Request for Information: Supercritical Carbon Dioxide-Based Turbomachinery for Concentrating Solar-Thermal Power Plants

DATE: December 20, 2023
SUBJECT: Request for Information (RFI)

Description

This request for information (RFI) is intended to inform the U.S. Department of Energy (DOE) Solar Energy Technologies Office (SETO) on the specific research, development, and demonstration opportunities to enable near term deployment of supercritical carbon dioxide (sCO_2) based turbomachinery for concentrating solar power plants.

Background

To build a clean and equitable energy economy and address the climate crisis, SETO invests in innovative research, development, and demonstration (RD&D) projects that work to drive down costs of solar technologies and develop next-generation products ready for commercialization. This RFI seeks information to help advance the goals of achieving carbon pollution-free electricity by 2035 and to "deliver an equitable, clean energy future, and put the United States on a path to achieve net-zero emissions, economy-wide, by no later than 2050."[1] DOE is committed to pushing the frontiers of science and engineering, catalyzing clean energy jobs through research, development, demonstration, and deployment (RDD&D), and ensuring environmental justice and inclusion of underserved communities.

Concentrating Solar-thermal Power (CSP) is unique as a renewable energy source that can be coupled to long duration thermal energy storage (TES) to drive a high efficiency power cycle. As longer durations of energy storage are needed to enable a clean electricity grid, there becomes a stronger case for the value of CSP. To successfully fill this role, the cost of CSP must continue to decline through a generational technology shift. SETO targets a CSP levelized cost of electricity (LCOE) of 5¢/kWh enabled in part by a power cycle which is more efficient and cheaper than present day steam Rankine cycles.

The use of supercritical carbon dioxide (sCO_2) as a working fluid in turbomachinery for a Brayton power cycle may offer the best opportunity to achieve SETO's LCOE target. sCO_2 technology is also symbiotic with concentrating solar technology in that it increases its electrical energy conversion efficiency with increasing temperatures.

[1] Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," January 27, 2021.

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After many years of research, the energy industry has focused on the recompression Brayton Cycle (RCBC) as the best means to support power production using sCO_2 turbomachinery when paired with concentrated solar. This thermodynamic cycle requires sCO_2 turbomachinery in the form of an expander, a main compressor, and a recompressor. Technoeconomic studies[2] have identified that CSP coupled with sCO_2 Turbomachinery would achieve widespread market deployment after achieving a levelized cost of electricity (LCOE) of ≤$0.05/kWh. In support of this goal, sCO_2 turbomachinery is expected to achieve a cost of ≤ $300/$kW_e$ and gross isentropic efficiency of ≥70% for the turbocompressor train.

Electric thermal energy storage (ETES) is an available technology solution using interim thermal energy storage. ETES based on sCO_2 turbomachinery typically relies on compressors and expanders, although there are variations in exactly how these components may be arranged, operating temperatures, and other key features.

There has been significant interest in sCO_2 turbomachinery development in the past that have resulted in significant build-outs and demonstrations of various aspects of this technology. sCO_2 turbomachinery research is currently being pursued in earnest internationally by turbomachinery suppliers, with significant interest from facility owners seeking a renewable solution to power requirements. ETES solutions are of interest to utility grid operators and merchant power producers seeking ways to overcome the diurnal nature of renewable technologies. Worldwide, stakeholders view sCO_2 turbomachinery as an increasingly significant component in their energy portfolios as the technology matures as a means to combat climate change. The DOE seeks to increase its presence in sCO_2 technology and support its US based stakeholders to remain competitive and relevant with respect to this technology going forward.

However, significant technological challenges remain, especially with respect to the development of sCO_2 turbomachinery components and ancillary equipment. The most challenging aspects yet to be overcome are related to dry gas seals and bearings, rotordynamic challenges, thermodynamic inefficiencies, transient and part load operation, couplings and gearboxes, and challenges associated with high temperature operation. Suppliers are struggling to meet cost targets, and actively pursue different material related research and manufacturing methods to address these challenges. Challenges also exist with respect to ancillary equipment needed to support novel sCO_2 turbomachinery applications.

Developers and financiers of sCO_2 based power generation and TES/ETES applications remain skeptical of sCO_2 turbomachinery based applications. Additional efforts to de-risk the technology and prove the value proposition of the power cycle may be appropriate in many

[2] 2019. The Potential Role of Concentrating Solar Power within the Context of DOE's 2030 Solar Cost Target. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71912.

cases. Significant upside must be proven to encourage early adopters to move away from traditional fossil fuel based power generation. Yet many recognize that sCO_2 turbomachinery based power generation and ETES projects are nearing the point where scale up is the next step in the R&D progression, and some early adopters have constructed significant facilities based on the technology.

Through this RFI DOE seeks insight into the specific challenges preventing more widespread deployment of sCO_2 turbomachinery based applications, and information regarding the prioritization of development activities. SETO collaborates with DOE's offices of Nuclear Energy (NE) and Fossil Energy and Carbon Management (FECM) to support the development of the sCO_2 Brayton power cycle. Questions focus on CSP based applications although development efforts will inherently share much with other thermal power plants.

