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CIMAC White Paper 1

Production Pathways for Hydrogen with a Zero Carbon Footprint

From the Greenhouse Gas Strategy Group

The first edition of this CIMAC White Paper was approved by the members of the CIMAC Council at its meeting on November 21, 2019.

Introduction

Like other sectors, the maritime sector also needs to contribute to the mitigation of climate change. The Initial IMO GHG Strategy set out targets for the maritime industry to reduce CO_2 emissions per transport work by 70% in 2050 and reduce total GHG emissions by at least 50% in 2050 compared to 2008 level[1].

The maritime sector requires fuel of approximately 270 million tons of oil equivalent (toe) per year[2] (1 toe ≈ 11630 kWh) and is thus facing the challenge to find alternatives to current fossil fuels. Biofuels have been controversially discussed. Amongst others, the discussions have been focusing on sustainability, traceability, the overall GHG reduction impact as well as the availability of biofuels in sufficient volumes for shipping. For example, it is projected that 6.3-7.8 Mtoe of advanced biofuels will be produced in the EU in 2030[3] - not even enough to supply the business-as-usual EU road and rail energy demand in 2030. Additionally, other industries are also interested in biofuels as an alternative to fossil fuels. Full electrification is difficult in deep-sea shipping due to the large distances, the high energy demand for powering deep-sea ships and its space requirements.

While biofuels might play a role particular in the transitional period and electrification might play a bigger role in short-sea and inland shipping, fuels based on hydrogen with a zero or net zero carbon footprint are key for deep-sea shipping to drastically reduce GHG emissions.

Electrolysis

Hydrogen can be produced via electrolysis using electricity from renewable energy sources like wind, solar or hydro. In the electrolysis water is split into hydrogen and oxygen. There are different forms of electrolysis, for example alkaline (ALK), proton exchange membrane (PEM) and high temperature electrolysis (HTE).

ALK electrolyzers are well established and the most wide-spread form of electrolysis for hydrogen production. PEM electrolyzers are commercially available, can operate more flexible and are more reactive than current alkaline electrolyzer technology. Generally, electrolysis has efficiency levels between 60-80%[4]. Low temperature electrolyzers like ALK and PEM have an efficiency level of about 65% (lower heating value) on average today. Higher efficiency levels can be expected through optimization, for example, through the reduction of current density in the stack. These measures come with higher specific acquisition cost because the overall cell area increases[5]. High temperature solid oxide electrolyzers (SOE) may offer the potential of improved energy efficiency (80-90%[6]), but the maturity level has clearly to be increased. While PEM electrolyzers require significant amounts of platinum for their catalyst, SOE production mainly requires ceramics and only few rare materials[7]. Another option is the high temperature co-electrolysis which has the potential of high efficiencies by combining two energy-intensive processes (electrolysis and carbon monoxide production via reverse water-gas shift reaction). The HT-co-electrolysis has the

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[1] Resolution MEPC.304(72)
[2] DNVGL (2019) – Maritime Forecast to 2050
[3] Transport&Environment (2017) – A target for advanced biofuels
[4] Kumar and Himabindu (2019) - Hydrogen production by PEM water electrolysis – a review
[5] BMVI und NOW (2018) - Studie IndWEDe
[6] Malins (2017) – What role is there for electrofuel technologies in European transport's low carbon future?
[7] IRENA (2018) – Hydrogen from renewable power

advantage of improved overall efficiency because the syngas is provided at pressure levels fitting with subsequent processing steps to produce liquid fuels.[8]

Under consideration of current efficiency levels, electricity supply in the grid has to be almost 100% from renewable sources for a net reduction effect for shipping. An alternative is the production at dedicated places which requires time and upfront investment for a setup.

Steam methane reforming, pyrolysis and CCS

As neither electrolysis on a large-scale, nor enough renewable electricity are yet available, other hydrogen production pathways could pose an alternative for a transitional phase. Using carbon capture and storage (CCS) with steam methane reforming (SMR) or carbon sequestration with pyrolysis could enable a faster transition to a large-scale hydrogen supply for many industries. Even though these pathways do not produce hydrogen with a zero carbon footprint, they could reduce emissions in the short-term or could later be transitioned to a production based solely on renewable energy sources.

