Institute of Clean Air Companies
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TO: U.S. Department of Energy Hydrogen Program
FR: The Institute of Clean Air Companies (ICAC)
RE: **Department of Energy's (DOE) Hydrogen Program Request for Information (#DE-FOA-0002529)**

The Institute of Clean Air Companies (ICAC) appreciates the opportunity to offer comments in response to DOE's Hydrogen Program Request for Information.

ICAC is the national trade association of companies that supply greenhouse gas management and air pollution control and monitoring systems, equipment and, services for stationary sources. For over 60 years, ICAC member companies have helped to clean the air by developing and installing reliable and cost-effective control and monitoring systems. ICAC is recognized as a trusted, unbiased technical resource for government and other stakeholders to understand the feasibility and relevant costs associated with innovative technologies.

ICAC's response will provide an overview of our perspective on developing pathways toward a low-carbon hydrogen economy. We support technology-neutral and flexible policies that enable cost-competitiveness and a diverse set of solutions to compete in the market. In addition, ICAC will provide responses to a number of DOE's questions regarding ideal regions for hydrogen infrastructure deployment, emissions reduction potential of various technologies, relevant research currently underway, and more.

Again, ICAC appreciates the opportunity to offer input to DOE and we look forward to answering any further questions should DOE seek additional information.

Sincerely,

Clare Schulzki
Executive Director, ICAC

I. Introduction

The Institute of Clean Air Companies (ICAC) appreciates this opportunity to respond to the Department of Energy's Hydrogen Program Request for Information (#DE-FOA-0002529).

ICAC is a trade association headquartered in Arlington, VA, and represents more than 30 companies in the air pollution control, greenhouse gas management, and emissions measurement industry. ICAC members have successfully developed and deployed solutions to address emissions challenges for more than 60 years and are uniquely positioned to provide their expertise developing the low-carbon hydrogen economy in the United States. ICAC members have successfully commercialized solutions for the industrial, power, oil and gas, and maritime sectors, and have worked to address challenges that emerge at the nexus of air and water pollution management. Pollutants managed by member technologies include mercury, acid gases, PM, NOx, SOx, VOCs, HAPs, GHGs, HCl, and coal ash. Our members have operations in all 50 states and range from multi-national corporations with thousands of employees to small businesses focused on local emission challenges.

ICAC is recognized as a trusted, unbiased technical resource for government and other stakeholders to understand what is technologically achievable and the relevant costs associated with technologies. ICAC members' experience in meeting emissions challenges equips our organization with valuable insights that can help inform the development of successful policies, regulations, and other mechanisms to support the advancement of low-carbon hydrogen. We support policies that are technology-agnostic and flexible to enable cost-competitiveness. All solutions will be needed to meet the anticipated demand for low-carbon hydrogen and to reach our mid-century decarbonization goals.

ICAC members have decades of experience with hydrogen and represent the full value chain for of all types of low-carbon hydrogen production methods and utilization options, from production and processing, through distribution and storage, to everyday industrial and consumer applications. Member companies are participating in ongoing low-carbon hydrogen projects around the globe, spanning all levels of technology development and production methods (e.g., green and blue hydrogen). ICAC supports all methods of low-carbon hydrogen production and focuses on lifecycle carbon intensity rather than the designated "color" of hydrogen production methods. In our response to this RFI, we use the color designations because they are recognized across industry and government. Colors also provide important information as to which feedstocks and energy sources are used. However, it is important to continue educating stakeholders that a color designation does not provide clear indications of the hydrogen's lifecycle carbon intensity.

ICAC members stand ready to provide support to DOE's Hydrogen Program and would welcome the opportunity to further meet to communicate our industry's perspective on the low-carbon hydrogen economy.

II. Overview of ICAC Perspective on a Low-Carbon Hydrogen Economy

Technology-Neutral, Flexible Policies to Enable Low-Carbon Hydrogen

In order to successfully secure American leadership in enabling net-zero carbon technologies, support sustainable development around the world, and benefit all Americans, a technology-neutral approach should be taken that focuses on carbon intensity and adequately supports the scale-up of proven technologies while de-risking earlier stage technologies from R&D to deployment. By allowing flexibility in government policies and initiatives, rather than prescribing specific solutions, the market will enable the best solutions to flourish.

