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Livø – A micro-scale smart energy system

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Smart energy system

A cross-sectoral and coherent energy system solution

Smart Electricity Grids

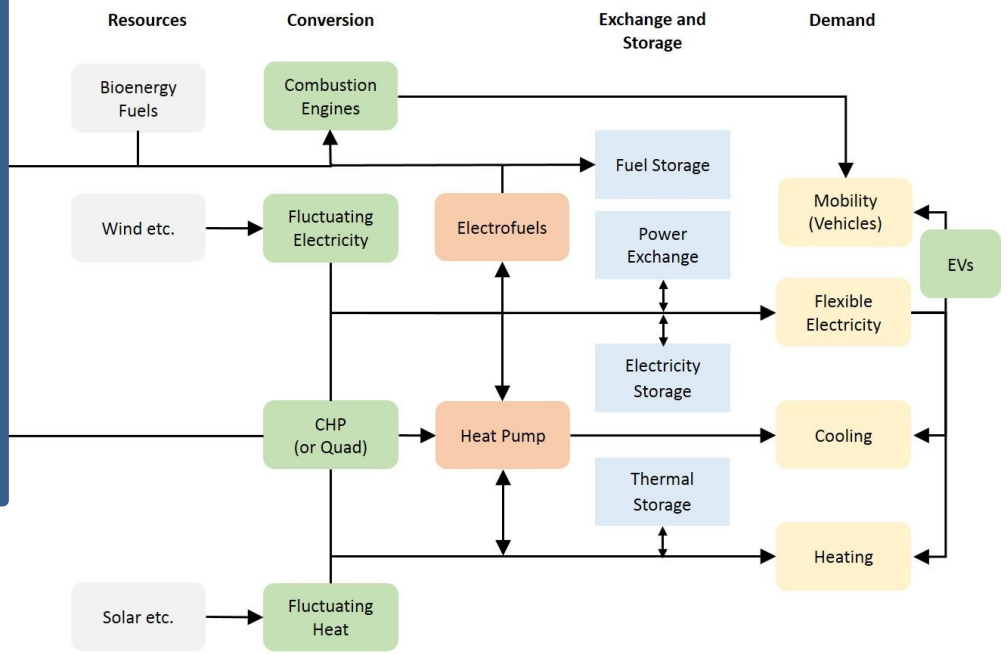
Connecting flexible electricity demands, heat pumps and electric vehicles to the variable renewable resources such as wind and solar power.

Smart Thermal Grids

Connecting the electricity and heating sectors, thermal storage to be utilised for creating additional flexibility and heat losses in the energy system to be recycled.

Smart Gas Grids

Connecting the electricity, heating, and transport sectors, enabling gas storage to be utilised for creating additional flexibility. If the gas is refined to a liquid fuel, then liquid fuel storages can also be utilised.



Using the smart energy system approach on the micro-scale

- The smart energy system approach has been extensively tested on many different countries, regions and cities.
- However, the micro-scale poses some different challenges than larger scales, as e.g.:
  - It excludes the use of technologies of a certain minimum size.
  - Small changes can have large effects (e.g. PV and clouds).
  - Tend to have less manpower in the day to day operation.
- The smart energy system approach on micro-scale is in this tested on an off-grid island.
- As all energy system balancing must be handled on the island, such a system highlights any potential balancing issues.

