Hall 8

Chillventa Specialist Forums 2024
Chillventa Fachforen 2024

CONNECTING EXPERTS.

ENGINEERED FOR EXCELLENCE

A NOVEL HEAT PUMP CONFIGURATION FOR VERY COLD WEATHER DISTRICT HEATING

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Honeywell

Dr Wissam Rached

Europe & MEA
Technical Leader

Honeywell

Wissam is a Technical Leader based in France. Currently, he manages the technologies performances improvement program withing EU Honeywell technical team. Within the last 24 years, Wissam had the opportunities to work on different R&D projects on energy storage, energy conversion and refrigerants development. His focus is on compression system applications like refrigeration, heat pump or organic Rankine cycle. Wissam earned a PhD in Energy from the university “Ecole des MINES Paritech” in Paris.

Simon Lintu
Senior Manager
Fortum

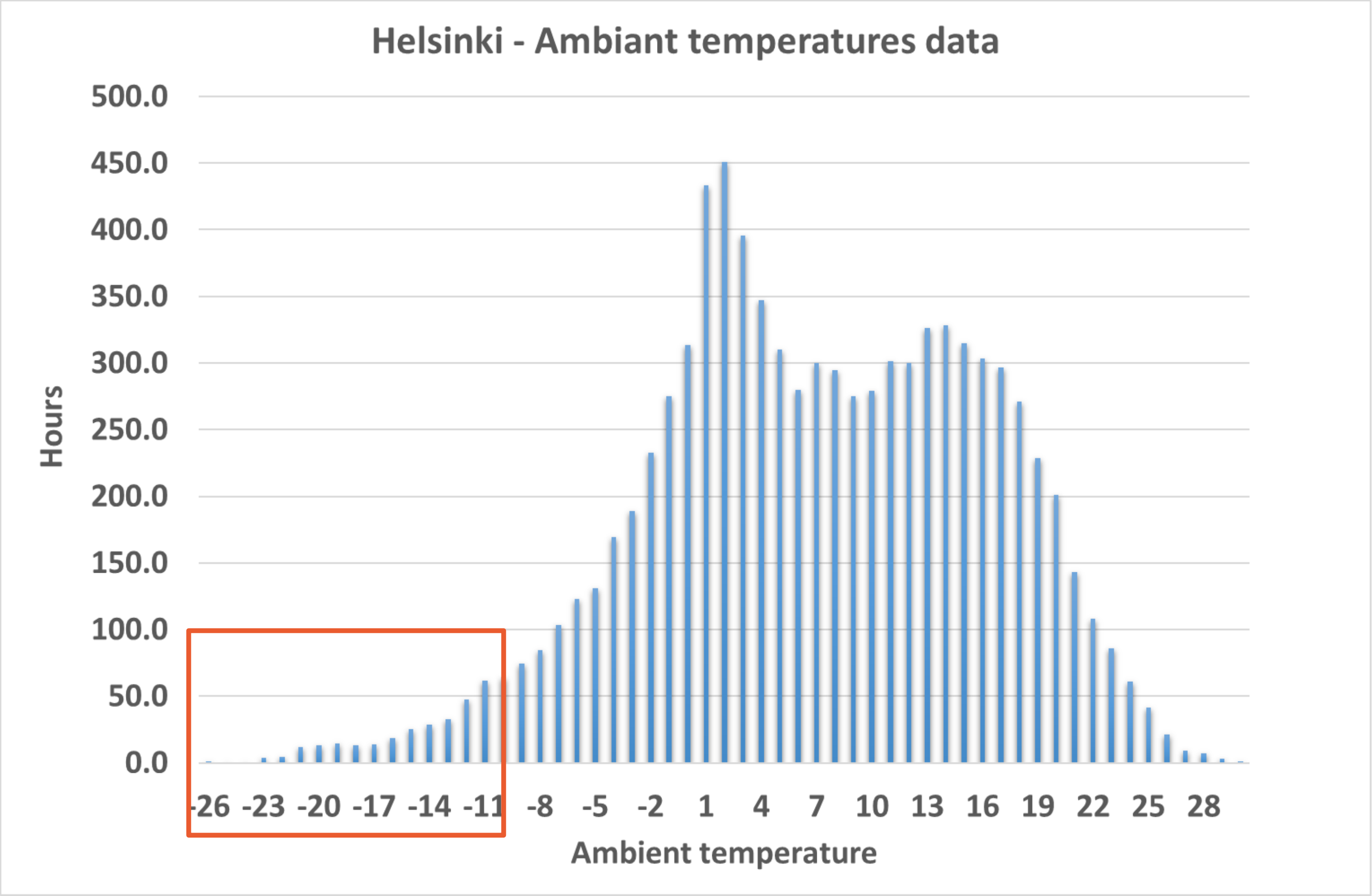
Simon Lintu is senior manager based in Finland. He currently leads a development team responsible for technical development in electricity-based district heating solutions. From R&D governance to new technical solutions and scaling-up new products and production plants. In the last years Simon have introduced new solutions for decarbonising district heating in Espoo Finland, including over 130MW of heat pumps, over 300MW of electrode boiler capacity and over 1600MWh of thermal energy storages.

Helsinki temperatures profiles

Temperature occurrence by hours as a function of the ambient temperature

Ambient temperature is lower than -10°C for 353h/year

5% is the percentage of heating needs at temperature lower than -10°C over the total needs