DOE can support the hydrogen economy by helping to scale-up proven technologies and drive down costs through large-scale demonstration projects for different production methods in regions with unique characteristics (e.g., end-users, storage options, resources, feedstocks, existing infrastructure). In parallel, DOE can work with industry to move earlier stage technologies along the development path through efficiency improvements, R&D, and pilot projects.

All methods will be required, as some production methods are more suitable for certain geographies and will be more desirable based on a variety of factors. For example, regions with ample renewable feedstocks and energy sources may be better suited for green hydrogen deployment. Alternatively, regions with existing infrastructure and production facilities may be better suited for blue hydrogen, where developers can retrofit a facility and utilize the existing assets in the region. Additionally, in the near-term, retrofitting an existing production facility will allow for larger volumes of low-carbon hydrogen to be produced. If end-users require a more limited volume, then green hydrogen produced with through electrolysis could be a better option. By supporting both near and long-term technologies, DOE can help reach maximum decarbonization as rapidly as possible.

Manufacturing and Infrastructure Needs for Scale-Up

For near-term proven technologies to become cost-competitive and meet the manufacturing needs required, there will need to be improvements in automation, scale, supply chain, and demand.

Scaling green hydrogen will likely challenge the manufacturing capacity of electrolyzers. As referenced by the International Energy Agency[1], the significance of the scale-up of production capacity is tremendous. Plans to greatly increase production capacity by a number of electrolyzer suppliers will need to be supported through actual orders, not just a large number of proposed projects in the FEED study process. This is a "chicken and egg" challenge for the market. The scale of individual projects proposals is 10-50 times larger than the entire production capacity of the electrolyzer industry prior to 2018. This scale-up will need to coincide with a very significant increase in the supply chain. The reliance on rare earth metals, for almost all proposed low-carbon technologies, is proving to be problematic. Production capacity of these materials will have to improve, but this issue could persist and act as a limitation to net-zero climate goals.

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[1] International Energy Agency. "Global electrolysis capacity becoming operational annually, 2014-2023, historical and announced." IEA, Paris.

Improved infrastructure for low-carbon hydrogen will also be needed to meet the anticipated demand for low-carbon hydrogen. For example, new pipelines will be necessary to transport hydrogen in regions where there are no existing production facilities. New storage in salt caverns, similar to the existing Strategic Petroleum Reserve, would enable the low-carbon hydrogen to be deployed 24/7.

Finally, while improved infrastructure and resources for hydrogen will certainly improve demand, incentives or regulations requiring the use of low-carbon hydrogen could significantly open new market opportunities and drive demand. These incentives would initially require government support to bridge the gap between grey hydrogen and low-carbon hydrogen while the cost curve continues to come down.

In the section below, we have provided feedback on the questions outlined in the RFI. We welcome the opportunity to further discuss our responses and to answer any additional questions.

III. ICAC Responses to RFI Questions

1. Please describe specific ideal regions to support a hydrogen demonstration project which have the necessary resources available for clean hydrogen production and infrastructure, including, but not limited to water, renewables, nuclear, natural gas (with CCS) or other energy resources captured from waste streams (e.g., landfill, flaregas, wastewater treatment).

b. Is there any existing hydrogen infrastructure or infrastructure that could be repurposed as part of a hydrogen demonstration? State specific location if available.

Focusing on co-location with existing hydrogen infrastructure will be critical to rapidly deploying low-carbon hydrogen production. The development of regional hubs in the near-term will center around the presence of existing hydrogen infrastructure for production and distribution, which in turn will support faster near-term deployment of more infrastructure. Viable use cases and end users must also be identified. Having multiple existing off-takers, including some willing to pay for a premium delivered hydrogen product, would be highly beneficial for any green hydrogen project. The gas could be treated in similar fashion to the current California RNG credits, as once it enters the pipeline, it only needs a viable flow path to the end user. Furthermore, certain policies and regulations in a given region will impact the business case for industry to participate in the hydrogen economy.