The test case of Livø

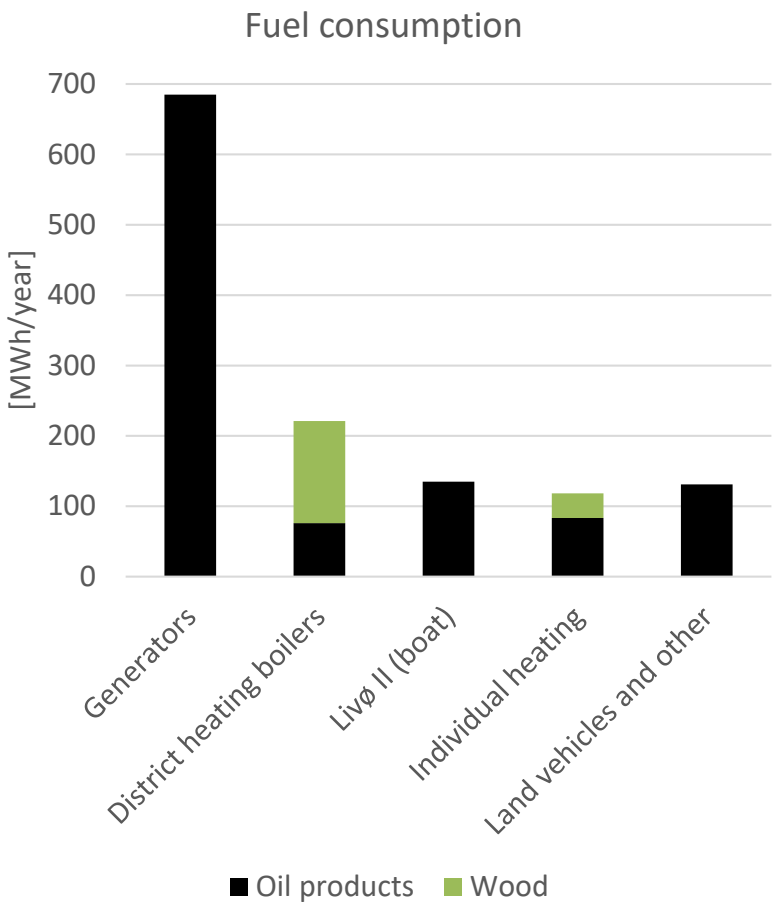
- Case: Danish island of Livø with an area of 320 hectares and 10 permanent residents.
- During the summer period around 25,000-30,000 tourists visit Livø.
- Energy demands for heating, electricity, forestry, agriculture, transport on the island and a boat.
- Owned and managed by the Danish Nature Agency.
- Many different planning constraints (e.g. nature protection legislation) making installation of many facilities difficult (or in some cases impossible).

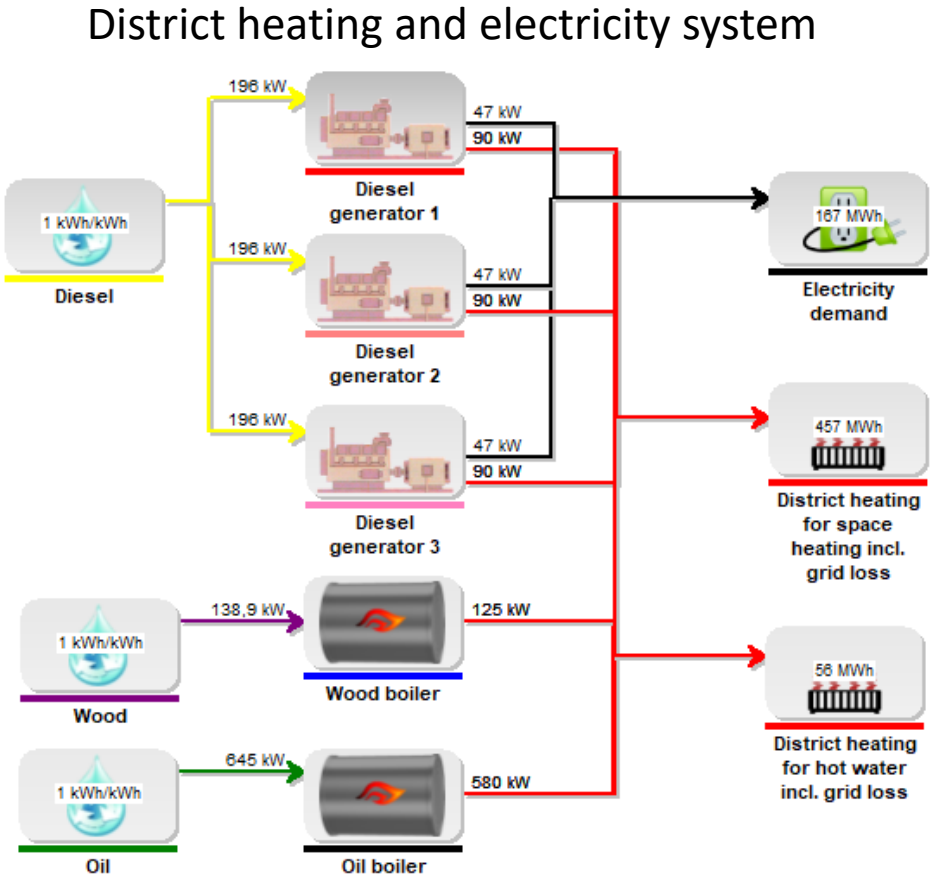
The research project

- The goal is to reduce the use of fossil fuels on the island, in order to:
  - Reduce emissions.
  - Reduce the costs for importing fuels.
  - Make the energy system an attraction for tourists.

