



HYDROGEN ON THE HORIZON: READY, ALMOST SET, GO?

WORKING PAPER | INPUTS FROM SENIOR LEADERS ON HYDROGEN DEVELOPMENTS

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WORKING PAPER

This Working Paper on hydrogen is part of a series of publications by the World Energy Council focused on Innovation. It was developed in collaboration with the Electric Power Research Institute (EPRI) and PwC.

EPRI and Gas Technology Institute (GTI) have created the [Low-Carbon Resources Initiative \(LCRI\)](#) to address the challenges and gaps in achieving deep carbon reductions across the energy economy. LCRI is focused on the value chain of alternative energy carriers and low-carbon fuels—such as hydrogen, ammonia, biofuels (including renewable natural gas, and synthetic fuels—and research, development, and demonstration to enable their production, storage, delivery, and use across the energy economy. These energy carriers/fuels are needed to enable affordable pathways to economy-wide decarbonization by mid-century. This five-year, global collaborative will identify and accelerate fundamental development of promising technologies; demonstrate and assess the performance of key technologies and processes, identifying pathways to possible improvements; and inform key stakeholders and the public about technology options and potential pathways to a low-carbon future.

PwC is a network of firms in 155 countries with over 284,000 people committed to delivering quality in assurance, advisory and tax services, including more than 20,000 professionals engaged in the energy, utilities and resources sectors. With its global strategy, The New Equation, PwC is responding to the challenges shaping the world today, with a focus on building trust and delivering sustained outcomes that create value for organisations, their stakeholders and broader society. Climate change is one of the world's most pressing problems, and PwC has committed to reach net zero greenhouse gas emissions by 2030 and is working with organisations to accelerate their own climate-based transformation. PwC and the World Energy Council have a common goal of promoting energy transition and sustainability by engaging with policymakers and leading industry players. Our shared view is that energy transition and sustainability are achieved through the interaction of robust policy frameworks and a strong, competitive energy industry.

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In a fast-paced era of disruptive changes, this working paper aims at facilitating strategic sharing of knowledge between the Council's members and the other energy stakeholders and policy shapers and contribute to a global dialogue on hydrogen's role in energy transitions.

This working paper builds upon earlier work by the Council and involved extensive research on national strategy developments and interviews with 38 experts from 23 countries, reflecting 61 % of the global Total Primary Energy Supply – TPES (2018 data, OECD) and 70% of global GDP (2019 data, WB).

INTRODUCTION

The World Energy Council, in collaboration with EPRI and PwC, aims to provide a better understanding of hydrogen development worldwide for the energy community, building on the expertise and experience of its global network. In this context, we published a new Innovation Insights Briefing on Hydrogen in July 2021, seeking to start a multi-stakeholder, multi-level community dialogue on hydrogen's role in energy transitions.

Our work has identified the following 4 areas for further discussion:

- 1 Significant divergences are emerging across countries and regions**, as national hydrogen strategies reveal varying attitudes towards hydrogen's role in energy transitions. This signals a need to embrace diversity – eliminating a one size fits all mindset – and enable differing technologies and use cases to be explored.
- 2 Confusion over 'colours' is stifling innovation**, with over-simplification and colour prejudice risking the premature exclusion of some technological routes that could potentially be more cost- and carbon-effective. There is a need for further dialogue which looks beyond colour to also explore carbon equivalence.
- 3 Demand-centric hydrogen perspectives are needed to advance the Humanising Energy agenda**. The current hydrogen conversation focuses heavily on supply, ignoring the role of hydrogen users. Discussions must explore what's needed to trigger demand, with a specific focus on the development of hydrogen infrastructure and a global supply chain.
- 4 The hydrogen economy could stimulate job creation and economic growth**, potentially helping to fulfil 'build forward together' ambitions post-COVID-19. Several national hydrogen strategies highlight jobs as an important driver of hydrogen development, with opportunities to reskill the existing workforce and upskill a new workforce.

