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Bringing Fusion to the U.S. Grid

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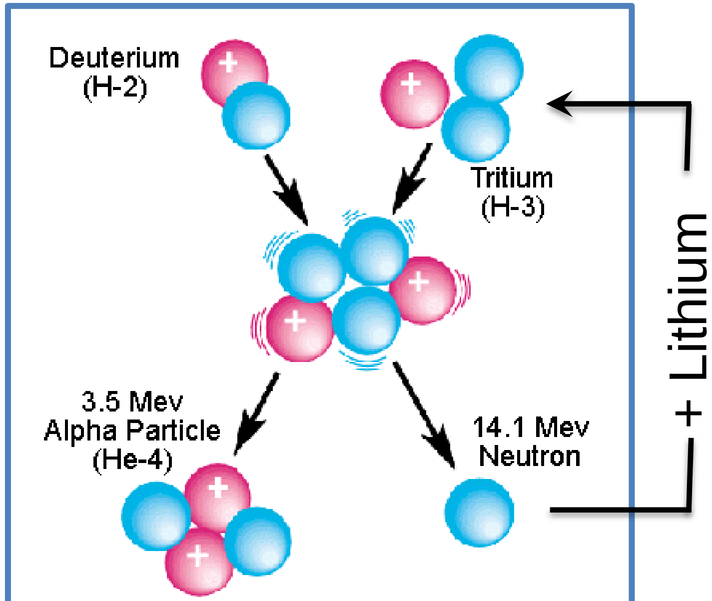
What is fusion, and why is it important?

<u>**Fusion**</u> occurs when two light elements combine to form heavier elements and release a <u>large amount of energy</u>.

- Powers the sun and other stars

Initiating a fusion reaction requires <u>very high temperatures</u> and confinement of the plasma.

Generating a self-sustaining plasma would enable electricity and energy production from fusion.



Deuterium-Tritium Fusion Reaction

Benefits of Fusion:

- Non-carbon emitting source of energy and electricity
- Dispatchable, firm energy generation
- Abundant fuel supplies (D, Li) and minimal long-lived radioactive waste

Non-DT fuel cycles are also being pursued.

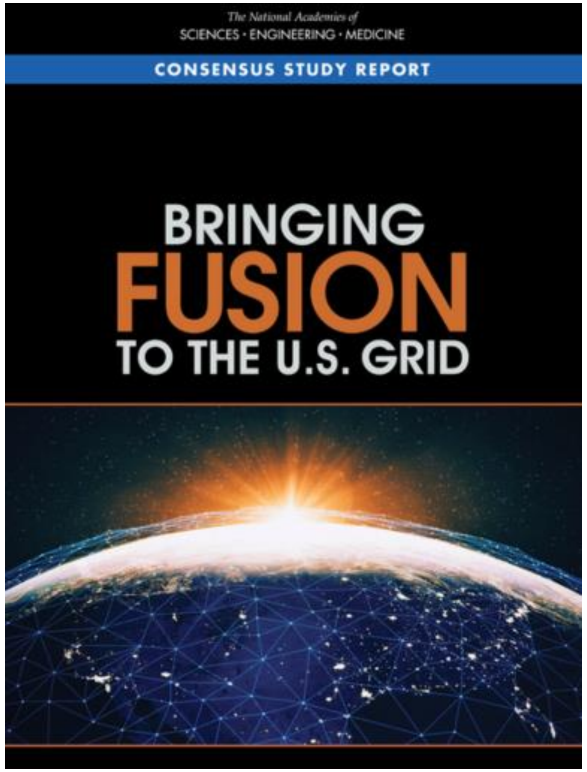
Key Takeaways

Recommendation: 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 Bold Decadal Vision seeks to accelerate the timeline.*

Recommendation: DOE should move forward now to foster the creation of national teams, including public-private partnerships, that will develop conceptual pilot plant designs and technology roadmaps that will lead to an engineering design of a pilot plant that will bring fusion to commercial viability.

Conclusion: Successful operation of a pilot plant in the 2035—2040 timeframe requires urgent investments by DOE and private industry — both to resolve the remaining technical and scientific issues, and to design, construct, and commission a pilot plant.