- The Danish Nature Agency's long-term goal is to get Livø to be CO_2 neutral.
  - Preferably without the need to import energy to the island.
- This project is a step in this process.

Former energy system on Livø





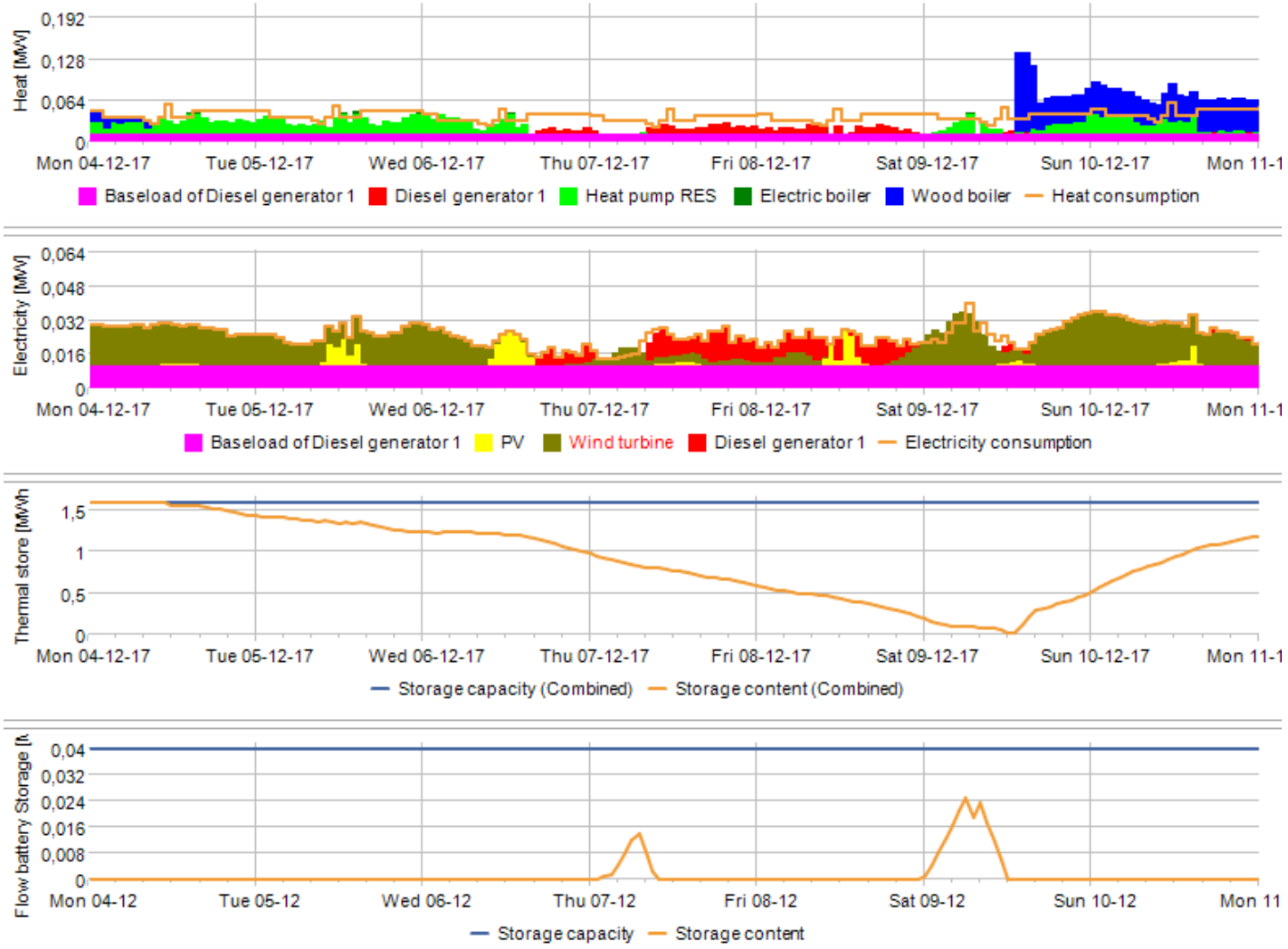
Changes made in the project period

- New diesel generators with heat rejection.
- New district heating system with lower temperatures (65°C forward).
- More buildings connected to the district heating grid.
- Electric boiler and air-to-water heat pump in the district heating system.
- Heat storage in the district heating system.
- One 25 kW_e wind turbine and 33 kW_e roof mounted PV.
- 40 kWh flow battery.
- Improved measurement and control system.

