# Discussion with the National Academies FPP Study Committee

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# ARPA-E is invited to address the following topics today

| Topic | Response |
| --- | --- |
| Ongoing activities at ARPA-E relating to this study | • *Multiple programs with a focus on applied fusion R&D guided by techno-economic metrics, bringing together publicly and privately funded efforts* |
| ARPA-E's potential interest in the study outcomes | • *Clarity on FPP goals will provide guidance on what types of federal R&D programs will be needed, including public-private partnerships, to enable the most cost-effective and expeditious route to commercial fusion energy, and how ARPA-E can help further catalyze and enable that route*<br>• *Articulation of market, economic, environmental, and safety requirements will inform both technical and T2M priorities for potential, new ARPA-E fusion programs* |
| Anything else that may be helpful to the committee as it considers its charge | • *Adequate weighting of market requirements in defining FPP goals and the size/nature of the leap from FPP to a commercially viable, grid-ready DEMO*<br>• *Incorporating appropriate levels of risk and innovation ("The biggest risk is not taking any risk.")*<br>• *Consideration of how to map FPP development/construction to an established energy-technology development/funding pathway* |

# Context:  ARPA-E and fusion energy

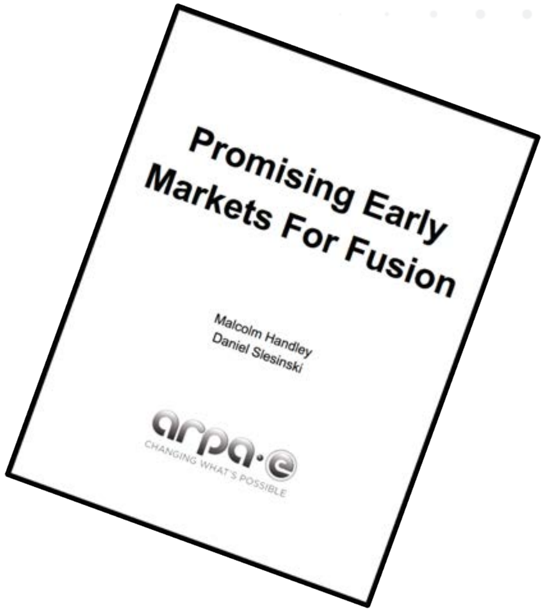
- High-risk, high-reward “bookend” of ARPA-E’s portfolio
- Risk mitigation for achieving cost-effective, deep decarbonization in the latter half of the century.

Focus on cost and timeliness metrics via potentially transformative advances.

How much does fusion need to cost to enable timely, commercial deployment?

| Item | Cost target |
|---|---|
| DEMO capital cost | \$2B, \$5/W |
| LCOE | Initially <75 \$/MWh<br>Longer-term <50 \$/MWh |
| Net-gain experiment | ~ $\mathcal{O}$(\$100M) |
| FPP | ?? |

Incentivizing/enabling public-private-philanthropic partnerships underlies ARPA-E’s fusion programs.




To be released soon!

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# Fusion-energy-related activities at ARPA-E

| Program | Focus | Funding (approximate), # of projects |
|---|---|---|
| ALPHA (2015–2020) | Science and technology of magneto-inertial fusion (MIT) as a potential lower-cost route to fusion energy | $30M, 9 projects |
| OPEN 2018 (2019–2022) | Potentially disruptive technologies across the full spectrum of energy applications | $11M, 3 fusion projects |
| TINA Fusion (2019–2021) | Diagnostic “capability teams” to support state-of-the-art diagnostic construction/deployment and data analysis/interpretation on ARPA-E-supported fusion experiments | $7.4M, 8 projects |
| BETHE (2020–2024) | Increase the number and maturity of lower-cost fusion-energy concepts to help further grow private-sector investments and partnerships → shorten the time scale to one or more net-gain demonstrations | $35M, 18 projects (plus another $5M from FES on 4 of the projects) |
| GAMOW (2020–2024) (joint w/FES) | Enabling technologies required for a commercially viable fusion power plant (first-wall/blanket, PFC/divertor, HTS magnets, electrical drivers and related, fusion materials, advanced manufacturing applied to fusion) → shorten the time scale between net-gain demonstration and a grid-ready, commercially viable DEMO | $30M, 14 projects (funding equally split between ARPA-E and FES) |
| Fusion Tech-2-Market (T2M) activities | ALPHA: Fusion IP landscape, cost study, modeling initial market entry, JASON study, review paper on ALPHA program<br>BETHE and beyond: Investor engagement, fusion market studies, updated cost study/tool, NGO engagement, supporting ARPA-E fusion project teams in securing next-step funding (see BETHE kickoff-meeting agenda) | ≲$1M |

