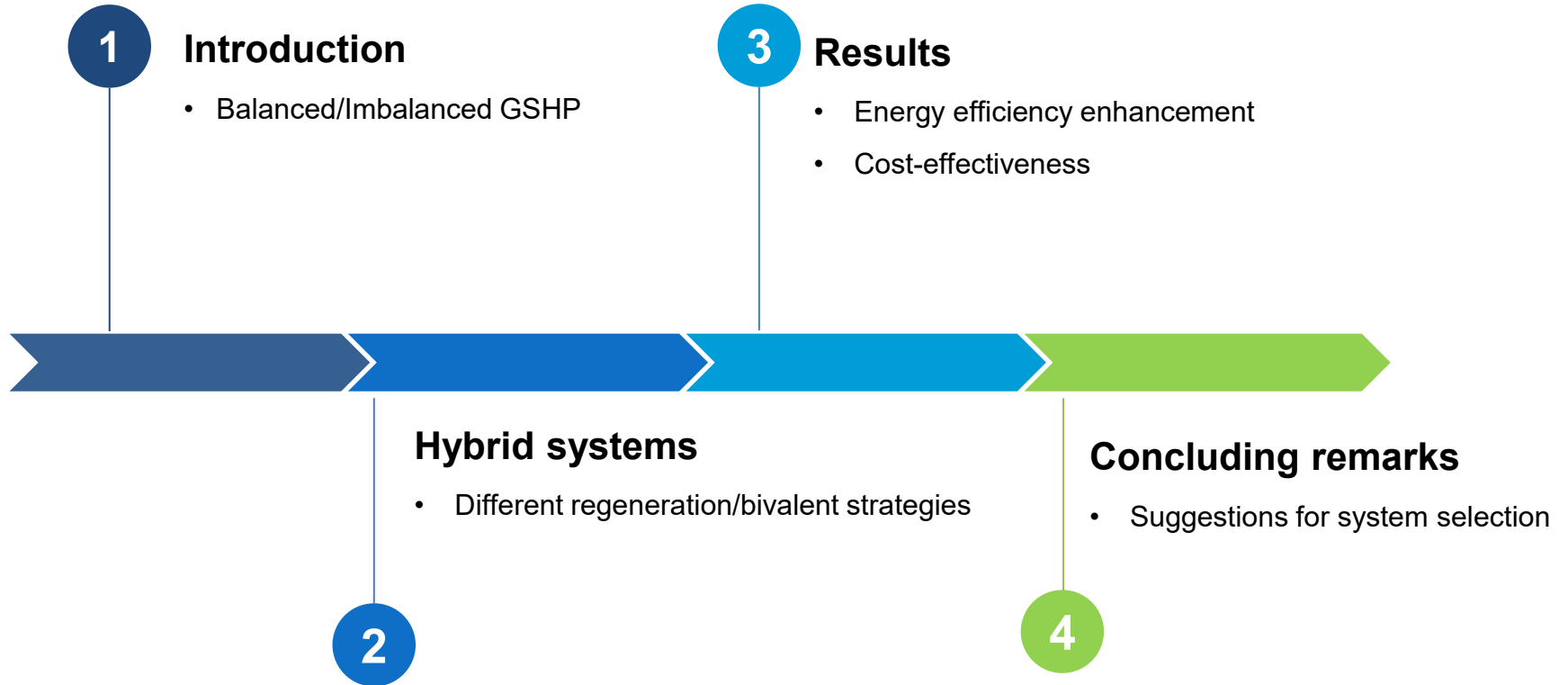
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Hybrid Ground Source Heat Pumps in Cold Climates Workshop
2025, Trondheim