2021

Text and boxes in red are recent developments

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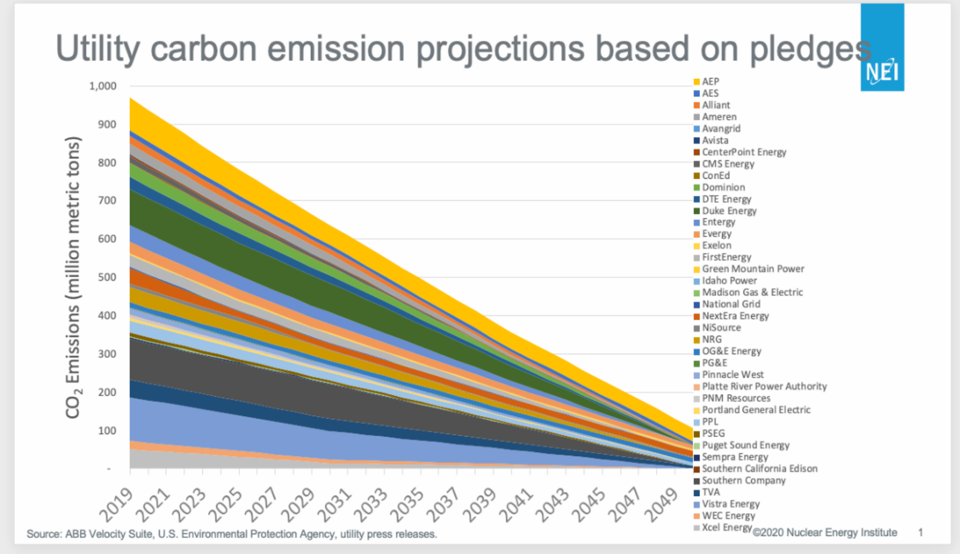
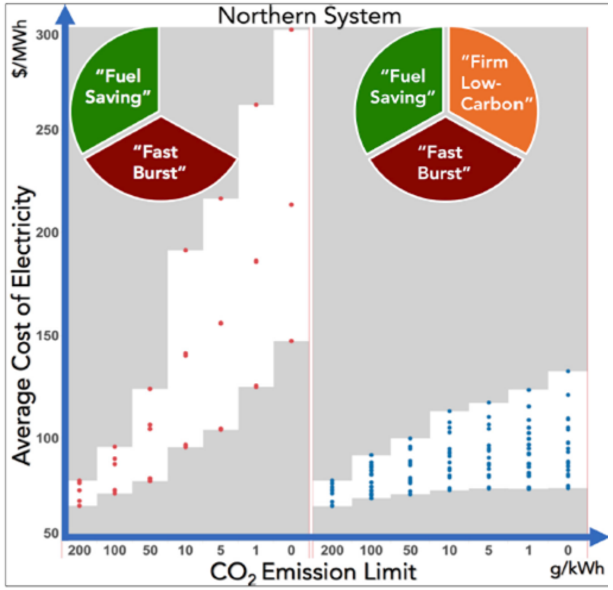
Role of the Pilot Plant:
Future Electricity Generation Market





Utilities foresee a transition to low-carbon electrical generation by 2050.

