DANISH TECHNOLOGICAL INSTITUTE

Super Supermarkets

Benefitting from excess heat

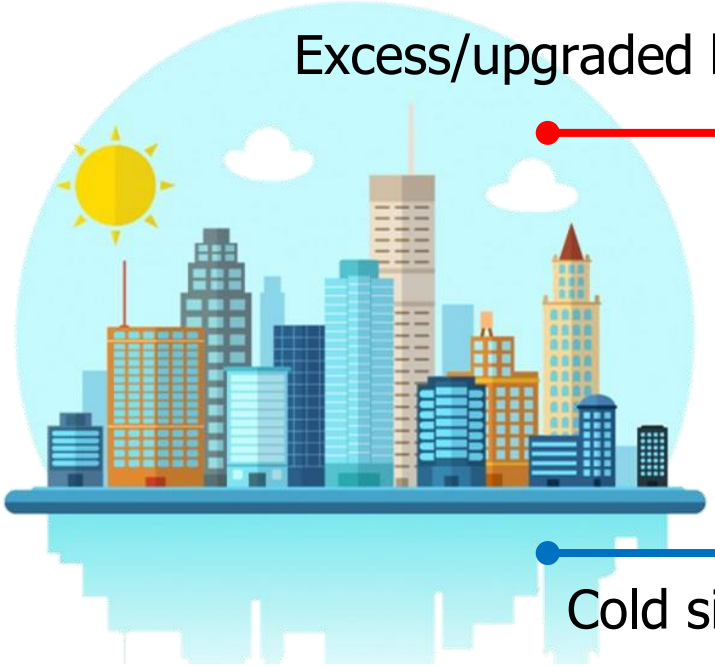
Heat recovery to the district heating grid

Christian Heerup, Danish Technological Institute

Super Supermarkets, short list

- Heat recovery with supply to district heating networks
- Back ground: 15 plants in operation in DK today
- Collate experience in the field of best practise - Guide book
- Data sampling on 6 existing plants
  - 3 with heat recovery to district heating
  - 3 for baseline for design of new heat recovery installation
- Installation of 3 new heat recovery installations in 2018
- Increased heat production (~air to water heat pump)
- Documentation and reporting of performance
- Business models including analysis of tax scenarios
- Investigate business model for flexible power consumption
- 13 partners financially supported by EUDP, budget € 660.000

Background of Project



Excess/upgraded heat

Cold sinks

- **Supermarkets**
- Data Centers
- Ice Rinks

- Ground Temperature in Summer, eg. GSHP

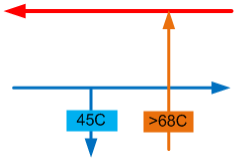
District Heating

District Cooling

Questions to be answered

- How heat is being delivered to district heating?
- How efficient is it to recover heat from supermarkets to district heating? i.e. what is the cost for generating kWh of heat sold to district heating network?
- Is it profitable?
- What is the best way to recover heat to district heating? What are the favourable conditions?
- What are the interesting application areas?

Open district heating by Fortum Värme

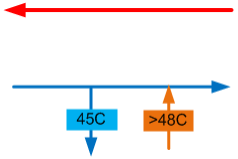


- **Spotvärme Prima:**

DH forward pipe with delivery temperature 68 – 103 °C, inlet return temperature 40-50 °C depending where in the DH-network

- **Spotvärme Inblandning:**

DH forward pipe with delivery temperature 68 °C, inlet return temperature 40-50 °C depending where in the DH-network



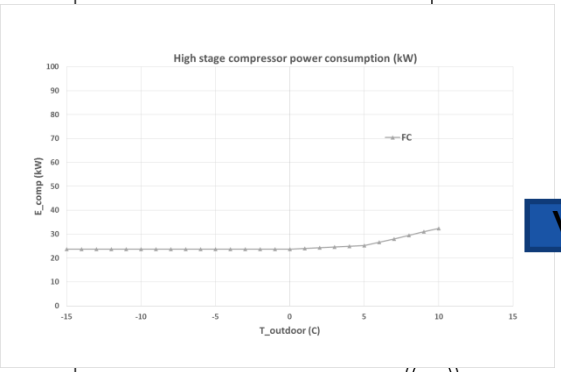
- **Return:**

DH return pipe with delivery temperature +3 °C higher than incoming return temperature, inlet return temperature 40-50 °C depending where in the DH-network

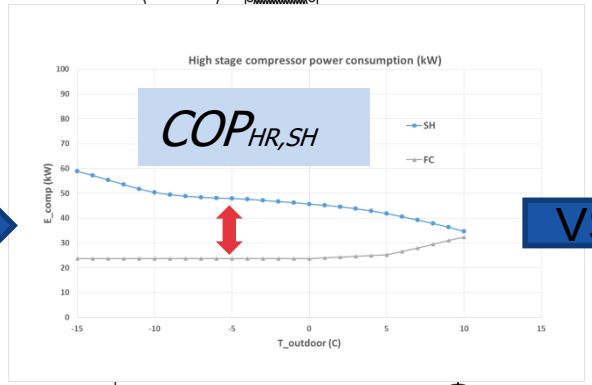
- **Restvärme:**

DC return pipe with delivery temperature 15 °C, inlet forward temperature 6 °C"

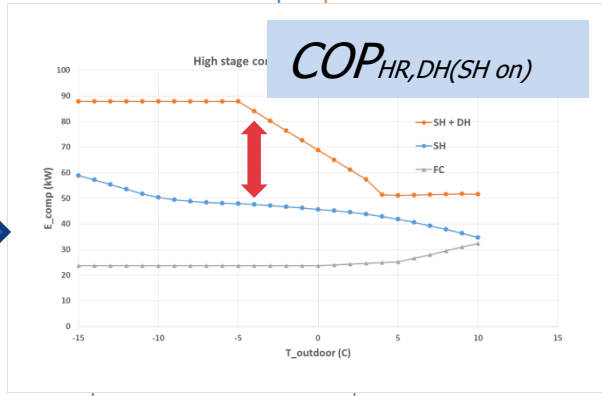
Supermarket CO2 refrigeration system with HR



