# U.S. Department of Energy (DOE) Hydrogen and Fuel Cell Technologies Office (HFTO)

## Development Assistance Opportunity for Roll-to-Roll Manufacturing of Hydrogen Fuel Cell and Water Electrolyzer Materials CRADA Call

Timeline:

- May 6, 2024: Announcement and publication of CRADA request for proposals
- June 3, 2024: Deadline for Concept Paper submission
- June 17, 2024: Concept Paper encourage/discourage decisions communicated (anticipated)
- July 15, 2024: Deadline for Full Application submission
- August 30, 2024: Selection and announcement of awards (anticipated)
- October 1, 2024: Project start date (anticipated)

  *CRADAs must be fully negotiated (including the Joint Statement of Work) and ready for submission to DOE for approval within 120 days of selection or the selected project may be canceled.*

Contact/Questions: The concept paper, full proposal, and all communications and questions regarding eligibility, the CRADA template, and application process should be directed by email to R2RCRADA@nrel.gov. Please be aware that all questions that are submitted and the respective answers will be posted here: https://www.nrel.gov/hydrogen/r2r-crada-call.html (barring those questions deemed unresponsive to the call). Applicants are encouraged to reach out directly to the listed R2R Consortium contacts with specific questions about available consortium capabilities.

Proposal Submissions: Applicants must submit a Concept Paper by 5 p.m. Eastern Time on the due date listed above to R2RCRADA@nrel.gov to be eligible to submit a Full Application. Full Applications must be received by 5 p.m. Eastern Time on the due date listed above to R2RCRADA@nrel.gov.

Notification of Selection: Once selections are finalized, applicants will receive an email from the DOE Hydrogen and Fuel Cell Technologies Office.

# Development Assistance Opportunity for Roll-to-Roll Manufacturing of Hydrogen Fuel Cell and Water Electrolyzer Materials

**Description**

The Alliance for Sustainable Energy, acting under its Prime Contract No. DE-AC36-08GO28308 with the U.S. Department of Energy (DOE) for the management and operation of the National Renewable Energy Laboratory (NREL), conducts research and development (R&D) in support of the DOE Hydrogen and Fuel Cell Technologies Office (HFTO) in conjunction with its Roll-to-Roll (R2R) Consortium partners Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Sandia National Laboratories (SNL).

The HFTO R2R Consortium's mission is to advance efficient, scalable, high-throughput, and high-quality manufacturing methods and processes for clean hydrogen technologies to accelerate domestic manufacturing and reduce the capital cost of durable and high-performing fuel cells and water electrolyzer systems. Consortium objectives include understanding material and process behavior to advance methods to increase energy efficiency, reduce material usage, reduce waste, and reduce equipment cost in manufacturing processes, as well as enabling high-throughput manufacturing processes. Core research includes activities in materials synthesis processes; colloidal science, rheology, and formulations; roll-to-roll coating process development; quality control technique development; advanced materials characterization (e.g., electron microscopy, X-ray scattering and spectroscopy); electrochemical testing; and advanced computing (e.g., synthetic reactor modeling, coating process modeling, machine learning, artificial intelligence). Additionally, the consortium collaborates with industry to develop scalable, affordable manufacturing processes and characterization tools.

The R2R Consortium is soliciting proposals for collaborative projects between industrial partners and the consortium. HFTO will provide funding (up to $1,500,000 per project) to the R2R Consortium national lab partner(s) to tackle challenges that are of mutual interest to the industrial partner and consortium. The selected projects will be conducted under joint cooperative research and development agreements (CRADAs) between at least two national laboratories (NREL, ORNL, ANL, LBNL, SNL) and the industrial partners.

Proposed projects should relate to the mission and objectives of the R2R Consortium (see mission and objectives above). Projects that address manufacturing challenges relevant to proton exchange membrane (PEM) fuel cells (FC) and water electrolyzers (WE) are of interest. Alkaline-based fuel cell and water electrolyzers may also be of interest as long as the proposed activities are within existing capabilities of the R2R Consortium and facilitate advancing near-term domestic manufacturing capabilities.

Projects shall focus on one or more of the following topic areas:

- Scaling catalyst or ionomer synthesis and processing methods.
- Roll-to-roll coating processes for catalyst layers, membranes, or other components.

- Advanced drying processes, such as infrared or microwave, for reduced energy intensity and/or emissions.
- Development or demonstration of in-line/at-line quality control or near real-time inspection tools and instruments.
- Process modeling or advanced data analytics (e.g., machine learning [ML], artificial intelligence [AI]).

