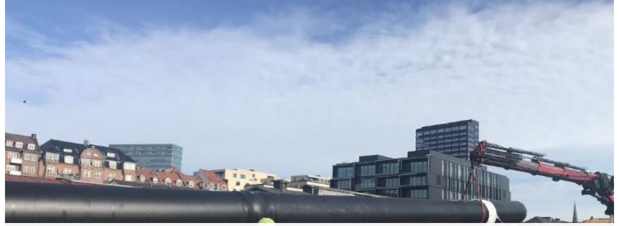
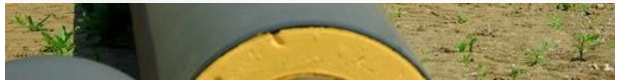



Integration of the heat pump technologies in the district heating sector in Serbia


Opportunities and challenges

Arandjelovac, Serbia, April 2025

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AGENDA

- Heat pump Technologies
- Integration of heat pumps – Opportunities
- Challenges
- Identified opportunities in Serbia
- Bringing Danish experience
- Solutions – as conclusion

Heat pump Technologies

Why heat pumps?

- Unlock potential for the new **LOW TEMPERATURE** heat sources
- Contributes to the phase-out of fossil fuels in the energy system
- Increase system efficiency and reduce CO2-emission
- To create a greener energy sector by using more different fuels and enable sector integration
- Relevant for both small, medio-sized and bigger energy DH companies
- An economically viable option

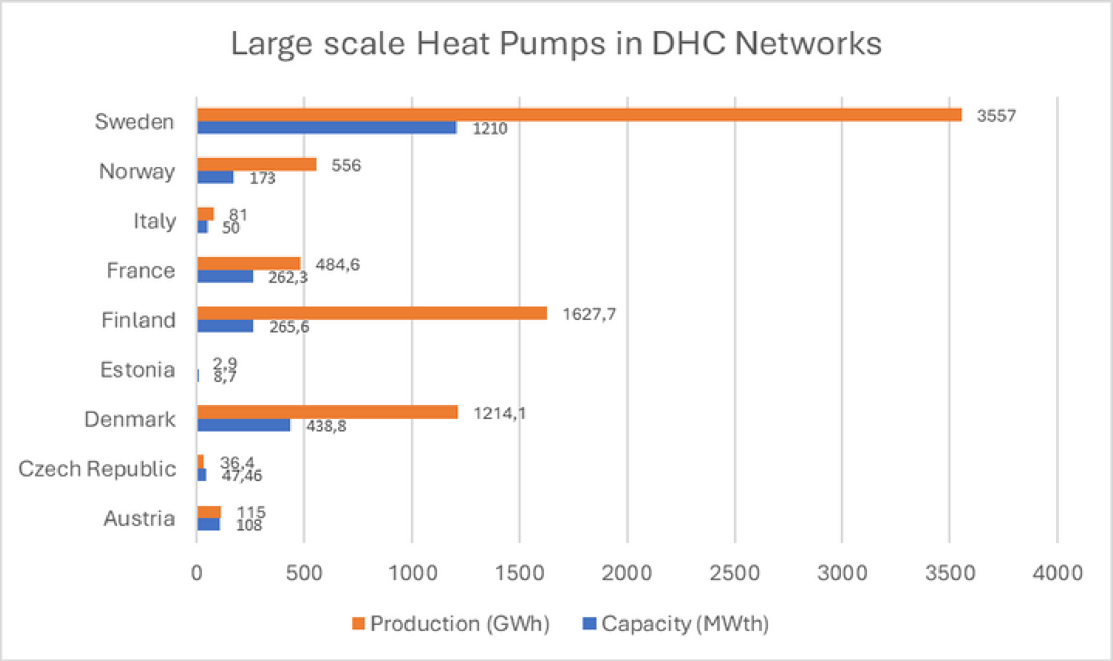
(Heat Roadmap Europe project estimates a potential 50% market share for District Heating by 2050 in Europe, with approximately 25-30% of installed capacity based on large electric heat pumps.)

*Euroheat&Power survey

State-of-art in the district heating sector in EU countries

2.5 GWth (2021) of

installed capacity of large heat pumps in DHC systems*



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Integration of heat pumps - Opportunities

Drivers opening the market

- EBRD Renewable District Energy Program in Serbia
- Energy crisis caused by the war in Ukraine and barriers in the natural gas supply
- National legal framework - LEERUE also envisages the development of a potential analysis for highly efficient cogeneration and the possibility of using efficient district heating/cooling in accordance with Article 14 of the EED
- NREAP underlines the introduction of district heating systems based on the use of RES and combined heat and power production;.
- Energy security of Republic of Serbia underlines intensification of use of RES in district heating systems in Serbia
- DH companies need to reduce the GHG emissions in the process of the decarbonization of the DH sector in Serbia

Benefits for the DH Companies

- The combination of district heating and heat pumps **are foreseen to have a key** role in the future district heating systems
- Could **cover the base heat load** reducing the current dependence on the natural gas.
- **Various technical solutions are available** and commercially proved
- **Heat pumps are modular** so district heating schemes can be designed to heat any number of properties of all sizes, from flats to detached houses.
- **Highly beneficial from an environmental perspective**
- **Increased employment**

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Challenges in Serbia

- Gas boilers are currently one of the most common heating technologies and with the lower CAPEX
- Old fashion non-condensing gas boilers do not recover heat from the flue gases
- Current possibilities of DH companies (in knowledge and finance)
- Insufficient hydraulic regulation of DHS (excessive flows and insufficient cooling of thermal substations)
- No single solution
- Increase the electricity price
- Lack of the heat pumps in the market
- Availability of sufficient numbers of trained installers

Integration of heat pumps – Some opportunities

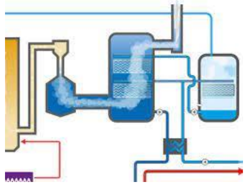
Identified projects

KRAGUJEVAC

Utilization of waste heat from data center for the heat pump

KRALJEVO

Heat pumps for flue gas condensation Central boiler house and Nova Kolonija boiler house



