HYDROGEN INITIATIVE LAUNCH SYMPOSIUM:
HYDROGEN FOR DEEP DECARBONIZATION

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Stanford Energy's new Hydrogen Initiative was formally launched with an amazing event on Monday, May 2, 2022 in the MacKenzie Hall on Stanford campus. There were keynote presentations by Tom Linebarger, CEO and Chairman of the Board, Cummins Inc., and by Sunita Satyapal, Director, U.S. Department of Energy’s Hydrogen and Fuel Cell Technologies Office, along with a fireside chat between Dr. Condoleezza Rice and Professor Arun Majumdar. The program included panels on Hydrogen Generation, Hydrogen Distribution and Storage, Hydrogen Utilization, and International Perspectives on Hydrogen, and finally, Research Showcases on Stanford University research and start-up companies.

There was general global consensus and excitement on the role that hydrogen can play in deep decarbonization to mitigate climate change while ensuring energy security, affordability and reliability, and a sense of urgency to accelerate its deployment. Significant/material challenges remain, including the cost of renewable hydrogen generation, lack of an existing infrastructure for distributing hydrogen both locally and globally, and finally storing hydrogen at scale. However, the potential for renewable hydrogen to decarbonize our society for both legacy applications such as fertilizer production and new applications such as transportation and steel making is compelling. The Hydrogen Initiative will tackle the complete hydrogen value chain: generation, distribution, storage and utilization. We have over 35 research groups exploring the various aspects of this chain, driving toward impactful innovation, and sponsoring new start-ups through its entrepreneurial spirit.

To find out more about the Stanford Hydrogen Initiative, please visit hydrogen.stanford.edu.

The Hydrogen for Deep Decarbonization Day on Monday May 2nd kicked off The Stanford Energy Solutions Week and simultaneously served as the launch event for the Stanford Hydrogen Initiative.

The day brought together ~120 industry leaders from industry, academia, non-governmental organizations, and government. In this report you will find the key take-aways of the rich presentations and panels throughout the day.

Throughout the day, a few themes emerged:

1. Hydrogen is essential to achieving deep decarbonization
2. Key challenges for hydrogen remain the cost of low carbon hydrogen and its dispatchability. Cost is on a downward trajectory, more innovation is needed around dispatchability.
3. Government action is essential to accelerate the transition

Overall, we left the conference excited by a general consensus around the role of hydrogen and with a sense of urgency to accelerate its deployment.

To see the full Energy Solutions Week agenda, please visit gef.stanford.edu/energy-solutions-week/agenda.
Professor Yi Cui, the director of the Precourt Institute for Energy shared his excitement about adding the Hydrogen Initiative to the Stanford Energy landscape and announced the four research projects selected as finalists for the Precourt Pioneering Projects:

- Beyond Carbon Capture: Recycling CO\textsubscript{2} to Decarbonize Steelmaking with Hydrogen and Photocatalysis Investigation of the Viability of Large-scale Hydrogen Storage in Natural Porous Formations/ Hydrogen Storage in Porous Media
- Bridging key knowledge gaps in PEM water electrolysis insights into high-performance systems with advanced microscopy and spectroscopy under operating conditions
- Blue hydrogen via methane pyrolysis for carbon nanotubes production and use

Consequently, The Hydrogen Initiative faculty co-directors Professor Friedrich Prinz and Professor Xiaolin Zheng shared their thoughts about the industry and the initiative.

Professor Prinz shared his optimistic view on the hydrogen economy: With the build-out of enormous amounts of green resources, hydrogen (and hydrogen-derived fuels) will become economically viable. Additionally, he stressed that we must fight the global war against temperature rise while we must avoid local wars caused by energy dependence.

Professor Zheng gave an overview of the current members of the Initiative and invited industry, governments, NGOs and academics to join the initiative. Additionally, she emphasized the need to increase efficiency of hydrogen to decarbonize hard-to-abate sectors.
Tom Linebarger, CEO and Chairman of the Board of Cummins Inc, delivered the first keynote titled “The Path to Zero Emissions and the Role of Hydrogen”. He shared a clear call to action, focused on transportation:

- Lower emissions today - starting now with low-carbon fuels makes a big difference
- Reduce well-to-wheel emissions
- Drive wide-scale customer adoption

Specifically for hydrogen, he highlighted that hydrogen is already broadly used today, but cost and dispatchability remain challenges. Subsidies and a carbon tax are needed to make economics pencil out until around 2035. Nonetheless, companies are investing today as they see clear progress in this direction. To achieve faster adoption, governments need to become more responsive. For example, time lags in the approval processes for subsidies slow down the deployment of real projects.
Sunita Satyapal, the Director of the U.S. Department of Energy’s Hydrogen and Fuel Cell Technologies, shared her view on Hydrogen and Fuel Cells in the US. She expressed a call for action and a clear “why now” for the clean hydrogen economy to take off. Survey results from the DoE Hydrogen Shot Summit identified the greatest barriers to widespread hydrogen use in the US: public awareness and understanding, cost to the end user and need for sufficient infrastructure. The DoE is very active in the hydrogen space, with consortiums such as H2New to accelerate progress of electrolyzers.