In total, up to $8,000,000 is available to support 5–15 projects, including up to $4,000,000 to support fuel cell technologies and up to $4,000,000 to support electrolyzer technologies. These projects should be conducted within a 24-month period. Applicants may request up to $1,500,000 of funding per project for the R2R Consortium national labs to conduct R&D to achieve the proposed project objectives. The national laboratories and DOE will not provide any monetary funds to industrial partners. Industrial partners are required to provide at least 50% cost share, which can be monetary funds or in-kind contribution (e.g., facilities, equipment, services, and staff time). If funding allows and subject to the quality and number of proposals received, additional requests for proposals may be solicited in the future.

**Eligibility**

Each application must include at least one non-national-laboratory participant as the prime applicant that will collaborate with two or more R2R Consortium national laboratory members to perform the proposed work. Eligibility for the prime applicant is limited to organizations that currently develop and manufacture components, devices, systems, and/or applicable manufacturing equipment in the above topic areas for commercial applications or that will be able to manufacture products as a direct result of the efforts of the CRADA. Prime applicants must have domestic manufacturing facilities or demonstrate proof of commitment to establish manufacturing in the U.S.

**Background**

HFTO has production volume and cost targets for fuel cells and water electrolyzers that will not be met without significant and timely advancements in high-volume manufacturing processes. Economies-of-scale through increased manufacturing volumes based on traditional assembly and processing methods will not suffice. For example, current PEM WE stacks produced in low volumes cost 9 times the ultimate HFTO target of $50/kW.[1] In addition, little roll-to-roll development work has been done to date on the less mature alkaline exchange membrane water electrolyzer technology. Likewise, reaching PEM FC cost targets requires a combination of manufacturing innovation and fuel cell technology advancements. Specific to heavy-duty vehicles, HFTO analysis provides guidance for cost reduction pathways toward a 2030 system cost goal of $80/kW (at a production volume of 100,000 systems per year) adjusted for 25,000 hours durability.[2] Critical to achieving this goal is the development and scaling of advanced fuel cell manufacturing. Based on analysis and industry feedback, HFTO has identified a near-term

[1] "Technical Targets for Proton Exchange Membrane Electrolysis." DOE Hydrogen and Fuel Cell Technologies Office. https://www.energy.gov/eere/fuelcells/technical-targets-proton-exchange-membrane-electrolysis

[2] "Hydrogen Class 8 Long Haul Truck Targets." DOE Hydrogen and Fuel Cell Technologies Office Program Record #19006. October 31, 2019. https://www.hydrogen.energy.gov/pdfs/19006_hydrogen_class8_long_haul_truck_targets.pdf

capacity target of 20,000 heavy-duty fuel cell stacks per year from a single production line or system as a critical capacity for overcoming obstacles to commercial viability.

Required materials scale-up and roll-to-roll advances include adaptation of existing processing methods and development of novel methods. Such advances have the potential to significantly impact the U.S. manufacturing sector, sustainable transportation adoption, industrial decarbonization, environmental security, and energy security.

**Objective**

The objective of this solicitation is to advance the fuel cell and electrolyzer industries, leading to low-cost, high-quality products, and to the creation and preservation of domestic manufacturing jobs and capacity. Awards will be granted in one or more of the following categories related to PEM or alkaline-based fuel cells and/or water electrolyzers. Proposals for solid oxide fuel cells and electrolyzers are not of interest at this time but may potentially be solicited at a future date. Proposals should emphasize at least one of the following categories:

- Process development for synthesis and scale-up of novel catalysts or ionomers or validation of novel synthesis technologies that have demonstrated performance and have potential to be low-cost.
- Advanced and high-speed roll-to-roll processing methods and/or equipment for production of membrane electrode assembly (MEA) components (e.g., catalyst layers, membranes, microporous layers), catalyst-coated membranes, gas-diffusion electrodes, or other cell components.
- Development or demonstration of metrologies and techniques for quality control (QC) inspection or non-destructive evaluation (NDE) of materials and components (e.g., precursors, catalyst powders, ionomers or membranes, ionomer or catalyst dispersions/inks, diffusion/transport media, coated layers, multi-layer assemblies), which are compatible with high-throughput processes.
- Impact of process parameter variation and process-induced material non-uniformities on device performance and durability.
- Application of computational tools for topics such as process simulation, machine learning, or process control.
- Drying process development and/or demonstration of technology that enables improved component performance, shorter dryer length, reduced energy intensity, and/or lower emissions.
- Process modeling or advanced data analytics that enables process condition prediction, optimization, or control for new ink materials and recipes or accelerated coating and drying process optimization.

