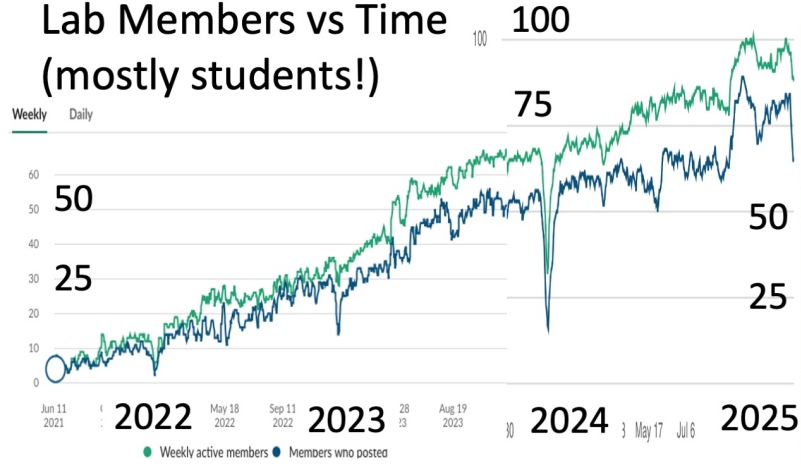
COLUMBIA PLASMA PHYSICS

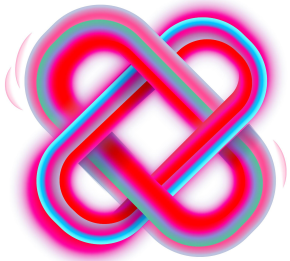
"Carlos Paz-Soldan, Columbia U., DOE FESAC Member"

- Foundational Plasma Science: On-Campus & National User Facilities
- Accelerating Fusion Industry: Sponsored Research & Milestone PPP
- Building the Fusion Workforce: Outreach, Internships, BSc's, PhD's

Lab Members vs Time (mostly students!)



FESAC Decadal Plan Subcommittee Mid-process Update to FPA



Presented by:
Prof. Carlos Paz-Soldan
On behalf of the FESAC Decadal Plan Subcommittee

FPA Meeting 12/03/24

FESAC Decadal Plan Subcommittee Members

Carlos Paz-Soldan (Columbia), Chair

Tammy Ma (LLNL), Vice-Chair

Arianna Gleason (SLAC)

Brenda Garcia-Diaz (SRNL)

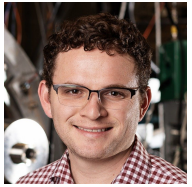
Brian Grierson (GA)

Carmen Menoni (CSU)

Chris Holland (UCSD)

Cristina Rea (MIT)

Davide Curreli (U. Illinois)



Derek Sutherland (Zap Energy)

Elizabeth Paul (Columbia)

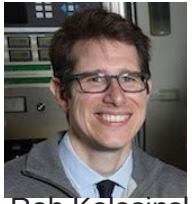
Katharina Stapelmann (NCSU)

Lauren Garrison (CFS)

Luis Delgado-Aparicio (PPPL)

Michael Porton (Tokamak Energy)

Paul Humrickhouse (ORNL)



Rob Kolasinski (SNL)

Ex-officio:

Anne White (MIT)

Brian Wirth (UTK)

Sam Barish (DOE Liaison)

Subcommittee Charge (slide 1/2)

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

Professor Anne White
Associate Provost and Associate Vice President for Research Administration
School of Engineering Distinguished Professor of Engineering
Department of Nuclear Science and Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue, 24-107
Cambridge, Massachusetts 02139

Dear Professor White:

The 2020 report of the Fusion Energy Sciences Advisory Committee (FESAC) Long-Range Plan (LRP) "Powering the Future: Fusion & Plasmas" states in its Executive Summary that "*Now is the time to move aggressively toward the deployment of fusion energy which could substantially power modern society while mitigating climate change.*" In addition, the same report states, "*Fulfilling the [fusion] energy mission demands a shift in the balance of research toward FM&T (Fusion Materials and Technology), which connects the three science drivers: Sustain a Burning Plasma, Engineer for Extreme Conditions, and Harness Fusion Energy.*" Furthermore, a key recommendation in the 2021 Consensus Study Report of the National Academies of Sciences, Engineering, and Medicine (NASEM) "Bringing Fusion to the U.S. Grid" was that "*For the United States to be a leader in fusion and to make an impact on the transition to a low-carbon emission electrical system by 2050, the Department of Energy and the private sector should produce net electricity in a fusion pilot plant in the United States in the 2035-2040 timeframe.*" The recommendations in these reports, which reflected the tremendous progress in fusion science and technology over the last decades as well as the rapid growth and significant investments of the private sector in fusion, contributed to the Administration's recognition of the potential of fusion energy to advance the goal to get to net-zero emissions by 2050.

