

**U.S. Department of Energy  
Office of Fossil Energy and Carbon Management**

**Request for Information (RFI)**

**DE-FOA-0003259**

**Issue Date:** December 12, 2023

**Program Area:** U.S. Department of Energy (DOE) Office of Fossil Energy and Carbon Management (FECM)

**Title:** High-Efficiency Gasification for Clean Hydrogen Production

**RESPONSES DUE:** February 12, 2024

**Purpose:**

The purpose of this Request for Information (RFI) is to inform DOE's research and development activities within the Hydrogen with Carbon Management Program's Gasification Systems area. This RFI solicits feedback from industry members, investors, project developers, nongovernmental organizations, academia, research laboratories, government agencies, and other stakeholders on technologies and strategies that companies are deploying, or could deploy, to increase clean hydrogen production from alternative, low-value feedstocks, excluding traditional coal and petcoke, at competitive costs and with market factors in play. The ultimate goal is to develop clean hydrogen production based on efficient gasification processes with carbon capture included to assure true net-zero or net negative carbon emissions performance per suitable life cycle analysis.

DOE is requesting information on strategies and technologies for developing innovative gasification designs for converting biomass/mixed waste feedstocks into syngas to enable the low-cost production of clean hydrogen. The program is motivated by the unique potential of carbon capture-friendly oxygen-blown gasification processes to convert solid mixed biomass and waste feedstocks to clean hydrogen, which is useful as a decarbonized energy carrier and for synthesis of decarbonized transportation fuels, chemicals, electricity, and other useful products. Advances made will contribute toward the Hydrogen with Carbon Management Program's overall efforts and DOE's Hydrogen Shot.

This RFI is solely for planning purposes; it is not a Funding Opportunity Announcement (FOA). DOE is not accepting applications to this RFI, nor will DOE reimburse any of the respondents' costs in preparing a response.

**Background:**

Historically, DOE programs in fossil energy development have considered the benefits and challenges of reducing the life cycle carbon intensity of power generation and large industrial processes, chiefly by means of cofiring biomass with traditional fossil fuels such as coal. In the gasification field, this was exemplified by conducting multiple investigations of integrated gasification combined cycle (IGCC) power plants co-utilizing various kinds of biomass and wastes (e.g., wood, sludge) with coal, as well as by performing operational trials at many of the well-known gasification plants, including Polk, Buggenum, Elcogas, Schwartze Pumpe, and Berrenrath.<sup>1</sup> The types of mixed feedstocks varied widely in these tests, but generally the percentages were limited to avoid operational issues such as with feeding, ash management, tar formation, and feedstocks supply logistics. At the time, the emphasis was on taking advantage of incentives to reduce carbon dioxide (CO<sub>2</sub>) emissions, provide cost savings by using cheap opportunity feedstocks, and increase waste disposal potential.

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<sup>1</sup> "Co-gasification and indirect firing of coal and biomass," R. Fernando, CCC/158, IEA Clean Coal Centre, November 2009.

However, a key lesson learned from these tests was exclusive feeding of waste materials or biomass in these systems would be problematic.

These mixed fuel trials are just one example of the rich industrial history of gasification, in which a significant amount of experimental/operational knowledge of these processes has been accumulated. Generally, this experience indicates an important connection between the type of fuel, its reactivity, and the appropriate gasification process. For a specific feedstock, the most effective gasifier could be selected with optimal results under traditional expectations. However, for mixed feedstocks, especially with fuels of mixed reactivity, a single high- or low-temperature gasifier is ineffective.

Currently desirable feedstocks (e.g., biomass, municipal solid wastes, and waste plastics, which are either sustainable or promote sustainability for human activities) are inherently mixtures with different reactivities that face challenges not well understood from the available knowledge base. For example, established experience/practices for biomass gasification may not adapt well to the constraints and restrictions to come, as those gasifiers tended toward air-blown, lower-pressure, and less thermally efficient technology choices. Biomass gasification faces multiple technical issues and challenges, despite its environmental advantages and sustainability potential. These technical issues and challenges include:

- Feeding issues—Non-uniform feedstocks with diverse physical characteristics and chemical compositions.
- Low mass density—Compounds feeding issues.
- Low energy density—Larger amounts needed compared to other fuels compounding feeding issues.
- Limited availability—Decays over time (half-life varies from one to 20 years, depending on species), requires large amounts of land to create, seasonal availability.
- High corrosivity—Ammonia, alkaline compounds in ash damage downstream components.

