NUCLEAR DISTRICT HEATING IN FINLAND

The Demand, Supply and Emissions Reduction Potential of Heating Finland with Small Nuclear Reactors

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THINK ATOM
Non-profit think tank

In a nutshell: How we can use small nuclear reactors to decarbonize our energy sector, especially outside electricity production.

Today we publish our first study, funded by Ympäristöpooli:
Why heat?

Half of global energy end-use is heat.
Mostly done with combustion.
Study structure

- District heating networks
- SMRs
- Modelling
- Emissions reduction potential
- Business cases and – models
- Licencing, regulation, public discussion...
DISTRICT HEATING SYSTEMS IN FINLAND

- Total demand 35+ TWh / year
- 40 largest use 80 % of energy
- 10 largest use 60 % of energy
- Four largest use 40 % of energy
- One largest use 20 % of energy

Distribution of Finnish DH networks by annual demand

District Heat Energy Sources in Finland - 2017

- Coal 23%
- Natural Gas 10%
- Peat 14%
- Wood fuels 18%
- Forest industry waste 12%
- Waste heat 9%
- Other biomass 6%
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District Heat Energy Sources in Finland - 2017

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- Natural Gas: 10%
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- Wood fuels: 18%
- Waste heat: 9%
- Forest industry waste fuels: 12%
- Other biomass: 6%
- Others: 6%
- Oil: 2%
- Peat: 14%
Small Nuclear Reactors

- Heat Only (24 – 400 MWt)
  - DHR-400, HAPPY, NHR200-II (China)
  - SECURE 200/400 MWt
  - “Finreactor” microreactor (24 MWt)

- Light Water / CHP (150 – 900 MWt)
  - NuScale (US, 200-2400 MWt)
  - SMART (S-Korea)
  - KLT-40S / RITM200 (Russia, 150-200 MWt)
  - BWRX-300 (GE Hitachi)

- Advanced / non-water
  - HTR-PM (China – pebblebed/gas)
  - IMSR (Canada – Molten Salt)
  - SEALER (Sweden - Lead)
  - PRISM/ARC100 (GE Hitachi - Metal)
Modelling

- District heating network sizes chosen:
  - 200, 500, 1500, 2400 and 7000 GWh/year
  - Poland cases: 2,500 and 14,000 GWh/year
- Reactor sizes chosen:
  - Heat only: 24, 200, 400 and 900 MWt
  - CHP: 200 MWt and 900 MWt
- Modelling done using:
  - Heat only production (most cases)
  - CHP (some examples)
  - District cooling potential (some examples)
Finland has some 20 DH systems between 150-350 GWhs.
Finland has a dozen DH systems between 350-750 GWh
Finland has five DH systems around 1,500 GWh
Finland has five DH systems around 1,500 GWh
Finland has three DH systems around 2,400 GWh.
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Three 200 MWt CHP reactors in a 2.4 TWh DH network

- Share of annual heat: 99%

- DH demand MW
- Heat production
- Electricity production
Finland has one DH system around 7,000 GWh
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Poland has around six systems with 2-3 TWh demand.
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Warsaw is projected to use ~14 TWh by 2040
Heat-only reactors can produce 60-70% of energy demand while running at high load factors of 80-90%.

CHP brings even more flexibility.

District cooling is also an option to increase the load-factor of heat only or CHP reactors.
Study used three values for emissions in DH:
- Current Average: $140 \text{ gCO}_2/\text{kWh}$
- Mix of natural gas, coal and peat that could be replaced at the margin: $250 \text{ gCO}_2/\text{kWh}$
- A mix of forest industry residues and side-products in cubic meters, averaging at 1 MWh / m$^3$
- For Poland, it assumed coal at $350 \text{ gCO}_2/\text{kWh}$
- ETS prices were at 20 and 50 € per ton.
Replacing average 140 gCO2/kWh, nuclear would save:
- 2.8 €/MWh at cost of 20 € / ton of CO2
- 7 €/MWh at cost of 50 € / ton of CO2

