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Green Hydrogen: Three Executable Strategies for Competitive Pricing

Third Belgrade Hydrogen Conference: Green Hydrogen as a Roadmap for the Energy Transition

Stephen B. Harrison, Managing Director, sbh4 consulting

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“Low carbon intensity comes with a premium price” – is this the only truth? Green molecules can be competitive in the following three cases…

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1. High utilisation electrolyser schemes with firm green power – the conventional wisdom
2. Intentionally intermittent electrolyser operation with zero, or negatively priced power – the new paradigm
3. Added value, competitively priced hydrogen derivatives - where the LCoH is less relevant

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1) High utilisation electrolyser schemes with firm green power – the conventional wisdom

AM Green (Greenko ZeroC) Kakinada, India: Integration of 1.3GW of hydrogen electrolysis into an existing ammonia plant to serve export markets. Uniper, RWE, Yara have signed offtake agreements / LoIs.

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https://power-to-x.de/en/am-green-ammonia-production-in-india-with-1-million-ton-capacity/

A new pumped hydro scheme at Pinnapuram in Kurnool will store electricity up-front of the electrolyser to ensure continuous hydrogen production when integrated with non-programmable wind and solar generation.

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2) Intentionally intermittent electrolyser operation with zero, or negatively priced power – the new paradigm

