Highlights of GAO-23-105813, a report to congressional addressees

March 2023

TECHNOLOGY ASSESSMENT

Fusion Energy

Potentially Transformative Technology Still Faces Fundamental Challenges

Why GAO did this study

Fusion could address many energy challenges by providing abundant, safe, low-carbon energy. Researchers have achieved scientific and technological advancements in recent years. Fusion energy companies have received billions of dollars of private investment in addition to federal grants.

GAO conducted a technology assessment on (1) the status, potential benefits, and limitations of fusion energy, (2) challenges that might affect the development or use of fusion energy, (3) policy options that might help enhance the benefits or mitigate challenges associated with fusion energy.

GAO reviewed key reports and scientific literature; interviewed stakeholders from government, industry, and academia; held focus groups with members of the public; attended a conference on issues related to fusion energy; and convened a meeting of experts in collaboration with the National Academies of Sciences, Engineering, and Medicine. GAO is identifying policy options in this report.

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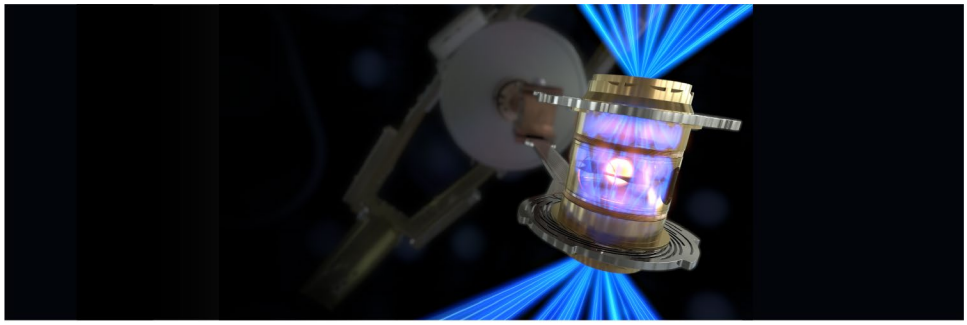
What GAO found

Nuclear fusion, the process that powers the sun and other stars, could produce electric power without carbon emissions, long-lived nuclear waste, or risk of meltdowns. Researchers and companies are pursuing many different concepts for fusion energy and have reported recent progress, such as the development of high-temperature superconducting magnets that could make fusion devices much more compact. Also, in 2022, an experiment at the National Ignition Facility achieved a key scientific milestone, generating more energy from a fusion reaction than the amount of direct energy spent to start the reaction.

National Ignition Facility



Source: Lawrence Livermore National Laboratory. | GAO-23-105813

However, several challenges must be overcome to achieve commercial fusion, and stakeholders' projections of this timeline range from 10 years to several decades. One key scientific challenge is in the physics of plasmas, the state of matter needed for fusion. Researchers do not fully understand the behavior of burning plasmas, those whose main source of heat is from the fusion reaction itself rather than an external source. Researchers have made advancements in this area but lack sufficient experimental data to validate their simulations. One key engineering challenge is the development of materials that can withstand fusion conditions for decades, such as extreme heat and neutron damage, and no facility exists where materials can be fully tested. More generally, the task of extracting energy from fusion to provide an economical source of electric power presents several complex systems engineering problems that have yet to be solved.

Public and private sector misalignments, regulatory uncertainty, and other factors also present challenges to fusion energy development. One area of misalignment is research priorities. Public sector efforts prioritize basic science, but fusion energy development requires an additional emphasis on technology and engineering research. Another factor is regulatory uncertainty, which could slow development of fusion energy, although developing appropriate regulations to ensure safety without constraining development is difficult. Doing so may require significant public engagement, but little is known about public perception of fusion energy in the U.S.

GAO developed four policy options that could help address these challenges or enhance the benefits of fusion energy. These policy options are provided to inform potential actions to address the public policy challenges identified in this technology assessment. They identify possible actions by policymakers, which include legislative bodies, government agencies, academia, industry, and other groups. See below for a summary of the policy options and relevant opportunities and considerations.

Policy Options to Help Address Challenges or Enhance Benefits of Fusion Energy

	Opportunities	Considerations
Sustain current efforts (report p. 32)	• Some challenges described in this report may be addressed by current efforts. • Could allow policymakers to observe and evaluate the impact of existing efforts, which could limit risk and save money.	• Current efforts may not address all challenges described in this report. • Current efforts alone may delay or inhibit the development of fusion energy, which could result in forgone benefits or negative impacts, such as to the environment.
Align public and private efforts (report p. 33) Implementation approaches: *Align programs, missions, and organizational structures with fusion energy development goals* *Expand use of public private partnerships* *Reduce barriers to collaboration* *Leverage international coordination*	• Could accelerate the demonstration and commercialization of fusion energy by enhancing research on materials, technology, and engineering needs. • Could leverage strengths across sectors and expand programs that, according to experts and interviewees, are underused and have been effective in advancing fusion energy development. • Standardized research and development agreements could accelerate research, encourage knowledge sharing between organizations and countries, and reduce time-intensive negotiation.	• Aligning public and private efforts can be time intensive and may require additional resources or legislative action, according to experts. • To achieve fusion energy development timeline goals, policymakers may need to pursue parallel efforts and take more risks, which could incur greater costs. • Could require additional resources or reallocation of existing resources from other programs.
Build shared assets for fusion energy (report p. 34) Implementation approaches: *Support facilities that address scientific and engineering challenges* *Support workforce development* *Assess sources of critical supplies and manufacturing capabilities*	• Could help fill critical research gaps on the path to fusion energy commercialization. • Could help ensure fusion energy development is not limited by critical workforce or supply shortages.	• Test facilities require significant investment and years to build and commission. • Workforce development takes significant time and resources. National lab representatives said that long-term funding is needed for education and training. • Stakeholders may disagree on the best options to support community assets that are usable for a range of fusion energy technologies.
Engage the public in decision-making (report p. 35) Implementation approaches: *Study public opinion through surveys and focus groups* *Educate through cross-sectoral forums* *Include affected communities in decision-making related to fusion facilities*	• Could help inform policy decisions, such as those related to regulation of and investment in fusion energy. • Could ensure community stakeholders' views are represented so that decisions do not negatively impact issues of public concern, such as traffic or the environment. • Could ensure that benefits, such as economic development, are shared broadly and inclusively with affected communities. • Alignment between communities and fusion developers could reduce barriers to their success.	• Engagement should be proactive, transparent, and should set realistic expectations for benefits, risks, and timelines. • It may be difficult to ensure broad participation and representation. • Engagement should be used to learn about the public's perspectives about fusion energy rather than to persuade the public to support fusion.

Source: GAO. | GAO-23-105813