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ITER and the prospects for commercial fusion FREE

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sion energy sciences and provided the Department of Energy's Fusion Energy Sciences Advisory Committee with strategic recommendations for addressing those opportunities.[2]

The private sector has invested hundreds of millions of dollars in pursuing novel approaches to accelerate the deployment of commercial fusion power plants (see, for example, PHYSICS TODAY, August 2018, page 25, and February 2019, page 28). The BETHE Project (Breakthroughs Enabling Thermonuclear-Fusion Energy) under the Advanced Research Projects Agency–Energy recently released a funding-opportunity announcement that targets transformational research "with the potential to be disruptive in the marketplace" and specifically encourages development of "timely, commercially viable fusion energy."

ITER will make important contributions to the mission of deploying commercially viable fusion. And public, private, and partnership groups are aggressively pursuing ways to accelerate commercial deployment. New designs may eliminate the physics challenges cited in the article by Richard Hawryluk and Hartmut Zohm.

ITER will not be on the critical path for commercial deployment, and the answer to when we will have commercial fusion is this: sooner than you think.

References

1. National Academies of Sciences, Engineering, and Medicine, *Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research*, National Academies Press (2019), p. 1.
2. American Physical Society Division of Plasma Physics, *A Community Plan for Fusion Energy and Discovery Plasma Sciences*, APS (2019).

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▶ **Hawryluk and Zohm reply:** Wallace Manheimer points out that remaining scientific and technological issues will need to be addressed to produce commercially competitive electricity from nuclear fusion on the completion of the ITER research program. True, ITER was not designed to produce net electricity, but power generation can be accelerated by doing more R&D in parallel with ITER's construction. The fusion community recognizes that; it was a central topic of the research initiatives highlighted in the 2019 National Academies of Sciences, Engineering, and Medicine report on burning plasma research.[1] Examples of such parallel activities that are underway include the proposed China Fusion Engineering Test Reactor and the new initiatives Jesse Treu and colleagues mention. Those efforts will profit from both the technological progress made during ITER construction and the physics understanding gained from its operation.

The "conservative design rules" Manheimer mentions are indeed recognized by the tokamak community. Research initiatives around the world are actively addressing them and seeking scientific and technological innovations to increase fusion power for a given facility size. Among them are increasing the magnetic field strength by using high-temperature superconducting magnets and increasing the power heat flux capabilities through the use of liquid-metal divertors.

Manheimer notes that fusion at an ITER-like tokamak can be used to breed nuclear fuel, such as uranium-233 from thorium-232. That may decrease the R&D effort in order to extend the parameters for fusion power plants, but it will entail other technological developments to breed ^{233}U from Th and incorporating them into a nuclear fission economy. Some ITER partners have considered that approach, but others find it less attractive because of its link to fission.

Treu and coauthors note the strong need for innovation, as identified in the National Academies report; the community consensus recommendations for a strategy to address those opportunities; and the increased role of private companies to accelerate development. We share with them the hope that new designs for fusion facilities combined with results from ITER can accelerate the development of commercial fusion.

Finally, the triggering mechanism for the transition to the high-confinement barrier (H-mode) in the edge region is an ongoing area of research that is building on early work by Akira Hasegawa, Masahiro Wakatani, and many others. Experimentally, the criterion for entering the H-mode is characterized in terms of an ion heat flux. For a fully developed H-mode state, the shear flow necessary to suppress turbulence in the edge region is provided by the zeroth-order diamagnetic flow—that is, the pressure gradient and not the turbulence itself. Hence, sustaining H-mode confinement after the transition has occurred does not rely on additional external energy or momentum input; it can be sustained by the heat flux arising from the α-particle heating. We now realize that this important aspect regarding sustaining the H-mode was not clear enough in our article.

Reference

1. National Academies of Sciences, Engineering, and Medicine, *Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research*, National Academies Press (2019).

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A proposal for APS action on police brutality

The shocking death of George Floyd on 25 May 2020 is unfortunately not a singular event in the US. Eric Garner, Michael Brown, Freddie Gray, Breonna Taylor, and Amadou Diallo—who was struck by 19 of the 41 bullets fired by four New York City police officers—are just part of a long list of unarmed Black Americans who have died at the hands of the police. That pattern of violence is deeply rooted in the history of Black–white relations in the US and the failure of the leaders of this country to deal with systemic racism. It is worth asking what an organization with a diverse membership such as the American Physical Society can do to effect change.

Yearly, APS hosts large meetings in cities around the US. Perhaps the time has come for the organization to include the treatment of Black Americans by the local police as a key criterion in choosing cities to host the society's meetings. Cities in which Black people have died at the hands