VS



VS

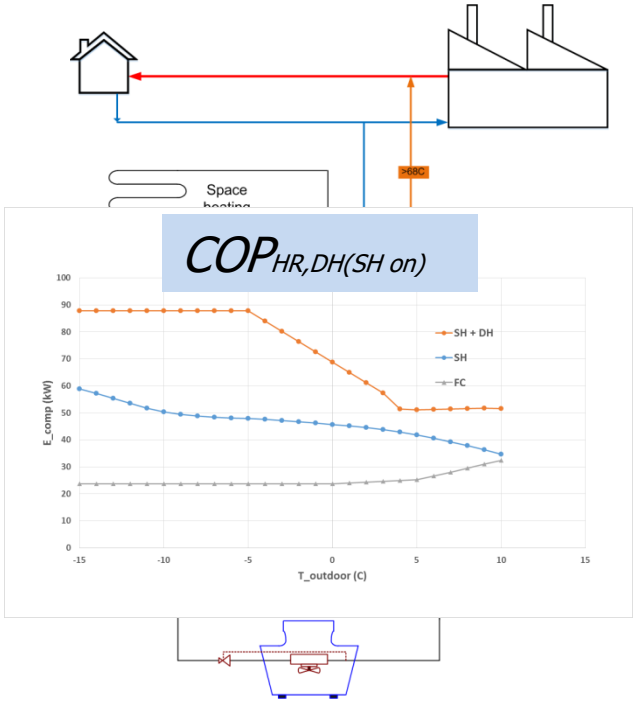


Floating condensing (FC)

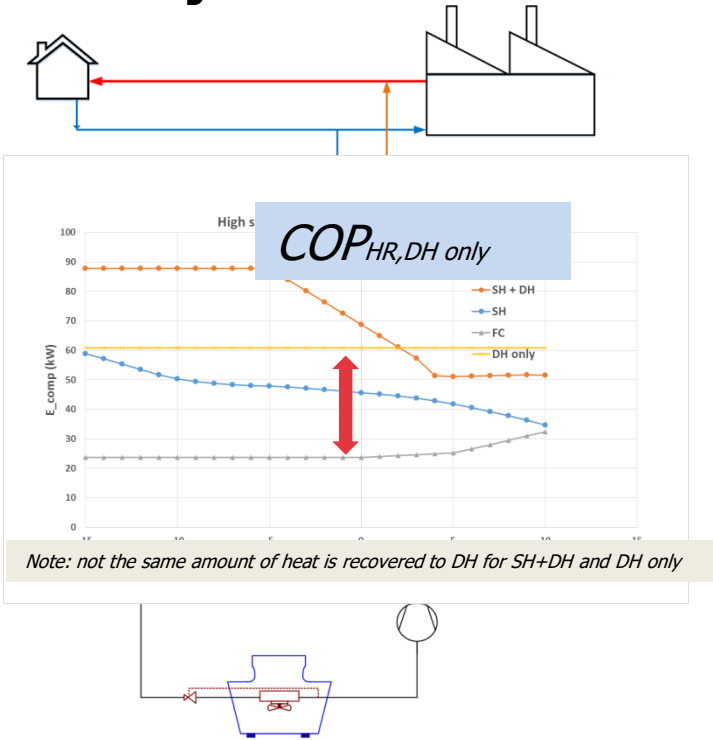
HR for space heating (SH)

HR for SH and district heating (DH): SH+DH

Supermarket CO2 refrigeration system with HR



VS



HR for SH and district heating (DH): SH+DH

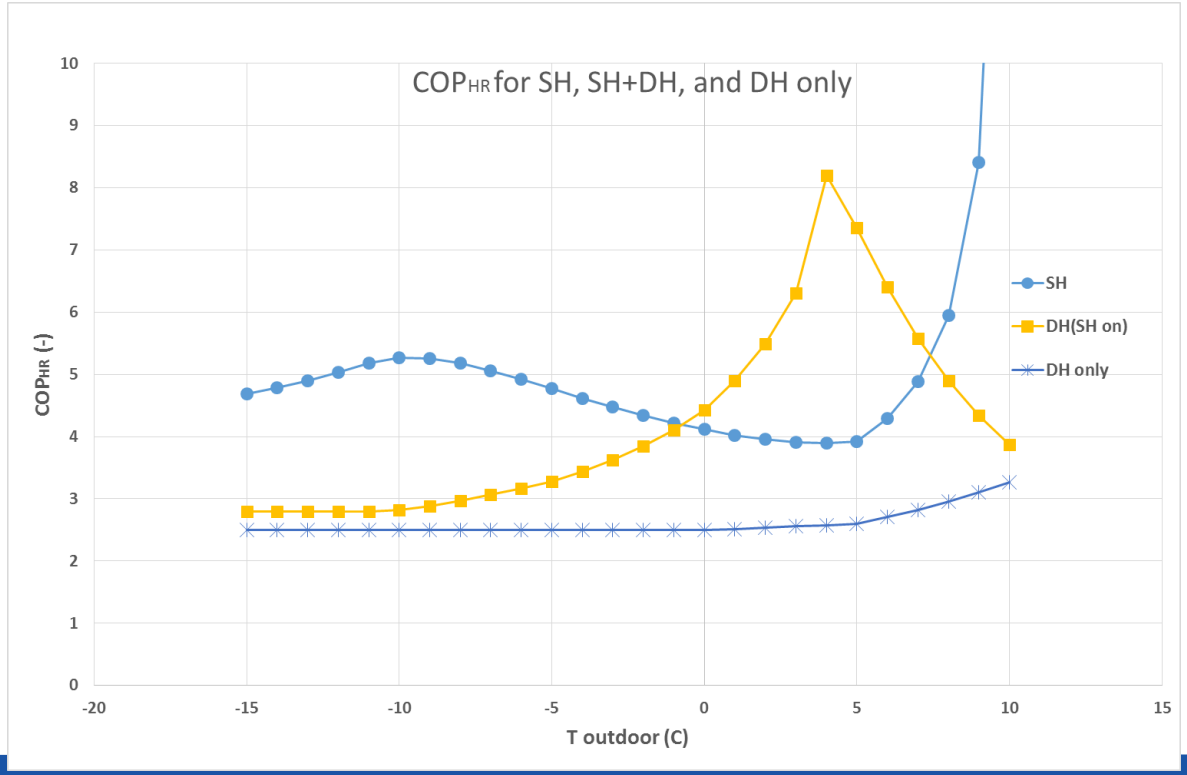
HR to district heating only DH only

Summary of the systems

- FC: floating condensing
- SH: heat recovery for space heating only
- SH+DH: heat recovery for space heating (priority) and to sell heat to DH
- DH only: heat recovery to district heating, no space heating recovery

