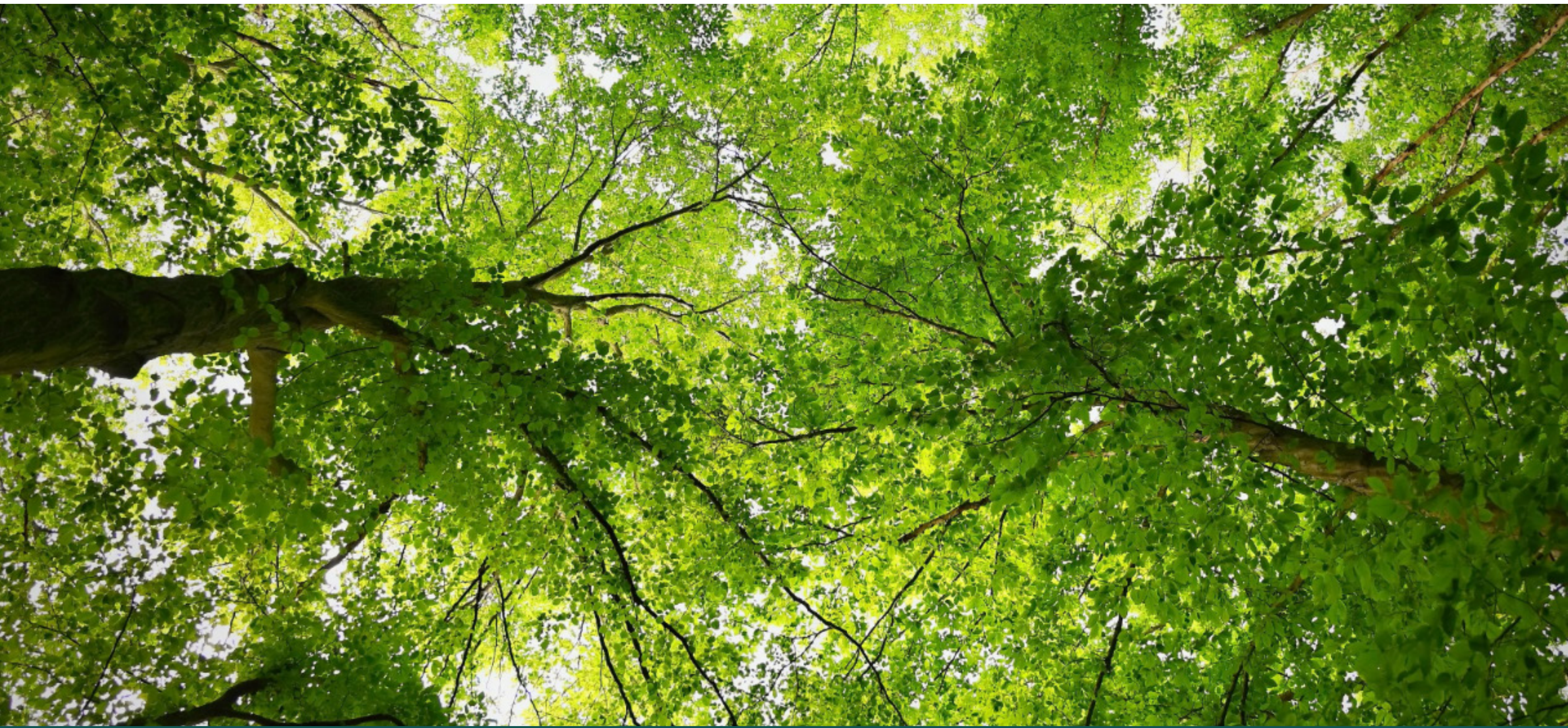
The 4 Pillars of e-NG

Unlocking Scalable Renewables and Accelerating Green Hydrogen Imports



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In light of the current energy crisis, the success of the energy transition has become even more important. In addition to climate protection, energy security and affordability, speed and scalability are now also recognized as fundamental success factors. The hydrogen derivative synthetic methane (e-NG) promises to address all of those concerns.

The German government addresses these points extensively in its coalition agreement. The implementation is already taking place, for example, through the updated National Hydrogen Strategy (NWS), the announced Carbon Management Strategy (CMS) and the establishment of the Climate-Neutral Electricity System Platform.

