H2Global Stiftung

Summary Minutes Meeting 4

Working Group 1 'Standardisation, Certification, Creditability & Tradability' & Working Group 2 'Supply Chain Development and Risk Management'

25.10.2022, 2 p.m. – 3:30 p.m.

I. Background and Goal[1]:

The meeting as part the H2Global Working Group 1 and 2 showcased selected results of the study *Site-specific, comparative analysis of the structural, technical, economic conditions in developing and emerging countries to identify existing challenges and suitable PtX paths or products*[2] conducted by Fraunhofer ISE. The study analyses a select group of countries with regards to their potential for large-scale renewable energy and PtX projects. The study also analyses various renewable energy / PtX technologies as well as different modes of PtX transportation along with their associated costs. Christoph Hank, Marius Holst, Sven Längle, Tom Smolinka, Christoph Kost, and Achim Schaadt presented the results of the research and gave extensive answers to questions from the group of donors.

II. Presentation of Fraunhofer ISE (Christoph Hank, Marius Holst & Christoph Kost):

1. Project overview, framework, and assumptions:

- The target year for this study is set at 2030 with the assumption being that the products are available in that year. Therefore,
    - 2025-2027 is the start of construction for RE parks and infrastructure such as grids, roads, ports;
    - In 2028-2029 manufacturing and delivery of central large components such as DAC (Direct Air Capture), electrolysis, synthesis/ liquefaction is carried out.
- The following criteria is included for renewable energy:

[1] The working groups' primary goal is to provide knowledge and recommendations to the public and, within the framework of its statutory purposes, to policy makers in order to support a rapid market ramp-up of green hydrogen and its derivatives. For compliance reasons, the accumulated knowledge will be published on our website and papers will be prepared in order to place the results in a broader context.

[2]This is the English translation of the original German title which reads as follows: *Standortspezifische, vergleichende Analyse der strukturellen, technischen, ökonomischen Gegebenheiten in Entwicklungs- und Schwellenländern zur Identifikation von bestehenden Herausforderungen und geeigneten PtX-Pfaden bzw. -Produkten.*

  - Electricity from “additional” renewable energy plants;
  - New dedicated networks for the transportation of electricity;
  - Based on wind and solar PV.
- For the electrolysis a fixed value of 1 GW_{el} is implemented. The electrolysis is powered on 100% renewable energy, without grid electricity.
- The following criteria is included for the synthesis/ liquefaction:
  - Mostly supplied by renewable energy;
  - Grid electricity is only used if the renewable generation is insufficient.
- The following criteria is included for the production infrastructure:
  - The renewable energy plant is located at the site of a suitable location, and the electricity transportation is carried out by additional grid capacities;
  - The PtX hub is based at the site of export terminal.
- CO_2 is provided by DAC. One additional scenario with a CO_2 point source is also simulated.
- The water supply is covered by sea water desalination in arid and water stressed regions.

2. PtX country-product-matrix:

- H2Global provided the country and product selection for this study.
  - Brazil: Ammonia, LH_2 (Liquid Hydrogen)
  - South Africa: Ammonia, Methanol, LH_2
  - Ukraine: Ammonia, GH_2 (Gaseous Hydrogen)
  - Colombia: Ammonia, Methanol, LH_2
  - India: Ammonia, Methanol, Jet Fuel, LH_2
  - Namibia: Ammonia, Methanol, LH_2
  - Tunisia: Ammonia, Methanol, GH_2
  - Algeria: Ammonia, Methanol, GH_2
  - Morocco: Ammonia, Methanol, GH_2
  - Mexico: Ammonia, Methanol, GH_2
  - Spain: Ammonia, Methanol, Jet Fuel, GH_2
  - Australia: Ammonia, Methanol, Jet Fuel, LH_2

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- H2Global defined the transport method for export. For countries in close proximity to Germany (Ukraine, Tunesia, Algeria, Morocco, Spain) the pipeline transport of gaseous hydrogen is specified. For all other products and countries, the transport is set via ship.

3. Methodology:

- The methodology for the techno-economic and environmental assessment is based on three consecutive parts:
  - Location analyses for large-scale RE and PtX
    - GIS (Geographic Information System) analysis of the countries with factors such as population density, topography, land use, weather, and infrastructure as guiding principles (Choice of 3-4 sites per country);
    - Costs (capital costs, grid power costs);
    - Final export destination;
    - Additional requirements (requirement for desalination/ availability of land);
    - Analysis of annual wind and solar timeseries;
    - Analysis of transportation routes.
  - PtX system optimization
    - Production and supply chains;
    - Use of genetic algorithms (to minimize costs by changing defined variables);
    - Dynamic, non-linear modelling.
  - Results output
    - Key performance indicators (Levelized cost of production, water consumption, energy flows, total PtX product etc.);
    - Optimization of e.g., ratio of wind/solar to electrolysis and hydrogen storage for cost optimum.

4. Technology parameters:

- Fraunhofer ISE gives an extensive overview and explanation of the chosen technological parameters for their simulation (list is not exhaustive):
  - Solar PV:

        - High efficiency modules;
        - Large arrays in open space without tracking;
        - Equator oriented with optimal tilt.
    - Wind: universal plant type of Enercon (E112 4500 kW, 124 m hub height);
    - Weather Data: Plant-specific generation time series according to Renewables Ninja (10-year average);
    - Electrolysis: PEM-based plant with a 30-year-life;
    - Ship Transportation: different ships for each PtX Product (Ammonia, Methanol, Liquid Hydrogen, Jet Fuel);
    - Pipeline Transportation: a dedicated pipeline for the project (where suitable).

