Green Hydrogen

Key challenges and perspectives from Denmark

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Introduction to speaker

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• PTX is not the primary technology, but necessary in the long run
• Useful for the “high-hanging-fruit” sectors
• DK has just started its process
• DK will use mix of PTX technologies
• There may be technical limitations in future for PTX utilization
Green Hydrogen - Basics

Renewable energy → Electricity → Water → Electrolysis → Green Hydrogen
Upgraded Green Hydrogen

where electrification is not possible

Renewable energy
Electricity
Water
Electrolysis

Hydrogen
Heavy road transport

Hydrogen
Shipping (ferries)

Hydrogen
Industry

Excess heat
District heating

E-fuels

Ammonia
Shipping

Methane
DME
e-gasoline
e-diesel
e-jet fuel

Shipping
Aviation
Heavy road transport
Direct electrification is most efficient

Electron-to-wheel efficiencies for zero emission cars

![Diagram showing electron-to-wheel efficiencies for different types of zero emission cars. The diagram compares Direct electrification (BEV), Hydrogen fuel cell vehicle (FCV), and Power to liquid conventional vehicle (e-fuels).]

- **Direct electrification (BEV)**: 77%
  - Total efficiency: 95%
  - Fuel production efficiency: 95%
  - Charging equipment (EVSE): 5% energy losses
  - Battery charge efficiency: 5% energy losses
  - H₂ to electricity conversion: 5% energy losses
  - Inversion DC/AC: 5% energy losses
  - Engine efficiency: 77% overall

- **Hydrogen fuel cell vehicle (FCV)**: 30%
  - Total efficiency: 61%
  - Fuel production efficiency: 61%
  - Charging equipment (EVSE): 5% energy losses
  - Battery charge efficiency: 5% energy losses
  - H₂ to electricity conversion: 46% energy losses
  - Inversion DC/AC: 5% energy losses
  - Engine efficiency: 70% overall

- **Power to liquid conventional vehicle (e-fuels)**: 13%
  - Total efficiency: 44%
  - Fuel production efficiency: 44%
  - Charging equipment (EVSE): 5% energy losses
  - Battery charge efficiency: 5% energy losses
  - H₂ to electricity conversion: 46% energy losses
  - Inversion DC/AC: 5% energy losses
  - Engine efficiency: 70% overall

**Source:** "Roadmap to decarbonising European cars", Transport & Environment, 2018
GREEN HYDROGEN TECHNOLOGIES IN PLAY
Electrolysers - Alkaline vs. PEM

Alkaline

Cheaper
No use of rare materials
Slightly better efficiency

Limited ramping
Very limited start/stop

PEM

Good ramping
Can cold start

Rare materials
More expensive
Electrolyser - Alkaline vs. PEM

Alkaline
- Cheaper
- No use of rare materials
- Slightly better efficiency
- Limited ramping
- Very limited start/stop

PEM
- Good ramping
- Can cold start
- Rare materials
- More expensive

BOTH
VRE both baseload and flex
VRE both baseload and flex

More VRE is to make this the default, not a rare occurrence

*Stable overproduction compared to general demand*

*Higher VRE production peaks*
Substantial industrial interest in hydrogen and power-to-x

CIP and partners
- Vision of 1 GW electrolysis
- 900,000 tons of ammonia

Industrial consortium announced May 25th 2020
- Ørsted, A.P. Møller - Mærsk, DSV Panalpina, DFDS, SAS, Copenhagen Airport
  - vision of 1.3 GW electrolysis plants for production of green fuels

Maersk Mc-Kinney Møller Center for Zero Carbon Shipping
- Linked to Maersk’s ambition on the first CO2-free ocean-going vessel no later than 2030
- 133 mill. € over the next 10 years
Examples of ongoing RD&D projects
Substantial industrial interest in hydrogen and power-to-x

Greenlab Skive
  Hydrogen, methanol and storage
  12 MW electrolysis +1.6 MWh battery

Everfuel and Shell
  Hydrogen
  20 MW -> 1 GW PEM for use in refining

Hydrogen Valley and Air Liquide
  Hydrogen
  1 MW PEM for transportation

Ørsted and partners (H2RES)
  2 MW electrolyses
  For transportation
PTX will grow to become a significant industry in Denmark's Energy system.
15,000 GWh in 2040
~8% of DK energy consumption 2020
Topics and messages
PTX in Denmark, lessons being learned and the role of PTX in the future

• Heavy transport, shipping and aviation will be major consumers of PTX
• Projections to have PTX as major part of Denmark’s energy system
• PTX less efficient and costlier than direct electrification – high hanging fruits
• The relevant industries, with support from government, are already working on PTX
Thank You