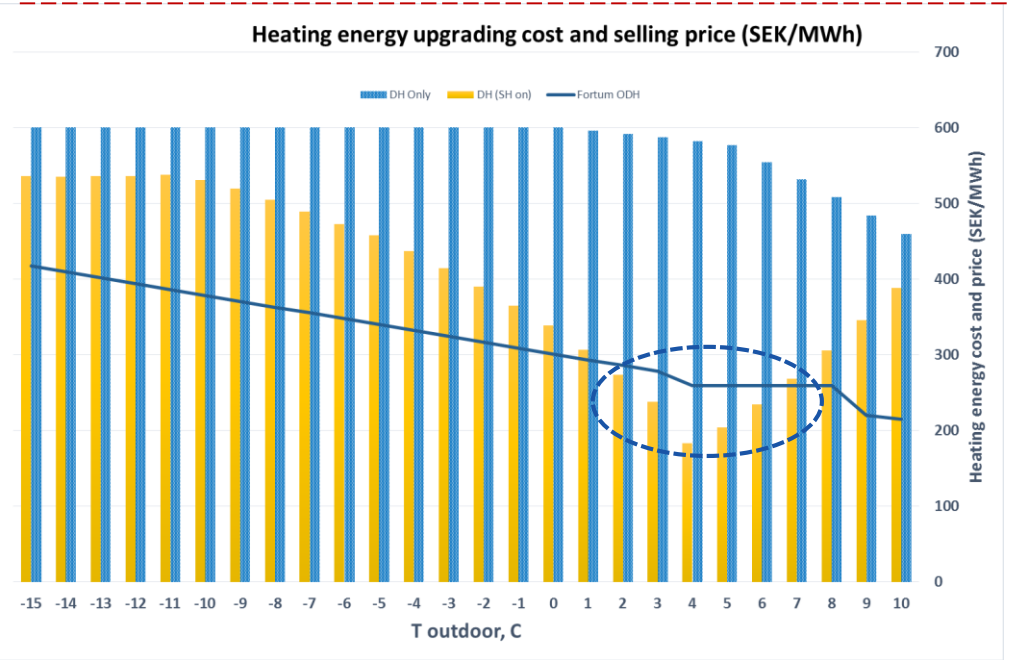
COP_{HR} of the different systmes

- High efficiency (i.e. heating COP) for the system SH+DH
- Rather low efficiency when recovery to district heating only is applied; COP_{HR} about 2,5



Cost of heat upgrading and selling price

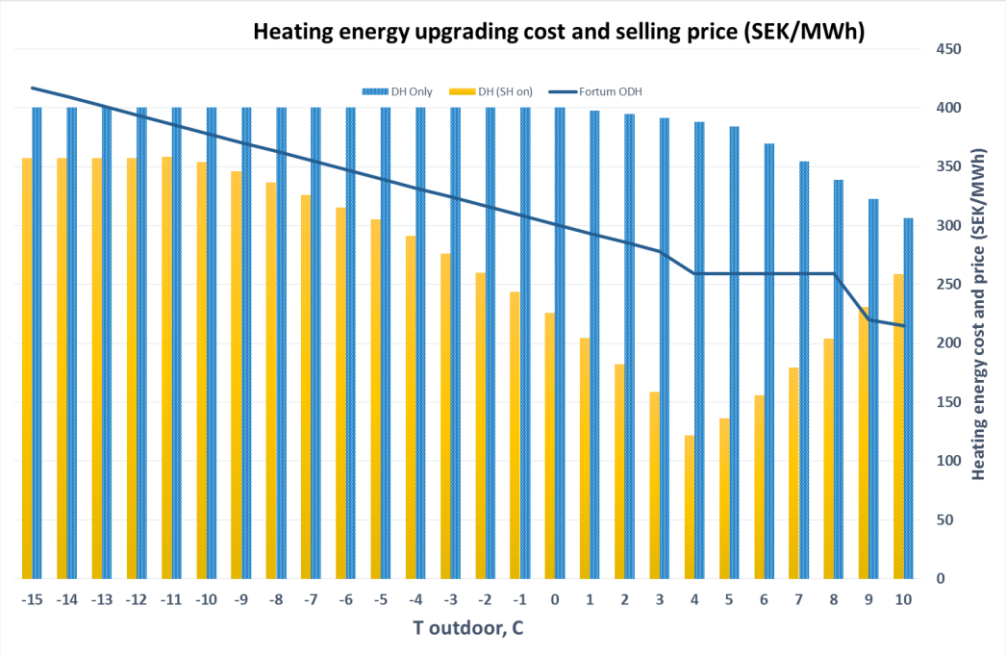
$$Fortum's\ ODH\ buying\ Price\ should\ be\ higher\ than\ Heat\ Upgrading\ Cost;\ > \frac{Electricity\ Price}{COP_{HR,DH}}$$



- Electricity price used is 1,5 SEK/kWh
- Full range of Fortum price needs to be implemented. It has been extrapolated for outdoor temperatures lower than 4° C
- Taxes are not included in the selling/buying price

UPDATED: Cost of heat upgrading and selling price

$$Fortum's\ ODH\ buying\ Price\ should\ be\ higher\ than\ Heat\ Upgrading\ Cost;\ > \frac{Electricity\ Price}{COP_{HR,DH}}$$

