Roadmap to Fusion Electricity

(based on deuterium-tritium magnetic fusion)

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This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

European Fusion Roadmap – 8 Missions

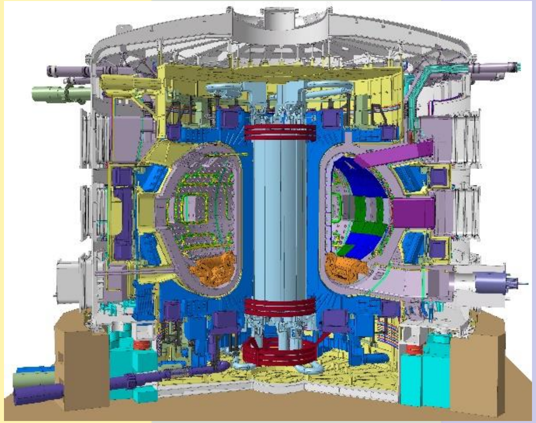
1. Plasma Regimes of Operation
2. Heat Exhaust Systems
3. Neutron Resistant Materials!
4. Tritium Self-Sufficiency!
5. Implementation of Intrinsic Safety Features!
6. Integrated DEMO Design
7. Competitive Cost of Electricity
8. Stellarator

European Fusion Roadmap

Short-term	Medium-term	Long-term

ITER

◆ **First plasma** ◆ **Full performance**

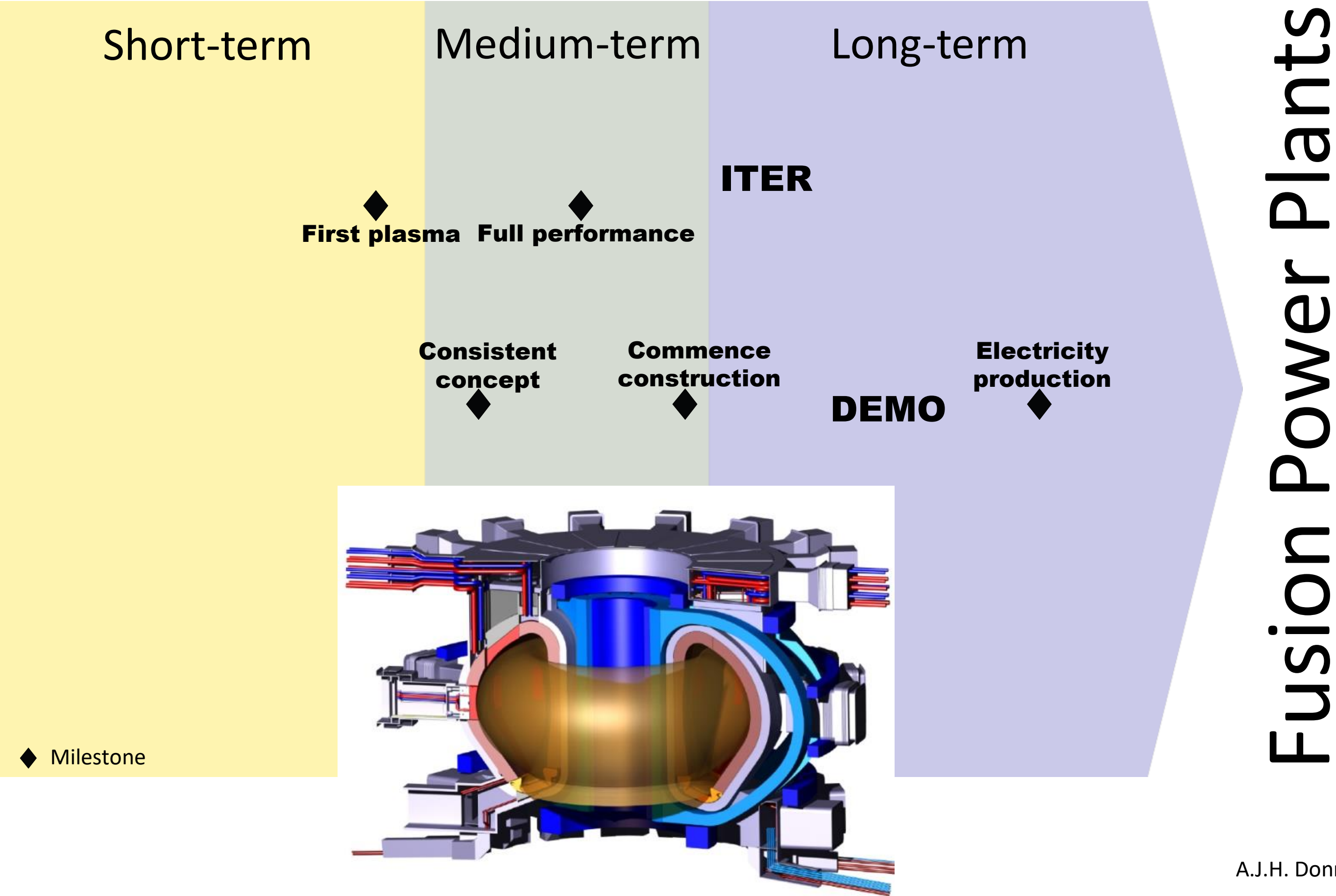


◆ Milestone

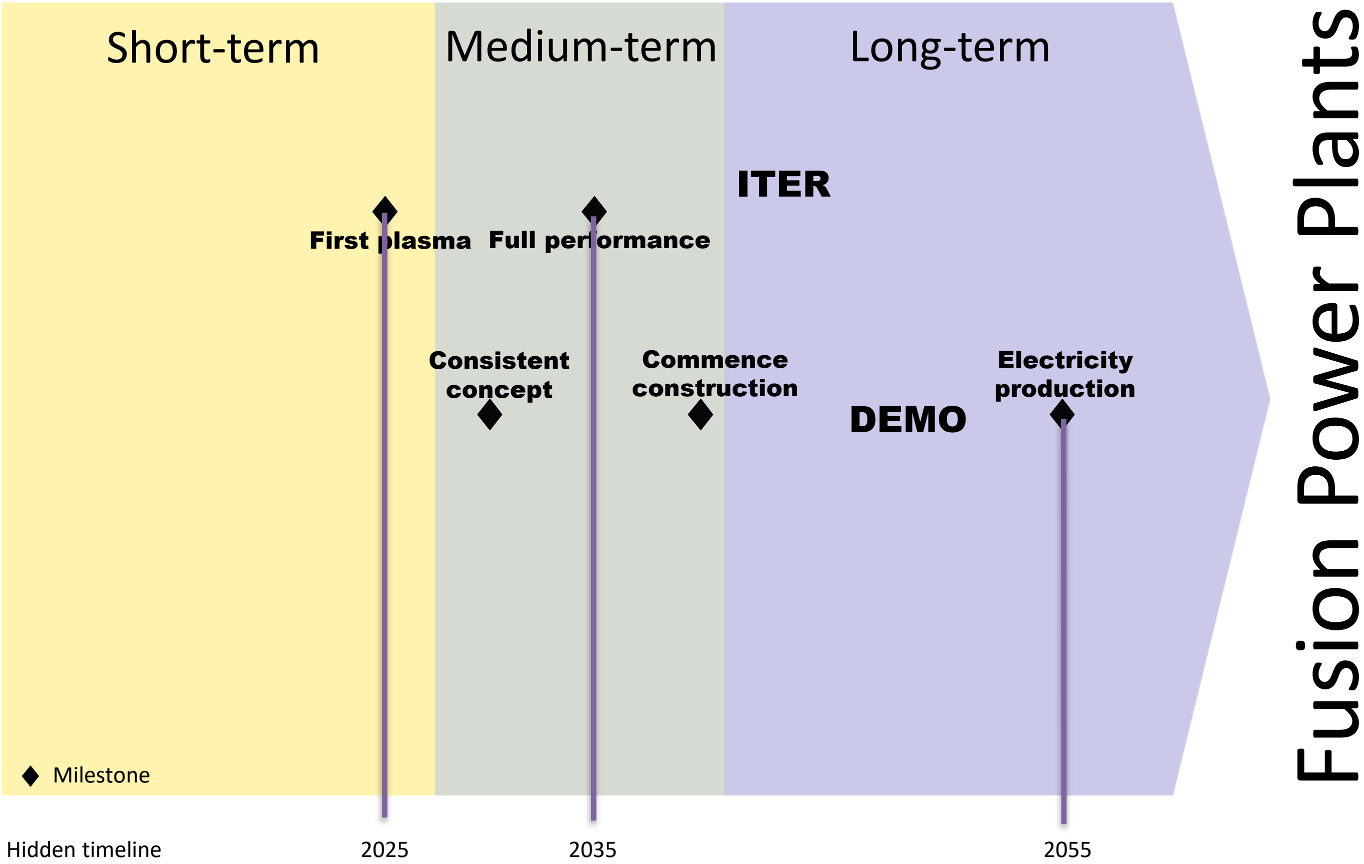
Fusion Power Plants

https://www.euro-fusion.org/eurofusion/roadmap/

