The role of 4th generation district heating in a future energy system based on hydropower

BENTE JOHNSEN RYGG*, KRISTINE ASKELAND, KARL SPERLING

reINVEST
@ReInvestEU

Renewable Energy Projects: Local Impacts and Sustainability (RELEASE)

Høgskulen på Vestlandet

AALBORG UNIVERSITY
DENMARK

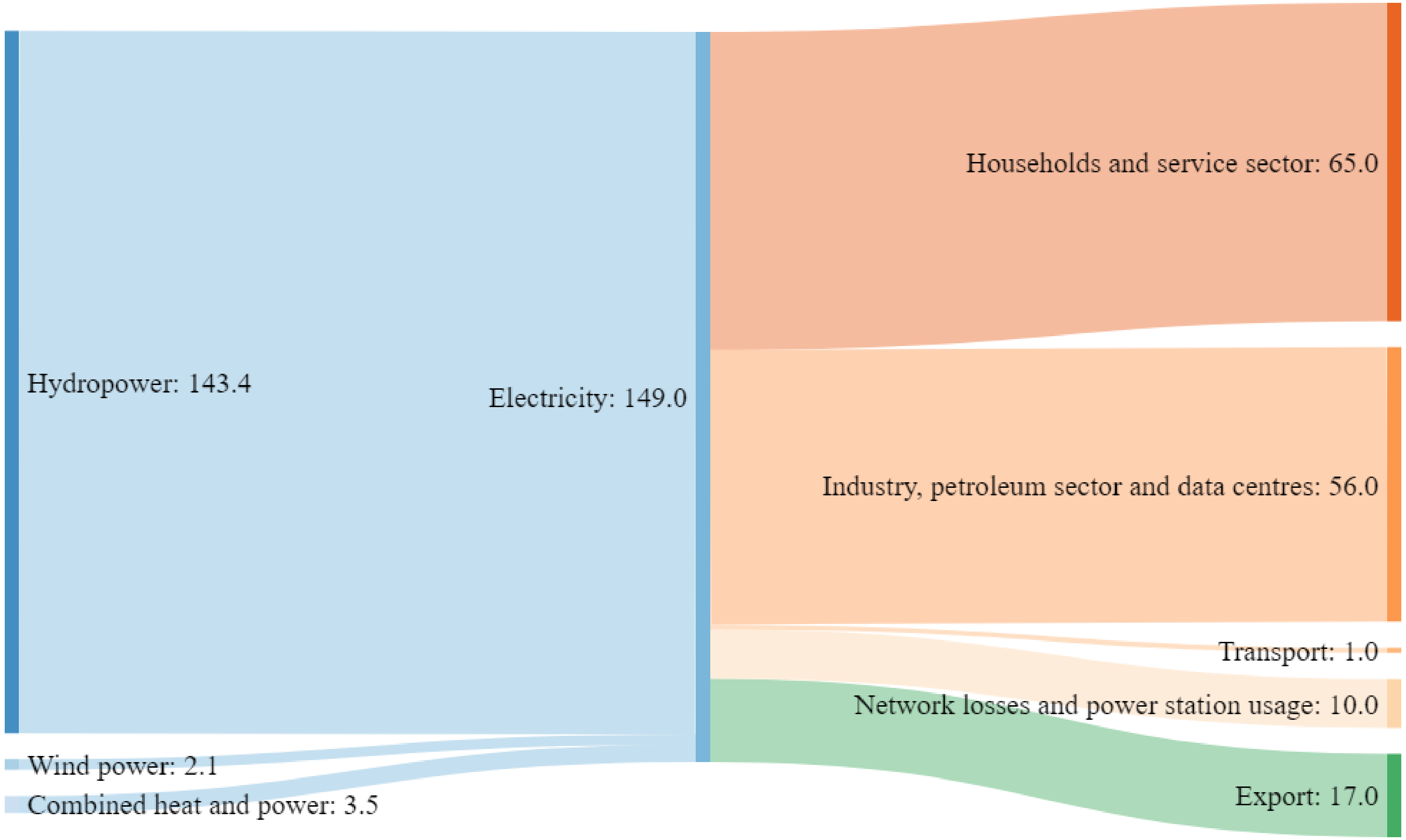
Background

- Hydropower is dominating the Norwegian energy system
- Development of district heating is modest (in a nordic context)
- Increased share of unregulated hydropower in the coming years
- Energy prices are expected to increase due to electrification and export

