Wasserstoff Campus Salzgitter

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On the factory premises of Salzgitter AG, green hydrogen and electricity are already being generated using wind energy.

Short-term solutions for green hydrogen in Salzgitter

Germany and the EU have an increasing need for green hydrogen for the rapid decarbonization of industry. An affordable supply by 2030 can be achieved through a combination of national production and strategic imports by sea. The Wasserstoff Campus Salzgitter examines key issues and provides answers regarding the necessary market evolution.

Salzgitter as a model region for climate-neutral industry

The goals of the hydrogen strategies in Germany and the EU clearly demonstrate that a rapid, affordable and large-scale supply of climate-neutral hydrogen is imperative. In order to address the challenges and unresolved issues associated with the development of a hydrogen economy, the Wasserstoff Campus Salzgitter was initiated in 2019. Salzgitter is characterized by powerful industry from steel, electronics and mobility sectors and is pursuing the aspiration of becoming a prominent model region for the successful transformation of industry and society towards climate neutrality. Salzgitter AG, for example, is implementing the complete transformation of its ironworks to green steel production by 2033 in its SALCOS® program. The Wasserstoff Campus Salzgitter has investigated the necessary supply of green hydrogen of the model region at affordable prices within the framework of the "GreenH$_2$SZ" project. This thesis paper presents results and derives therefrom essential messages for decision-makers in politics and business.

Wasserstoff Campus Salzgitter

John-F.-Kennedy-Str. 43 - 53
38228 Salzgitter

Contact
MAN Energy Solutions SE
· Dipl.Ing. Sebastian Schnurrer
Fraunhofer Institute for Surface Engineering and Thin Films IST
· Dr.-Ing. Jan Beuscher
· Florian Scheffler, M.Sc.

E info@wasserstoff-campus-salzgitter.de

Key messages

1. “The production of green hydrogen in Germany is competitive.” At approx. 4 € /kg H_2, green hydrogen from Northern Germany will be competitive with imports in 2030. In the depicted import example of Tunisia, the costs for hydrogen via the ammonia route are calculated at approx. 4.70 € / kg H_2. Green hydrogen from Northern Germany therefore forms the basic building block for a sufficient supply: Investments in large-scale electrolysis plants and renewable energy production must be expedited in Germany in parallel to imports.

2. “The German hydrogen market needs immediate investment security.” Only by promptly creating boundary conditions can the goals of the German market evolution – with self-generation from an electrolysis capacity of up to 10 gigawatts by 2030 – be achieved. The electrolysis market therefore urgently requires large-scale reference projects, which must be facilitated through favorable electricity purchase criteria. Reference projects in the home country strengthen the international reputation of German companies and are a component of a strong industrial policy.
However, domestic renewable energies and electrolyzers cannot alone satisfy the growing demand for hydrogen in Germany. Diversified, sustainably certified and reliable hydrogen imports are therefore necessary and must be strategically established. A suitable regulatory framework must include as well as viable electricity purchase conditions, certification and market models for green hydrogen and synthesis products that can be applied in various market segments.

3. “The acceleration of the market evolution will be achieved through existing technologies.” The acceleration of the market evolution for large-scale import chains can be achieved through the widespread deployment of technologies that are already available today, thereby enabling a faster decarbonization of infrastructures and fossil-fuel consumers. Methane, methanol, and ammonia, which are suitable carriers for hydrogen transport, already have large sales markets and available transport infrastructures, such as ships, terminals, and storage facilities. As a result, they offer the best options for a near-term entry into large-scale hydrogen imports and can simultaneously replace fossil fuels and avoid greenhouse gas emissions. In order to utilize ammonia and methane imports as carriers of green hydrogen, early infrastructure planning and investment certainty are essential. Currently emerging liquefied natural gas (LNG) terminals can be prospectively converted to climate-neutral energies with synthetic methane from green hydrogen, provided that CO_2 capture and CO_2 exports are made possible in Germany. In addition to the costs of the individual processes and conversions, it is imperative that further factors are taken into account: Existing infrastructure and technological maturity are absolute prerequisites for making green hydrogen available quickly and for achieving climate-protection goals. The large-scale import of liquid hydrogen will only be competitive after 2030, when sufficiently large transport ships are available.