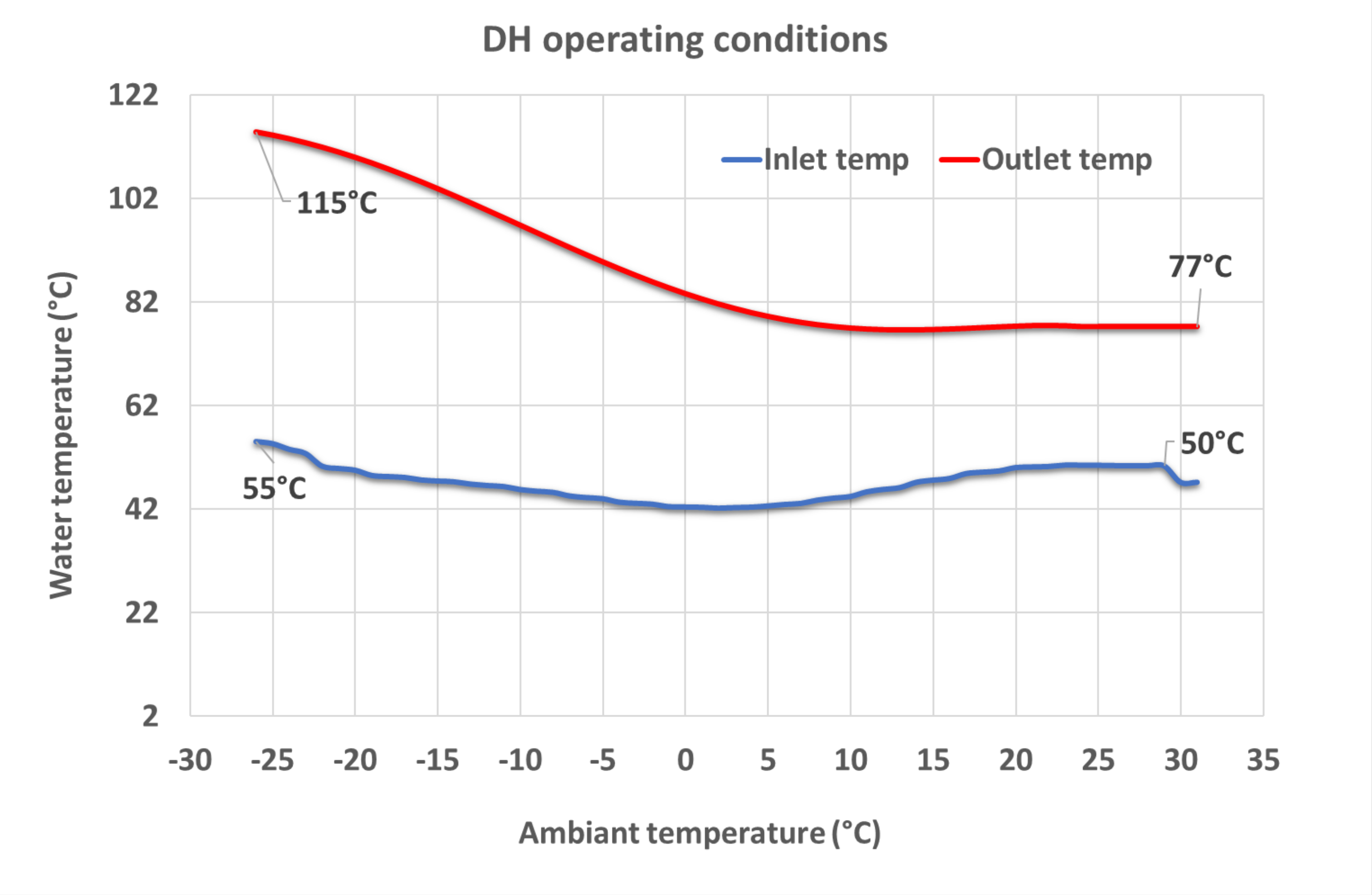


Helsinki temperatures profiles

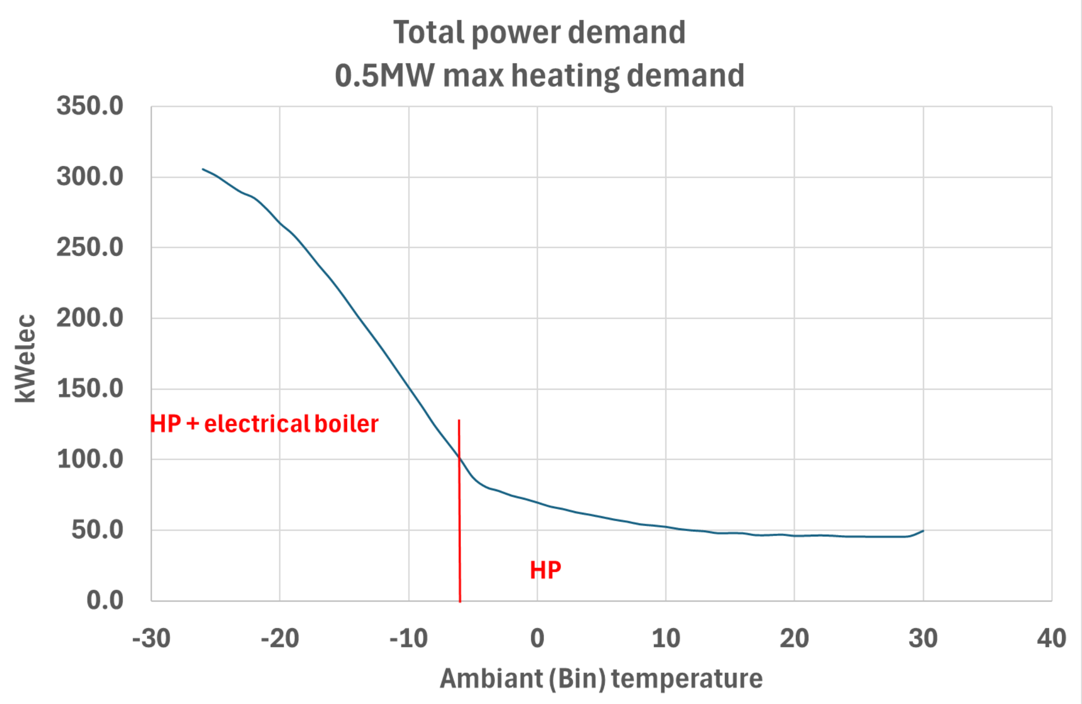
Delivered water and average return water temperatures from the district heating network

Water entering DH source is heated from 50°C up to 77°C in summertime and up to 115°C in Wintertime

District heating should deliver heat for both heating and hot water usages



DH challenge, requirements and available heat source options



In Summertime, DH heat source should be able to deliver water at lower temperature (75°C) with low-capacity (40%) demand for Hot water usage only

HP technologies can be used to recover heat from data center chillers at temperature around 35°C

HP Option delivering water at 90°C max temperature combined with electrical boiler is considered as the reference configuration.

Challenge :
High electricity consumption at low ambient

What HP configuration can cover the hole DH needs without boiler ?

HP advanced configurations

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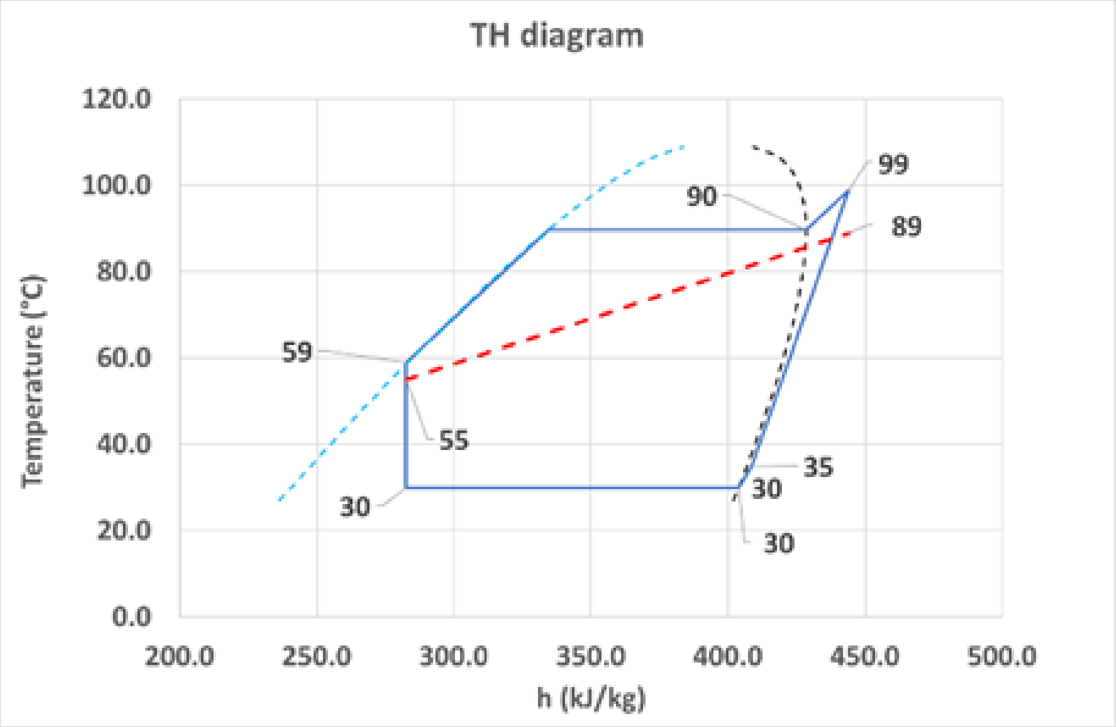
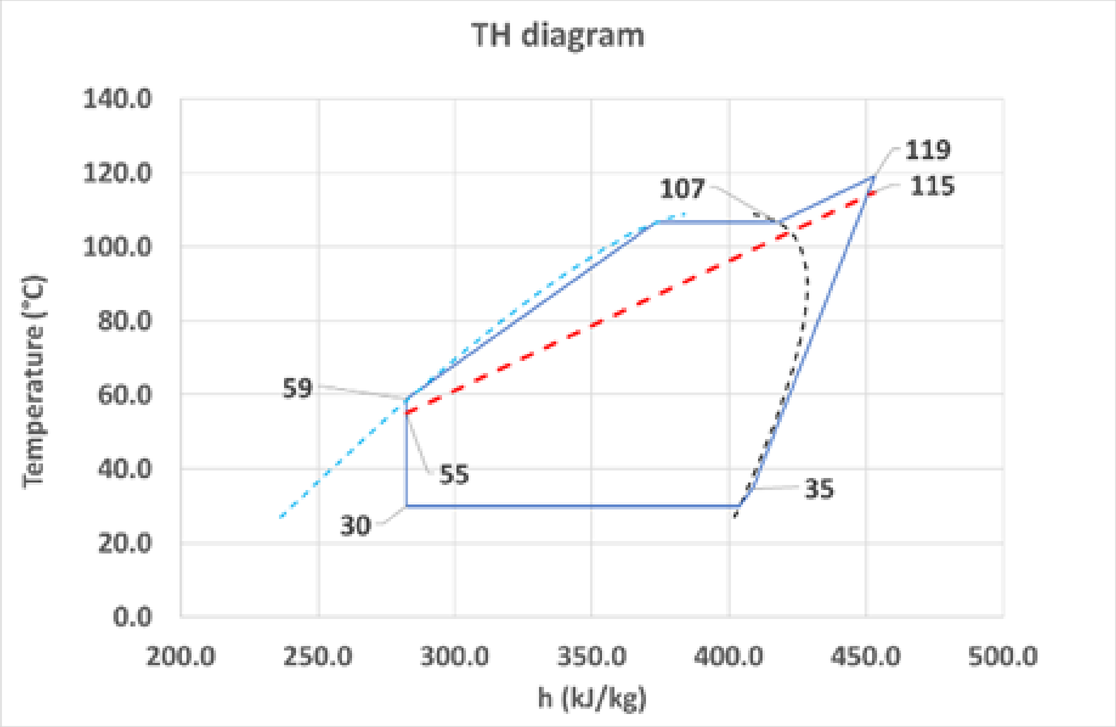