Høgskulen på Vestlandet

AALBORG UNIVERSITY DENMARK

Electricity use in Norway



Electricity used for individual heating:
38.9 TWh

Høgskulen på Vestlandet

AALBORG UNIVERSITY DENMARK

Working research question

What role can 4th generation district heating play in a future, highly electrified Norwegian energy system?

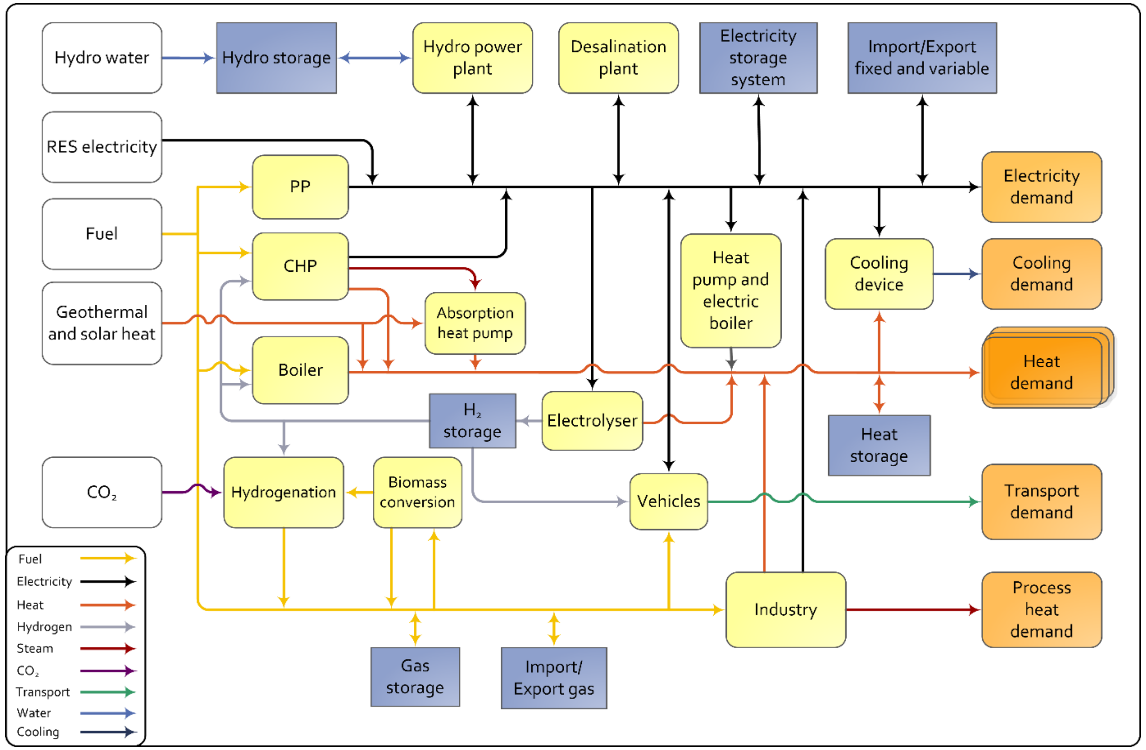
Methodology - EnergyPLAN

Deterministic input/output model seeking to optimize operation according to predefined simulation strategies and priorities