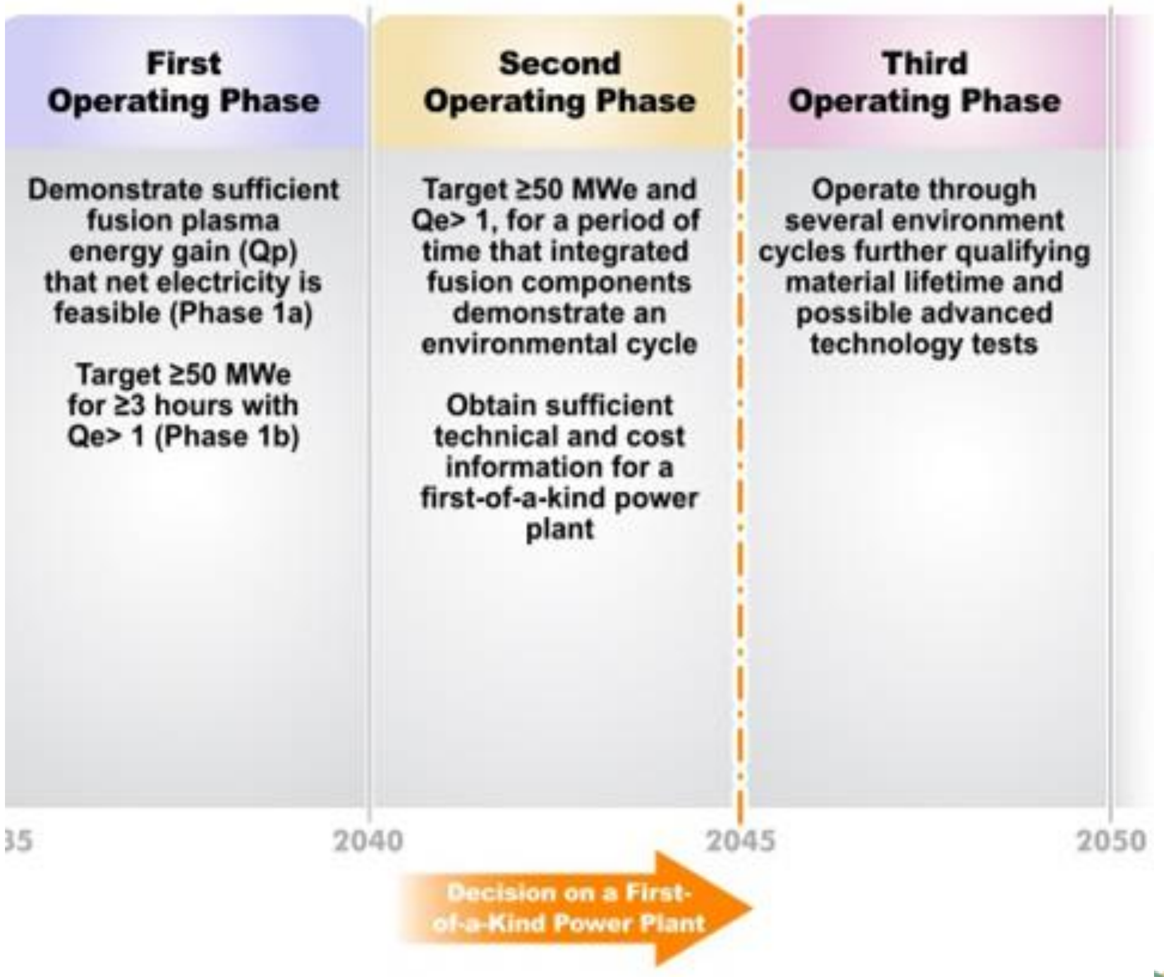
- *Need to accelerate the transition*

Firm low-carbon/non-carbon electrical energy generation will be needed to decrease the cost.

A pilot plant must provide the technical and economic information needed for utilities to operate future plants.

Goals for a Fusion Pilot Plant

Conclusion: A pilot must produce an amount of fusion power and energy that is sufficiently representative of the market needs in order to meet the pilot's goal of demonstrated integrated performance and cost, while also demonstrating net electricity gain Qe > 1 and produce peak net electrical power ≥ 50 MWe.



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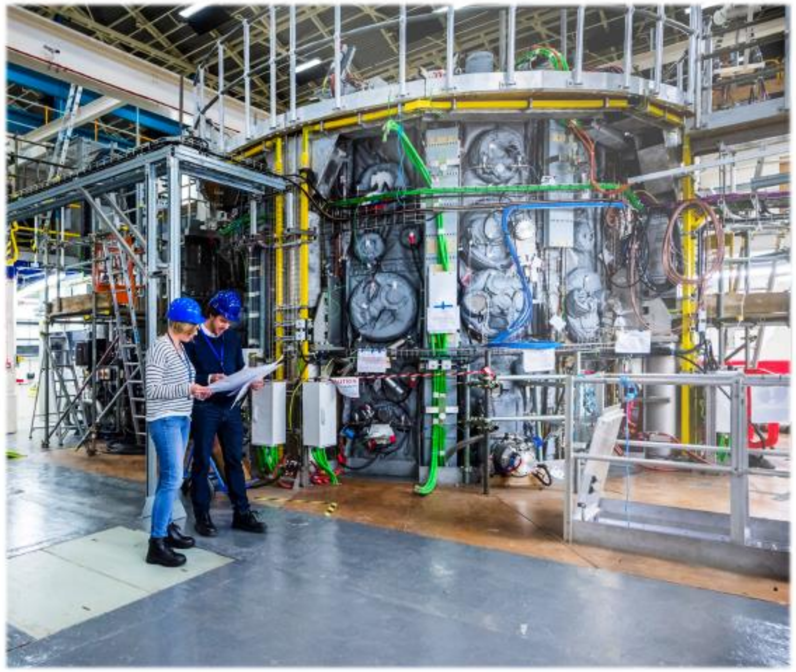
NASEM Report Provides a National Strategy for a Fusion Pilot Plant

