Energy system pathways of a decarbonization of the Norwegian oil-dependent economy

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Outline

Transition pathways

01 Norwegian energy system

02 TIMES energy system pathways
Part I – Norwegian energy system
The Norwegian energy system

- Electricity generation mainly based on hydropower
  - 2017: 96%
  - Large water reservoirs - 50% of European capacity
- Cold climate → High demand for space heating
- Historically electricity has been relatively inexpensive
  - Energy-intensive industry
  - Electricity based heating system
- Large potential for onshore and offshore wind power
- EVs dominate new car sale
- Petroleum sector- oil & gas export
  - 25% of EUs gas demand in 2017
  - 2 % of global oil demand
Final energy consumption in Norway

Final energy demand, TWh

- Electricity
- Coal
- Oil
- Natural gas
- Bio
- Waste
- District heat

2000: 53%
2010: 30%
2015: 53%
2016: 30%
2017: 53%
A transition requires CO₂ cuts in transport, industry, and oil and gas.
Norwegian GHG emission targets

• **2030**: non-ETS target
  • Minimum 45% reduction in 2030 compared to 2005
  • Minimum 31% reduction in 2030 compared to 2017

• **2050**: Climate neutrality
  • 80-95% reduction compared to 1990
  • 1990: 51.2 Gton CO₂ eq.
  • 2017: 52.9 Gton CO₂ eq.
Energy system

- Biomass resources are limited and have multiple applications

Potential harvest $\approx 50$ TWh

Norwegian forest

- Heat
  - Eff. $\approx 50\%$
- Industry products
  - $\approx 50\%$
- Charcoal
- Export
  - $\approx 50\%$
- Biofuel production
  - $? \ TWh$
  - Eff. $\approx 50\%$
- Transport
  - 2017: 52 TWh
- Import?
- Other bioresources?
Norwegian petroleum sector

- Official production prognosis from Norwegian Petroleum: https://www.norskpetroleum.no/
- Erna Solberg, November 2018: «The person shutting down the Norwegian petroleum sector is not yet born»
Relationship between electricity use and GDP
PM17
Official Prognosis: 0.8 % GDP growth per year and capita

Constant
0 % GDP growth per year and capita

BNP-2015
Replace GDP from oil and gas

Power intensive industry cannot replace all welfare from oil & gas
Illustration of 500 TWh

Aluminium smelters
- Current
- New

Wind farms
- Current
- New
Part II – TIMES energy system pathways

Norwegian Energy Road Map 2050
Norwegian Energy Roadmap 2050

- **Norwegian pathways to a low-carbon energy system in 2050**
  - Presumption: Norwegian welfare is remained with a phase-out of petroleum sector
  - New revenue from service and industry sector

- **Impact of low carbon future on the energy system, power sector and the overall economy**
  - Energy system model: TIMES-Norway
  - Power market model: EMPS
  - CGE model: REMES
TIMES-Norway 2015-2050

- Developed together with the Norwegian Water and Resources Directorate
- Norwegian Spot price regions
- Detailed end-use and power sector
- 260 time-slices
- Currently converted to VEDA_FE from Answer
- Flexible temporal resolution
- High detailed demand sectors
- Ongoing research focus:
  - Flexibility
  - Transport and Buildings
Norwegian Energy Roadmap 2050

• **Norwegian pathways to a low-carbon energy system in 2050**
  - Norwegian welfare level is remained
  - Constant GDP per population
  - Sensitivity
    - 0.8 % increase in GDP per pop and year

• **Scenarios**
  - **REFerence**
    - Petroleum activity according to official prognosis
    - No CO2-limitation
  - **INDustry**
    - Petroleum activity = 50% of current activity
    - Income loss covered by
      - New industry
      - Hydrogen production NG with CCS
      - Biofuels limited and high costs
  - **SERvice**
    - No petroleum activity
    - Welfare loss covered by
      - Highly increase in service sector
      - High energy efficiency implementation
      - Biofuels at current cost and unlimited
Demand projections vary between scenarios - Change from 2015 to 2050

• REF
  • Industry and buildings +7%
  • Road transport +51%

• SER
  • Industry and buildings -7%
  • Road transport: 0%

• IND
  • Industry and buildings +26%
  • Road transport +51 %

• IND-0.8%
  • Industry og buildings +60%
Results- Final energy demand 2030 & 2050 depends on end-use demand and technologies

- **Final energy demand 2050, relative 2015**
  - REF: 5%
  - SER: -22%
  - IND: -2%
  - IND-0.8%: 18%

- **Electricity share 2050**
  - REF: 56%
  - SER: 63%
  - IND: 72%
  - IND-0.8%: 71%
  - (2015: 51%)
Results- Emission cuts is most challenging in Industry
Results- Electricity consumption increases in all scenarios except SERvice

<table>
<thead>
<tr>
<th>Sector</th>
<th>2015</th>
<th>REF</th>
<th>SER</th>
<th>IND 0%</th>
<th>IND 0.8%</th>
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</thead>
<tbody>
<tr>
<td>Industry</td>
<td>+9%</td>
<td>+36%</td>
<td>+76%</td>
<td>-23%</td>
<td>+9%</td>
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<tr>
<td>Buildings</td>
<td>-5%</td>
<td>+11%</td>
<td>+3%</td>
<td>-5%</td>
<td>+11%</td>
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<tr>
<td>Transport incl. H2-prod.</td>
<td></td>
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<td></td>
<td>+24%</td>
<td>+13%</td>
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</tbody>
</table>

Electricity consumption 2050, TWh/year

- Industry
- Buildings
- Transport incl. H2-prod.
Results - Fuel use in transport sector is scenario dependent

- Bio fuel share 2050
  - REF 11%
  - SER 75%
  - IND 22%

- Electricity share 2050
  - REF 18%
  - SER 25%
  - IND 32%

- Hydrogen share 2050
  - REF 0%
  - SER 0%
  - IND 46%
Results- Significant new wind power investments in all scenarios

<table>
<thead>
<tr>
<th>Year</th>
<th>Hydropower</th>
<th>Wind power</th>
<th>PV</th>
<th>Other</th>
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<tbody>
<tr>
<td>2015</td>
<td>2 TWh</td>
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<tr>
<td>2030</td>
<td></td>
<td>17 TWh</td>
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<tr>
<td>2050</td>
<td></td>
<td>49 TWh</td>
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<tr>
<td>2050</td>
<td>87 TWh</td>
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Power generation, TWh/year

- **Hydropower**
- **Wind power**
- **PV**
- **Other**
Power generation INDustry scenario depends on policy and technology development

- IND1: Basis
- IND1E: No energy efficiency
- IND1T: 2017-taxation
- IND1W: Onshore wind power <26 TWh
- IND1W2: W + increased grid fee 10 øre/kWh
- IND1W3: W + double grid fee
- IND1W4: W3 + cheaper PV
Conclusions- Norwegian energy system pathways

- There are several transition pathways to a low-carbon Norwegian energy system
  - Dependent on future revenue streams
  - Technology development; e.g. hydrogen & sustainable biofuels
- A low-carbon future requires considerably changes to the Norwegian energy system
  - More electrification/ H2 and use of biomass
  - New power generation
- Actions are required today to facilitate a Norwegian transition to a low-carbon energy system
  - Alternative revenue streams than oil and gas
  - Infrastructure
Thank you

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