Hourly resolution

Market economic simulation strategy

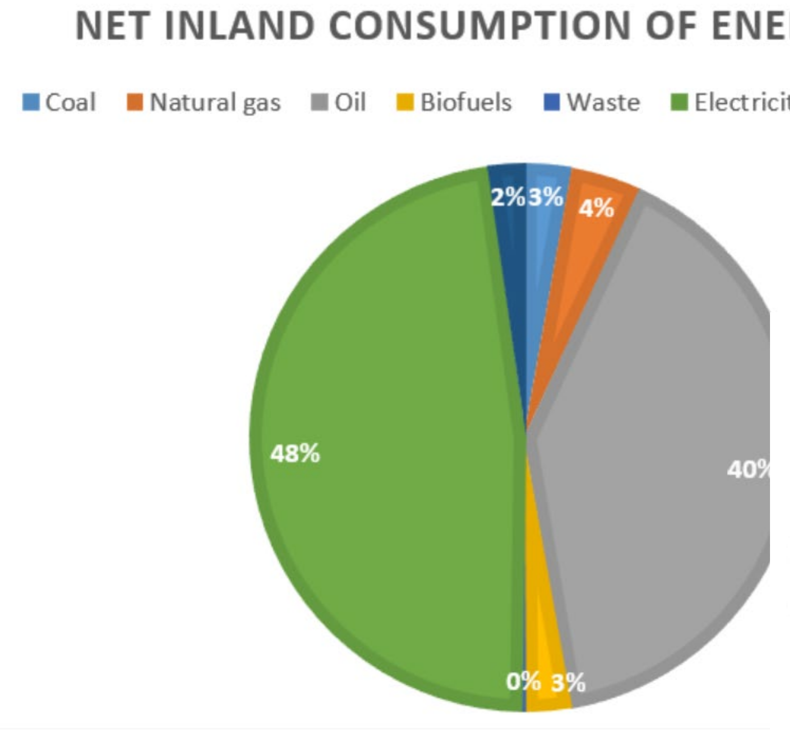
- Minimizing short-term electricity consumer costs and minimizing short term district heating costs