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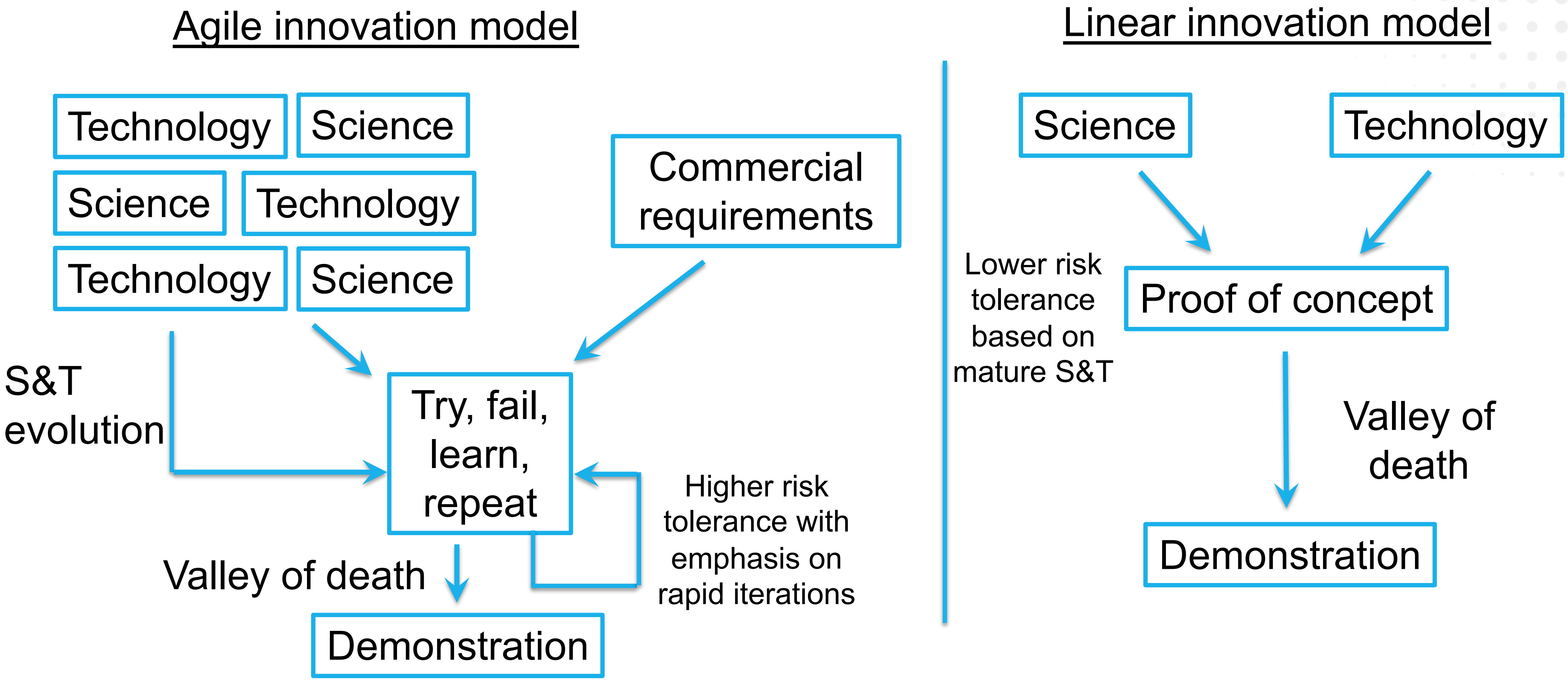
GAMOW project selections publicly announced today (Sep. 2, 2020).