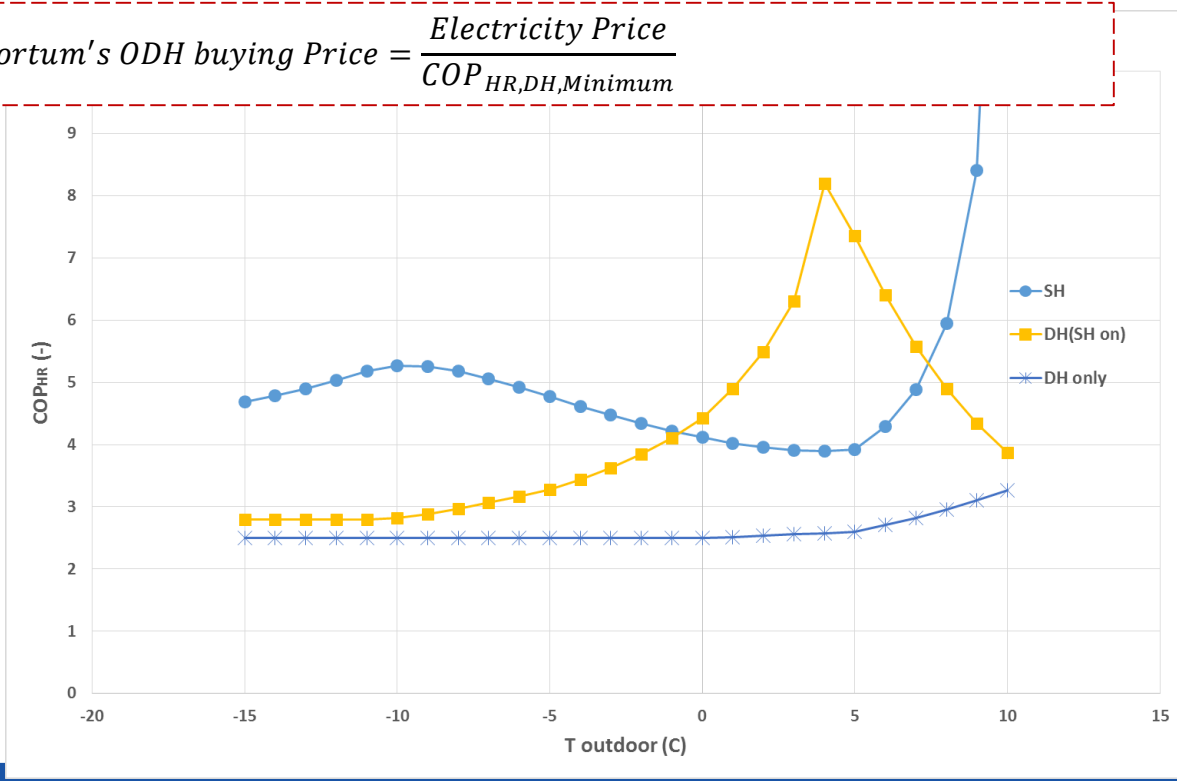


- Electricity price used is 1 SEK/kWh
- Full range of Fortum price needs to be implemented. It has been extrapolated for outdoor temperatures lower than 4° C
- Taxes are not included in the selling/buying price

COP_{HR} of the different systems

$$Fortum's\ ODH\ buying\ Price = \frac{Electricity\ Price}{COP_{HR,DH,Minimum}}$$

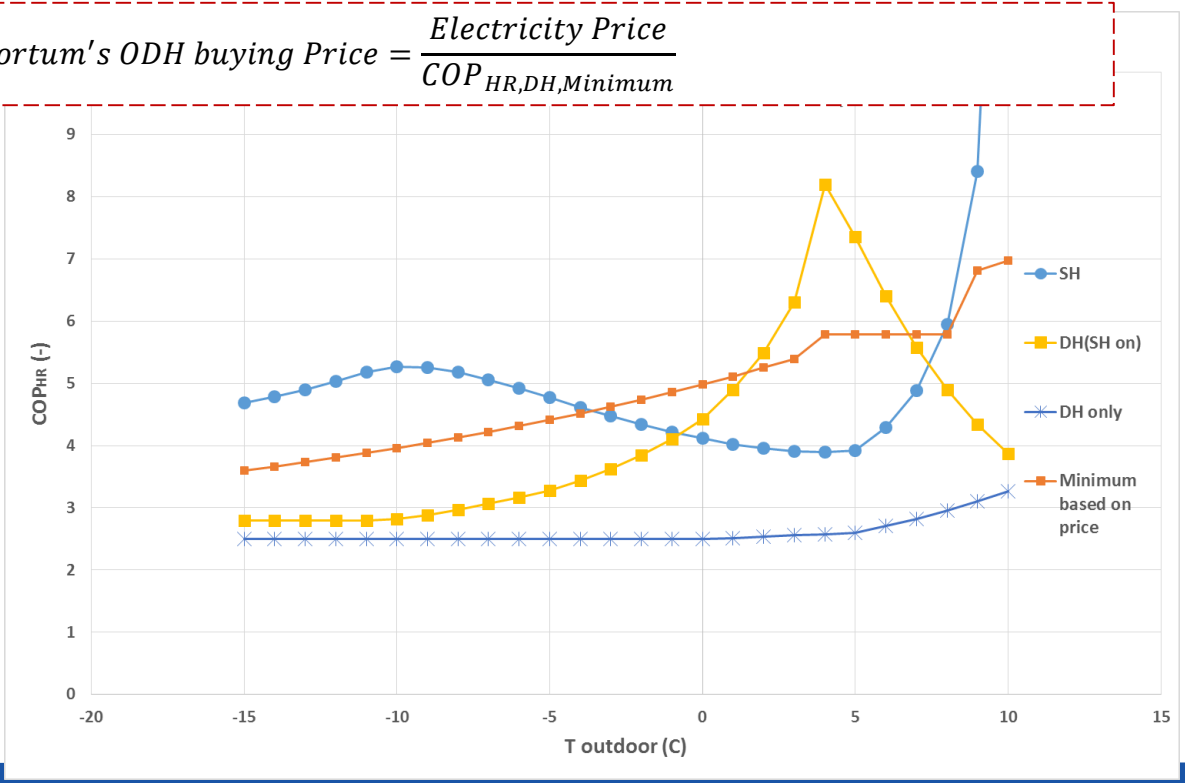
- Assuming electricity price of 1,5 SEK/kWh



COP_{HR} of the different systems

$$Fortum's\ ODH\ buying\ Price = \frac{Electricity\ Price}{COP_{HR,DH,Minimum}}$$

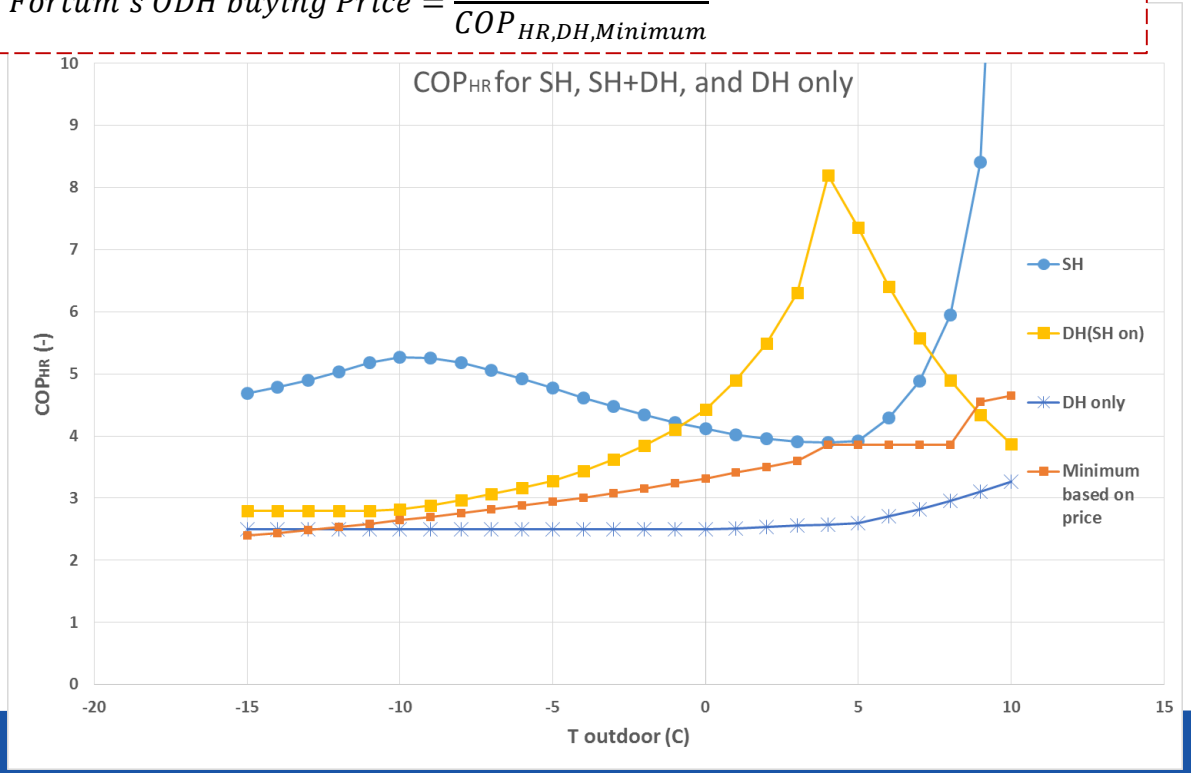
- Assuming electricity price of 1,5 SEK/kWh
- Heat should be recovered at quite high COP in order to make the solution profitable; $COP_{HR,DH}$ should be higher than 6 for most of the cases