To help inform the dialogue on these 4 topics, we are releasing 3-part series working papers for the hydrogen road builders, providing additional insights on:

- National Hydrogen Strategies;
- Inputs From Senior Leaders On Hydrogen Developments;
- Hydrogen Demand And Cost Dynamics.

This Working Paper presents inputs from senior energy leaders on hydrogen and critical issues that are emerging related to hydrogen development. This Working Paper builds upon interviews with 38 experts from 23 countries, reflecting 61 % of the global Total Primary Energy Supply - TPES (2018 data, OECD) and 70% of global GDP (2019 data, WB).

To gather new critical insights on hydrogen state of play, opportunities, and challenges worldwide, the World Energy Council conducted 25 interviews with 28 energy thought leaders across 22 countries between February and April 2021. We also drew valuable additional insights from 10 interviews focused on hydrogen strategies in the Asia and Pacific region conducted at the end of 2020, as well as 10 interviews previously conducted in 11 countries in 2020 by the Council as part of its German Member Committee's hydrogen study.¹ Together, these interviews highlighted new aspects of interest while also reflecting existing issues particularly critical for hydrogen's development within the energy system.

JOBS

OPPORTUNITIES TO MAINTAIN AND CREATE JOBS

While hydrogen may seem driven by a decarbonisation ambition, there is also a socio-economic opportunity. Many interviewees highlighted hydrogen's role in either maintaining or creating new jobs. Hydrogen could reuse or repurpose existing infrastructure and operations to help retain the workforce in countries with fossil fuel resources and related industries. Alternatively, it could help create new jobs in countries exploring export opportunities of both hydrogen and related technologies with senior energy leaders stressing the need to build a local hydrogen economy to properly address both social and economic impacts.

"Exporting hydrogen countries also need to figure out how to create local value for hydrogen, to develop job opportunities." MAX CORREA ACHURRA, MINISTRY OF ENERGY, CHILE

"In developing countries, governments will need to support local production instead of relying on imports to create more ownership and opportunities (jobs, market development) so that adoption develops faster."

DAVID MUTHIKE, KENGEN LTD, KENYA

"Spain is creating 'Just Transition' zones where hydrogen production can help avoid rural depopulation and achieve the demographic challenge objectives by benefiting communities that suffered from the closure of coal power plants. Spain has a responsibility to take care of them"

JOSÉ LUIS CABO SÁNCHEZ, MINISTRY OF ECOLOGICAL TRANSITION AND DEMOGRAPHIC CHALLENGE, SPAIN

For both transitioning and new job opportunities, the need for training has been highlighted as a critical short-term issue, with senior energy leaders emphasising the more general need to improve hydrogen literacy for the overall population as well as training a skilled workforce. The identification of competencies and skills along the hydrogen value chain is a critical area for cooperation between government, industry, and academia to develop the necessary talent pool for new opportunities. Some companies already see hydrogen as an opportunity to attract new talent.

"There is an expectation that the hydrogen industry will become one of the cleanest energy industries and will support the development of low carbon sources of electricity. It relies on high end technologies and can attract the new generation to work for energy companies." EVGENY PAKERMANOV, RUSATOM OVERSEAS, RUSSIA

"Currently one of the greatest challenges is related to the lack of education, awareness and knowledge on green hydrogen from the authorities, the potential consumers and the future suppliers."

DANIEL CÁMAC, HYDROGEN PERUVIAN ASSOCIATION, PERU

¹ (World Energy Council - Germany/ Weltenergieerat - Deutschland, 2020).



In today's early hydrogen development, dialogue surrounding potential job opportunities is just beginning and needs further analysis to understand the full implications of hydrogen development. However, many see post-pandemic recovery plans as an opportunity to increase hydrogen infrastructure and capacities for new growth opportunities, while recognising that social challenges will likely take priority, particularly in the immediate term.