In March 2022, the White House Office of Science and Technology Policy and the Department of Energy co-hosted a summit on *Developing a Bold Decadal Vision for Commercial Fusion Energy*, which called for accelerating the viability of commercial fusion energy in partnership with the private sector. As a first major step in achieving the Bold Decadal Vision (BDV), the Fusion Energy Sciences (FES) program issued a Funding Opportunity Announcement (FOA), "Milestone-Based Fusion Development Program", to accelerate the development of a fusion pilot plant (FPP) by working with private industry. This initiative is also consistent with the Energy Act of 2020, which expanded the scientific mission of FES with supporting "*the development of a competitive fusion power industry in the U.S.*"

The private sector responded enthusiastically to this FOA, and in May 2023, FES announced $46 million in awards to eight fusion startup companies. The Office of Fusion Energy Sciences (FES) budget request for fiscal year (FY) 2024 includes additional support for the BDV, specifically enhanced support for the Milestone Program, the establishment of fusion research and development (R&D) centers to resolve critical science and technology gaps, and support for future facilities studies including a fusion prototypic neutron source.

The BDV builds upon the FESAC LRP and the NASEM report and accelerates the timeline to an FPP. The FESAC LRP and the American Physical Society/Division of Plasma Physics (APS/DPP) Community Planning Process provided important community input on prioritization among various FES program elements. Given recent developments, it is necessary to re-assess the alignment of the FES program with the FESAC LRP and the expanded mission of the FES program in addressing the BDV in a decadal timeframe. Namely, what new opportunities exist for accelerating fusion energy development and what are some unique synergistic opportunities with discovery plasma science and technology.

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Subcommittee Charge (slide 2/2)

We are therefore asking FESAC to form a subcommittee to re-assess the program elements and their alignment with the FESAC LRP science drivers and the BDV, within the four major categories of the FES budget structure: Burning Plasma Science: Foundations (which includes Advanced Tokamak, Spherical Tokamak, Theory & Simulation, Public-Private Partnerships, and Inertial Fusion Energy); Burning Plasma Science: Long Pulse (which includes the FES international collaborations under Long Pulse: Tokamak, international collaborations and domestic efforts under Long Pulse: Stellarators, and Materials & Fusion Nuclear Science); Burning Plasma Science: High Power (which includes ITER Research); and Discovery Plasma Science (which includes General Plasma Science, High-Energy Density Laboratory Plasmas, and Measurement Innovation).

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concepts represented in the Milestone Program awardees. In particular, identify a scope that will address near-term scientific and technological gaps impacting the design and construction of an FPP on the pathway to commercialization within the timeframe of the BDV. For the scope within a program element that is not identified as critical to support the LRP Science Drivers or the BDV, identify specific elements that can be deferred with