**R2R Consortium Capabilities**

Proposed projects must be a partnership between the applicant (an industrial entity, see Eligibility section above) and two or more national labs that are part of the R2R Consortium. Specific capabilities covered by the R2R Consortium labs are listed below (point of contact listed in parentheses):

- Catalyst and ionomer synthesis/process development (Jessica Macholz; Alexey Serov)
- Computational fluid dynamics (CFD) modeling of novel synthetic reactors for catalysts and ionomers production (Alexey Serov)
- Lab-scale roll-to-roll other precision coating systems (Scott Mauger)
- Fluid property characterization (e.g., rheology, particle size, surface tension, sedimentation, etc.) (Nelson Bell)
- MEA assembly assistance (Scott Mauger)
- In situ visualization of coating and film formation (Kenny Higa)
- Electrochemical and cell performance evaluation (Tim van Cleve)
- State-of-the-art microscopy (David Cullen)
- Surface characterization (Alexey Serov)
- X-ray and neutron characterization facilities (Debbie Myers)
- Process modeling for coating and drying (Randy Schunk)
- Machine learning and artificial intelligence (Yuepeng Zhang)
- In-line QC measurements and resulting design improvements (Peter Rupnowski)
- Techno-economic and/or life cycle analysis (Alex Badgett)

**Intellectual Property and Proprietary Data**

DOE, NREL, ORNL, ANL, LBNL, and SNL respect the importance of industry's intellectual property and data security while balancing the need to document the benefits of public expenditures. Provisions relating to proprietary information and intellectual property are set forth in the CRADA template. In addition, if company proprietary information is included in the proposal, the specific information should be marked as such, and the consortium members will treat that information as confidential.

**CRADA Information**

For each CRADA project, the participant and each national laboratory conducting work for the project must enter into a CRADA based on the provided R2R CRADA template. No changes are allowed to the template. Each applicant should review the R2R CRADA template carefully to understand and agree to the general terms, including intellectual property rights and requirements and the U.S. competitiveness provision, prior to submitting an application.

**Application Process**

A two-part proposal process will be used. Applicants must first submit short Concept Papers that will be reviewed by the consortium and HFTO based on specific criteria listed below. Based on the Concept Paper, applicants will either be encouraged or discouraged from submitting a Full Application. Applicants who are encouraged will work with the consortium to prepare and submit Full Applications. Full Applications will be reviewed by the consortium and HFTO based on specific criteria listed below. Final selection of projects will be decided by HFTO. The following sections define the content of and review criteria for the Concept Papers and Full Applications. Note that although no Community Benefits Plan is required for the Concept Papers, such plans are a high priority for DOE and a Community Benefits Plan will be required for the Full Application, as defined below.

Important note: It is recommended that Concept Papers and Full Applications be developed jointly with the consortium laboratories. This recommendation is made to ensure that proposals optimally leverage and align with the expertise and capabilities of the R2R Consortium. This goal is reflected in the Full Application review criteria, as detailed below. To promote equity in the application process in the event that the applicant cannot engage with the consortium within the timeframe of the Concept Paper application, no interaction or collaboration is required for the Concept Papers; however, applicants are encouraged to state consortium capabilities (as described above) that are needed for the proposed work effort. Applicants are required to collaborate with the R2R Consortium in preparation of Full Applications.

**Concept Paper Preparation**

Concept Papers are due at 5 p.m. Eastern Time on June 3, 2024. Inquiries related to eligibility, the CRADA template, and application process as well as the Concept Papers for submission should be directed to the following email address: R2RCRADA@nrel.gov.

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

Concept Papers must include the following sections under corresponding headings and be arranged in the order presented below. The total response is limited to 2 pages. All pages must be formatted to fit on 8.5 x 11 inch paper with margins not less than one inch on every side. Use Calibri typeface, a black font color, and a font size of 12 point or larger (except in figures or tables, which may be 10 point font). A symbol font may be used to insert Greek letters or special characters, but the font size requirement still applies. References must be included as footnotes or endnotes in a font size of 10 or larger. Footnotes and endnotes are counted toward the maximum page requirement.

| Section | Description |
|---|---|
| Contact Information | Should include the project title and principal investigator, company, email address, and phone number |
| Technical Approach | Applicant should concisely describe:<br>• The specific process, product, or technology being developed, refined, or validated.<br>• The key shortcomings, limitations, and challenges being addressed.<br>• The goals or key objectives of the project.<br>• The relevance of proposed project toward meeting DOE targets. |
| Role of R2R Consortium | • Description of why working with the R2R Consortium is critical to addressing the challenge<br>• Description of the high-level roles of the R2R Consortium and/or expertise and capabilities needed for the project |
| Project Impact | • Expected impact of the work effort, such as increased process speed, development or validation of new equipment or process |

| | |
|---|---|
| | capabilities, reduced number or energy intensity of processing steps, improved quality, cost, and/or emissions reduction<br>• How outcomes of the proposed project will impact the commercialization plan and domestic manufacturing and technology competitiveness |
| Preliminary Budget Request | High level justification for requested budget, including description of proposed cost share |

**Concept Paper Evaluation**
The primary categories and relative ranking criteria used to evaluate submissions will be:

Overall Responsiveness and Viability (100%)

- Importance of the described effort to accelerate domestic manufacturing and deployment of commercially viable fuel cell and water electrolyzer products.
- Degree to which collaboration with the R2R Consortium uniquely enables accelerated solutions to synthesis, processing, and/or manufacturing challenges.
- Alignment of project goals with HFTO technical objectives and targets, such as potential for reduction in manufacturing costs.
- Qualifications and expertise of the key technical personnel who are active participants in the proposed project.