# ARPA-E's interest in study outcome: inform potential new fusion-energy-related program ideas and T2M activities

- Potential, new focused programs (nominally 3-year, $30M programs)
  - Specific technical areas standing to benefit most from potentially transformative R&D (spanning fusion core, enabling technology, RAMI, balance-of-plant, environmental/regulatory)
  - Not presently supported anywhere else
  - Higher-risk than other sponsors wish to accept

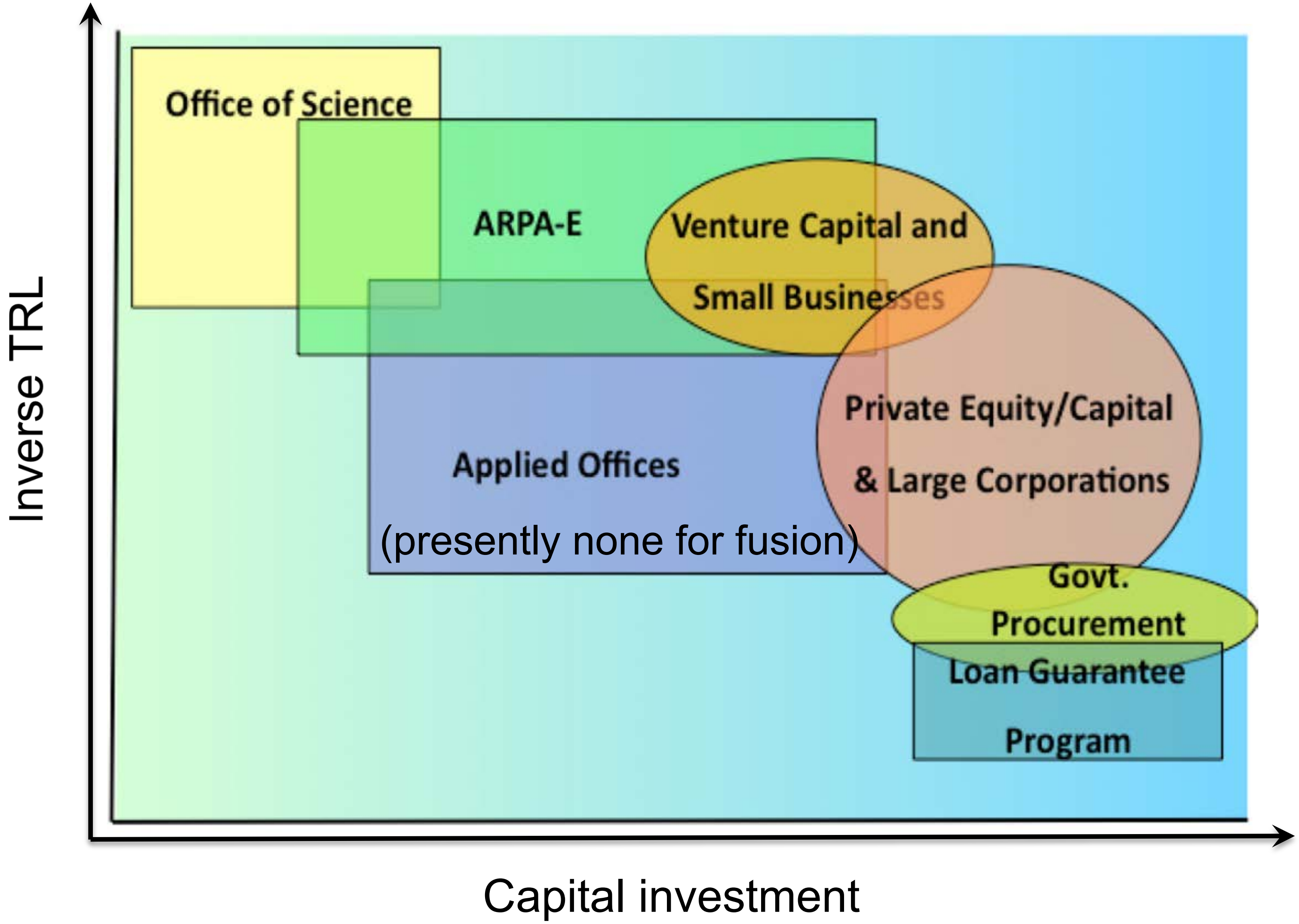
- Refinement/prioritization of fusion T2M activities
  - Market
  - Economic/cost
  - Environmental
  - Safety/regulatory