KRUŠEVAC

Heat pump utilizing treated water from Wastewater treatment plant

NIŠ

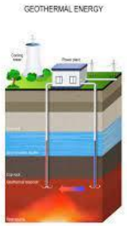
Large capacity heat pump using water from Nisava river

NOVI PAZAR

Heat pump utilizing the drinking water at boiler house Lug

PARAĆIN

Heat pump using geothermal water from well at the zone of textile factory including construction of new DH network and heating substations



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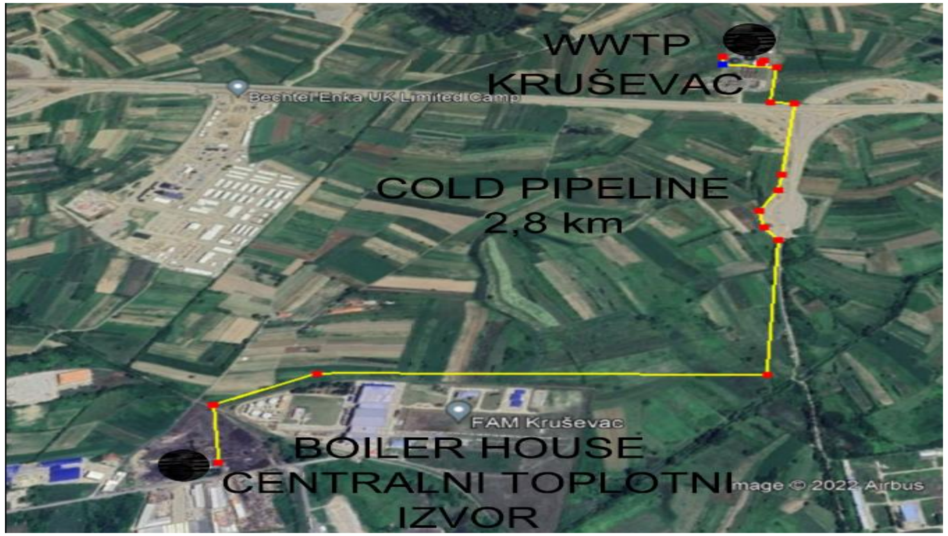
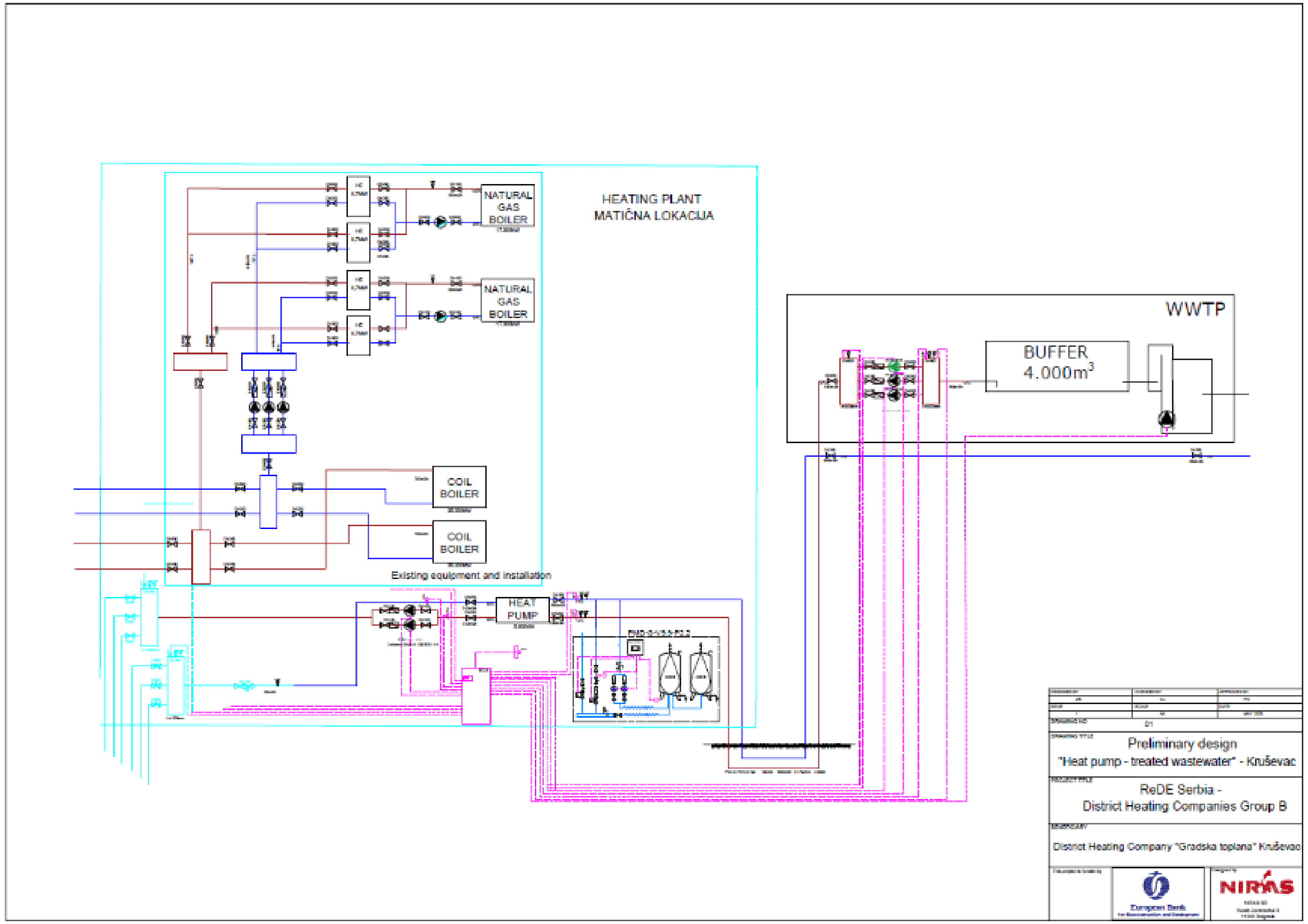
Identified opportunities in Serbia