4. “Ensuring the supply to industry necessitates accelerated deployment of the hydrogen-pipeline network with connections to German ports.” Hydrogen pipelines are the most cost-effective option for supplying industrial sites. The timely connection of German ports and electrolysis sites to the pipeline network of the “European Hydrogen Backbone” is essential in order to provide industrial customers with hydrogen that is imported and produced close to the coast. Existing gas infrastructures should be used in the best possible way for future hydrogen transport.

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Fig. 2: Scenario results: Cost of import supply chains in 2030 for an H_2 supply in Salzgitter in the Tunisia scenario, compared to hydrogen production costs from offshore and onshore wind for electrolysis locations in Lower Saxony in 2030.

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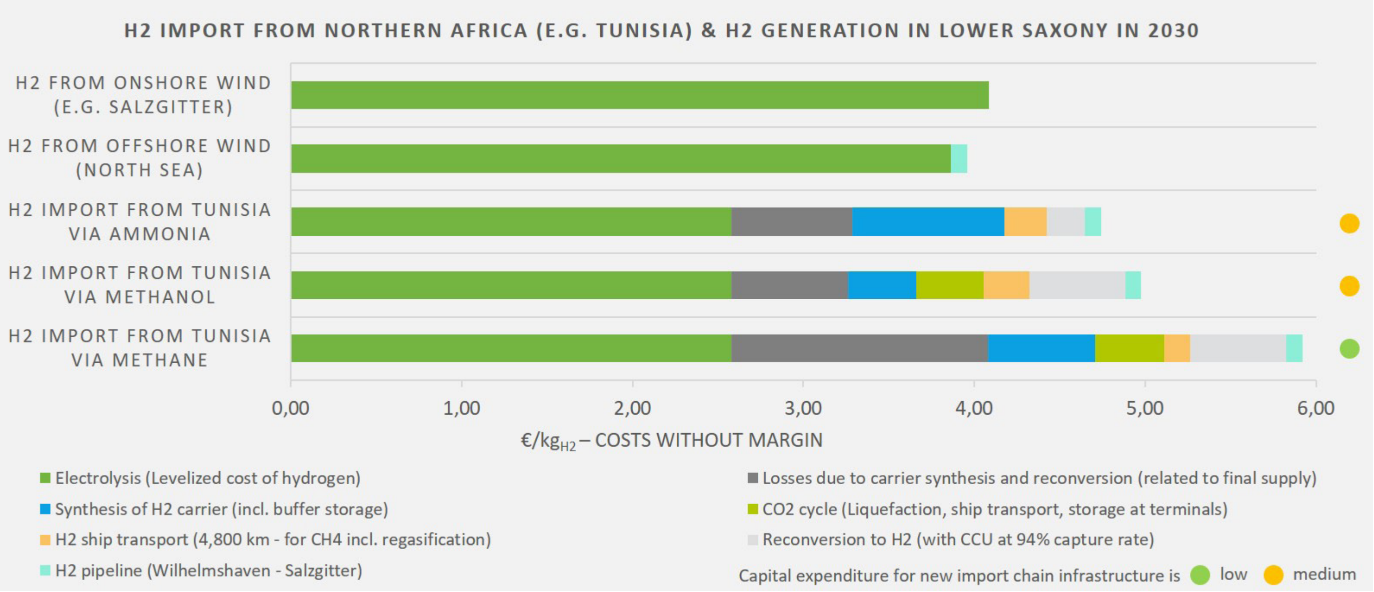

