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HYDROGEN ENERGY DIALOGUES
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THE INTERPLAY OF HYDROGEN AND NATURAL GAS

HOSTED VIRTUALLY BY:

THE NATURAL GAS INITIATIVE
STANFORD UNIVERSITY

ENERGY DIALOGUES LLC

Final report prepared by

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Naomi L. Boness, Ph.D.
"San Francisco Energy Dialogues: Executive Summary"

This executive summary was prepared from audio recordings of the event hosted at Stanford University on June 16, 2021.

Introduction

The Stanford Natural Gas Initiative (NGI) and Energy Dialogues LLC convened a virtual symposium on June 16, 2021, to discuss the potential role of hydrogen in a decarbonizing world, and specifically the interplay between hydrogen and the existing natural gas system.

The Stanford NGI and Energy Dialogues LLC are grateful to our partners on this event: Chart Industries and Baker Botts, who provided support and participated on the steering committee to engage energy leaders from across the globe.

Sixty thought leaders from academia, industry, NGOs, and government convened to explore hydrogen technologies, policy, and deployment opportunities.

The event was comprised of one keynote presentation and two panel discussions, in addition to two roundtable working sessions designed to facilitate dialogue among small subsets of the participants. The full program is provided in the appendix.

The final product from the event is this report that summarizes the main takeaways and recommendations for further efforts.

The Hydrogen Opportunity: Perspectives of Developers, Users, and Investors

The initial discussion centered on the opportunities and challenges for the adoption of hydrogen in a variety of sectors as part of a low-carbon, renewable energy future. As companies reinvent themselves with net-zero targets, hydrogen has been identified as a realistic and reliable fuel source, as part of a diverse decarbonization portfolio. Hydrogen will play an increasingly important role. The current global production of Hydrogen is approximately 70 million tons per year, primarily for refining and ammonia (fertilizers), with 70% produced from steam reforming of natural gas and 27% from steam reforming of coal. However, the IEA believes Hydrogen use will grow to as much as 210 million tons per year by the end of this decade and 530 million tons per year (~15% of global energy consumption) by 2050 in order to meet net-zero emission goals.

There are sectors such as industry (high temperature processes) and heavy-duty transportation that will face major challenges associated with electrification. Novel applications, for example, the use of fuel cells in forklifts, demonstrates the viability of hydrogen in specific markets, over alternatives such as batteries. There are also several emerging markets such as heavy industry and shipping.

Experts discussed the role of a gaseous fuel to provide redundant delivery infrastructure as well as the benefits of chemical storage of energy. In particular, the increasing number of climate events annually (wildfires, hurricanes, etc.) renders the need for robust energy storage and options for back-up power supply. There are inefficiencies associated with hydrogen, but it was widely agreed that there are situations where those losses are worthwhile.

Current hydrogen production generates about 830 million tons of CO2 per year, equivalent to about 2.3% of global CO2 emissions. Utilizing hydrogen for decarbonization requires eliminating associated CO2 emissions, either through carbon capture and storage (CCS) or by generating the hydrogen with non-CO2 forming processes such as electrolysis.

Participants discussed the pros and cons of blue hydrogen (steam methane reforming with CCS) relative to green hydrogen (electrolysis of water). In the near-term, it was argued that blue hydrogen is economically more feasible at $1-2 per kg, compared with green hydrogen that is currently in the range of $3-8 per kg. Mitigating CO_2 emissions from steam methane reforming does not significantly increase the production cost of hydrogen. The federal 45Q tax incentive for carbon, capture and storage (CCS) in conjunction with state incentives such as the Low Carbon Fuel Standard (LCFS) in California significantly improve the economics for blue hydrogen. Blue hydrogen might enable hydrogen demand to grow and could be transitioned as renewable energy shares increase and green hydrogen costs are reduced. There are a locations where green hydrogen projects are economic, for example along the gulf coast and internationally in Saudi Arabia and western Australia.

Experts discussed how the hydrogen investments of today have similarities to the early solar markets and similar cost reductions are to be expected. Investments are actively being made in blue and green hydrogen projects. International oil companies and utilities believe they have the capabilities and project management skills to enable the scale-up of hydrogen. Today, hydrogen is really considered a specialty gas, so investments in the supply chain to recharacterize hydrogen as a fuel are being made.

The policy landscape is changing very rapidly with enormous incentives such as the recent German policy to remove the renewable energy tie-in tariff for green hydrogen, equivalent to $3.5 per kg and independent of other incentives. In the U.S., hydrogen projects are being incentivized by the production tax credit and investment tax credit. This is analogous to the investment tax credit for solar in the early 2000's. Blue hydrogen is supported by the federal 45Q credit for carbon capture and storage and discussions of direct pay are underway as well as raising the credit to ~$85/ton. Purchasing mandates for utilities requiring a certain percentage of renewable energy will be critical to establishing markets.

Hydrogen hubs and industrial centers in Europe, e.g., Ravenna, Teesside, Rotterdam, offer the ability to drive scale. Hydrogen clusters will likely be a model replicated in the U.S. with policies such as the Endless Frontiers Act and the DOE H2@Scale. It is expected that there will be 5 key hubs within the U.S.

Using the existing infrastructure, in particular the natural gas pipelines, will be incredibly important to the growth of hydrogen markets and the delivery of hydrogen. There are a few pilot projects where 5-15% of hydrogen has been injected into pipelines but establishing nationwide blending standards is still in progress.

Participants discussed the critical concerns and challenges facing the development of a hydrogen economy. For blue hydrogen, upstream methane emissions have received a significant amount of attention and reducing leakage rates to less than 0.25% will be essential for continued use of methane as a feedstock. For all types of hydrogen, there are significant challenges associated with infrastructure including but not limited to the capacity for hydrogen storage and distribution and the transport of CO_2 to storage sites. Ports have dense industrial centers and offer an opportunity to build out the necessary infrastructure.