European Fusion Roadmap



European Fusion Roadmap

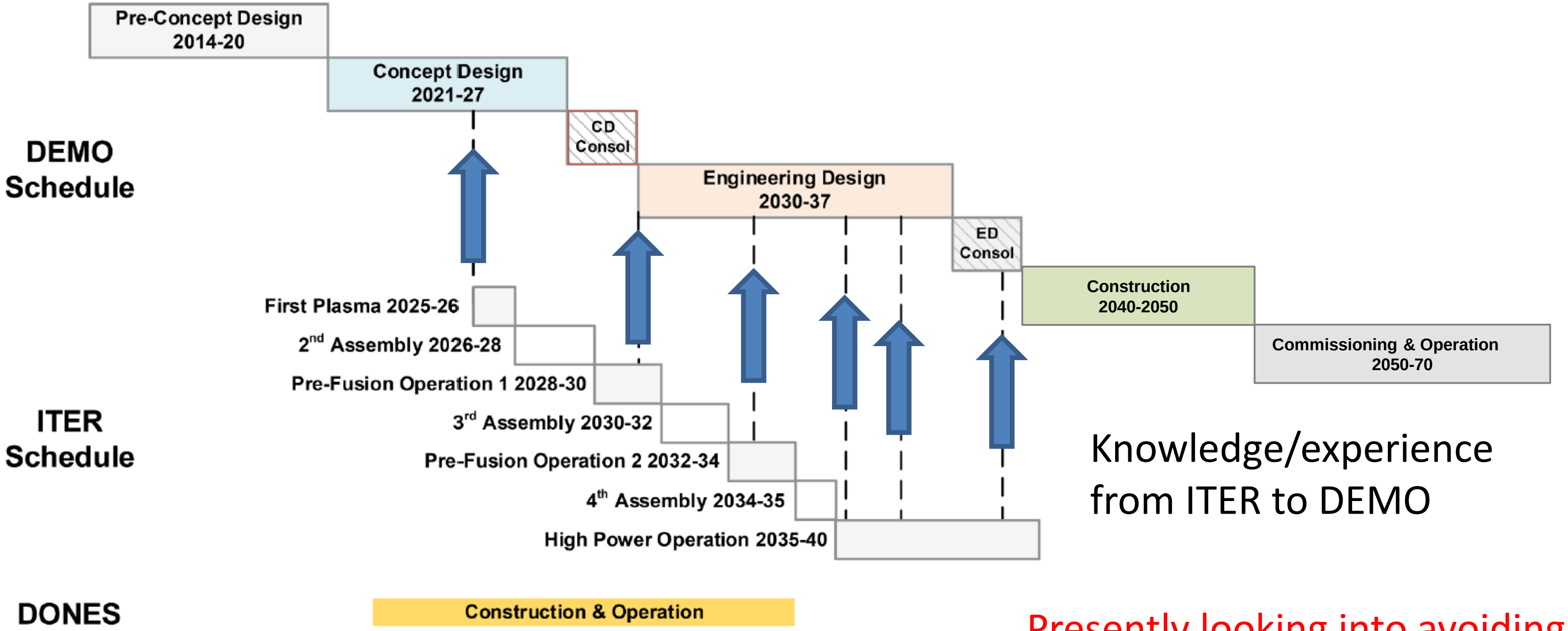


Hidden timeline
of 2018 Fusion Roadmap

Why does DEMO come so late?

- Long-lead challenges on the roadmap
  - Develop feasible tritium-breeding technologies (testing on ITER)
  - Develop neutron-tolerant materials (testing on IFMIF-DONES)
    - Is this enough to obtain license for building/operating DEMO?