KRUSEVAC - Heat pump utilizing treated water from Wastewater treatment plant





Identified opportunities in Serbia

Key parameters

Parameters	Unit	Value
Baseline scenario		
Heat production "Centralni toplotni izvor"	[MWh/year]	98,000
Specific heat production costs	[EUR/MWh]	56.0
Annual energy cost	[EUR]	5,487,781
Project scenario		
Heat pump installed capacity	[MW]	5.8
COP		3.60
Heat production from heat pump	[MWh/year]	25,891
Electricity consumption for HP and pumping	[MWh/year]	7,987
The percentage of energy that will be provided by the heat pump	[%]	26.42%
Total annual cost savings	[EUR]	691,123
Annual CO2 emissions reduction	[tCO2]	300
Cumulative cost savings for 20 years	[EUR]	13,822,460
Estimated value of investment	[EUR]	6,113,445
LCOH – Baseline scenario	[EUR/MWh]	56
LCOH – Project scenario	[EUR/MWh]	41
Simple payback period	[years]	8.8
Simple payback period with 20% of grant	[years]	7.1

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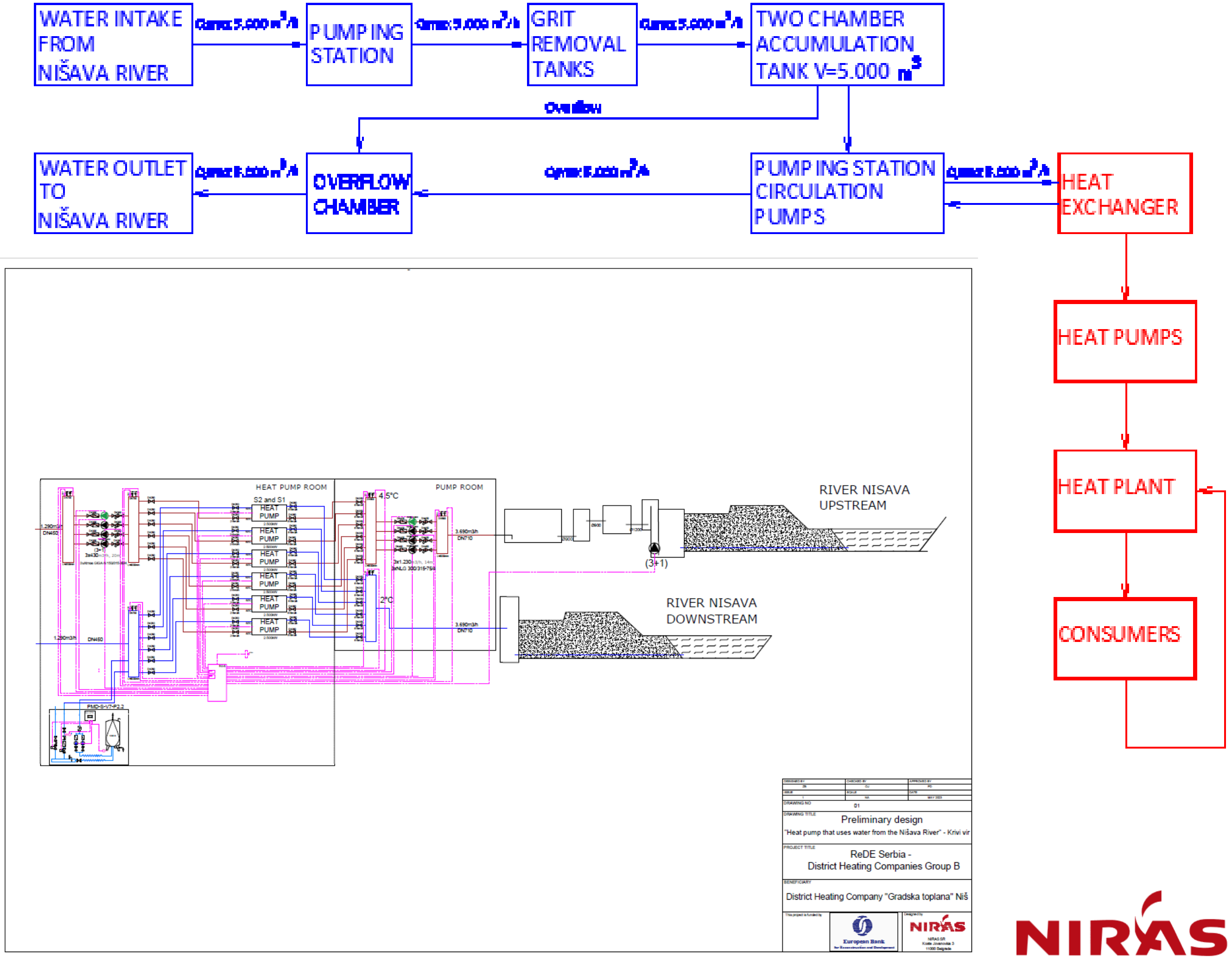
Identified opportunities in Serbia

NIS - Large capacity heat pump using water from Nisava river



Identified opportunities in Serbia

Key parameters

Parameters	Unit	Value
Baseline scenario		
Heat production at BH Krivi Vir	[MWh/year]	134,000
Specific heat production costs	[EUR/MWh]	56.0
Annual energy cost	[EUR]	7,503,701
Project scenario		
Heat pump installed capacity	[MW]	15
COP		3.50
Heat production from heat pump	[MWh/year]	66,960
Electricity consumption for HP and pumping	[MWh/year]	20,727
The percentage of energy that will be provided by the heat pump	[%]	49.97%
Total annual cost savings	[EUR]	1,780,516
Annual CO2 emissions reduction	[tCO2]	727
Cumulative cost savings for 20 years	[EUR]	35,610,320
Estimated value of investment	[EUR]	13,888,600
LCOH – Baseline scenario	[EUR/MWh]	56
LCOH – Project scenario	[EUR/MWh]	40
Simple payback period	[years]	7.8
Simple payback period – 20% grant	[years]	6.2

