LARGE SCALE HYDROGEN PRODUCTION AND LIQUEFACTION

Petter Neksåa,b and David Berstad\textsuperscript{a}

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\textsuperscript{a} SINTEF Energy Research, Department of Gas Technology, NORWAY
\textsuperscript{b} NTNU, Department of Energy and Process Engineering, NORWAY

Contact: Petter Nekså (petter.neksa@sintef.no) and David Berstad (david.berstad@sintef.no)
Outline

1. *HYPER*- LIQUEFIED HYDROGEN PRODUCTION FROM SURPLUS WIND/HYDRO POWER AND FOSSIL SOURCES IN NORWAY (KPN project)
2. Scale and duty targeted by *Hyper* – possibilities in a Norwegian context
3. Research tasks in the *Hyper* project on hydrogen production and liquefaction
4. Conclusions
The Hyper concept
Scale and duty requirements – production volume rate and storage

• Envisioned production volume: **500 tons per day**
  - Required volume for one 160 000 m³ ship loading every 3 weeks (16 calls annually)
  - Comparison, Snøhvit LNG plant: 60–70 calls per year

• Energy flux in the hydrogen product stream:
  - 5.8 kg/s * 142 MJ_{HHV}/kg ≈ **820 MW_{HHV}**

• Corresponds to about **7 TWh per year** of energy output

• Theoretical minimum storage volume: 160 000 m³. Sketch below indicates size of 5 aligned 40 000 m³ spherical LH2 storage tanks (200 000 m³)
Main criteria
- Natural gas availability
- Grid power availability
- Port availability

Important cost drivers
- Natural gas price
- Electricity cost
- CAPEX
Scale and duty requirements –
Energy requirement

If 500 tons per day of hydrogen is produced **entirely by water electrolysis**

- Water splitting (70–75 % conv. efficiency ≈ 1 100–1 200 MW_{el}) and hydrogen compression, liquefaction and utilities (≈ 200–300 MW_{el}) total power requirement: ≈ 1.2–1.5 GW_{el}

- Annual electrical energy requirement (95% availability):
  - **11–13 TWh_{el}/a**
  - Corresponds to almost 10 % of annual hydro power production (most likely to be consumed in one point)

If 500 tons per day of hydrogen is produced **entirely by natural gas reforming**

- Natural gas requirement:
  ≈ 0.7–0.8 GSm³/a

- Compared to Hammerfest LNG: 15% of the NG liquefaction capacity and CO₂ sequestration about 2.5 times current rate

- Hydrogen liquefaction, CCS, utilities:
  ≈ 0.2–0.3 GW_{el}

- Annual electrical energy requirement (95% availability):
  - **1.4–2.2 TWh_{el}/a**
Norway's current energy production potential

- Norway's vast fossil energy surpluses are mainly exported
- The energy surplus from renewable hydropower and wind power is expected to increase in the long term
- Fossil resources will remain dominant in a fairly long-term time horizon
The Hyper concept with conventional technologies (baseline to be improved)

- Natural gas
- Furnace gas
- Air
- Water
- Waste O₂

**Feedstock**
- Pre reformer
- Steam-methane reformer
- High-temperature water-gas shift
- Low-temperature water-gas shift

**Components**
- Furnace
- Pressure-swing adsorption polishing
- aMDEA CO₂ absorption unit
- CO₂ conditioning and compression
- Waste O₂
- H₂ compression
- CH₂ buffer storage
- H₂ Liquefiers
- LH₂ storage

**Outputs**
- H₂
- Mainly H₂
- Mainly H₂ + CO₂
- Captured CO₂
- Boil-off H₂ and gas return
- Exhaust

**Other**
- Alkaline water electrolysis
- Water
Important research tasks in Hyper

Mature technology options exist for all parts of the production system, but advances are still required to improve the chain efficiency:

• Natural gas reforming, $\text{H}_2/\text{CO}_2$ separation, $\text{H}_2$ purification
  o Novel part-technologies (e.g. Pd membranes) and new combinations of complementary technologies
  o Carbon capture rate (CCR) → Target: 90-95 %

• Hydrogen liquefaction
  o Scaling up: 5-15 t/d → Target: x 10
  o Efficiency improvement: 11–13 kWh\textsubscript{el}/kg\textsubscript{LH}_2 → Target: ÷ 50 %

• Electrolysis
  o Optimal sizing and operation of the electrolysis system for renewable hydrogen
    → Target: Optimal integration of electrolysis

Obtaining detailed knowledge needed for value chain analysis on a level from unit operations to overall system evaluation
Conclusions

- Norway has a large potential for utilising its energy resources for large scale hydrogen production for export
  - A major portion of the hydrogen should probably be produced from natural gas with CCS
  - Several production sites in Norway are interesting for further investigation
  - More detailed case studies to understand barriers and cost picture are needed

- The Hyper project will contribute investigate the potential for large scale hydrogen production and liquefaction in Norway
  - through evaluation and analysis of the different elements required for hydrogen production and liquefaction

- Hydrogen production and export from Norway may be a very interesting option to:
  - valorisation of our energy resources
  - contributing to reductions in global CO₂ emissions - transport, industry and power prod
  - realising new industrial-scale CCS projects
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Contacts: Petter Nekså (petter.neksa@sintef.no) and David Berstad (david.berstad@sintef.no)

Project website: http://www.sintef.no/hyper
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