The three main factors that govern the cost of electrolytic hydrogen

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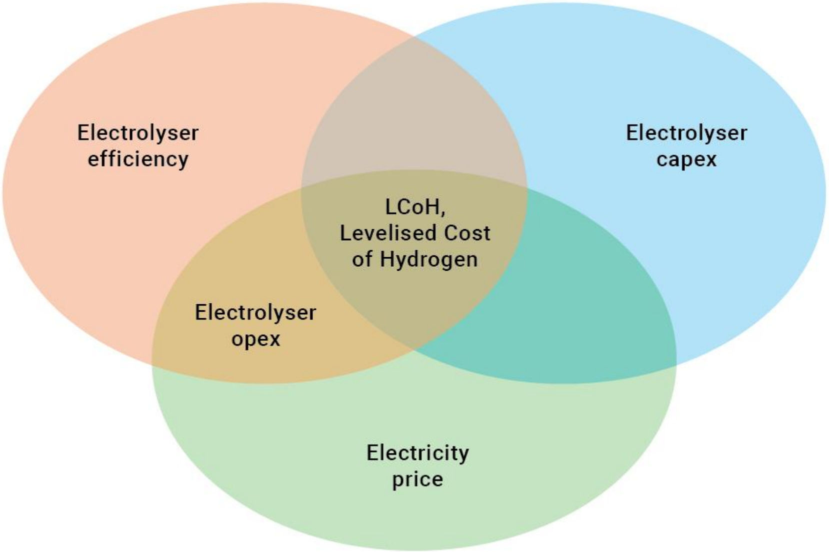
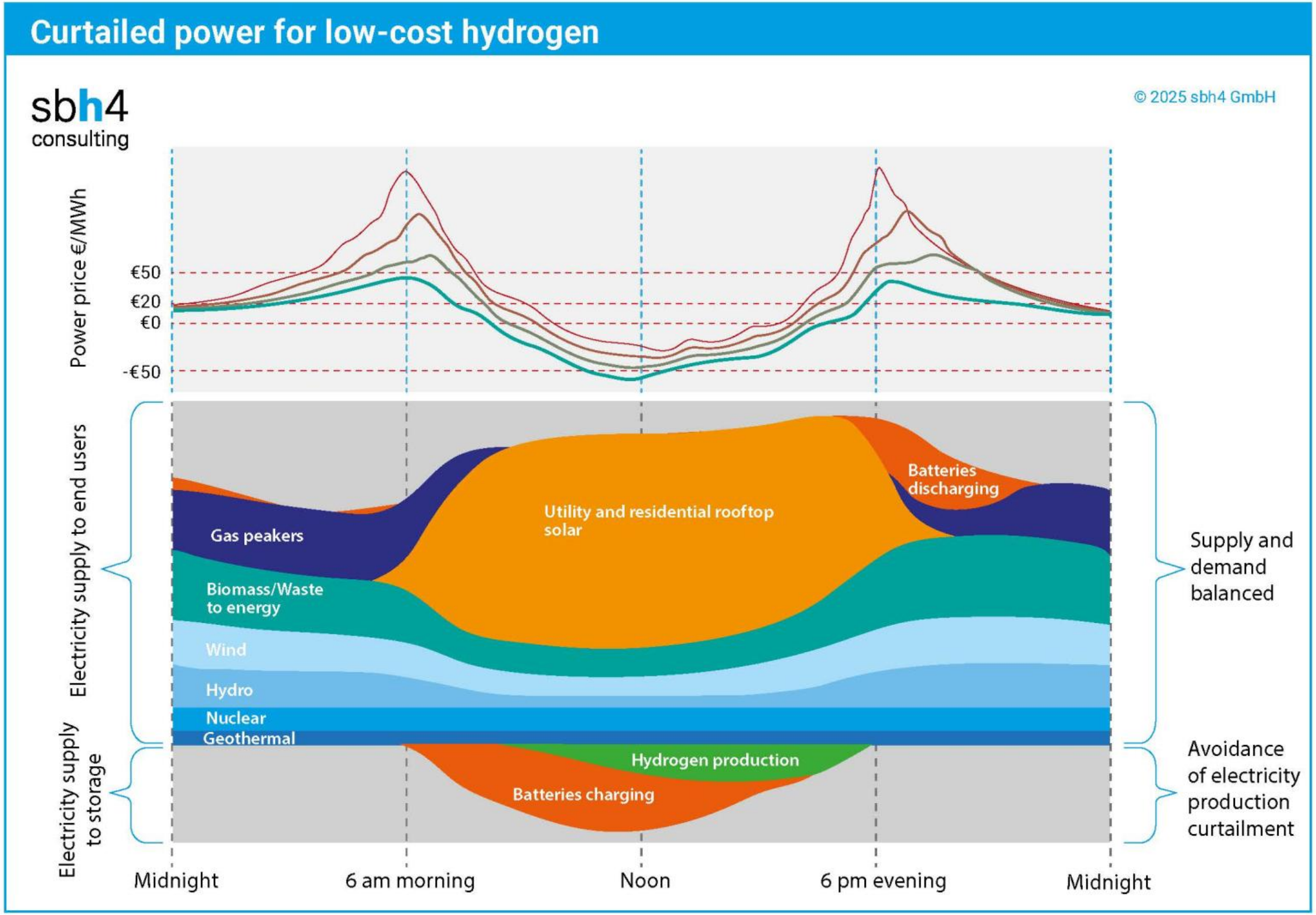


Notes

- Electrolyser efficiency: conversion of power to hydrogen (kWh/kg H_2)
- Electricity price: cost to purchase a unit of electricity (€/kWh)
- Electrolyser opex: incremental cash cost of hydrogen production (€/kg H_2)
- Electrolyser capex: the initial capital investment in the electrolyser system (€)
- Levelised Cost of Hydrogen (LCoH): the unit cost of hydrogen levelized over the operating period considering capital cost, depreciation over the operating period (eg 20 years) at the project capital depreciation rate (eg 8%), and the operating cost (€/kg H_2)
- Other operating costs such as labour and maintenance are incurred, but these are secondary to the cost of electricity

Over a 20-year operating period, the cost of electricity will dominate the cost of electrolytic hydrogen.



"Intentionally intermittent" electrolyser operation can exploit periods of negative and zero-priced electricity in electricity market structures which use pricing to balance supply and demand to preserve grid integrity.

Electrolyser technology selection for intentionally intermittent operation favours PEM systems due to low turndown and high number of permissible offs per day.

