Electric vehicles or use of hydrogen in the Norwegian transport sector in 2050?

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Agenda

- Research motivation
- STREAM model
- 2050 scenarios - reference, EV and H₂
- Scenario results
  - In a Nordic content
Research motivation Norway

- highest number of electric vehicles per capita in the world
  - 43,442 EV per December 2014

Radical restructuring of fuel use and vehicle stock

System integration with the electricity market
- A significant share of the electricity demand will come from the transport sector - directly or in-directly via H₂ production

- Larger share of wind in the power supply in the future
- Limited domestic biomass resources
- Need for a flexible demand?

- EV or H₂?
  - Which costs?
  - Interaction with the energy sectors?

Need for holistic systems analysis: Model simulations
STREAM model

**Inputs**
- Energy Demand
- Production
- Conversion Factors
- Technological Development
- Fuel Prices
- Costs
- Emission Factors

**Calculation**
- Demand and Production

**Flow Model Inputs**
- Time Series (heat, wind, solar, electricity consumption)
- Flexibility of Electricity Consumption
- Heat Storage
- Priority of dispatch into the grid and the DH network

**Duration Curve Model Inputs**
- Operating Hours
- Enforced Electricity Export
- Heat Surplus

**Outputs**
- Energy balance
- Fuel Consumption
- Import/Export (Fuels)
- Emissions
- Costs (Capital, Fuel, O&M, Energy Savings, CO₂)
Scenarios for 2050

Carbon Neutral Scenario (CNS) from NETP

Electric Vehicles (EV)

Hydrogen (H₂)
Reference - Carbon Neutral Scenario - CNS

Bar chart showing the proportion of different energy sources by mode of transportation:
- Car
- Bus
- Train
- Aviation & ferries
- Trucks & cargo vans
- Train, goods
- Shipping, goods
- Aviation, goods

Energy sources include:
- UPG Biogas
- Hydrogen
- Biodiesel
- Methanol
- Ethanol
- Natural gas
- Diesel
- Gasoline
- Electricity
Electric Vehicles Scenario - EV

- Car: 90% Electricity, 10% Biogas
- Bus: 80% Electricity, 20% Biogas
- Train: 90% Electricity
- Aviation & ferries: 50% Methanol, 50% Ethanol
- Trucks & cargo vans: 70% Methanol, 30% Ethanol
- Train, goods: 80% Electricity, 20% Ethanol
- Shipping, goods: 90% Methanol
- Aviation, goods: 100% Methanol
Hydrogen Scenario - H₂
## Technology mix in the electricity sector

### Electricity production

<table>
<thead>
<tr>
<th>Technology</th>
<th>Base</th>
<th>CNS 2050</th>
<th>EV</th>
<th>H₂</th>
<th>Base</th>
<th>CNS 2050</th>
<th>EV</th>
<th>H₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Plant</td>
<td>0.1%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gasturbine</td>
<td>4%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wind, offshore</td>
<td>-</td>
<td>5%</td>
<td>5%</td>
<td>10%</td>
<td>-</td>
<td>5.9</td>
<td>7.7</td>
<td>15.1</td>
</tr>
<tr>
<td>Wind, onshore</td>
<td>1%</td>
<td>7%</td>
<td>12%</td>
<td>13%</td>
<td>0.9</td>
<td>8.7</td>
<td>16.8</td>
<td>19.7</td>
</tr>
<tr>
<td>Biomass</td>
<td>-</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Waste incineration</td>
<td>-</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.4%</td>
<td>-</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Photo voltaic</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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</tr>
<tr>
<td>Nuclear</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Geothermal</td>
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<td>-</td>
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<tr>
<td>Coal CCS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Biomass CCS</td>
<td>-</td>
<td>1%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hydro</td>
<td>94%</td>
<td>87%</td>
<td>82%</td>
<td>76%</td>
<td>117.5</td>
<td>113.9</td>
<td>113.9</td>
<td>114</td>
</tr>
<tr>
<td>Electricity imports</td>
<td>1%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1%</td>
<td>123.8</td>
<td>130.9</td>
<td>139.5</td>
</tr>
<tr>
<td><strong>Total production</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>123.8</td>
<td>130.9</td>
<td>139.5</td>
<td>149.9</td>
</tr>
</tbody>
</table>
In contrast to the other Nordic countries, there is not a demand for the transport sector to have a flexible fuel demand in order for the Norwegian energy systems to adjust to a larger share of EV or H₂.
Total annual system costs and the difference between the CNS and the EV scenario (mill €)
Annual system costs and the difference between the CNS and the H₂ scenario (mill €)

Total Annual System Cost [mill €]

Total annual system costs for NO-H₂ compared to NO-CNS [mill €]
Innovation and technological path - H₂

Total additional annual cost of H₂ vs. CNS scenario

- 68% Danish case
- 75% Electricity to H₂
- 80% Electricity to H₂
- 85% Efficiency improvement
- 90%

Change of parameters from reference (normalised values)
In a Nordic context

- Large deployment of wind
- Need for flexibility - especially in DK
  - H₂ generation from electrolysis is more flexible than charging EV

- Hours with excess wind generation which release hydro-power capacity
  - Reduce the need for additional capacity in the H₂ scenario
  - Increase the value of Hydro power

- Biomass resources in Finland and Sweden
  - Bio-fuels cheaper
    - depends on the development of 2nd and 3rd generation bio-refineries
Main findings

- EV could reduce the socio-economic cost of the system in 2050

- The Norwegian hydropower supply is very flexible and can therefore easily adjust to the variable electricity generation from wind energy
  - no demand for the transport sector to have a flexible fuel demand in order for the Norwegian energy systems to adjust to a larger share of EV or H₂.

- More Nordic integration and use of excess generation might decrease the cost of the H₂ scenario
Thank you for your interest

Questions?

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Resources available and used (PJ)

- Crude Oil
- Coal
- Wave
- Geothermal
- Solar
- Hydro
- Wind
- Waste
- Biomass (manure)
- Biomass (Energy crops)
- Biomass (Straw, woodwaste)
- Nuclear
- Natural Gas

Legend:
- NO-EV
- NO-H2
- NO-CNS
- Base
- Available resources