Design requirements for a Finnish district heating reactor considering domestic deployment and export potential

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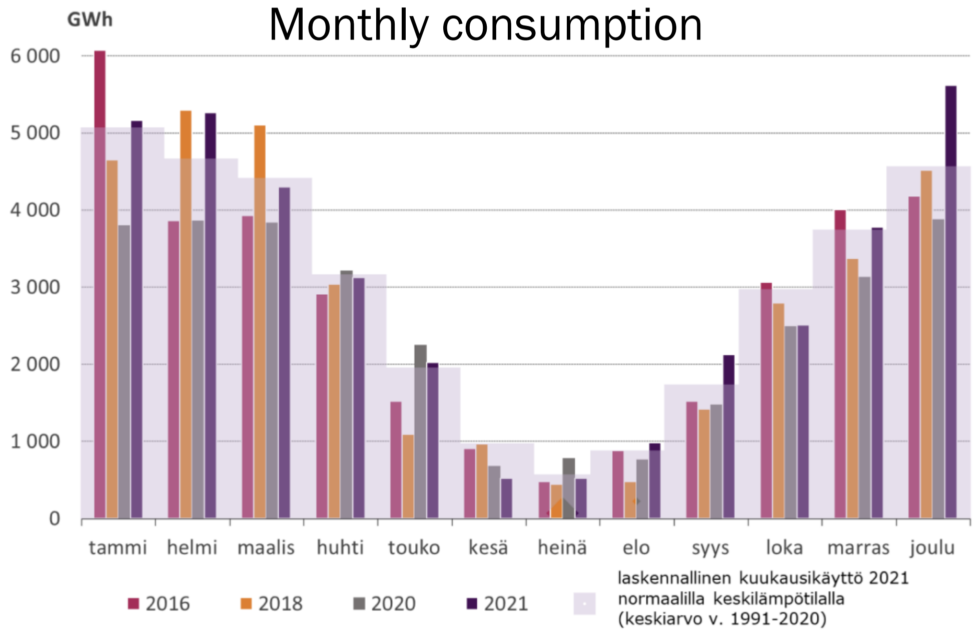
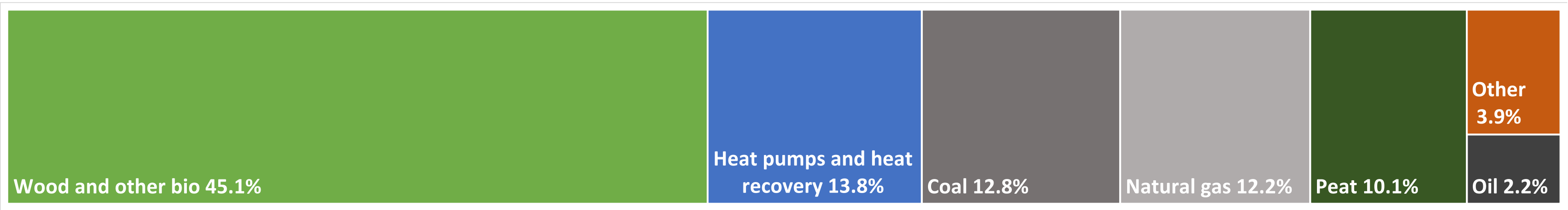
District heating (DH) in Finland

Production	35.1 TWh
Produced in CHP plants	55 %
Distribution network	16 090 km
Network heat losses	5..15 % (avg ~8.6 %)
Supply temperature	65...115 °C
Heating degree days	5367