Single-stage cycle with deep subcooling

Heat pump can deliver hot water at 90°C using one stage compression with deep subcooling



Supercritical cycle at high temperature

Heat pump can deliver hot water at 115°C running at supercritical mode if needed. Deep subcooling is also applied

HP advanced configurations

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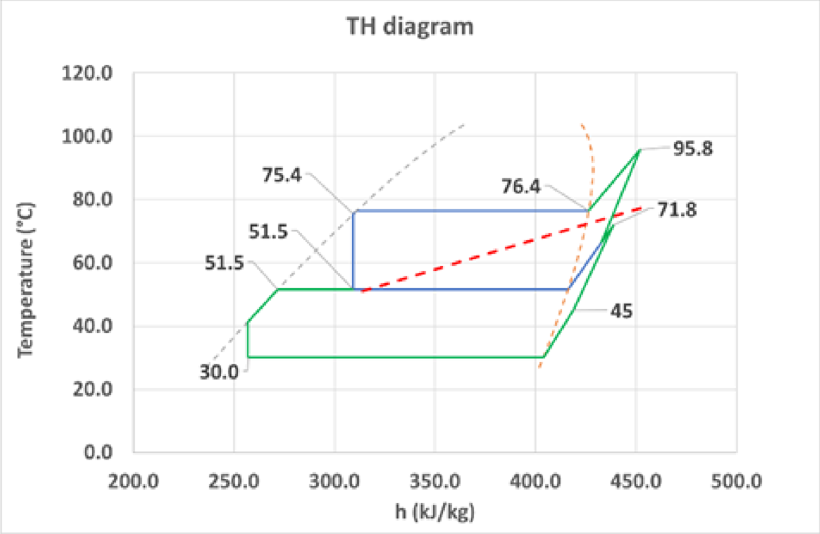

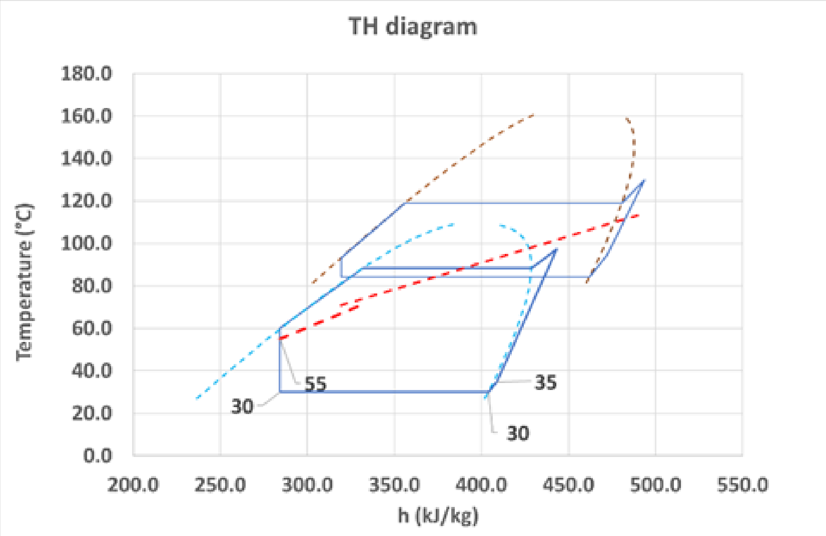

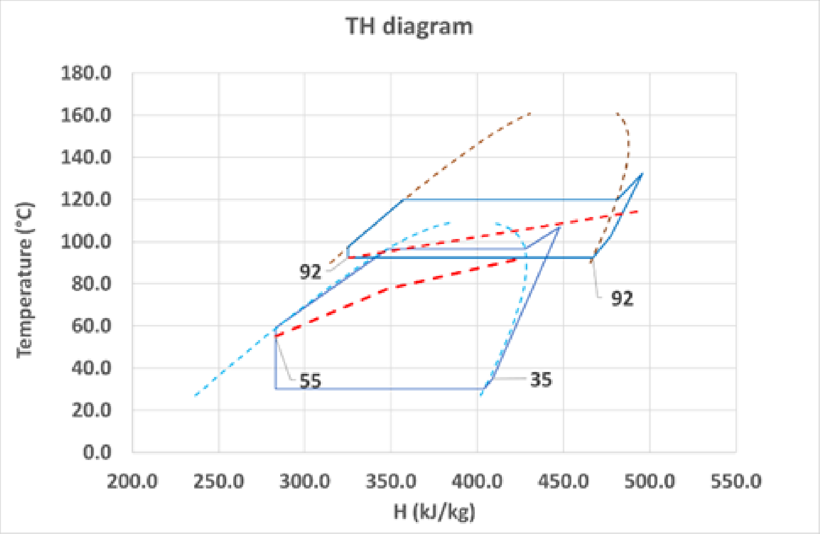

Two-stage cycle

Heat pump can deliver hot water at 90°C using two stage compression with injection and deep subcooling

Cascade cycle

Heat pump can deliver hot water at 115°C

Two separate cycle with two different working fluids

Partial cascade cycle

Heat pump can deliver hot water at 115°C

Two separate cycle with two different working fluids

HP advanced configurations : Partial cascade cycle with deep subcooling

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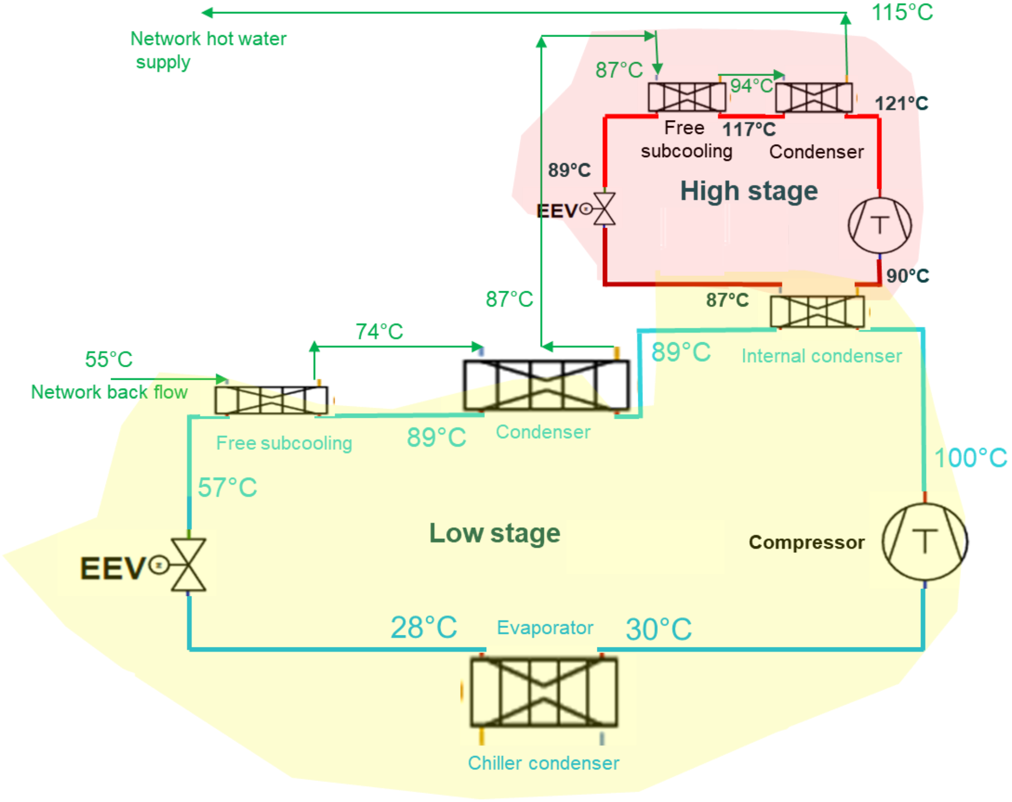