Outline



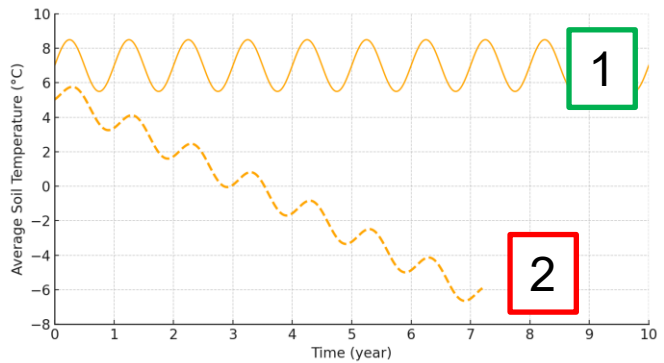
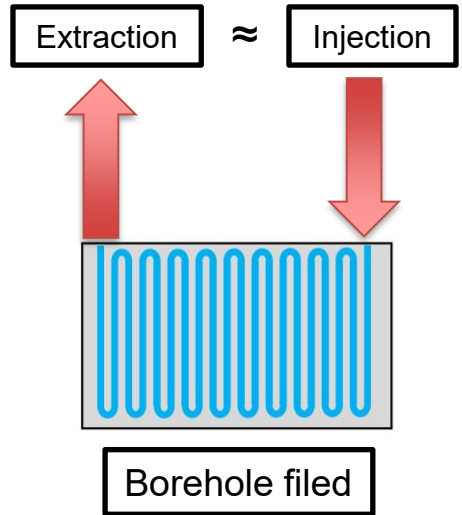
Balanced vs. Imbalanced heat injection/extraction

1 Balanced heat extraction/injection

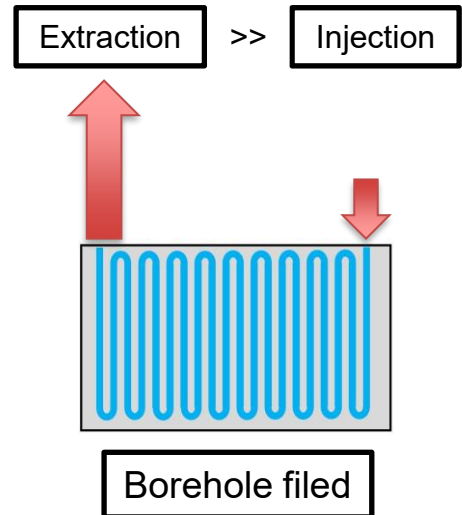
- ✓ Example: office with balance heating and cooling needs
- ✓ Periodic yearly cycles

2 Imbalanced heat extraction/injection

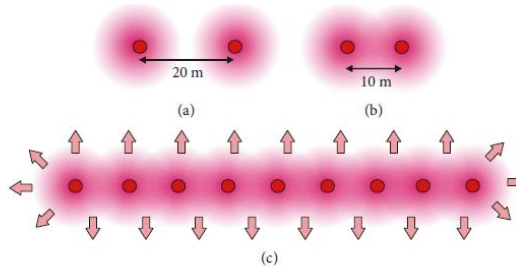
- ✓ Example: residential buildings in cold climates
- ✓ Progressive decrease of ground temperature



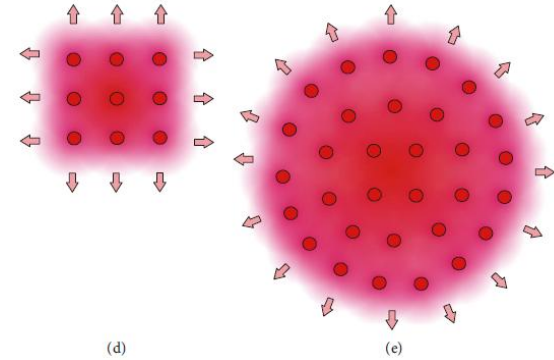
T. You, et al. in Energy and Buildings, 2015



