FESAC Facilities Construction Projects Report

Brian Wirth,
Department Head and
UT-ORNL Governor's Chair Professor

2 December 2024

THE UNIVERSITY OF TENNESSEE KNOXVILLE

DEPARTMENT OF NUCLEAR ENGINEERING

Dr. Berhe's Charge

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

December 1, 2023

To: CHAIRS OF THE OFFICE OF SCIENCE FEDERAL ADVISORY COMMITTEES:
Advanced Scientific Computing Advisory Committee
Basic Energy Sciences Advisory Committee
Biological and Environmental Research Advisory Committee
Fusion Energy Sciences Advisory Committee
High Energy Physics Advisory Panel
Nuclear Science Advisory Committee

The Department of Energy's Office of Science (SC) has envisioned, designed, constructed, and operated many of the premiere scientific research facilities in the world. More than 38,000 researchers from universities, other government agencies, and private industry use SC User Facilities each year—and this number continues to grow.

Stewarding these facilities for the benefit of science is at the core of our mission and is part of our unique contribution to our Nation's scientific strength. It is important that we continue to do what we do best: build facilities that create institutional capacity for strengthening multidisciplinary science, provide world class research tools that attract the best minds, create new capabilities for exploring the frontiers of the natural and physical sciences, and stimulate scientific discovery through computer simulation of complex systems.

To this end, I am asking the SC advisory committees to look toward the scientific horizon and identify what new or upgraded facilities will best serve our needs in the next ten years (2024-2034). More specifically, I am charging each advisory committee to establish a subcommittee to:

1. Consider what new or upgraded facilities in your disciplines will be necessary to position the Office of Science at the forefront of scientific discovery. The Office of Science Associate Directors have prepared a list of proposed projects that could contribute to world leading science in their respective programs in the next ten years. The Designated Federal Officer (DFO) will transmit this material to their respective advisory committee chairs. The subcommittee may revise the list in consultation with their DFO and Committee Chair. If you wish to add projects, please consider only those that require a minimum investment of $100 million. In its deliberations, the subcommittee should reference relevant strategic planning documents and decadal studies.
2. Deliver a short letter report that discusses each of these facilities in terms of the two criteria below and provide a short justification for the categorization, but do not rank order them:

    a. **The potential to contribute to world-leading science in the next decade.** For each proposed facility/upgrade consider, for example, the extent to which it would answer the most important scientific questions; whether there are other ways or other facilities that would be able to answer these questions; whether the facility would contribute to many or few areas of research and especially whether the facility will address needs of the broad community of users including those whose research is supported by other Federal agencies; whether construction of the facility will create new synergies within a field or among fields of research; and what level of demand exists within the (sometimes many) scientific communities that use the facility. **Please place each facility or upgrade in one of four categories: (a) absolutely central; (b) important; (c) lower priority; or (d) don't know enough yet.**

    b. **The readiness for construction**. For proposed facilities and major upgrades, please consider, for example, whether the concept of the facility has been formally studied; the level of confidence that the technical challenges involved in building the facility can be met; the sufficiency of R&D performed to date to assure technical feasibility of the facility; the extent to which the cost to build and operate the facility is understood; and site infrastructure readiness. **Please place each facility in one of three categories: (a) ready to initiate construction; (b) significant scientific/engineering challenges to resolve before initiating construction; or (c) mission and technical requirements not yet fully defined.**

Many additional criteria, such as expected funding levels, are important when considering a possible portfolio of future facilities, however, for this assessment I ask that you focus your report on the two criteria discussed above.

I look forward to hearing your findings and thank you for your help with this important task. I appreciate receiving your final report by May 2024.

Sincerely,

Asmeret Asefaw Berhe

Asmeret Asefaw Berhe
Director, Office of Science

Sub-Committee Members - Big Thank You!

Prof. Brian Wirth, U. of Tennessee - Knoxville (Chair)

Prof. Carlos Paz-Soldan, Columbia University (Vice-Chair)

Dr. Felicie Albert, Lawrence Livermore National Laboratory

Mr. David Babineau, Savannah River National Laboratory

Dr. Kate Bell, Sandia National Laboratories

Dr. Cami Collins, Oak Ridge National Laboratory

Prof. Evdokiya Kostadinova, Auburn University

Dr. Rajesh Maingi, Princeton Plasma Physics Laboratory

Prof. Jaime Marian, U. of California - Los Angeles

Dr. Thomas Sunn Pedersen, Type One Energy

Dr. Erica Salazar, Commonwealth Fusion Systems

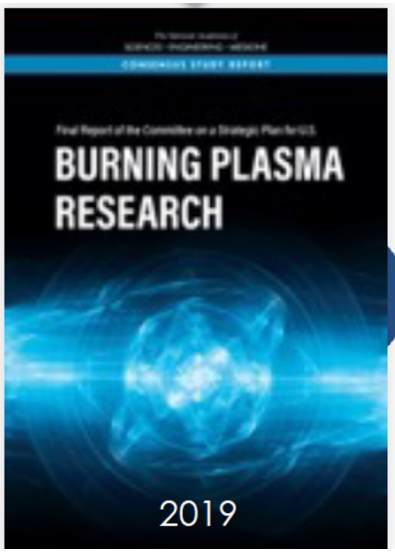
Dr. Chase Taylor, Idaho National Laboratory