Asmeret Asefaw Berhe
Director, Office of Science

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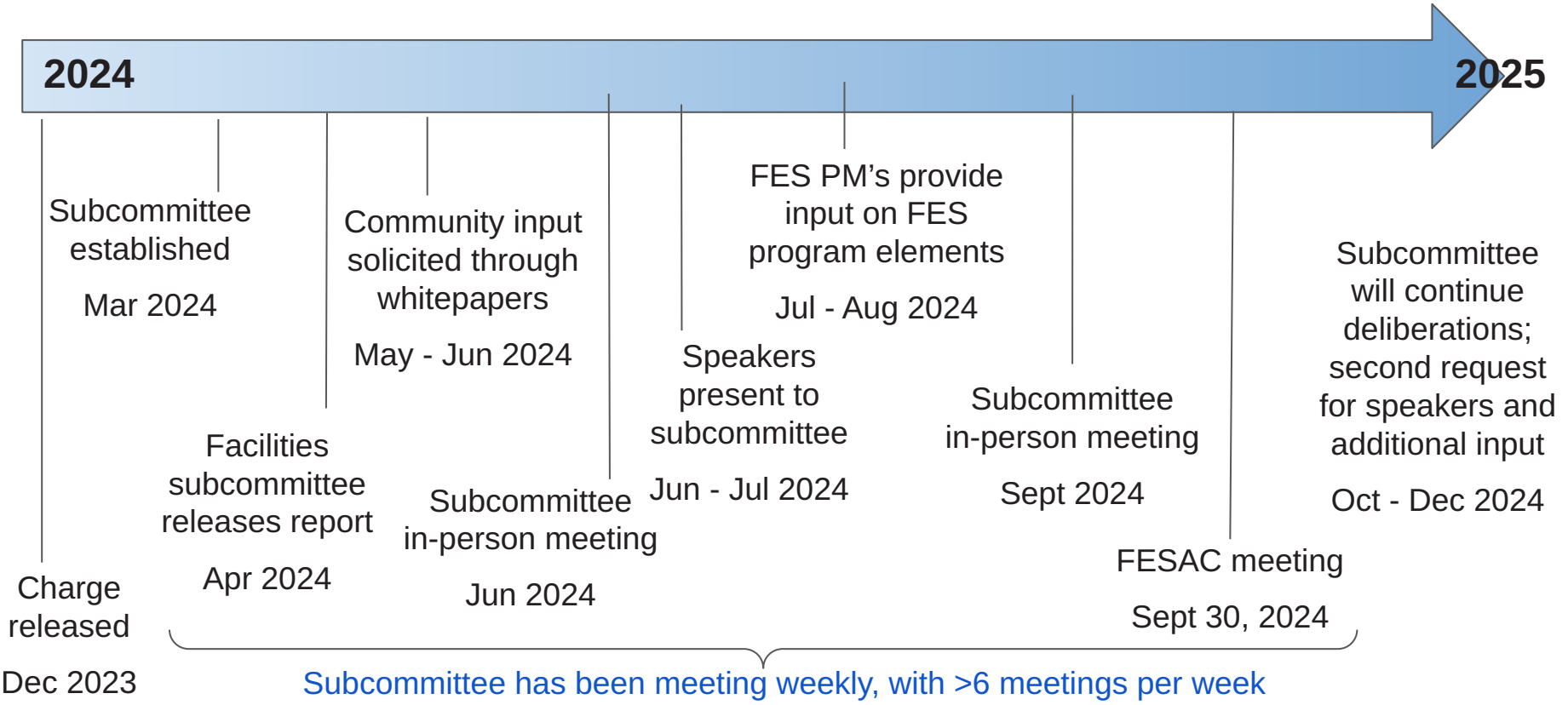
For each program element in each category, identify opportunities or current plans to contribute to the FESAC LRP FM&T and fusion plasma science gaps establishing the basis of an FPP in the context of the BDV, taking into consideration the diversity in FPP concepts represented in the Milestone Program awardees. In particular, identify a scope that will address near-term scientific and technological gaps impacting the design and construction of an FPP on the pathway to commercialization within the timeframe of the BDV. For the scope within a program element that is not identified as critical to support the LRP Science Drivers or the BDV, identify specific elements that can be deferred with minimal or modest impact on the FES Program to enable redirection in support of the LRP FM&T gaps and the BDV. Identify the program elements that need to be increased to meet the goals of the LRP FM&T gaps establishing the basis of an FPP in the context of the BDV and those that can be decreased.

Asmeret Asefaw Berhe
Director, Office of Science

Timeline


2024
2025
Charge released
Dec 2023
Subcommittee established
Mar 2024
Facilities subcommittee releases report
Apr 2024
Community input solicited through whitepapers
May - Jun 2024
Subcommittee in-person meeting
Jun 2024
Speakers present to subcommittee
Jun - Jul 2024
FES PM's provide input on FES program elements
Jul - Aug 2024
Subcommittee in-person meeting
Sept 2024
FESAC meeting
Sept 30, 2024
Subcommittee will continue deliberations; second request for speakers and additional input
Oct - Dec 2024
Subcommittee has been meeting weekly, with >6 meetings per week

New input was requested on a subset of our charge

Since the FESAC LRP and NASEM reports were completed, there has been a significant change in the fusion energy landscape; in particular private investment in fusion has more than tripled to over $6B. We view this part of the charge as an **opportunity to provide input to DOE on the role of the public program** in this context and on **possible new public-private partnership mechanisms**. We also recognize the chance to call out **new synergies and opportunities for interactions** between fusion science and technology R&D and broader plasma science and technology R&D.