The US Gulf Coast region is a high-potential opportunity for clean hydrogen hub development. There are existing pipeline networks in the region that could serve as a market hub along the Gulf Coast. Additionally, there are existing geologic formations to serve as storage caverns in the region. ICAC members currently utilize the industry's first and only commercial hydrogen storage cavern, which is a solution-mined salt cavern located approximately halfway along the 350-mile Gulf Coast network. It can store 2.5 billion cubic feet of high-purity hydrogen at high pressures.

The available resources and feedstocks in the Gulf Coast are also very conducive to developing the regional hub in the US Gulf Coast.

ICAC members' portfolios of environmental technologies would support regional hubs focused on any of the following production pathways:

- Water electrolysis with renewable electricity feedstocks
- Retrofit of existing steam methane reformers with post-combustion CO2 capture facilities
- Emerging green hydrogen production demonstrations
- Emerging blue hydrogen production demonstrations

i. Are there any other considerations in the region for large-scale hydrogen production?

For blue hydrogen projects, CO_2 utilization or geological disposal must be cost-effective or heavily subsidized. The 45Q tax credit gets partly there, but more support is required to realize a higher number of successful projects. CO_2 industrial utilization is limited compared to the capture volumes from even modest blue hydrogen production.

5. Please quantify the amount of emissions reduction anticipated and in what timeframe.

a. What is the carbon dioxide emissions reduction potential (in tonnes per year) from cradle to plant gate and in what time frame?

Globally, new grey-fired SMR hydrogen projects, still in the early stages of the project execution life cycle, are being evaluated for CO_2 emissions capture both post- and pre-combustion with established CO_2 capture and removal technologies. These CO_2 emissions capture and removal technologies add significant costs to these established projects. Most of these projects will come online in 2024 to 2026. Additionally, producers are exploring the emissions reduction potential for retrofitting existing facilities with carbon capture technologies.

Projects that are coming online after this time are early enough in the project lifecycle to be reviewed for blue hydrogen advanced reforming technologies, as opposed to grey-fired SMR technologies used in most grey-fired SMR hydrogen plants that exist today. The average time online for existing grey-fired SMR hydrogen plants is 20 years.

In order to future proof these new hydrogen plants, blue advanced reforming technologies should be considered as they can provide 95+% CO_2 capture and a lower cost of hydrogen production. The blue advanced reforming technologies help to manage the cost of CO_2 emission removal by eliminating the more difficult-to-remove post-combustion CO_2 emissions from the Grey-fired SMR. The technologies reduce the overall CO_2 emissions by improving the heat integration, intensification, and natural gas feed efficiency and utilization within the flowsheet.

c. If there is potential for other emissions reduction (e.g., NOx, SOx, particulates), please specify anticipated amounts and in what time frame, as well as anticipated beneficiaries of the reductions.

ICAC members have a history of managing emissions like NOx, SOx, and particulates. We have also led in the development of acid gas, HAPs, and mercury emissions controls. Deploying hydrogen-fueled public transportation to replace diesel-fueled vehicles in communities would improve air quality. Support for this transition would not only provide positive health benefits, but it could also enable job creation if the hydrogen is produced locally. This would create demand for low-carbon hydrogen and help advance technologies in the low-carbon hydrogen economy.

7. Please specify the job opportunities in the region that would be available because of the proposed project(s).

Including hydrogen in the energy transition will require hydrogen production plants that are five to ten times larger than the average existing hydrogen production plants being used for refining for clean fuels and three to five times the average existing syngas production plants feeding ammonia and methanol production facilities.

Current plants require large amounts of skilled labor to operate, service, and maintain these facilities as well as manufacture the components and heavy-duty equipment, build, and execute the project.

While the larger-scale plants needed may not have a proportional increase in the amount of labor needed, the number of blue hydrogen plants needed to reach the net-zero goals of 2050 far exceed the number that currently exist for oil refinery hydrogen, ammonia, and methanol production combined. These skilled laborers exist today. In addition, there are established programs to educate and develop these trade skills.