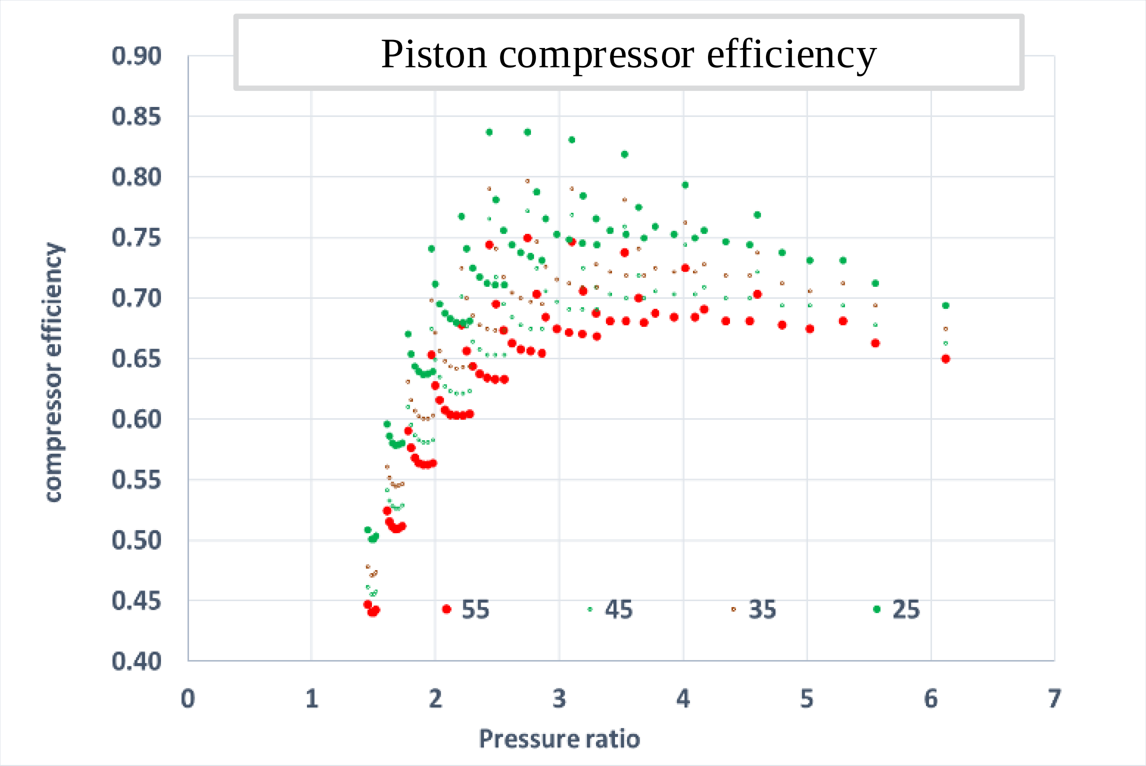
HP configuration using two different refrigerants in a partial cascade architecture

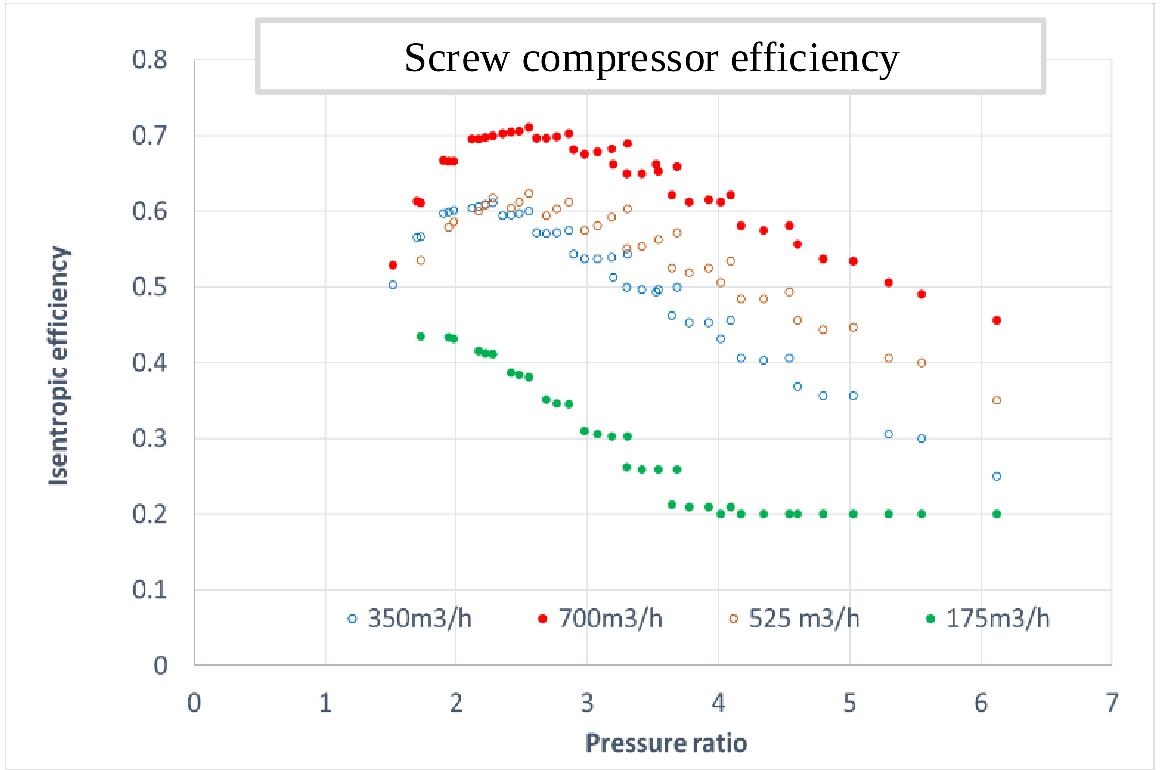
The low stage system can operate alone in summertime at low capacity and low water temperature output

The two stages can run at low or achievable pressure ratio without any technical constraints

High stage compressor need to operate at high evaporating temperature (80-90°C) which is a challenging condition for available compressors

Compressors analyses



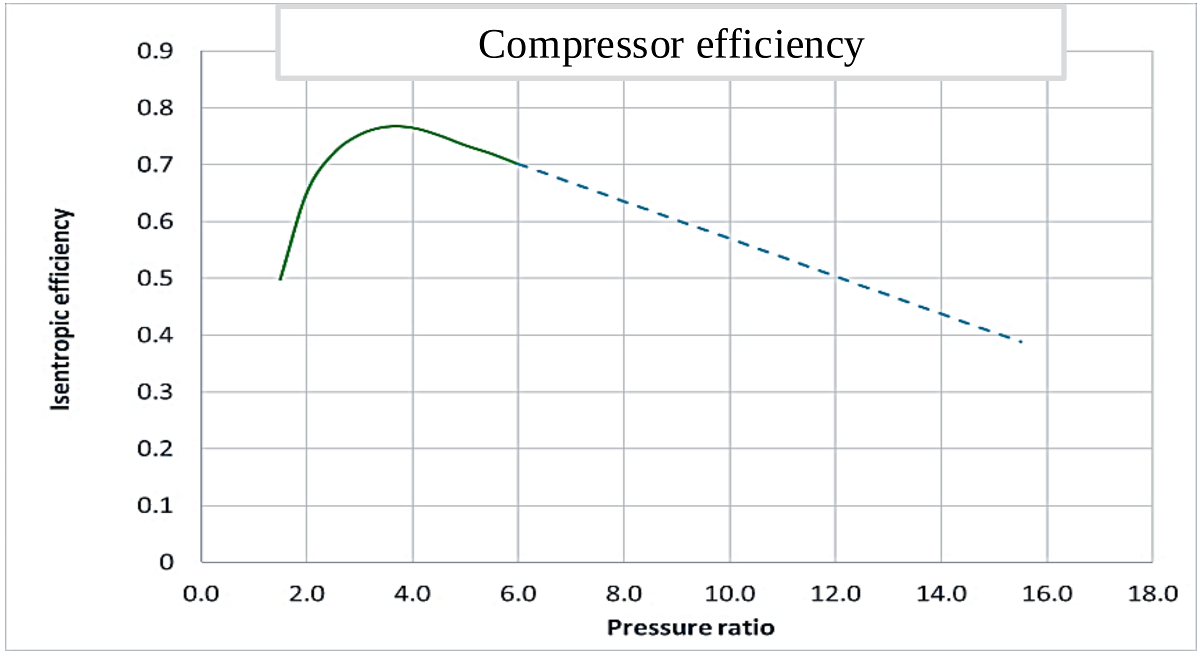


Piston compressor efficiency increase at lower operating speed
Efficiency decrease at high pressure ratio