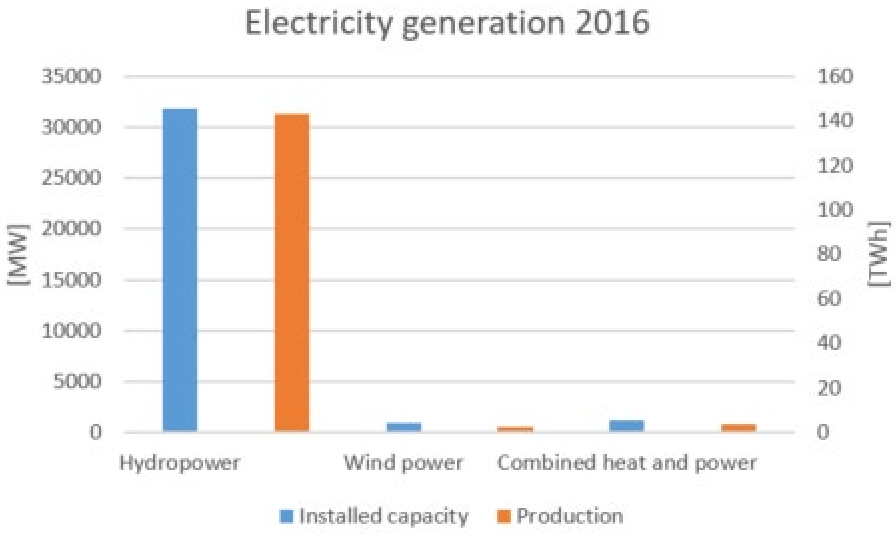


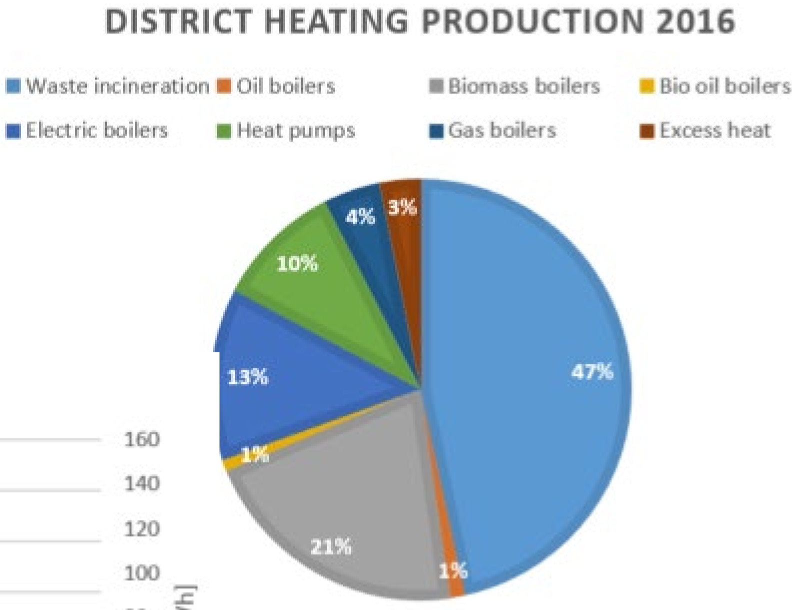
Høgskulen på Vestlandet

AALBORG UNIVERSITY DENMARK

The Norwegian energy system 2016







Construction of reference scenario

Delimitation: Electrofuels for transport sector

Step 0: 2016 energy system model

Step 1: Electrification of transport sector

Step 2: Electrification of heating sector

Step 3: Increased electricity demand in industry sector

Step 4: Expansion of RES production according to NVE’s ”Kraftmarkedsanalyse 2017-2030”

Uncertainties regarding data inputs

Data regarding district heating capacities is unavailable

- Capacities are estimated based on expected full load hours

Data regarding types of facilities for district heating production units are not specified

- Assuming all boilers for production from combustion (except waste incineration), but could in theory be combined heat and power plants

Lack of data regarding thermal storage capacity for DH

Lack of data regarding heat demands etc.

- Estimation of demands vary between different sources
- Distribution of demands based on degree days, but does not take into account the variation in hot water demand

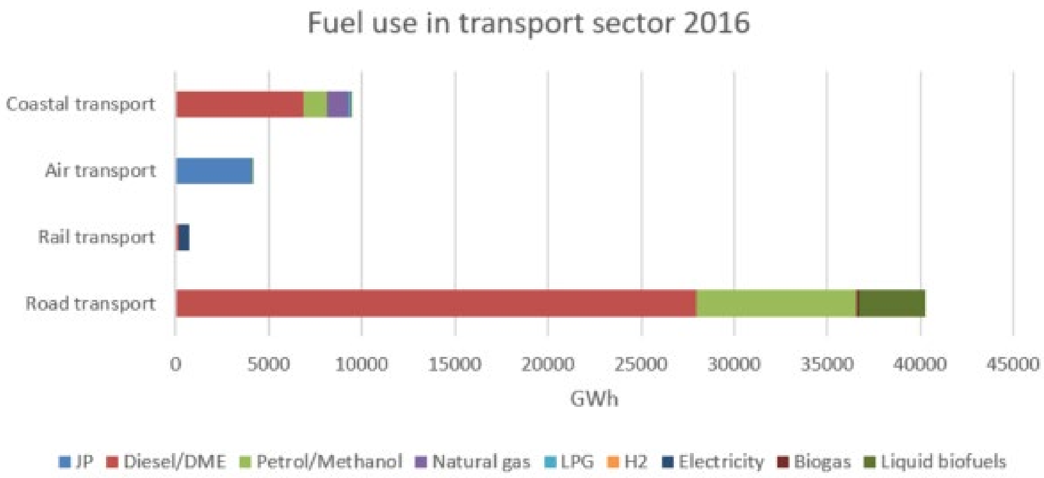
Step 0: 2016 energy system model

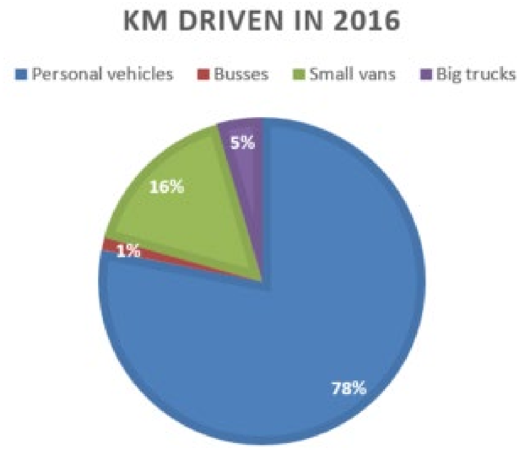
Energy system model based on statistical data for the energy system in 2016