- Integrated fusion and electric power performance
- Materials and manufactured components
- Fuel and Ash
  - D-T fuel cycle – need for tritium breeding
  - Alternative fuel cycles to D-T
- Reliability and availability
- Environmental and safety consideration
  - Regulatory framework is required



UK is moving ahead rapidly in developing a regulatory framework.

- *NRC has held hearings*

Goals for a Fusion Pilot Plant:
Economic Considerations

Finding: On the basis of today's energy market and costs, the fusion First-of-a-Kind power plant will need to have a total overnight construction cost less than \$5 billion to \$6 billion in order to be viable in the present U.S. electrical marketplace with a projected operation life of at least 40 years for the plant.

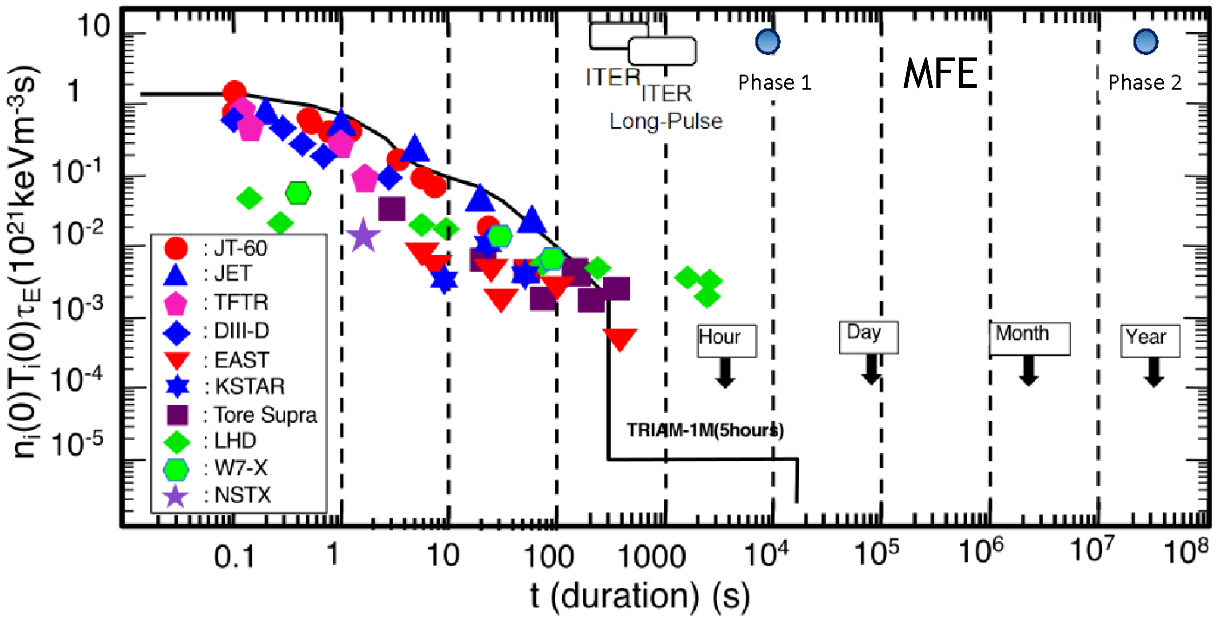
Conclusion: A fusion pilot plant should have a generating power >50 MWe and total overnight construction cost <5-6 B\$.

