

Flexible nuclear co-generation as a heat supply for district heating

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Starting point

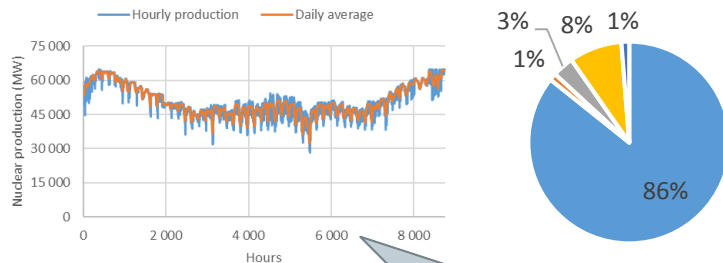
- Presented work is based on visiting researcher period related cooperation agreement between VTT Technical Research Centre of Finland and The French Alternative Energies and Atomic Energy Commission CEA
- Chosen topic of research combined VTT's expertise on **district heating** and **energy systems** with French interest on **nuclear co-generation**, **impact of increasing share of renewables** and need for **emission reductions** within the heating sector

Background

French energy system context

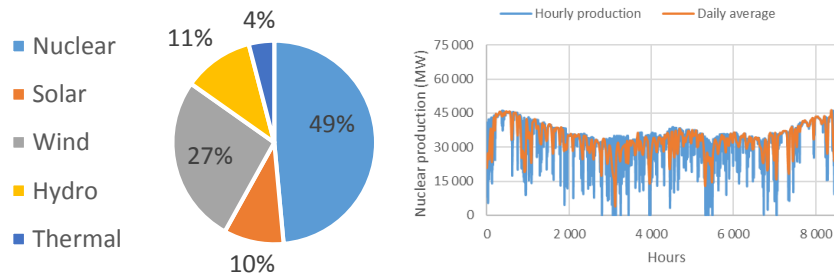
- France has ambitious goals for increasing wind, solar production
- Nuclear power not an ideal match; can cope with up to 30 % wind, solar

Year 2014: 540 TWh



Residual demand, i.e. what is left for nuclear to produce.

Scenario Ampère 2035*: 606 TWh

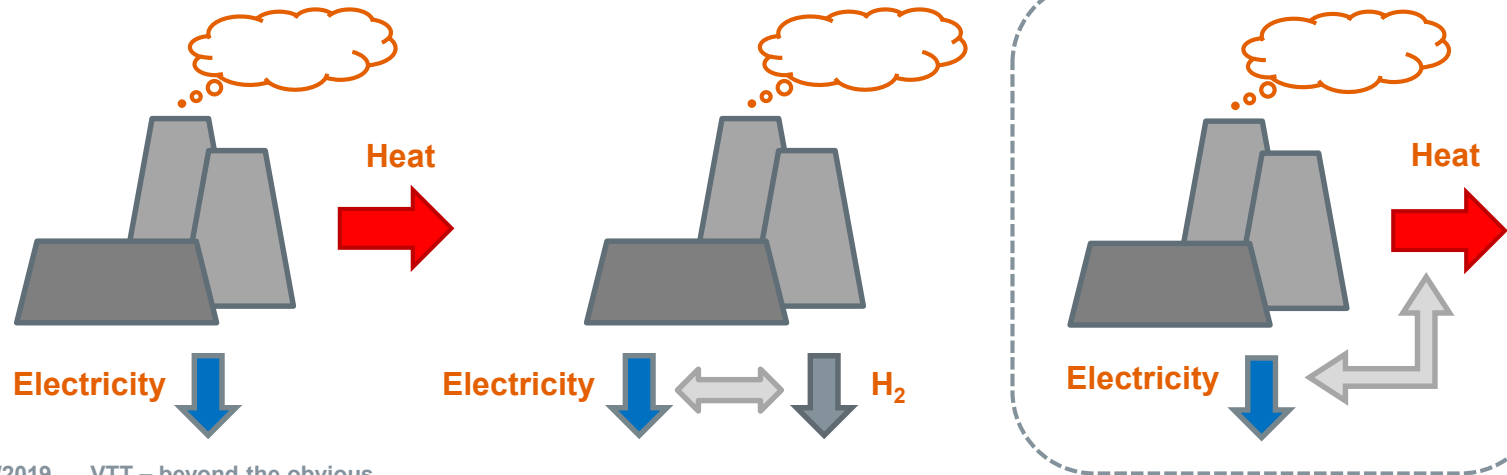


*) Réseau de Transport d'Électricité (RTE)

https://www.rte-france.com/sites/default/files/bp2017_chapitre_06.pdf

What could be done in nuclear sector?