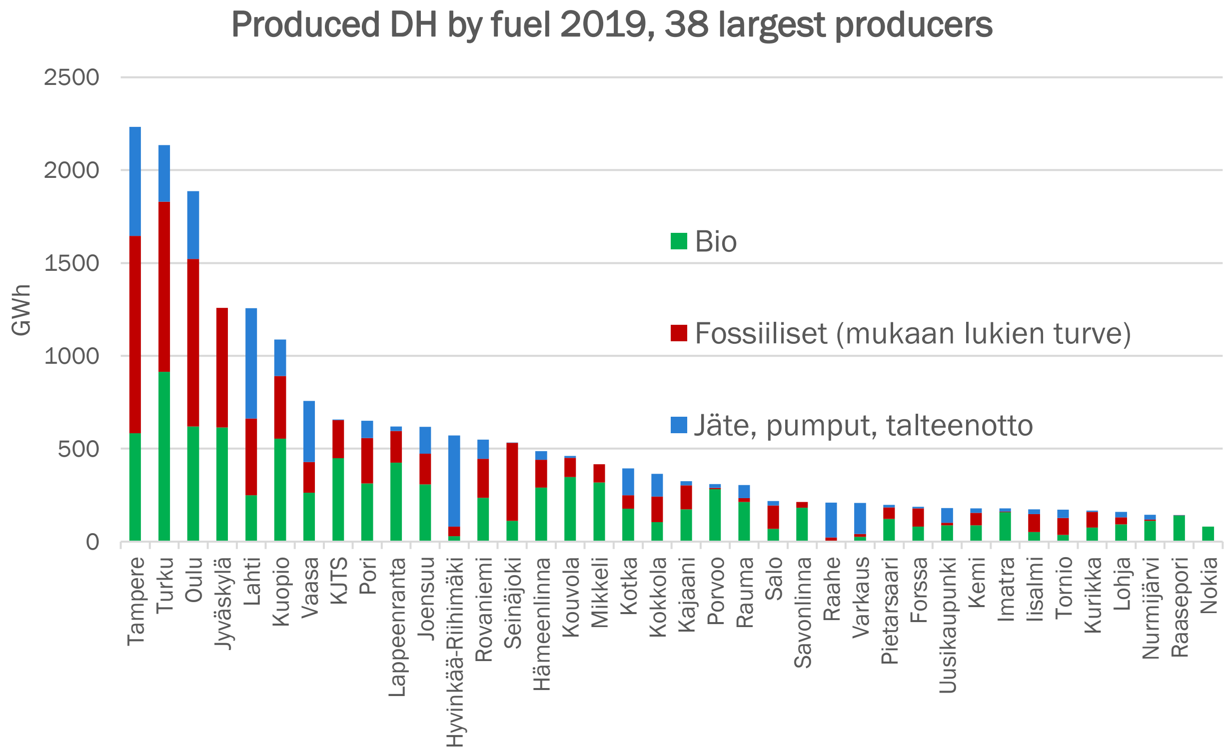


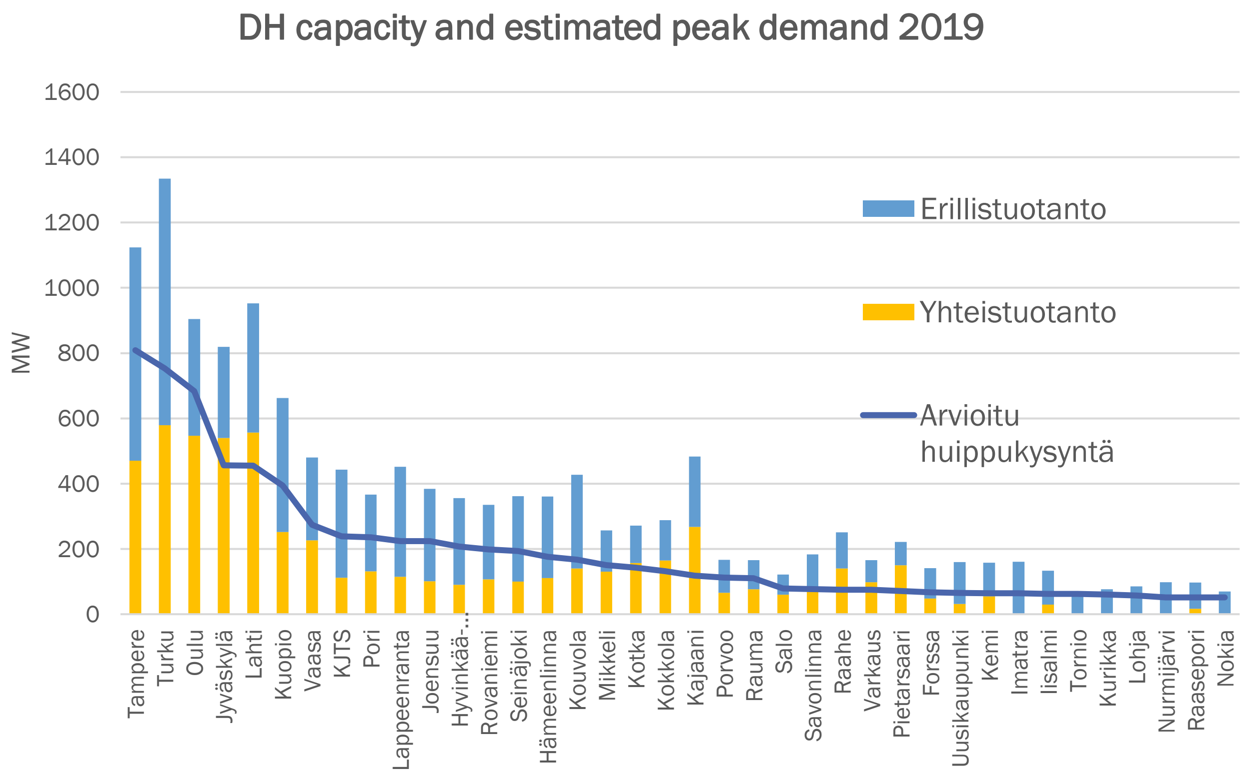
DH production profile



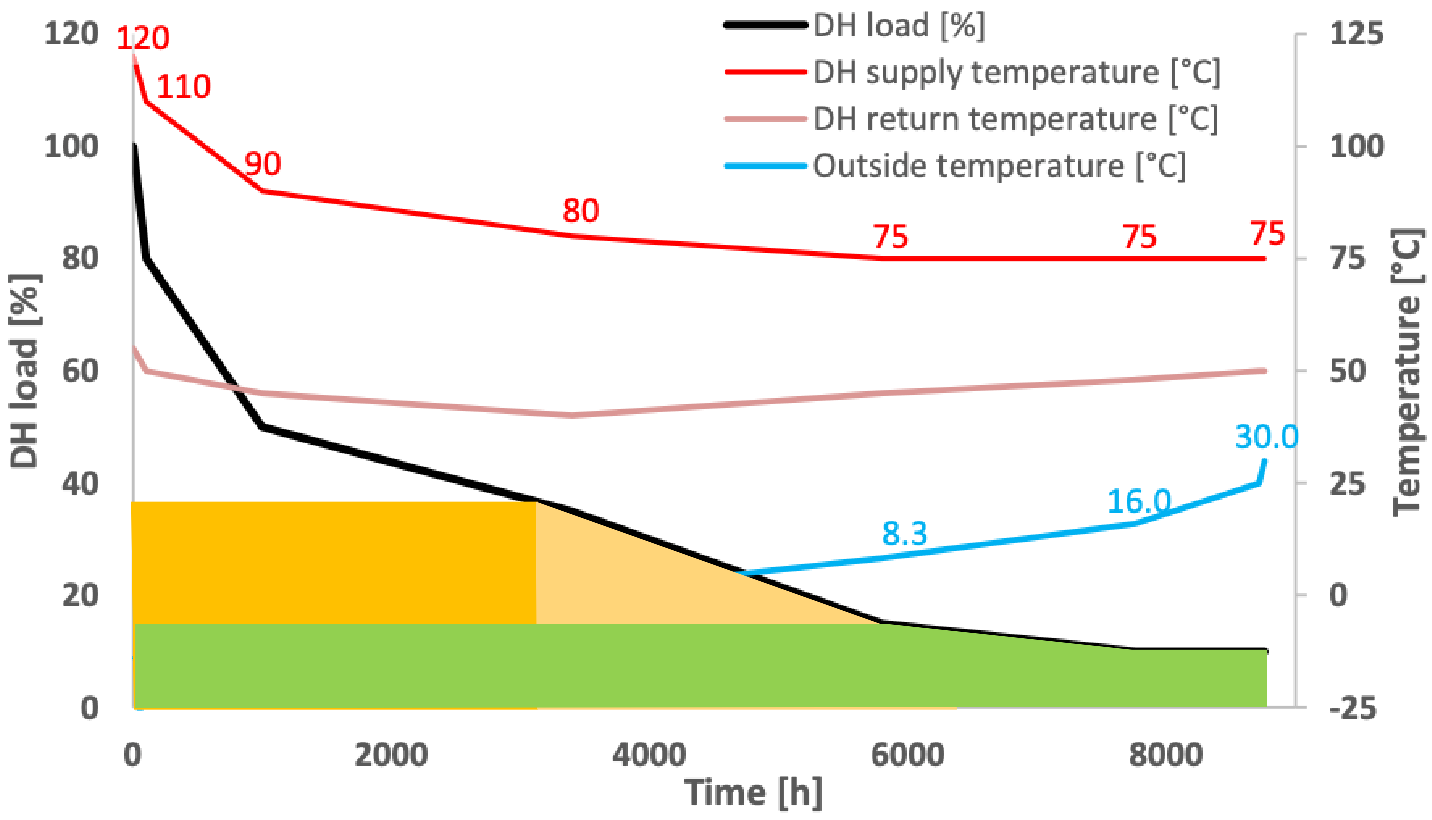
Regional DH statistics in Finland

