Open models of optimal system operation in central vs. decentral heat supply

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- Central fossil (natural gas) CHP,
- central peak load boiler
- central thermal storage,
- 1 primary,
- 8 sub-networks.

“How to include renewable heat using Power-to-Heat?”
Open energy modeling framework
Open energy modeling framework – oemof

https://oemof.org
https://github.com/oemof

Next developer meeting
2019/12/04-06 in Berlin
oemof_heat

Project funded by BMWi

Duration: 3 years (2017-2020)
- Space heating,
- District heating networks,
- Special temperature levels.

Developing heat components for simulation and optimization models
- Heat pumps,
- District heating networks,
- Solar thermal collectors,
- Thermal storages.
Case study
Case study – District heating system

Fictitious system

- 1 primary network,
- 8 sub-networks,
- Aggregated synthetic thermal load profiles for consumers in sub-networks.

Serve heat demand at minimal cost while maximizing revenues through electricity sale.
Assumptions

- Linear model,
- cost assumptions,
- electricity spot price timeseries,
- aggregated load profiles for sub-networks,
- constant losses in DHN pipes,
- heat source at constant temperature level 10°C,
- temperature level in subnets constant, thus constant COP for heat pumps throughout the year,
- perfect foresight,
- minimize costs, maximize revenues.
Scenario overview

Setup scenarios along three main axes:

<table>
<thead>
<tr>
<th>System configuration</th>
<th>Regulatory framework</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decentral heat pumps</td>
<td>Status quo</td>
<td>2018</td>
</tr>
<tr>
<td>(Central resistive PtH)</td>
<td>Flex Friendly</td>
<td>2030</td>
</tr>
<tr>
<td>(No PtH)</td>
<td></td>
<td>2050</td>
</tr>
</tbody>
</table>
Scenario: Status Quo – Energy carrier prices
Scenario: Status Quo – Energy carrier prices

Sources:
- Electricity spot market price [2]
- Gas price [3]
- Grid usage fees [4]
- EEG levy [5]
- Other taxes §3 StromStG; §2 KAV
Scenario: Status quo | 2018

- Heat pumps not used.
- CHP serves base load,
- gas boiler serves peak load in winter.
- Thermal storage allows CHP to pause in hours of low electricity prices in summer.
Scenarios: Status quo | 2018, 2030, 2050

Economic operation of heat pumps in 2050. 
~ 50% of heat produced by heat pumps in 2050, 
Significant emission reduction.
Scenario: Status Quo – Energy carrier prices

Status quo

Sources:
- Electricity spot market price [2]
- Gas price [3]
- Grid usage fees [4]
- EEG levy [5]
- Other taxes §3 StromStG; §2 KAV
Scenario: Flex friendly – Energy carrier prices

No levies and lower grid usage fees, introduce CO2-tax.

Sources:
- Electricity spot market price [2]
- Gas price [3]
- Grid usage fees [4]
- EEG levy [5]
- Other taxes §3 StromStG; §2 KAV Graichen and Lenck 2018

Flex friendly
Scenario: Flex friendly – Energy carrier prices

When spot price < 0
Taxes significantly reduced.
Network charges = 0.
Scenario: Flex friendly | 2018

- Heat pumps serve as main heat producer.
- CHP operates when heat load is high and while electricity prices are high.
- Storage charged by CHP.
- Gas boiler is used when electricity production is not economic.
Scenarios: Flex friendly | 2018, 2030, 2050

- Heat pumps serve base load.
- CHP/Gas boiler serve peak load.
- Increasing usage of gas boiler in 2030, 2050.
- Emissions are reduced significantly.
Conclusion

- Heat pumps can play an important role in district heating systems.
- Economic operation is sensitive to energy carrier price structure and revenues of electricity sale.
- Heat pumps not economic under status quo assumptions in 2018.
- Flex-friendly price structure allows economic operation.
- Roles are changed: Heat pumps serve base load, CHP switches to intermittent operation. CHP operation replaced by gas boiler at low electricity prices.
- Emissions can be reduced significantly.

Code and data will be published online together with the journal publication.
Let’s discuss!

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Sources


Electricity prices
Specific emissions

Specific emissions of grid electricity

- Status quo 2018
- Flex friendly 2018
- Status quo 2030
- Flex friendly 2030
- Status quo 2050
- Flex friendly 2050

Specific emissions [tCO2/MWh]
Scenario: Status quo/Flex friendly | 2018

Status quo 2018

Flex friendly 2018
Scenario: Status quo/Flex friendly | 2050

**Status quo 2050**

- **CHP**
- **Gas boiler**
- **Heat pump**
- **Discharge storage**

**Flex friendly 2050**

- **CHP**
- **Gas boiler**
- **Heat pump**
- **Discharge storage**