- Nuclear plant economy improves if excess heat can be utilised (district heating, industrial loads)
- Nuclear plant could produce H_2 with electrolysis if no electricity is needed
- Flexible utilisation by redirecting steam between heat and electricity production



Previous work

Dr. Camille Cany

- *“Interactions between nuclear and variable renewable energies in the French energy transition: adopting the power mix towards more flexibility” (PhD thesis)*
 - Nuclear fleet can cope up to 30 % VRE based electricity production in power mix
 - Declining economic performance
 - Co-production of electrical and hydrogen and heat production

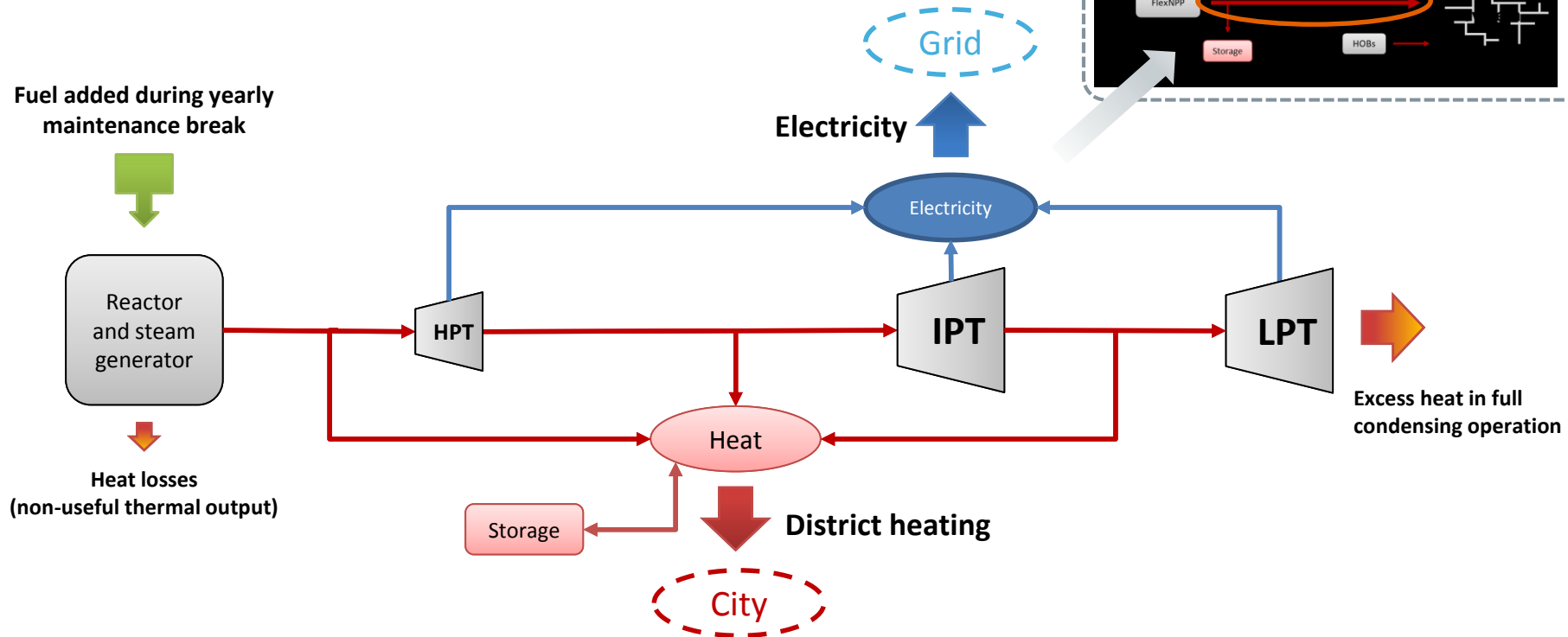
Input for this study:

Feasible sites for nuclear co-generation, nuclear plant characteristics, district heating demand profiles, electricity price scenarios.

