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

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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?
STREAM model

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

Model Calculations:
- Demand and Production

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

Flow Model

Duration Curve Model

Operating Hours

Enforced Electricity Export

Heat Surplus
Scenarios for 2050

Carbon Neutral Scenario (CNS) from NETP

Electric Vehicles (EV)

Hydrogen (H₂)
Reference - Carbon Neutral Scenario - CNS

[Graph showing percentage contributions from different sources for Car, Bus, Train, Aviation & ferries, Trucks & cargo vans, Train, goods, Shipping, goods, and Aviation, goods.]

- UPGR Biogas
- Hydrogen
- Biodiesel
- Methanol
- Ethanol
- Natural gas
- Diesel
- Gasoline
- Electricity
Hydrogen Scenario - H₂

The graph shows the distribution of energy sources for different sectors:
- **Car**: Predominantly hydrogen, with small contributions from biodiesel and electricity.
- **Bus**: Similar to cars, but with slightly less hydrogen and more biodiesel.
- **Train**: Mostly hydrogen, with minor contributions from biodiesel and electricity.
- **Aviation & ferries**: Mix of hydrogen, biodiesel, and methanol.
- **Trucks & cargo vans**: Predominantly hydrogen, with some biodiesel.
- **Train, goods**: Similar to trains, but with a bit more electricity.
- **Shipping, goods**: Mostly hydrogen, with small contributions from biodiesel and methanol.
- **Aviation, goods**: Predominantly hydrogen, with small contributions from methanol.

**Fuel Cell Car**

- **Hydrogen tank**
- **Anode**
- **Membrane**
- **Cathode**
- **Electro engine**
- **Batteries**
- **Power electronics**
- **O₂**
- **H₂O**

**Legend**
- UPGR Biogas
- Hydrogen
- Biodiesel
- Methanol
- Ethanol
- Electricity

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## Technology mix in the electricity sector

<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>
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</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>
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<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>
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<tr>
<td>Photo voltaic</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nuclear</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Geothermal</td>
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</tr>
<tr>
<td>Coal CCS</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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</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>
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<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>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total production</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>
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</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 €)
Innovation and technological path - $H_2$

![Graph showing the change of parameters from reference (normalised values) and the total additional annual cost of $H_2$ vs. CNS scenario. The graph includes points for 75% electricity to $H_2$, 80% electricity to $H_2$, 85% efficiency improvement, and 90% efficiency improvement, with a Danish case indicated.

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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