Step 1: Electrification of transport sector

Assumptions:

- 100% electrification of petrol and diesel in road transport for personal vehicles and small vans
  - No electrification of big trucks
- 100% electrification in rail transport
- 50% electrification of diesel and petrol based coastal transport
- 0% electrification in air transport





Resulting increase in electricity demand:

- +7.41 TWh

Step 2: Electrification of heating sector

Assumptions:

- No increase in heat demand related to increase in population
- Assuming full electrification of individual heating using heat pumps
  - Air-to-air heat pumps for space heating demand (COP: 2)
  - Electric boilers for hot water demand – assuming 25% of heat demand is used for hot water

Resulting increase in electricity demand:

- +5.61 TWh

Step 3: Increased electricity demand in industry sector

Expected future increase in electricity used for:

- Industry → +3.3 TWh
- Petroleum sector → +11.3 TWh
- Data centres → + 3.5 TWh

Resulting increase in electricity demand:

- +18.1 TWh

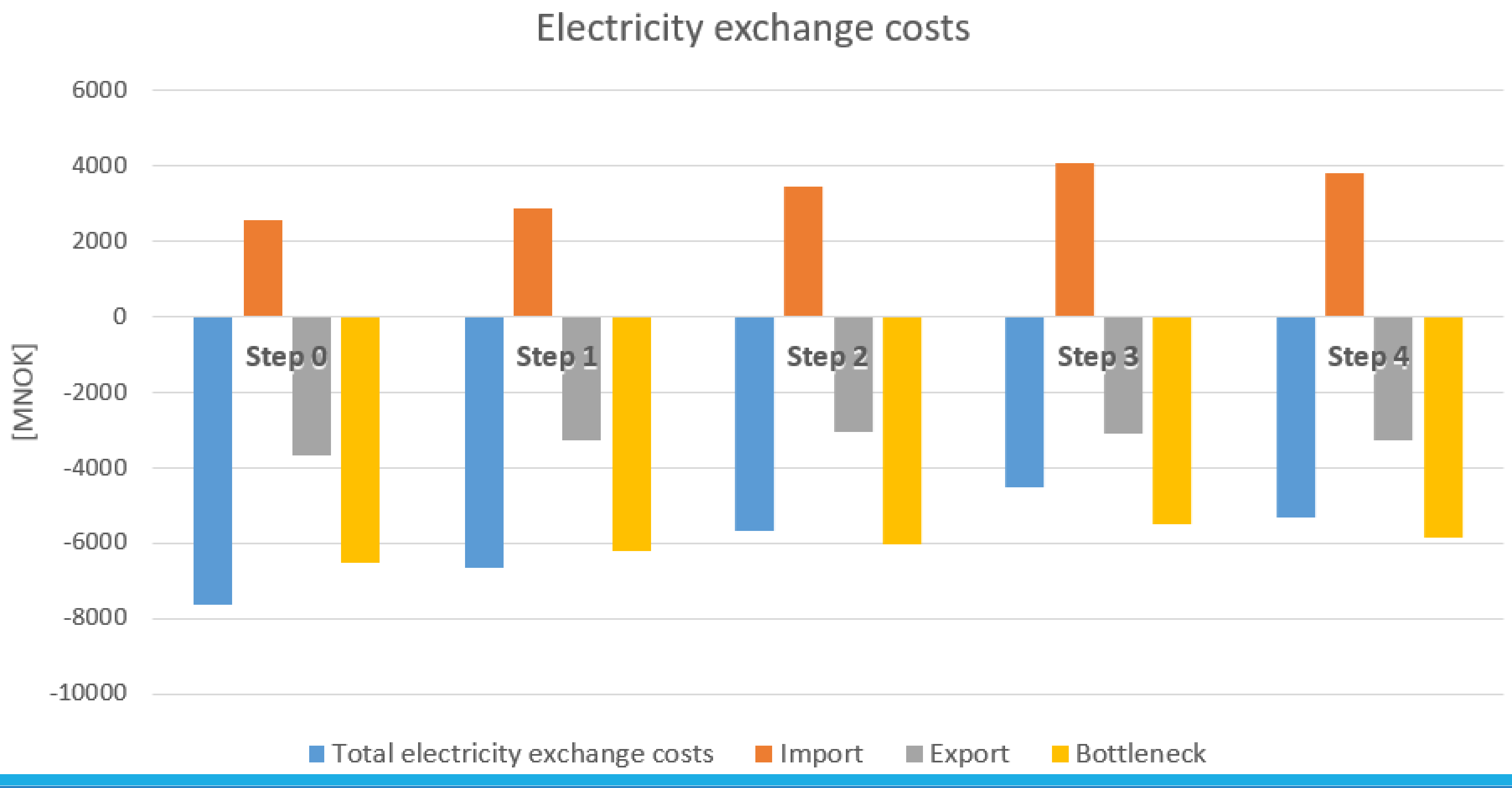
Unclear if these increases leads to a decrease of fossil fuels used in the sector, and if so, how much.