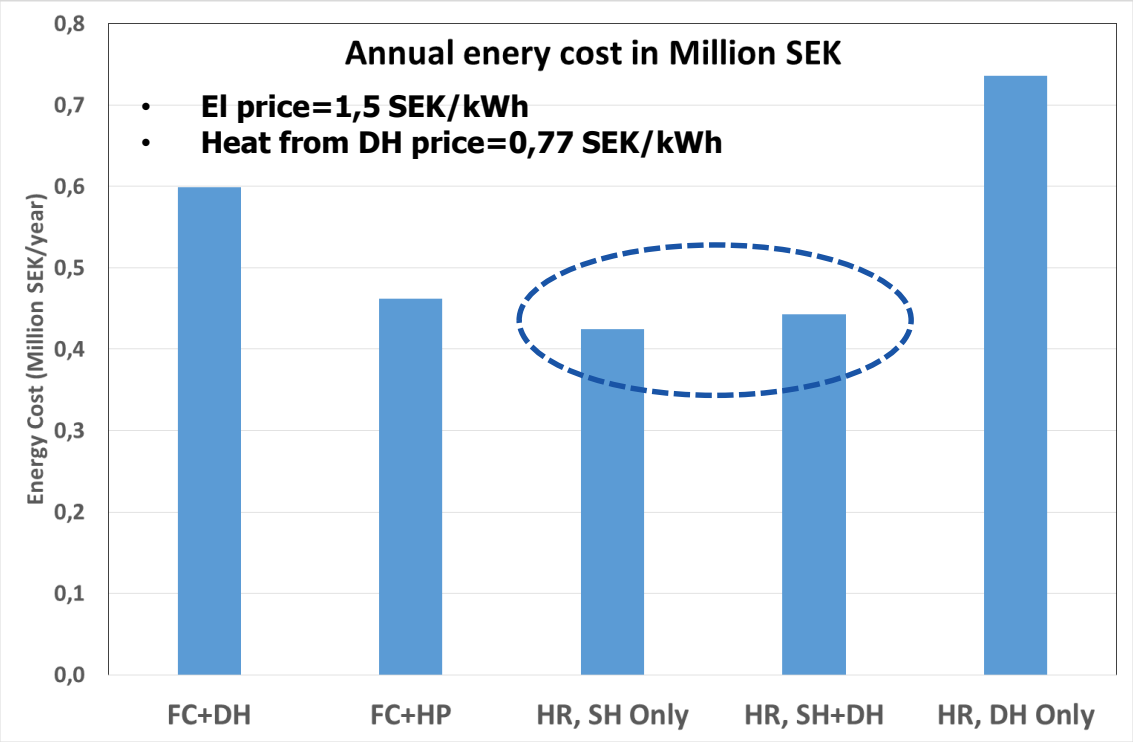
UPDATED: COP_{HR} of the different systems

$$Fortum's\ ODH\ buying\ Price = \frac{Electricity\ Price}{COP_{HR,DH,Minimum}}$$

- Assuming electricity price of 1 SEK/kWh
- Heat should be recovered at COP higher than 2,7-4,8 in order to make the solution profitable, depending on the outdoor temperature

