H2@Scale 2020 CRADA Call

Timeline:
07/01/20: H2@Scale CRADA Call release date
08/14/20: Deadline for proposal submission by email by 5 p.m. Mountain Daylight Time
(e-mail restricted to <20 MB for entire email with all attachments)
September 2020: Selection and announcement of awards
12/31/20: CRADA must be fully negotiated (including the Joint Work Statement) and ready for submission to DOE for approval, or project will be abandoned.

Objective:
Through this request for proposals (RFP) being issued by the National Renewable Energy Laboratory (NREL), the U.S. Department of Energy's (DOE's) Hydrogen and Fuel Cell Technologies Office (HFTO) seeks to (1) accelerate development of hydrogen fueling technologies for medium- and heavy-duty fuel cell vehicles, and (2) address priority R&D barriers to enabling hydrogen blending in natural gas pipelines at scale, in support of the DOE's H2@Scale initiative. This RFP also seeks to increase industrial and stakeholder engagement in H2@Scale through investment and active participation in the associated projects.

Contact:
The full proposal and any technical inquiries or communications should be directed by email to H2atScaleCRADAcall@nrel.gov.

H2@Scale Laboratory CRADA Call

Background

H2@Scale is a DOE initiative[1] that supports innovations to produce, store, transport, and utilize hydrogen across multiple sectors. The intent of H2@Scale is ***for hydrogen to enable—rather than compete with—energy pathways across applications and sectors.*** The overall vision of H2@Scale recognizes hydrogen's versatility as a flexible energy carrier and is further described in Figure 1. Primary energy sources—fossil fuels, nuclear, and renewables—are shown on the left, and these sources are used to provide energy for the conventional electric grid, shown in red. One can use electricity, either directly from the grid or through dispatchable resources, to produce hydrogen, or one can use resources such as fossil fuels and biomass to generate hydrogen directly, bypassing the electric grid. Once hydrogen is produced, one can store that hydrogen and feed it back to the grid through a combustion turbine or use it for microgrids and remote power through fuel cells. The hydrogen can also be injected into the natural gas "grid" as shown through the beige circle. Other applications for hydrogen include current consumers, such as oil refineries and chemical plants, as well as emerging sectors, such as medium- and heavy-duty (MD/HD) vehicles.

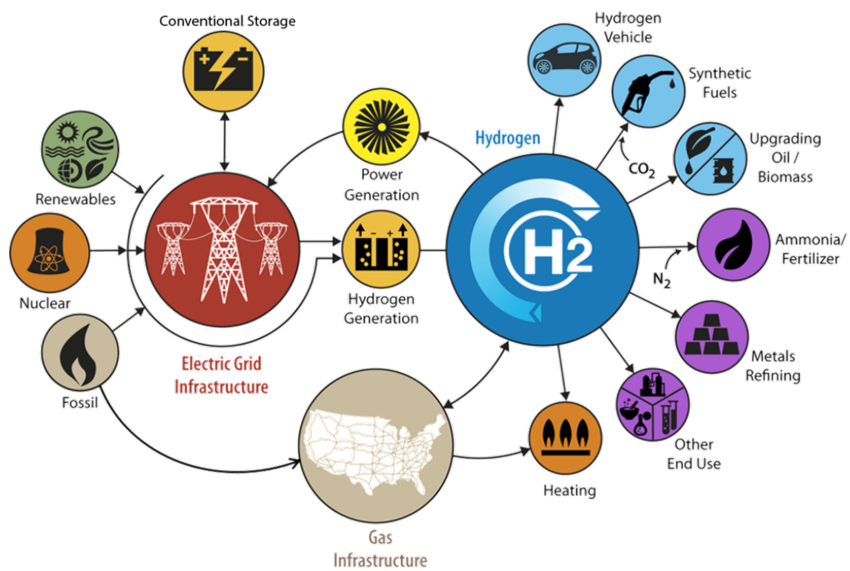

Figure 1. The H2@Scale vision: hydrogen can be produced from diverse domestic resources and is a central input to many important end uses in the industrial, chemical, and transportation sectors

In 2017, the first H2@Scale CRADA Call was issued, seeking R&D on diverse aspects of hydrogen production, distribution, and use. That call resulted in more than 25 cooperative research and development agreement (CRADA) projects being selected with industry, academia, and non-profit organizations. R&D within these projects spanned many disciplines, including modeling and analysis, materials compatibility R&D, testing of grid-integrated hydrogen production technologies, safety R&D, component manufacturing, development of co-products with hydrogen production, and performance verification of hydrogen technologies.