Capital region	Tot. production	Fossil/bio/other (%)	Tot. capacity	CHP %	Peak demand
	11200 GWh	77.5 / 5 / 17.5	6100 MW	36.9	4050 MW





DH reactor potential in Finnish networks



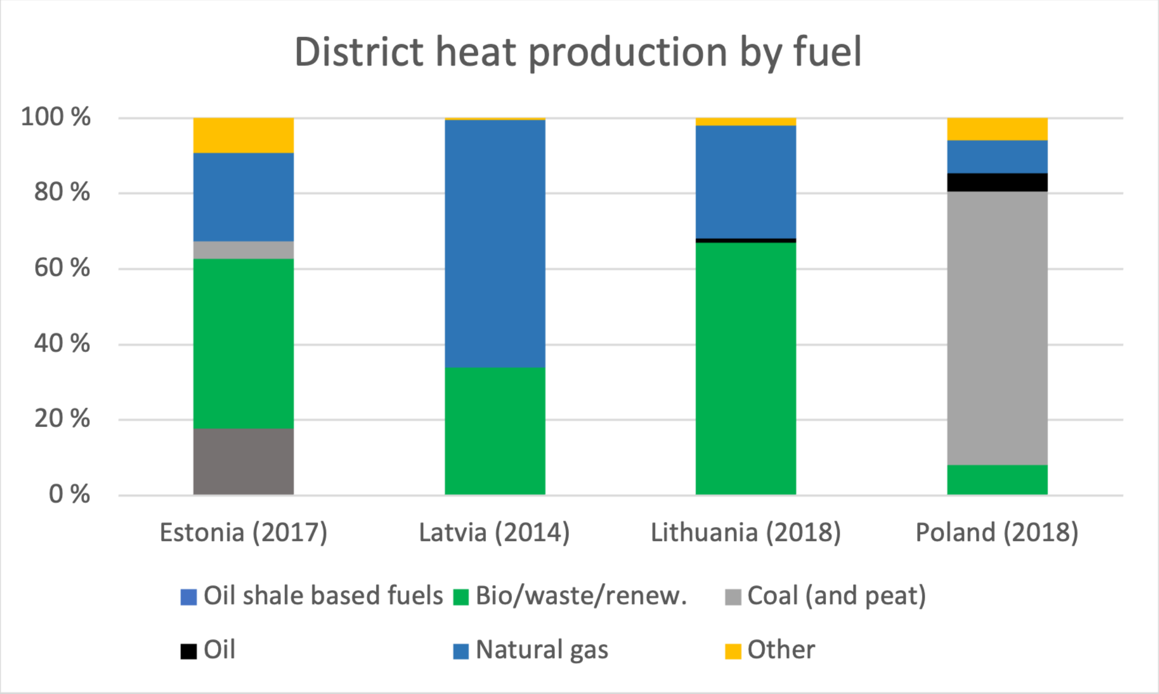
Theoretical number of small DH reactors that could be accommodated considering replacing fossil and bio-based fuels.