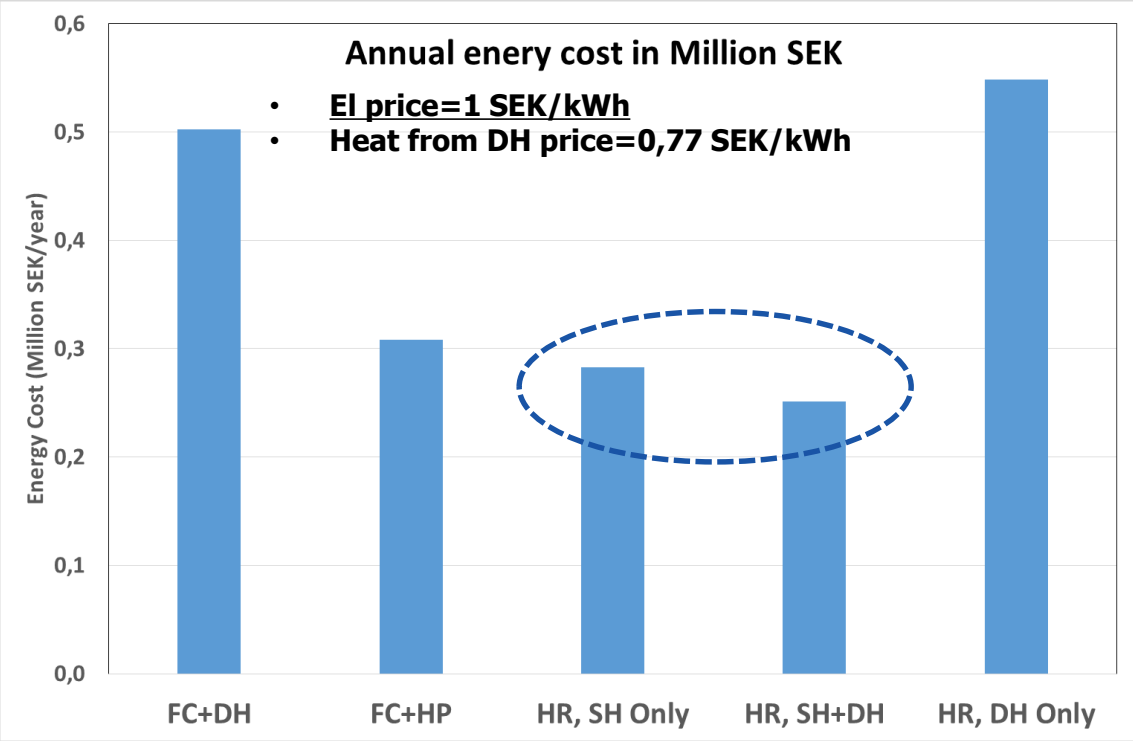


Comparison of Annual Energy Cost



- Heat recovery for space heating is an efficient solution with the highest economic advantage
- No profit made by recovering heat to DH

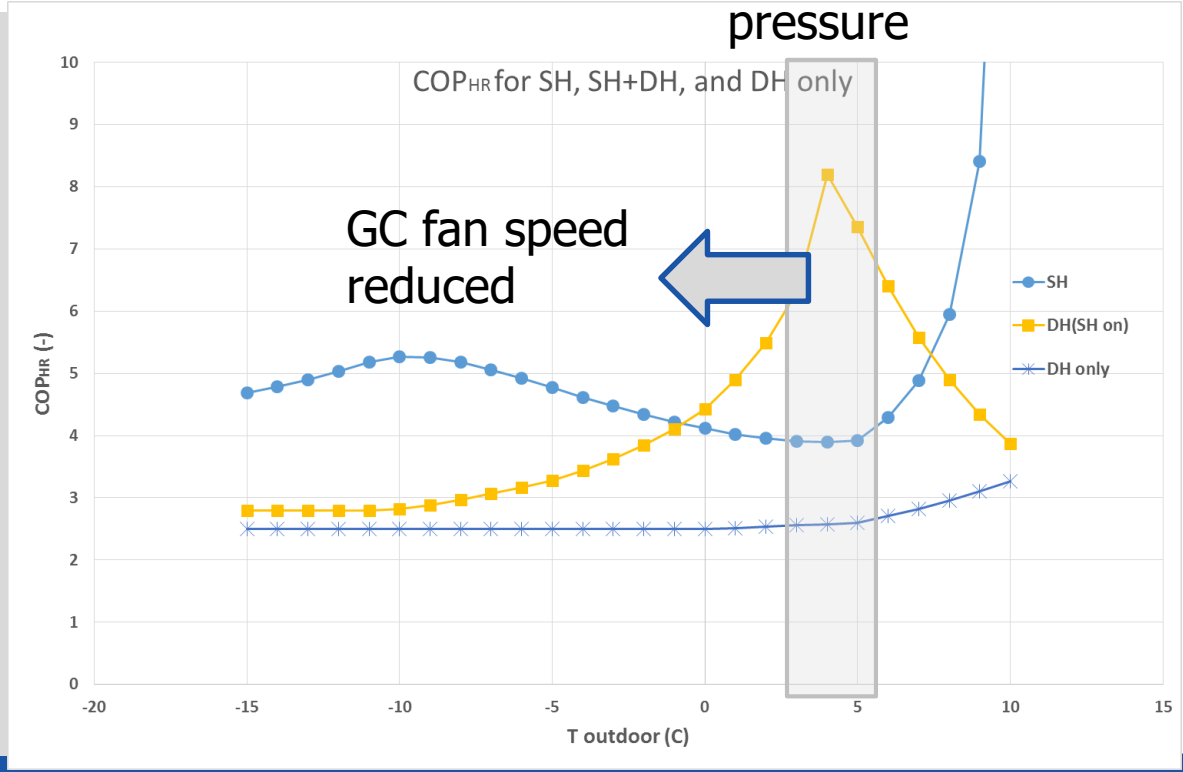
UPDATED: Comparison of Annual Energy Cost



- Heat recovery for space heating is an efficient solution with the highest economic advantage
- Small profit made by recovering heat to DH

At what conditions should heat be recovered to DH?

- Recovering heat to district heating has reasonable heating COP; $COP_{,HR,DH}$ between about 2,5 and 8.
- Recover heat to space heating should be priority
- Refrigeration capacity should be large to provide all heating demand in the building with excess capacity to recover to DH
- Recover moderate amount of heat to DH with high efficiency rather than large amount with low efficiency