Purpose

This RFI solicits feedback from industry, academia, research laboratories, government agencies, and other stakeholders on two separate topic areas:

- **Category A:** sCO_2 Turbomachinery Sub-Component De-Risking
- **Category B:** sCO_2 Turbomachinery Market

This is solely a request for information and not a Funding Opportunity Announcement (FOA). EERE is not accepting applications.

Disclaimer and Important Notes

This RFI is not a Funding Opportunity Announcement (FOA); therefore, EERE is not accepting applications at this time. EERE may issue a FOA in the future based on or related to the content and responses to this RFI; however, EERE may also elect not to issue a FOA. 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 EERE chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of EERE funded awards, will be subject to Congressional appropriations and direction.

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. EERE 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. EERE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that EERE is under no obligation to acknowledge receipt of the information received or

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provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind EERE to any further actions related to this topic.

Confidential Business Information

Pursuant to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit via email, postal mail, or hand delivery two well-marked copies: one copy of the document marked "confidential" including all the information believed to be confidential, and one copy of the document marked "non-confidential" with the information believed to be confidential deleted. Submit these documents via email or on a CD, if feasible. 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 EERE 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 Categories and Questions

Category A: sCO_2 Turbomachinery Sub-Component De-Risking

1. In order of priority, what are the sub-components of an expander most in need of de-risking to improve the reliability and performance of the expander? The word sub-component refers to all pieces that comprise the machine, including casing, rotor, seals, bearings, nozzles, thermal management systems, inlet guide vane assembly, *etc.?* What activities are most appropriate at this time?
2. In order of priority, what are the sub-components of a compressor (or re-compressor) most in need of de-risking to improve the reliability and performance of the compressor? What activities are most appropriate at this time?
3. In order of priority, what are the sub-components of an expander-compressor-generator arrangement most in need of de-risking to improve the reliability and performance of an expander-compressor-generator arrangement? What activities are most appropriate at this time?

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4. SETO has a stated goal of reducing turbomachinery cost to below 300 $/kW$_e$. What research and/or demonstration efforts would need to be conducted to improve materials and manufacturing readiness level to attain such goals?
5. Aside from the expander or compressor, what research needs to be conducted for ancillary pieces of equipment in need of further R&D to support sCO_2 turbomachinery applications that you feel are being underfunded (e.g., stop/control valves, generators, gearboxes, turbine control systems, test loops, etc.)?
6. What, in the order of priority, should be the focus of SETO research regarding scaleup of turbomachinery from the current state of the art? How can such scaled up equipment be tested, *i.e.*, in what facilities? What turbomachinery efficiency and cost metrics are appropriate targets for scaleup?
7. With respect to sCO_2 demonstration efforts, what are the most significant challenges to the success of these efforts and how can these issues be avoided?
8. What specific research, demonstration, or development efforts would be most impactful to enable broad development of CSP with sCO_2 in the US?
9. Are there additional thoughts sCO_2 Turbomachinery R&D efforts?

Category B: sCO_2 Turbomachinery Market

1. What do you believe is the capacity of sCO_2 turbomachinery (stated in MWe, gross power) that is most likely to be the optimum size, considering both economics and performance, to meet the demands for sCO_2 applications in support of power generation? State what technology is most likely to be used in power generation applications and why the optimum exists for the specific application. (*e.g.*, CSP, nuclear, Allam cycle, *etc*).
2. What do you believe is the capacity of sCO_2 turbomachinery (stated in MW$_e$, gross power) that is most likely to be the optimum size, considering both economics and performance, to meet the demands for sCO_2 applications in support of ETES/TES? State what you believe to be the most likely energy storage medium (*e.g.,* particles, molten salt, other solid media, etc).
3. In order of priority, state what you believe makes developers of green and brown field sites the most hesitant to adopt sCO_2 turbomachinery technology.
4. In what areas do you believe US based sCO_2 turbomachinery suppliers <u>lead</u> other international sCO_2 turbomachinery suppliers?
5. In what areas do you believe US based sCO_2 turbomachinery suppliers <u>lag</u> other international sCO_2 turbomachinery suppliers?
6. Do you believe that the early adopters of sCO_2 based power generation technology will be in the US? If not, where and why not?
7. Do you believe that the early adopters of sCO_2 based TES/ETES technology will be in the US? If not, where and why not?

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8. How likely do you believe sCO_2 based turbomachinery applications will be implemented in the US without additional US policy changes? Be specific, if possible.
9. In your opinion, how has the recent US Infrastructure Act and Inflation Reduction Act subsidies for green energy projects affected the deployment of sCO_2 turbomachinery in the upcoming years?
10. What specific activities would be most impactful to enable broad deployment of CSP with sCO_2 in the US?
11. Are there additional thoughts sCO_2 Turbomachinery Market?

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to SETO.RFI.CSP@ee.doe.gov no later than 5:00pm (ET) on January 31, 2024. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (.docx) attachment to the email. Only electronic responses will be accepted.

Please identify your answers by responding to a specific question or topic if applicable. Respondents may answer as many or as few questions as they wish.

EERE will not respond to individual submissions or publish publicly 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.

Respondents are requested to provide the following information at the start of their response to this RFI:

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

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