“When considering hydrogen development today, we must consider the social factor post-COVID with an increase in poverty and a higher level of unemployment.” MASSIMILIANO CERVO, H2 HELIUM, BRAZIL

MACROENVIRONMENT

A POTENTIAL DISRUPTION OF THE ENERGY SUPPLY LANDSCAPE

Hydrogen has the potential to significantly impact the energy market and disrupt many countries' positioning within it. Many senior energy leaders have emphasised hydrogen's role in helping to diversify energy supply and become more self-sufficient for both energy supply and products (e.g., fertilisers). Developing countries with a high renewable energy capacity could produce and then export their own fuel to create potential for economic, social and environmental development. The emergence of new players in renewable energy production is prompting a move towards more distributed supply. At the same time, current fossil fuel producers also have a role to play in the hydrogen economy where they can use their existing resources with carbon capture, as blue hydrogen can play an important role to scale up the market. Senior energy leaders differ on the future role of hydrogen derived from fossil fuels, ranging from use only in the market ramp up phase to being indispensable in the long-term to meet growing demand.

“Diversification is a key to security of supply. With hydrogen, you can spread your eggs in different baskets. Hydrogen production will reduce our dependency on other countries for energy resources and will create local employment.” DIDIER HOLLEAUX, ENGIE, FRANCE

Hydrogen could contribute to the circular economy by using surplus renewables, processing waste resources, or through carbon capture, use and storage technologies in the case of blue hydrogen. National strategies have put significant emphasis on hydrogen development to reach decarbonisation targets, but experts claim little attention has so far been given to hydrogen's role in a circular economy that could bring innovative solutions as well as job and economic opportunities. Moreover, the low-efficiency characteristic of hydrogen production through electrolysis, coupled with the high material intensity of renewable energy sources, increases the interest in utilising recycling pathways for hydrogen generation to increase its sustainability while reducing its carbon footprint.

“Hydrogen has tremendous potential in the circular economy to help reduce waste: biomass, plastic, solid waste, organic waste, sewage, biogas, bio-ethanol and energy surplus.” MONICA SARAIVA PANIK, BRAZILIAN H2 ASSOCIATION, BRAZIL

“One of the biggest challenges for hydrogen is to scale it down for use in different areas, for the general public.” MÓNICA GASCA ROJAS, MINISTRY OF ENERGY, COLOMBIA

While being in early development, hydrogen is a very political topic with demand being pushed by several governments from a top-down perspective. The debate surrounding hydrogen sources and colours (see Working Paper - National Hydrogen Strategies) illustrates the diverging visions and interests among countries invested in its development.

“The colour debate will be settled by price. The minute green hydrogen cost equals blue hydrogen cost, blue hydrogen will not make sense anymore.” PADDY PADMANATHAN, ACWA POWER, SAUDI ARABIA

Moreover, there may be lessons from previous energy market developments applicable to hydrogen. Many interviewees referenced lessons from the solar panel market, insisting that technology development and manufacturing need to go together (see Working Paper - National Hydrogen Strategies). In this context, China's role with hydrogen is currently a key unknown. Other countries, such as India, Russia, the United States of America, and the Gulf States, have not yet published formal strategies but are showing interest or activity within the hydrogen domain. Russia has already officially issued the Hydrogen Energy Development Roadmap to 2024 showing its strong ambitions in the sector. Further unfolding of their plans will affect hydrogen's potential uptake and the development of an international market.

There is a particular focus on COP26 where hydrogen could play an important role to meet the goals set by the Paris Agreement during COP21. The update of the countries' Nationally Determined Contributions (NDCs) could be a game changer for hydrogen uptake.

SOCIAL LICENCE

DEVELOPING HYDROGEN LITERACY TO BUILD ACCEPTANCE

The social license for hydrogen relates to its public acceptability and understanding of its technologies and uses. The current low awareness creates both risks and opportunities. Studies suggest that the key influences on acceptance and adoption of hydrogen are public perception and understanding of its safety, cost, and environmental benefit, particularly in comparison with renewable and non-renewable sources of production.² Effective communication and outreach campaigns are imperative to raise awareness and acceptance.