In terms of technology breakthroughs and solutions, participants discussed lowering the cost of electrolyzers and finding hydrogen distribution and storage solutions that scale. Focusing on applications where hydrogen is almost at parity, e.g., diesel, would require smaller incentives and mobility applications require less technology development than hydrogen for grid storage and closed loop decarbonization systems.

What Will the Hydrogen Infrastructure of the Future Look Like?

The growth and scaling of the hydrogen economy will depend not only on developing markets, but on building the required infrastructure. Interestingly, experts see the hydrogen economy developing in a very different manner to other power sources. The reality is that there are very different macro drivers such as ESG sustainability and hydrogen is being considered by many different industries and sectors as a ubiquitous decarbonization solution. The development of infrastructure will be region specific and dependent on the available resources.

With regard to green hydrogen, electrolyzers are well established and a mature technology, but there is a need to move further down the cost trajectory in order to compete with grey/blue hydrogen. In addition to capital costs, the overwhelming factor driving high green hydrogen costs is the renewable electricity feedstock.

Experts discussed centralized hydrogen production through large Giga Watt scale electrolyzers vs decentralized modular facilities close to the market demand. Large plants have the benefit of reducing unit cost through high capacity. The benefit of smaller on-site production is that the hydrogen does not need to be transported long distances to market. Hydrogen transportation cost is significant and subject to many regulatory constraints.

There was consensus that to cost effectively transport hydrogen, a liquid molecule is probably an important part of the solution. Experts agreed that there is a lot of technology development on the horizon for hydrogen storage and distribution. As hydrogen markets evolve, transportation over long distances and potentially internationally will require the evolution of standards and regulations. Currently, most of the hydrogen is transported on tube trailers, but as the market grows this might not be as viable and hubs and on-site production will become more necessary.

In terms of policy, incentives are needed to both support production and create market demand. At the end of the day, stimulus is necessary to initiate the hydrogen market and kick start projects, but the business must be self-sustaining. Incentives that allow for access to clean renewable electricity for hydrogen production would be of huge benefit to the green hydrogen production sector. Furthermore, incentives for green hydrogen or green ammonia would also help create a market pull.

A discussion was held on transitioning the existing hydrogen market (70 million tons per year globally) to green or net-zero carbon hydrogen. Incentives could be put in place to motivate refineries and ammonia facilities for example to purchase clean hydrogen. In California, the low carbon fuel standard, is an example of a successful policy that has motivated purchase of low carbon fuels.

There are many hydrogen projects underway and a plethora of partnerships and collaborations between companies, government agencies and NGOs. A major catalyst for the hydrogen economy will be the connection of these projects through regional infrastructure.

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The Interplay of Hydrogen and Natural Gas

8:00am PST Welcome & Opening Remarks

8:15am

Stanford Keynote: Hydrogen as a Key Building Block in the Energy Ecosystem

Speaker: Adam Brandt, *Director,* ***Stanford Natural Gas Initiative***

- Hydrogen fundamentals - setting the stage
- How is hydrogen produced, transported and stored?
- How does hydrogen fit into an integrated energy landscape?
- What is the value of diversity and hydrogen/gas molecules in the electric grid?
- Where could big decarbonization impacts be made?

8:45am

Panel 1: The Hydrogen Opportunity: Perspectives of Developers, Users and Investors

- Where do near-term opportunities for hydrogen reside?
- What investments are currently made in the sector? How can investments and collaboration accelerate the adoption curve?
- What policies can help to make net-zero hydrogen economically feasible? Tax credits and incentives to shift from high- to lower-carbon technologies and processes

Moderator:

Naomi Boness*, Managing Director,* ***Stanford Natural Gas Initiative***

Confirmed Speakers:

Dev S. Sanyal*, Executive Vice President, Gas and Low Carbon Energy,* ***BP***

Kevin Kopczynski*, Vice President, Strategy and M&A,* ***Plug Power***

Jawaad Malik*, Vice President, Strategy and Sustainability and Chief Environmental Officer,* ***SoCalGas***

Julio Friedmann*, Senior Research Scholar at the Center for Global Clean Energy Policy,* ***Columbia University***

9:30am Networking Coffee Break

9:45am

Round Table 1:

Technology Innovations *- what breakthrough technologies and solutions will be needed for hydrogen to reach its full potential?*

OR

Drivers and Limitations to Building a Hydrogen Economy *- where will investment come from? (What are lessons learned from hydrogen deployment in other parts of the world?) What will be most commercially viable applications for hydrogen?*

10:30am

Panel 2:

What Will the Hydrogen Infrastructure of the Future Look Like?

- To what extent will hydrogen be able to utilize the existing natural gas infrastructure?
- Storage as a vital piece of the infrastructure puzzle: what is the role of hydrogen in the energy storage infrastructure?
- A shift from "grey" to "blue/green" hydrogen - what technologies, policies and collaborations will be necessary to achieve goals?

Moderator:
Jason Bennett*, Partner and Head of the Global Projects Group,* ***Baker Botts L.L.P.***

Confirmed Speakers:
Jill Evanko*, CEO & President,* ***Chart Industries***
Steve Szymanski*, Vice President of Sales & Marketing,* ***Nel Hydrogen***

11:15am

Round Table 2:

Natural Gas & Hydrogen: Collaborators or Competitors?

- *How can existing natural gas infrastructure help hydrogen reach its potential and markets?*
- *What collaboration will be necessary to tip the carbon footprint towards net-zero?*

12:00pm *Closing Remarks*