Energy system flexibility and costs by means of electrofuel production for the transport sector

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Iva Ridjan Skov
Decarbonizing the transport sector

- Small vehicles
- Rail
- Planes
- Ships
- Busses
- Lorries

4th International Conference on Smart Energy Systems and 4th Generation District Heating 2018 #SES4DH2018
Transport demand in Denmark
IDA Energy Vision 2050

- Cars and vans < 2 t
- Commercial vehicles < 6 t
- Busses
- Lorries
- Rail
- Sea
- Aviation
- Other

Total demand 32.5 TWh
75% of personal transport electrified
35% of commercial vehicles electrified
Transport fuels in IDA Energy Vision 2050

Original fuel mix based on IDA Energy Vision 2050 Reference case

New fuel mix

7.36 TWh (including 5% losses)
85% of buses
>90% of lorries
Renewable fuel pathways

1. Wind, PV etc. → Alkaline → Biogas plant → Gas cleaning → Chemical or biological synthesis → Methane

2. Wind, PV etc. → Alkaline → Biomass gasification → Gas cleaning → Chemical Synthesis → Methanol, DME, Methane, Jet fuel

3. Wind, PV etc. → Alkaline → CO₂ capture → Point → Air → Chemical Synthesis → Methanol, DME, Methane, Jet fuel

TRL 8-9, TRL 7-8, TRL 5-7, TRL 3-8
Case A. Total demand: 7.36 TWh
60% Biogas hydrogenation: 4.42 TWh
20% biomass hydrogenation: 1.47 TWh
20% CO$_2$ hydrogenation: 1.47 TWh

Biogas plant

Manure + organic waste

Electricity

SOEC/Alkaline

Methanation

Methane CNG

Heavy transport demand

Energy PLAN

Advanced energy system analysis computer model

AALBORG UNIVERSITY DENMARK

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Case B. Total demand: 7.36 TWh
60% biomass hydrogenation: 4.42 TWh
20% biogas hydrogenation: 1.47 TWh
20% CO\textsubscript{2} hydrogenation: 1.47 TWh
Case C. Total demand: 7.36 TWh
60% CO$_2$ hydrogenation: 4.42 TWh
20% biogas hydrogenation: 1.47 TWh
20% biomass hydrogenation: 1.47 TWh
Scenarios to test energy system flexibility

1. **Smart Energy System** (100% buffer capacity SOEC and one week H2 storage)
2. **High Temperature synergies** (100% buffer capacity SOEC with increased efficiency. Same storage)
3. **Alkaline** (100% buffer capacity. Same storage)
4. **Reduced electrolyser** (50% buffer capacity. Same storage)
5. **Base electrolyser** (Minimum capacity with no storage)

Across all scenarios:
- similar capacities of power plants an wind
- Excess el. production: 5% of total el. demand
## Electrolyser capacities

<table>
<thead>
<tr>
<th>Electrolyser capacity (MWe)</th>
<th>Reference</th>
<th>Case A: Biogas hydro</th>
<th>Case B: Biomass hydro</th>
<th>Case C: CO2 hydro</th>
<th>Efficiency</th>
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<tbody>
<tr>
<td>SES</td>
<td>8464</td>
<td>8132</td>
<td>8216</td>
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<tr>
<td>HT synergy</td>
<td>7456</td>
<td>7164</td>
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<td>Alkaline elt</td>
<td>9756</td>
<td>9374</td>
<td>9470</td>
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<td>Reduced elt</td>
<td>7317</td>
<td>7031</td>
<td>7103</td>
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<tr>
<td>Base elt</td>
<td>4878</td>
<td>4688</td>
<td>4735</td>
<td>5020</td>
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</table>
Energy system costs

Reference | A: Biogas 60% | B: Biomass 60% | C: CO2 60%

SES | HT synergy | Alkaline elt | Reduced elt | Base elt

M€

20000 | 20500 | 21000 | 21500 | 22000 | 22500

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Biomass consumption

- Reference
- A: Biogas 60%
- B: Biomass 60%
- C: CO2 60%

Legend:
1: SES
2: HT synergy
3: Alkaline elt
4: Reduced elt
5: Base elt
Fuel costs €/GJ

**METHANE - WEIGHTED AVERAGE COST**

<table>
<thead>
<tr>
<th></th>
<th>SES</th>
<th>HT SYNERGY</th>
<th>ALKALINE ELT</th>
<th>REDUCED BUFFER</th>
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<tr>
<td>Case A</td>
<td>33</td>
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<td>41</td>
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</table>

€/GJ

**METHANOL/DME - WEIGHTED AVERAGE COST**

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<tr>
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<td>38</td>
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<td>35</td>
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</table>

€/GJ
Fuel costs €/GJ – sensitivity analysis

METHANE - WEIGHTED AVERAGE
30€/MW ELECTRICITY

<table>
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<tr>
<th></th>
<th>IDA</th>
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<td>22</td>
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METHANE - WEIGHTED AVERAGE
120€/MW ELECTRICITY

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</table>
Methane price structure
Case C – CO₂ hydrogenation

Similar trend in all scenarios!
Three main findings

• Capacity and type of electrolysers has a high impact on energy system costs, fuel costs and biomass consumption

• Electricity costs can take between 30-90% of the fuel price depending on system design and electricity cost

• Smart Energy System operation could have similar energy system and fuel cost to continuous operation
Thank you!

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