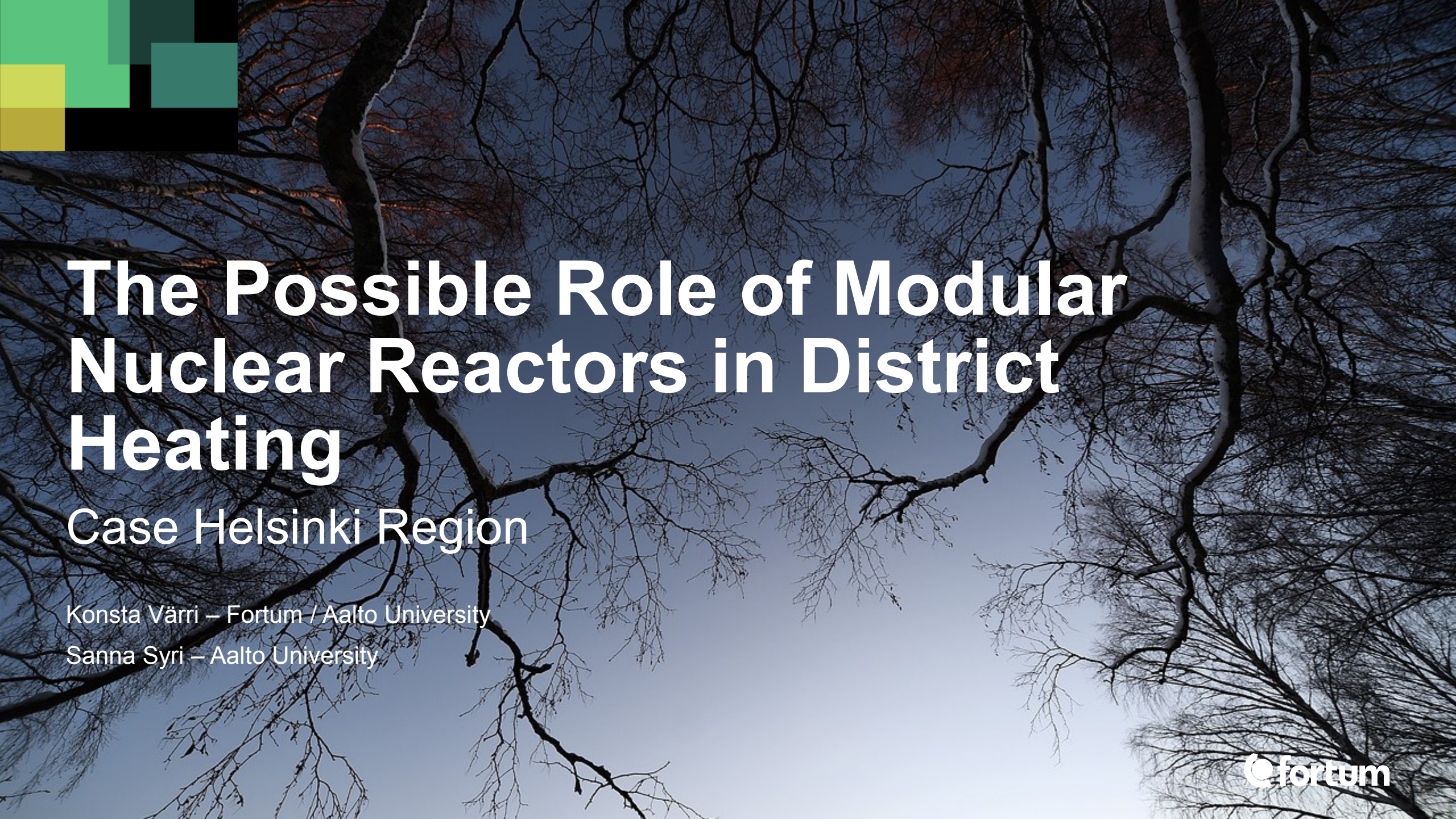

The Possible Role of Modular Nuclear Reactors in District Heating

Case Helsinki Region

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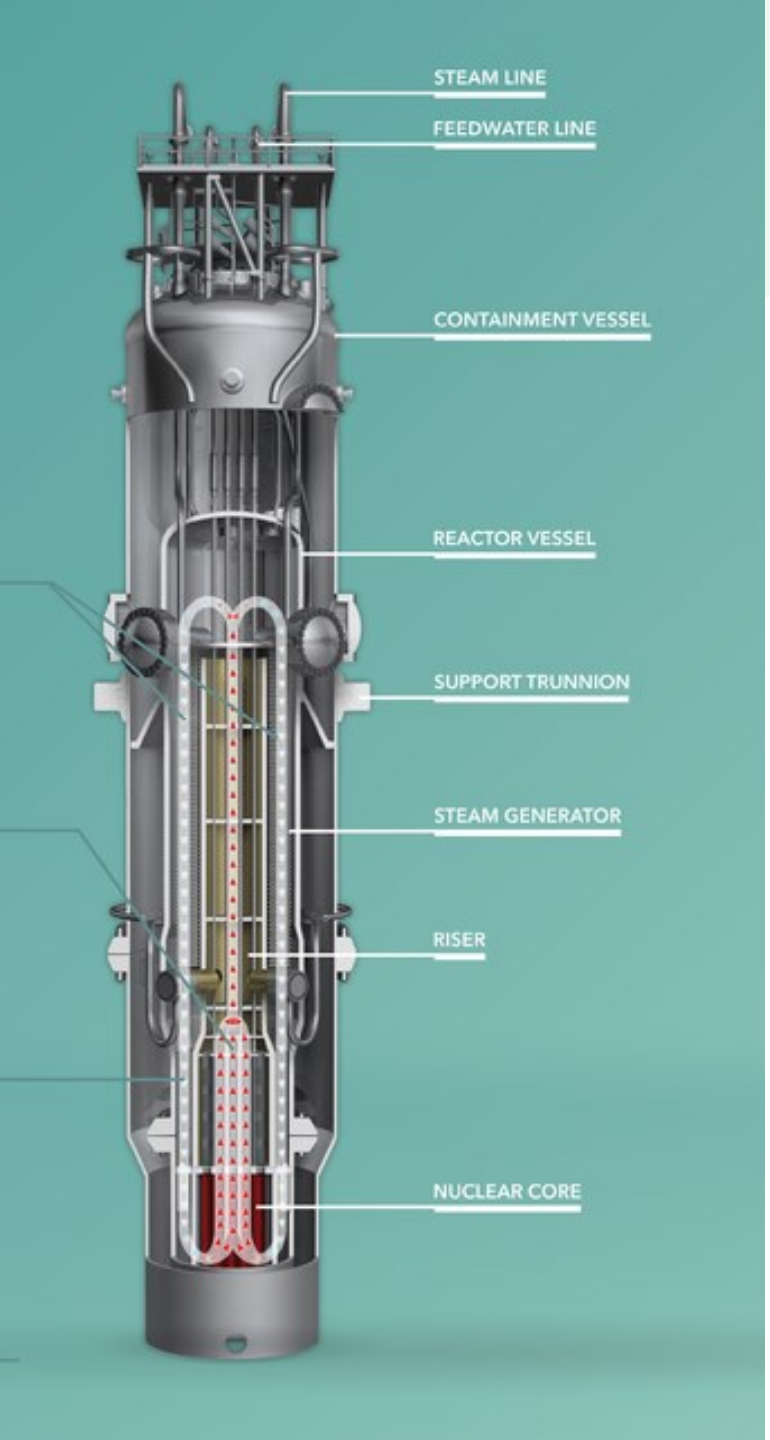
Content

Introduction

- Finland has an ambitious set of government level climate goals further fortified by those of individual cities
  - Coal ban in 2029
  - Carbon neutral 2035
- District heating is still heavily reliant on fossil fuels and peat
- Especially in the Helsinki Metropolitan area the fossil fuels will most likely be replaced with biomass
  - Potential competitors and replacements for biomass include deep geothermal, data center waste heat and now, SMRs
- Motions put forward in multiple municipalities and city councils to evaluate the potential of SMRs for DH
- **Under what assumptions would SMRs be a valid choice for heat production?**



SMR District Heating

Why SMRs

- SMRs would be able to provide stable CO_2 free energy at a scale smaller than traditional NPPs
- Safety through eg. passive systems and potential for smaller EPZs – deployable closer to cities
- Modular factory based manufacturing
  - Potential for reduced costs through larger volumes and learning
  - Higher quality fabrication
- Questions left outside of the study
  - Licensing – legislation currently under revamp in Finland
  - EPZ size