Solution for imbalanced heat injection/extraction



H. Skarphagen, et al. in Geofluids, 2019



Small scale – non-compact configuration

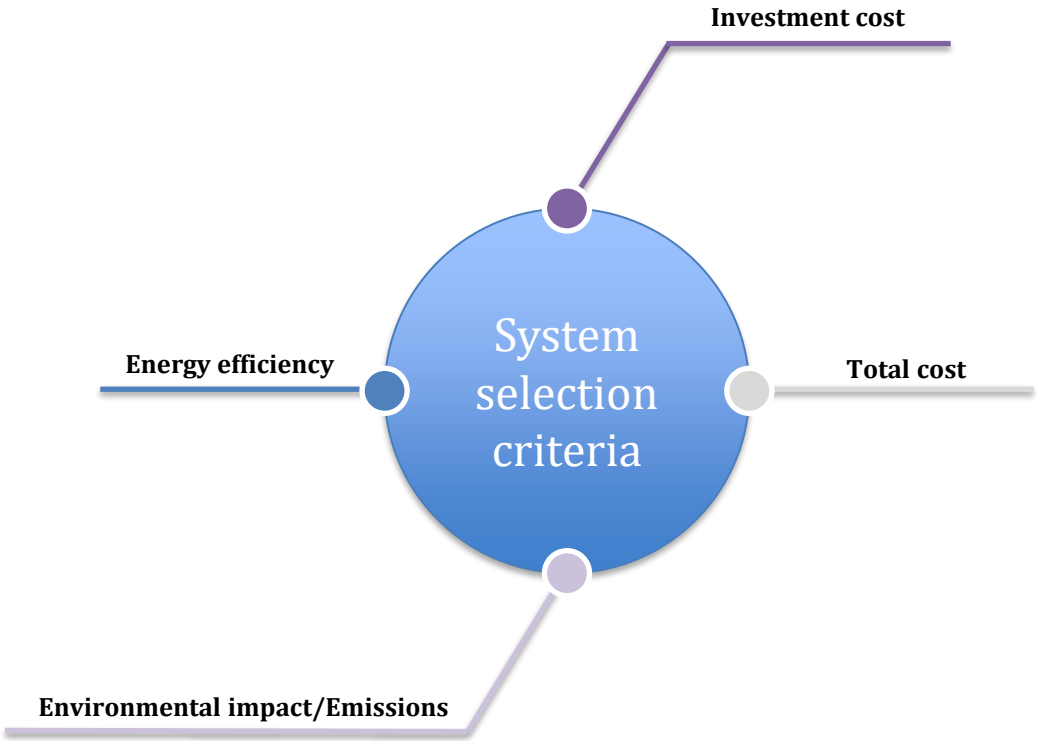
➤ Natural regeneration

Compact configuration – Higher scales

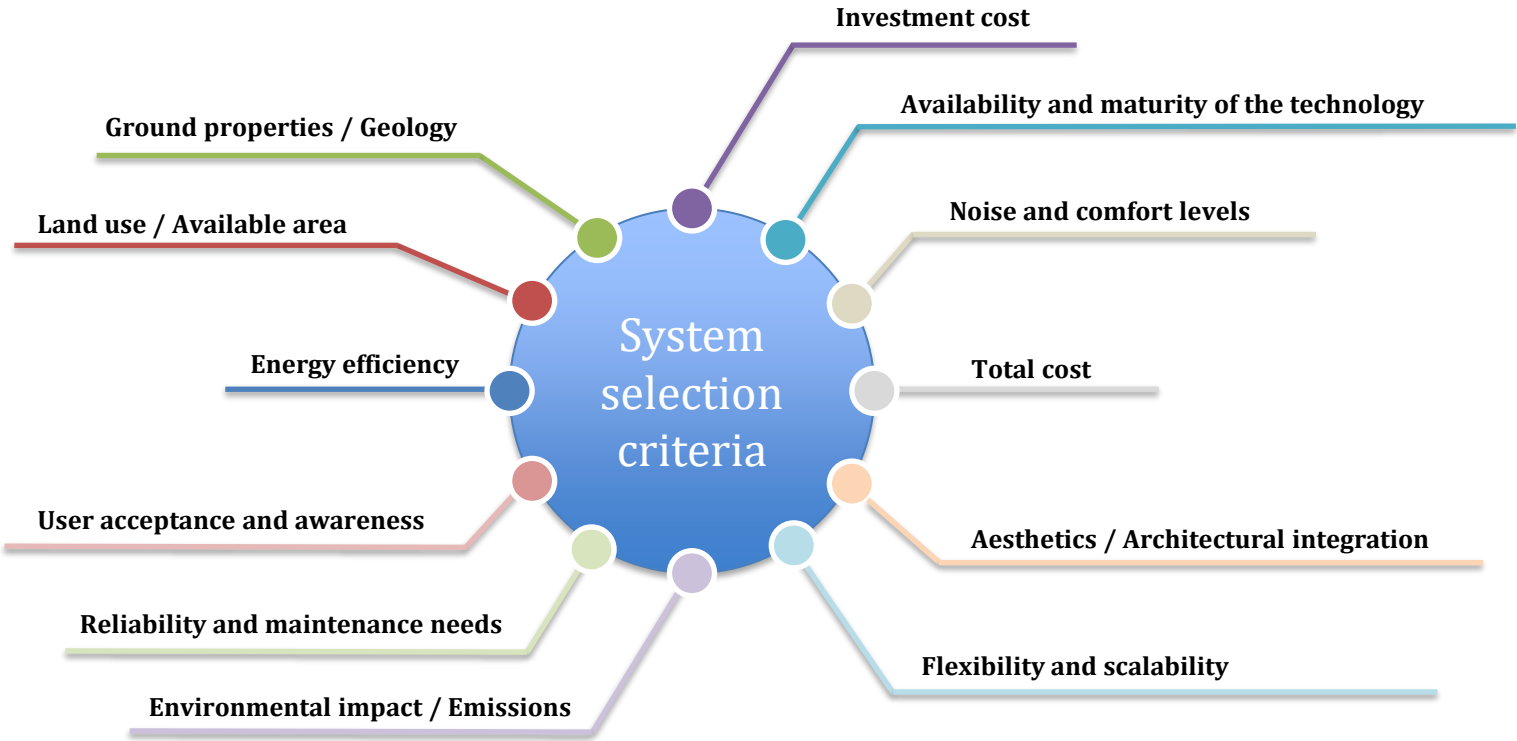
➤ Artificial regeneration