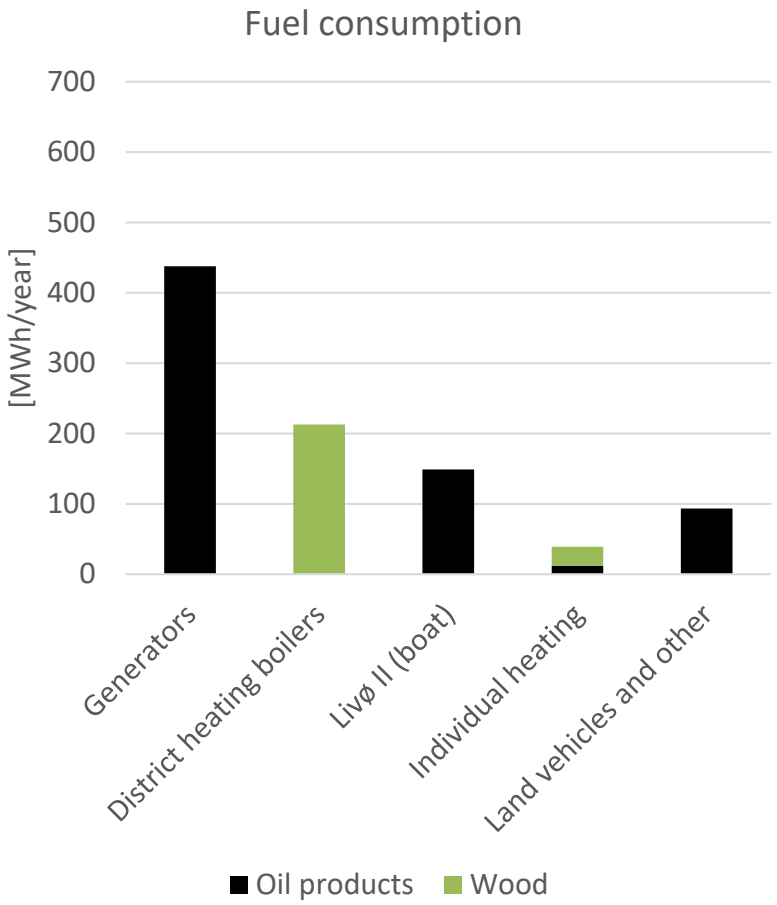
Evaluation of the new energy system

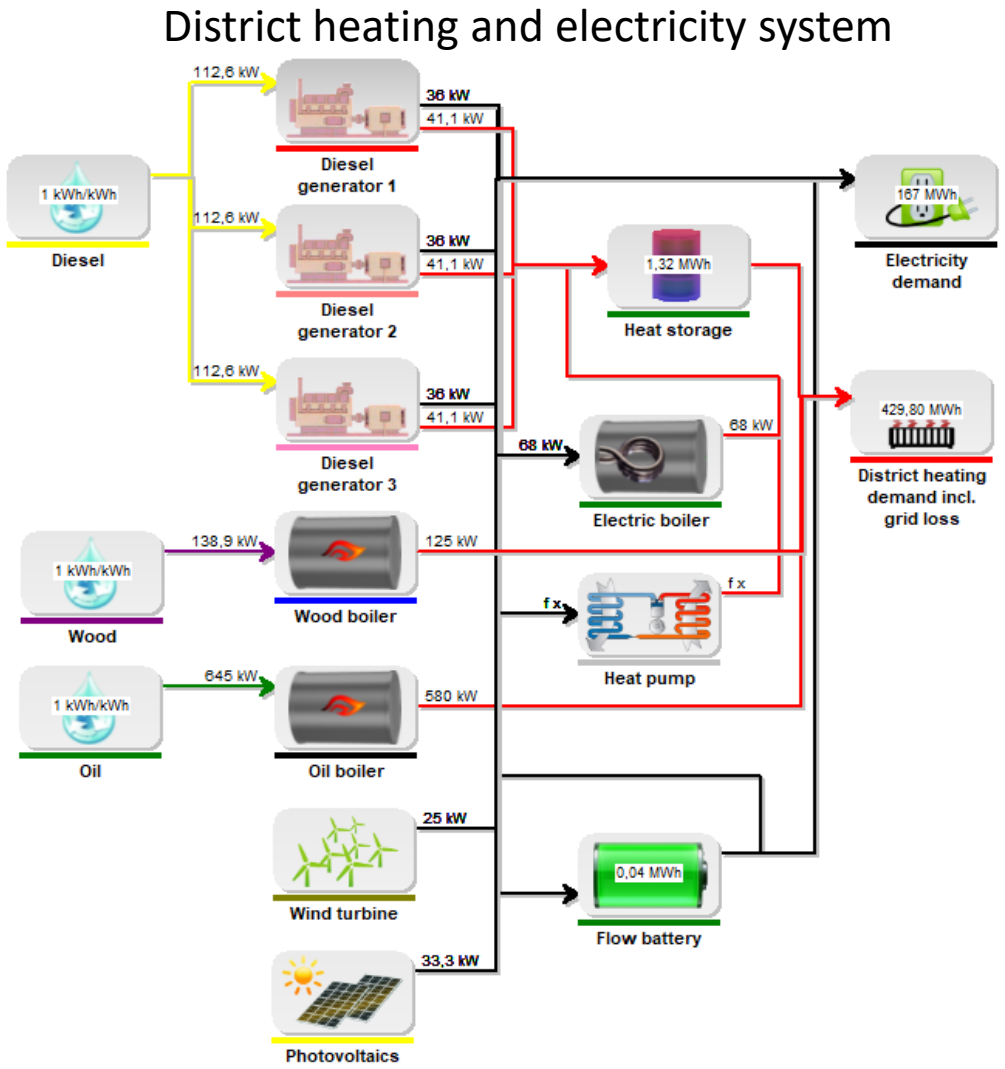
- Currently, not all the changes are fully implemented, and as such the effects on the electricity and district heating systems have been simulated in a energy balancing model.
- The simulation has been done in energyPRO.
- energyPRO is:
  - A deterministic energy balancing tool.
  - Conversion units are operated based on a priority list (least-cost or user-defined).
  - Simulations can be done down to 10 minutes steps over any given timespan (here hourly steps over a year).