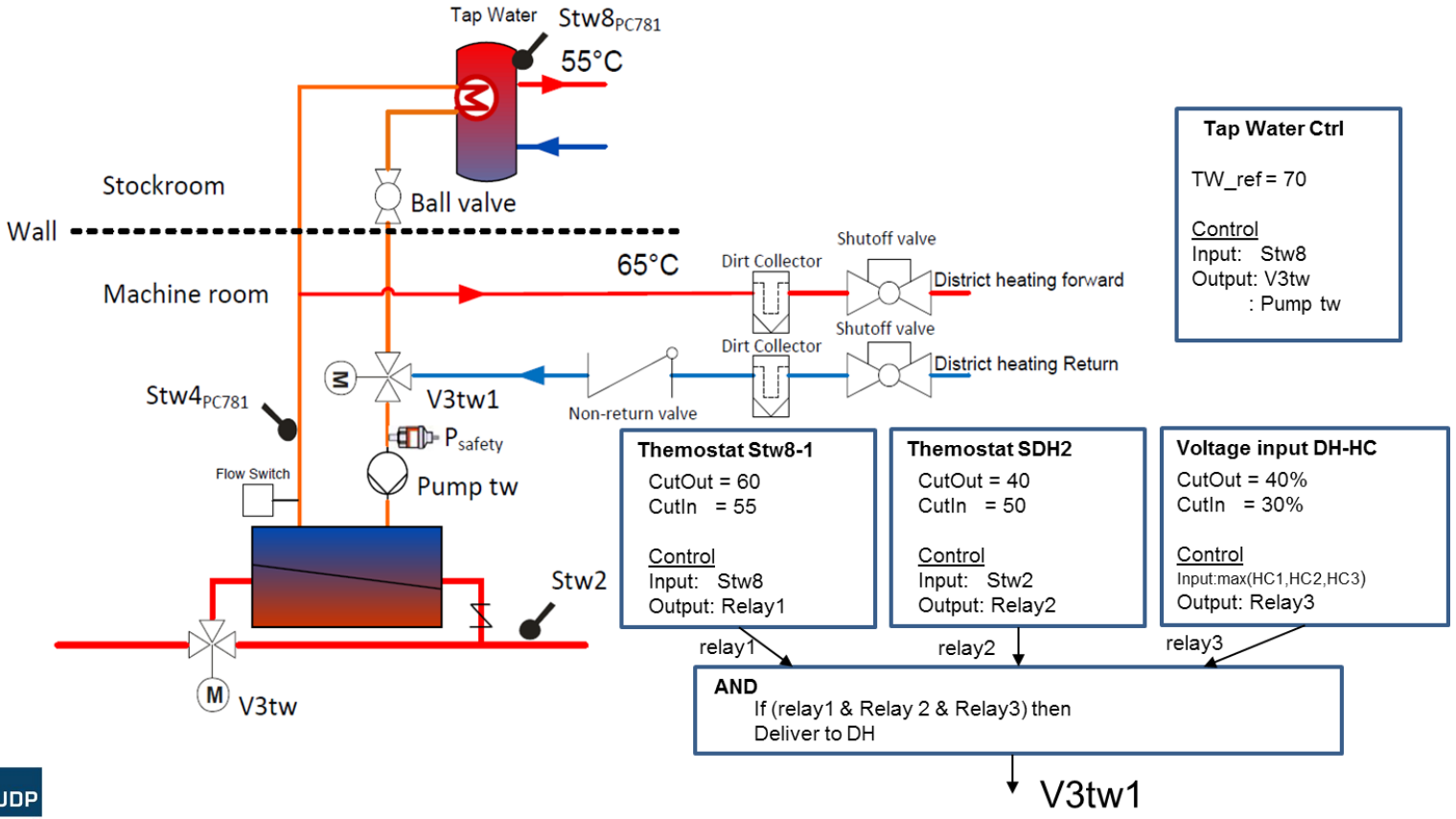
HR Operating modes

DANISH TECHNOLOGICAL INSTITUTE

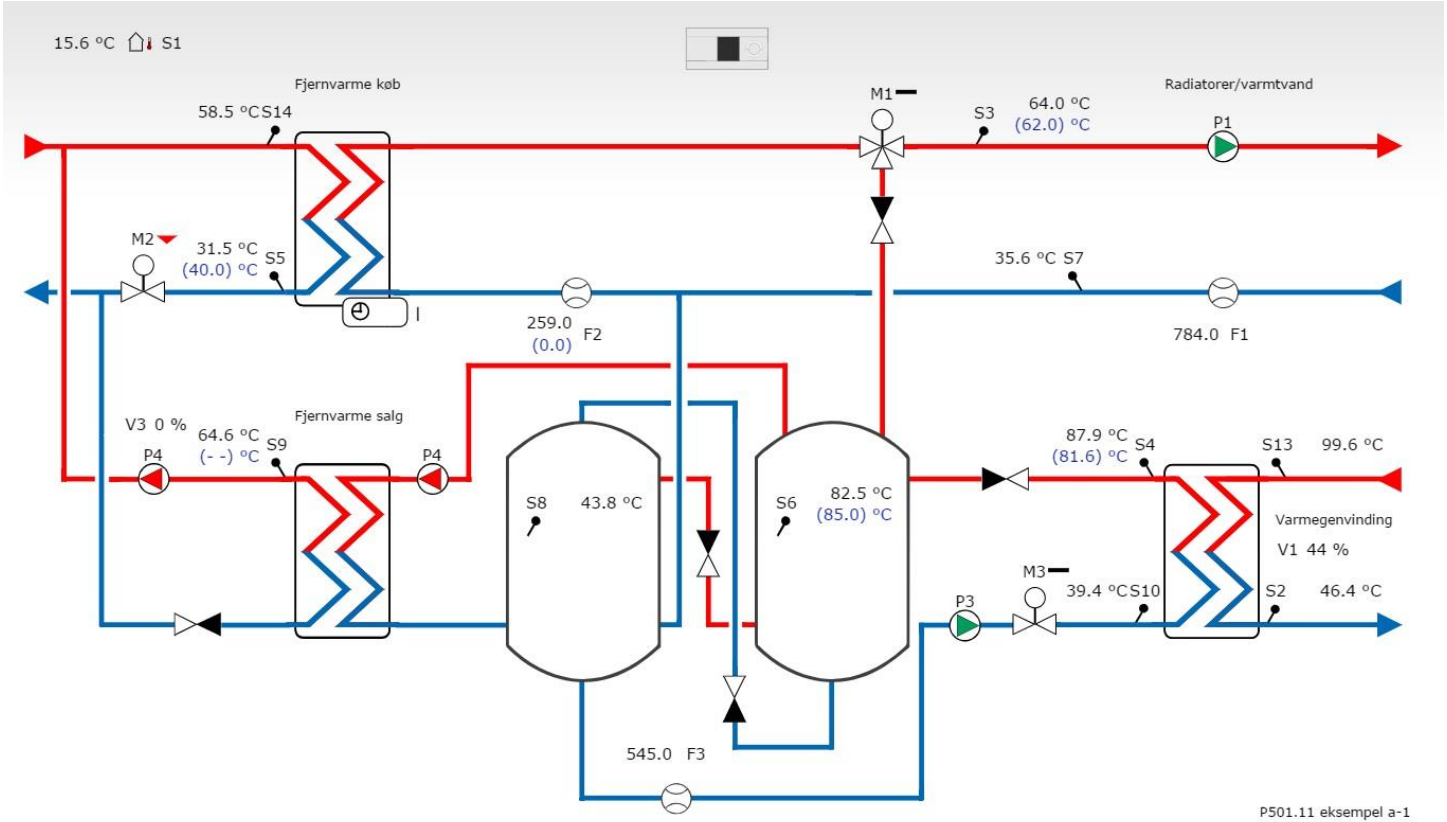
HR operating modes/ tax issues overview									
	Tax issue winter only	Space heating	Hot water comfort	Hot water proces	District heating supply	District heating return	District heating return cooling		
CO FC (cooling only, floating condensing temperature)									
HR FC (heat recovery, floating condensing temperature)	x	x	x	x	x				
HR HP (heat recovery, heat pump mode)	x	x	x	x	x	x			
HR AL (heat recovery, heat pump mode, auxillary load)	x	x	x	x	x	x	x		

EUDP Energiteknologisk udvikling og demonstration

Høruphav solution



Danfoss A1:
System principles (Indirect, with sales)