Area	Number of 24 MWth reactors
Capital region	46
Tampere	7
Turku	8
Oulu	7
Jyväskylä	6
Lahti	3
Kuopio	3
Vaasa	1
KJTS	3
Pori	2
Lappeenranta	2
Joensuu	1
Rovaniemi	2
Seinäjoki	2
Hämeenlinna	1
Kouvola	1
Mikkeli	1
Porvoo	1
Rauma	1
Total	**98**

DH in Baltic countries and Poland

- Estonia, Latvia, Lithuania and Poland were analysed for export potential of the Finnish DH reactor.

District heat	EST	LVA	LTU	POL
Production (TWh)	4.5 (2017)	7.51 (2020)	8.98 (2018)	74.2 (2018)
Network length (km)	1 455	2 000	2 885	20 139
CHP share	50% (2017)	71% (2018)	41% (2018)	66 % (2018)
Grid heat loss avg.	21 %	11.8 %	15,3 %	11.8 %
Heating degree days	4 176	3 806	3 807	3172



DH in Baltic countries and Poland

- Potential regions in EST, LVA and LTU correspond to larger or medium sized Finnish cities in DH consumption, Poland is on another scale as the 2nd largest DH producer in the EU.

Estonia (rough estimation)

Region	DH cons. (GWh)	Pop.
Harju	1 664	605 029
… Tallinn	1 186	
Ida-Viru	538	134 259
Tartu	373	153 317

Latvia

Region	DH cons. (GWh)	Pop.
Riga	2 313	632 614
Latgale	521	260 226
Pierīga	480	370 589

Lithuania (very rough estimation)

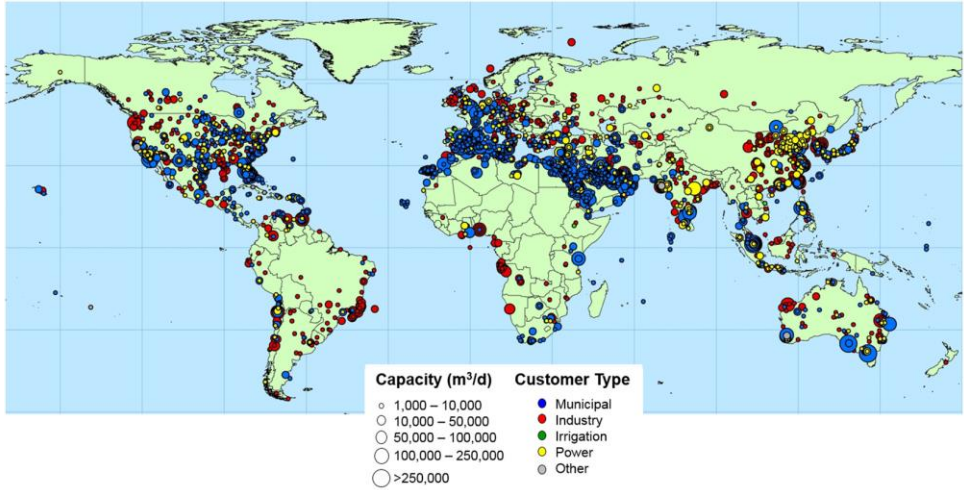
Region	DH cons. (GWh)	Pop.
Vilnus	1 438	820 000
Kaunas	985	562 000
Klaipėda	559	319 000