Recognizing the limitations on domestic green hydrogen production, there is a growing shift in focus towards import concepts that involve green hydrogen derivatives. In line with this, the German Government is set to publish a Hydrogen Import Strategy by the end of 2023 as an addition to the NWS.

Hydrogen derivatives such as ammonia, methanol or methane (e-NG) are urgently needed in large quantities for specific applications in sectors where direct electrification and efficiency measures have reached their limits, e.g. shipping, aviation and various industrial applications.

The recent update to the NWS thus represents a significant milestone, acknowledging the importance of hydrogen imports and the production of derivatives, with explicit recognition of e-NG as one of the key solutions.

With the help of the German LNG import terminals and the existing natural gas infrastructure, import concepts can be implemented quickly and in a sustainable manner. The terminals were planned, financed and built at record speed and contribute significantly to the energy security of Germany and Europe today. With the concept of H2 readiness, LNG terminals, infrastructures and power plants are also expected to contribute quickly and effectively to the ramp-up of green hydrogen and thus to climate protection. This challenge can be effectively addressed with the help of green synthetic methane (e-NG). e-NG is based on green hydrogen and climate-neutral CO_2 and has the same chemical formula as fossil natural gas. It can be added to it by up to 100%, unloaded via LNG terminals, transported via the existing infrastructure, and used in a variety of ways.

The CO_2 is either extracted from biogenic sources or from the atmosphere through Direct Air Capture (DAC); or the CO_2 is captured during the use of e-NG and returned to the green hydrogen source in a closed loop. The significant difference to fossil natural gas is the sustainable production and use of e-NG, which avoids CO_2 emissions to the atmosphere or methane slip, which occurs with fossil natural gas primarily at the beginning of the value chain. Since e-NG is produced synthetically in a controlled industrial reactor and liquefied directly afterwards, there are no methane emissions as in the case of natural gas production.

The case of e-NG illustrates that green hydrogen in combination with carbon management must be considered as a partner of renewable energies in order to fully exploit the potential of technology in the fight against climate change. This concept is explained in depth in the following 4 chapters.

1. e-NG is a competitive form of hydrogen import via the sea

Hydrogen transport by sea is a major challenge due to its low volumetric density and the limited availability of transport ships. Therefore, either an energetically demanding liquefaction or a conversion and reconversion of green hydrogen to ammonia, LOHC (liquid-organic hydrogen carrier), methanol or e-NG is required. There are always efficiency losses and additional costs associated with the conversion steps. The overall efficiency of ammonia, methanol, and e-NG is comparable at about 50-55%. Similar to other applications, e-NG has a significantly lower greenhouse gas emission balance than e.g. blue hydrogen.

For optimal efficiency, the energy integration of process steps is required. The utilization of dual-gas ships, which transport e-NG to the customer and return with CO_2 to the production site, can save significant costs. Economic efficiency can be further increased if existing LNG and natural gas infrastructure is used to import e-NG [1]

- For example, there are existing shipping fleets and ports for the transport of e-NG/LNG as well as CO_2. As of 2021, there were about 700 [2] LNG tankers world wide that are used for methane transport.
- In Europe alone, there are already 29 LNG terminals for the import of liquefied methane and another 33 are planned [2].

• CO2 has also been transported safely in northwestern Europe for more than 30 years with six dedicated ships by sea, and by tank wagons on land.

Making use of the existing infrastructure allows the e-NG supply chain to scale up quickly and achieve attractive costs by leveraging existing facilities.

2. High technology maturity of e-NG enables rapid hydrogen import ramp-up

There are several technologies for green hydrogen transport that are at different stages of maturity [3]. Ammonia and methanation are the most advanced. Technologies such as LH2 (liquid hydrogen) and LOHC are still at an early stage of development and require major advances in materials science and process engineering.