Dr. Martin Leurent

- *“Nuclear plants as an option to help decarbonising the European and French heat sectors? A techno-economic prospective analysis” (PhD thesis)*
 - Cost and emission reduction potential by nuclear based heating systems have been confirmed in several case studies in European and French cities
 - DH systems in France need to be developed in order to reach the full potential
 - Buildings without centralised heat distribution system are a major barrier for development

Flexible nuclear co-generation



Case study and model definition

Paris, Lyon and Dunkirk

Why these locations?

- All potential cities due to a nearby nuclear site and an existing DH system
 - Current DH systems are small vs. available heat from a NPP
- Future systems considered!

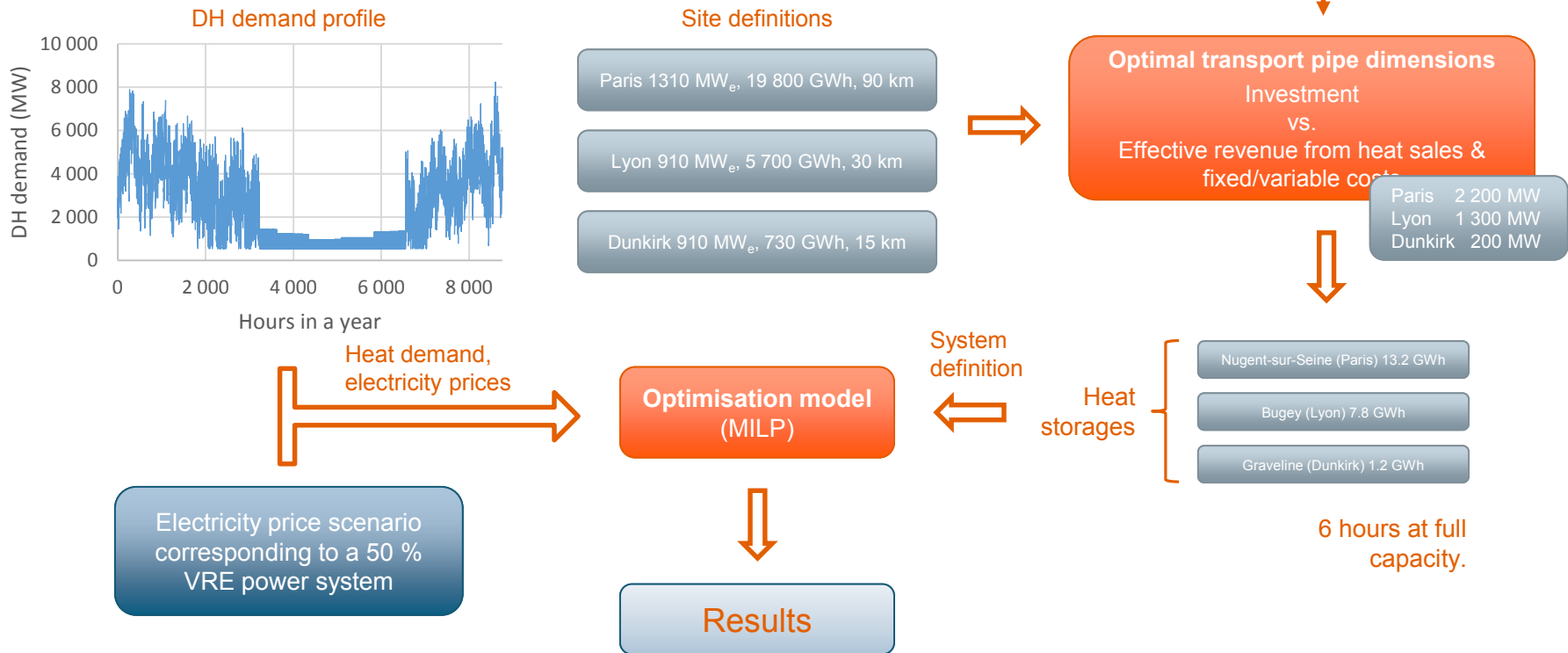
Amount of heat required?

- Yearly heat demand (potential) evaluation based on Heat Roadmap Europe studies

Shape of the heat demand profile?

