Industrial Innovation Initiative

a partnership between Great Plains Institute and World Resources Institute

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Background

The Department of Energy's (DOE) Hydrogen and Fuel Cell Technologies Office has a crucial role to play in advancing the full scope of clean hydrogen strategies key to achieving industrial decarbonization by midcentury. Pivotal to this effort will be making clean hydrogen affordable enough to commercially scale. The DOE's Hydrogen Energy Earthshot marks a necessary and ambitious step toward developing an economically viable clean hydrogen economy. This goal cannot be accomplished alone and there is a critical need for cross-agency coordination if the US is to leverage hydrogen resources to advance decarbonization priorities effectively and efficiently. In response to the Request for Information regarding Regional Clean Hydrogen Manufacturing, Recycling, and Electrolysis (DE-FOA-0002698-RFI), the Industrial Innovation Initiative (I³) has prepared the following document.

About I³

The Industrial Innovation Initiative (I³) is an ambitious coalition which aims to advance solutions key to decarbonizing the industrial sector through policy development and implementation, technology demonstration and adoption, and demand-side market development. The Initiative builds on years of stakeholder engagement and extensive work by its co-conveners, Great Plains Institute and World Resources Institute, to collaborate with government officials and advance decarbonization solutions important to the industrial sector.

I³ values a stable climate, a safe and healthy environment, thriving livelihoods for American workers, and a strong US economy. Therefore, I³ supports policies that will put American industry on a path to net-zero emissions, retain and create high-wage jobs, and advance technology leadership and economic competitiveness. The Initiative convenes key industry, environmental, labor, and other stakeholders, to advance cross-cutting strategies, policies, and programs for achieving industrial decarbonization by midcentury.

Part I: Clean Hydrogen Manufacturing and Recycling

B) Supporting domestic supply chains for materials and components

The industrial and manufacturing sector, which includes the production of metal, mineral, chemical, and petroleum products, among others, employs millions of Americans and supports state and local economies. Decarbonization must occur in a way that preserves industries, their contributions to the US economy, as well as the direct and upstream jobs they provide. Supporting domestic supply chains for hydrogen production materials and components will ensure those good, upstream jobs are secured and retained for US workers.

Scaling up the US hydrogen economy could yield about $140 billion in annual revenue and support 700,000 jobs throughout the hydrogen value chain by 2030, and $750 billion in annual revenue and up to 3.4 million jobs by 2050.[i] Deploying clean hydrogen technologies will retain and grow high-wage domestic supply chains, industry, and manufacturing jobs.

As industrial processes switch to low- and zero-carbon hydrogen for heat, fuel, and feedstocks, federally designed workforce training programs can create and protect good jobs, minimize worker displacement, encourage and develop new labor skills, and avoid stranding many assets. Developing this workforce is critical to install, operate, and maintain industrial systems and retain high-wage jobs at industrial facilities. In preparation for these workforce training programs, the federal government can convene utilities, companies, trade groups, education providers, labor organizations, and local workforces to ensure that training programs are appropriately targeted to meet the needs of all stakeholders and adhere to high road labor standards.

H) Developing strategies to increase consumer acceptance of/participation in recycling of fuel cells

A significant opportunity for developing the social license to deploy hydrogen projects, such as fuel cell recycling, lies in the quality of public and community engagement. Communities should be contacted, informed, and solicited for comment early and frequently throughout the process of a project's development. Requiring robust community engagement, education, and public participation is critical for building project and technology support, as the people living and working in the area will better understand what is changing and how it will impact them. Public studies of the local environmental, economic, and community benefits of cleaning up the industrial sector through clean hydrogen solutions can help build understanding and support among impacted communities. The public comment period should not be seen as a rubber stamp requirement, but instead be treated as an opportunity to understand, respond, and act to resolve any concerns of the community

Part II: Clean Hydrogen Electrolysis Program

1) Electrolyzers including, low-temperature electrolyzers (i.e. liquid alkaline or membrane-based); high-temperature electrolyzers that combine electricity and heat to improve the efficiency of clean hydrogen production; advanced reversible fuel cells that combine the functionality of an electrolyzer and a fuel cell; and other advanced electrolyzers, capable of converting intermittent sources of electric power to clean hydrogen with enhanced efficiency and durability.[20] Please state the specific electrolyzer technology your response relates to.

> **b.** What metrics and methods could enable and/or validate progress towards the $2/kg goal?

There are several large-scale indicators for measuring progress towards $2/kg for low and high-temperature electrolytic hydrogen production. To gauge the foundational preparedness for large-scale deployment and industrial scale up, first consider the Technological Readiness Level (TRL) of different electrolysis technologies. Achieving TRL 9, the highest level before routine deployment, shows enough investment in the production pathway to enable additional investment in supportive manufacturing and infrastructure. In the case of electrolysis, TRL 9 signals readiness for more zero-carbon energy production, both dedicated and curtailed, to reduce the operating costs of electrolysis; additionally, dedicated renewable energy capacity and cost are useful metrics of hydrogen production costs.