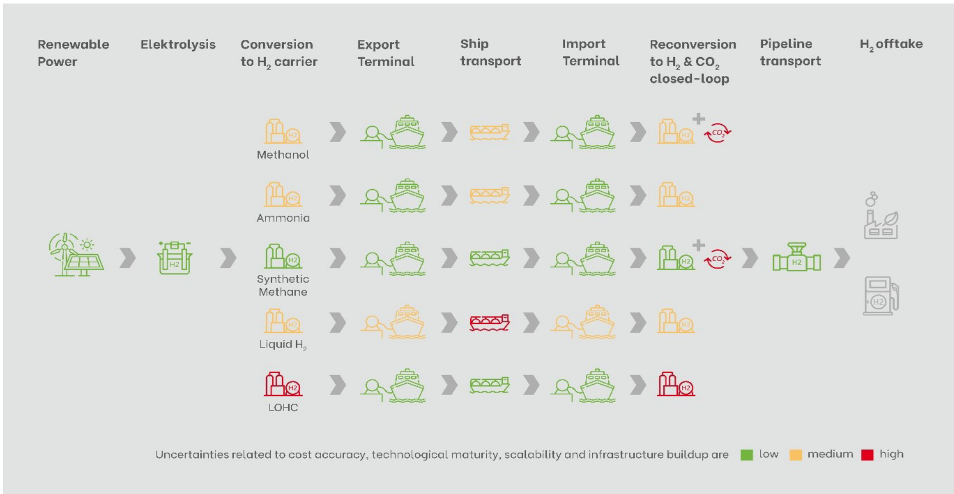
• For instance, ship transport of liquid hydrogen near the absolute temperature minimum (-253°C) is not only energetically but also technically challenging.

• Risk factors in the production, transport and use of ammonia in various fields of application, for example due to its toxicity, can be minimized by technical solutions. Nevertheless, it is important that ammonia can be converted back into hydrogen if it is to be used outside existing applications in the future. This process (cracking) requires high energy input and temperatures of 500-1050°C. So far, ammonia cracking for hydrogen production is not available on a commercially relevant scale (TRL 4) and still faces process engineering challenges [4].

In contrast, methanation of CO2 and hydrogen has a Technology Readiness Level (TRL) of 7 [1] to 9 [5] and is available on a large scale from established companies. Technologies for liquefaction, shipping, and methane cracking are also commercially available and in operation at large scale. In addition, there is operational experience in Germany: since 2013, methane has been produced directly from green hydrogen and CO2 in Werlte (Lower Saxony) at the former Audi e-Gas plant with a nominal capacity of 6.3 MW. The largest hydrogen and CO_2 methanation plant in the world, with a capacity of 60 000 m3/h, is currently being built by INPEX and Osaka Gas in Japan [1]. In addition, several industrial plants for the methanation of syngas (hydrogen, CO and CO_2) are in operation, with production rates of up to 2 bcm/a.

Reconversion of methane to hydrogen is also well established: steam reforming is the most widely used hydrogen production technology in the world. Currently, e-NG is the most technically advanced hydrogen transport route for energy delivery.

Comparison of hydrogen import routes by ship: e-NG highest technology maturity [6]



3. Leveraging the value of existing energy infrastructures

Investment in renewable energy has grown exponentially in recent years and is on the verge of overtaking investment in fossil fuels [7]. Nevertheless, there is still a large capital stock of facilities for the transportation and use of hydrocarbons such as methane and of oil products where investments continue to be made. In Germany, for example, LNG terminals are being developed on behalf of the German government at a cost of approximately EUR 10 billion, while in Qatar another methane liquefaction plant worth USD 10 billion is being tendered [8]. The same applies to the global shipping fleet of 600 vessels, valued at USD 80 billion: currently there are orders for 163 more LNG carriers worldwide, at an estimated new price of USD 250 million each [9].

The existing infrastructure give e-NG a huge advantage in terms of speed over other hydrogen transport routes, which need to be built first.

Decision makers in the energy industry need to focus on harnessing these investments for the energy transition. For example, the new land-based LNG terminals built in Germany could be used to import green molecules through e-NG. Existing LNG export facilities (pipelines, terminals, ships) located in current energy supplier countries and existing production in plant engineering can also be repurposed to avoid fossil lock-in effects.

Techno-economic models are also increasingly taking into account the existing stock of plants. In the energy policy discussion, however, attention is often only given to prime costs, which are usually based on the assumption that all facilities will be built from scratch. This not only distorts the debate about costs, but also does not take into account the advantages in the ramp-up speed.