# Adequate consideration of (1) commercial requirements and (2) degree of inherent risk tolerance and reliance on innovation




R. J. Pearson et al., Tech. Forecasting Soc. Change **158**, 120064 (2020)

# Mapping FPP into existing energy-technology development, funding, and deployment pathways




Adapted from former ARPA-E director A. Majumdar's House Science testimony, 2010

# Different types of public-private-partnership programs can accelerate R&D and ensure commercial alignment up to and including FPP and DEMO

| Development stage | Objectives | Possible program mechanisms |
|---|---|---|
| **Foundational R&D (broad in scope)** | Build underpinning science and tools; advance fusion concepts to a threshold level of stability/confinement | Largely federal grants and cooperative agreements |
| **Earlier-stage R&D needs driven by industry** | Provide access to federally funded expertise, capabilities, and/or facilities | Voucher program, e.g., INFUSE and industry FOAs, e.g., the one from NE |
| **Proof of concept** | Increase plasma performance as measured against the fusion triple product, toward achieving net energy gain in a manner that projects to a commercially viable system | Cost-share program (e.g., NASA/COTS-like milestone reimbursement or federal match of private funds) |
| **Reactor materials, subsystems, and engineering** | Develop, test, and qualify high-duty-cycle driver systems, reactor materials/components, and fuel-cycle technologies | Industrial partnerships, e.g., recent Eni/ENEA partnership to build a Divertor Test Tokamak |
| **Pre-commercial pilot plant** | Fully test and qualify integrated operation of all subcomponents and close all remaining technical and licensing gaps (i.e., the first grid-ready prototype) | Major industrial partnerships, such as the ones being pursued for the DOE-NE Versatile Test Reactor and advanced-reactor demonstration program. |
| **First-of-a-kind commercial demonstration (DEMO)** | First commercial system with electricity on the grid | Financed by a combination of industrial companies, utilities, private investments, and/or federal loans |

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Adapted from *ARPA-E Perspectives on a Fusion-Energy Cost-Share Program*, internal ARPA-E/DOE document (Feb. 6, 2020, updated April 6, 2020).