5. **Country location analysis:**

- Fraunhofer ISE explains in detail the location analysis via GIS analysis, location parameters, annual wind and solar time-series, and transport route analysis. The results are shown for three selected countries.
- Brazil:
    - Rio Grande do Norte has very high wind and solar potential and is situated close to the coast;
    - Bahia North has high wind and solar potential, an existing pipeline, and power-grid infrastructure;
    - Rio Grande do Sul has high wind potential but moderate solar potential. It is also located close to the coast.
- Namibia:
    - Walvis Bay has moderate wind potential but high solar PV potential. It is located close to relevant infrastructure;
    - Windhuk also has moderate wind and high solar potential. IT is also located close to relevant infrastructure;
    - Lüderitz has good wind potential and wind turbines are currently under construction. The solar potential is high, and the site is located close to infrastructure;

    - Keetmanshoop has good wind potential, high solar potential, and is located close to infrastructure.
- Morocco:
    - Bouarfa has moderate wind potential, high solar potential, and the site has available open areas;
    - Essaouira has high wind potential, high solar potential, and is located close to the coast;
    - Tan-Tan has high wind potential, high solar potential, and is located close to the coast. It also has available open areas.

6. Preliminary results of techno-economic assessments:

- Hydrogen is produced based on 100% dedicated local renewable energy;
- The water supply via desalination is possible at negligible costs;
- In the case of H2 transport via pipeline: If the conversion of existing natural gas pipelines to hydrogen is possible, this transport vector offers unbeatable value for import of re-newable energies at large-scale;
- CO2 provision via Direct Air Capture is location -independent but investment and energy intensive and with high space requirements. The utilization of unavoidable carbon point sources is sensible where possible;
- A combination of wind and photovoltaics is beneficial for the system capacity utilization.
- The transport of liquid hydrogen comes with high costs. Also, the availability of large-scale LH2 ships in 2030 on a global scale is still an open question;
- Liquid hydrogen benefits from high pathway efficiency and dynamics and a reduced H2 buffer storage demand;
- Import via the ammonia pathway has the lowest overall supply costs;
- The liquid hydrogen and methanol pathway come with slightly increased supply costs (~+15% depending on location).

III. Questions and Answers:

- Why did you confine the capacity of the electrolyser to 1 GW? That way you have not considered economies of scale.
    - 1 GW was a limitation set by the study requirements.

- Why did you choose the PEM electrolyser rather than the alkaline electrolyser? On the market we see that the majority of electrolysis is based on the alkaline technology.
    - If we only look at the costs of electrolysis, alkaline systems might be cheaper compared to the PEM electrolyser. However, the PEM electrolyser performs better with dynamic loads.
- Did you consider any form of battery extension to include peak shaving for the electrolyser?
    - In this study we did not consider any battery capacity. Of course, in a real system, batteries for peak shaving are necessary.
- You considered different types of ships but did not focus on port facilities as they are also relevant.
    - A dedicated focus on port infrastructure and other relevant facilities was not part of this specific study.
- In general you are considering DAC, but in Morocco you also considered CO2 point sources. Did you also consider the possibility of using biogenic carbon? For example, in Brazil there are plenty of sources of biogenic carbon.
    - No, we did not consider biogenic carbon as that was beyond the scope of this specific study.
- Did you consider CIS (Cargo Information Service) or CFR (Cost and Freight) for transport? Do the overall costs include the transportation and storage at the destination as well?
    - We did not consider storage costs in Germany as that was not the focus of this study.
- How is the availability of water assessed? In which countries will desalination plants be used?
    - We considered desalination in all countries included in this study apart from Brazil, Ukraine and Colombia. For the assessment we used the Water Stress Index.
- You showed different sizes of ships from 11,000 tonnes to 110,000 tonnes. Can all ports accommodate ships of these sizes?
    - There is some uncertainty with regards to port sizes. We considered all ports that are ranked “small” on the World Port Index. They would need to increase the capacity or think of other solutions like bunkering of the product e.g. 1 km

offshore and then a pipeline delivering it in-land. However, this aspect was not part of this specific research.

- With regards to CO2 provision: You assumed DAC (Direct Air Capture) and point sources. What costs of transportation have you taken into consideration to transport CO2 from point sources to the sites?
  - We only considered the capture cost. We can assess the proximity, transportation etc. in future projects but the project proposal for this specific study did not enable this. Long distances would mean that costs increase.
- What are the advantages/ disadvantages of countries such as Australia, Spain, and Saudi Arabia as compared to developing countries? Can you give us a short overview?
  - This will be part of the final report. We have identified the regions, but we still need to do a techno-economic analysis. For Australia and Spain, it will be interesting how Australia performs as compared to Spain with regards to transportation costs and energy losses.
- Have you looked at Liquid Organic Hydrogen Carriers (LOHC) such as Toluene?
  - No. We did not do that in this specific case, but we have a separate study where we considered Toluene.
- Have you considered large-scale underground hydrogen storage? Is that something you would be willing to include?
  - We did not focus on large-scale underground storage of hydrogen in this study. We could think about implementing that in our model in the future.
- How can a level playing field be ensured in terms of the requirements on imported H2 versus domestically produced H2?
  - A global standard is envisioned. That would ensure a level playing field for all producing countries.

IV. Further procedure:

If there are ideas for speakers or desirable input for the upcoming session from among the participants, participants are asked to provide feedback on them to the team of H2Global Foundation.