US Department of Energy
Advanced Research Projects Agency-Energy (ARPA-E)

Request for Information (RFI)
DE-FOA-0002874
on
Enabling Technologies for Improving Fusion Power Plant Performance and Availability

Objective:

Fusion energy has the potential to provide a safe, abundant, firm, zero-carbon-emitting source of primary energy, electricity, and heat. In order to achieve its potential and meaningfully contribute to the target of global net-zero emissions, fusion must demonstrate competitive economics on a short timeline. Therefore, there is an urgent need to provide a technological pathway to economical fusion power plants (FPP).

This RFI seeks broad input on two overarching themes: (A) Improving fusion power plant performance and (B) Increasing fusion power plant availability. While power plant performance and availability are intertwined in determining the cost of electricity, theme (A) includes technologies targeting the efficiency of plasma heating schemes, and advanced laser driver technologies, as well as economic and high-gain targets for inertial fusion energy (IFE). Theme (B) focuses on "designer" materials for plasma-facing and structural components. Candidate materials (solid and self-healing) should include, but not be limited to, the following features: minimized half-lives of materials, reduced dust formation, minimized fuel retention (e.g., hydrogen), minimized displacement per atom due to neutron irradiations, and high heat resistance (> 600 °C). Specifically, this RFI focuses on three technology areas for developing this pathway towards economically competitive fusion energy. The areas are:

- Efficient and low-cost drivers for plasma heating and assembly
- Novel first-wall and structural materials
- Low-cost, high-performance targets for inertial fusion energy (IFE)

The Advanced Research Projects Agency-Energy (ARPA-E) of the US Department of Energy seeks information that could inform ARPA-E's potential research and development (R&D) funding for these three areas.

Please carefully review the REQUEST FOR INFORMATION GUIDELINES below and note in particular: the information you provide will be used by ARPA-E solely for program planning, without attribution. **THIS IS A REQUEST FOR INFORMATION ONLY. THIS NOTICE DOES NOT CONSTITUTE A FUNDING OPPORTUNITY ANNOUNCEMENT (FOA). NO FOA EXISTS AT THIS TIME. Respondents shall not include any information in their response to this RFI that might be considered proprietary or confidential.**

Background:

ARPA-E identifies and funds applied research and development to translate science into breakthrough energy technologies with large commercial impact. The ALPHA (Accelerating Low-Cost Plasma Heating and Assembly)[1], BETHE (Breakthroughs Enabling THermonuclear-fusion Energy)[2], and GAMOW (Galvanizing Advances in Market-Aligned Fusion for an Overabundance of Watts)[3] fusion programs, each contribute to enabling timely, commercially viable thermonuclear fusion energy. However, there remain technological and economic gaps that need to be closed to enable timely demonstration and deployment of fusion energy. To close these gaps, a path forward should include the development of low-cost enabling technologies that improve fusion power plant performance as well as increase plant availability.

Improving performance with innovative heating schemes and high-performance targets

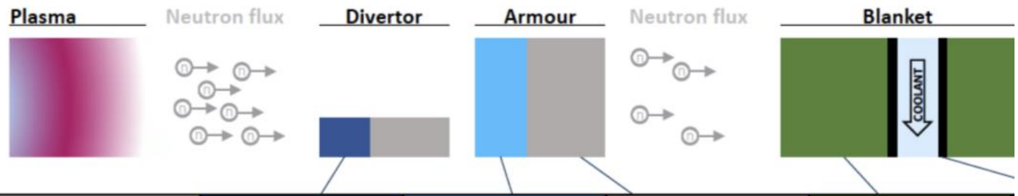
For both magnetic fusion energy (MFE) and laser inertial fusion energy (IFE) concepts, increasing the wall-plug efficiency (WPE) of plasma heating systems and lasers, respectively, reduces the required recirculating power and therefore increases the fraction of the fusion power which can be delivered to the grid, thereby reducing the levelized cost of electricity (LCOE). An additional challenge for IFE concepts is the need for large quantities (~million/day) of low-cost targets designed for to the chosen laser technology that can survive injection into the target chamber at high velocity.

Increasing FPP availability through accelerated discovery of novel fusion materials

Presently, there is no solution for a plasma-facing material that can handle the expected heat, neutron flux, and particle load without significant erosion and melting, requiring periodic replacement at high cost. Figure 1 shows a qualitative description of the environment for different components of FPPs[4]. The development of materials with the ability to survive the harsh reactor environment is essential for cost competitive fusion energy.

The economic viability of a FPP is improved significantly with the development of novel structural materials with better reliability and longer life. Structural materials development for FPPs must also require consideration of change in nuclide composition (transmutation) under neutron irradiation. Additionally, some of these newly created nuclides may be radioactive, leading to activation of the material.

[1] https://arpa-e.energy.gov/technologies/programs/alpha
[2] https://arpa-e.energy.gov/technologies/programs/bethe
[3] https://arpa-e.energy.gov/technologies/programs/gamow
[4] UK Fusion Roadmap 2021-2040 United Kingdom Atomic Energy Authority



Challenge	Divertor strike plate (detached divertors)	Armour surface	Armour substrate	Blanket breeder, multiplier and casing
Neutron radiation	HIGH	VERY HIGH	HIGH	MEDIUM
Temperature	VERY HIGH	YES	YES	MEDIUM
Heat flux	HIGH	YES	YES	NO
Magnetic stresses from coils	SOME	YES	YES	YES
Corrosion	(IF ACTIVE COOLING)	NO	YES	YES
Mechanical load	SOME	YES	YES	YES
Helium generation	HIGH	HIGH	HIGH	MEDIUM
Cooling fluid pressure	NO	NO	YES	NO
Plasma erosion	MEDIUM	YES	NO	NO
Tritium absorption	YES	YES	LOW	YES

Fig. 1: Qualitative descriptions of the environments that different components of a FPP are exposed to under operating conditions[4].