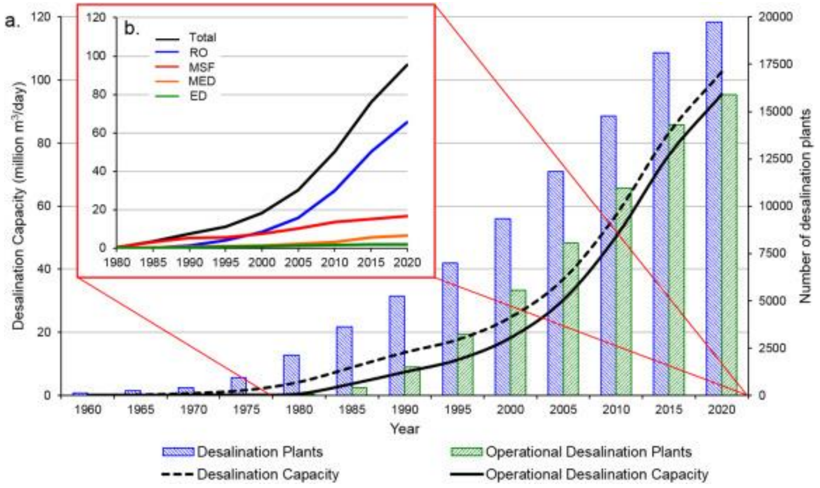
Poland

Region	DH cons. (GWh)	Pop.
Mazowieckie	13 268	5 425 000
Śląskie	9 310	4 492 300
Dolnośląskie	4 945	2 891 400
Łódzkie	4 917	2 438 000
Wielkopolskie	4 832	3 496 500
Pomorskie	4207	2 346 700
Małopolskie	4086	3 410 400
…	…	…

Alternative use case in desalination

- In addition to DH, desalination seems as a potential application for low temperature LWR.
- Huge need for desalination in some parts of the world, e.g., Middle East and North Africa have almost 50 % of the current production capacity.
- Highly energy intensive and majority of desalination plants use fossil fuel based energy.





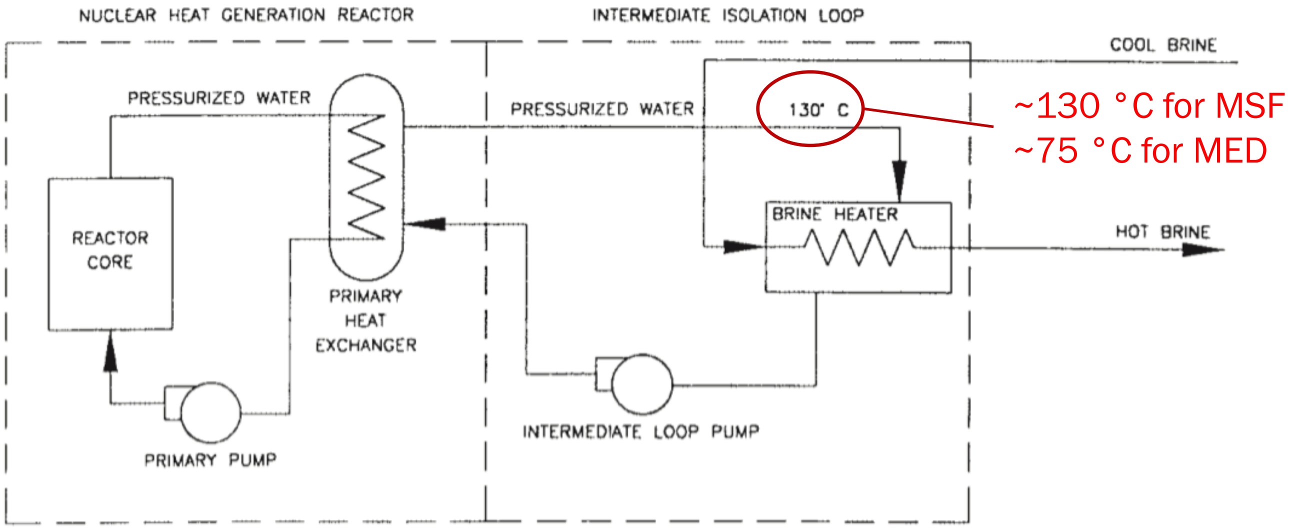
EcoSMR

Alternative use case in desalination

- Desalination can use heat and/or electricity as various techniques exist. Multi-stage flash (MSF) and multiple effect distillation (MED) take heat at 70-130 °C. Membrane processes like reverse osmosis (RO) utilize electricity.