Screw compressor efficiency decrease at lower operating speed
Efficiency decrease at high pressure ratio

HP advanced configurations: Compressors model

- No compressors available to fulfill all advanced configurations needs.
- For comparison reason, one isentropic efficiency profile is extended and used for all the configurations.
- Further development are ongoing to use compressor manufactures data when available to enhance model results

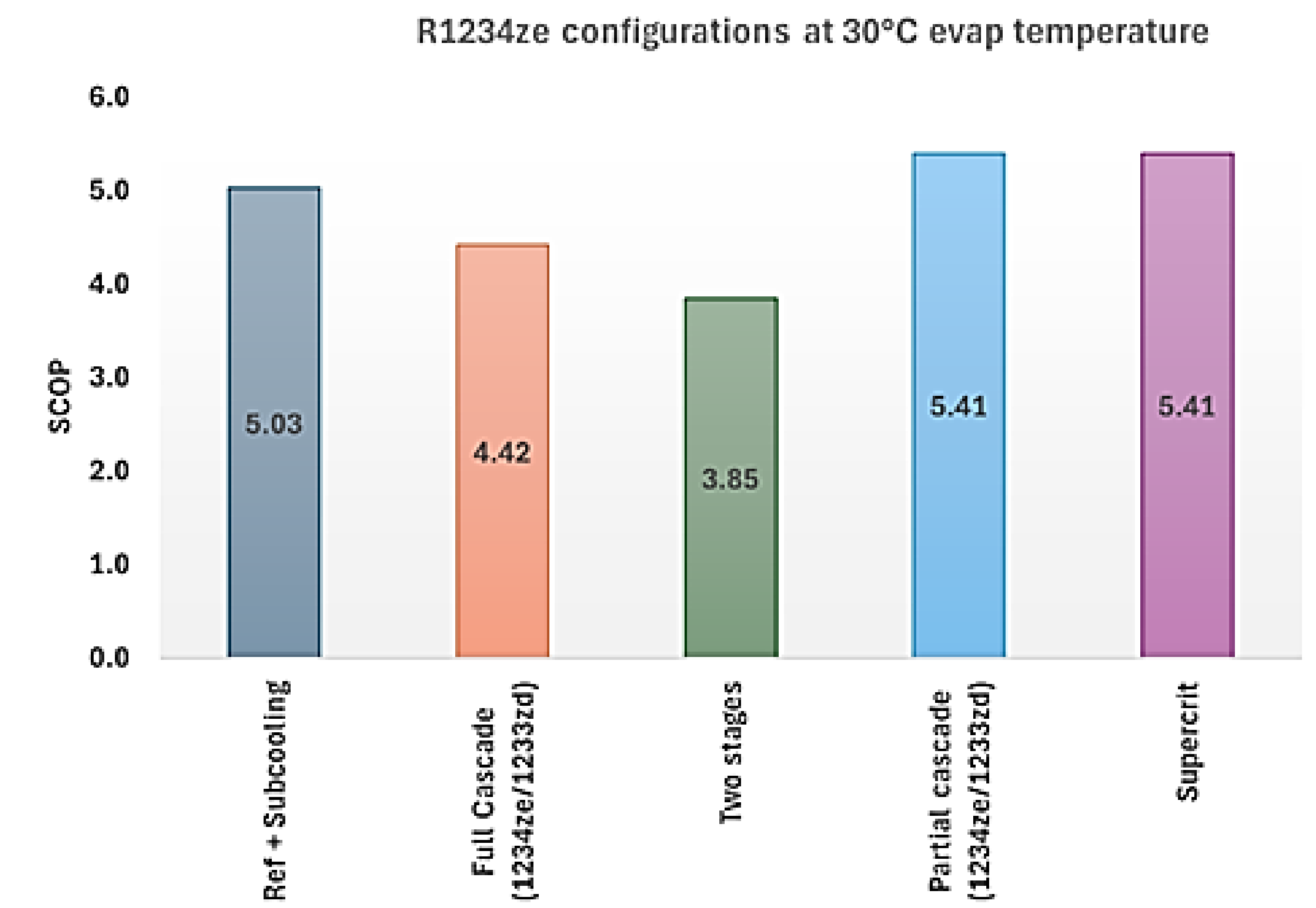


Modeling results

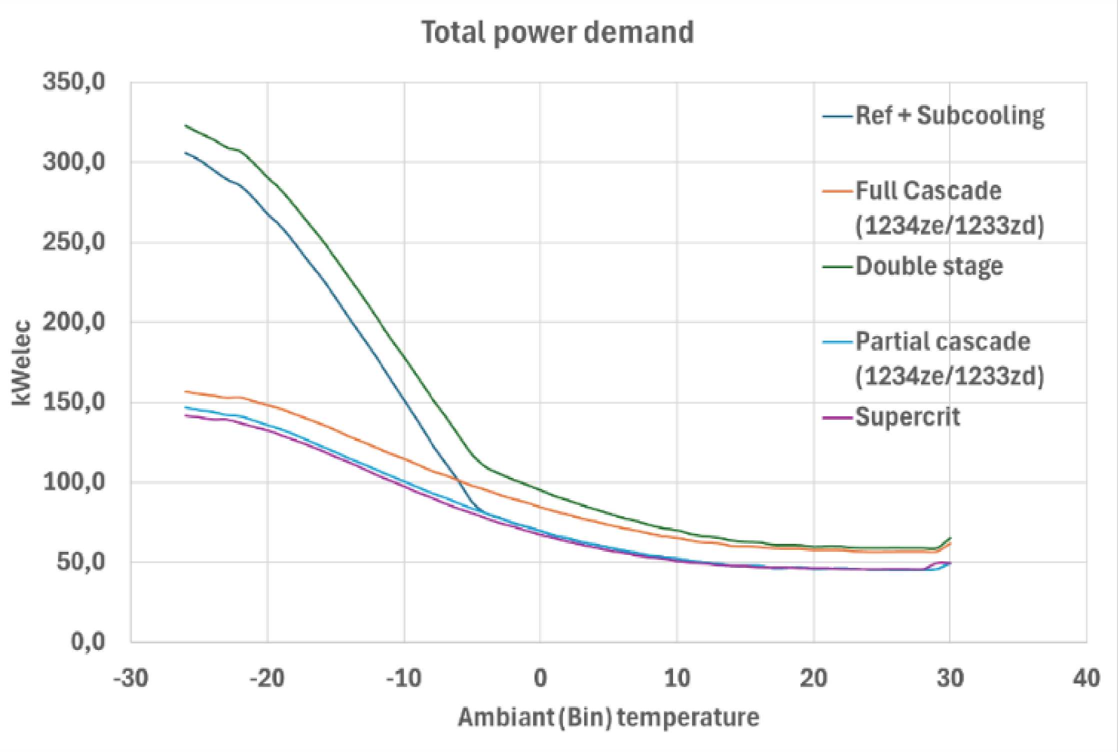
SCOP of DH configuration using R1234ze(E) or R1234ze(E) and R1233zd(E) as working fluids