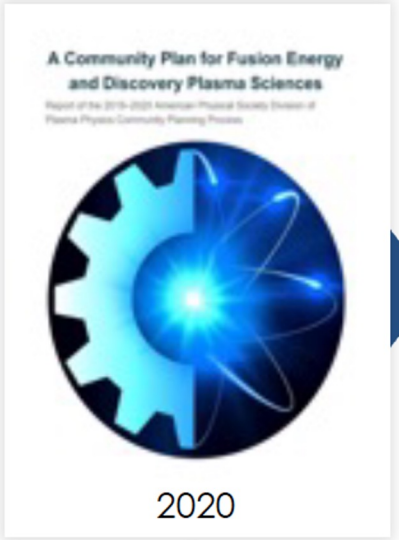
Dr. Kathreen Thome, General Atomics

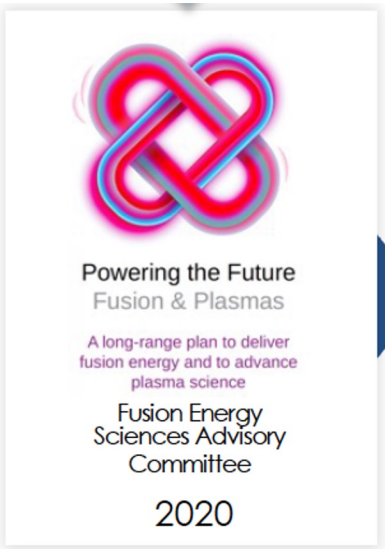
Prof. Troy Carter, U. of California - Los Angeles (ex-officio)

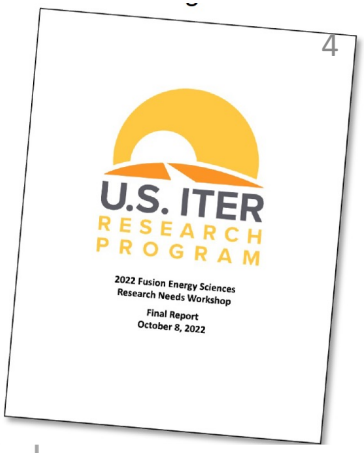
Prof. Anne White, Massachusetts Institute of Technology (ex-officio)

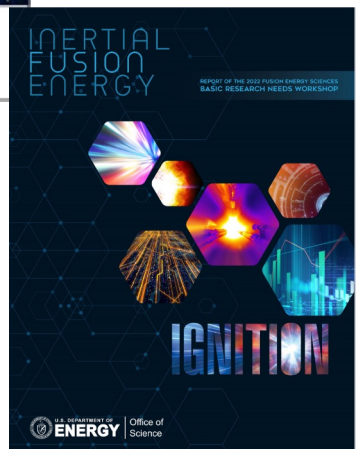
Prior reports & recent events informed our discussions











2022 Whitehouse event to launch ‘Bold Decadal Vision’ and milestone-based public-private partnerships

2022 & 2023 demonstrations of fusion scientific gain from IFE in the US & 69 MJ fusion heating over 6 seconds in the UK

We were provided the "FES List" of 10 Facilities:

BCTF (Blanket Component Test Facility)
DIII-D (eXcite) Upgrade
FCTF (Fuel Cycle Test Facility)
FIRST (Fusion Integration Research and Science Test Facility)
FPNS (Fusion Prototypic Neutron Source)
HHF (High Heat Flux Facility)
ITER
MEC-U (Matter in Extreme Conditions Petawatt Laser Upgrade)
NSTX-U LMCE (NSTX-U Liquid Metal Core Edge Facility)
Midscale Stellarator

Two facilities were added by the committee:

EXCITE Options
New Inertial Fusion Energy (IFE) Concepts and Upgrades

The "FES List" is Public
- *available on FESAC's website*

Charge to subcommittee specified to (only) evaluate upgrades to existing facilities

Process - Webinars

One webinar per facility was held and advertised to the community

One or two per week from Mid-February to early April.

Speakers selected based on white paper submissions

Included a “community overview” with consensus elements whenever feasible

Q&A done in the open, community Q&A also included

Essential element of our process as a sub-committee

https://sites.google.com/view/fesac-fcp/home

WE THANK THE ORAU/ORISE TEAM for the technical support of these webinars !

WE THANK THE COMMUNITY FOR THEIR INPUT !

Process - Conflict of Interest (COI) & Consensus

In consultation with FES Designated Federal Official (DFO), the Subcommittee Chair and Vice-Chair defined a process to address COI.