Example of one week of operation in December

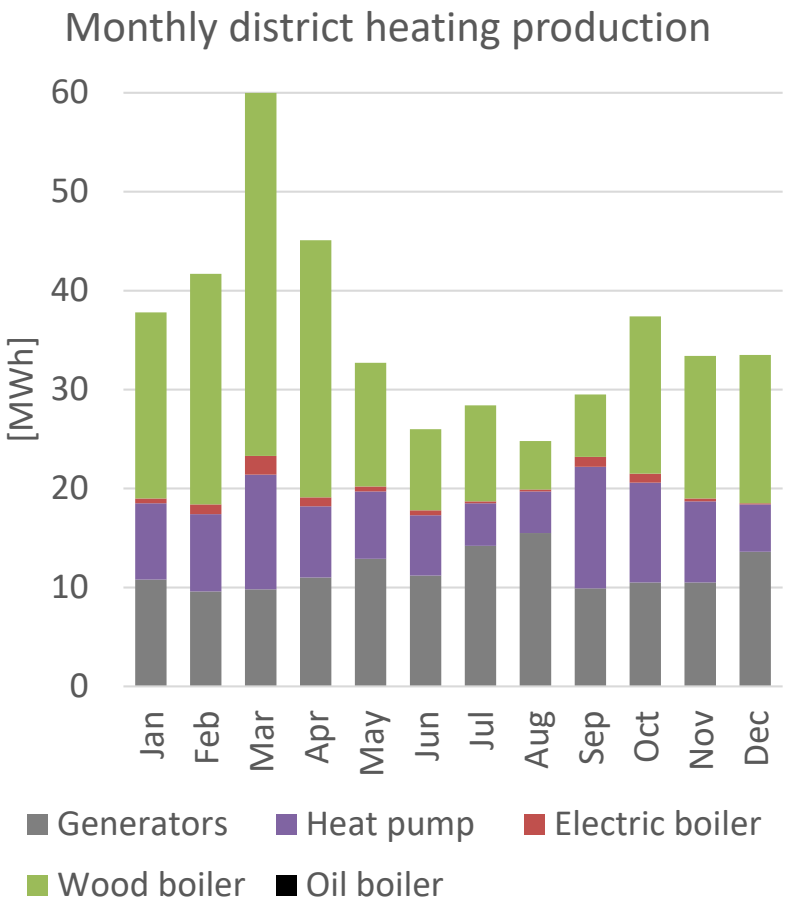


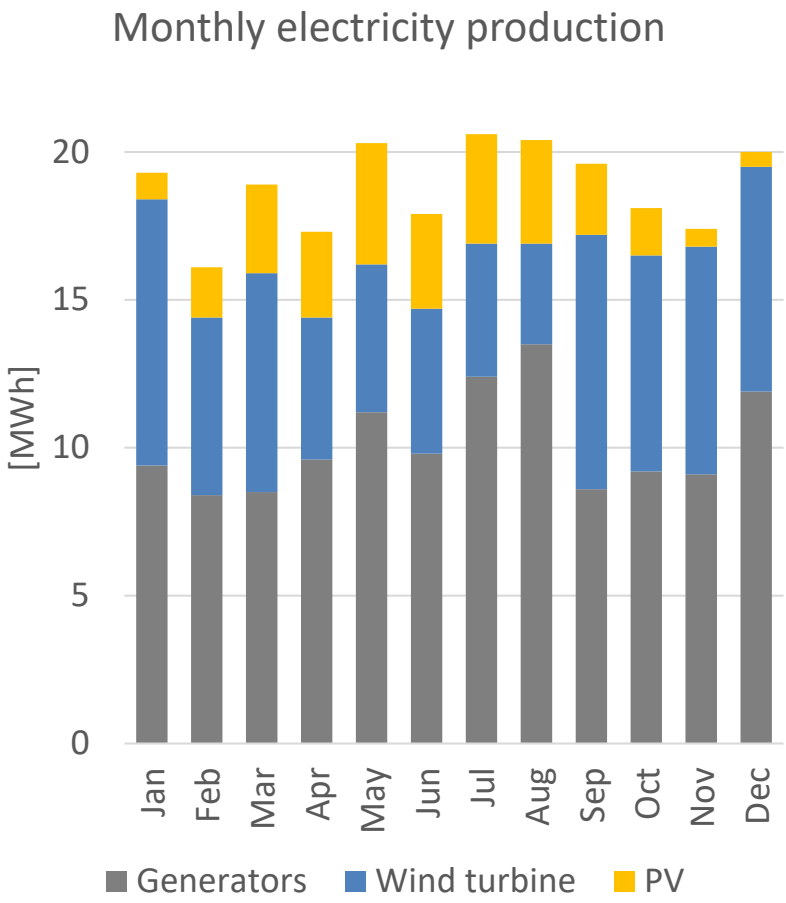
New energy system on Livø after the current project is fully implemented