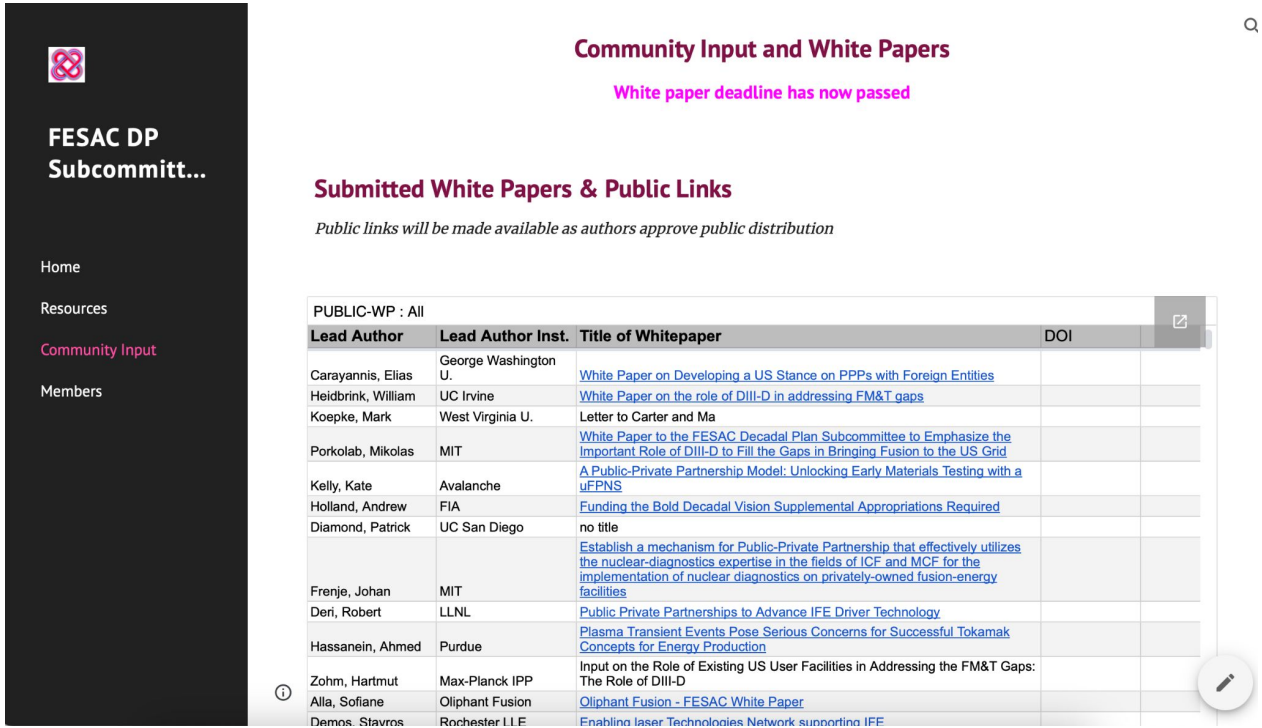
To that end, we requested two kinds of input:

(1) We are planning to bring guests to talk with the subcommittee on relevant topics (e.g. PPP activities in other sectors). We welcome suggestions for speakers/guests using this form.

(2) Concise (< 5 pages) white papers addressing this piece of the charge are welcome, including **proposals for new PPP mechanisms, proposals for approaches for better coupling between the private and public efforts, and opportunities for synergies with fundamental and applied plasma science.**

76 white papers were received - thank you!