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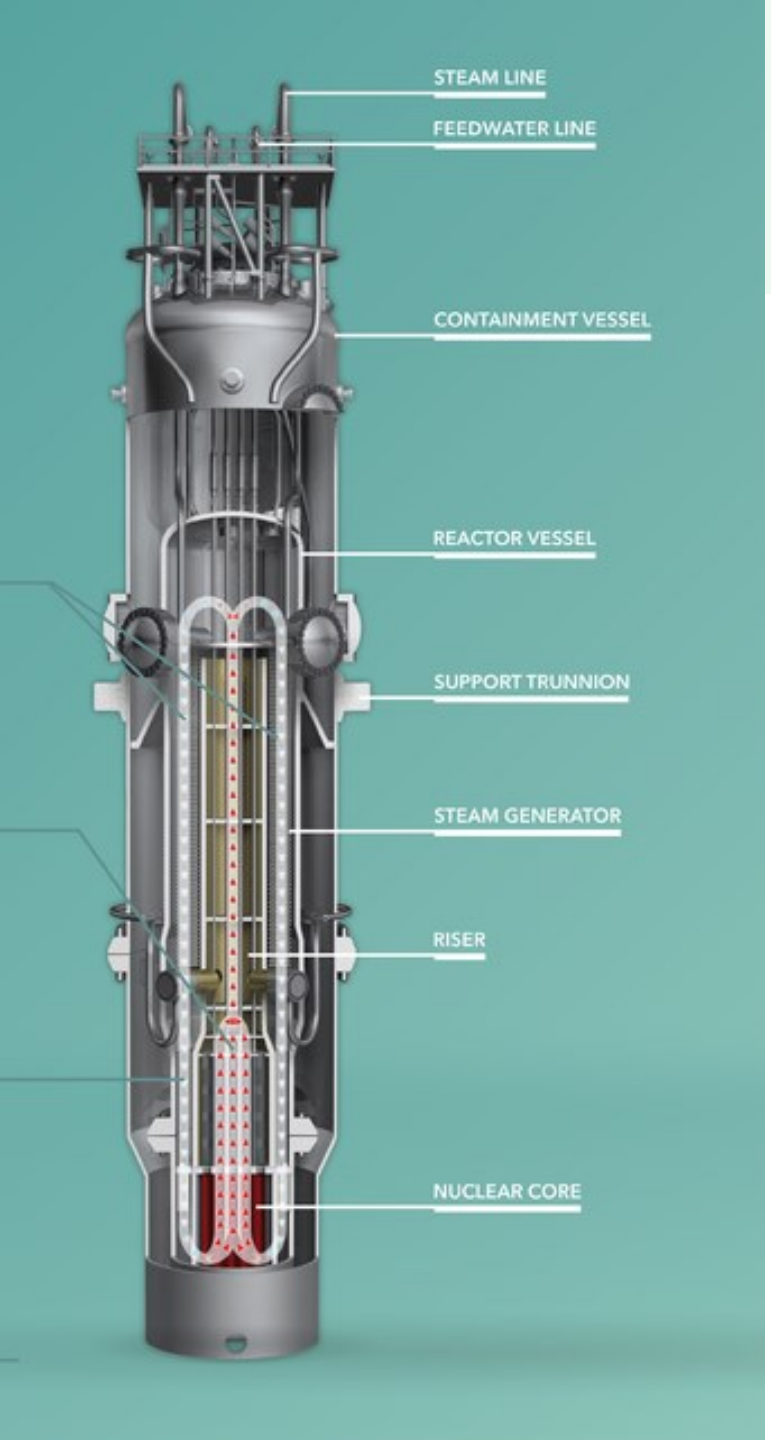

SMR District Heating

Design Used

- NuScale as a generic IPWR
  - Based on the older data of a 160 MWt / 50 Mwe module
  - Very preliminary data and presumptions especially regarding costs
  - Considered either as a HOB or a CHP plant
    - HOB 2 x 150 MW_{dh}
    - CHP 3 x (100 MW_{dh} + 30 MW_e)

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Materials and methods

Results primarily derived from running 2 separate models

Hourly heat demand and production

- Fulfills the yearly production based on heat demand, electricity price, available plant capacity and the variable costs of the plants
- Based only on the heat demand, CHP electricity is presumed to be sold at market price and the profit is subtracted from the production cost of heat
- Simplified but provides a reasonable basis for investment analysis

Investment model

- Based on the new build plants being completed in 2030
- New plants built primarily for heat production
- The potential CHP plant is considered as an incremental investment on top of the baseline HOB

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Helsinki Metropolitan Area District Heating in 2030

- Hypothetical base concept of integrating the various DH networks in the greater metropolitan area
- Rough approximation based on the currently existing plant fleet and data from Nordic Energy Technology Perspectives 2016

Plant Type	Capacity (MW_{dh})
Gas HOB	2500
Gas CHP	1000
Pellet HOB	400
Woodchip CHP	500
Waste CHP	150
Electrical Boilers	50
Heat pumps	200