1 https://www.energy.gov/eere/fuelcells/h2-scale

The 2020 CRADA Call is focused specifically on two priority areas of R&D within HFTO's Hydrogen Infrastructure and Codes & Standards subprograms: (1) hydrogen fueling technologies for MD/HD fuel cell vehicles, and (2) technical barriers to hydrogen blending in natural gas pipelines.

MD/HD fuel cell vehicles represent one of the most attractive use cases for hydrogen due to the aggressive requirements for power and energy storage onboard.[2] Growth of this sector will require the development of technologies that can fuel hydrogen up to 5 times faster than light-duty vehicle fueling[3] while still meeting the pressure and temperature requirements for onboard hydrogen storage tanks. This CRADA Call seeks R&D projects to advance novel cryopumps, compressors, dispenser components, and fueling methods for use in heavy-duty fueling.

Hydrogen blending is an emerging area of interest worldwide due to the potential for blends to enable "one-way" energy storage (electrons being stored in chemical form and not necessarily being converted back into electrons at the same location), support grid resiliency, and reduce emissions while leveraging existing energy infrastructure. Blending involves production of hydrogen from renewable or nuclear resources and injection of the hydrogen into natural gas pipelines, such that the blend is then used by conventional end users of natural gas. This concept can support grid resiliency by leveraging intermittently available renewable and nuclear power at times of the year when the generators may otherwise have been curtailed or shut down. Once the hydrogen is produced, if it is blended into existing natural gas infrastructure it can ultimately be used to generate power and heat in turbines and building appliances that conventionally rely on natural gas. At the point of use, a 30% blend of hydrogen by volume can reduce emissions by more than 10%. As a result of these cross-sector benefits, hydrogen blending is now being demonstrated in several flagship projects worldwide at a wide range of concentrations, including as high as 20%. However, comprehensive information on hydrogen effects on materials and equipment is not widely available, which inhibits utility planning around blending at a large scale. To address the R&D gaps associated with hydrogen blending at scale, several DOE offices formed a "Big Idea" in 2020 known as HyBlend. Priority areas of R&D identified by the HyBlend team include materials compatibility, pipeline compressors, hydrogen combustion in end uses, technologies for separating hydrogen from blends downstream of injection, compatibility of blends with underground reservoirs, and techno-economic and life cycle analysis. HyBlend is led by HFTO with support from the Office of Fossil Energy, Advanced Manufacturing Office, Building Technologies Office, and Advanced Research Projects Agency–Energy. This CRADA Call seeks R&D projects to address HyBlend priorities. While HFTO is the primary office providing funding to this Call, other offices engaged in HyBlend may co-fund selected CRADA projects pending available funds.

Collaboration with H2@Scale National Laboratories

Qualified partners are sought to participate in CRADA projects with the DOE's national laboratories on two priority areas of R&D: (1) advancing hydrogen fueling technologies for MD/HD vehicles, and (2) addressing R&D barriers to the blending of hydrogen in natural gas pipelines. Selected projects must include one or more national laboratories and shall also include partners from one or more of the following: industry, universities, non-profits, institutes, codes and standards organizations, associations, or other relevant stakeholders. The target range for total project cost is expected to be from $500,000 to $3,000,000 per year per project. Selected projects must be 1–2 years in length. Partners must provide cost share of at least 20% of the total funding for the project. Cost share may be in-kind or cash, but cash cost share is strongly encouraged. Cost share from other DOE offices is not permitted. For domestic

[2] http://www.fchea.org/us-hydrogen-study

[3] https://www.hydrogen.energy.gov/pdfs/19006_hydrogen_class8_long_haul_truck_targets.pdf

institutions of higher education, domestic non-profit entities, or U.S. state, local, or tribal government entities, the cost share requirement is 10%.

Multiple CRADA projects are sought under this CRADA call, subject to the availability of funding. Project selections will continue to be made on a rolling basis given the availability of funds. Proposals submitted with a higher degree of funds-in cost share will have a greater likelihood of being considered for funding.