These issues severely limit the use of biomass as a primary feedstock, especially for mid- to large-scale applications, as is in the United States, which does not host large-scale biomass gasification projects—though small-scale biomass gasification demo projects currently exist worldwide. These projects vary widely in biomass feedstock type, gasifier technology, and application.

Due to DOE's current interests in gasification-based hydrogen production with genuine net-zero carbon emissions performance, the exclusive use of non-traditional feedstocks, and ambitious cost reductions and Hydrogen Shot goals, these challenges need revisited for gasification of alternative feedstocks, including biomass. The key guiding principles and conditions of current interests are as follows:

- Process basis—Gasification for clean hydrogen production (clean hydrogen defined as decarbonized hydrogen with zero carbon emissions or better on a life cycle analysis basis).
- Feedstocks—Biomass, carbonaceous waste materials (e.g., plastics), municipal solid waste (MSW), industrial wastes. Mixed alternative feedstocks consist of a combination of two or more of these types.
- Gasifier type—High-pressure, high-efficiency gasifiers.
- Restrictions on gasifiers—Oxygen-blown gasifiers enabling ease of carbon capture (no air-blown gasifiers).
- Restrictions on feedstocks—No coal and no petcoke as feedstocks.

#### **Requested Information:**

**You may respond to as few or as many of the questions below. Please use the question numbers as headings in your response and refer to the questions in the body of your response. Please be as specific as possible in all responses.**

#### **Questions (Topic: High-Efficiency Gasification for Clean Hydrogen Production):**

*NOTE: **Alternative feedstocks** is defined as biomass or biomass wastes, municipal solid waste (MSW), industrial wastes, carbonaceous waste materials (e.g., plastics or plastics wastes), or any combination of the above.*

1. What gasification technologies (e.g., fluidized bed, entrained flow) do you believe can be best leveraged for DOE's goal of realizing low-cost clean hydrogen production from alternative feedstocks? Explain the benefits of indicated technologies in this context.
2. What is the current industry capability for gasification of alternative feedstocks, indicating size of gasification system and specific feedstocks utilized?
- 3A. What are the challenges with high-efficiency, pressurized, oxygen-blown gasification (specifically excluding air-blown gasification) using alternative feedstocks?
- 3B. What solutions or suggestions do you have for addressing the above challenges?
- 3C. Are high-efficiency gasifiers in the size range of approximately 70–200 megawatt-thermal (MWth; syngas heating value), that run entirely on alternative feedstocks, feasible? Please explain?
- 4A. What is your prior experience with the modeling of alternative feedstocks in high-efficiency, high-pressure gasifiers (e.g., fluidized bed, entrained flow gasification)? Please provide examples of gasifiers modeled, including specific feedstocks of interest.
- 4B. What modeling tools/methods did you use in simulating high-efficiency, high-pressure gasifiers (e.g., fluidized bed, entrained flow gasification) with alternative feedstocks? Were any tools/methods particularly beneficial for this purpose?
- 5A. What is your prior experience with injection/introduction of alternative feedstocks into high-efficiency, high-pressure (e.g., oxygen-blown entrained flow, oxygen-blown fluidized bed) gasifiers?
- 5B. What modifications, if any, did you make to the gasification system itself to ensure steady, continuous operation using the alternative feedstocks? Were any other precautions necessary?
6. Can you identify/provide any publicly available documentation on injector/feeder development for alternative fuel gasification systems, particularly those that could be deployed in high-efficiency, high-pressure, oxygen-blown (e.g., fluidized bed, entrained-flow) gasification systems?
7. What are potential tradeoffs between innovative feedstock preparation to enable use of conventional injectors/feeders, and innovative injectors/feeders to take conventional/current pretreated feedstocks for introducing fuel into high-efficiency, high-pressure, oxygen-blown gasifiers?
- 8A. Indicate and provide the scale (e.g., XX MWth) and Technology Readiness Level (TRL) (see Appendix A) stage of any successful gasifier test facility using alternative feedstocks that you are aware of. What alternative feedstocks were/are used?
- 8B. What issues, if any that you are aware of, did the above test facilities face when incorporating the alternative feedstocks?
- 8C. What solutions or workarounds were implemented to overcome the above issues at gasification test facilities?
9. What is your access to (existing) commercial industrial or utility-scale, oxygen-blown gasification systems? Please include project site locations and provide an assessment of availability for a test facility.
10. What advanced fluidized bed or entrained flow gasification technologies originally explored for conventional feedstocks (coal/coke) could be leveraged for increased performance and efficiency in alternative feedstock gasification processes?
- 11A. Can existing high-efficiency (e.g., fluidized bed, entrained flow) gasification plants take advantage of waste plastics as replacement feedstock?
- 11B. What issues, if any that you are aware of, are the most challenging when it comes to using waste plastic as a feedstock in fluidized bed or entrained flow gasifiers, and what steps can be taken to overcome these issues?