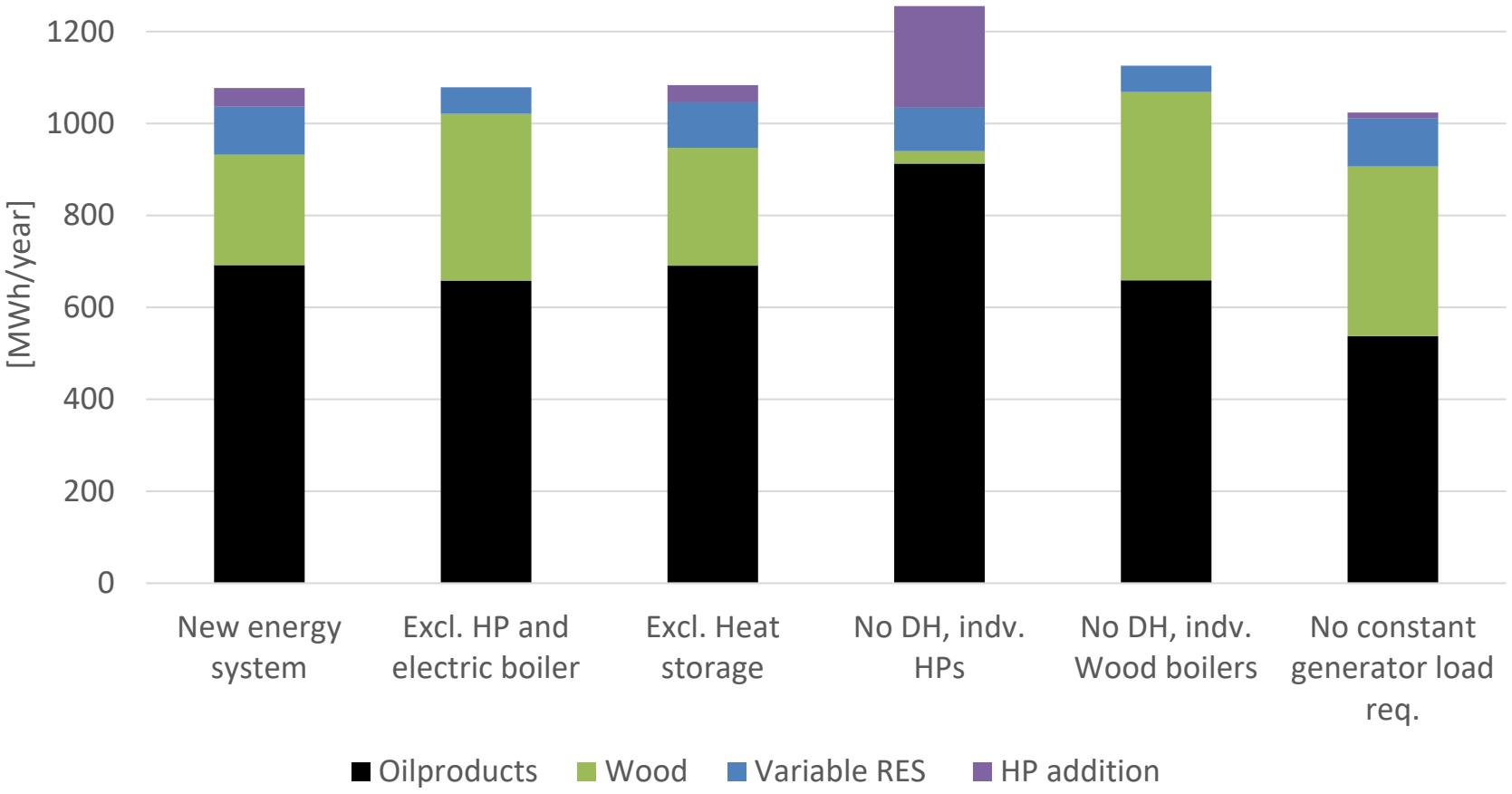


Monthly production of district heating and electricity





Variations on the new energy system



Beyond the new energy system

- The requirement for operating the generators every hour has to be replaced (batteries, flywheel, etc.).
- Wind power is normally heavily utilized in Denmark, and could be useful on Livø. However, the planning restrictions make it unlikely to have a lot of wind power capacity.
- PV alongside batteries is likely to be the main variable RES source.
- The biomass potential from the forestry is around 790-890 MWh/year (the new energy system uses around 240 MWh/year).