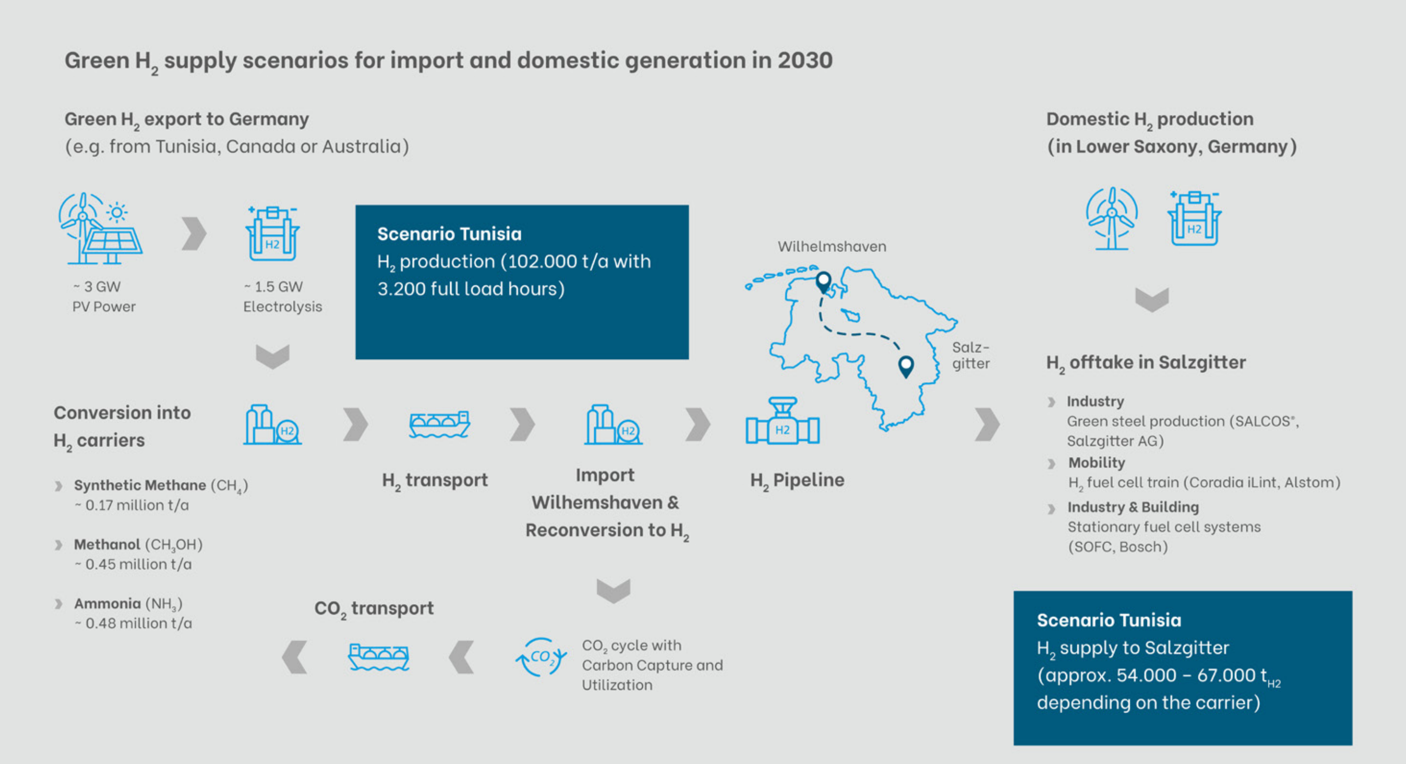

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Fig. 3: Modelling of the hydrogen import scenario 2030 from Tunisia with different hydrogen carriers for hydrogen offtake in Salzgitter.

Which hydrogen requirements will arise by 2030? The scenarios calculated here are based on a hydrogen supply for the Salzgitter location as an industrial hydrogen consumer for the target year 2030. As an example, Salzgitter AG is planning a continuously increasing external hydrogen supply for the SALCOS® transformation program. This will increase from just under 10,000 tonnes in 2027 to more than 250,000 tonnes per year at the end of the 2030s and will therefore constitute the dominant hydrogen consumer in the region. As a comparison, the EU has set a target of achieving a hydrogen supply of 20 million tonnes by 2030.*

How can this hydrogen demand be met? The regional production of hydrogen from the onshore wind potential in southeast Lower Saxony and the offshore potential of the North Sea is compared to imports from countries with high generation potentials from renewable energies and an early readiness to enter the market (see Fig. 3). Examples of export countries are Portugal, Tunisia (MENA region), Canada or Australia. Domestic hydrogen production can provide a rapid contribution, but is constrained by limited wind-power generation and the regulatory framework for electricity supply.