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Bringing Danish experience

District heating Roskilde, Denmark – 8 MW heat pump

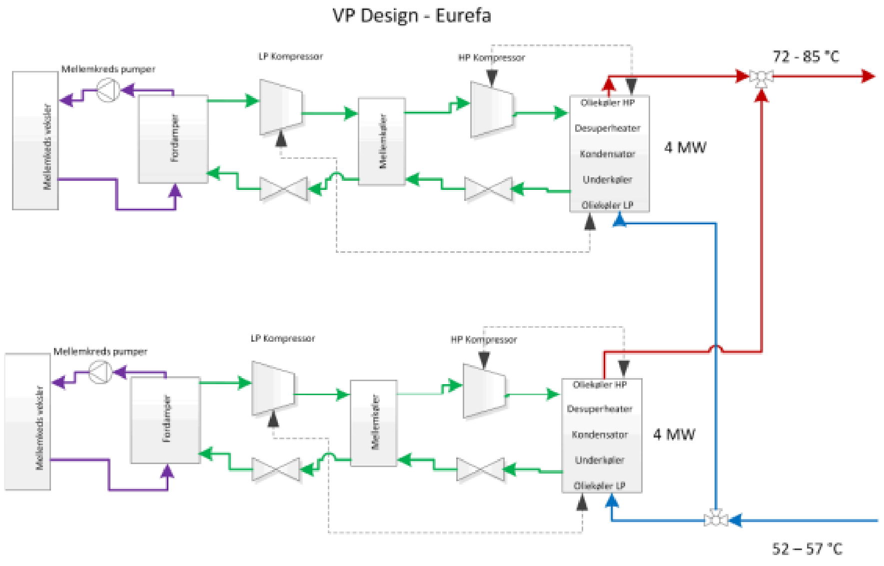
Overview

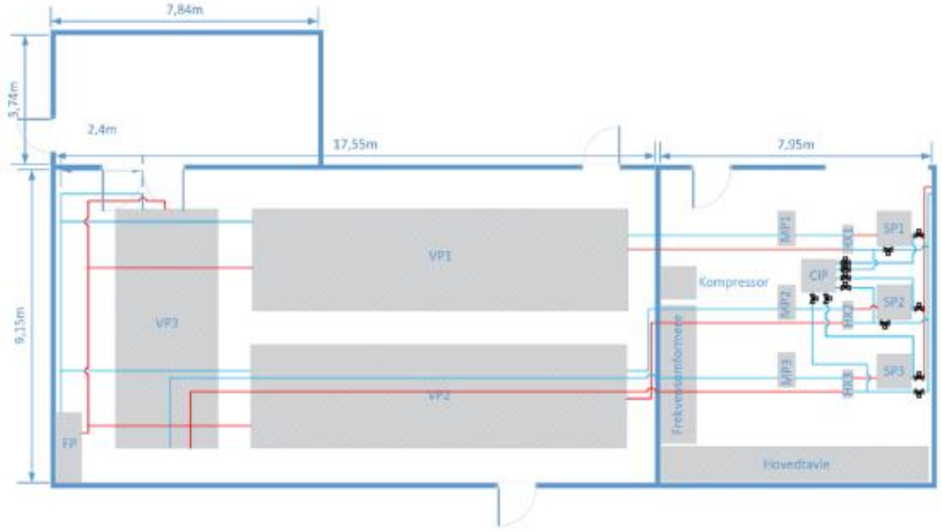
- The client is the utility company FORS covering three Danish municipalities. Responsibilities: district heating, wastewater cleaning, and more
- The client wanted to decarbonise heat production by up to 15% of production capacity
- Motivations for selecting heat pump technology:
  - Improved conditions for heat pump projects: taxes and legislation
  - Possibility of financial support from the Danish government
- NIRAS scope in the project included:
  - Heat pump system basic design: Integration, interfaces, constraints
  - Transformer station and electrical connection to grid
  - Permits
  - EPCM
- NIRAS was builder's adviser all the way from conceptual engineering to commissioning

District heating Roskilde, Denmark – 8 MW heat pump

Conceptual Engineering

- Client concerns
  - ➢ Environmental impact
  - ➢ Economic impact
  - ➢ Energy efficiency
  - ➢ Timeline
- Conceptual Engineering included:
  - ➢ Conceptual design of heat pump system incl. technical and economic comparison of three different technical solutions
  - ➢ Layout for installation in existing building





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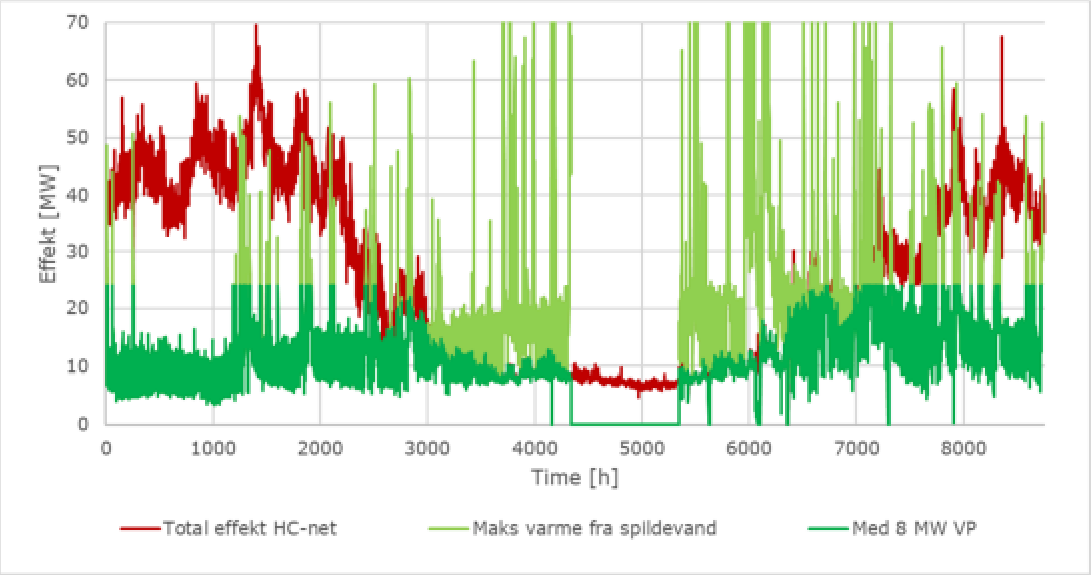
District heating Roskilde, Denmark – 8 MW heat pump