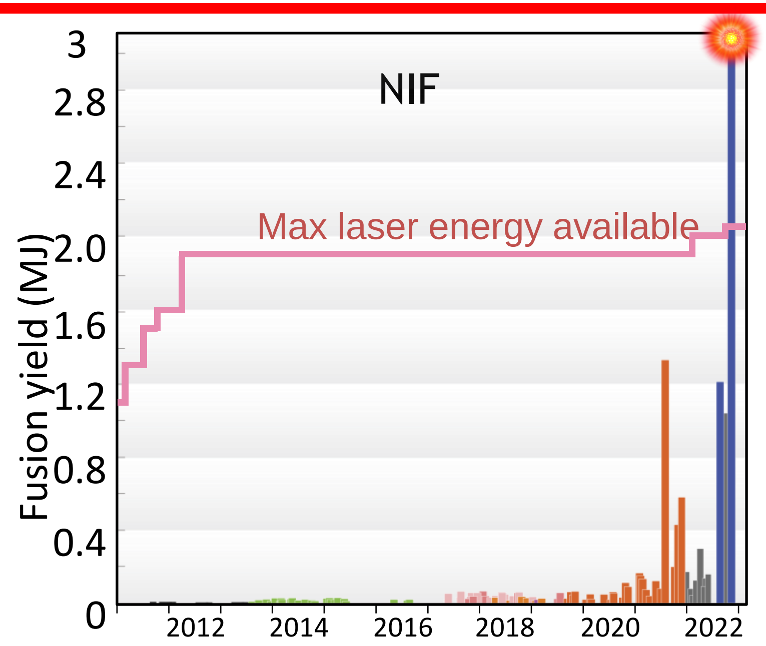
Innovation and Research Investments are Targeted to Meet Technical and Economic Goals

- We need to:
  - Reduce the cost of the pilot plant and accelerate the schedule
  - Improve the economics of a First-of-a-Kind power plant
- ***Recommendation:*** To meet the challenge of having a viable design by 2028 and initial pilot plant operation in 2035-2040, innovations in fusion confinement concepts and technology to extract fusion power and close the fusion fuel cycle should be developed in parallel. This will enable the engineering design of a pilot plant and the construction decisions to be accelerated by a combination of government and private funding.

Innovation and Research in Fusion Plasma Confinement

The pilot plant design will need to be based on a vetted, well-established confinement physics basis for achieving net plasma gain well in excess of unity.





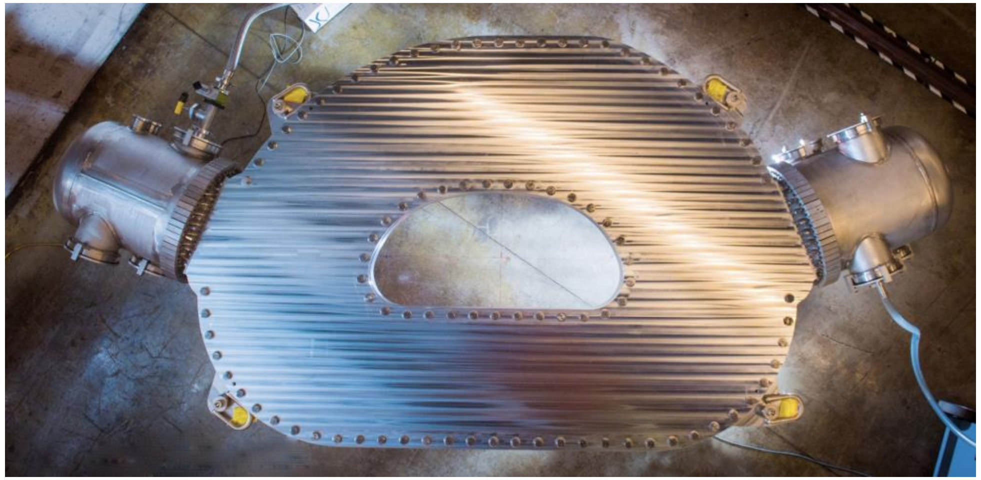
MFE has achieved energy gain ~0.6 and NIF (ICF) has achieved energy gain of 1.5 relative to heating power to the plasma/target

Computer simulations coupled to experiment are driving performance improvement and design