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https://itm-power.com/news/stablegrid-group-selects-itm-power-for-710-mw-of-energy-infrastructure-projects-in-germany

Offtakers in industries such as ammonia production, refineries and iron / steel making need continuous hydrogen supply. There must be a large hydrogen storage buffer to balance intermittent production with continuous offtake. This can be achieved with underground hydrogen storage.

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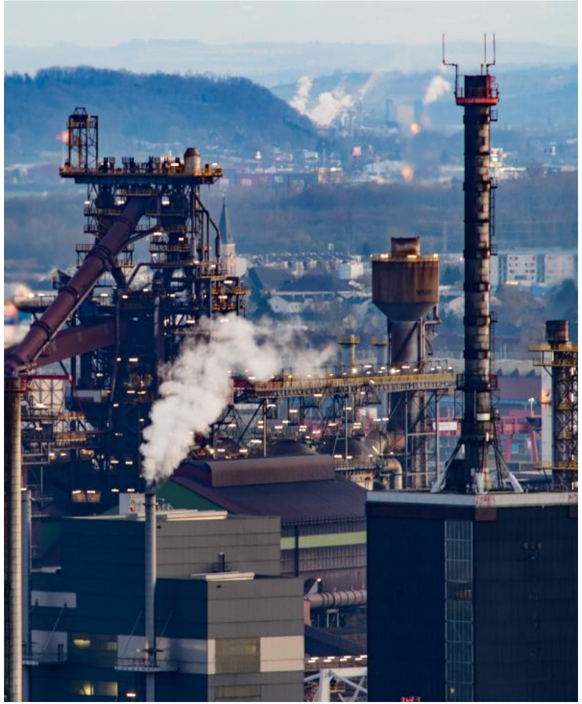

3) Added value, competitively priced hydrogen derivatives - where the LCoH is less relevant

Atome, Itaipu dam, Paraná River, Paraguay: green CAN from 250MW of pressurised alkaline electrolysis on the 14GW hydro dam. Green hydrogen is the first block in a complex value chain to CAN for export.

Adding value to hydrogen with ammonia and its derivatives

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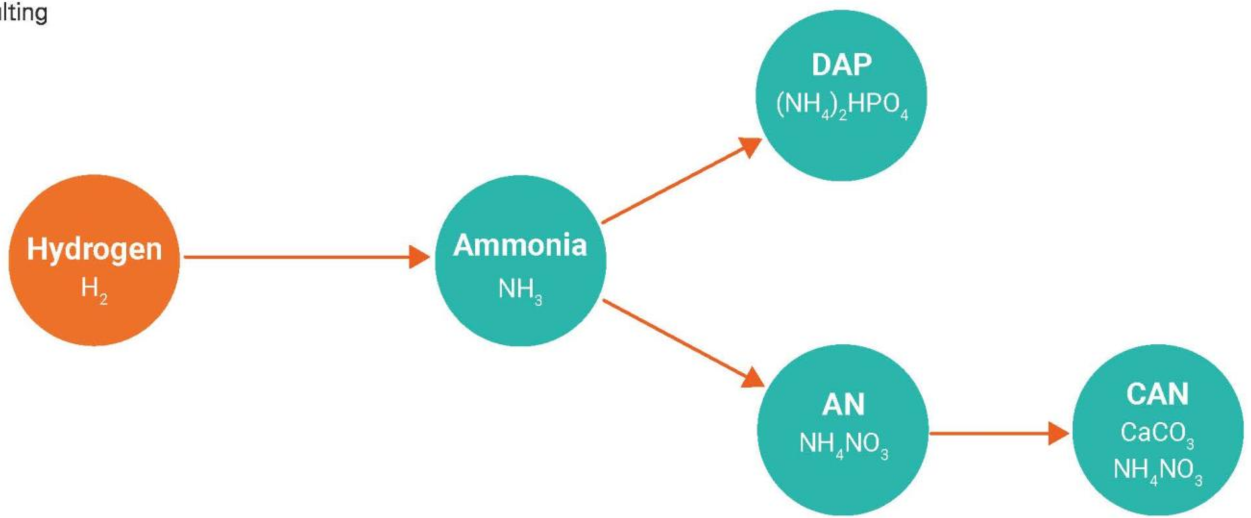