Conceptual Engineering

- Conceptual Engineering included:
  - ➢ Integration in district heating system
  - ➢ Integration with wastewater system

Drifts-punkt	Antal ti-mer	Varmeeffekt 2x4MW	Total Varme mængde	El	COP	EER
	[h]	[kW]	[MWh]	[MWh]	[-]	[-]
1	0	0	0	0	0	0,00
2	720	8500	6121	2826	3,44	3,12
3	2489	8500	21156	8776	3,35	3,04
4	2489	8500	21156	7629	3,95	3,58
5	1814	8500	15422	4890	4,15	3,76
Total	7512	8499	**63854**	**18942**	**SCOP**	**3,40**



District heating Roskilde, Denmark – 8 MW heat pump

Conceptual Engineering

- Conceptual Engineering included:
  - CIP-system
  - Filtering
  - Intermediate glycol circuit
  - CAPEX estimation
  - Business case development

	EUREFA	SVEDAN	GEA
Construction site works	400.000	400.000	400.000
Civil works	820.000	820.000	820.000
Heat pump system	24.600.000	18.900.000	24.600.000
Intermediate loop heat exchanger	4.230.000	3.310.000	4.230.000
Rearrangement of wastewater system	2.640.000	2.640.000	2.640.000
CIP system	500.000	500.000	500.000
In-line filter system	520.000	780.000	520.000
Internal piping	1.260.000	1.580.000	1.260.000
SCADA	400.000	400.000	400.000
Electrical works incl. Transformer	9.840.000	9.840.000	9.840.000
Ventilation	470.000	470.000	470.000
Other construction works	500.000	500.000	500.000
Pumps	1.180.000	1.180.000	1.180.000
District heating pipes and connections	6.980.000	6.980.000	6.980.000
Consultancy	2.500.000	2.500.000	2.500.000
Contingency - 10 %	5.684.000	5.080.000	5.680.000
Total	62.524.000	55.880.000	62.520.000

District heating Roskilde, Denmark – 8 MW heat pump

Basic Engineering and tendering

- Preparation of complete tendering material
- Engineering design
- Defining conditions for contractors to compete
- Definition of guaranteed values and procedure for their testing and evaluation
  - Performance tests for five operational conditions
  - Correction for ambient conditions
  - Penalty for underperformance
  - Penalty for late delivery
- Evaluation of offers from contractors:
  - Price: Bill of quantities
  - Quality: Building and civils, process design, maintenance
  - Lifetime costs: Electricity costs, operation and maintenance
  - Risk: Timetable and organization

Document nr.:
TS - Tender Specifications
TS1 Bill of Quantities
TS2 BoQ specifications

SP - Specifications
SP0 - General specification
SP1.1 - Waste water - secondary loop
SP1.2 - Heat Pump Plant
SP2.1 - Buildings and Civil Works
SP3.1 - Automation
SP3.3 - Other Electrical

DG - Drawings
DG0.1.1 - Site Overview
DG1.1.1 - PFD
DG1.1.2 - Pipe and cable plan
DG1.1.3 - Kotes
DG1.1.4 - Bjergmarken_layout
DG2.1.1 - Discharge building (UB)
DG2.1.2 - Sewage Plan in Existing Sludge Building
DG3.1 - Heat pump plant_Control System Configuration

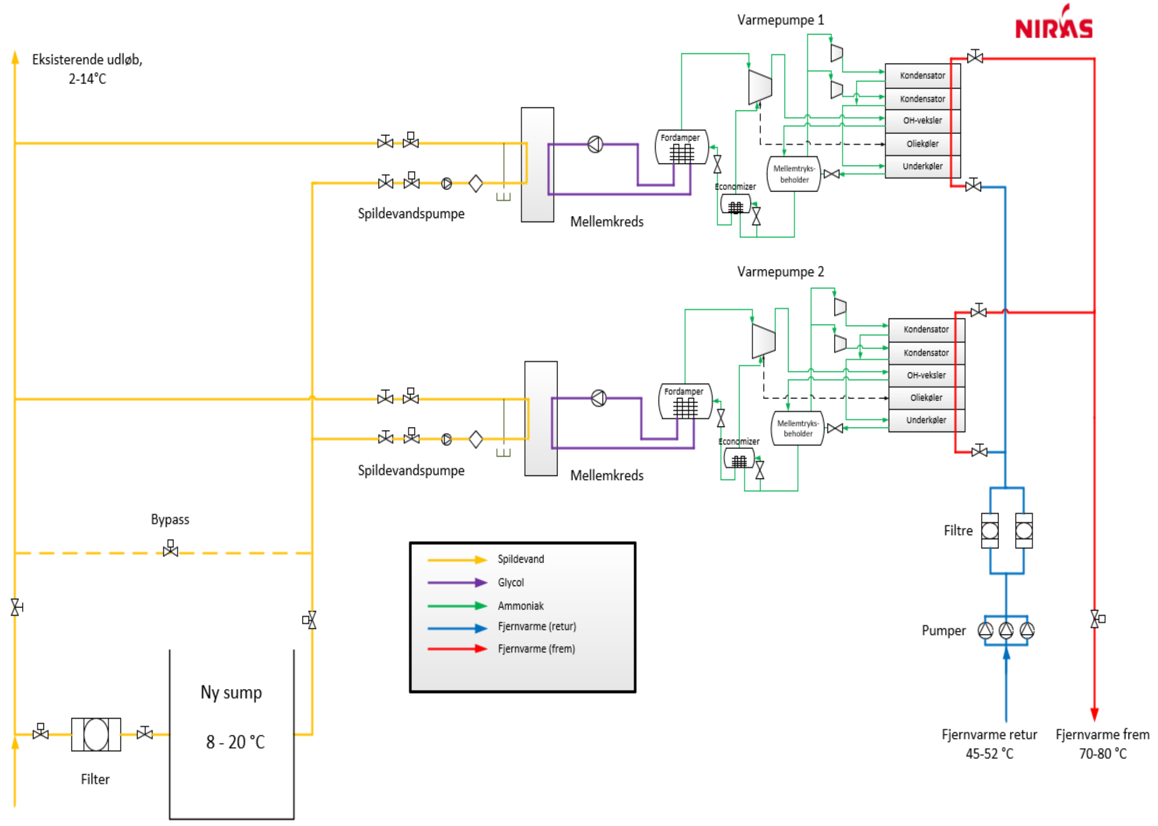
UB - Tender conditions
UB 1 - FORS Tender conditions (B&B document)
UB 1.1 - Evaluation model
UB2 - Time Schedule