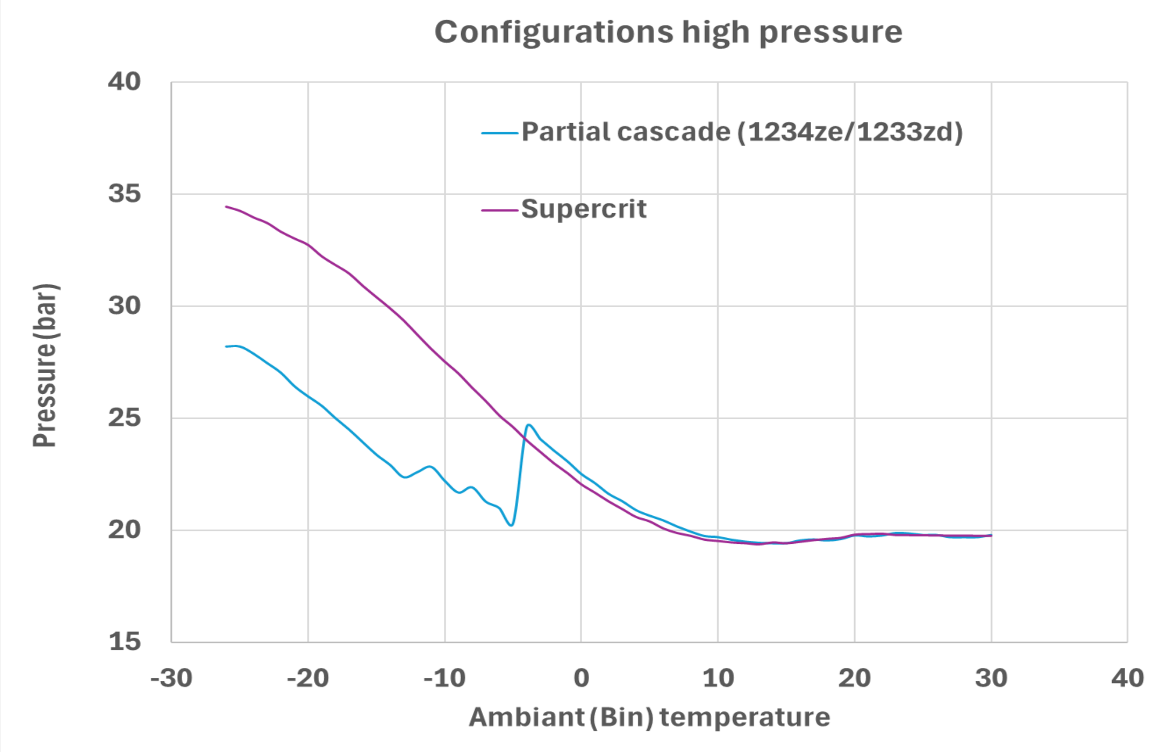
Partial cascade and supercritical configuration show better SCOP results

Two stage configuration is not suitable with deep subcooling use



Modeling results





Cascade, Partial cascade or supercritical configurations can be used for electrical boiler replacement

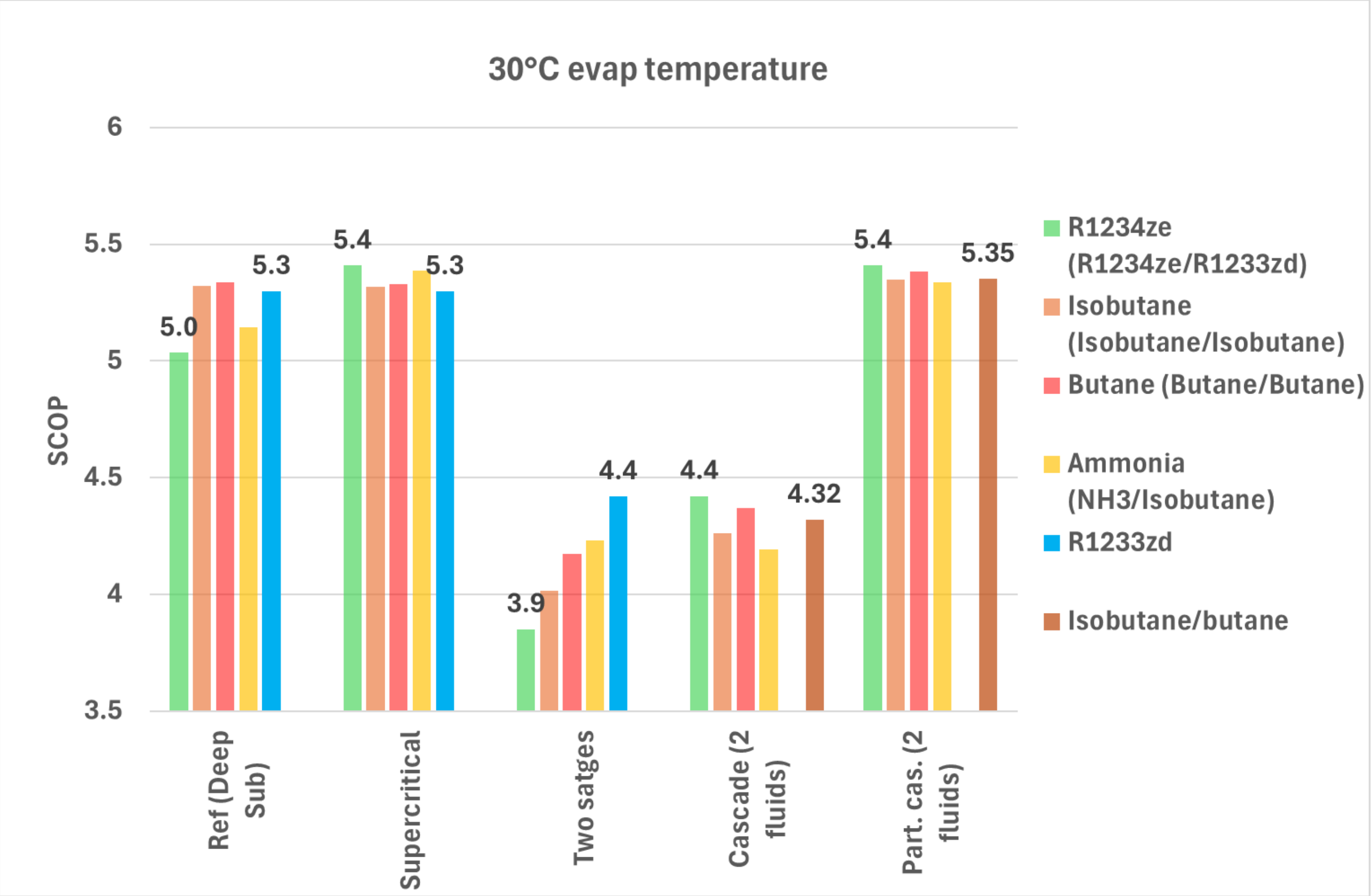
Supercritical configuration max pressure and high-pressure ratio are challenging question for compressor selection

Modeling results

- Fluids impact on the SCOP results is minor versus configuration impact.

- No matter the fluid combinations, the Partial cascade and supercritical configurations show the best SCOP values