Understanding public perception is crucial in forming national hydrogen policies and managing the transition to a hydrogen economy. Some studies reveal improving public awareness, particularly of the environmental benefits and safety standards, reduces concern,³ while others found those with better knowledge of the technology have increased scepticism as they are aware of its challenges.⁴ As a potentially disruptive technology, hydrogen risks being stuck in very niche markets. Therefore, clear social acceptance and legitimacy for users is essential, particularly as we move from applications in industry and "Business-to-Business" (B2B) sectors (in which the general public does not take part) towards applications closer to them.

"If you make hydrogen sound too special, that's when you start to scare people."

JIM SKEA, IMPERIAL COLLEGE LONDON, UK

The development of safety standards and training are crucial for public reassurance with experts highlighting emergency handling as a priority topic. In addition, for public perception, the location of hydrogen storage facilities can be a concern if existing ports and new infrastructure are located in densely populated areas and can negatively affect perceptions due to lack of awareness and understanding of hydrogen.

Experts suggest that governments and industries need to anticipate social acceptance issues as part of their hydrogen agendas. Ill-informed speculations around hydrogen need to be addressed through targeted communication outreach campaigns, educational programmes, and deployment hubs.

Initiatives for develop social acceptance of hydrogen are emerging in the form of cooperation with local governments and businesses and via communication and community outreach to explain hydrogen's benefits and risks. Some countries are creating "Hydrogen Hubs" to act as accessible information points for community knowledge of hydrogen and importantly to present its benefits for jobs and economic growth. Countries are using public events to increase general knowledge around hydrogen, such as South Korea introducing a "Hydrogen Day" to focus on hydrogen safety in major cities cooperating with industry and local government and Japan using the 2020/21 Olympic and Paralympic Games as a platform to promote hydrogen by using fuel cell vehicles and buses and powering the athletes' village with hydrogen.

² (Carr-Cornish, 2019).

³ (Mourato et al., 2004).

⁴ (Kontogianni et al., 2013).

“We need a huge effort in promoting the understanding of complexity, and we are lacking that in our society. We have educated generations in simple choices (good vs. bad). We are entering the age of complexity; our energy transition is towards complexity. We need to move away from a monolithic approach (e.g.: “fossil fuels are bad, therefore remove fossil fuels”).” STEFANO BESSEGHINI, ARERA, ITALY

At the local level, and to facilitate bottom-up discussion, hydrogen assemblies can build community familiarity through early and transparent participation between communities and projects, for example through dialogue between project developers and neighbouring communities.

“Involving the public as early as possible is an important part of the roadmap.”

WILSON SIERRA, MINISTRY OF INDUSTRY, ENERGY AND MINING, URUGUAY

DIALOGUE

A NEED FOR FURTHER DIALOGUE AND EXCHANGE AMONG THE ENERGY COMMUNITY

One key topic emerging from the interviews with senior energy leaders is the wish for further dialogue to facilitate, accompany, or accelerate hydrogen development. Hydrogen dialogue can already be seen between countries (e.g., via the signature of Memorandums of Understandings) and between stakeholders (e.g., public-private partnerships). However, there is also a desire for more discussion at the regional level with more than two countries, between regions, as well as at the international level.

The dynamic between cooperation and competition is evolving. Cooperation is seen as particularly crucial on a regional level to enable integrated projects that could strengthen positioning in the global market, for instance to define Guarantees of Origins for hydrogen and a related certification mechanism (see Working Paper - National Hydrogen Strategies). This is also seen within the field of research & development (R&D) where cooperation between countries, companies, and academics is driven by a common interest to launch competitive products and pilot projects, particularly during the scaling up phase before competition can take place.

“International cooperation is needed to tackle hydrogen’s international challenges – safety, social acceptance, cost.” MARTIN SCARONE, MINISTRY OF INDUSTRY, ENERGY AND MINING, URUGUAY

However, many senior energy leaders reflected that competition is starting to take shape on the supply side, with countries battling for the export markets (e.g., for green fertilisers). Competition is also growing within countries between the different sources of hydrogen (e.g., blue vs. green hydrogen). Cooperation is happening in Europe, but interviewees highlighted competition emerging when subsidising companies comes into play, notably in the context of receiving EU funding from the COVID-19 recovery package.