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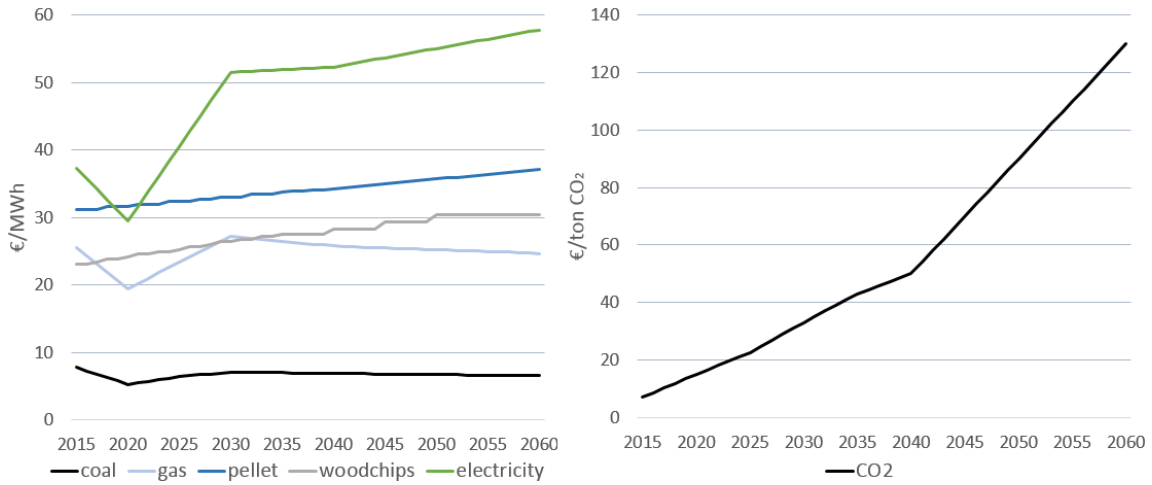
Energy System

Fuel Pricing, Taxes and Other Presumed base data



Realized heat price	**47.5 €/MWh**
Tax for gas CHP	**13.7 €/MWh**
Tax for gas HOB	**19.9 €/MWh**
Electricity tax + transmission costs (heat pumps)	**22.53 + 30 €/MWh**
UO2 fuel price	**2.05 €/MWh**
Municipal Solid Waste gate fee	**30 €/MWh**
Corporate tax rate	**20 %**

Energy System

Plant Data

HOB	MSW	Woodchip	Pellet	Natural Gas	NuScale SMR	Heat Pump	Electrical Boiler
heat capacity (MW_{dh})	300	300	300	300	300	20	20
efficiency$_{(dh)}$ (%)	97.6	108	108	104	93.8	380	99
lifetime (a)	20	20	20	25	60	25	25
capex (€/MW_{dh})	1 595 000	500 000	250 000	90 000	1 506 667	590 000	60 000
variable O&M (€/MWh_{dh})	5.4	1.851	2.7	1	1.26	1.7	0.5
fixed O&M (€/MW_{dh}/a)	53 000	11 600	0	1 900	30 000	2 000	1 020
CHP	**MSW**	**Woodchip**		**Natural Gas**	**NuScale SMR**	**Offshore wind**	**Onshore Wind**
heat capacity (MW_{dh})	300	300		300	300	0	0
power capacity (MW_e)	110	145		391	90	12	4
total efficiency (%)	97	95		90	81,3	100	100
lifetime (a)	20	30		25	60	30	30
capex (€/MW_e)	7 000 000	3 000 000		800 000	9 408 750	1 990 000	910 000
variable O&M (€/MW_e)	45,15	8,06		4,20	6,33	2,70	2,30
fixed O&M (€/MW_e/a)	0	45 556		27 800	150 000	37 800	22 300

Presumed WACC of 5% for HOBs, 6.5% for CHP and 8% for SMR

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Reliability of the Data

General

- Data sourced from multiple reports with often conflicting expectations
  - Reducing the CO_2 price to the level of EU's own scenario reduces the viability of the Nordic Energy Technology Perspectives 2016 data
- Plant data primarily from a single source
  - Required significant scaling and evaluation
  - References taken from plants both recently completed and currently under construction

