FINNISH ENERGY (ENERGIATEOLLISUUS RY)

Large heat pumps in district heating systems

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What is the objective of the study by VALOR?

The aim of the study has been to investigate potential utilization areas of heat pumps as part of district heating systems i.e. as a production form in the district heating chain

– The study was limited to ”large” heat pumps, which feed heat directly into the district heating system and which can be considered to have a fairly significant role in the heat production (heat production capacity of more than 1-3 MW)

– The study did not include customer-/property-specific heat pumps that operate at or near the place of heat usage

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Why have large heat pumps grown in prevalence and popularity as part of district heating systems?

Uncertainty over the future price development of electricity	Decline in the average price of electricity	Increased regulatory requirements towards the share of renewable energy
Uncertainty over the future price development of fuels	Progress in the technology of heat pumps	Increased drive for energy efficiency (utilization of surplus heat)
Uncertainty over the future development of the aggregate heat consumption load	Increased demand for district cooling	Success of earlier heat pump investments in major towns

Source: VALOR-analysis, expert interviews

What are the benefits of heat pump plants as part of district heating systems?

Increases the flexibility of the district heating system

- Expands the heat production portfolio
- Enables greater reactivity (quick start-ups and low start-up costs)
- Optimizes the run-time of base load plants by minimizing the number of start-ups and time used for suboptimal production
- Improves the profitability of the entire district heating system
- Enables taking advantage of the volatility of the electricity market (with thermal batteries)

Protects from (market) risks

- Hedges against fluctuations in the price of electricity
- Hedges against fluctuations in the prices of fuels
- Protects against individual plant/production unit failures
- Enables combined production of district heating and district cooling

Enables better utilization of surplus heat production

- Enables the utilization of low temperature heat sources
- Enables the utilization of otherwise redundant heat sources

Increases renewable heat production

- Increases the proportional share of renewable heat production in the heat production mix
- Does not cause local emissions
- Boosts the positive image around district heating

Source: VALOR-analysis, expert interviews

Are investments into heat pumps profitable?

- District heating systems are highly capital intensive
- The key determinant to the profitability of heat pump investments are their impact on the aggregate profitability of the district heating system
- If investments into heat pumps induce improvements into the utilization rate and/or production efficiency ratio (input-output ratio) of the district heating systems, the investments can be highly profitable
- Inversely, it can be concluded that heat pump plants are most profitable in systems where the heat pump can be employed to ensure the alignment between the output of the existing heat production units and the aggregate heat consumption load (i.e. demand for heat)
- Due to sizeable initial investments for a heat pump plant, the window of profitability for heat pump plants is narrow, and the profitability of the investment cannot withstand large operating expenses

Source: VALOR-analysis, expert interviews

Which are the key requirements for a profitable heat pump investment case?

1. The heat pump has a natural role of the district heating system and the pump improves the utilization rate and production efficiency ratio of the entire system
2. There is access to a heat source that is close to the district heating consumption load (e.g. waste water, bodies of water, flue gases, or surplus heat from nearby properties)
3. The heat source is permanent by nature, suitable by temperature and stable in terms of availability of heat
4. The heat produced by the heat pump does not need to be primed or can be primed by utilizing readily available plants/production units
5. The heat from the heat source is free or available at a very low price
6. Carrying out the heat pump investment is not contingent on considerable investments into bolstering the power grid
7. A thermal battery is readily available or it can be constructed without significant investments
8. The heat pump can be used to produce district cooling as well as district heating

Source: VALOR-analysis

What is the typical role of heat pump plants in particular district heating systems?

Size of system	Other plants connected to the heat pump	Role/aim of the heat pump	Running mode of the heat pump	Size of plant (% of heat production)	Typical heat sources
Small	Heat boiler	Minimizing heat production costs, replacing fossils	Continuous, base load	20-90%	Industrial processes, flue gases, bodies of water, soil
Medium sized	CHP plant, (heat battery)	Maximizing CHP load factor	Supports CHP-production	5-30%	Same as in small + cleaned urban waste water
Large	CHP power plant, energy storage units (heat and cooling batteries)	Maximizing the margin for the entire heating system	Continuous or sporadic based on specific need/situation	5-20%	Cleaned urban waste water, surplus heat from properties

Indicative assessment of the attractive sizes of plants is based on the results of simulation(1)

1. Based on Danish 2014 Elspot price series – annual average price for electricity at 31 €/MWh and price fluctuation considerable
Source: VALOR-analysis

What other strategic benefits are associated with heat pumps?