- ✓ Solar thermal
- ✓ Excess heat from space cooling
- ✓ Ambient air

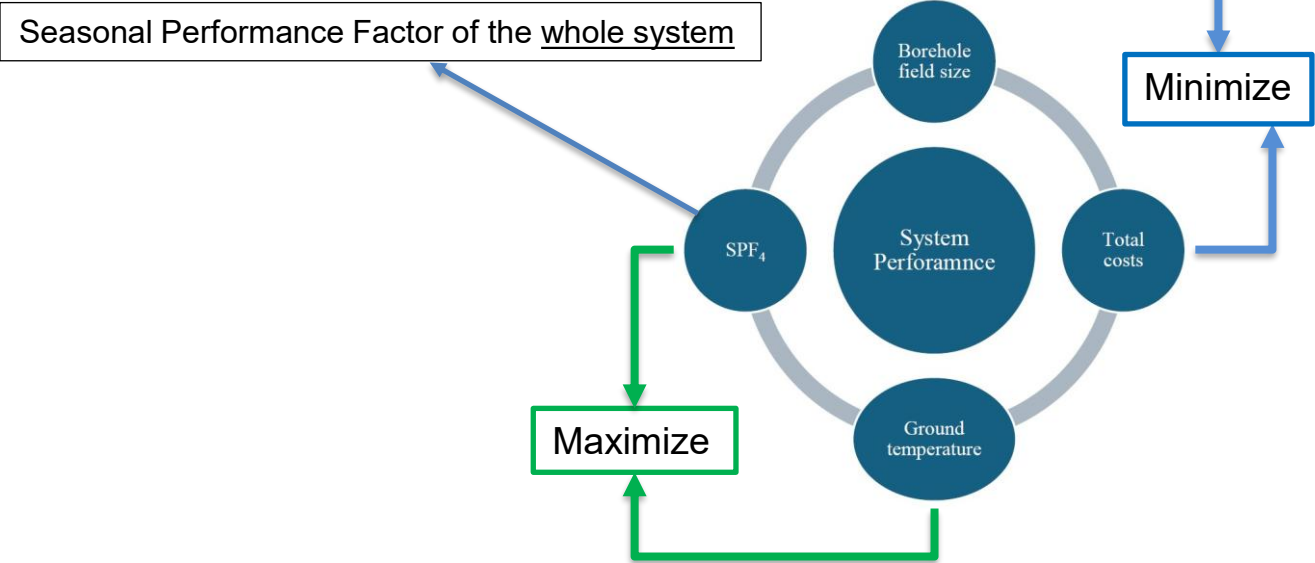
Selection criteria



Selection criteria

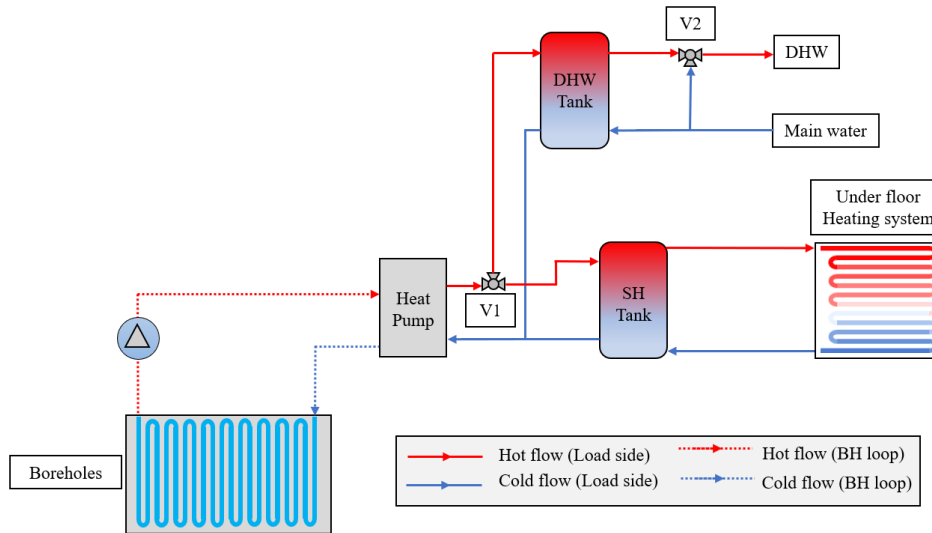


Optimizing the system performance of GSHP systems



GSHP system

The system is simulated using TRNSYS over 20 years