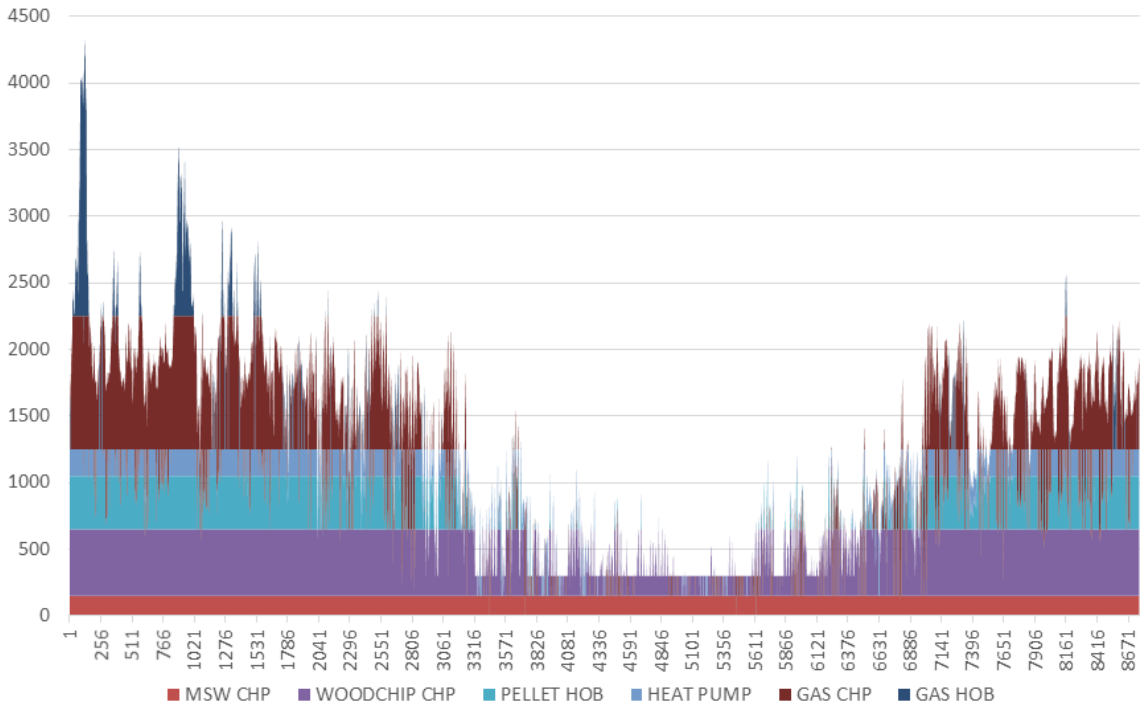
NuScale SMR

- Investment data based on a 12 module FOAK plant from the company itself
  - Single module assumed to be 1/12 of the full plant scaled up by 30%, some cost reductions for HOB
- Other data from multiple sources
  - Capital costs remain a significant question
  - Licensing costs ignored