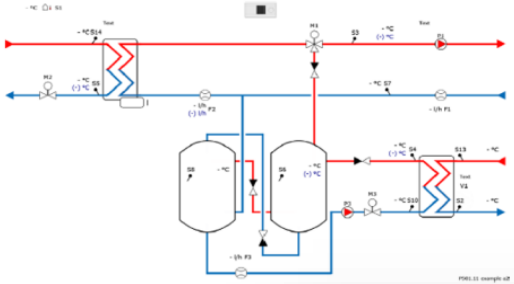


Danfoss A2, A3, A4:

DANISH TECHNOLOGICAL INSTITUTE

Heat Recovery Unit: A2 solution

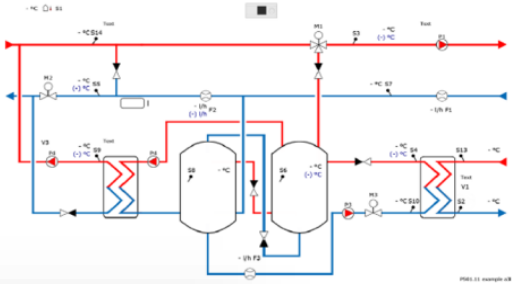
System principles (Indirect, without sales)



17 | Department (slide master)

Heat Recovery Unit: A3 solution

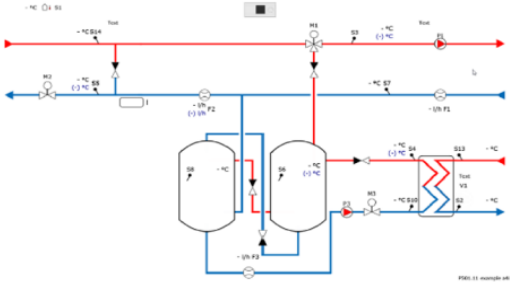
System principles (Direct, with sales)



ENGINEERING TOMORROW

Heat Recovery Unit: A4 solution

System principles (Direct, without sales)



19 | Department (slide master)

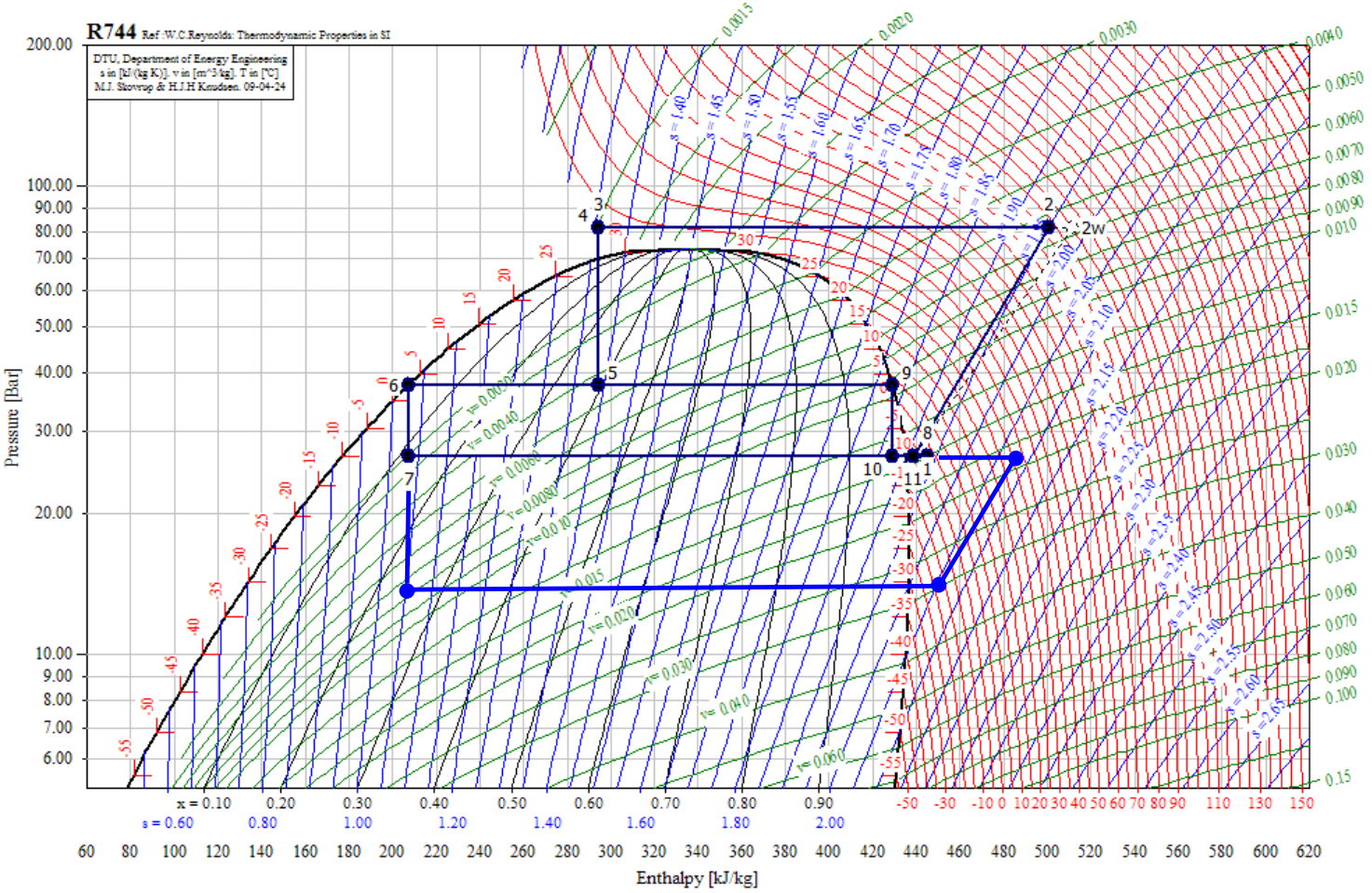
ENGINEERING TOMORROW

EUDP Energiteknologisk udvikling og demonstration

Questions?

The 13 Partners + EUDP:

CLEAN **Project Manager,** Danfoss A/S, Coop Holding A/S, Dansk Fjernvarme Forening,
Dansk Fjernvarmes Projektselskab A.m.b.a., Bramming Fjernvarme A.M.B.A,
Mølholm Fjernvarme Andelsselskab, Bjerringbro Varmeværk, Danish Technological Institute
KTH Royal Institute of Technology, Ivar Lykke Kristensen Rådg Ing., AK-Centralen A/S, OK a.m.b.a.
EUDP, Energy Technology Development and Demonstration Program,The Danish Energy Agency



ANISH
CHNOLOGICAL
STITUTE

EUDP
Energiteknologisk udvikling og demonstration