HYDROGEN PRODUCTION FROM COAL

Current demand – Total global hydrogen demand in 2018 was around 115 MtH_2/y. It was produced local to the point of use, almost entirely from fossil fuels and was used primarily as feedstock in the refinery and chemicals industries. Based on the energy input required to produce the hydrogen, coal accounted for 27% of this hydrogen demand, and natural gas for over 70%. Electricity as an energy input for electrolysis, accounted for less than 1% of the hydrogen demand and was mostly generated from fossil fuels.

Future demand – Hydrogen global demand is forecast to increase to possibly 650 MtH_2/y by 2050, representing around 14% of expected world total energy demand. More conservative forecasts estimate future demand at 180–275 MtH_2/y in 2050. This corresponds to a potential 160–570% increase from current hydrogen demand.

Uses for hydrogen – Hydrogen is likely to be adopted in applications where it is the only viable decarbonisation alternative, or where it has a proven advantage over competing solutions. This includes the continued use as feedstock in the chemical industry, feedstock use in iron and primary steelmaking industries, fuel for long-distance shipping and storage uses in 'island' power systems. Additional applications could include aviation, long-distance haulage, use in buildings to complement electrification and storage/buffering in interconnected power systems.

There will be regional variations in this future demand depending on local factors including resource availability, political support, existing gas infrastructure and greenhouse gas emission reduction targets. Heating of buildings for example is likely in countries with good gas infrastructure, whereas locations with existing industrial ports could become hubs for lower cost, lower-carbon hydrogen. A key advantage of hydrogen as an energy carrier is that as a chemical fuel, it can be transported globally so it could be produced in regions with the best resources and used in others where there is high demand.

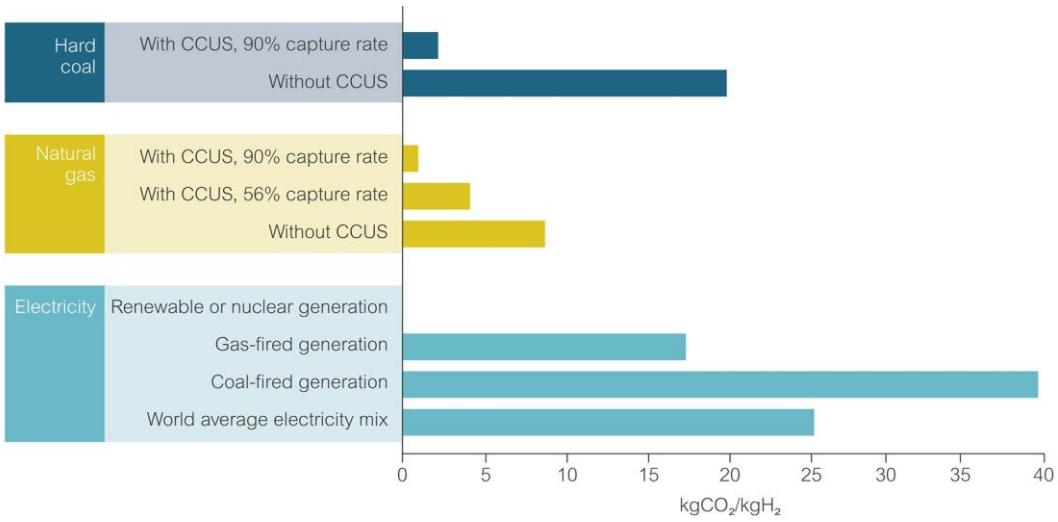
Hydrogen production technology – The three main routes available for the production of hydrogen, depending on the fuel feedstock, are reforming of natural gas, gasification of coal and electrolysis of water. Hydrogen production from coal using gasification is a well-established technology, used for decades by the chemical and fertiliser industries, particularly in China. There are three key examples of the technology including carbon capture utilisation and storage (CCUS) in operation, producing hydrogen from coal, coke or asphaltene with a combined capacity of around 0.6 MtH_2/y. They are the Great Plains Synfuel and Coffeyville plants in the USA and Sinopec Qilu in China. These facilities demonstrate that large-scale production of low emissions hydrogen using carbon capture can already be technically and commercially feasible.

Cost of hydrogen – Low-carbon hydrogen production from coal gasification with CCUS is lower cost than low-carbon hydrogen based on water electrolysis, typically by a factor of approaching three. Coal gasification with CCUS costs typically 1.6–2.4 $\$/kgH_2$; the lowest cost is in China. Learning by doing through large-scale commercial roll-out together with cost reduction through technology innovations could reduce the cost by perhaps 10–15%, with Capex reductions of 45–50% reduction possible by 2050.

In regions with access to low-cost renewable electricity, low-carbon hydrogen produced using water electrolysis could in time become a competitor with low-carbon hydrogen from coal or natural gas, possibly from 2025-35. However, hydrogen production from water electrolysis will typically operate 'mid-

merit' at around 35–70% capacity factor. With a large existing unabated fleet of gas- and coal-based hydrogen production, much of which is in China, the cost of hydrogen assessment would indicate that the transition to large-scale, low-carbon hydrogen will require significant deployment of CCUS plant on existing coal-fired gasification plant.

Emissions from hydrogen – For coal gasification plant, the addition of CCUS at an assumed 90% capture rate can reduce the carbon intensity of this process to below 3 $kgCO_2/kgH_2$. This is good, but not consistent with net-zero emissions, so capture technology with increased capture rates approaching 100%, or technologies such as supercritical CO_2 working fluid cycles, should be explored in the medium-long term. Cofiring biomass or waste with the coal feedstock, coupled with CCUS, could lead to net-zero or even negative CO_2/kgH_2, which would help to 'future proof' the gasification plant.



CO_2 intensity of hydrogen production (IEA, 2019c)

Natural gas-based production will generally be lower emission than coal gasification due to the inherent fuel properties where natural gas has a hydrogen/carbon molecular ratio of 4:1 compared with typically 0.1:1 for coal. For water electrolysis, the CO_2 intensity depends on that of the electricity used to produce it. Where this is entirely from renewable electricity sources, the carbon intensity is close to zero. However, to reduce the cost of hydrogen, or to match demand-side hydrogen requirements, the electrolyser may be operated at higher load factors where the impact of using water electrolysis could actually be detrimental. Thus the water electrolysis process should be used at a capacity factor that allows it to use mainly renewable electricity.

Hydrogen strategies and next steps – The number of countries with hydrogen strategies and roadmaps is growing. Funding to support these strategies is increasingly significant, particularly related to low-carbon hydrogen based on water electrolysis and its support to increasing renewables penetration. However, to move towards the increased uptake of hydrogen, near-term actions are required to overcome barriers and reduce costs. This includes policy actions to support sending positive long-term signals to potential investors, stimulate demand for clean hydrogen in existing and new markets, reduce investor risk and develop business models, set the agenda for technology R&D and finally to support the establishment of a regulatory framework. Deployment of hydrogen from fossil fuels with CCUS at scale is required, where the 'Hub and Cluster' model to improve the economics of clean hydrogen production should be pursued.

Compliance with SDGs – Finally, in terms of the wider SDG goals, hydrogen, including low-carbon hydrogen from coal, is a key technology contributing in particular to SDG 7- affordable clean energy for all, SDG 9- industry innovation & infrastructure and SDG 13- climate action.

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Each executive summary is based on a detailed study which is available separately from: www.sustainable-carbon.org. This is a summary of the report: Hydrogen production from coal by Greg Kelsall, ICSC/313, ISBN 978-92-9029-636-2, 109 pp, August 2021