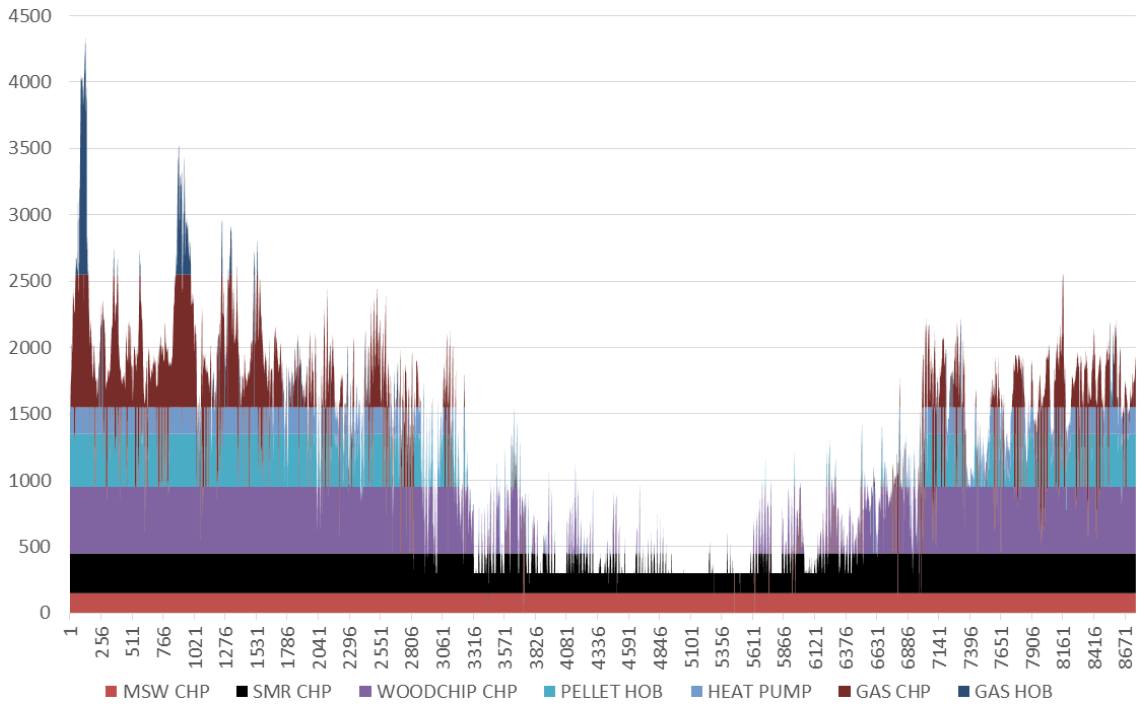
Results

Simulated DH production in 2030

Base case 2030



Addition of SMR HOB/CHP 2030



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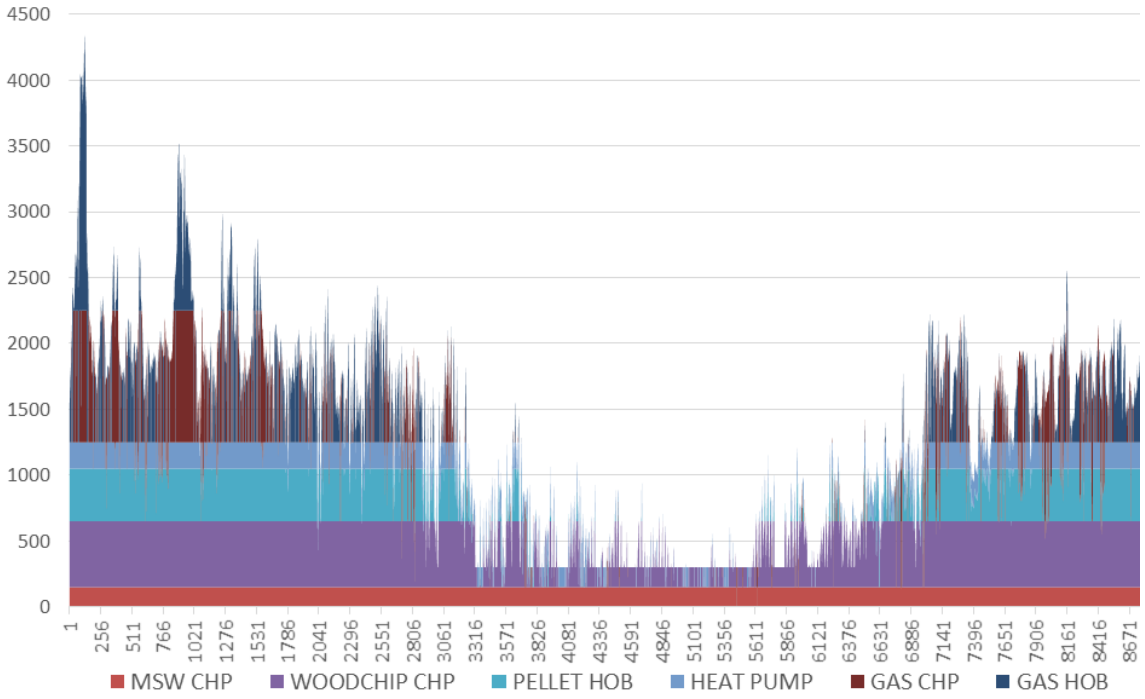
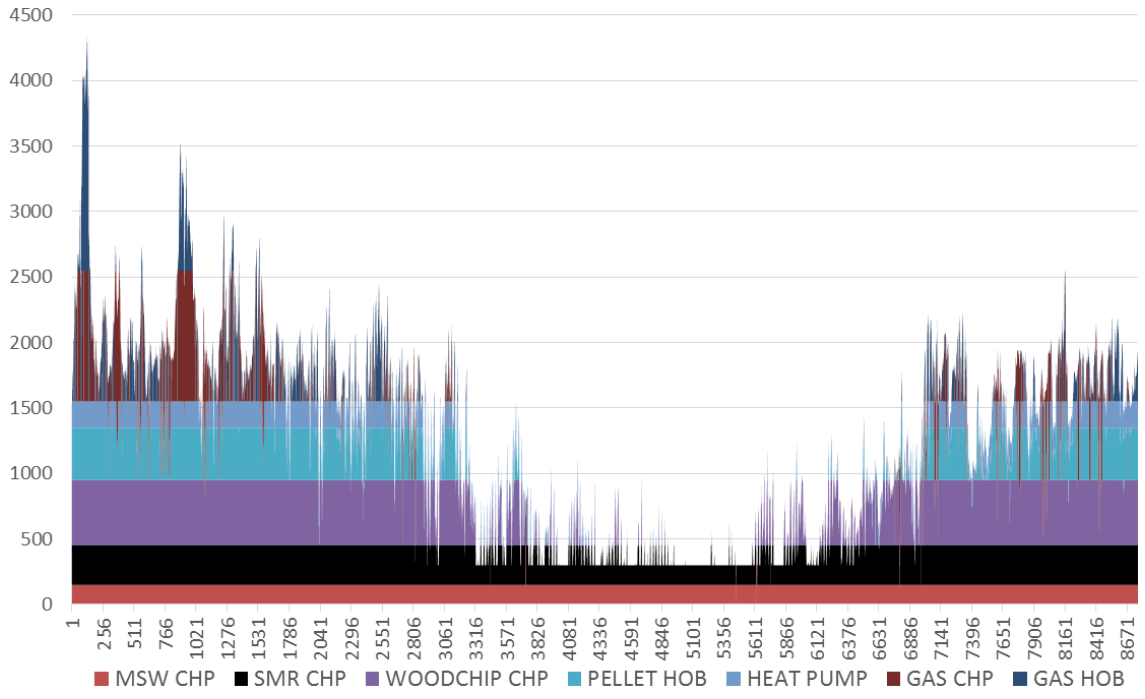
Results

Simulated DH production in 2050

Base case 2050



Addition of SMR HOB/CHP 2050



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Evaluation of Full Load Hours (FLH)

Limits of the model

- No start-up costs
- No maintenance breaks
- The plants that would form the baseline of the production if invested in are presumed to reach at least 8000 hours
- Others evaluated through the development of FLH counts over the period of 20 years
- Wind power FLH counts from the Nordic Energy Technology Perspectives 2016 report