Energy consumptions of different desalination processes (Data: Ghaffour et al. 2013. Desalination 309, p. 197-207

	Thermal energy (kWh/m³)	Electrical energy (kWh/m³)	Typical brine feed *T* (°C)
MSF	7.5…12	2.5…4	90…120
MED	4…7	1.5…2	60…75
RO	-	0.5..4	ambient

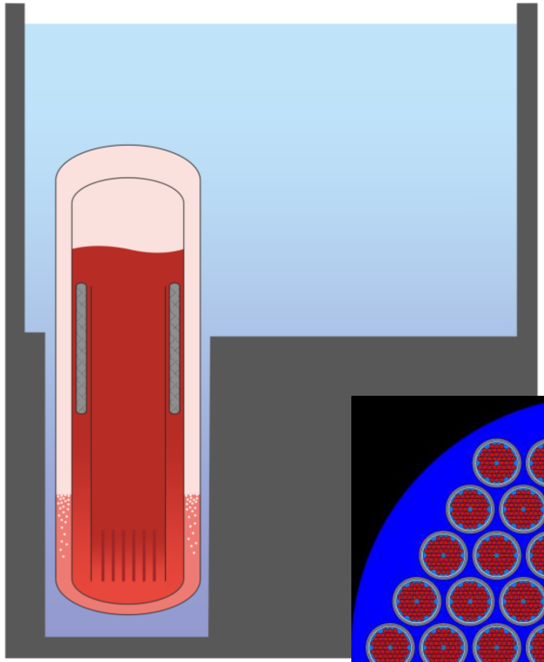


Coupling a nuclear heat plant with MSF or MED desalination facility (Figure: IAEA)

Eco SMR

Domestic design

- Two Finnish reactor concepts already proposed with some novel design solutions
- Existing domestic computational tools, experimental capabilities and expertise for reactor design and demonstration of the functioning of systems and components
- Major components such as pressure vessels and heat exchangers of moderate size and for the modest operating pressures and temperatures could well be manufactured in Finland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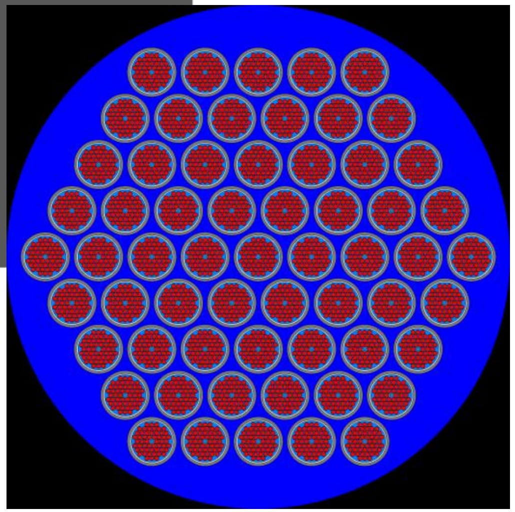
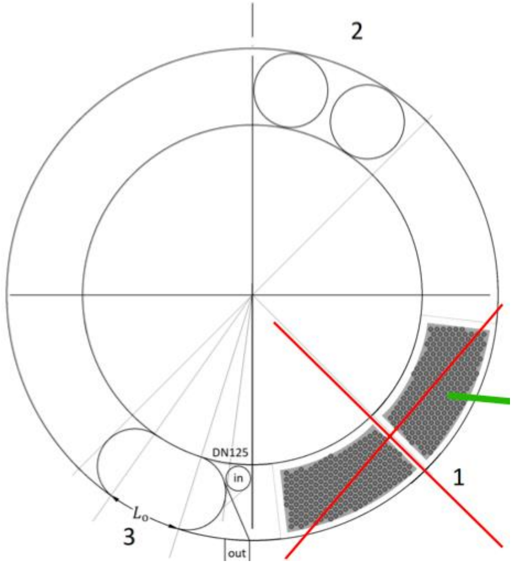
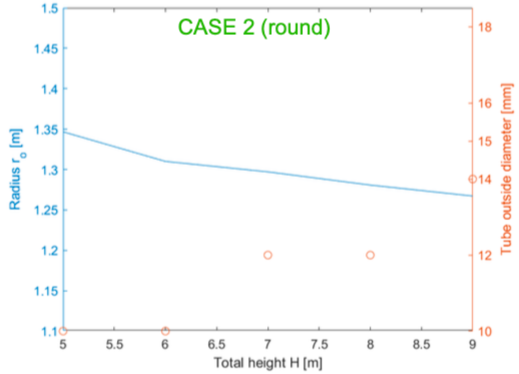