Autonomous and accelerated discovery of novel materials for FPPs will enable realizing fusion power within a reasonable timeframe. Advancements in enabling technologies in the areas of high-throughput material synthesis and characterization will certainly help with these efforts. Successes in earlier data-driven approaches that fuse high-throughput materials synthesis and characterization with machine learning algorithms and closed-loop discovery automation should be leveraged to reduce the development timeline.

Purpose and Need for Information

The purpose of this RFI is solely to solicit input for ARPA-E's consideration and to inform the possible initiation of an R&D program on enabling materials and technologies for fusion energy. In particular, ARPA-E is interested in information that would: (A) increase FPP performance through efficient and low-cost plasma heating for MFE concepts and laser drivers for IFE concepts, as well as low-cost, high-performance targets for IFE; (B) improve FPP viability through accelerated discovery of novel fusion materials. Any future related R&D effort, if successful, would solve some of the greatest challenges of commercial fusion energy and establish a new manufacturing base for fusion energy technology in the US.

ARPA-E will not provide funding or compensation for any information submitted in response to this RFI, and ARPA-E may use information submitted to this RFI on a non-attribution basis. Based on the input provided in response to this RFI and other considerations, ARPA-E may decide to issue a FOA. If a FOA is published, it will be issued under a new FOA number. No FOA exists currently. ARPA-E reserves the right to not issue a FOA in this area.

REQUEST FOR INFORMATION GUIDELINES:

ARPA-E is not accepting applications for financial assistance or financial incentives under this RFI. Responses to this RFI will not be viewed as any commitment by the respondent to develop or pursue the project or ideas discussed. ARPA-E may decide at a later date to issue a FOA based on consideration of the input received from this RFI. No material submitted for review will be returned and there will be no formal or informal debriefing concerning the review of any submitted material. ARPA-E reserves the right to contact a respondent to request clarification or other information relevant to this RFI. All responses provided will be taken into consideration, but ARPA-E will not respond to individual submissions or publish publicly a compendium of responses. **Respondents shall not include any information in the response to this RFI that might be considered proprietary or confidential.**

Responses to this RFI should be submitted in PDF or Word format to the email address ARPA-E-RFI@hq.doe.gov by **5:00 PM Eastern Time on Monday, November 21, 2022**. ARPA-E will not review or consider comments submitted by other means. Emails should conform to the following guidelines:

- Please insert "Responses for RFI DE-FOA-0002874" in the subject line of your email, and include your name, title, organization, type of organization (e.g., university, non-governmental organization, small business, large business, federally funded research, and development center (FFRDC), government-owned/government-operated (GOGO), etc.), email address, telephone number, and area of expertise in the body of your email.
- Responses to this RFI are limited to no more than 10 pages in length (12-point font size).
- Responders are strongly encouraged to include preliminary results, data, and figures that describe their potential methodologies.
- Please indicate the RFI questions (e.g., 3i, 6ii, etc.) being addressed whenever possible.

Questions:

Responders should provide the following information, though a response to each item on the list is not required. The questions are grouped into two broad themes and further into different categories.

A. *Improving performance with innovative heating schemes and high-performance targets*

1. *State of the art (SoA) of heating systems and driver and target technologies*

  i. Describe heating challenges for Magnetic Fusion Energy (MFE) and identify the key functional elements that would enable greater than 80% efficiency.
  ii. Describe the SoA of high rep rate laser system and identify subsystems that would enable a 10x increase in rep rate and substantial increase in wall plug efficiency.
  iii. Describe the status of target delivery for inertial fusion energy (IFE) as well as the final optics for laser beam delivery.

2. *Drivers & Metrics*

  i. What are the relevant subsystems that would benefit from accelerated innovation? What set of metrics led to the choice of the subsystems?

ii. Provide metrics that could be included to estimate the contribution of these systems in the LCOE.

3. *Organization & Capabilities*

   i. Describe the key stakeholders' capabilities that would enable the development and deployment of innovative heating systems, or advanced driver technologies and/or target driver architecture.

4. *Economics*

   i. Describe what you view as the major technical and market risks associated with developing novel architecture enabling high rep high power energy lasers as well as target-drivers.

B. ***Increasing FPP availability through accelerated discovery of novel fusion reactor materials***

5. *Accelerated Materials Discovery Framework*

   i. Describe the limitations of existing accelerated materials discovery frameworks which prevent new materials from being deployed in full-scale systems.
   ii. To what extent could machine learning (ML) / artificial intelligence (AI) be used "end-to-end" to jointly accelerate both materials discovery and synthesis?
   iii. What are the relevant high-throughput synthesis and characterization methods for refractory alloys?

6. *Materials & Metrics*

   i. What are the relevant high-throughput properties screening tests that are important for the discovery of plasma facing components (PFCs) and structural materials, including determination of performance under irradiation?
   ii. Describe the technological gaps that needs to be closed for current PFC and structural materials under consideration for various fusion concepts.
   iii. What are the tangible metrics to be considered for the discovery of PFCs and structural materials for FPPs?
   iv. While ion beams are used as proxies to mimic material irradiation, can you describe potential R&D efforts that would reduce the cost of future 14 MeV neutron sources for material testing?

7. *Organization & Capabilities*

   i. Describe what capabilities an organization should have or develop to deliver an integrated high-throughput framework for materials discovery.
   ii. Describe the key stakeholders that would enable the development and deployment of this technology.

8. *Economics*

   i. Describe what you view as the major technical and market risks associated with developing novel structural materials for fusion reactors.
   ii. What are the economics of a FPP, and what are the appropriate cost metrics to consider?