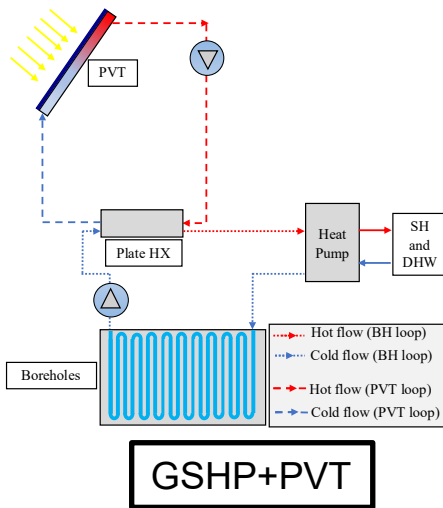


M. Liravi, et al. in Energy Conversion and Management, 2024

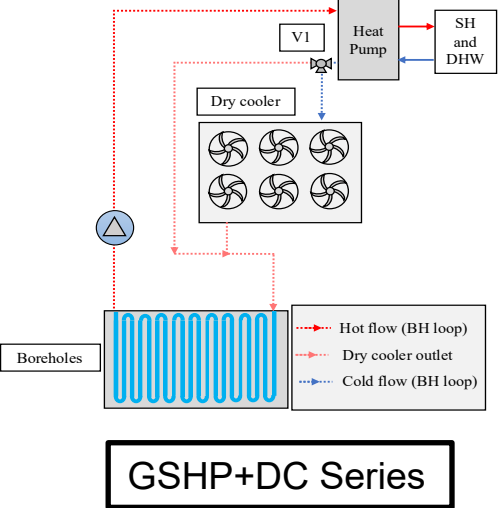
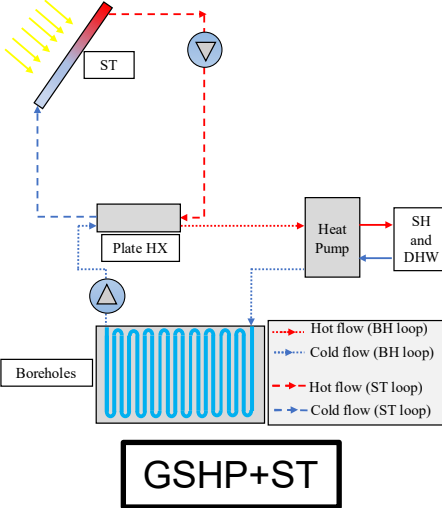
- ✓ The baseline is GSHP system with net heat extraction from the ground
- ✓ Space heating and domestic hot water – without cooling