There are likely to be existing high-skilled fossil industry jobs located in regions with existing hydrogen infrastructure. These high-skilled workers can transfer their skills to the clean energy sector if low-carbon hydrogen production occurs in these fossil-heavy regions.

8. In regard to environmental justice communities/neighborhoods that could make better use of minority serving institutions, or could benefit DEI/underrepresented groups (URG) through internships or training opportunities, please identify:

a. Any challenges or barriers that need to be addressed.

Environmental justice considerations are necessary and important factors in the development of decarbonizing strategies and impacted communities need to benefit from the energy transition. Support for cost-effective energy transitions and infrastructure investment by all stakeholders, such as government, community groups and industry, is key in helping address environmental justice considerations. It is important for the low-carbon hydrogen industry to ensure air quality improvements in communities where their facilities are located through the use of air pollution control technology. Industry can also support the local community by funding initiatives to deploy clean-burning hydrogen in end-users in the area to reduce emissions from existing sources. Additionally, supporting workforce development is critical to bring up the economic situation in the community where operations occur.

9. Please provide input on any fundamental science, basic or applied research, and innovation needs and challenges that may be required for, or be informed by, the demonstration projects. In addition, please identify scientific user facilities or computational tools that would provide the required innovations or resolve the remaining challenges.

Blue hydrogen technologies are both currently available and proven. They have been built and operated on existing world-scale refinery hydrogen and syngas production plants for ammonia and methanol production, equivalent to 300 to 900 MW energy capacity. These technologies are ready for scale-up and have the resultant cost-effectiveness that comes from widespread use at this scale.

Green hydrogen technologies are slightly earlier in their development compared to technologies for blue hydrogen. However, it is vital to develop both sets of solutions in parallel to meet future demand. In addition to further R&D, there are manufacturing challenges for electrolysis components, which government support could help resolve. ICAC members would welcome the opportunity to further discuss these challenges with DOE.

The research and information from Idaho National Laboratory (INL) will help inform DOE of the needs and challenges association with scaling hydrogen. INL is engaged in integrating hydrogen production with existing and new nuclear plants. While the stated mission is nuclear-focused, the work also centers on advancing hydrogen solid-state electrolyzer technology. Some designs integrate steam from the nuclear plant, but most rely on available electrical power. Expanding INL funding with intent on accelerating timetables will support efforts to make hydrogen production cost competitive.

ICAC members have first-hand knowledge of current INL, and its partner, Electric Power Research Institute's Low-Carbon Resources Initiative group's, efforts. This research effort needs to be a primary targeted investment by DOE in the advancement of low-cost electrolysis technology. DOE should work with INL to identify any major barriers that DOE assistance can help to overcome. While INL does have a self-developed technology, it is most intent on advancing the knowledge base for industrial manufacturers and accelerating development. Partnership with DOE would be extremely valuable and likely a highly successful public/private partnership.

10. Are there systems integration or prototyping facilities available or needed that could benefit the project and de-risk large-scale deployment? Please describe any testing facilities that could be used or are required.

Most existing industrial facilities do not tend to require a dedicated energy facility. They utilize energy from the established grid, which provides energy to a number of different industrial, transportation, commercial, and residential uses. In order to prove commercial viability for hydrogen in the energy transition, the hub and cluster approach provides the ability to bring together multiple industrial users and a transportation system to establish a balanced supply of demand at scale. Hub and cluster models promote multiple synergies between producers and users, de-risks investments, and better establishes the true cost of energy at larger scales.

11. Please provide any other information that would be relevant to determining appropriate hydrogen demonstration projects and associated locations.

Lessons of the Past and Present

To be most successful in effectively transitioning our energy supply in the hydrogen-space, we should be mindful of lessons learned from previous technology advancement projects. Examining some of the demonstration projects since the 1990s, such as the efforts to commercialize integrated gasification combined cycle (IGCC) and carbon capture on coal-fired power plants, we see that unrealistic expectations for scale and growth proved problematic. The DOE Clean Coal Demonstration Program in the 1990's initially engaged owners in aggressively advancing the gasification technology. Each of the technology for the projects had unique new designs characteristics that were immediately scaled up and executed in full-scale size. The drive for positive economic commercialization, in light of the externalities governing technology transitions, contributed to project failures.

