What is the benefit of sector coupling?

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Professor MSO
DTU Management
The aim of the FutureGas project is twofold:

1) *In an energy system context to facilitate the integration of the gas system with the power system, the district heating system and the transportation sector taking into account possible synergies*

2) *To facilitate a cost-efficient uptake of renewable gases, hereby in the longer term substituting natural gas and fossil fuels*

Period: 2016-2020

www.futuregas.dk

Creds to Mason Lester for model runs
Potential benefits

• Using variable renewable power sources to decarbonise other sectors
• Providing stability and storage to the power grid
• Utilising excess heat
Integrated energy systems

Resources

- VRE electricity
- Bioenergy
- VRE Heat
- Natural gas

Conversion

- Electricity import/export
- Variable electricity
- Electricity and heat generation
- Solar thermal
- Gas systems (including local systems, transportation of methane, syngas, biogas and H2)
- Gas storage
- Anaerobic digestion
- Thermal gasification
- Gas catalysis
- Heat storage
- Power to heat
- Electrolysis
- Electricity storage

Demand

- EV
- Transport
- Residential
- Industry

Gas systems (including local systems, transportation of methane, syngas, biogas and H2)
Integrated energy systems
Part I

– What is the value of the gas grid and Power to heat?
Balmorel

Input
Heat and electricity demand
Fuel prices and emissions
Efficiencies and costs
Hourly distribution of demands and production from RE sources
Capacities of existing plants and transmission
Time aggregation

Output
Energy conversion
Fuel consumption
Electricity import/export
Emissions
Investments in plants and transmission lines
Prices on traded energy
Total costs

Modes
LP or MIP (e.g. economy of scale)
Myopic investments or Rolling horizon

Assumptions
Economic rationality
Perfect markets
Perfect foresight within a year

Scenarios

• Model
  – Denmark, Germany, Sweden, and Norway
  – Includes individual heating and industry
  – Does not include transport sector

• Scenarios
  – Base - Balmorel
  – No gas - BALMOREL
    • No natural gas or biogas
  – No E to H - BALMOREL
    • No electricity to heat i.e. no HP or ELC boilers
## Biomass Costs and CO2 Constraint – Late Sprint

<table>
<thead>
<tr>
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<th>2050</th>
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Power and Heat Sector Emissions Constraint (MtCO2eq) - Late Sprint

DEA, Analyseforudsætninger
Change in Total System Costs - Denmark

![Bar chart showing the change in total system costs for Denmark in 2030 and 2050 with and without EtoH and gas.]
Normalized

Total System Cost - Denmark

System Cost - Base2030 [M€]

-400 -200 0 200 400 600 800 1000 1200 1400

Base NoEtoH NoGas Base NoEtoH NoGas

2030 2050

Fuel Costs  Generation Costs  Transmission Costs
Conclusion

• Both PtH and the gas grid will add value to future energy systems of up to 340 MEUR/yr
• The gas grid provides the highest value in the short term
• PtH provides the highest value in the longer term
• With no PtH, we need more natural gas in 2030 and more biomass both in the short and the long term
• With no gas grid, we require more biomass and wind
Part II
– What is the value of power to fuels, hydrogen, and EVs?
**Balmorel**
Energy system optimization model covering the Nordic power and district heating sectors.

**OptiFlow**
Generalized spatiotemporal network optimization model which facilitates modelling of renewable gas and fuel production.

**Diagram**
- **Balmorel**
  - Energy balance
  - District heat balance
  - Electricity and district heat demands

- **OptiFlow**
  - Gas and liquid fuel demands

- **TIMES-DK**

**Least-cost power and district heating system**
- Hourly district heating prices
- Hourly electricity prices

**Optimisation of RE gas and fuel production**
- Power and DH production from RE-gas
- Excess heat from thermal gasification
- Electricity consumption in electrolysis

**Background system**
Model characteristics

– Year 2050
– Fossil independent energy system
– High biomass costs
– Denmark, Germany, Sweden, and Norway
– Includes standard electricity and district heating demands (not other industry or individual heat)
– Includes projected transport energy demands
  • Adapted from TIMES-DK results
– Based on Mason Lesters Masters Thesis Balmorel-Optiflow model
Scenarios

– Base
– No P to X
  • No P to X transport fuel technologies (electrofuels)
– No hydrogen
  • No direct use of hydrogen for transport
– No EVs
  • No electric vehicles

• Limitations
  – Only changes to transport sector i.e. no analysis in the use of hydrogen for industry, nor analysis of hydrogen for electricity storage
  – Includes hydrogen storage technology for transport use only
  – Hydrogen can be produced variably according to price signals and demands
  – Fuel demands are assumed constant over the year
Energy Demands

- Electricity and District Heating Demands
  - 2050 Nordic Energy Technology Perspective
- Transport Fuel Demand
  - TIMES-DK results

Transport Fuel Demands

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<th>No EVs</th>
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Fuel Price, Potentials and CO2 cost

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<tr>
<th>Fuel</th>
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<th>Potential [PJ]</th>
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Nordic Energy Technology Perspective 2016, IEA
Change in Danish System Costs

Scenario

Change in system Costs [M€]

Base  No P-to-X  No H2  No EVs
Energy Consumption - 2050 Denmark

Fuel Consumption (PJ)

Base No P-to-X No H2 No EVs

Scenario

Biomass
Excess Heat
Muniwaste
Solar
Wind
Conclusion

• EVs have the greatest value to the Danish energy system

• PtX and H2 have value but not as much since best e-fuels are using biomass for their carbon source

• Wood pellets are imported if no EVs are available and - to a lesser extent - with no PtX and no H2
• The white paper addresses the potential benefits of energy sector coupling: PtH, PtG, PtX, and EV's

• Work in progress:
  – Coordinated by DTU
  – International collaboration between leading researchers, industry and institutions in the field of energy sector coupling

https://www.etip-snet.eu/about/working-groups/wg-1/
The End

Questions or comments?
maem@dtu.dk

Extras
Energy Demand - Denmark

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<td>Individual</td>
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Energy Demand - Denmark
Change in Total System Costs

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<table>
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<tr>
<td>2050</td>
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Normalized Total Danish Energy System Costs

Total System Cost - Denmark

System Cost - Base\textit{2030} [M€]

<table>
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