GSHP vs. other Hybrid Ground Source Heat Pump systems

Regeneration strategies



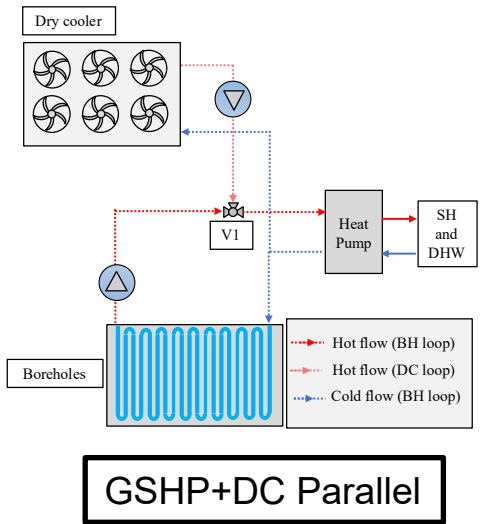
✓ 0.5 and 1 PVT/kW_{HP} or ST/kW_{HP}



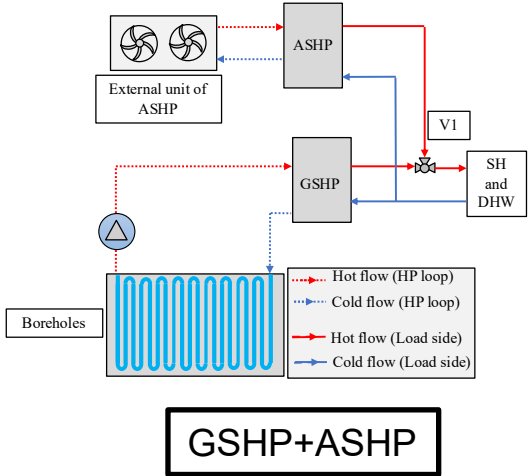
✓ 0.8, 1.2 and 1.6 kW_{DC}/kW_{HP}

GSHP vs. other Hybrid Ground Source Heat Pump systems

Bivalent alternatives – ambient air assisted layouts



- ✓ 0.8, 1.2 and 1.6 kW_{DC}/kW_{HP}
- ✓ The control strategy is based on temperature limit – 0, 2.5 and 5 °C

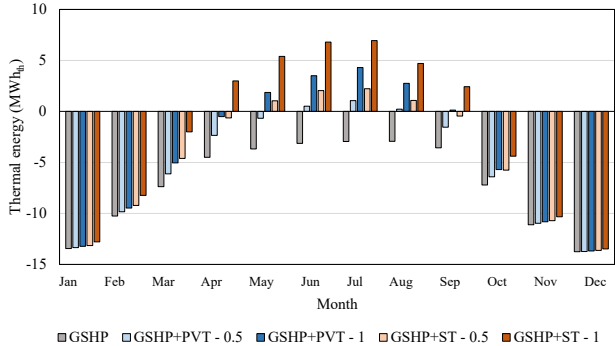


- ✓ 66% of GSHP rated heating capacity
- ✓ Control strategy, similar to GSHP+DC parallel – 0, 2.5 and 5 °C

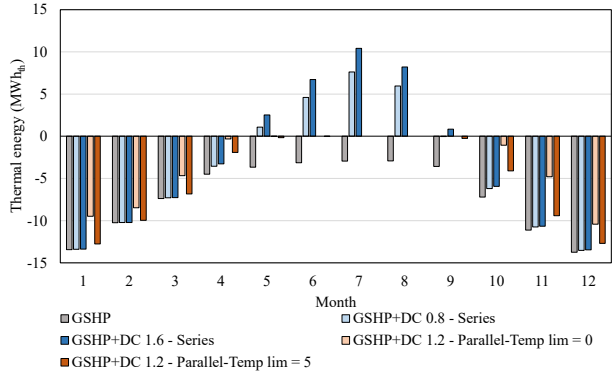
GSHP vs. other Hybrid Ground Source Heat Pump systems

Impact on annual net heat extraction

ST and PVT



DC in series and parallel



System type	Condition	Annual net heat extraction (MWh)	Difference (%)
GSHP		83.88	-
GSHP+PVT	0.5 PVT/kW _{HP}	63.17	-24.7
	1 PVT/kW _{HP}	45.90	-45.3
GSHP+ST	0.5 ST/kW _{HP}	51.76	-38.3
	1 ST/kW _{HP}	22.00	-73.8
GSHP+DC - Series	0.8 kW _{DC} /kW _{HP}	45.71	-45.5
	1.2 kW _{DC} /kW _{HP}	39.38	-53.1
	1.6 kW _{DC} /kW _{HP}	35.48	-57.7
GSHP+DC - Parallel	1.2 kW _{DC} /kW _{HP}	39.22	-53.2
	Temp lim = 0 °C		
	1.2 kW _{DC} /kW _{HP}	58.09	-30.7
	Temp lim = 5 °C		
GSHP+ASHP	Temp lim = 0 °C	39.94	-52.4
	Temp lim = 2.5 °C	50.15	-40.2
	Temp lim = 5 °C	58.81	-29.9