Additionally, Dr. Satyapal invited all students, post-docs and early career professionals to join the IPHE Early Career Network. She ended her presentation by quoting H. Luccock:

“No one can whistle a symphony. It takes a whole orchestra to play it.”
The first panel on hydrogen for industrial applications comprised representatives from across a wide range of industries including Ashok Belani (Board of Genvia), Jerry Griffin (Delta Airlines), Peter Sawicki (Mitsubishi), and Craig Scott (Toyota). The panel was moderated by Professor Friedrich Prinz of Stanford.

Each of the panelists shared some of the work they are doing towards advancing the hydrogen economy. Their respective companies are all pursuing strategies towards zero emissions from their operations and/or the use of their products. Delta, for example, is on a path to a vision of “zero impact aviation” while Toyota is working on zero emission drivetrains for heavy duty trucks to completely decarbonize port operations.

Mitsubishi is part of the Advanced Clean Energy Storage project which is building out a salt cavern for long-duration hydrogen storage paired with a hydrogen capable gas turbine in Utah. Part of the pitch for this project is that deploying hydrogen as a long duration energy storage medium will lower overall energy system buildout cost by 20% across the US.

Genvia, a joint venture of CEA, Schlumberger and others is working on commercializing its solid oxide electrolyzer for industrial applications. Its primary focus is to reduce cost, echoing the call from Tom Linebarger in the keynote. The panelists were unanimous in their call to governments to increase support. Incentives and funding at all levels are needed. Furthermore, clear signals in which direction policy is moving is helpful to enable private sector investment.

On the topic of scaling, the panel was asked for their opinion regarding labor shortages. While there is a lack of experienced labor in this new industry, they reported it being relatively easy to hire skilled employees into the industry.

“People are not the issue. That would be an excuse. People rise to the occasion.”

A decade ago, the world over-delivered on the DoE’s sunshot. Back then, the world thought it would be very difficult and scale made the difference. If we believe the panel, the same will happen with hydrogen - only that unlike with solar panels, this time the US and EU will not leave the scaling part to China.
The Stanford Research Showcase included a snapshot of some of the research at Stanford related to clean hydrogen.

Matthias Ihme, Assistant Professor of Mechanical Engineering, shared his view on ammonia (NH₃) as a pretty competitive hydrogen carrier. Professor Ihme and his team are researching NH₃ synthesis and utilization, including Porous Media Combustion as an enabling technology for carbon-free energy conversion.

Tom Jaramillo, Associate Professor of Chemical Engineering, shared some of his research on electrolyzers including precious metal catalysts, dealing with impure water sources and direct solar-to-hydrogen systems.

Finally, Xueli (Sherry) Zheng, Research Scientist of Materials Science and Engineering, shared her research on hydrogen-based direct iron reduction as a pathway to decarbonize steelmaking.
Condoleezza Rice, Professor in Global Business and Economy and former Secretary of State, shared her concerns about the shock through the international system as countries try to navigate the critical Russia-Ukraine situation and crisis. For the US, she highlighted the need to find diversified sources of oil and gas in the short term and a price on carbon to enable the transition in the medium-term. She stressed the importance of nuclear energy in the transition and the need for policies/regulations to provide certainty to accelerate the transition for incumbent players. She closed the session by sharing her excitement about Stanford’s new Doerr School of Sustainability. Her advice for the new school? She encouraged academia to be transparent in their assumptions, highlighted the importance of attracting the very best talent and leaving space for bottom-up idea creation.
The second panel on generation and distribution of hydrogen included various companies that have long dealt with hydrogen including Kathy Ayers of Nel, David Edwards of Air Liquide, Matt Pitcher of Technip Energies, and Leonardo Spanu of Shell. The panel was moderated by Professor Xiaolin Zheng from Stanford.

The panel highlighted the complexities involved in scaling the hydrogen industry:

- Diverse market drivers ranging from different regulation, timelines, and needs
- Short term economics are challenging - need to scale production while also creating off-take agreements
- Transition in supply/distribution - we will start with local and on-road distribution and over time shift to regional and international distribution with pipelines and shipping

Regarding distribution, one of the key challenges the panelists highlighted is scaling transportation. Liquefaction is limited in scale and has high costs while there is a lack of pure hydrogen pipelines and converting existing pipelines comes with its own regulatory, safety, and cost challenges. For longer-distance transportation, ammonia is set to be the largest hydrogen carrier in the short term while liquid hydrogen and/or liquid organic (LHOC) will likely play a larger role in the medium term.

On electrolyzer technology, the key message was that these technologies have different applications with alkaline being deployable at significantly larger scales than proton exchange membrane electrolyzers (PEM) to date. However PEMs are better suited for ramping up and down with intermittent renewable electricity supply. One key opportunity for PEM is to redesign the stack for industrial applications - they were originally conceived for submarines and redesigning them could enable significant cost and efficiency improvements.