Import routes to the German coast, on the other hand, offer greater scaling potential but have a longer implementation time. Only by combining production in Germany with imports will it be possible to ensure sufficient availability of hydrogen in 2030 and, thereby, the achievement of the targets for climate protection.

How will industrial consumers with high demands for green hydrogen be supplied? The plans for the European Hydrogen Backbone envisage the construction of a European hydrogen network by 2030. This will be based on pipelines in Northwest Germany, the Netherlands and Belgium and will initially be supplied through the gas-import terminals in Antwerp, Rotterdam, Wilhelmshaven and Brunsbüttel. The import chains by sea examined here envisage a dedicated supply to German industry via energy partnerships and sea transport to Germany.

How can hydrogen be imported via ship in 2030? Hydrogen import is performed via various hydrogen carrier media, which can be transported as liquid energy carriers in available tankers until 2030. Liquid hydrogen and LOHC (liquid organic hydrogen carrier) are not considered here due to high uncertainties and low technological maturity for gigawatt-scale capacities until 2030 (see Fig. 4). Large-scale import scenarios can already be realized in a timely manner with ammonia (NH_3), methane (CH_4), or methanol (CH_3OH) thanks to available synthesis and transport infrastructures. Following import via planned terminals, such as in Wilhelmshaven, the hydrogen carrier can, depending on demand, be converted back into pure hydrogen in order to reach industrial locations such as Salzgitter via a future hydrogen-pipeline network.

Direct marketing of these three energy carriers in existing markets is also possible, thereby significantly reducing the entry risk for hydrogen transport via these molecules.

*Source: European Commission 2022, REPowerEUPlan

With which assumptions can a hydrogen price for a large-scale supply in 2030 be modeled? The basis for the modeling is formed by the assumed investment costs for large-scale plants for electrolysis (approx. 470 €/kW) and the necessary steps for synthesis, liquefaction and reconversion to hydrogen from a capacity of several 100 MW upwards. Investment costs from infrastructure (e.g. terminals in ports, pipeline networks) are considered proportionally to the utilization. In addition, there are costs for operation and maintenance.

The major cost factor for hydrogen is constituted by the operating costs and, consequently, by the applied electricity price for a specific number of full-load hours for the electrolyzer per year. Here, the corresponding levelized cost of electricity of reference projects in Germany and abroad as well as market developments are assumed. All assumptions are based on reliable values from technical literature and manufacturer specifications.

Which steps are considered in the modeling of the hydrogen supply from generation through to purchase? How can the CO_2 demand for carbon-based hydrogen products be fulfilled? The analysis and evaluation of the import chains is essentially based on the specific synthesis, storage, transport and reconversion steps for the hydrogen carrier(ammonia, methanol, methane). The model encompasses all losses and energy requirements along the entire chain and therefore provides a comprehensive picture of the respective costs (see Fig. 2). The supply chains with methane and methanol differ from ammonia in that a CO_2 closed-loop is formed with a high-efficient carbon capture and storage technology. As a result, around 94 % of the CO_2 is recycled and supplied for the next hydrogen carrier synthesis step. As an example, the CO_2 is stored during reconversion in Wilhelmshaven and then transported back in liquefied form via ship to the overseas plant where the green hydrogen is produced. The initial CO_2 demand for methane and methanol synthesis can be met from industrial point sources with hard-to-abate emissions(e.g. from cement factories). In addition, around 6 – 8 % of the annual CO_2 demand is fed into the not completely closed cycle.

The nitrogen for ammonia synthesis will be created economically via air separation in the country of production for each transport route.