- 12A. Given high chlorine content for some carbonaceous feedstocks (e.g., plastics), how high can the chlorine content be (on a mass basis) before impacts on downstream systems become problematic? How does the gasifier type affect the use of high chlorine content feedstocks?
- 12B. Are there other elements or compounds present in alternative feedstocks that need specification or gasifier modifications to address downstream issues or challenges?
- 13A. If existing high-efficiency (e.g., fluidized bed, entrained flow) gasification technologies could take advantage of high thermal value alternative feedstocks, what might be the potential benefits (e.g., increased quality of gasification and resultant syngas)?
- 13B. Is there an available supply chain for utilizing large quantities of high-quality alternative feedstocks in your region? If not, could one reasonably be established?
- 14A. What would be the level of cost share with DOE that you would support on gasification projects at maturity of TRL 5+ utilizing alternative feedstocks for clean hydrogen production?<sup>2</sup>
- 14B. What scale (e.g., XX MWth) of project do you feel is most appropriate given the current state of the technology?
- 14C. What would you estimate the total cost (DOE + cost share) to be of a gasification project using alternative feedstocks at the scale suggested above if it started in 2024? What are the largest cost concerns for undertaking such a project and how could DOE assist in addressing these concerns?
15. What other concerns or comments do you have regarding the gasification of alternative fuels that are not addressed in the above questions?

### Disclaimer and Important Notes:

This RFI is not a FOA; therefore, DOE is not accepting applications at this time. DOE may or may not elect to issue a FOA in the future based on or related to the content and responses to this RFI. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if DOE chooses to issue a FOA regarding the subject matter.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. DOE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. As previously stated, DOE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that DOE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind DOE to any further actions related to this topic.

### Proprietary Information:

Because information received in response to this RFI may be used to structure future programs and FOAs and/or otherwise be made available to the public, **respondents are strongly advised NOT to include any information in their responses that might be considered business sensitive, proprietary, or otherwise confidential.** If, however, a respondent chooses to submit business sensitive, proprietary, or otherwise confidential information, it must be clearly and conspicuously marked as such in the response.

### FREEDOM OF INFORMATION ACT:

Responses received under this RFI are subject to public disclosure under the Freedom of Information Act. Because information received in response to this RFI may be used to structure future programs and funding opportunity announcements and/or otherwise be made available to the public, **respondents are strongly advised to NOT include any information in their responses that might be considered business sensitive**

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<sup>2</sup> Note DOE requires a minimum of 20% on R&D phase cooperative agreements and 50% on demonstration or commercial application phase.

(e.g., commercial or financial information that is privileged or confidential), trade secrets, proprietary, or otherwise confidential.

Consistent with 10 CFR 1004.11, DOE requires that any person submitting information that they believe to be confidential and exempt by law from public disclosure should submit **two well-marked copies**: one copy of the document marked “confidential” which must clearly and conspicuously identify the business sensitive, trade secrets, proprietary, or otherwise confidential information, and one copy of the document marked “non-confidential” with the information believed to be confidential deleted. **Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise.** The Government is not liable for the disclosure or use of unmarked information and may use or disclose such information for any purpose.