- Members self-identified COI based on affiliation and/or research and service activities with an existing or proposed facility.
- Subcommittee Chair and Vice-Chair assigned Primary and Secondary reviewers for each facility, ensuring COI/pCOI was avoided.
- Primary/Secondary reviewers led discussion in Subcommittee meetings to identify additional questions remaining after webinar, and to draft the additional facility writeup and 'strawman' answer to charge Questions 2a & 2b.

- All members of the Subcommittee participated in all facility discussions and contributed to the development of consensus assessment and report!
- Important that 'every voice is heard' and that no Subcommittee members felt regret that they did not have a chance to voice their opinion(s) – this led us to consensus

Criteria to Identify Facilities that:

'Best Serve Fusion and the Bold Decadal Vision'

- Urgency of timeline with decadal impact on fusion industry/science;
- Alignment with FESAC LRP and BDV;
- Response to Charge Questions 2a/2b;
- Opportunities for partnerships that could accelerate timeline and/or reduce costs;
- Technology gaps that would be closed by a facility and/or contribution to world-leading fusion science

These criteria were applied holistically to our evaluation and also incorporated a preference for facilities that supported multiple fusion power plant concepts

No predetermined number of facilities in this category

Facilities that Best Serve Fusion

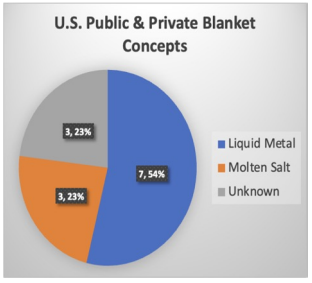
A strong consensus was developed in the Subcommittee that four facilities 'Best Serve Fusion' (in alphabetical order): Blanket Component Test Facility (BCTF), Fuel Cycle Test Facility (FCTF), Fusion Prototypic Neutron Source, and ITER.

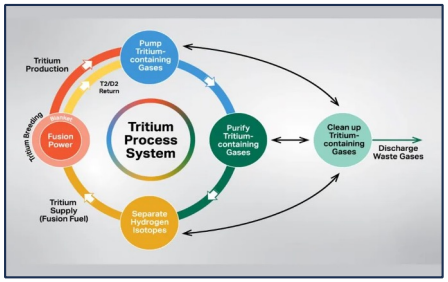
- Each of these facilities support multiple pathways to fusion energy, including ITER which has/will provide knowledge transfer about fusion technology & engineering experience at reactor scale, including system integration, precision engineering and quality control

The other eight facilities were all deemed 'important' (in response to Q2a). Many of these facilities were associated with single-concept fusion confinement approaches

These facilities are highly important and well-deserving of FES support

The readiness for construction varied significantly between all facilities





Parameter	Capability by 2028	Capability by 2033
Damage rate	5-10 dpa/yr (Fe eq.)	15 dpa/yr (Fe eq.)
Sample volume	≥50 cm^3	≥300 cm^3
Spectrum	Gaseous & solid trans. consistent with 14 MeV fusion n spectrum	
Temperature range	~300 to 1200 °C	
Temperature control	3 ind. controlled regions	
Flux gradient	≤20%/cm in plane of sample	


ITER tokamak pit (October 2022). Credit: ITER Organization

Leveraging of Partnerships for Facilities

Comment: FES alone cannot afford the full range of important facilities

The committee identified several modalities to leverage partnerships to accelerate readiness for construction and share costs

Leveraging other agencies (NNSA, BES, NSF) for mission-adjacent work

Leveraging Public-Private Partnerships for concept-specific facilities

Leveraging International Partnerships where strategically relevant

Closing the ITEP-equivalent gap

Several facilities seek to close facets of the “ITEP-equivalent” gap

ITEP = Integrated <<Tokamak>> Exhaust and Performance

As stated in LRP: *“Closing the [ITEP-equivalent] gap is necessary to ensure FPP readiness”*

An ITEP-equivalent gap must be closed for any MFE concept

Each of the proposed single plasma core concept confinement facilities closing ITEP-equivalent gaps are very (b) important and well-deserve FES support

Summary

- New fusion facilities addressing critical technology and science gaps are urgently needed to meet the timelines of the BDV and private industry to provide economically-attractive fusion energy to the U.S. grid, especially related to the growing excitement about fusion (IFE Q>1 and UK-AEA demonstration of 69 MJ fusion power)
- We thank the community for the rapid input and participation in our community webinars as part of the evaluation of 12 facilities/facility upgrades for fusion
- Our Subcommittee developed a strong consensus that four facilities 'Best Serve Fusion' - BCTF, FCTF, FPNS and ITER. *Each of these facilities support multiple pathways to fusion energy, including ITER which has/will provide knowledge transfer about fusion technology*
- Our Subcommittee developed consensus evaluation that the remaining eight facilities were deemed important. Each of the facilities were evaluated to be at varying levels of readiness for construction. No further attempt to prioritize or rank these facilities was performed, consistent with the charge from Dr. Berhe