Step 4: Expansion of RES production

Assumptions regarding expansion of RES capacity in Norway towards 2030:

- Wind: 15 TWh
  - Capacity increase: 883 MW → 7140 MW
- Biomass: 0 TWh
- Hydropower: 7 TWh
  - Assuming all dammed hydro and equal inflow/storage/generation capacity share as in 2016
  - Generation capacity increase: 30 274 MW → 31 253 MW
  - Storage capacity increase: 86 500 GWh → 89 296 GWh
    - Estimation based on the 2016 model!
- Solar: 1 TWh
  - Capacity increase: 13.6 MW → 1500 MW

Results steps 0-4: Electricity exchange



Characteristics of 4th generation DH systems

Low supply and return temperatures

- Utilization of low temperature heat sources
- Higher COP’s for heat pumps

Large, low temperature storage capacity

Heat savings and lower heat demands

Higher total system efficiency

District heating potentials

District heating is a geographically local heating solution

- Potentials must be found locally both for what concerns production as well as customer base

Consumer cost price for alternative heating solutions affects the district heating potential

Two forms of potentials:

- Potential within existing DH areas
- New DH areas

National potentials

- District heating potential was estimated to 11.5 TWh in 2020
  - DH can be increased with 5.6 TWh

Scenarios

DH scenario 1

Keeping existing DH as it is

30% heat savings in buildings converted to DH

Large scale heat pumps for base load
- Sea water heat pumps
- COP 3.5
- Full load hours: 4000 h/year
- Installed capacity: 245 MWe (1225 MWth)

Electric boilers for peak load
- Full load hours: 500 h/year
- Installed capacity: 999.6 MW