“Competition is healthy – it will create speed and drive. We need more agility when responding to the market.”

PIERRE HERBEN, ANGLO AMERICAN, SOUTH AFRICA

More dialogue could help to raise demand and there is space for enhanced multi-stakeholder dialogue around hydrogen development at the regional and international level.

Facilitating hydrogen uptake: Increasing private sector interest in developing hydrogen

The private sector interest in hydrogen is growing with the Hydrogen Council noting that of the 228 announced projects valued at \$345 billion, only 20%, or \$70 billion, were publicly funded. One driver for private sector interest in low carbon hydrogen comes from their Environmental, Social, and Governance (ESG) ambitions. Firms are shifting towards more environmentally sustainable processes and end-use products, driven by their investors' and consumers' interest in higher ESG-performance.

Some companies suggest that carbon labelling has the potential to steer consumers towards "green" products to help scale demand for low carbon hydrogen end-products. One interviewee suggested that "it can have as much impact as carbon pricing on the uptake demand for hydrogen". Labelling could encourage consumers to pay extra to cover the cost premium for food produced with green ammonia or for manufactured cars using low-carbon steel leading to a shift in consumer preference towards supporting these products.

ENABLING ENVIRONMENT

A NEED FOR FRAMEWORKS TO BRING DOWN COST AND DE-RISK INVESTMENT

The cost of low-carbon hydrogen, including its storage and transport to final users, is the main barrier preventing hydrogen take-off today (see Working Paper – Demand and Cost Dynamics). Most agree that the price drop in the coming years is a given, following similar cost curves that solar and wind power technologies undertook during the last decade.⁵ Many interviewees consider mass production allowing for economies of scale, overall demand increase, and an important decrease in the cost of renewables themselves will decrease the cost of hydrogen.

"The experience on solar energy and fast price decrease supports the development of hydrogen."

MARÍA JOSÉ GONZALEZ, MINISTRY OF INDUSTRY, ENERGY AND MINING, URUGUAY

"Significant economies of scale are possible. In a fuel cell, the more you make, the cheaper it becomes, because you start to industrialise the production."

NICOLAS POCARD, BALLARD POWER SYSTEMS, CANADA

To achieve cost reduction, an emphasis has been put on reducing the cost of hydrogen production and transport technologies. Senior energy leaders are divided regarding the role innovation and new hydrogen technologies could play in the cost decrease, and whether new hydrogen technologies will be the main factor for price reduction. Current national strategies are largely focused on hydrogen technology R&D. However, most countries appear to be waiting to commit longer-term support for R&D and commercial adoption for hydrogen technologies until the success of this early-state R&D and early deployments in driving down the cost of hydrogen technologies is established.

"In the end, we will have much more hydrogen in the system than what is thought of today as it will be able to compete with locally produced cheap electricity."

A.J.M VAN WIJK, TU DELFT, NETHERLANDS

Innovation to bring down the cost of hydrogen and de-risk investment can also happen via policy frameworks and tools, notably regulation. Overall, most policy instruments presented in the national strategies have cost reduction

⁵ (IRENA, 2020).



and de-risking investments as the end goal. Among the many tools considered, several interviewees have pointed at the implementation of a carbon price to reduce the gap between hydrogen and competing alternatives.

Other enablers for hydrogen demand uptake relate to supporting the kickstart of hydrogen projects, issuing contracts, and organisations taking and sharing the risks. Many interviewees, in particular among the private sector community, have highlighted the need for a policy framework helping them take the risks and secure long-term investments. This could be done, first and foremost, by governments providing a clear direction or vision for hydrogen and, secondly, by ensuring visibility and a certain stability of policies over time.

Many stakeholders have also pointed out in the interviews that a “chicken and egg” problem exists between hydrogen supply and demand and the need for innovative frameworks and measures, at the national, regional and international level to get out of this cycle. As most senior energy leaders still consider themselves in a “hydrogen learning curve”, many of these tools are yet to be created.

ANNEX

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*awaiting membership approval

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