- Partial cascade configuration will be considered for a TCO analyses



Cost analyses

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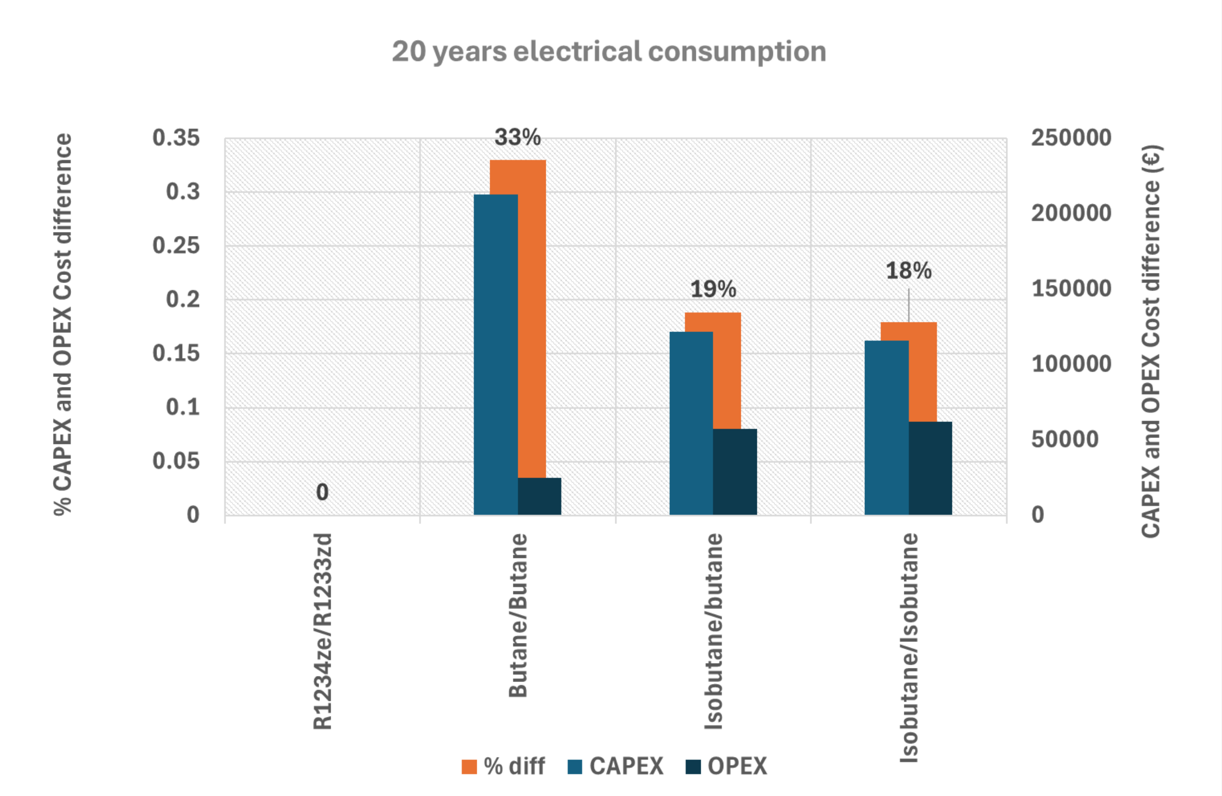
- The partial cascade configuration is considered with different refrigerants.
- Main parameters for cost estimation are related to refrigerants properties
  a. Refrigerant volumetric capacity and pressure level (impact on compressors and components size)
  b. Refrigerant safety classification : between 15 to 50% cost increase when using A3 fluids versus A1 (+15% considered for A3 and +6% for A2L in this presentation)

Fluid	R1234ze	Isobutane	Butane	R1233zd (E)
Critical T (°C)	109	134	151.9	165.6
NBP (°C)	-18.9	-11.7	-0.5	18.3

Preliminary refrigerants impact on TCO results

- Safety classification A1 for the R1233zd, A2L for the R1234ze and the high pressure and volumetric capacity of R1234ze contribute to:
  - Achieving the best TCO values when combined with a partial cascade system configuration.
  - 18 to 33% cost decrease versus other refrigerants. (Highest cost deference is related to CAPEX aspects)



Results for a 0.5MW max capacity DH network

Fortum DH heat pump project study

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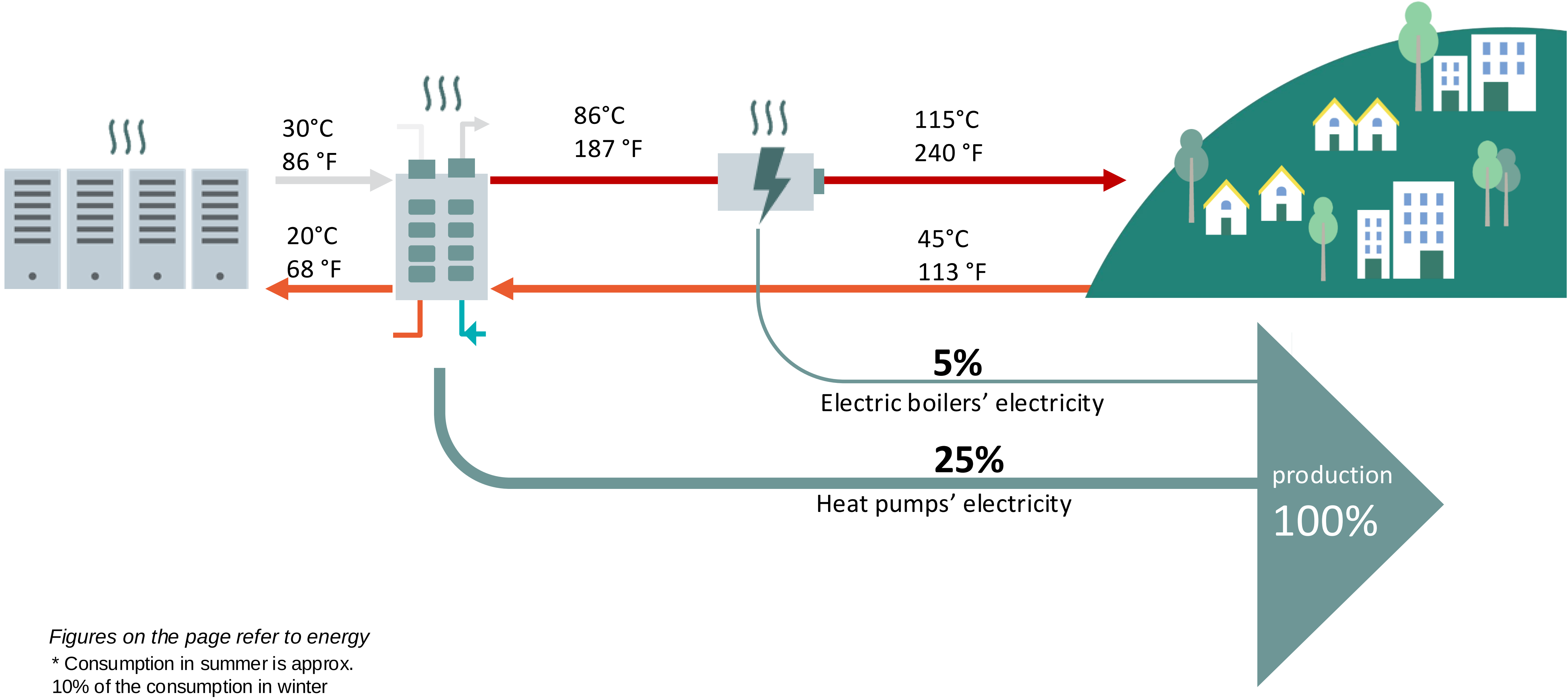