How can differing H_2 routes be certified? The greenhouse gas emissions that arise during, amongst other things, CO_2 capture and the transport routes must be allocated in each individual case to the respective imported tonne of hydrogen or the directly used product.This is necessary in order to be able to implement a transparent and sustainable certification of the imported hydrogen in different carriers in comparison to green hydrogen production in Germany in the future.

What levels of H_2 generation prices can be achieved? The calculated generation and import costs in Fig. 2 demonstrate that Lower Saxony offers

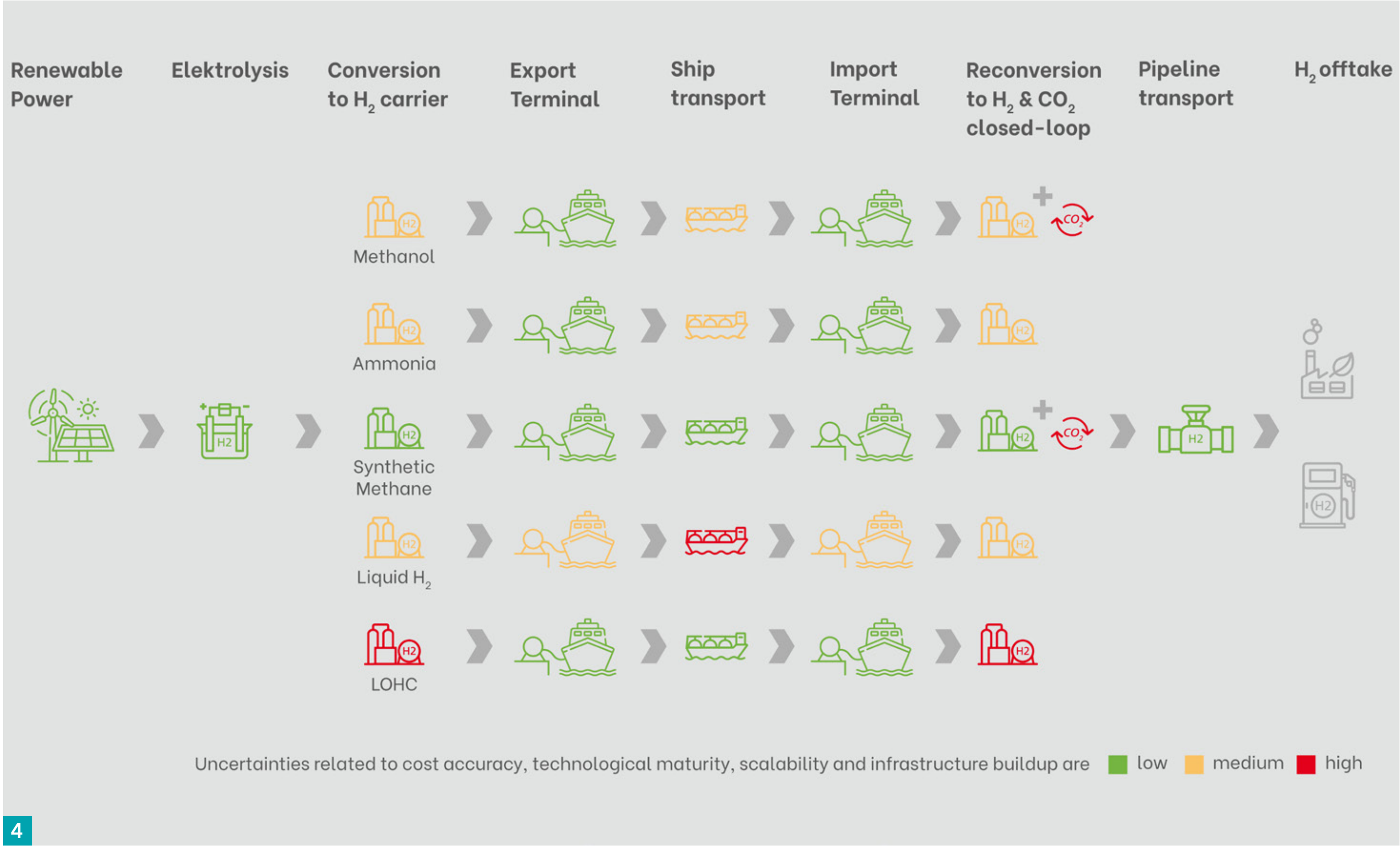

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Fig. 4: Technological maturity and market availability of the respective technologies and infrastructure for future hydrogen supply chains.

ideal generation locations as a result of its high potential from offshore and onshore wind energy.