Technical Innovations and Research Opportunities

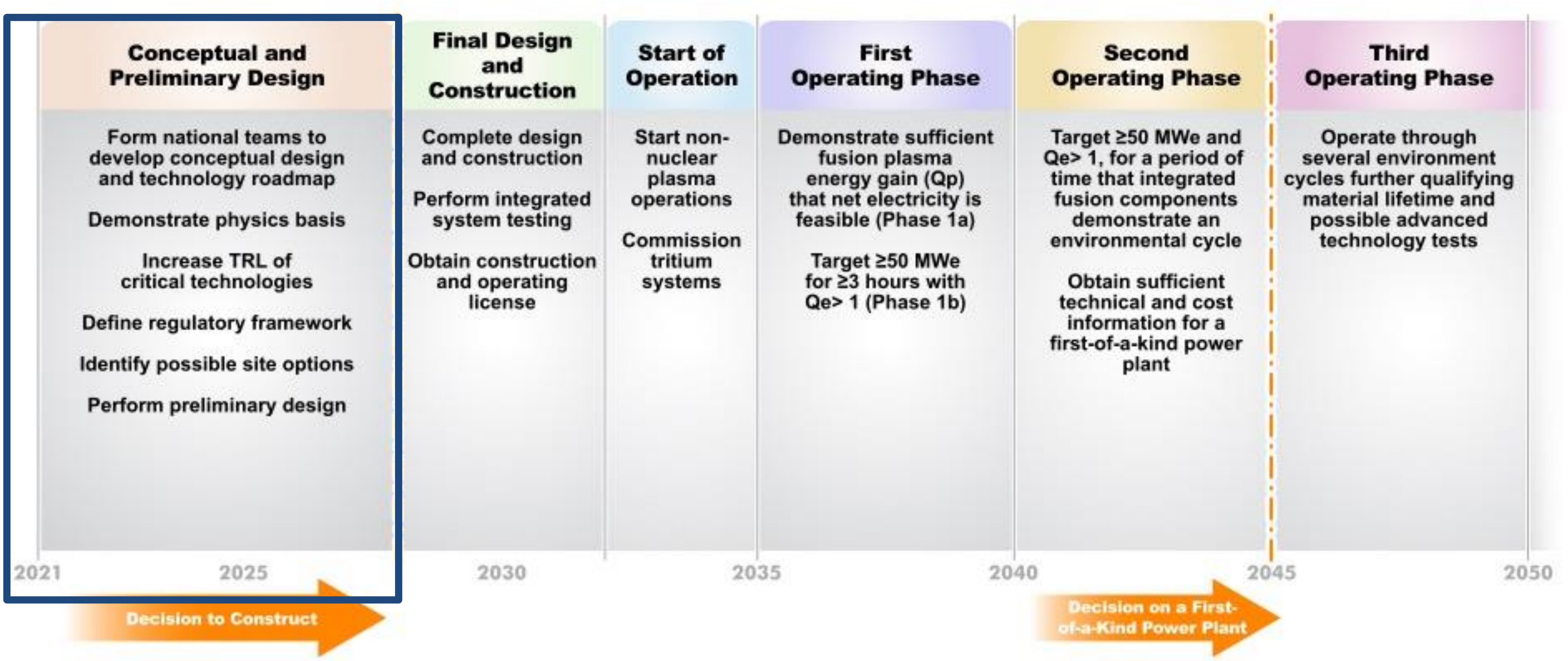
- Important examples include:
  - High temperature superconducting magnets
  - Structural and function materials: neutron degradation assessment
  - Plasma heating systems and actuators including target fabrication for IFE
  - Closing the fuel cycle: tritium processing, developing a breeding blanket

- Many elements are at a low level of technical readiness
  - But appropriate investment can result in rapid advancement



Commonwealth Fusion Systems and MIT announced achievement of 20T large bore HTSC coil

Strategy and Roadmap Identifies Immediate Actions



- *The Bold Decadal Vision seeks to accelerate the timeline.*

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Fusion to Power the Grid: The Path is Clear

- The goals, innovations and a timeline have been identified
- U.S. has played a major role in the development of fundamental science for fusion
  - U.S. can take the lead in this technology or
  - Let other countries take the lead

Committee Members

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For more information, please visit the study website at

http://nas.edu/fusion