Participating Laboratories and Areas of Interest

Areas of interest (AOIs) and participating national laboratories in this CRADA Call are described below. **Points of contact at each national laboratory are listed below; these individuals can support applicants interested in better understanding lab capabilities or conceptualizing collaborative R&D:**

- National Renewable Energy Laboratory: Cory Kreutzer, Cory.kreutzer@nrel.gov
- Sandia National Laboratories: Jon Zimmerman, jzimmer@sandia.gov
- Idaho National Laboratory: Richard Boardman, Richard.boardman@inl.gov
- Pacific Northwest National Laboratory: Jamie Holladay, Jamie.holladay@pnnl.gov
- Argonne National Laboratory: Ted Krause, krauset@anl.gov
- Oak Ridge National Laboratory: Claus Daniel, danielc@ornl.gov
- Los Alamos National Laboratory: Rod Borup, borup@lanl.gov
- Savannah River National Laboratory: Scott McWhorter, scott.mcwhorter@srnl.doe.gov
- Brookhaven National Laboratory: Alex Harris, alexh@bnl.gov
- Ames Laboratory: Vitalij Pecharsky, vitkp@ameslab.gov
- National Energy Technology Laboratory: Jared Ciferno, jared.ciferno@netl.doe.gov
- Lawrence Berkeley National Laboratory: Adam Weber, azweber@lbl.gov
- Lawrence Livermore National Laboratory: Brandon Wood, wood37@llnl.gov

AOI 1: Fueling Components for Heavy-Duty Vehicles

Participating Labs: All labs are eligible to participate fully
Estimated Number of Projects: 3–4
Estimated DOE Funding Available (for use at National Laboratories): $3M–$5M/year for 2 years

The deployment of MD/HD fuel cell electric vehicles will require development of technologies and methods capable of up to 5 times faster hydrogen fueling rates compared to light duty vehicles.[3] Development of such high-throughput technologies requires innovation to ensure that they are durable, safe, and cost competitive at scale. In this topic, R&D proposals are sought to advance high-throughput hydrogen fueling technologies to enable their use in MD/HD applications.

MD/HD fueling methods are currently under development worldwide and are targeting several different conditions at the outlet of the dispenser, including gaseous hydrogen at 700 bar, 500 bar, 350 bar, cryo-compressed, as well as liquid hydrogen. Each of these fueling methods has a value proposition under different circumstances, depending on the size and vocation of the vehicle fleet and proximity to other hydrogen demands. Lower-pressure 350 bar storage has typically been used for MD vehicles (e.g., bus fleets) that require less driving range (i.e., less onboard hydrogen storage). High-pressure, 700 bar hydrogen storage would provide increased vehicle range and is particularly relevant at fueling stations aiming to serve both light- and heavy-duty vehicles. Liquid hydrogen dispensing could enable even longer driving ranges and may have a value proposition in the future, given the potential for faster fill times, elimination of costly compression and energy-intensive pre-cooling, and growth in domestic liquefaction capacity. Further, MD/HD fleet vehicles likely will have more constant and predictable duty cycles (compared to light-duty vehicles), which could mitigate hydrogen boil-off losses.

In this topic, proposals are sought to advance MD/HD fueling technologies and methods through partnerships between industry and national laboratories. Capabilities at the national laboratories that have proven successful in informing technology design and development in the past include, but are not limited to, facilities to test components in high-pressure hydrogen and cryogenic conditions, visualization and modeling techniques to detect damage formation in components over time, materials expertise and test facilities to inform component design, and modeling capabilities to simulate cost and emissions associated with varying station designs. In this AOI, proposals that leverage existing capabilities at the national laboratories and avoid duplication of capabilities across the national lab system are encouraged. Technology areas of particular interest include, but are not limited to, compressors, dispensers, cryogenic pumps, analysis to inform fueling station design, and heavy-duty fueling methods that can inform standards development organizations leading fueling protocol development. Proposals focused on MD/HD fueling methods should be coordinated with ongoing industry-led efforts and international efforts in this space, as appropriate, to ensure that any protocols and components are harmonized.