Replacing mix of gas, coal and peat at 250 gCO2/kWh, nuclear would save:
- 5 €/MWh at cost 20 € / ton of CO2
- 12.5 €/MWh at 50 € / ton of CO2

In Poland at 350 gCO2/kWh, nuclear would save:
- 7 €/MWh at cost of 20 € / ton of CO2
- 17.5 €/MWh at cost of 50 € / ton of CO2
<table>
<thead>
<tr>
<th></th>
<th>Saved $CO_2$ (first two rows) or forest residue (bottom row)</th>
<th>Saved euros in ETS (millions/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total heat produced: 10 TWh</td>
<td>0.84 Mton $CO_2$</td>
<td>at 20 €/ton $CO_2$ 42</td>
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<tr>
<td>Nuclear heat produced: 6 TWh</td>
<td>1.5 Mton $CO_2$</td>
<td>at 50 €/ton $CO_2$ 75</td>
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<tr>
<td>CO$_2$ saved at 140 gCO$_2$/kWh</td>
<td>6 Mm$^3$</td>
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<tr>
<td>CO$_2$ saved at 250 gCO$_2$/kWh</td>
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### MEDIUM AND LARGE NETWORKS – EMISSIONS SAVINGS

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<th>Total heat produced: 7 TWh</th>
<th>Saved CO₂ (first two rows) or forest residue (bottom row)</th>
<th>Saved euros in ETS (millions/year)</th>
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<tbody>
<tr>
<td>Nuclear heat produced: 5 TWh</td>
<td>0.7 Mton CO₂</td>
<td>at 20 €/ton</td>
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<td>CO₂ saved at 140 gCO₂/kWh</td>
<td>1.25 Mton CO₂</td>
<td>at 50 €/ton</td>
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<tr>
<td>Forest residue saved (Mm³)</td>
<td>5 Mm³</td>
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- Five 1.5 TWh systems: 7 TWh
- Three 2.4 TWh systems: 7 TWh
- Helsinki: 7 TWh
<table>
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<tr>
<th>CO2 saved at 140 gCO2/kWh</th>
<th>Saved CO2 (first two rows) or forest residue (bottom row)</th>
<th>Saved euros in ETS (millions/year)</th>
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</thead>
<tbody>
<tr>
<td>CO2 saved at 250 gCO2/kWh</td>
<td>2.1 Mton CO2</td>
<td>42.0</td>
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<tr>
<td>Forest residue saved (Mm^3)</td>
<td>3.75 Mton CO2</td>
<td>75.0</td>
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<tr>
<td></td>
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<td>15 Mm^3</td>
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POSSIBLE ROADMAP - BAU

Roadmap for nuclear decarbonization of district heating in 20 years Capacity in MWt

- 2019: Prep. legislation
- 2020: 1st DiP
- 2021: 1st site & CL
- 2022: Construction & commissioning & OL
Finnish (and European) legislation and regulation needs substantial changes to make SMRs more feasible. As does using nuclear in novel ways, such as for district or industrial heat.

Chicken and egg problem:

- Preparing these changes needs someone with a project.
- Starting a project requires legislation and regulation to be in place and favourable to control the risks.
CONCLUSIONS AND KEY FINDINGS

Many suitable reactors are becoming available already in the 2020s.

Bottlenecks are in legislation, regulation and politics.

There is room for 2+ GWt nuclear capacity.

Nuclear heat levelized cost is around 15-30 €/MWh.

Heat-only SMRs could displace practically all fossil fuels in DH while likely lowering costs for heat production.

CHP adds to flexibility and allows for more fuels to be displaced, saving biomass for more valuable uses and improving domestic power grid capacity situation.
THANK YOU.
AND THANKS FOR FINNISH ENERGY YMPÄRISTÖPOOLI FOR FUNDING THE STUDY.

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think deep decarbonization