Levelized cost of hydrogen of around 4 € /kg can be achieved. More favorable electricity prices and increased electrolysis full-load hours would allow a price of approx. 2.5 €/kg to be achieved by 2030 at locations rich in sun and wind, such as in Tunisia. All costs shown are levelized costs

What additional costs arise for import chains compared to generation in Germany? All of the considered import routes exceed the generation costs of green hydrogen in the Salzgitter area.

Whilst both the shipping costs for the H_2 carrier and the pipeline transport in Germany are barely significant, the additional costs are primarily determined through the synthesis step following electrolysis and the reconversion into pure hydrogen following import via ship, which is assumed here to be in accordance with demand. Depending on the carrier, differing quantities of hydrogen are produced after reconversion or pipeline feed-in- all routes are based on the same electrolysis capacity, but include varying losses. The costs shown (Fig. 2) relate in each case to the quantity of hydrogen supplied in Salzgitter.

Which technical and regulatory uncertainties influence the modeling of the H_2 import routes? Individual processes, such as ammonia cracking, are still subject to high levels of uncertainty, as these plants have not yet been realized in the required capacity and process configuration (see Fig. 4). Whilst the operation of a CO_2 capture and the subsequent export of CO_2 have no legal basis in Germany to date, the H_2 methane route can, compared to ammonia, build upon robust assumptions for the reconversion through a reformation for meeting a pure hydrogen demand.

Are new terminals necessary for the seaborne import of hydrogen products? The H_2 methane route can be implemented via newly announced LNG terminals in Germany and can therefore utilize fossil infrastructures proportionally for climate-neutral energy sources. For the ammonia import, investments in port infrastructures – with storage and cracking facilities– are necessary, as planned in e.g. Wilhelmshaven.

Conclusion

Northern Germany and especially Lower Saxony offers altogether excellent conditions for initiating and accelerating the market development of the hydrogen economy in the energy transition. This applies both to the necessary domestic production at competitive generation costs of approx. 4 €/kg H_2 and to the realization of timely imports of green hydrogen via the newly emerging LNG terminals on the North Sea. Lower Saxony thereby also represents the nucleus of the German hydrogen pipeline network, in order to be able to supply industrial locations such as Salzgitter. In the short term, the implementation of industrial reference projects for the production of green hydrogen in Germany is inevitable. A secure investment framework with favorable electricity supply criteria for the electrolysis operation is absolutely essential for this. Simultaneously, diversified imports must be prepared within secure energy partnerships. The significantly cheaper purchase of electricity in countries with a high potential for renewable energies will lead to a timely cost reduction of local green hydrogen production towards 2 €/kg H_2, thereby enabling imports and achieving scaling effects in electrolysis production. With the technologies already available today, hydrogen in the form of ammonia, methane or methanol can be imported via ship on a gigawatt-scale and utilized in various applications for rapid decarbonization. ■

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Fraunhofer Institute for Surface Engineering and Thin Films IST
Bienroder Weg 54 E
38108 Braunschweig
Telephone +49 531 2155-0
Fax +49 531 2155-900
E-Mail: info@ist.fraunhofer.de
Internet: www.ist.fraunhofer.de/

Project management:
MAN Energy Solutions SE
Stadtbachstrasse 1
86153 Augsburg
Telephone +49 821 322-0

Authors:
Dipl.-Ing. Sebastian Schnurrer, MAN ES
Dr.-Ing. Jan Beuscher, Fraunhofer IST
M. Sc. Florian Scheffler, Fraunhofer IST

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Project partners:
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