Proposals should describe the current state of the technology of focus, the intended application (vehicle class and vocation), and quantitative metrics targeted as a result of the proposed work. Proposals are encouraged to include letters of support from industry stakeholders (e.g., vehicle manufacturers or station operators). DOE funding must be cost shared at 20% using in-kind or cash resources. The intent of this CRADA Call is that all DOE funds be costed at the national laboratories.

AOI 2: HyBlend

Participating Labs: This AOI covers many R&D disciplines, and the lab R&D lead for each discipline is restricted as described below. All labs are allowed as R&D partners. Use of the H-Mat consortium is highly encouraged, and no funding will be provided for duplicating any capabilities already available at national labs unless strong justification is provided.

- Metallic materials compatibility: Sandia National Laboratories
- Polymer materials compatibility: Pacific Northwest National Laboratory
- Techno-economic analysis: National Renewable Energy Laboratory
- Life cycle analysis: Argonne National Laboratory
- Testing and development of building appliances: Oak Ridge National Laboratory
- Development of separation technologies for hydrogen from blends: Open eligibility
- Compatibility of underground reservoirs with blends: Open eligibility

Estimated Number of Projects: 1–2

Estimated DOE Funding Available: $5M–$7M/year over 2 years (includes potential for funding from other DOE offices in addition to HFTO; funds are to be costed at National Laboratories)

The HyBlend AOI is seeking R&D to accelerate the potential for hydrogen blending into natural gas pipelines. R&D priorities in this AOI include materials compatibility, pipeline compressors, compatibility of natural gas reservoirs with blends, performance of building appliances in blend service, and associated techno-economic and life cycle analysis. Materials compatibility refers to the impact that hydrogen has on the strength and life of materials (e.g., metals, polymers). Applicants proposing R&D on materials compatibility in this AOI are strongly encouraged to leverage DOE's H-Mat consortium of national laboratories. H-Mat is led by Sandia National Laboratories and Pacific Northwest National Laboratory, with participation from Savannah River National Laboratory, Oak Ridge National Laboratory, and Argonne National Laboratory. H-Mat labs have world-renowned experimental facilities and expertise in the area of materials compatibility and have used these capabilities for decades in R&D on metallic and composite pipeline materials, storage vessels, seals, and polymers and metals used in other hydrogen fueling applications. R&D from H-Mat labs has resulted in the development and revision of key codes and standards that guide design of hydrogen components in industry (e.g., the American Society of Mechanical Engineers Boiler and Pressure Vessel Code and Hydrogen Piping and Pipelines Code).

Hydrogen blending at scale requires an understanding of the hydrogen compatibility of materials used in existing pipelines, planned pipeline modernization efforts, pipeline compressors and ancillary equipment, and end uses of blends (such as combustion turbines or heating appliances). To address these areas, proposed R&D should be informed by industry stakeholders (e.g., utilities and component or system developers) to ensure that experimentation is focused on priority materials and components and is representative of real-world conditions. For example, the impact of non-methane constituents commonly found in natural gas on pipeline materials' compatibility with hydrogen must be understood. Additionally, available knowledge on the structural integrity of existing natural gas pipelines must be better understood and utilized to predict remaining life given the introduction of hydrogen blends. One of the outcomes of the HyBlend project will be a collection of mechanical test data in hydrogen environments representative of blending conditions, to inform decisions on allowance of hydrogen concentrations for pipeline materials. Applicants in this AOI must agree to share non-proprietary data generated in proposed projects with existing H-Mat databases on materials compatibility to enable the information to be shared publicly.[4] Ultimately, this data in conjunction with data being generated in projects worldwide can enable global harmonization of acceptable levels of hydrogen concentration in natural gas pipelines.

Another R&D priority is the performance of pipeline compressors in blends. In natural gas infrastructure, compressors are installed every 50–100 miles to keep natural gas pressurized throughout the system. These compressors utilize reciprocating and rotating components (e.g., pistons, impellers) to pressurize natural gas. R&D is needed to assess the impact that hydrogen blending has on the efficiencies, pressure ratios, and durability of current compression concepts, and to identify strategies to mitigate these effects.