GSHP vs. other Hybrid Ground Source Heat Pump systems

General conclusions – Performance enhancement in each layout

Category	Layouts	SPF ₄ enhancement	BH size reduction	Ground stability	Comment
Regeneration	GSHP+ST	Green	Green	Green	Highest regeneration, stabilizes ground temp, enhances SPF ₄
	GSHP+PVT	Light Green	Green	Light Green	Moderate regeneration + electricity, supports BH downsizing, ground stability lower than ST
	GSHP+DC series	Green	Green	Green	Strong regeneration, moderate SPF ₄ enhancement
Bivalent	GSHP+DC parallel	Yellow	Yellow	Light Green	Improves efficiency in certain control, weaker ground support, limited BH reduction
	GSHP+ASHP	Red	Yellow	Light Green	No SPF ₄ enhancement, weak ground stability, not ideal for reducing BHs

Key message:

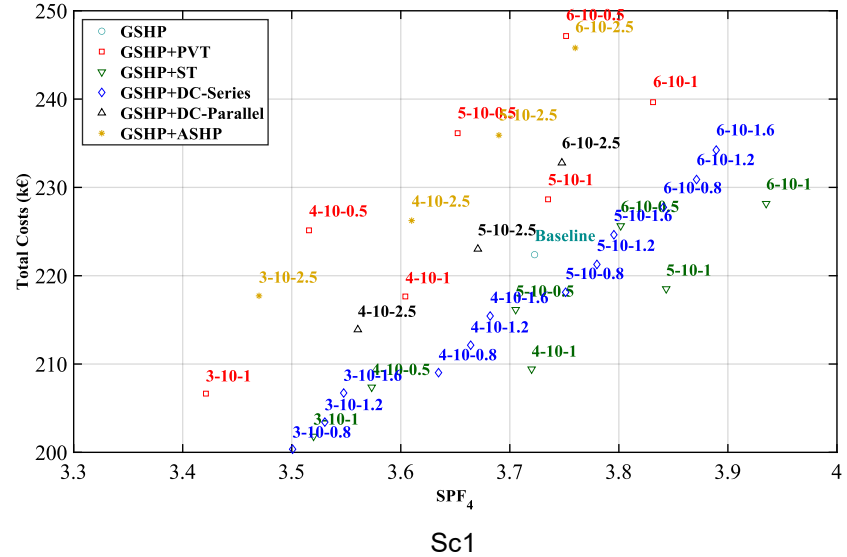
- Energy efficiency enhancement + BH reduction: ST and DC-Series
- Moderate achievements: PVT
- Limited effect: DC-Parallel & ASHP

GSHP vs. other Hybrid Ground Source Heat Pump systems

Comparison of the results

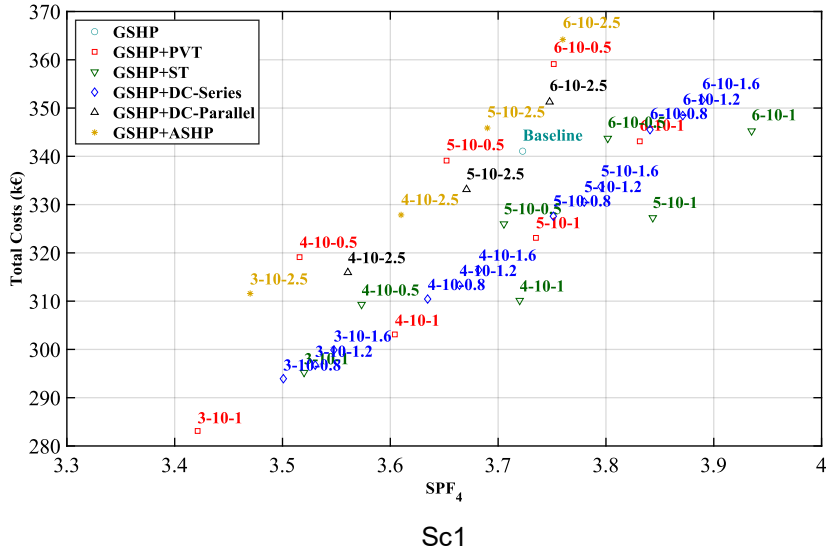
Scenario 1:

El price = 1 NOK/kWh - BH drilling cost = 550 NOK/m



Scenario 2:

El price = 1.5 NOK/kWh - BH drilling cost = 1000 NOK/m



GSHP vs. other Hybrid Ground Source Heat Pump systems

Key findings

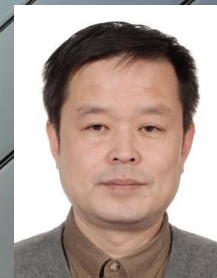
- ✓ Regeneration strategies: more effective for efficiency improvement
- ✓ Bivalent strategies: ground balance – depends on system operation strategy.