https://sites.google.com/view/fesacdpsubcommittee/home



Lead Author	Lead Author Inst.	Title of Whitepaper	DOI
Carayannis, Elias	George Washington U.	White Paper on Developing a US Stance on PPPs with Foreign Entities	
Heidbrink, William	UC Irvine	White Paper on the role of DIII-D in addressing FM&T gaps	
Koepke, Mark	West Virginia U.	Letter to Carter and Ma	
Porkolab, Mikolas	MIT	White Paper to the FESAC Decadal Plan Subcommittee to Emphasize the Important Role of DIII-D to Fill the Gaps in Bringing Fusion to the US Grid	
Kelly, Kate	Avalanche	A Public-Private Partnership Model: Unlocking Early Materials Testing with a uFPNS	
Holland, Andrew	FIA	Funding the Bold Decadal Vision Supplemental Appropriations Required	
Diamond, Patrick	UC San Diego	no title	
Frenje, Johan	MIT	Establish a mechanism for Public-Private Partnership that effectively utilizes the nuclear-diagnostics expertise in the fields of ICF and MCF for the implementation of nuclear diagnostics on privately-owned fusion-energy facilities	
Deri, Robert	LLNL	Public Private Partnerships to Advance IFE Driver Technology	
Hassanein, Ahmed	Purdue	Plasma Transient Events Pose Serious Concerns for Successful Tokamak Concepts for Energy Production	
Zohm, Hartmut	Max-Planck IPP	Input on the Role of Existing US User Facilities in Addressing the FM&T Gaps: The Role of DIII-D	
Alla, Sofiane	Oliphant Fusion	Oliphant Fusion - FESAC White Paper	
Demos, Stavros	Rochester LLE	Enabling laser Technologies Network supporting IFE	

All white papers received are listed

If author permission was received, WPs are publicly linked

We are answering the following charge questions for each program element

Theory and Simulation (incl. SciDAC)
PPPs (INFUSE, Milestone, Private Facility Res.)
Measurement Innovation / Diagnostics
Discovery Plasma (GPS + HED)
Inertial Fusion Energy
Stellarator (small scale & international)
International ST + AT
Small-scale & Enabling Tech
FM&T Engineer (PFC/PMI + Structural Materials)
FM&T Harness (Blankets & Fuel Cycle, RAMI)
FM&T Sustain (Enabling Technology)
FES User Facilities - NSTX-U
FES User Facilities - DIII-D

1. How does the program element align the with FESAC LRP technology and science drivers?
2. How does the program element align with the FESAC LRP recommendations?
3. How does the program element contribute to establishing the basis for an FPP in the context of the NASEM Report/BDV?
4. What is the current impact of the program element on workforce, workforce diversity, and continuing U.S. leadership in fusion and plasma science?
5. What program elements can be deferred/decreased to make room for other needed investments?
6. What elements are missing or need additional investment to align with LRP/BDV?

We are building off the CPP and LRP process that resulted in community-led, consensus report

CPP:
year-long community-led process. Whitepapers, webinars, town halls and 5 major workshops (including final plenary in Houston 2020); Open process, with community review/vetting of draft reports

LRP:

- response to charge "…should identify and prioritize the research required to advance both the scientific foundation needed to develop a fusion energy source, as well as the broader FES mission to steward plasma science."
- "Optimized FES program over the next ten years" (FY22-FY31). Consider three budget scenarios: constant level of effort, modest growth (2% above inflation), and unconstrained but prioritized

This is us !

The LRP clearly stated “modest growth” implications

“The return on the investment of the relatively small increment from the constant level of effort to the modest growth scenario is substantial. It accelerates the fusion energy mission and gives excellent science per incremental dollar by continuing to support the high-impact work being done across the program.”

“However, there are still significant costs incurred and opportunities missed in this scenario. Most notably, meeting the goal of FPP readiness by the 2040s remains highly unlikely, significant reductions to the US tokamak program are still required, and some important time-sensitive opportunities for US leadership such as construction of MEC-Upgrade cannot be acted upon.”

LRP Page 46

Workforce continuity is being taken seriously

- Our charge clearly indicates emphasis on workforce continuity:

> ***In your deliberations, you should consider the impact of your recommendations on workforce continuity, diversity of the workforce, and continuing U.S. leadership in fusion and plasma science***

- A growing fusion program should offer opportunities for performers
- We're considering these areas as workforce continuity vehicles
  - Public-Private Partnerships & Private Facility Research
  - International Collaborations
  - Transitioning into FM&T programs

Additional charge element: PPP Modalities

- Our charge includes an opportunity to advise DOE-FES on the ongoing efforts towards advancing public-private partnerships:

> ***"In addition, the subcommittee should identify the role of the public sector … in … advancing commercial fusion applications going forward"***