R&D is also needed to assess the impact of blends on performance of appliances in buildings (e.g., space and water heaters, stoves) and to develop techniques to manage these effects. Differences between the flame behavior of hydrogen and natural gas can influence the performance of conventional appliances (e.g., heat transfer rates). In hydrogen blending demonstrations worldwide, performance testing has indicated that many building appliances designed for natural gas service can operate in hydrogen at concentrations up to 20% with minimal change.[5] However, given the substantial differences in design of components in the United States relative to those in other countries, and the differences in governing

[4] The H-Mat database for metallic materials compatibility is available here: https://granta-mi.sandia.gov/mi-viewer/index.aspx. A similar database for polymeric materials is under development.
[5] https://hydeploy.co.uk/app/uploads/2018/12/15055_HD_PH2_PROJECT_REPORT_v2.pdf

efficiency standards, testing on domestic appliances is necessary to enable blending in the United States. Within this AOI, up to $2 million total (over the course of two years) may be available for testing and development of building components for blend service.

R&D is also needed to assess the impacts of blending on existing reservoirs for natural gas storage underground. In the United States, the natural gas pipeline network is integrated with underground facilities that store natural gas in bulk and at pressure. These facilities include depleted oil and/or natural gas reservoirs and fields, aquifers, and salt cavern formations. As hydrogen is introduced into the natural gas system, underground storage facilities almost certainly will be exposed to this higher concentration of hydrogen. The increased presence of hydrogen in underground storage can lead to changes in microbial activity, leading to methane or acid formation, microbial corrosion of storage-related equipment, sealing enhancement, and/or injection obstruction. These effects can vary depending on storage type and environmental conditions. R&D is needed to assess the effects that hydrogen blending has on storage structures and equipment and to identify strategies to mitigate these effects.

In addition, techno-economic and life cycle analyses are sought to characterize the cost of hydrogen blending in specific scenarios and to characterize emissions benefits. Modeling scenarios should be informed by external stakeholders to ensure that they represent conditions of interest to industry, including renewable penetration on the grid and grid operating conditions. Analysis may also include comparisons of the value proposition of hydrogen blending to alternatives such as the production of synthetic natural gas or large-scale hydrogen storage. Previous studies have explored the potential for separating hydrogen from natural gas blends at the point of use but found costs to be prohibitive.[6] Any advances should be investigated if progress can enable lower-cost approaches that make delivery of hydrogen through the existing natural gas infrastructure more viable. Assessments also may be conducted to inform potential future demonstration projects in any area relevant to the HyBlend concept.

Information generated from proposed R&D should be intended for public dissemination to inform stakeholder planning around blending. Coordination of scopes of work with R&D being funded by states, industry, and international organizations is encouraged. Cost share of 20% is required and may come from a combination of in-kind efforts and cash. Cash cost share is highly encouraged.

A cohesive, coordinated, and critical mass team effort is encouraged where appropriate, rather than separate bilateral projects.

Eligibility

Each application must include at least one non-national-laboratory participant that will collaborate with one or more DOE national laboratories to perform the proposed work. Eligibility of the participants is limited to (1) for-profit entities, educational institutions, and non-profits that are incorporated (or otherwise formed) under the laws of a particular state or territory of the United States and have a physical location for business operations in the United States and (2) U.S. state, local, and tribal government entities. The applicant must identify how it meets the eligibility requirements of the CRADA Call in its application.

[6] https://www.nrel.gov/docs/fy13osti/51995.pdf

Funding Requirements

DOE funds in each CRADA project are to be used for activities undertaken within the participating national laboratories for services, staff time, and facilities necessary to support each selected project; DOE funds provided to national labs for CRADA projects may not be costed outside of the national laboratories. The DOE funding will be provided directly to the national laboratory (or laboratories) in support of their work under the H2@Scale initiative. The CRADA project sizes may vary but must include at least 20% cost share. For education institutions, non-profits, or U.S. state, local, or tribal government entities, the cost share requirement is 10%.

CRADA Requirements

For each CRADA project, the participant and each national laboratory conducting work for the project must enter into a CRADA based on the H2@Scale Template CRADA. Only changes to incorporate optional or alternate language approved in the DOE CRADA Order (DOE O 483.1B) and changes considered non-substantive can be made to the H2@Scale Template CRADA. No changes are allowed to the U.S. competitiveness provision. If the participant fails to agree to the terms of the CRADA with the national laboratories within thirty (30) days from selection, DOE may rescind the selection. Each applicant should review the H2@Scale Template CRADA carefully to understand the general terms, including intellectual property rights and requirements and the U.S. competitiveness provision, that will apply to its CRADA project.