Product	H_2 % in product	Grey H_2 value/ton	H_2% of value	Blue H_2 value/ton	H_2% of value	Green H_2 value/ton	H_2% of value	Green H_2 value/ton	H_2% of value
Hydrogen	100%	$1,500	100%	$2,000	100%	$3,000	100%	$5,000	100%
Ammonia	17.8%	$600	44.5%	$689	51.7%	$867	62%	$1,223	73%
AN	5.0%	$340	22.1%	$365	27.4%	$415	36%	$515	49%
CAN	3.5%	$300	17.5%	$318	22.0%	$353	30%	$423	41%
DAP	6.9%	$600	17.3%	$635	21.7%	$704	29%	$842	41%

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DAP production

- Ammonia is reacted with phosphoric acid to make diammonium phosphate (DAP)

Adding value helps

- These value-added ammonia derivatives dilute the increased cost of green or blue hydrogen versus the grey hydrogen baseline sbh4

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AM Green (Greenko ZeroC) Kakinada, India: lessons from the world's second GW-scale green hydrogen project.

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1. The fossil-fed hydrogen production at the front-end of an existing ammonia synthesis plant will be replaced by electrolytic green hydrogen production.

2. The renewable power supply is via the existing grid infrastructure with renewable power purchase agreements from remote providers.

3. To ensure a firm electricity supply, power will also be purchased from a pumped-hydro facility which is remote from this facility.

4. The electrolyser park will be 1,300 MW. John Cockerill pressurised alkaline electrolysers are proposed, with the potential for local electrolyser manufacturing and maintenance.

Atome, Paraguay: FOAK integrated green hydrogen / ammonia / AN / CAN plant.

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1. The end-product is Calcium Ammonium Nitrate, CAN. Hydrogen is 3.5% of the product, by mass. Green hydrogen is used to enable the production of a high-value product.

2. Given the high amount of capital required for the end-to-end process, high utilisation is key. This requires a firm renewable power supply, which is provided by access to the Itaipu hydro dam. Intermittent operation with high-capacity hydrogen storage would be an alternative.

3. To ensure that the green CAN is competitive with fossil-based alternatives, the cost of the initial energy source (electricity) must be comparable to the cost of the grey alternative (natural gas). However, since there is a complex process which adds significant value to the initial energy source, cost parity of the energy input is less important than a pure hydrogen project.

4. The project can serve export markets which have a demand for CAN. For example, in Germany the use of AN as a fertilizer is not permitted, and the use of CAN is one of the few alternatives. Yara is an offtaker, with access to export markets.

Introduction to Stephen B. Harrison and sbh4 consulting

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Stephen B. Harrison is the founder and managing director at sbh4 GmbH in Germany. His work at sbh4 over the past 8 years has focused on hydrogen, industrial decarbonisation, CCU/S, biofuels, e-fuels and clean fertilizers.

With a background in industrial gases, including 27 years at BOC Gases (AFROX), The BOC Group and Linde Gas, Stephen has intimate knowledge of hydrogen and many other gases from commercial, technical, operational and safety perspectives. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies.

Stephen supports the IFC to track down and evaluate the most attractive green hydrogen, biofuels and decarbonisation projects worldwide. He has also supported EIB and ADB on several hydrogen and CCS initiatives.

Stephen has extensive due diligence and investment advisory experience in the clean-tech sector. Private Equity firms, investment fund managers and green-tech start-ups are regular clients.

Industrial corporations often seek his guidance on their industrial decarbonisation plans and growth strategies to offer products and services to the emerging hydrogen economy and energy transition.

Startups are increasingly turning to Stephen to guide their technology development roadmaps from a solid techno-economic basis. He also advises and supports their tech-to-market strategies.