Enables customer cooperation

- District heating customers are a priori active in advancing renewable heat sources – putting it bluntly: ”In the future, the district heating provider does not engage the customer in new ventures, the customers engage the company – if they want”

➔ The district heating providers must construct for their customers cooperation models and services that respond to the needs of customers while simultaneously maximizing the benefits for the whole DH system

➔ *Example: customers should be given the opportunity to acquire (production) shares in a centrally constructed heat pump plant, after which the production and benefits of the plant would be allocated to the customers by measure of their shares (compare solar power plants)*

Improves the image of the district heating company

- The positive overall image of heat pumps bolsters the modernization of the district heating industry, which is commonly perceived as old-fashioned, as well as creates an image of customer-centricity and environmental friendliness for the companies

Which are the key messages of the report to other stakeholders?

- Large heat pumps as integrated components of district heating systems are a prime manifestation of district heating companies' aim to foster economically and environmentally efficient heat production solutions – executed in cooperation with heat customers
- **Lawmakers and regulators should not through building codes force property developers to invest in property-specific energy production facilities,** because compared to centralized heat pump plants, uncoordinatedly constructed small heat pumps lead to partial optimization, poor functionality and maintenance of systems as well as increased greenhouse gas emissions

- Releasing surplus heat into the environment at a considerably higher (or lower) temperature creates a significant burden to the environment
- Consequently, **utilizing surplus heat should be considered as a environmental act**, from which there should be no financial liabilities for the utilizing party

VALOR Source: VALOR-analysis

What is the aggregate utilization potential of large heat pumps in Finland?

Size of system	Consumption in the system, GWh	Potential for large heat pumps, %	Total consumption, GWh	Total potential, GWh
Small	Under 200	4 – 10%	4 500	200 – 500
Medium sized	200-800	6 – 10%	7 100	400 – 700
Large	Over 800	12 – 15%	19 900	2 400 – 3 000
Combined	-		31 600	**3 000 - 4 200**

- The outlined estimate is equivalent to 9 – 13% of the annual consumption of district heating in Finland (currently production is at less than 2% of district heating consumption, at around 600 GWh)
- The underlying potential is highest within large systems as the heat pumps there can be used simultaneously for the production of district cooling, too
- In small and medium-sized systems the potential is contingent on the access to surplus heat in each individual system – analyzing the potential would require a separate study

APPENDICES

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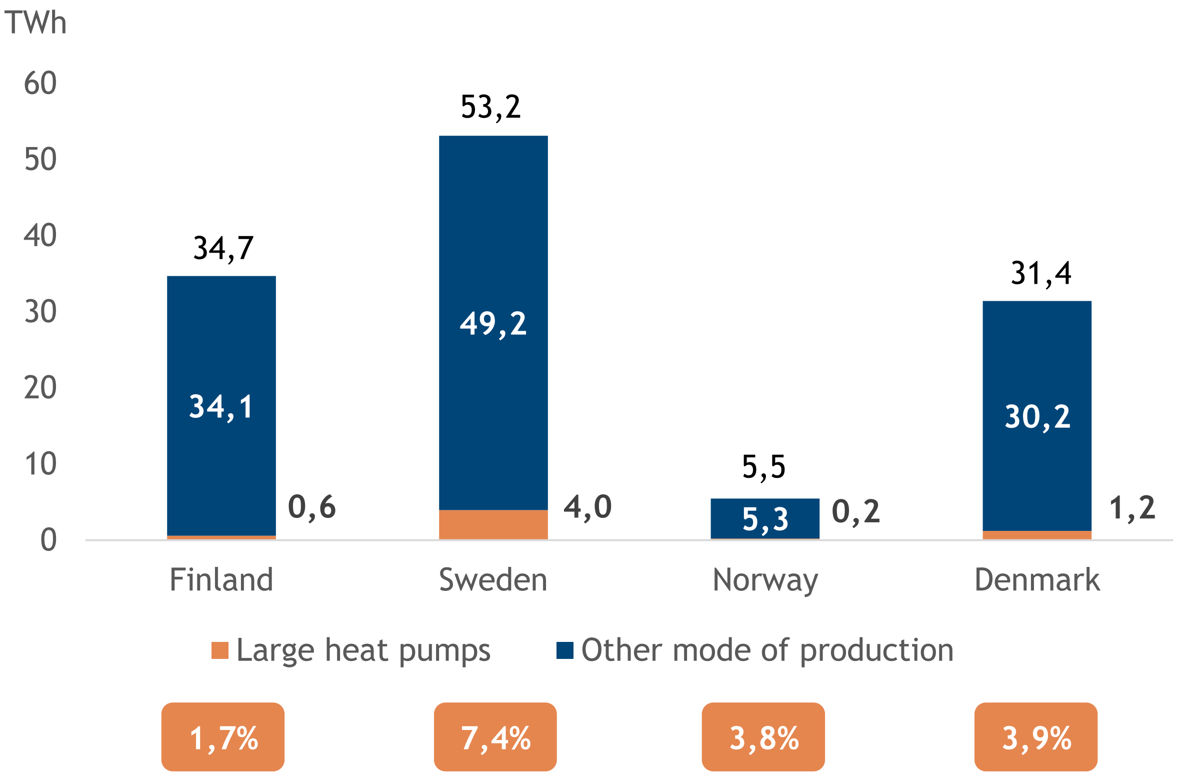
Heat pump projects carried out in the Nordics