Pre-design of a heat exchanger for a small DH reactor

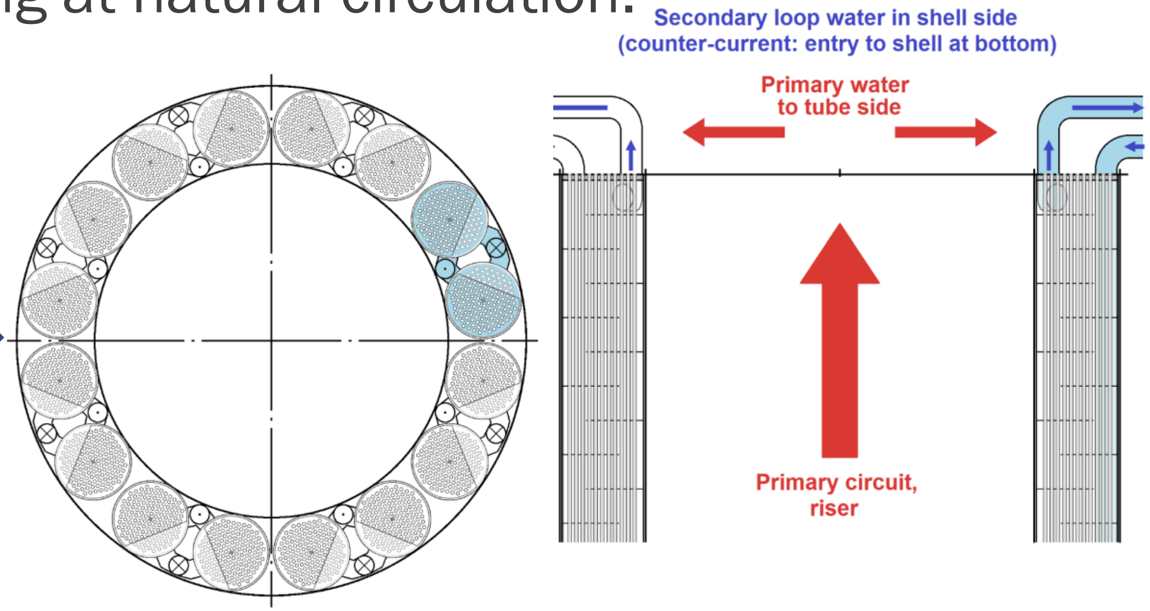
- Already some design optimization performed for a shell and tube heat exchanger for a small DH reactor operating at natural circulation.



Selection of optimal heat exchanger type and configuration



Optimizing dimensions



Design proposal

Conclusions

- Finnish DH networks could accommodate tens of small reactors replacing fossil and bio-based fuels.
- A few small DH reactors could likely be exported to the Baltics (capital regions) while Poland represents a significant potential market considering its current DH capacity and production profile.
- Coupling with MSF or MED desalination processes seem as a promising alternative use case with significant export potential.
- Good domestic capabilities to design, manufacture and test components and systems for Finnish DH reactor; most straightforward and cost effective when components represent standard equipment.
- A DH reactor fit for Finnish DH networks should have a size in few tens of MW_{th} considering deployment also outside capital region. It would preferably be capable of operating at part load and need to be cost competitive with ~9 month annual use.