**Full Application Preparation**
Full Applications should be jointly developed by the R2R Consortium and the applicant. Proposals are due at 5 p.m. Eastern Time on July 15, 2024. Inquiries related to eligibility, the CRADA template, and application process as well as the Full Application for submission should be directed to the following email address: R2RCRADA@nrel.gov.

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

Proposals must include the following sections under corresponding headings and be arranged in the order presented below. The total response is limited to the defined sections and must adhere to the listed section page limits. All pages must be formatted to fit on 8.5 x 11 inch paper with margins not less than one inch on every side. Use Calibri typeface, a black font color, and a font size of 12 point or larger (except in figures or tables, which may be 10 point font). A symbol font may be used to insert Greek letters or special characters, but the font size requirement still applies. References must be included as footnotes or endnotes in a font size of 10 or larger. Footnotes and endnotes are counted toward the maximum page requirement.

| Section | Page Limit | Description |
|---|---|---|
| Cover Page | 1 | The cover page should include the project title, principal investigator(s), both the technical and business points of contact, the project location(s), R2R Consortium laboratories involved, requested federal funding, proposed cost share, a non-proprietary summary, and any statements regarding confidentiality. |
| Technology Description | 10 | Applicants are required to describe:<br>• The specific process, product, or technology being developed, refined, or validated.<br>• The current state-of-the-art in the relevant field and application, including key shortcomings, limitations, and challenges.<br>• The goals and objectives of the project as well as the expected outcomes.<br>• Relevance of proposed project towards meeting DOE targets.<br>• Projection of improvements in areas such as process speed, number of processing steps, energy intensity, production capability, or other advances to current state-of-the-art.<br>• How outcomes of the proposed project will impact the commercialization plan, domestic manufacturing, and technology competitiveness.<br>• Projection of economic benefit, industrial energy savings, and/or greenhouse gas/pollutant emission reductions.<br>• Expected key personnel and R2R Consortium member roles and resources, including proposed work areas, staff time, and testing/characterization needs, with justification for the need of consortium members and resources.<br>• Appropriate milestones with quantifiable metrics throughout the project to demonstrate progress towards the project's goals and objectives.<br>• Estimate and justification of requested federal funding and the in-kind or funds-in cost-sharing. |
| Community Benefits Plan | 3 | Applicants are required to describe:<br>• Diversity, equity, inclusion, and accessibility (DEIA) goals and milestones that are integrated into the research goals and project team.<br>• Specific actions the applicant would undertake to achieve DEIA goals, including any engagement with minority serving institutions, minority business entities, and nonprofit or community-based organizations.<br>• A plan for engaging workforce stakeholders and/or potential long-term workforce impacts that may result from project success. |
| Addendum | None | 1-page resumes of principal investigator and key team members |

**Full Application Evaluation**
Selection of winning proposals will be at the discretion of DOE HFTO. The primary categories and relative ranking criteria used to evaluate submissions will be:

Impact (50%)

- Importance of technology development to accelerate domestic manufacturing and deployment of commercially viable fuel cell and water electrolyzer products.
- Degree to which collaboration with the R2R Consortium uniquely enables accelerated solutions to synthesis, fabrication, and processing challenges.
- Potential for reduction in manufacturing costs and quality improvements.
- Alignment of project goals with HFTO technical objectives and targets.
- Importance of testing and experimental results and generated metadata to the interested and impacted stakeholders.

Technical Merit and Workplan (40%)

- Adequacy and feasibility of proposed work plan to meet clearly articulated goals of the project.
- Degree to which the proposed budget is commensurate with the work plan.
- Qualifications and expertise of the key technical personnel who are active participants in the proposed project.
- Ability of industrial partners to support the proposed activities, commitment of individuals, other partners, available facilities, and equipment, etc.

Community Benefits (10%)

- Extent of engagement of organizations that represent disadvantaged communities as a core element of their mission, including minority serving institutions, minority business entities, and nonprofit or community-based organizations.
- Quality of the project's DEIA goals, as measured by the goals' depth, breadth, likelihood of success, inclusion of appropriate and relevant milestones, and overall project integration.
- Clear and comprehensive plan for engaging workforce stakeholders and/or evaluating the possible near- and long-term implications of the project for the U.S. workforce.

In determining final selections, HFTO may also consider technological and geographical diversity of the existing DOE project portfolio and newly selected projects from this CRADA opportunity.

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.

**Anticipated Schedule**
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