- A sample of typical French DH demand scaled to match yearly demand

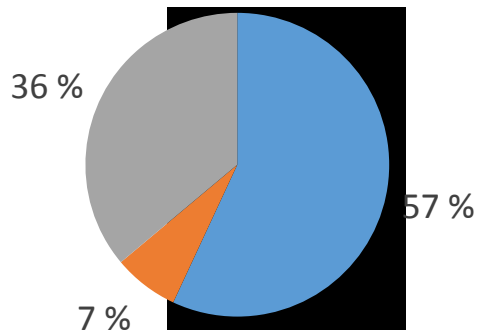
Optimisation model definition



Results

Yearly district heating supply

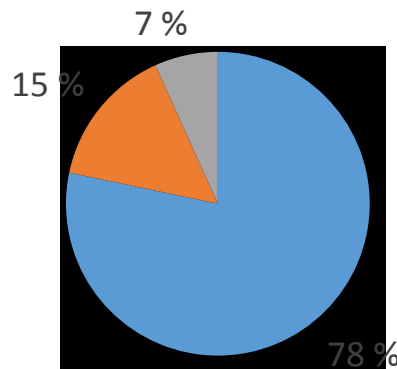
Paris



Storage cycles

105

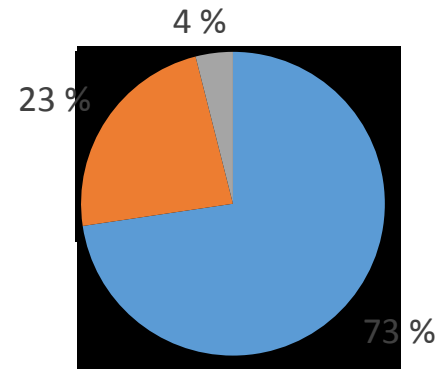
Lyon



Storage cycles

109

Dunkirk

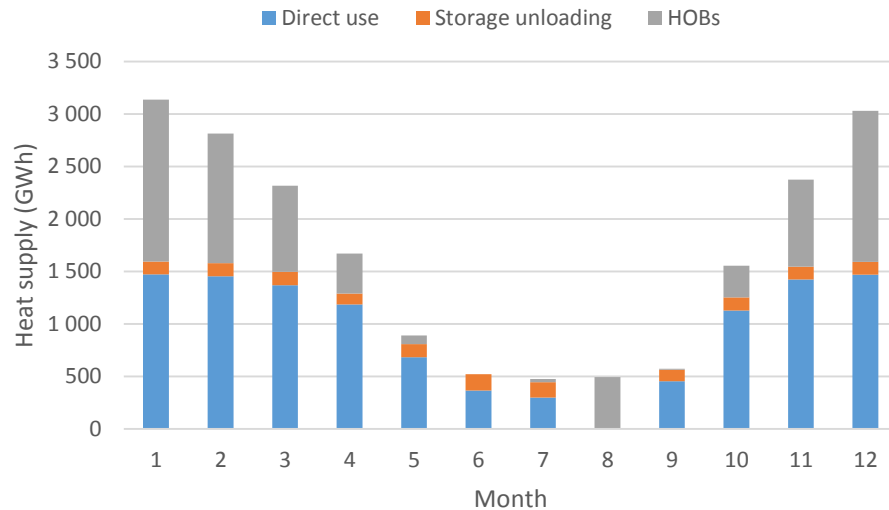
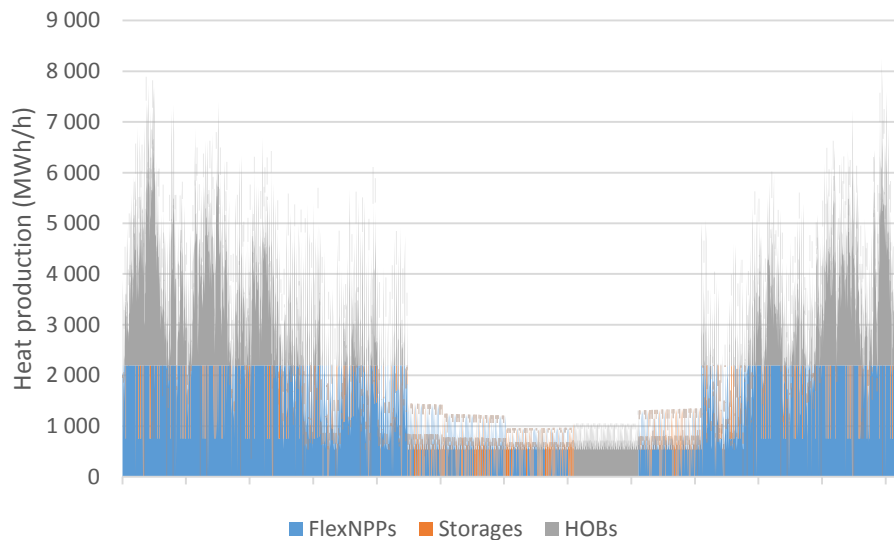