DH scenario 2

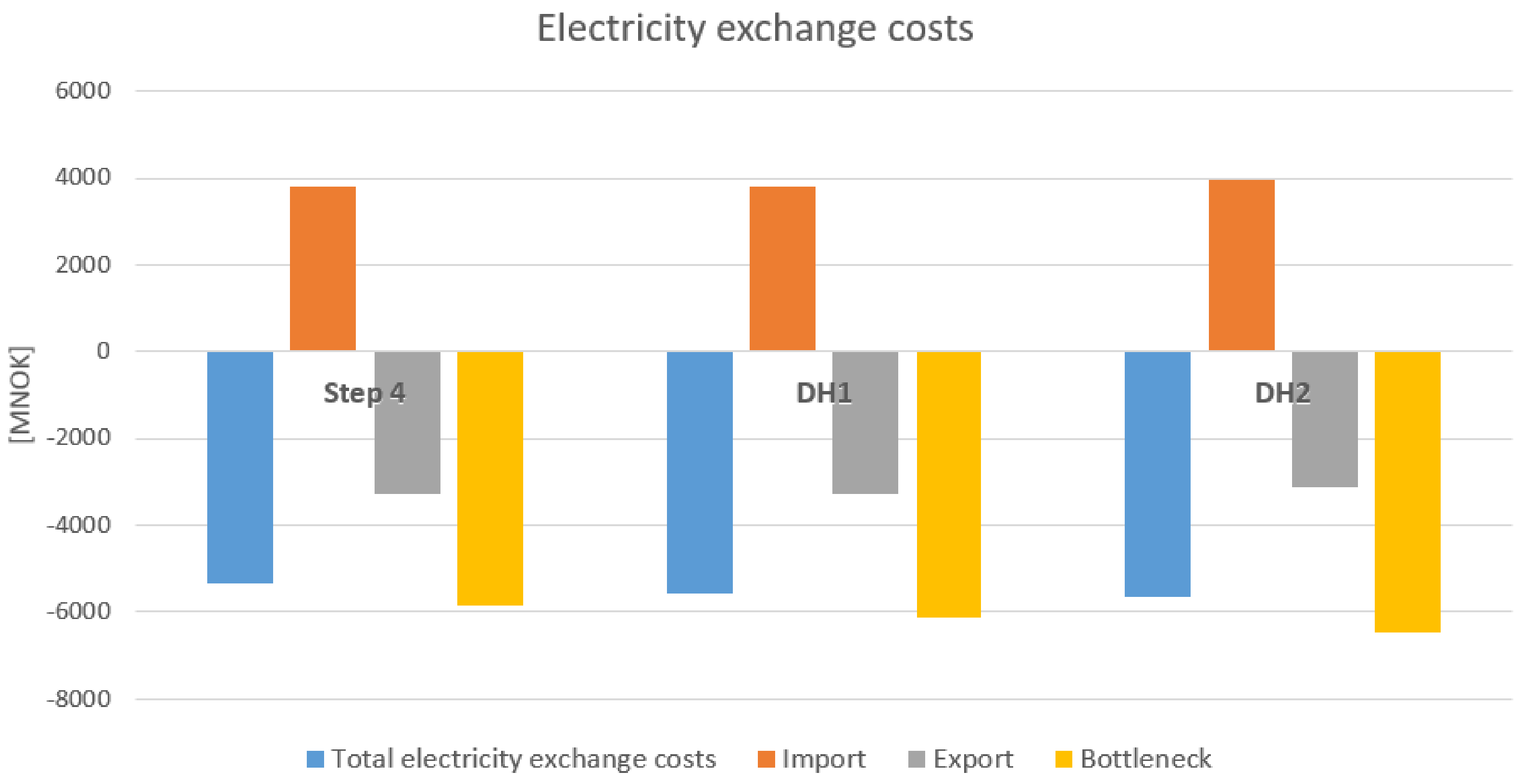
Keeping existing DH as it is

30% heat savings in buildings converted to DH

Biomass based units for base load
- Dry wood biomass boiler
- Efficiency: 85%
- Full load hours: 4000 h/year
- Installed capacity: 986 MWth

Electric boilers for peak load
- Full load hours: 500 h/year
- Installed capacity: 999.6 MW

Preliminary results DH scenarios



Preliminary conclusions

An expansion of district heating based on heat pumps can lead to a marginally higher income from electricity exchange due to increased income from export and lower cost for import in the given system

- However, expansion of DH has a cost that is not analyzed to detail in this study

The amount of DH introduced is too small to make a large impact for what concerns income from electricity exchange and total fuel consumption.

- Due to a high electricity and fuel demand for industry sector.

Future work

Clearer definition of DH potential

Hourly distribution of future demands

Introduction of low temperature excess heat for DH

Analyzing the role of thermal storage capacity

Analyzing the relation between investment costs in district heating and changes in operational cost of the system