Pilot projects should be the focus for introduction of new technologies, not full-scale deployments. Any project with even a few new system technologies incorporated will ultimately be challenged both financially and will result in an extended schedule as when the lessons of the new system are learned this results in extensive equipment modifications prior to successful commercial operation. In some IGCC cases, this can even be fatal to the entire project even getting to commercial operation or significant long-term operational challenges. The recent plant Ratcliffe Project failure is a good recent example of what occurs when too many "firsts" are attempted.

Approach to Technology Advancement

Until the cost of carbon emissions is fully internalized, DOE must address the gap between the cost of low-carbon hydrogen production and its market value. This requires an appropriate government and business cost-sharing model. New types of facilities are needed at scale and demand uncertainty is high in early-stage development. Full FEEDS are required, as well as new commercial arrangements and integration with early infrastructure in the hub and cluster approach.

ICAC believes DOE should consider its approach to technology advancement within the energy sector. Successful projects, albeit fewer, should become the norm for DOE project involvement. This will ultimately facilitate additional Congressional funding for more aggressive investments.

The common 80% DOE share for technology development, 50% for pilot projects, and 20% for commercialization has proven to be inadequate for mitigating risk for owners and participating financial institutions. The DOE goal should encompass nurturing these important projects through commercialization. Ending funding after the initial project at scale does not provide a path to get a project all the way to commercialization. Initial projects require overcoming brutal start-up challenges, project delays and reliance on an inadequately developed supply chain.

A potential improved DOE approach for technology commercialization would include:

1. **80% DOE cost share** for technology development including both bench pilot scale projects. The goal within this funding commitment should be to advance a 15-20% pilot scale project.
2. **50% DOE cost share** for initial scale-up project. These projects should NOT include any systems or processes that have not been fully proven in prior pilot scale projects.
3. **40% DOE cost share** for 2nd scale-up project. This project should reengage the initial scale-up project vendors, suppliers, engineering, and construction as much as practical. The 40% share may seem a little high, but the project will be significantly burdened with projections of financial shortfalls experienced in the 1st scale-up project.
4. **20% DOE cost share** for 3rd scale-up project. In this project, the supply chain matures and can aggressively drive costs out of the project. The engineers and constructors have known quantities and validated construction plans. This is the first project that could benefit from an experienced EPC provider taking performance guarantees and provide commercialized project pricing.

Fuel and operational costs dominate the costs of hydrogen production, which leads to a revenue-based approach that allows leveraging private sector capital. The "Contract for Difference" approach that the UK is deploying for its clean hydrogen energy hubs serves as an appropriate example of an effective cost-sharing strategy.

This approach establishes a reference price for the hydrogen production and a strike price for the long-term price once the cost of carbon emissions is fully internalized. The government supports the difference between the reference and the strike prices as the cost curve comes down, and once the cost of carbon emissions is internalized the strike price is achieved. The level of government support is reduced over time as competition increases and underlying price discovery is enabled. Support is paid directly to the producer bearing the costs. The approach can be structured with different funds for different types of clean hydrogen production at various stages of development and is agnostic to the use case for the hydrogen, so the market can enable the best solutions to succeed.

DOE Involvement in Energy Sector Projects

Engaging DOE in a cost-sharing structure will have costs and benefits for businesses, and we must ensure that the benefits always exceed the added costs and risks.

DOE Costs:

1. Engaging DOE for funding requires a significant owner investment. Project proformas by developers and utilities have confidentially identified added costs in the 10-20+% range to organize a project around a DOE cost-share. The 20% cost-share of a scale-up project does not sufficiently cover additional costs and risks.
2. DOE is on an annual funding schedule which can extend project durations and burden the project with the financial costs of schedule delay.
3. There are limitations to these types of contracting approaches as well. DOE involvement demands reportability and compliance measures that are not well-aligned with perceived

risks by the needed engineering, procurement, and construction contractors. These projects will not have contracting entities willing to take substantive performance, schedule, or cost wrap of a project.