Lastly, the panel highlighted the need for different technologies. The optimal solution will depend on local renewable energy availability, natural gas prices, and possibilities for sequestration. To fully decarbonize, we will need a wide range of technologies.

The panel ended with advice to academics to go talk to industry to understand their needs.
The third panel of the day was focused on International Perspectives and National Strategies for Hydrogen. Moderated by Professor Steven Chu, the panel included Ashok Belani (Chairman of the Genvia Board), Tony Chan (President of the King Abdullah University of Science and Technology), Stephen Eglash (Director, Applied Energy Division at SLAC), Kazuaki Osumi (Director General at NEDO Silicon Valley, and Gauri Singh (Deputy Director-General, IRENA).

Ashok Belani shared the importance of partnerships and the need for process transformation both on the demand and production side. Kazuaki Osumi shared the context behind Japan’s goal to make hydrogen and ammonia at least 1% of Japan’s power generation mix by 2030. Steve Eglash advocated for an agnostic approach to hydrogen and a two-way dialogue between SLAC and the Hydrogen Initiative. Gauri Singh stressed the importance of bilateral agreements between countries to exploit hydrogen export potential of countries like Chile and Namibia with cheap renewable resources. Most panelists agreed on an expected evolution of the clean hydrogen industry from local to regional to international from the short to long-term. Finally, there was general agreement on the need to tackle the chicken-and-the-egg problem between clean hydrogen suppliers and users to enable scale/faster deployment.
In the second part to the Stanford Research Showcase, three areas of research on hydrogen storage, distribution, and usage were shared.

**Wendy Gu**, Assistant Professor in Mechanical Engineering, talked about her work on how existing pipelines can be upgraded to transport hydrogen. Her team looks at hydrogen embrittlement in metals. They developed strain-gauge based imaging techniques paired with dynamic imaging of micro-cracking to study embrittlement behavior to enable broader deployment of hydrogen using existing infrastructure.

**Anthony Kovscek**, Professor in Energy Resources Engineering, talked about the need for subsurface storage. California curtailed more than 1.5TWh in 2021, equivalent to 30 million kg hydrogen. To reach this scale, subsurface storage is the only path to scale. His team is looking at how to make this work.

**James Swartz**, Professor of Chemical Engineering, shared his work on carbon negative commodity chemicals. His team is working on producing Succinic acid today, which serves as a pilot for producing biofuels and other commodity chemicals through a similar methodology.
In the start-up panel, four Stanford alums and current CEOs shared some of their work: Rob Hanson of Monolith, Ted McKlveen of Verne, Nicolas Pinkowski of Nitricity, and Jimmy Rojas of EvolOH. The discussion was moderated by Mayank Girdhar, Sloan Fellow at the Stanford Graduate School of Business.

Monolith is a methane pyrolysis company and can produce at $1/kg hydrogen today. Verne is working on cryo-compression tanks to enable more hydrogen-storage on fuel-cell trucks.

Nitricity produces “lightning fertilizer” using air, water, and electricity to make fertilizer. EvolOH is developing AEM electrolyzers, combining the benefits of alkaline and PEM electrolyzers.

All four founders highlighted the important role Stanford played in founding and building their companies to date. Their main message both for aspiring entrepreneurs and for universities is to foster more interaction with industry so that the focus is on real world problems.

HIGHLIGHTS:

- The Stanford network is a great accelerant for startups
- For budding entrepreneurs: go talk to people in the industry. Tap into alumni networks, academics, etc. to uncover real world needs
- For schools: make the real world problems more visible to students - they are there and we need all bright minds to work on them.
KAREN BAERT is devoting her professional life to helping the world get to net zero, and believes clean hydrogen is a key enabler in that transition. Her work experience includes Management Consulting at Bain & Company and climate tech Venture Capital at Breakthrough Energy Ventures. She is a joint MBA and MS Environment & Resources graduate student at Stanford and holds a Master’s degree in Renewable Energy Engineering from the Technical University Berlin.

NAOMI BONESS is the managing director of the Natural Gas Initiative at Stanford University, co-managing director of the Stanford Hydrogen Initiative and a coinstructor of a graduate seminar class on the Hydrogen Economy. She is an experienced practitioner in the energy sector with a focus on natural gas, hydrogen and decarbonization in both the developed and the developing world. Prior to Stanford, she held a variety of technical and management positions at Chevron. Naomi is also a Director for a renewable fuels company and an advisor for a hydrogen startup. As an advocate for women and gender equality, she is a member of the organizing committee for the Women in Clean Energy, Education and Empowerment (C3E) Initiative. Naomi holds a Ph.D. in geophysics from Stanford University, a M.Sc. in geological sciences from Indiana University and a B.Sc. in geophysics from the University of Leeds.

THILO BRAUN is passionate about tackling some of the most hard to decarbonize industries in the transition to a carbon free economy. His work experience includes Management Consulting at McKinsey & Co and scaling Lilium, an electric aircraft company, as an early employee to a team of over 500. He is a joint MBA and MS Environment & Resources graduate student at Stanford and holds a Master’s degree in Aeronautical Engineering from Imperial College London.

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