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EDITORIAL

Preface to the Special Issue: Strategic Opportunities for Fusion Energy

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The *Journal of Fusion Energy* provides a forum for discussion of broader policy and planning issues that play a crucial role in energy fusion programs. In keeping with this purpose and in response to several recent strategic planning efforts worldwide, this *Special Issue on Strategic Opportunities* was launched with the goal to invite fusion scientists and engineers to record viewpoints of the scientific opportunities and policy issues that can drive continued advancements in fusion energy research.

The level of strategic planning activity during the past 3 years has been significant. The U.S. Department of Energy requested the Fusion Energy Sciences Advisory Committee (FESAC) to establish three subcommittees to advise how "to capture the science of ITER" [1], how to prioritize "scientific facilities to ensure the optimal benefit from Federal investments" [2], and how "to exert long term leadership roles within and among" the areas of burning plasma science and discovery plasma science [3]. From April 2012 through October 2014, fusion scientists and engineers in the U.S. contributed over 220 white papers and participated in a dozen workshops at the request of these three FESAC subcommittees. Additionally, at the time this *Special Issue* was announced, the U.S. DOE's Fusion Energy Sciences (FES) program initiated a series of four technical workshops "to seek community engagement and input for future program planning activities" [4] where several hundred additional white papers and presentations were prepared describing a wide range of technical approaches to advance fusion science and the frontiers of plasma science.

The European and Japanese fusion communities have also completed recent strategic planning activities. In 2012, the European Commission charged the European Fusion Development Agreement (EFDA) to prepare a roadmap to fusion electricity by 2050 [5], which was formulated using input from experts, discussions with industry, and feedback from a community workshop. The European roadmap is a goal-oriented program to produce "a demonstration fusion power plant (DEMO), producing net electricity" to start operation before 2050. While the U.S. emphasizes the science of fusion energy, the European program moves away from being "science-driven, laboratory based" towards a venture that is "industry-driven and technology-driven" [5]. In Japan, the Working Group on Fusion Research was established in 2013 under the Ministry of Education, Culture, Sports, Science and Technology (known as "MEXT"), and this Working Group developed a Japanese strategic roadmap for the development of a fusion DEMO. As described by Hiroshi Yamada and co-authors in this *Special Issue* [6], the purpose of DEMO is to improve the prospects for "the economic and social rationality of fusion energy competitive with other energy sources." The Working Group identified eleven technical research and development elements that must be resolved for DEMO while also acknowledging a difficulty: it is too early to specify a design for DEMO. To resolve these uncertainties, the Working Group suggested a dual-path strategy for fusion development [6], "the DEMO design activity … [should] play a role not only to promote and boost secure

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progress of the main stream options [for a fusion DEMO] but also to promote innovative technological developments for breakthrough."

This *Special Issue on Strategic Opportunities* was announced at the end of February 2015. An open call for papers was circulated broadly to scientific and technical professional societies, asking fusion researchers to submit manuscripts describing important and timely matters of program direction. Authors of white papers were encouraged to submit their contributions for this issue, and international contributions were encouraged. Topics of interest include, but were not limited to opportunities and strategies to: (*i*) Advance the physics and engineering of magnetic confinement toward fusion energy (including compatible first wall approaches, structural materials, blanket systems, diagnostics and control), (*ii*) Advance the physics and engineering of inertial confinement toward fusion energy, (*iii*) Explore the promise of new fusion energy concepts, technologies and strategies (including high temperature superconducting magnets, fusion-fission hybrids and advanced fusion fuels), and (*iv*) Explore prospects and impact of advances in predictive capabilities. A particular challenge facing the field is how best to combine targeted development of fusion energy technology with broader research to simplify and improve the fusion energy concepts as an attractive energy source.

The *Special Issue* contains sixteen articles presenting options for a broad approach to fusion energy science development. Eight articles presented technical descriptions of research opportunities most of which were based on white papers originally prepared for the FESAC strategic planning activities. The eight remaining articles were discussion papers containing viewpoints and personal opinions for fusion energy research and development strategies. Four of the sixteen papers were from non-U.S. authors. As guest editors of this *Special Issue*, we appreciate the contributions of the authors. The sixteen articles represent the breadth of scientific and technological opportunities in fusion energy science and also the wide range of opinions in the community how best to pursue these opportunities. The opportunities and views expressed in these articles are a successful outcome from the open call for papers. Each article benefitted from expert peer-review; however, neither the guest editors nor the Editor and Board of the *Journal of Fusion Energy* necessarily endorse the strategic plans and views contained in these articles.

Five of the articles containing technical descriptions of research opportunities included innovative research plans to address key challenges of the tokamak approach to fusion energy, and three articles presented non-tokamak opportunities. Kotschenreuther et al. [7] and Soukhanovskii and Xu [8] review efforts to understand and optimize the divertor configuration in order to reduce target heat loads while maintaining high confinement of the fusion core. Raman et al. [9] describe deep particle fueling and momentum injection using compact tori (CT) and using off-axis current drive from electron Bernstein waves (EBW) in order to optimize the performance of the steady-state advanced tokamak and spherical tokamak. Whyte et al. [10] describe how the recent industrial maturity of high-temperature, high-field superconductors open up the possibility of more compact fusion reactors and the design of demountable and modular magnets that vastly improves simplicity in the construction and maintenance of the coils and the internal components required for fusion. Pace et al. [11] describe experiments that can be performed using today's research tokamaks to investigate the feasibility of enhanced fusion yield with spin polarized fuel. Simonen [12] reviews the recent results from gas dynamic trap (GDT) at the Budker Institute of Nuclear Physics in Russia that have motivated reconsideration of the mirror concept: achieving high-beta stability with axisymmetric coils, high electron temperature, and the elimination of micro-instabilities caused by mirror losses. Finally, Wurden et al. [13] and Sinars et al. [14] present new directions for fusion research that combine strong magnetic fields with pulsed inertial fusion concepts.

The eight discussion papers within the *Special Issue* describe viewpoints and personal opinions for fusion energy research and development strategy. In addition to the previously mentioned dual-path strategy from the Japanese Working Group [6] that boosts progress of the mainstream approach embodied by the tokamak and stellarator while also promoting innovative technological developments and breakthroughs, Donne et al. [15] argue for an extended operation and enhancements of the JET tokamak that will make experiments on JET even more relevant for ITER; Lopes Cardozo, Lange, and Kramer [16] put into perspective the high initial development costs for fusion and note that these high initial costs are both expected and tolerable on a longer time frame; Stacey [17] and Manheimer [18] review the application of fusion technology to treat fission waste and breed fissile fuel; Hornfeld [19] and Sheffield [20] make observations on the necessity for international collaboration and fusion concept innovation in the strategic directions of fusion energy research; and Wurden et al. [21] call for a renewed effort in fusion powered space propulsion as part of a larger effort for planetary defense against what would be a devastating collision with a comet.

We hope this *Special Issue* serves as an important record of today's exciting opportunities to advance fusion energy. We also hope this issue will serve to encourage other fusion scientists to submit manuscripts that strengthen the open discussion of broader policy and planning issues that play a crucial role in energy fusion programs.

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