Layout	Possibility to reduce boreholes / field area	Potential for lower total cost	Lower total costs for same SPF ₄	Higher SPF ₄ at same total costs	Overall cost and energy performance ranking
GSHP+ST	Yes	Yes	Yes	Yes	1
GSHP+DC Series	Yes	Yes	Yes	Yes	1
GSHP+PVT	Yes	Yes, at Sc = 1 or <u>Opt</u> only	Yes, at Sc = 1 and <u>Opt</u> only	Yes, at <u>Opt</u> only	2
GSHP+DC Parallel	Yes, at Sc =1 only	Yes, at Sc = 1 only	No	No	3
GSHP+ASHP	Yes, at Sc =1 only	Yes, at Sc = 1 only	No	No	4

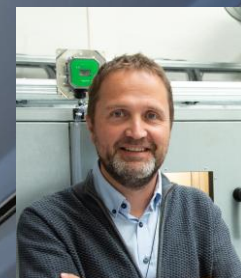
Thank You for Your Attention!



*Mohammad
Liravi*



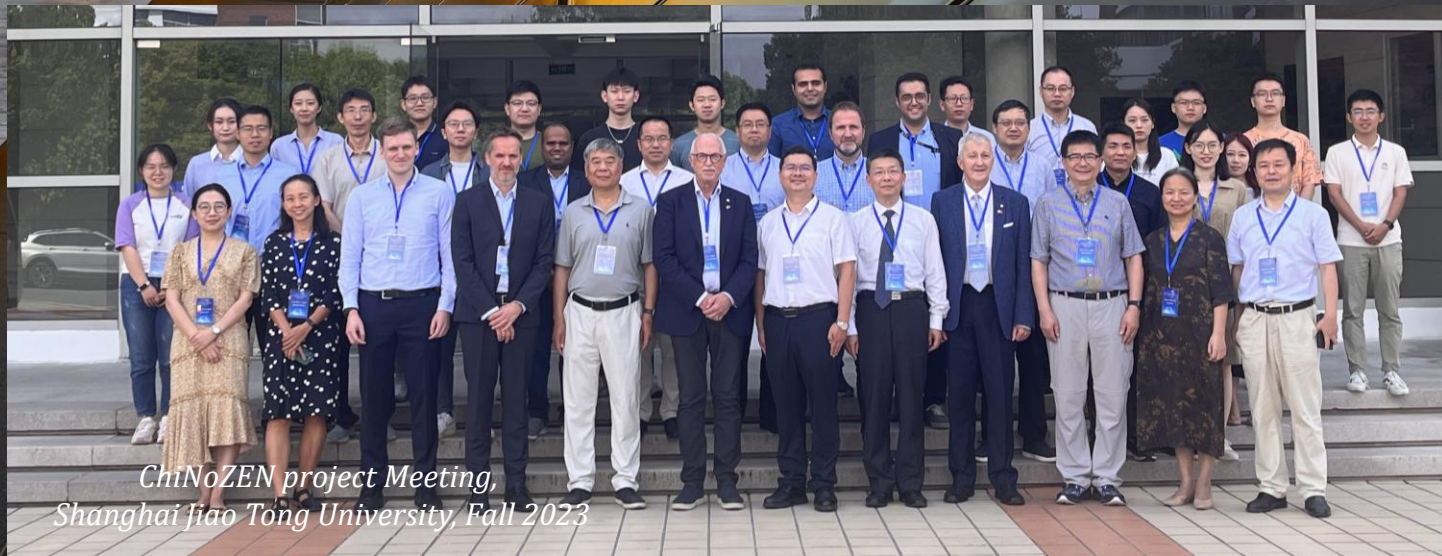
*Yanjun
Dai*



*Laurent
Georges*



PhD thesis
Link



*ChiNoZEN project Meeting,
Shanghai Jiao Tong University, Fall 2023*

GSHP vs. other Hybrid Ground Source Heat Pump systems

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