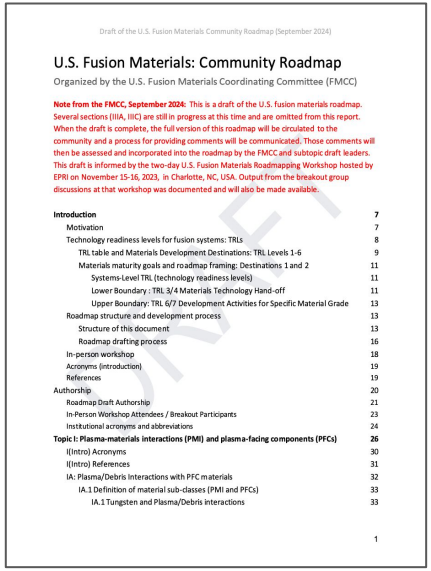
- Since the FESAC LRP and NASEM reports, significant increase in private investment to over $7B, mostly to US companies

- We plan a dedicated effort to provide timely input on this topic

We also thank the community for their white paper input

Fusion Materials & Technology: The Next Frontier

- Broad recognition among the community that significant low TRL mission critical elements remain in this category
- Several community efforts actively defining programmatic scope


Draft of the U.S. Fusion Materials Community Roadmap (September 2024)

U.S. Fusion Materials: Community Roadmap

Organized by the U.S. Fusion Materials Coordinating Committee (FMCC)

Note from the FMCC, September 2024: This is a draft of the U.S. fusion materials roadmap. Several sections (IIIA, IIIC) are still in progress at this time and are omitted from this report. When the draft is complete, the full version of this roadmap will be circulated to the community and a process for providing comments will be communicated. Those comments will then be assessed and incorporated into the roadmap by the FMCC and subtopic draft leaders. This draft is informed by the two-day U.S. Fusion Materials Roadmapping Workshop hosted by EPRI on November 15-16, 2023, in Charlotte, NC, USA. Output from the breakout group discussions at that workshop was documented and will also be made available.

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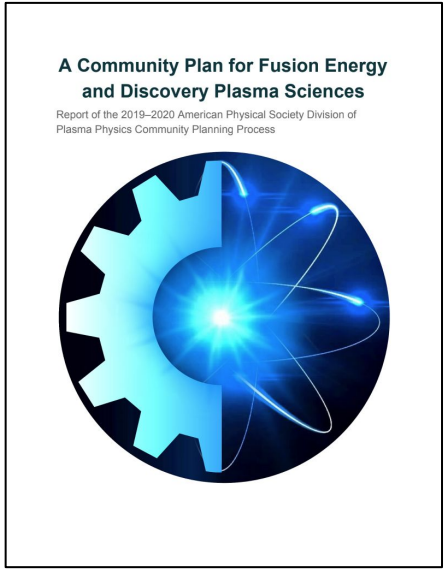


Other opportunities in FM&T: New Facilities

- FESAC Facilities Construction Projects Subcommittee labored throughout the spring and came to a strong consensus on:

- Three facilities beyond ITER that "Best Serve Fusion"
  - Blanket Component Test Facility (BCTF)
  - Fuel Cycle Test Facility (FCTF)
  - Fusion Prototypic Neutron Source (FPNS)

- These facilities will not be realized without significantly increasing emphasis and budget for FM&T programs
  - Concept maturation and cost estimation required to assess readiness

