

# Comparison of Cost and GHG Emissions of Hydrogen Import Pathways to Germany from European Countries and Overseas

Prepared by Markus Schwenk, Sphera Solutions GmbH

# Background

Hydrogen (H<sub>2</sub>) is expected to play a key role in the future European energy system, especially in the heavy-duty mobility sector, as it can be produced from renewable electricity and used with almost no greenhouse gas (GHG) emissions and without any compromise in vehicle range compared to conventional diesel vehicles. On the other hand, establishing a European H<sub>2</sub> supply and refueling system, similar to the existing diesel and natural gas supply system represents a great technical challenge and will lead to high economic costs.

**Production in Middle East (Qatar)** 

# Methodology

The study compares the environmental impact and economic cost of several different pathways to import H<sub>2</sub> from other European countries and from overseas to Germany. This includes production via renewable electrolysis (various electricity sources) as well as conventional production via natural gas steam reforming. The whole logistics chain is analyzed from a lifecycle perspective (GHG/LCC analyses) for different transport modes (ship, truck-trailer, pipelines) as well as physical states of H<sub>2</sub> (liquid-LH<sub>2</sub>, gaseous-GH<sub>2</sub>). Refueling is assumed to be carried out at large-scale hydrogen stations for long-haul heavy-duty trucks in a further developed hydrogen economy in year ~2035.

#### LH<sub>2</sub>-Ship **Production in Western Europe** • LH<sub>2</sub> Transport (trailer) Existing NG Pipeline • GH<sub>2</sub> Transport (trailer) GH<sub>2</sub>-Pipeline ····· H<sub>2</sub> Pipe to be build • Pipeline (+ GH<sub>2</sub> trailer) LH<sub>2</sub> Ship pathway • Pipeline (+ LH<sub>2</sub> trailer) **Production in North Africa (Morocco)** • LH<sub>2</sub> Ship + EU distribution (as above) • Pipeline + EU distribution (as above)

# • LH<sub>2</sub> Ship + EU distribution (as above)

#### GHG results in kg CO<sub>2</sub>e/kg H<sub>2</sub> 11,3 12 11 10 $LH_2$ refueling $\leftarrow$ → GH<sub>2</sub> refueling 8,0 9 (-29%) 8 9,9 6 5 1,9 1,4 (-82%) 1,4 1,3 1,3 (-83%) 1,3 1,3 1,3 1,2 (-88%) (-87%) (-88%) (-89%) (-88%) (-88%) (-89%) (-90%)0,6 0,6 1,4 Pipe + LH2 tr. LH2 trailer LH2 trailer LH2 trailer LH2 trailer GH2 trailer Pipeline On-site LH2 trailer Pipeline LH2 trailer LH2 ship LH2 ship LH2 ship Sea Pipeline LH2 ship Sea Pipe Electrolysis Electrolysis Electrolysis SMR (incl. CC) Electrolysis Electrolysis Electrolysis Electrolysis ■ Dist. + Stor. + Liq. Diesel supply Sea transport Production ■ Diesel combustion ■ EU liquefaction ■ Refueling Compression EU transport EU transport distance: 200 km 10 Cost results in €/kg H<sub>2</sub> LH<sub>2</sub> refueling ← → GH<sub>2</sub> refueling 6,7 5,4 1,3 4,9 4,7 0,9 4,2 3,5 3,3 3,5 3,5 3,9 3,6 Today's diesel 1,0 cost ~1 €/I 1,0 0,4 0,3 0,4 0,3 5.4 0,9 0,9 0,9 2 2,9 2,9 Pipe + LH2 tr. LH2 trailer LH2 trailer LH2 trailer LH2 trailer LH2 trailer GH2 trailer Pipeline On-site LH2 trailer Pipeline EU transport 💛 Sea transport — Sea Pipeline LH2 ship LH2 ship Sea Pipeline LH2 ship LH2 ship Production ightharpoonupElectrolysis SMR (incl. CC) Electrolysis Electrolysis Electrolysis Electrolysis Electrolysis Electrolysis

# **Assumptions**

#### **Production in Western Europe**

500 MW Capacity: 250 Mio € Capex:

Electricity cost: 5,5 €ct/kWh (Wind)

12 €ct/kWh (Grid)

~4.100 h/a Full load hours:

### **Production in North Africa**

4.000 MW Capacity: 2.000 Mio € Capex: Electricity cost: 1,1 €ct/kWh Full load hours: ~2.600 h/a

## **Production in Middle East**

4.000 MW Capacity: 2.000 Mio € Capex: 1,1 €ct/kWh Electricity cost: Full load hours: ~2.600 h/a

### Sea transport

LH<sub>2</sub> ship distance North Africa (NA): 2.700 km (Casablanca (Morocco) to Rotterdam)

LH<sub>2</sub> ship distance Qatar: 11.800 km (Doha to Rotterdam)

NA-Gibraltar pipeline: 30 km Gibraltar-Rotterdam pipe: 2.500 km

### **EU transport distance**

Rotterdam-Germany: 200 km

## References

Sphera knowledge database, based on H<sub>2</sub> project experience, supplier data and academic publications (US DOE  $H_2$  publications (2010-2019), Forschungszentrum Jülich publications (2017-2020), FCHJU (2010-2020) and many others)

- Takeaways ➤ Reduction of lifecycle GHG emissions up ➤ to ~90% compared to conv. diesel
  - High GHG emission reduction at all pathways except on-site production
  - > On-site production with higher GHG emissions because of grid electricity mix
- International supply of renewable H<sub>2</sub> with total cost well below 4 €/kg
- > Total supply chain cost of H<sub>2</sub> prod. in the EU of ~5 €/kg (LH<sub>2</sub>) vs. ~5,5 €/kg (GH<sub>2</sub>)
- > On-site production with higher cost per kg because of high grid electricity price

Contact: Markus Schwenk mschwenk@sphera.com