Additional metrics for specific technologies include:

- Low-temperature Electrolysis (i.e., Alkaline and Proton Exchange Membrane): The production efficiency of low-temperature electrolysis is limited by the corrosive impacts of increasing the reaction temperature—barring corrosion, higher temperatures increase the hydrogen yield. Larger scale production could be enabled by innovations that reduce material corrosivity, as measured by the amount of time and temperature at which materials reach the corrosion “break-away” point.[ii]
- High-temperature Electrolysis (i.e., Solid Oxide Electrolysis Cell [SOEC]): Two key obstacles of SOEC are the high temperatures needed to achieve their optimal efficiency and cost of rare-earth and scarce minerals. Because higher temperatures require more energy, two useful metrics would be higher efficiency of energy and hydrogen generation; that is, how much energy can be produced by a given input (e.g., solar, wind, nuclear) and how much hydrogen at a given temperature. And while the cost of rare-earth metals, specifically declining costs, could be a useful metric as well, it will likely be more suitable to test and prove the compatibility of innovative materials. In which case, patents for innovative SOEC materials may prove a useful indication of commercial readiness.[iii]

While I^3 does not promote specific projects, it is worth noting the value of existing demonstration projects that are working towards a $2/kg goal. Demonstrations utilizing excess clean energy will be valuable in the short-term to test state-of-the-art hydrogen production technologies or capacity for hydrogen in meeting local energy demand. For example, there are several hydrogen production plants co-located with nuclear power stations using dedicated or excess capacity, which are advantageous as they are not subject to intermittency issues. Every scale of demonstration that proves the viability of clean hydrogen production and use will be vital to achieve $2/kg.

5) Technologies that integrate hydrogen production with clean hydrogen compression and drying technologies, clean hydrogen storage, transportation or stationary systems, and renewable power or nuclear power generation technologies.24 Please note the technology or technologies discussed in the response.

> **c.** What electrolyzer, distribution, storage, and end-use technologies should be prioritized in demonstration projects?

Industrial End Uses

While there are many valuable end uses for clean hydrogen, industry represents a hard-to-abate sector that will require reliable and affordable access to low- and zero-carbon hydrogen in order to achieve midcentury decarbonization goals under virtually any scenario. Clean hydrogen will be uniquely important to the industrial sector in the near and medium term as substituting fossil fuels for clean hydrogen can reduce both on-site process and fuel emissions. As such, I^3 identified clean hydrogen as a key industrial decarbonization solution in our recent Policy Blueprint.[iv] Hydrogen produced through electrolysis holds great promise as a zero-carbon fuel and chemical feedstock as it is produced from clean energy resources, utilizes existing workforces and infrastructure, can create jobs, and can displace fossil-based medium- and high-grade heat in industrial applications that are hard to electrify.[v]

Continued funding for research, development, demonstration, and deployment will be critical to improving upon and integrating nascent clean hydrogen production, transportation, and storage technologies into the industrial facilities where they are needed most. Demonstration projects will be the proving ground for these technologies, attract private investment, and help to build market confidence in these solutions. Additionally, production cost reduction will be key in bringing clean hydrogen use to scale. Industrial and manufacturing facilities will need clean hydrogen to reach cost parity with existing fossil-based feedstocks and fuels to maintain the tight margins many manufacturers face and preserve market competitiveness.

Transportation & Storage

Transporting and storing hydrogen can be price prohibitive for producers and consumers that are unconnected by infrastructure to market hubs. Access to federal low-interest loans and grants for hydrogen pipelines, rail, and maritime transport will incentivize the construction of infrastructure linkages between regionally dispersed producers and consumers and avoid the higher costs and emissions associated with truck transport. Blending small amounts of hydrogen into natural gas pipelines, where possible based on case-by-case assessments, can also jumpstart local usage for smaller producers distant from dedicated hydrogen pipelines or hubs.[vi] Further developing storage infrastructure, like brine wells and salt caverns, enables hydrogen to be sold and dispatched when needed, which can also overcome production variability. The ability of hydrogen to provide long-term storage enables dispatchable low- and zero-carbon electricity to support the integration of variable renewable generation resources on the grid. Clear guidelines for safe transport, storage, and use of hydrogen will also be necessary to build out the requisite infrastructure for a nationwide hydrogen market.

Renewable & Nuclear Hydrogen Production

Scaling up electrolytic hydrogen powered by renewable or nuclear energy will require a vast expansion of available zero-carbon electricity. The capacity of regional balancing authorities and electric generation dispatch markets to take on new load must be considered. Transmission constraints and the projected retirement of nuclear and other baseload power plants are also important considerations. The federal government should work with states and regional grid authorities to enact policies that facilitate expansion and hardening of transmission and distribution infrastructure. In areas with abundant renewable or nuclear energy resources, there should be incentives that allow excess capacity energy generation to be moved via transmission infrastructure to areas with less abundant zero-carbon energy resources for hydrogen production via electrolysis. This would increase confidence in the value of additional renewable resource development and in the viability of low- and high-temperature electrolysis projects. Hydrogen hub developments should allow for co-location of hydrogen production and renewable energy resources. However, to scale up this solution to the degree necessary for midcentury decarbonization of this challenging sector, reliable transmission of low-cost, zero-carbon electricity will be critical.