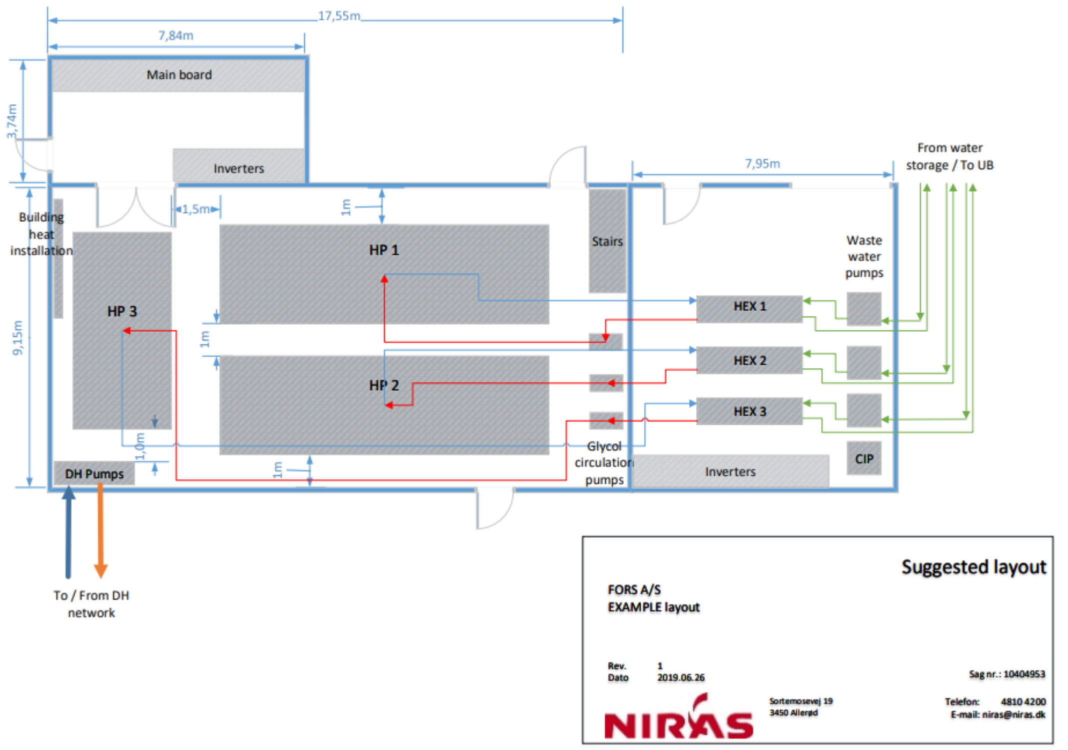
BT - Guarantees
BT1 - Guaranteed values
BT2 - Design and build contract (B&B document)
BT3 - ABT 18 (B&B document)
BT4 - Servicekontrakt (B&B document)

AP - Appendix
AP0.1.1 - Local Plan
AP0.1.2 - Project description
AP0.1.3 - VVM desciption
AP0.1.4 - Discharge Permission
AP0.1.5 - VVM Natura 2000
AP1.1.1 - Akk. lab. data Bjergmarken - 2018
AP2.1.1 - Existing Sludge building
AP3.1.1 - FAT_Certificate
AP3.1.2 - SAT_Certificate
AP3.1.3 - SIT_Certificate

District heating Roskilde, Denmark – 8 MW heat pump

Basic Engineering and tendering





District heating Roskilde, Denmark – 8 MW heat pump

Basic Engineering and tendering

Evaluation of offers:

E **Evaluation**

Result		
	Evaluation criteria	**Amount**
1	Price	53.159.448,00
2	Quality	40.000.000,00
3	Lifecycle cost	123.292.490,98
4	Risk	15.000.000,00
	Evaluation	**231.451.938,98**

Numbers for evaluation		
Maximum value	**El [DKK/kWh]**	**Number of years**
40.000.000,00		
	0,563	10
15.000.000,00		

(grey)	Energy/project specific data
(blue)	Weights - to be filled out before tender proces
(yellow)	Evaluation parameters from tender

1	**Price**	**Amount**
1.1	Bill of quantities	53.159.448,00
1.2	Extra	-
	Evaluation	**53.159.448,00**

2	**Quality**	**Amount**	Grade	**Weight**
2.1	Building and civils	4.000.000,00	0	10%
2.2	Plant	24.000.000,00	0	60%
2.3	Maintenance	12.000.000,00	0	30%
	Evaluation	**40.000.000,00**		100%

3	**Lifecycle cost**	**Amount**
3.1	Electricity	123.292.490,98
3.2	Operation and maintenance (BOQ)	
	Evaluation	**123.292.490,98**

Electricity cost - 1 year					
Driftstilstand nr.	**1**	**2**	**3**	**4**	**5**
District heating GWh	15	21	21	6	0,8
EER	2,76	2,92	2,95	3,13	3,13
El udgift mio	3,06	4,05	4,00	1,08	0,14

4	**Risk**	**Amount**	**Grade**	**Weight**
4.1	Time table	9.000.000,00	0	60%
4.2	Organization	6.000.000,00	0	40%
	Evaluation	**15.000.000,00**		100%

Correction scheme for evaluating guarantee values:

Waste water T [°C]	Operating condition				
	1	2	3	4	5
8	0,0%	-3,8%	-5,1%	-9,3%	-13,6%
9	1,2%	-2,5%	-3,9%	-8,1%	-12,4%
10	2,5%	-1,3%	-2,6%	-6,8%	-11,2%
11	3,8%	0,0%	-1,3%	-5,5%	-9,9%
12	5,1%	1,3%	0,0%	-4,2%	-8,6%
13	6,5%	2,7%	1,4%	-2,8%	-7,3%
14	7,9%	4,1%	2,8%	-1,4%	-5,9%
15	9,4%	5,5%	4,2%	0,0%	-4,5%
16	10,8%	7,0%	5,7%	1,5%	-3,1%
17	12,4%	8,5%	7,2%	3,0%	-1,6%
18	13,9%	10,1%	8,8%	4,6%	0,0%
19	15,5%	11,7%	10,4%	6,2%	1,6%