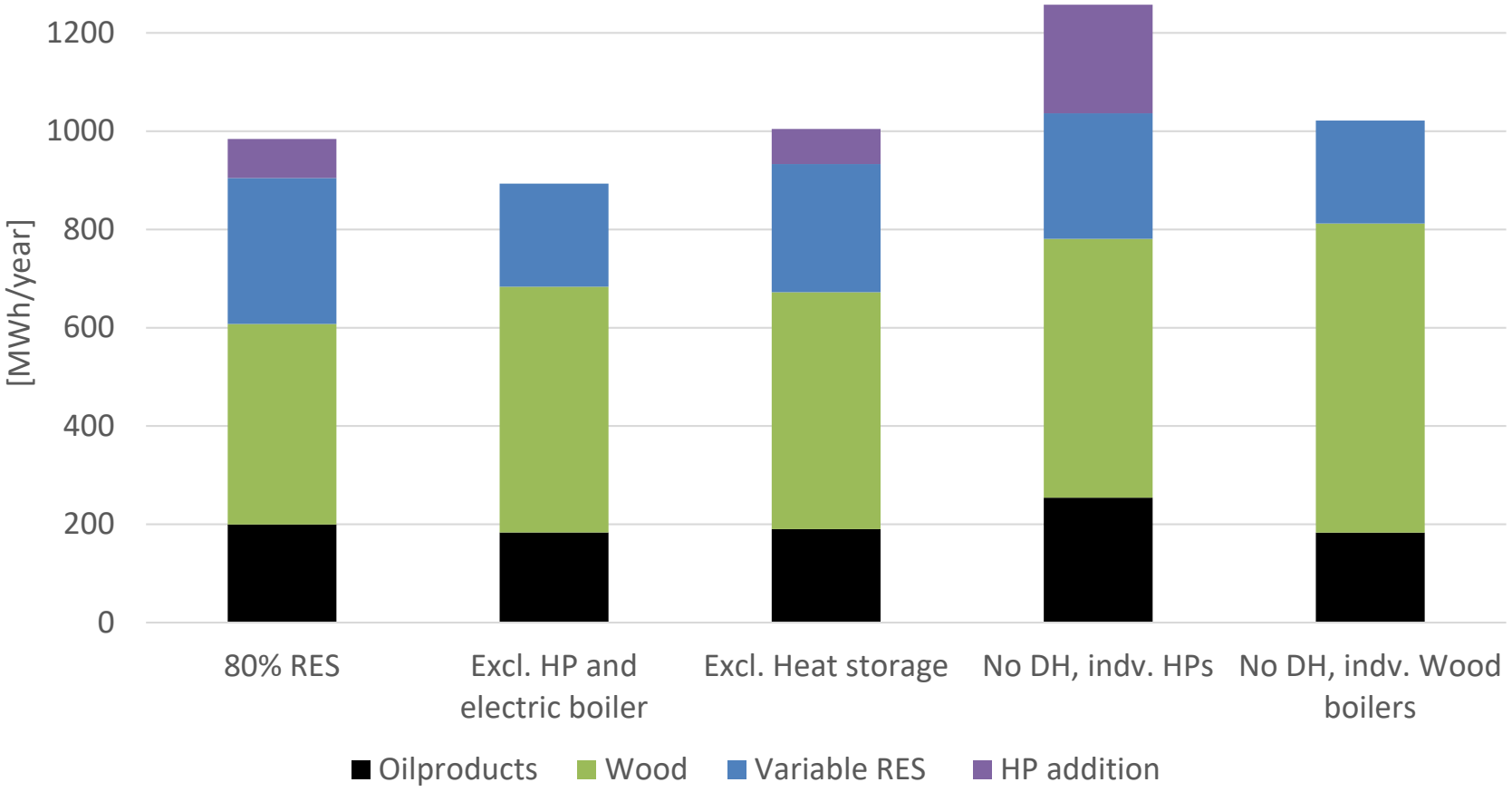
- The boat (Livø II) has to be changed from using diesel. Electricity might be an option in the future.
- The transport on the island have to be changed from diesel. Electricity could be an option, as the distances are short.

A potential future 80% renewable energy scenario

Changes made compared to the ”new energy system”:

- Removal of baseload requirement of generators.
- The boat (Livø II) on electricity (charged only on Livø).
- Electric vehicles for transportation on Livø.
- Reduced the forward temperature in the district heating system to 55°C.
- Double existing air-to-water heat pump capacity.
- PV capacity increased to 300 kW-e.
- Battery capacity increased to 400 kWh (Lithium-ion).
- 28 kW_e biomass-fired CHP (20% electric efficiency).

Variations on the 80% renewable energy scenario



Conclussions

- The connection between the district heating system and electricity system makes it possible to utilize more energy from wind power and PV.
  - Especially the electric boiler is useful for balancing of the electricity grid due to its fast response rate.
- Despite the grid loss in the district heating grid, the fuel consumption (oil and wood) is lowest with the district heating system.

- Smart energy system approach is useful on the micro-scale as it enables increased flexibility.
  - However, it is important to understand the local potentials and restrictions.