9) Environmental justice, diversity, equity, and inclusion

> **a.** What are specific ideas and opportunities for including disadvantaged and tribal communities and addressing environmental justice, diversity, equity, and inclusion in carrying out the research and development goals, electrolyzer system research and demonstration projects?

While clean hydrogen production has the potential to create many positive externalities such as reduced air pollution (as a result of fuel switching from fossil resources to clean burning hydrogen), fewer greenhouse gas emissions, and new domestic job opportunities, it is critical that environmental justice concerns associated with electrolysis are raised and addressed with potentially impacted communities. Of note are issues around water use and scarcity. Water use and water competition will depend upon the region. Communities located in arid areas or with limited access to clean drinking water will feel the pressures associated with electrolysis more severely than water rich regions. Demineralization is a commonly used technology which allows for water use from a variety of sources in industrial processes. Research and development into the level of water purity required for electrolysis and potential means of purification should be supported to ensure the strain on clean water resources is minimal.

Other environmental justice issues of potential significance are those of land use and energy project siting. Clean hydrogen and electrolysis projects will be dependent on clean electricity sources. Renewable energy projects, like solar or wind farms, commonly face siting issues when communities are not sufficiently engaged or where the political majority is opposed to renewable energy. The Department of Energy should thoroughly study or fund studies for both the negative and positive externalities associated with a project so that the community and developers alike have a clear understanding of the local environmental justice issues at play.

Community engagement should be strategic, in those invited to the discussion, the methods of information sharing, and the solicitation of comments. Impacted and frontline communities should be brought into project development discussions early and often. Further, organized labor and labor unions should be consulted and serve as active participants in the outreach process. Transparency will be key in building trusting and equitable relationships with local communities. Project updates, studies, and opportunities to engage should be clear and accessible to interested parties, as should opportunities and venues for comment.

Furthermore, the workforce opportunities that arise from industrial projects that deploy clean hydrogen technologies, both in initial construction and for ongoing operations, should be accessible to those in frontline communities. Workforce development programs and collaboration with local organized labor unions will help ensure the economic and community benefits of clean industrial projects go to those who have historically and disproportionately born the negative impacts of industry.

I^3's coalition of industry stakeholders are here to connect

The information contained within this document represents a small fraction of the collective knowledge and expertise of our participants. Members of I^3 are ready and willing to connect with the Department of Energy's Hydrogen and Fuel Cell Technologies Office to provide key industry, labor, environmental, power, and business perspectives from our stakeholder group. The Initiative meets monthly and is happy to schedule ad hoc meetings to facilitate vital discussions such as these. If you would like to connect with us directly, please reach out to I^3 Project Manager, Gabrielle Habeeb, at ghabeeb@gpisd.net, and we will gladly arrange a meeting.

NOTES

[i] Fuel Cell and Hydrogen Energy Association, *Road Map to a US Hydrogen Economy*, published 2020, https://www.fchea.org/us-hydrogen-study.

[ii] F. P. Lohmann-Richters, et. al., *Review - Challenges and Opportunities for Increased Current Density in Alkaline Electrolysis by Increasing the Operating Temperature*, Journal of The Electrochemical Society, **168** 114501, (2021), https://iopscience.iop.org/article/10.1149/1945-7111/ac34cc.

[iii] Mandeep Singh, Dario Zappa, and Elisabetta Comini, *Solid oxide fuel cell: Decade of progress, future perspectives and challenges*, International Journal of Hydrogen Energy, Volume 46, Issue 54, (2021), Pages 27643-27674, https://doi.org/10.1016/j.ijhydene.2021.06.020.

[iv] Industrial Innovation Initiative, *Decarbonizing Industry by 2050: A Federal and State Policy Blueprint*, published

November 9, 2021, https://www.industrialinnovation.org/blueprint.
[v] IPCC, "Summary for Policymakers," *in Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, ed. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, et al. (Geneva, Switzerland: World Meteorological Organization, 2018), https://www.ipcc.ch/sr15/ chapter/spm/; IEA, Net Zero by 2050 (Paris: IEA, 2021), https://www.iea.org/ reports/net-zero-by-2050.
[vi] M.W. Melania, O. Antonia, and M. Penev, Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues (National Renewable Energy Laboratory, March 2013), https://www.nrel.gov/docs/fy13osti/51995.pdf. The efficacy and feasibility of blending hydrogen into existing pipeline networks is dependent on several factors and would require further study and improvements to maintenance and monitoring systems.