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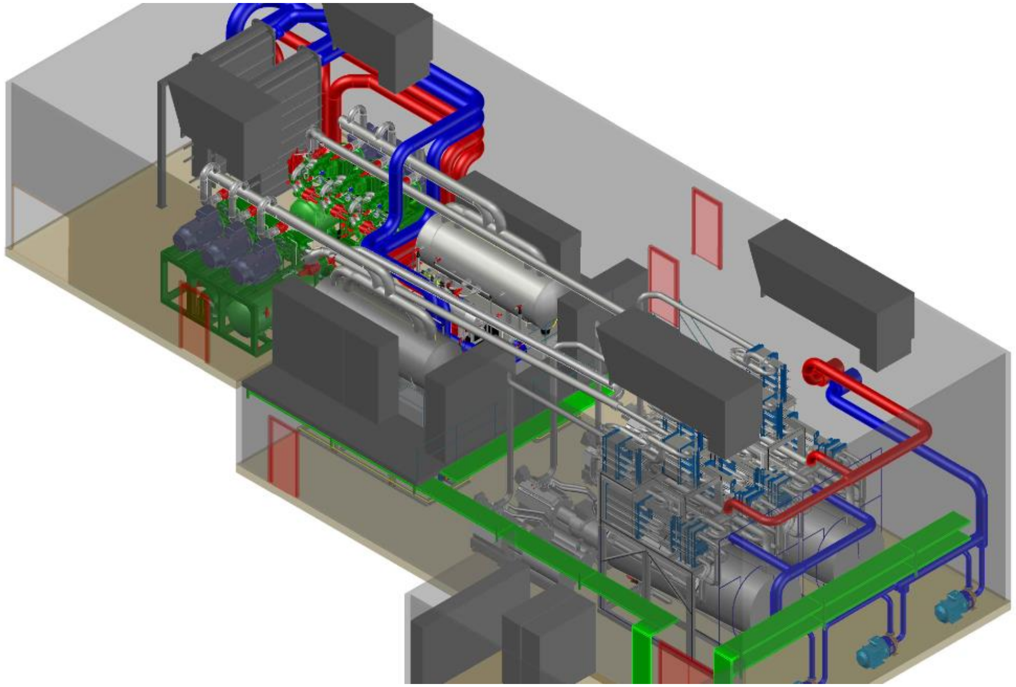
District heating Roskilde, Denmark – 8 MW heat pump

EPCM during construction and commissioning

- Sample of NIRAS tasks during construction:
  - ✓ Weekly meetings with contractors
  - ✓ Coordination of interfaces between contractors and external parties
  - ✓ Design reviews
  - ✓ Change handling
  - ✓ Oversights
  - ✓ Monitoring FAT and SAT
  - ✓ Monitoring guarantee testing
  - ✓ Deficiency review



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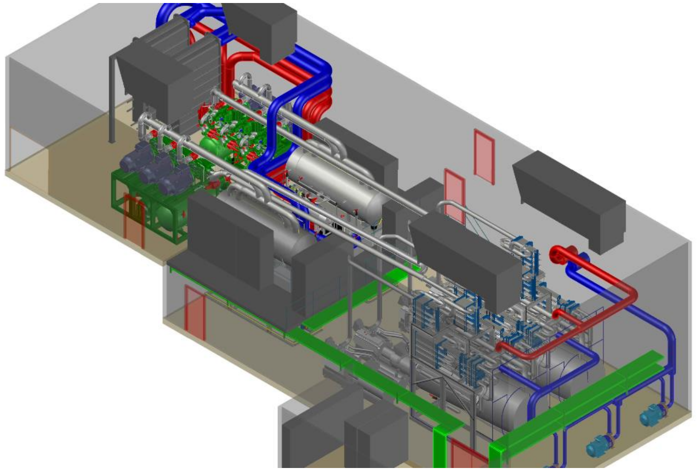
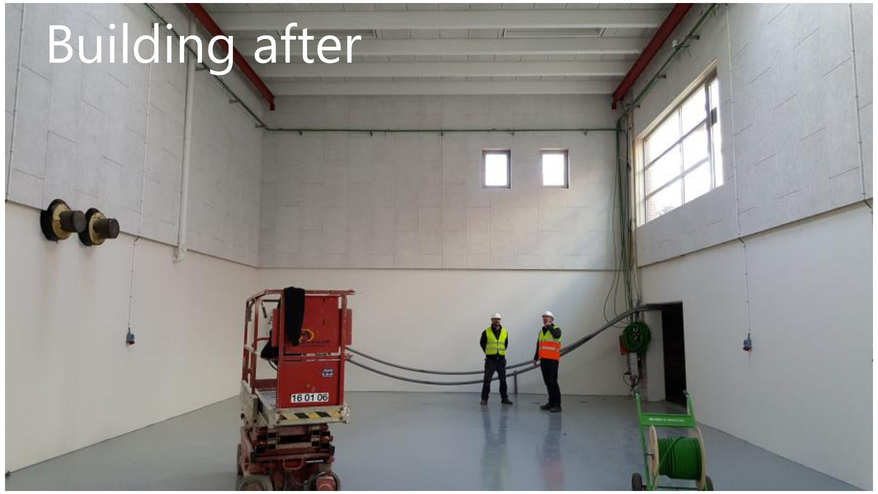
District heating Roskilde, Denmark – 8 MW heat pump

EPCM during construction and commissioning





District heating Roskilde, Denmark – 8 MW heat pump

EPCM during construction and commissioning

District heating Roskilde, Denmark – 8 MW heat pump

Project status and learnings

- Buffering capacity on cold side essential due to variations in wastewater flow – evaluation of dynamics of source and sink essential
- Wastewater handing is challenging – sludge infiltration
- Construction in existing building is possible, but this case was challenging due to small building compared with heat pump size
- Close collaboration with operational personnel at wastewater facility was essential
- Heat pump system is now operational
- NIRAS is involved in follow-up activities on optimization of operation based on electricity prices and expected COP of the system