Figures on the page refer to energy

* Consumption in summer is approx. 10% of the consumption in winter

Fortum DH heat pump project study

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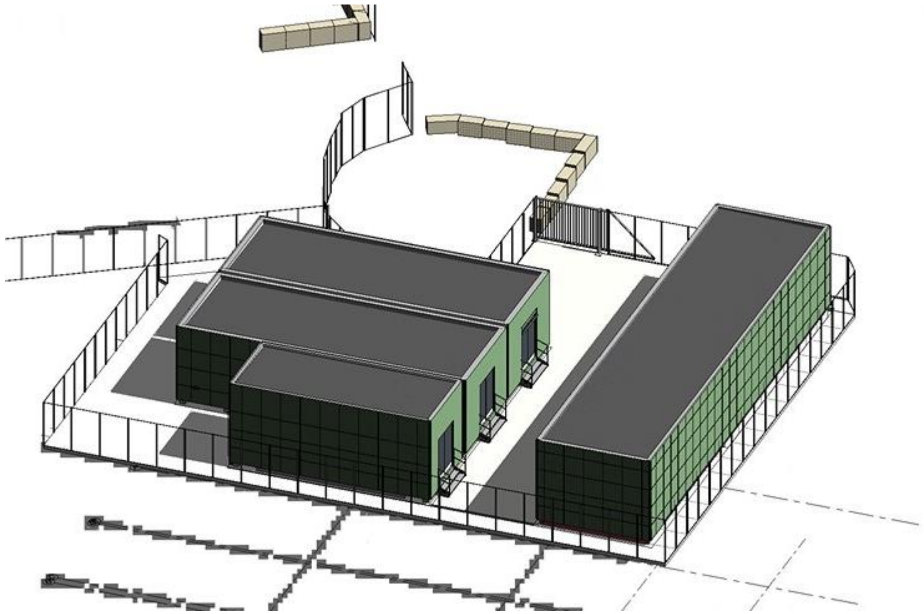
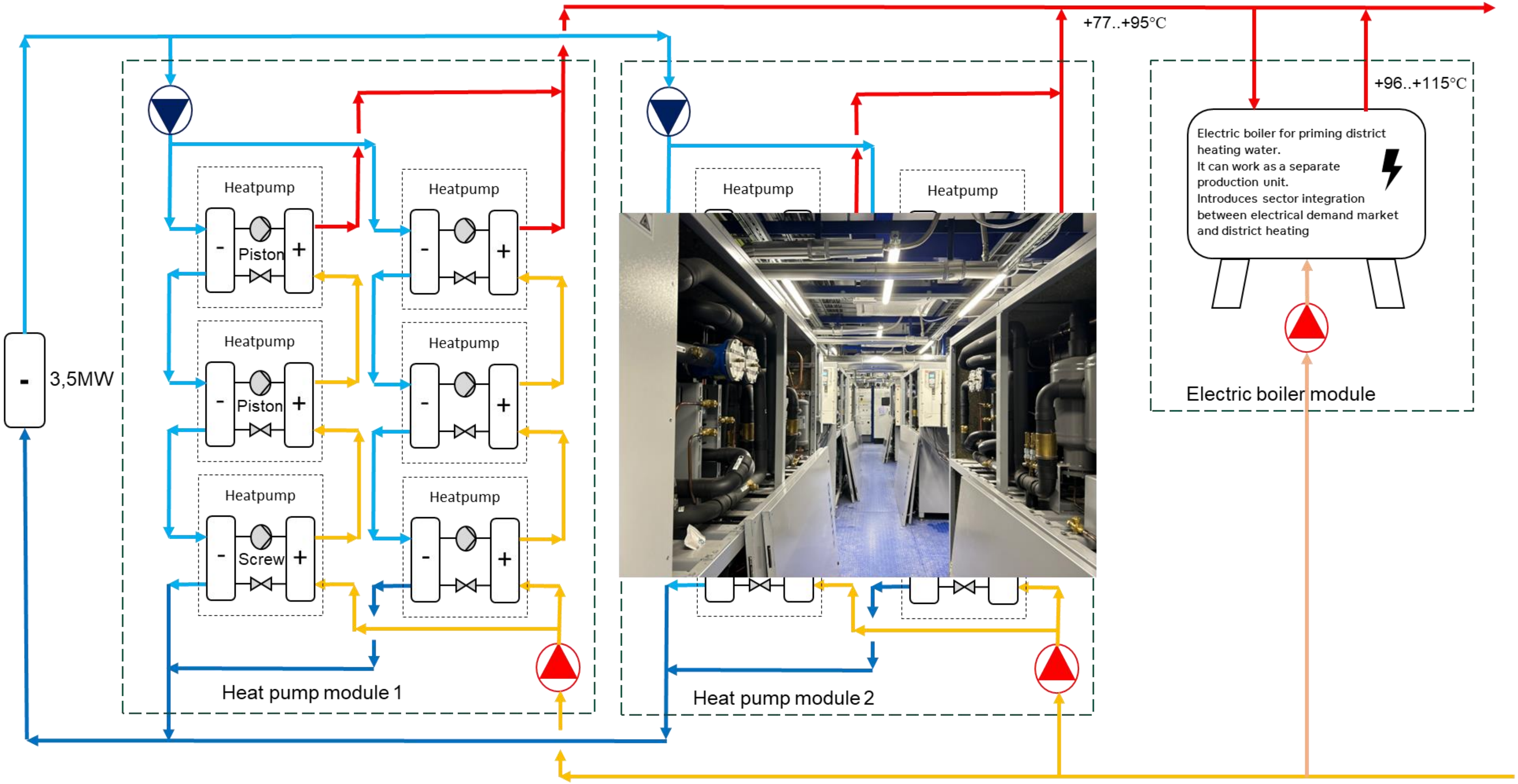
- Energy source – 2 datacentres
- Heat recovery 3,5MW
- Heat production 5,3…6MW
- Electrical boiler 2.5 MW

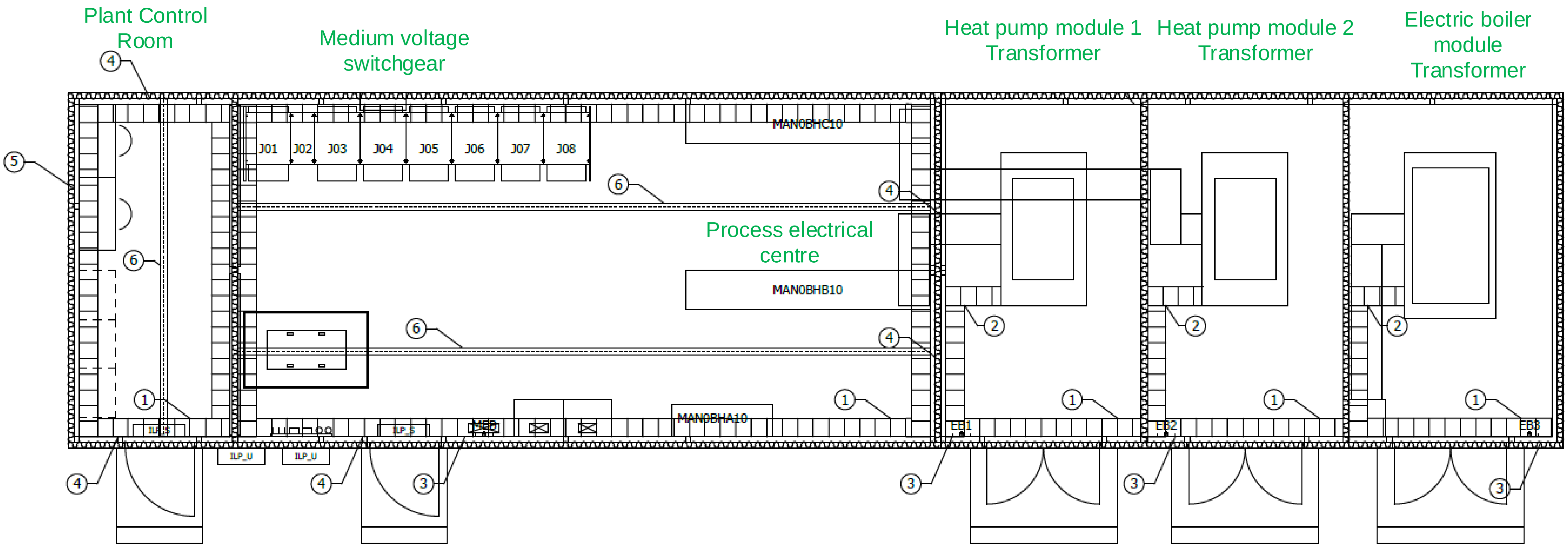


Finland DH heat pump project study



Finland DH heat pump project study

E-House



Finland DH heat pump project study

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Heat pump modules

3.8m€

Electric boiler module

0.8m€

E-House module

1.4m€

6m€

Finland DH heat pump project study

New Heat pump modules

+0,76m€

Electric boiler module

-0,8m€

E-House module

-0.83m€

-1,43m€

OPEX
-0,05m€

SCOP
3,2->5!

(Exclude from savings; foundation, land lease, less design costs, less risks to electricity market fluctuations because of better COP)

Conclusions

- Preliminary study shows cost savings mainly because of less modules and lower infrastructure costs.
- Peak electricity consumption and SCOP have key impact on the TCO :
- New heat pump solution will be beneficial especially in situations, where additional electrical boiler production would have limited utilization, and the novel solution would lead to CAPEX reductions.
- Improvement of COP average from 3.5 to 4.5 would warrant a CAPEX increase of more than 100k€/MW
- Project timeline can in some case be increased because of lower electrical connection
- Profitability of the approach via improvement of COP in instances, where a large site with electrode boilers is built regardless of the heat pump solution needs further investigation.

HP Cost €/kW	Impact	TCO
Cascade Technologies	↑	
Total capacity	↓	
SCOP value		↓
Project timeline	↓	↓
Standardization	↓	

THANK YOU

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