DOE Benefits:

1. DOE involvement can legitimize projects and provide additional benefits for an owner. Projects are more likely to be recognized by financial institutions.
2. DOE can be a good project advocate. Clear DOE communication to the public on the benefits of the project, breaking down permitting and environmental justice barriers, and providing positive feedback to Congress ensuring continued funding through commercialization will all support project deployment. We are witnessing some of this positive impact in the nuclear NRC licensing process. DOE's insistence that the status-quo permitting process is inadequate provides much of the needed pressure for positive change.
3. Intentionally targeting engagement and support by DOE will be important for long-term support to protect project reputation. Initial projects that experienced cost overruns born by the owner or due to changing market conditions lose support. The Petra Nova carbon capture facility is an example of a project that significantly benefitted from the long-term DOE support. Prior to the shutdown, DOE could have aggressively advocated for the project's inclusion in the 45Q tax credit program, despite it already being in commercial operation.

DOE Support of U.S. Companies:

1. A more aggressive DOE cost-share is needed to allow the owners to bear some of the technology, schedule, and performance cost risks until the technology is proven enough for U.S. companies to take on the risks. Large U.S. engineering, procurement, and construction (EPC) firms that support the power sector are often not willing to shoulder the risk of initial scale-up projects. As these projects can involve billions of dollars, almost all large U.S. contracting firms that are not willing to bet the company on any first-of-a-kind project.
2. Foreign company engagement is another alternative approach, rather than relying on U.S. contractors given the considerations in item 1 above. Engaging Korean or Japanese EPC contractors may provide benefits to managing these risks. They commonly take more aggressive project risks and have a good track record of project success. As many of these companies have direct and indirect added financial backing from their governments, they are able and willing to shoulder more of these scale-up risks. They also have a longer-term vision of the markets and tend to justify more aggressive "investment" in their project involvement.
3. DOE must remain fully committed to commercializing these technologies in the U.S. The U.S. previously missed an opportunity to advance ICGG technology to commercial scale in the U.S. market, which led to a technology transfer to other markets.

Gasification

Hydrogen production from gasification technologies has significant potential to financially compete against Steam Methane Reforming (SMR) with carbon capture. While gasification technologies have primarily been realized and fully commercialized within China's market, the intellectual property for much of this technology remains U.S.-owned. These carbon capture projects could integrate continued use of coal or biomass with subsidies and result in net-negative emissions.

Commentary on $1/kg goal

Cost predictions of green electrolyzer hydrogen production are reliant entirely on excess renewables at very cheap power prices. Full green hydrogen deployment could double the power utilized in the U.S. market. As intermittent wind and solar power grow in their market penetration, investments to maintain grid reliability must also grow significantly. Higher capital costs will occur if two to three times the number of electrolyzers are deployed. Electrolysis "behind the meter" with higher capacity factors might sound attractive, but it also requires much higher renewable capacity and more expensive storage capacity, exceeding the 4 or 6-hour lithium battery capabilities. Ultimately, the grid will provide the best low-carbon source of renewable power in a diverse system environment where the support infrastructure can be best optimized.

The U.S. hydrogen market cannot rely only on a green hydrogen path. The path for blue hydrogen must be maintained and deployed successfully in the U.S. market. Localized constraints, such as excess renewables, water availability, and existing infrastructure, could economically benefit green while other regions will support blue hydrogen production. Each pathway would maintain a similar carbon emission impact.

Producing hydrogen at a cost less than natural gas steam methane reforming will be extremely challenging. Solid state electrolysis may be a technology that will greatly lower production costs, but it will also be important to focus on incentives for local production of rare earth metals utilized in designs.

IV. Conclusion

Again, ICAC would like to thank DOE for the opportunity to respond to the Hydrogen Program Request for Information. ICAC members have a strong history in tackling emissions challenges and we hope to provide you with valuable insights on hydrogen deployment strategies. ICAC supports technology-neutral and flexible policies that enable cost-competitiveness and a diverse set of solutions to compete in the market. We welcome an opportunity to further discuss these thoughts with you. We are happy to answer additional questions or clarify any points made.

Contributing ICAC Members:

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