More to consider - Working fluid

General for heat pumps – technology selection based on the natural refrigerants

- **Ammonia heat pump:**
  - Well-proven technology for supply temperatures up to 85 °C
  - Examples of supply temperatures up to 90 °C are available, but high ammonia pressures makes the compressors operate close to maximum conditions (robustness of the solution needs consideration)
  - A two-stage solution (two compressors in series) is necessary, due to large temperature difference between heat source and supply temperature
  - Suppliers offer standard skid mounted solutions
  - FAT test possible
  - COP (ratio of heat produced to electricity consumption) is high
- **CO_2 heat pump**:
  - Several application examples in district heating (in Denmark) for temperatures up to around 75 °C – skid mounted solutions
  - Demonstration projects have carried out for temperatures up to around 100 °C (not a standard solution yet)
  - COP is generally lower than ammonia heat pumps
  - Hot water return temperature needs to be below 40-45 °C for acceptable performance
  - FAT test not possible
- **Other heat pump types (less mature technology):**
  - Olvondo, Helium as working fluid based on Stirling technology, high temperature possible
  - Hybrid Energy, ammonia/water mixture

Designs

Comparison: one heat pump of 2.2 MW and two heat pumps of 1.1 MW

1 heat pump

- 2.2MW hot water
- **Pros**
  - Less equipment
  - Floor space
- **Cons**
  - Air cooler needed → noise impact
    - Needed for more unit controls
  - Special → not off the shelf unit
    - Possible not standard components
  - 1 heat pumps due size runs at not optimal minimum demand (more heat than demand)
- Estimated total costs: 1.1 M€

(based upon Mayekawa specialty HP)

2 heat pumps

- 2x 1.1 MW hot water
- **Pros**
  - Standard unit
  - Maintenance
  - Redundancy
  - System backup
  - Easier heat pump ramp up/ ramp down compared to 1 large
  - Easier control
  - Always one heat pump operating on ideal performance conditions
  - Interaction control demand with the second one
  - Sharing of dynamic loads between 2 heat pumps
    - Less stress on system -> longer service intervals
- **Cons**
  - Floor space
  - More components
  - Change to building
- Estimated total costs: 1.12 M€

(based upon Mayekawa HPs)

Shut-down factors

- In case of unexpected failure, for example:
  - Electric motor failure.
    - Critical due to long lead times from sub suppliers. (can be weeks)
  - Main components compressor (screw, crankshaft etc.)
    - Critical due to long lead times from compressor supplier (can be weeks)
  - Failures of mechanical couplings
    - Less critical since often stock item (3-8 hours)
  - Gasket failure
    - Less critical since often stock item and part of regular service kits (3-8 hours)
  - Oil filter change
    - Less critical since often stock item and part of regular service kits (2-3 hours)

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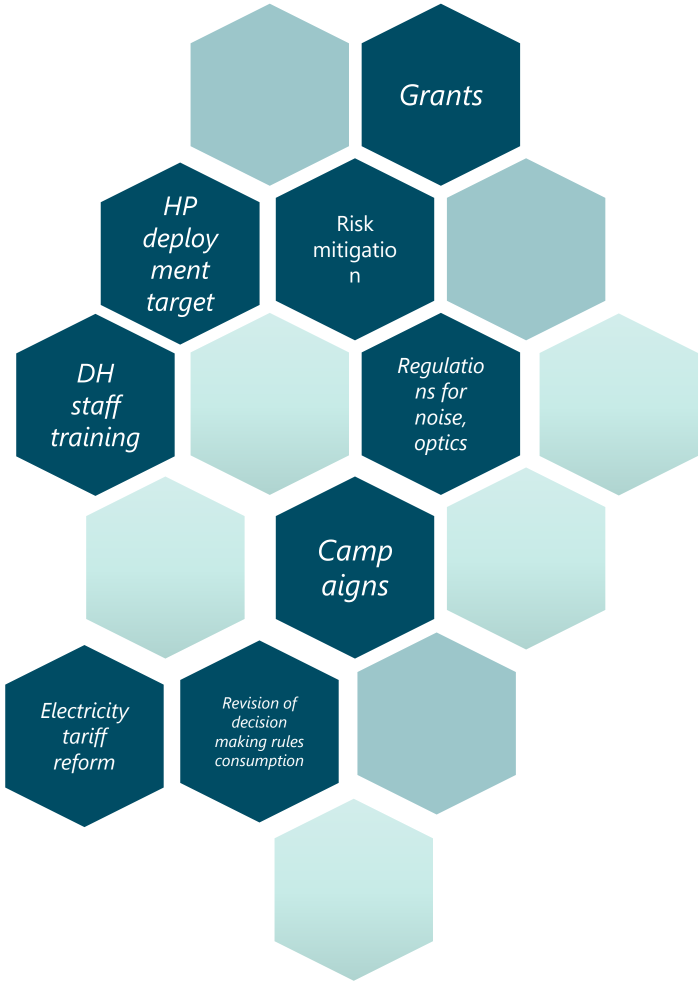
Solutions to overcome the challenges – as conclusion



Cost barriers solutions

- **Upfront costs:** Grants, Low-interest loans, Tax rebates, Risk mitigation schemes for medium- to large-scale projects
- **Operating costs:** Rebalancing electricity and fossil fuel taxes, Electricity and heat tariff reforms, Support for building insulation and heat distribution system upgrades, Quality and settings control after installation, DH staff training

Non-cost barriers solutions

- One-stop-shop platforms
- Regulation changes for optics, noise and building permissions
- Revision of decision-making rules
- Minimum energy efficiency requirements for buildings connected to DH
- Information campaigns towards consumers
- Education programms

Supply side solutions

- Long-term certainty in policy support and regulations, as well as visibility into forthcoming regulation changes
- National heat pump deployment targets and roadmaps
- Securing of heat pump component supply chains

Realising your sustainable potential

NIRAS Energy

Thank you for your attention!

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