Nowadays, 95% of hydrogen production is fossil-fuel based with SMR as the most common production way[9]. Mainly natural gas is used for SMR with high temperature and pressure, and the help of a nickel catalyst. The captured CO_2 from the exhaust gases of SMR can be used in other industry sectors or it can be stored. However, CCS is not matured enough and an energy-consuming process, plus transport and storage. It requires the establishment of a sound and standardized regulatory framework and monitoring to avoid negative environmental impacts or carbon leakage[10].

Pyrolysis is the thermal decomposition of carbon-based materials in the absence of oxygen. During pyrolysis, carbon is extracted in its pure form as a powder (char). Logistics for pure carbon handling and disposal are simple and long-term underground storage is easily possible. It can also be used in the chemical industry. Production cost are possibly below the hydrogen pathway from renewable electricity via electrolysis at least for a transition period[11].

Demand for renewable energy and hydrogen derivates

The maritime sector will be in competition for hydrogen with a (net) zero carbon footprint and derived fuels with various sectors globally, e.g. aviation, off-highway and road transport. Additionally, the entire natural gas pipeline grid required for heating and power generation purposes on a seasonal basis must be fed with renewable energy carriers – based on hydrogen – too. Figure 1 shows schematically the before mentioned production pathways and applications in various sectors.

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[8] Kopernikus Projekt (2019) – Optionen für ein nachhaltiges Energiesystem mit Power-to-X Technologien
[9] IRENA (2018) – Hydrogen from renewable power
[10] UBA (2018) – Carbon Capture and Storage
[11] Machhammer and Maß (2019) - Hydrogen as the basis for mobility with a low carbon footprint

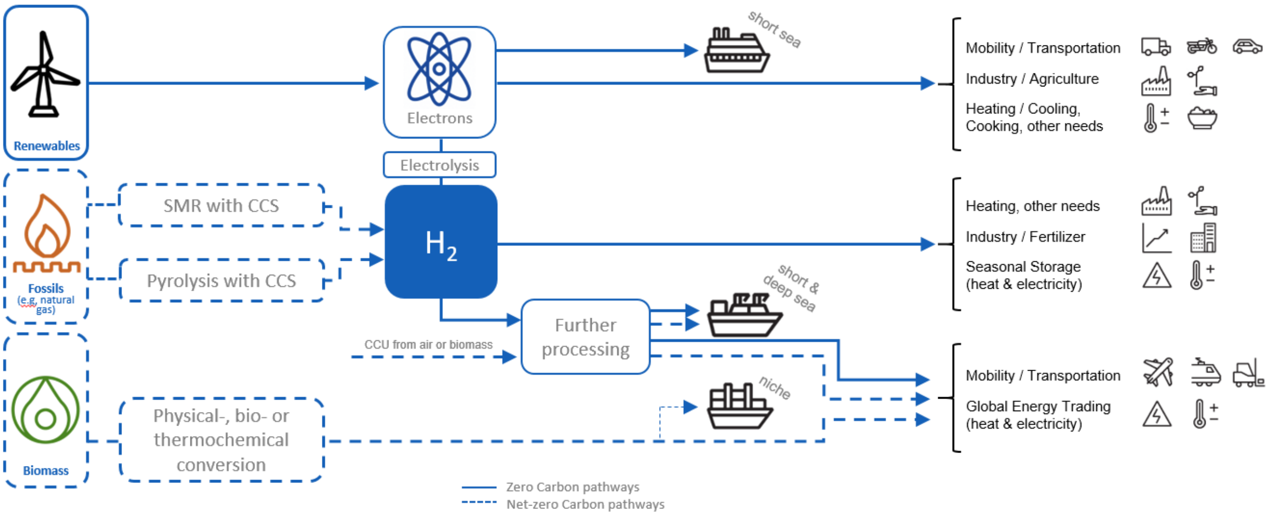

Figure 1: Simplified schematic view of hydrogen production pathways, biomass and fossil pathways as transitional technologies; CCS= Carbon Capture and Storage; CCU= Carbon Capture and Utilization; SMR= Steam Methane Reforming (Source: ABB, 2020)

Thus, many industries, which currently still produce hydrogen from natural gas, need to switch to zero carbon energy sources for hydrogen production in the future. This change requires dedicated renewable electricity for large-scale production of hydrogen to ensure that the decarbonization of the public electricity grid is not affected. Bearing in mind the lead-time for a setup of renewable energy and carbon-free hydrogen production facilities, major investments are needed in near-term.

Imprint

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