Plant type	FLH count
Waste CHP	8000
Woodchip CHP	8000
Pellet HOB	4700
Gas HOB	1000
Gas CHP	3500
SMR CHP/HOB	8000
Heat pump	5200

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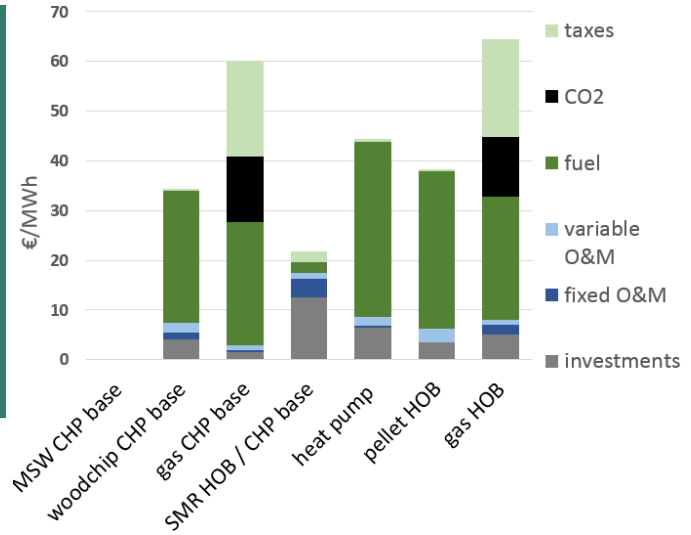
Results

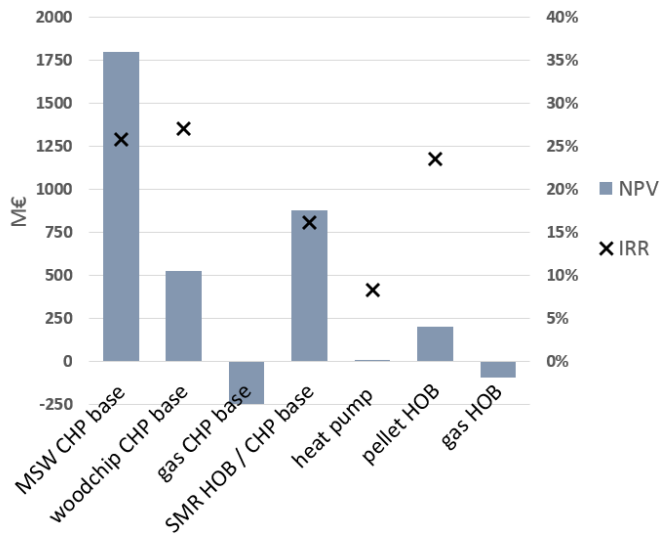
HOB and CHP investment – LCOH, NPV and IRR

- The results should primarily be evaluated as very preliminary and guiding
  - HOB values are most likely inflated
  - Uncertainty of the data
  - Considerations regarding the sustainability and logistics of fuel
  - The MSW CHP can, for example, be seen printing money, but the plant is oversized and fuel sourcing would be a significant challenge
- Below are the realized IRRs for the CHP-options if taken as a whole

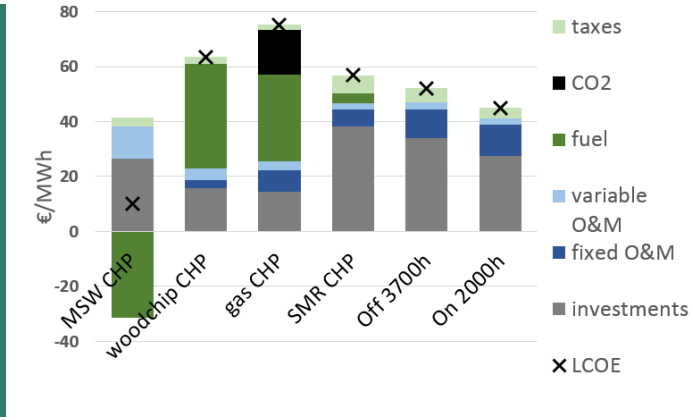
	MSW	Woodchip	Gas	SMR
IRR (%)	21,97	11,59	-	11,93