Storage cycles

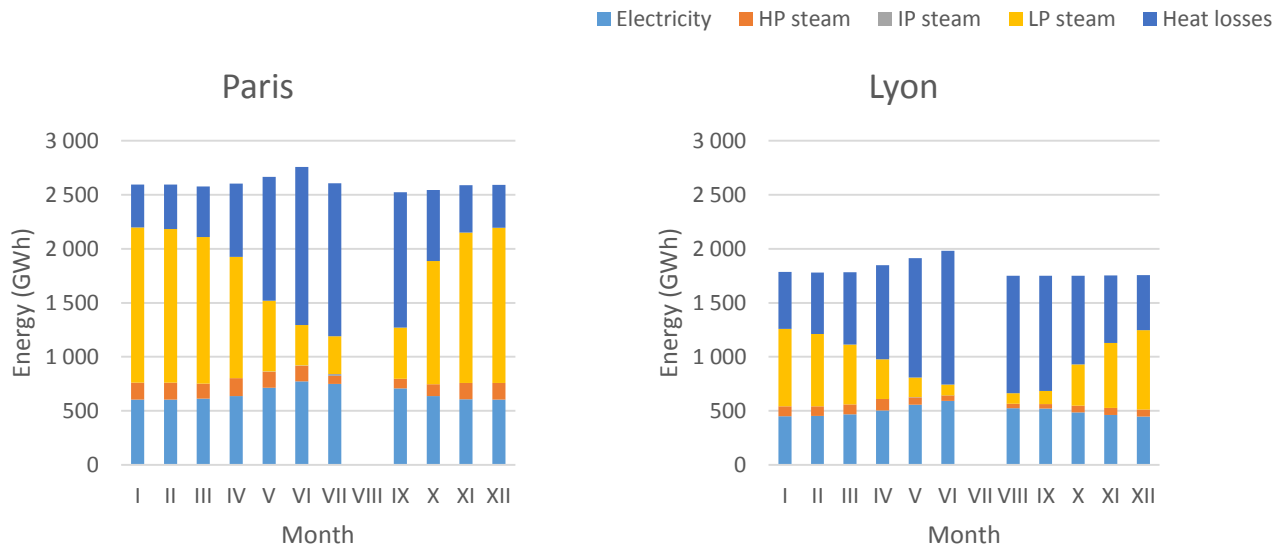
143

■ Direct use ■ Storage unloading ■ HOBs

Hourly and monthly DH supply in Paris

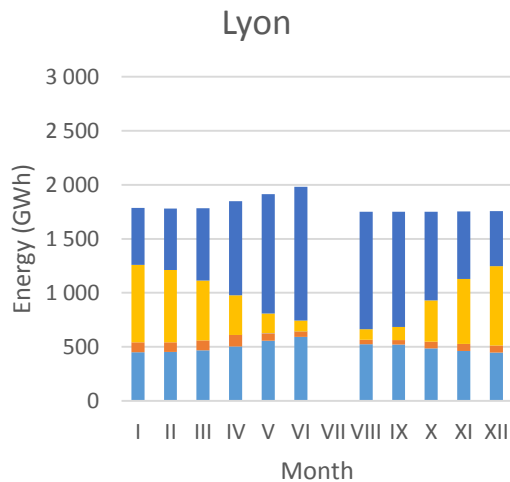


Monthly operation of the units



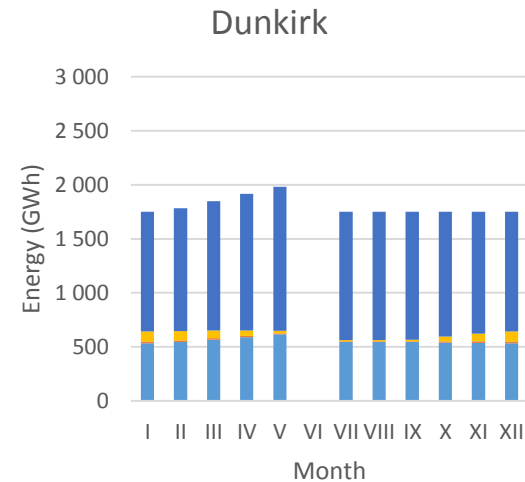
Overall efficiency

70%



Overall efficiency

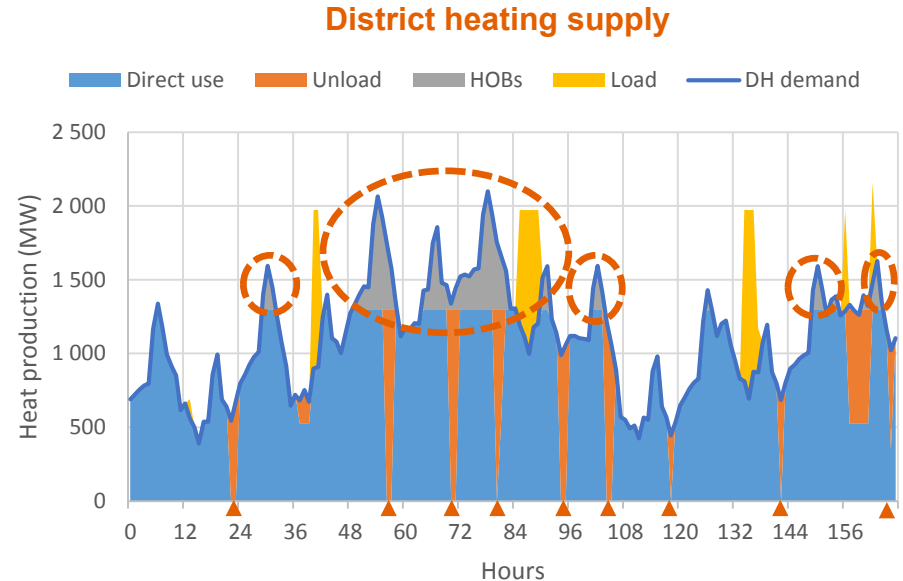
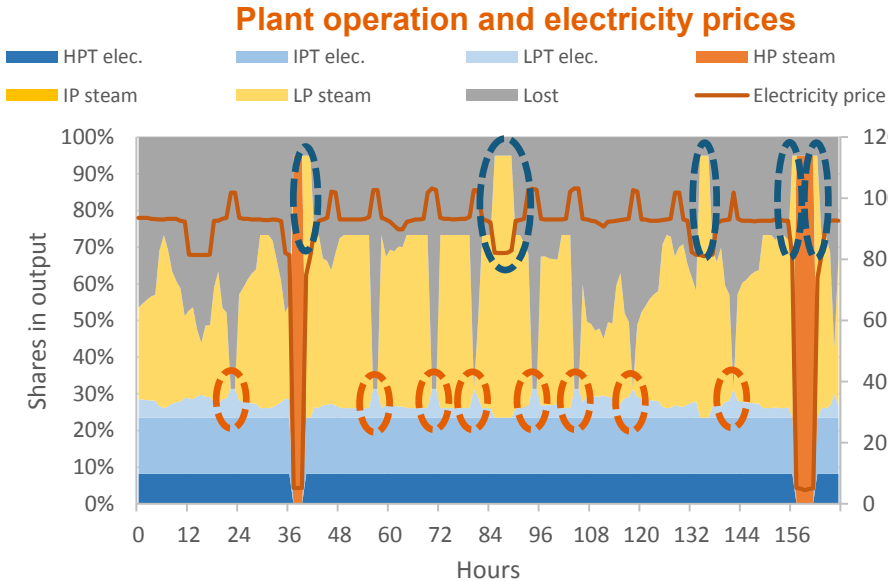
54%



Overall efficiency

34%

Operation during an example week in Lyon



- Transmission pipe capacity reached, peak boilers supplying DH – outside the peaks mostly following DH demand
- Electricity price peaks; electricity production maximised, thermal storage used for supplying DH
- Low electricity prices; low pressure turbine bypassed, thermal storage loaded
- Very low electricity prices; high pressure steam used for heat production, no electricity production

Conclusions

Conclusions

- Flexible nuclear co-generation operates as envisioned
 - Thermal storage heavily utilised
 - Well-suited for daily balancing activities
 - Only use of high and low pressure steam is relevant
 - Results applicable for any co-generation type of production
- Concept is only a part-solution for providing needed flexibility
- Current DH systems in France small and require development
 - Scale of DH system sets limitations for the utilisation
- Possibilities for further research:
 - Defining more detailed cost structures, different thermal storage capacities, more varied DH supply (e.g. heat pumps) for a specific case