	City	Company	Heat output capacity of the pumps (cooling capacity)	Heat source
	Akaa	Elenia Lämpö	0,6 MW (0,5 MW), entire HR 1,7 MW	Flue gases
	Espoo	Fortum	2x20 MW (2x7,5 MW)	Waste water
	Helsinki	Helen	5x18 MW (5x12 MW)	Waste water, cooling water
	Riihimäki	Ekokem/HLV	2x4,5 MW (2x2 MW)	Flue gases, DH return water
	Mäntsälä	Mäntsälän Sähkö (Nivos)	Yht. n. 3 MW	Data center
	Turku	TSE	2x20 MW (2x14 MW)	Waste water
	Gothenburg	Göteborg Energi (Rya verket)	2x50 MW + 2x30 MW	Waste water
	Lund	Lunds Energi	3,6 MW	Particle accelerator, geothermal
	Stockholm	Fortum Sverige	4x27 MW + 2x24 MW + 4x25 MW (Ropsten 1-3)	Sea water
	Drammen	Drammen Fjernvarme	3x4,5 MW	Sea water
	Oslo	Oslofjord Värme (Sandvika)	2x6,5 MW (2x4,5 MW)	Waste water
	Trondheim	NTNU	1,1 MW	Data center
	Dronninglund	Dronninglund Fjernvarme	3 MW	Stored solar energy

Source: Company reports and public statements, VALOR-analysis, expert interviews

Large heat pumps as a share of total district heating production in the Nordics currently



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Source: Each country's statistics agency; Figures for Finland and Sweden from 2014, Figure for Denmark from 2015, figure for Norway from 2012

Specific factors affecting the overall profitability of heat pump investments

Minimal initial investment	High and sustainable operating profitability
• Proximity of heat source to consumption load (minimal need for transfer pipeline) • Access to affordable space • Non-existent or limited need to prime the produced heat • High-quality power grid that does not require bolstering to enable the use of heat pump • Sensible size and role for the heat pump plant • Opportunities for investment support (i.e. grants) • Optimal-sized thermal batteries	• Heat source that is permanent by nature, suitable by temperature and stable in terms of availability of heat • Low or negative payments for heat availability • Sufficiently long annual running time of the plants • Positive effect on the utilization rate or production (input-output) ratio of the base-load heat production plants • Opportunity for storage of produced energy (thermal battery) • Potential to produce combined district heating and cooling • Low electricity price • Fluctuating demand for heat (accentuating the potential of the heat pump to improve the profitability of other power plants / hedge the margin of the entire district heating system) • Opportunity to participate in secondary power markets • Low power transmission costs • High consumer price of district heating/cooling

Source: VALOR-analysis, expert interviews

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