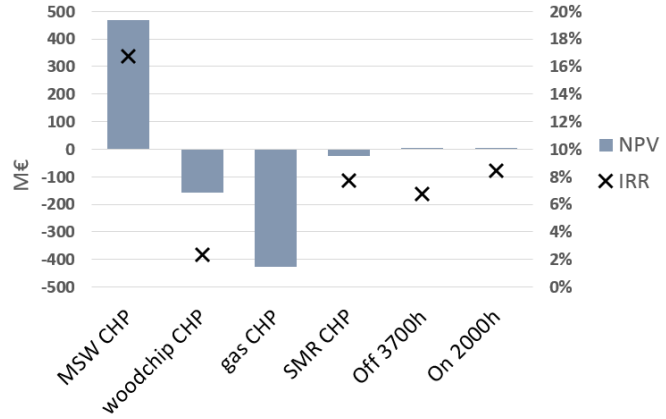
HOB





CHP

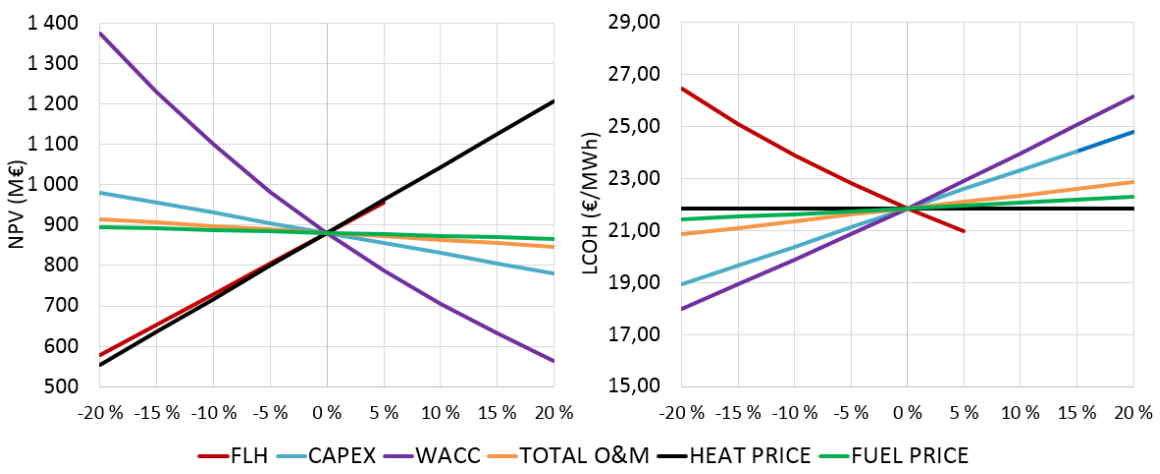




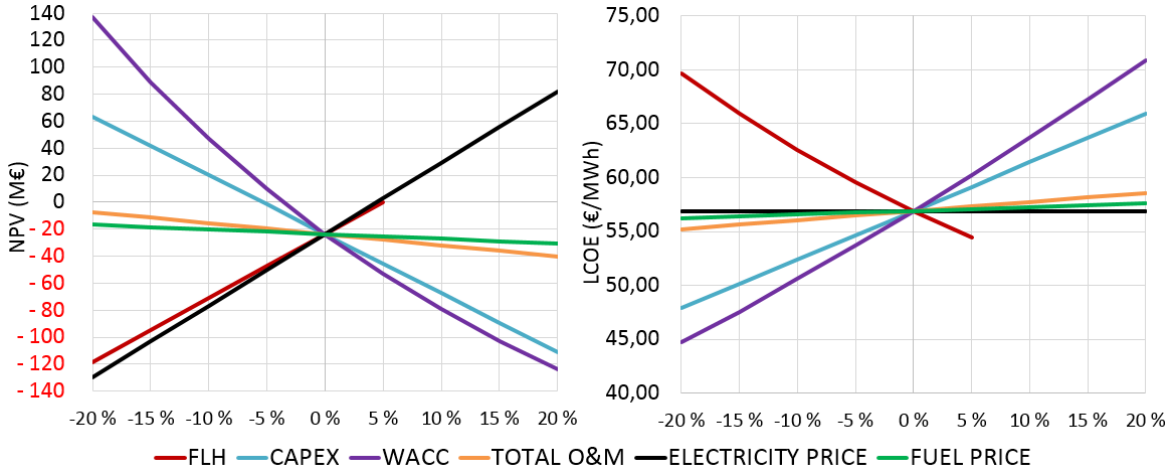
Results

Sensitivity analysis of the SMR

HOB



CHP



- Focus primarily on the WACC
  - Profitability of the investment is also vulnerable to CAPEX, the achieved full load hours and the realized heat price

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Conclusions

SMR HOBs can be deemed promising

- SMR technology itself seems suitable for DH production
- SMR HOB would be the second best choice for sustainable baseload heat production after MSW CHP if viewed purely as investment
- Profitability of the SMR CHP is more questionable
  - Depends highly on the development of electricity markets, the effects of the increased share of intermittent generation and the tools chosen for balancing the system.

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Next Steps

- The data is still uncertain and these preliminary conclusions should only be considered as an rough outline.
- Further research is key
  - Taking into account more diverse SMR-types, especially heat only plants
  - Many others have also done good work along these lines
    - In Finland for example, especially VTT
- SMR still need to be taken into account in legislation both on national and international level so that they could be given an opportunity
  - Co-operation between regulators, utilities and vendors should be encouraged
  - The Finnish legislation update and projects like ELSMOR seem like promising starts

Thank you

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