Selected e-NG export projects: great interest in Japan, U.S. [1]

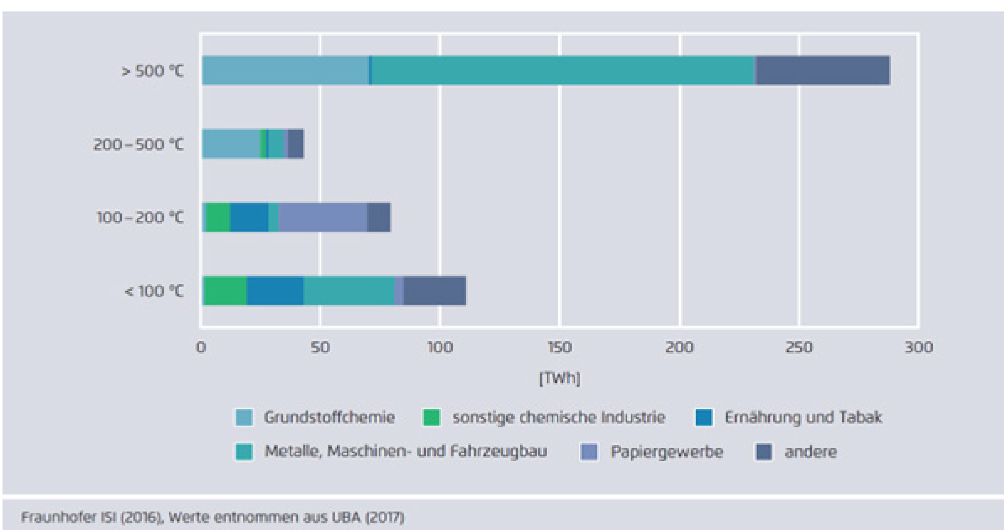
Involved companies	Export-country	Import-country	Announcement	Volume	Description
Tokyo Gas, Osaka Gas, Toho Gas, Mitsubishi Corp.	United States	Japan	2022	0.13 Mt/yr bis 2030	Feasibility study for e-NG production at Cameron LNG Terminal in the U.S.
Osaka Gas, Tallgrass Energy, Green Plains	United States	Japan	2022	0.2 Mt/yr bis 2030	Feasibility study for the production of e-NG at the Freeport LNG Terminal in the USA
Osaka Gas Australia, Santos	Australia	Japan	2023	0.06 Mt/yr bis 2030	Pre-FEED of a demonstration plant for the production of e-NG in Australia. FID planned in 2026.
TES, Total Energies	United States	Germany	2023	0.1-0.2 Mt/yr	1 GW electrolysis and methanation in Texas. FID planned in 2024.

4. Decarbonization of the industry needs solutions for immediate application, such as e-NG

Energy-intensive companies in Germany are facing increased pressure compared to competitors abroad due to the high level of ambition in reducing emissions. Although these challenges are being addressed by climate and industrial policy, there is a need for an offer that enables a gradual switch to renewable energies at predictable investments. Electrification of all industrial plants is either technically impossible or not cost-effective given current electricity prices for the German industry and the necessity for a time-consuming and costly grid extension. Conversion to green hydrogen is also proving difficult, as discussions on the development of the hydrogen network have not yet been concluded and access cannot be guaranteed timewise.

e-NG offers today's natural gas users the possibility of a seamless transformation through the flexible blending of e-NG with fossil natural gas. This transition does not require any technical conversion measures and is therefore not capital intensive. The supply of sufficient quantities of green e-NG can be scaled easily, as no complete conversion of plants is required and a permanent supply of 100% of the new energy carrier is ensured.

Final energy consumption for the generation of industrial process heat by temperature level [10]



e-NG thus offers a climate-neutral solution for the immediate and gradual conversion of existing plants that currently run on natural gas and use the existing connection to the gas grid. This applies, for example, to gas-fired power plants, chemical plants for material use or for the generation of high-temperature heat. The prerequisite is either the use of atmospheric or biogenic CO_2 in the production of e-NG (methanation) or the installation of a CO_2 capture plant at the consumer, whereby the emitted CO_2 is returned to the green hydrogen source in the closed CO_2 cycle.

E-NG is also expected to meet RFNBO [11] GHG reductions criteria outlined by the EU's RED II and its subsequent Delegated Acts. Specifically, these mandates stipulate that renewable fuels must demonstrate a minimum 70% decrease in GHG emissions when compared to the fossil benchmark, which possesses an emission factor of 94 gCO2eq/MJ. This translates to a permissible maximum emission factor of 28 gCO2eq/MJ for the renewable fuels' supply chain. A preliminary audit of TES's value chain and GHG assessment reveals that its e-NG sourced from Texas and delivered to Germany comfortably exceeds this mandate, boasting a reduction of over 80%. In comparison, fossil natural gas extracted from the US and shipped to Belgium [12], including its subsequent consumption carries a total emission factor of 80 gCO2eq/MJ.

Sources

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