If you choose to provide business sensitive, trade secrets, proprietary, or otherwise confidential information, you must include a cover sheet marked as follows identifying the specific pages containing business sensitive, trade secrets, proprietary, or otherwise confidential information:

**Notice of Restriction on Disclosure and Use of Data:** Pages [List Applicable Pages] of this response may contain business sensitive, trade secrets, proprietary, or otherwise confidential information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI DE-FOA-0003259. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

In addition, (1) the header and footer of every page that contains business sensitive, trade secrets, proprietary, or otherwise confidential information must be marked as follows: “Contains Business Sensitive, Trade Secrets, Proprietary, or Otherwise Confidential Information Exempt from Public Disclosure” and (2) every line and paragraph containing such information must be clearly marked with double brackets or highlighting. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

## **Evaluation and Administration by Federal and Non-Federal Personnel**

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to DOE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be reviewed by support contractors and private consultants.

## **Request for Information Response Guidelines**

Responses to this RFI must be submitted electronically to: [Hydrogen Gasification RFI@NETL.DOE.GOV](mailto:Hydrogen_Gasification_RFI@NETL.DOE.GOV) with the subject line “DE-FOA-0003259 RFI” no later than **5:00 p.m. (ET) by February 12, 2024**.

Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25 MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (\*.docx) or Adobe Acrobat (\*.pdf) attachment to the email, 12-point font, 1-inch margins. Only electronic responses will be accepted.

DOE will not respond to individual submissions or publicly publish a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

DOE requests respondents provide the following information at the start of their response to this RFI:

- Company/institution name;
- Company/institution contact; and
- Contact's address, phone number, and e-mail address.

If a FOA related to this RFI is released, it will be posted at Grants.gov (<http://www.grants.gov>) and at FedConnect (<http://www.fedconnect.net>). Entities who may be interested in applying for awards under a possible FOA are strongly encouraged to register at these sites to receive notification of announcements regarding the FOA. If DOE decides to issue a FOA, applications can only be submitted through Grants.gov.

On behalf of the FECM Team, thank you in advance for providing your input on this important topic and contributing to the U.S. DOE's success in achieving its objectives.

## Appendix A. Description of DOE Technology Readiness Levels (TRL)

| Relative Level of Technology Development | Technology Readiness Level | TRL Definition                                                                             | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------------------------------|----------------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>System Operations</b>                 | <b>TRL 9</b>               | Actual system operated over the full range of expected mission conditions.                 | The technology is in its final form and operated under the full range of operating mission conditions. Examples include using the actual system with the full range of wastes in hot operations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>System Commissioning</b>              | <b>TRL 8</b>               | Actual system completed and qualified through test and demonstration.                      | The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning. Supporting information includes operational procedures that are virtually complete. An Operational Readiness Review (ORR) has been successfully completed prior to the start of hot testing.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                          | <b>TRL 7</b>               | Full-scale, similar (prototypical) system demonstrated in relevant environment             | This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning (1). Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Technology Demonstration</b>          | <b>TRL 6</b>               | Engineering/pi lot-scale, similar (prototypical) system validation in relevant environment | Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants.(1) Supporting information includes results from the engineering scale testing and analysis of the differences between the engineering scale, prototypical system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment. |
| <b>Technology Development</b>            | <b>TRL 5</b>               | Laboratory scale, similar system validation in relevant environment                        | The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants (1) and actual waste (2). Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.                                                                                                                                                                                                                                                                             |

| Relative Level of Technology Development | Technology Readiness Level | TRL Definition                                                                       | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------------|----------------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Technology Development                   | TRL 4                      | Component and/or system validation in laboratory environment                         | The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small scale tests on actual waste (2). Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRL 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function. |
| Research to Prove Feasibility            | TRL 3                      | Analytical and experimental critical function and/or characteristic proof of concept | Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative tested with simulants.(1) Supporting information includes results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants.<br>Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.                                                                              |
| Basic Technology Research                | TRL 2                      | Technology concept and/or application formulated                                     | Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies.<br><br>Supporting information includes publications or other references that outline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.                                                                                                                                                                                                        |
|                                          | TRL 1                      | Basic principles observed and reported                                               | This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental work that consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

<sup>1</sup> Simulants should match relevant chemical and physical properties.

<sup>2</sup> Testing with as wide a range of actual waste as practicable and consistent with waste availability, safety, ALARA, cost and project risk is highly desirable.

Source: U.S. Department of Energy, "Technology Readiness Assessment Guide". Office of Management. 2011.