Summary and Conclusions

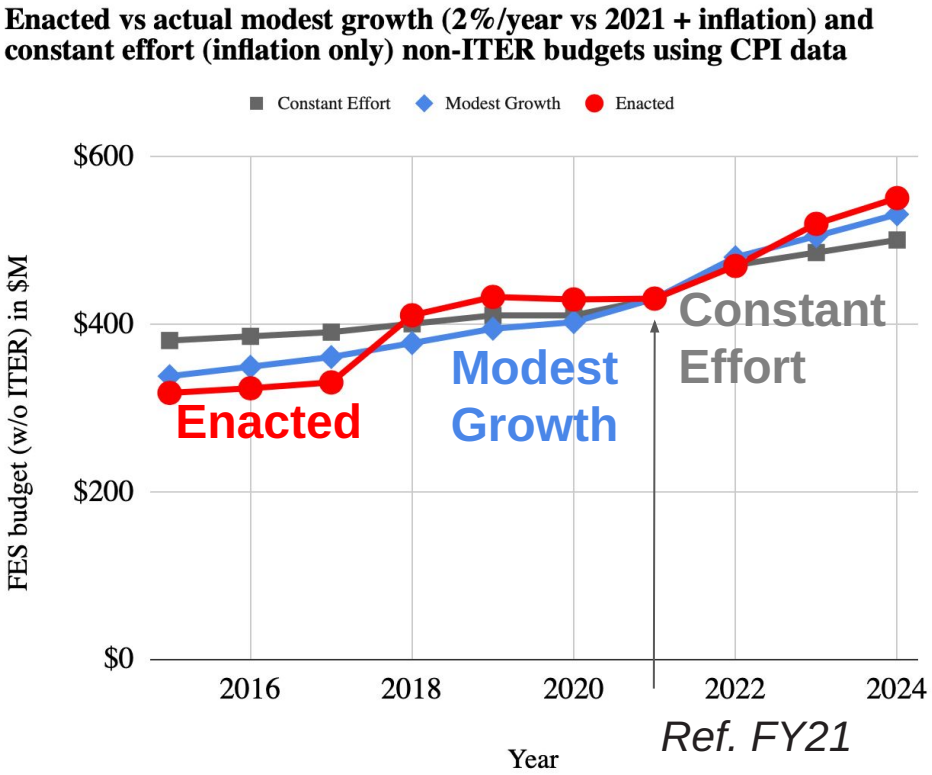
- Our process and deliberations are now well underway
  - *We **greatly value** all the community input received thus far*

We look forward to providing FESAC with our consensus recommendations at the conclusion of our process

Expect FESAC Meeting in Feb 2025
for the presentation of the draft final report

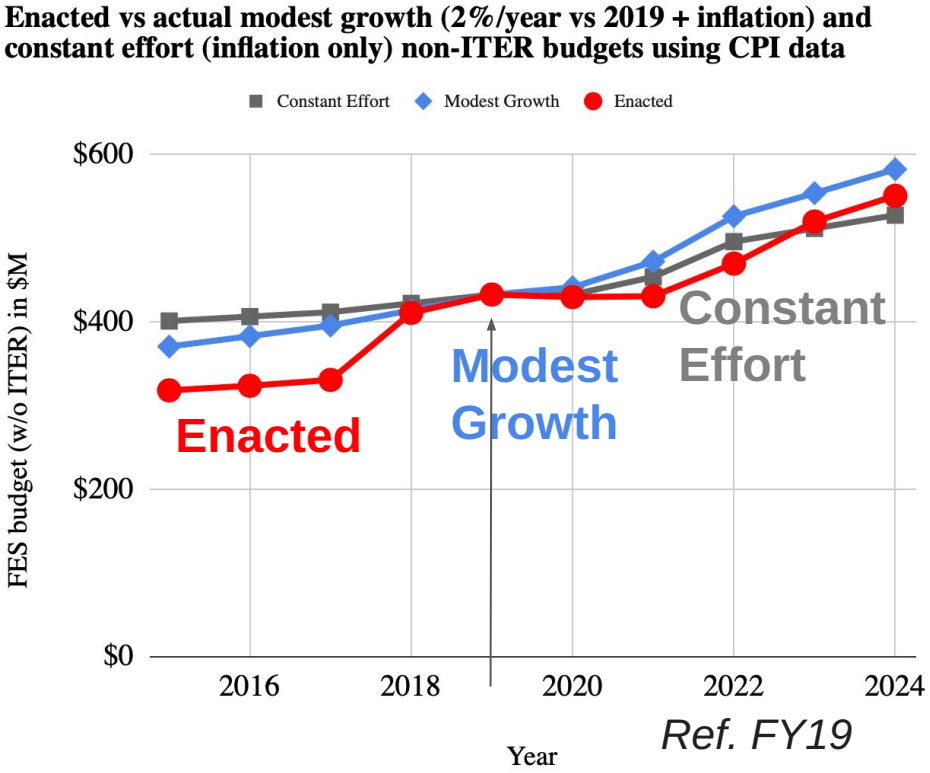
Bonus Slides - Decadal Plan Sub-Committee

Inflation has significantly modified budget landscape



- Use LRP publication (FY21) as ref. point, non-ITER only
- Just to keep up with inflation, "constant effort" required sizable budget increases
- Growth in budget is **closest to modest growth**
- We have not felt the increase:
  - Milestone, IFE hub, FIRE just starting
  - We have already felt inflation

Inflation has significantly modified budget landscape



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- Ref. FY19 (LRP ref. point), *not even modest*