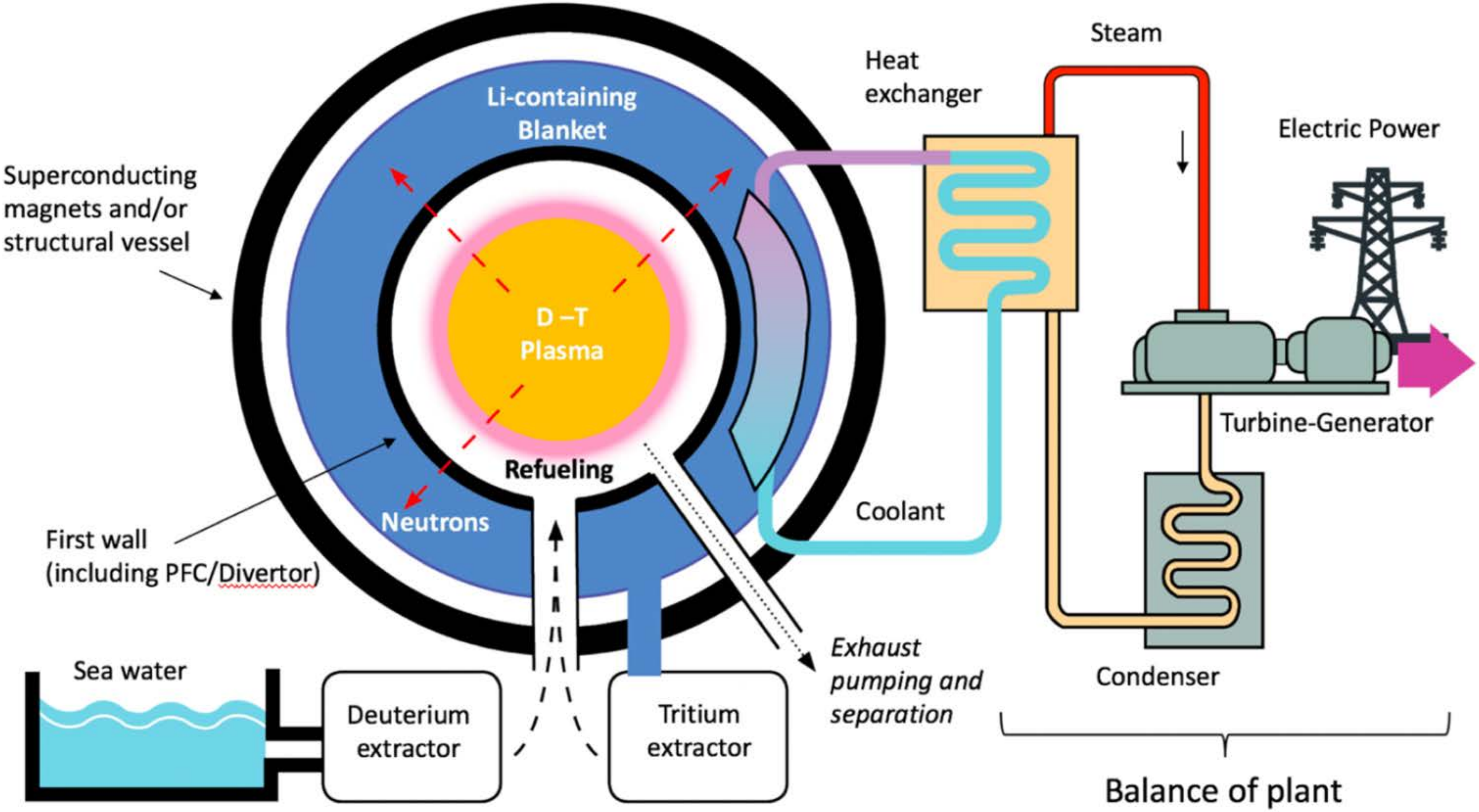
# If it works…

# *will it matter?*

# BETHE ($35M) –18 new projects, including FES partnership* on 3 of the projects ($5M)

- Category A: advance the performance of lower-maturity, lower-cost concepts
  - Axisymmetric mirror with RF/NBI, Wisconsin
  - Sheared-flow stabilized Z pinch, Zap Energy
  - Centrifugal mirror, Univ. Maryland, Baltimore County
  - Muon-catalyzed fusion, NK Labs
  - Sustained spheromak, Univ. of Washington
  - Plasma-jet-driven MIF, LANL
- Category B: lower the cost of higher-maturity concepts through targeted new technologies and/or advanced-manufacturing techniques
  - Pulsed HTS central solenoid, CFS*
  - Stellarator simplification using permanent magnets, PPPL*
  - Advanced IFE target designs, LLE
  - Laser-driver development (DPSSL), LLE*
  - Laser-driver development (excimer ArF), NRL*
  - HTS nonplanar coils, Type One Energy
- Category C: "capability teams" (modeling, machine learning, diagnostics) to support Cat.-A teams
  - Moment-kinetic models, Virginia Tech
  - Data-enabled fusion technology, SapientAI
  - Simulation resource team, LLE
  - RF scenario modeling, MIT
  - Doppler-free saturation spectroscopy, ORNL
  - Electromagnetic/particle diagnostics, LANL

# Joint ARPA-E/FES GAMOW program ($30M) seeks innovative solutions from the first wall to the heat exchanger to enable commercially viable fusion energy




GAMOW project descriptions: click here.
Project selections publicly announced today (Sep. 2, 2020).