Proprietary Data in Proposal

An applicant should not include proprietary information in the proposal unless such information is necessary to understand and evaluate the proposed project. If proprietary information is required to be included in the proposal, the proprietary information should be marked as such on the specific pages that contain this information. DOE, the national laboratories, and the external reviewers will treat properly marked proprietary information as confidential to the extent allowable under U.S. law.

Proposal Preparation

Proposals should be no more than 15 single-spaced pages using 12-point font (Times New Roman preferred), should be in single PDF file format, and must include the following components under headings corresponding to the bullets below:

- **Title page** (not counted in page limit) with proposal title, principal investigator(s), brief company description, and non-proprietary summary. Include name, address, phone number, and email address of the lead applicant (organization) for both contract issues and for scientific issues.
- **1.0 Abstract:** Describe the specific product, component, analysis, or process being developed, refined, or validated. Include how the national laboratory unique capability is essential to execute the work. State the AOI being applied to.
- **2.0 Project Description:** Describe the project in enough detail that it may be evaluated for its feasibility, impact, relevance to AOI objectives, and appropriate use of national lab capability.
- **3.0 Potential Technology Advances:** Identify R&D challenges that, if addressed, will result in significant technological advances.
- **4.0 Required Resources and Budget:** Describe the expected DOE and national laboratory member resources, including proposed work areas, staff time, and any testing/characterization needs. Include a summary of any testing to be done and the goals this testing is expected to

achieve, including specific locations and laboratories to be used. This should include a budget of all project expenses by each national lab and project partner.

- **5.0 Cost Sharing:** Provide a detailed table describing the proposed cost sharing, clearly articulating cash vs. in-kind.
- **6.0 References (not counted in the 15-page limit).**
- **7.0 Team:** Include single-page resumes of key project participants (not counted in the 15-page limit).

Proposal Evaluation

Selection of winning proposals will be determined based on available funding and input from DOE, national laboratories, and external reviewers. The primary categories and relative ranking criteria used to evaluate submissions will be as follows.

Technical (60%)

- Relevance of proposed work to the goals of H2@Scale.
- Overall technical merit.
- Potential impact of the collaboration on the technical challenge being addressed (e.g., national lab and industry leveraged effort).
- Impact of collaboration on other interested and impacted stakeholders (e.g., through sharing of data or experimental results with other members of the H2@Scale consortium).
- Degree to which the current state of the technology and the proposed advancement are clearly described.
- Extent to which the collaboration specifically and convincingly demonstrates how the applicant will move the state of the art to the proposed advancement, validation, demonstration, etc.

Programmatic (40%)

- Adequacy and feasibility of proposed work plan to meet clearly articulated goals of the project.
- Appropriate use of national lab capabilities, resources, and expertise.
- Clear estimated level of support requested from national laboratories and strong justification, including table of cash and in-kind cost share (if in-kind cost share is contained in the proposal) to be provided by the industrial partner.
- Importance of technology development/demonstration/analyses to general market acceptance.
- Qualifications and expertise of the key technical personnel who are active participants in the proposed project.
- Ability of the industrial partner to support proposed activities, commitment of individuals, other partners, available facilities and equipment, etc.

The proposal, and any technical inquiries, should be directed to H2atScaleCRADAcall@nrel.gov.

Once a proposal is received, a confirmation email will be sent within one week stating the date and time of receipt.

Preference will be given to high-scoring proposals that also meet the objectives of H2@Scale. If all funds are not allocated, subsequent requests for proposals may occur.

Following selection and depending on the scope of work proposed, HFTO may request or require submission of a Safety Plan and/or involvement of DOE's Hydrogen Safety Panel to assist in safety planning. Participants in the CRADA projects will be encouraged to share best practices and lessons learned developed over the course of the project via DOE's H2Tools portal (https://h2tools.org/). H2Tools hosts an anonymous database of lessons learned from safety incidents (https://h2tools.org/lessons, with no attribution to parties involved) to educate and inform the hydrogen community.