DEMO design in parallel to ITER construction and operation



A: Validated assembly, integrated design, testing & commissioning, superconducting magnets, vacuum vessel fabrication validation
B: Integrated diagnostics validation, Electron Cyclotron Resonance Heating performance, disruption characterisation, divertor remote maintenance validation
C: H-mode transition threshold, validation of ELM control & disruption mitigation, Neutral Beam & Ion Cyclotron Resonance Heating performance, diagnostics validation, validation of BB fabrication
D: Burn scenarios, bootstrap fraction, first wall heat loads, tritium plant validation, full Heating &Current Drive validation
E: TBM Validation, operational scenario refinement, Q=10 (short pulse)
F: Q=10 (long pulse)

Knowledge/experience from ITER to DEMO

Presently looking into avoiding hard coupling between DEMO and ITER

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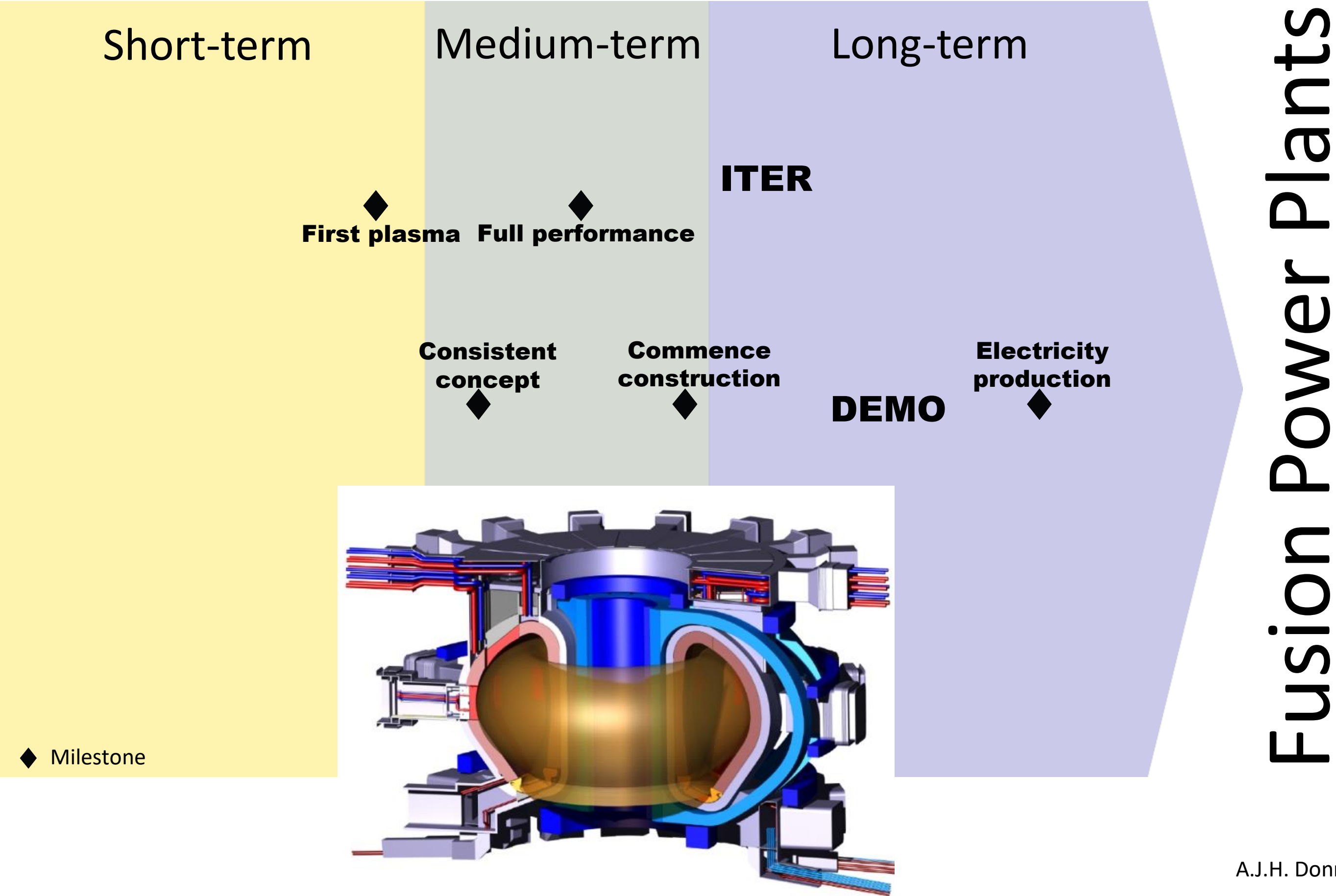
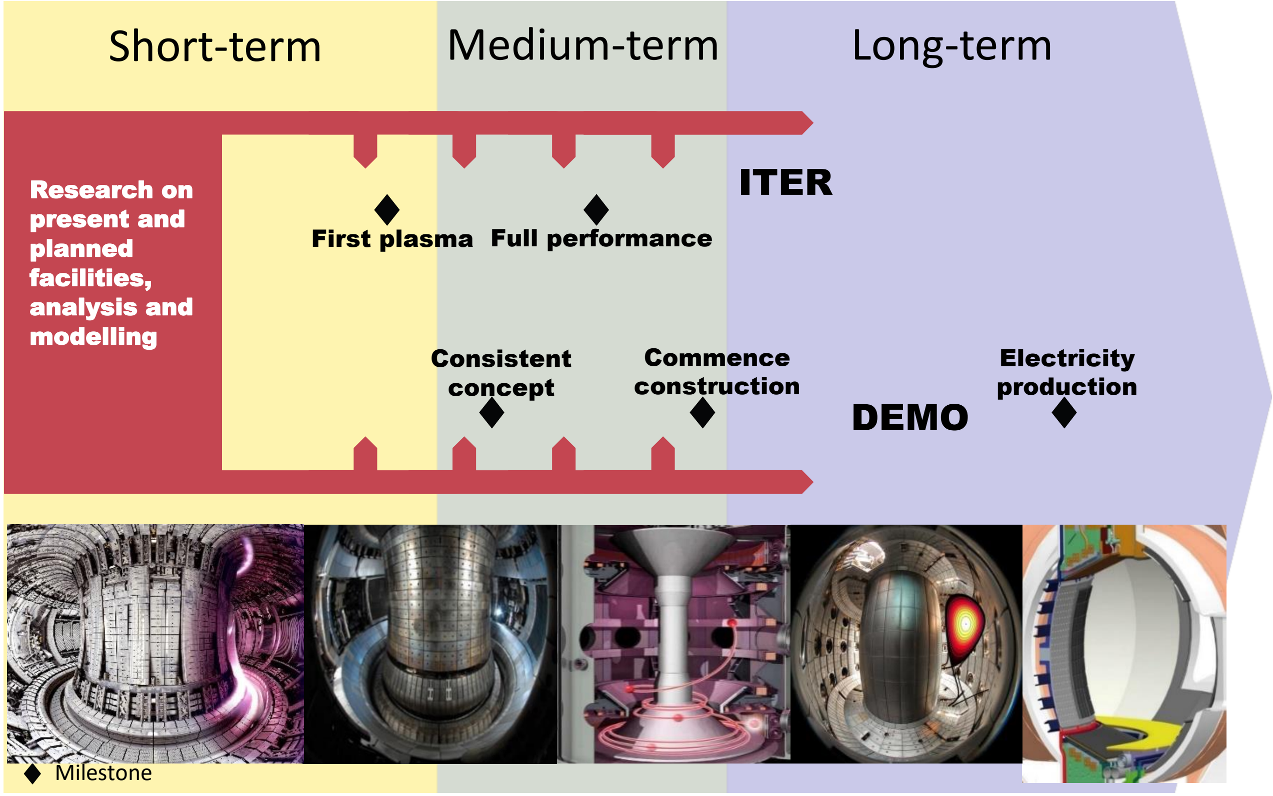
Are there additional risks?

- Tokamak is a pulsed device and is prone to disruptions and instabilities (can we mitigate this risk?)
- Stellarator is intrinsically continuous and doesn’t have disruptions
  - But stellarator is one generation behind tokamak
  - Given excellent results of W7-X we should continue exploring Stellarator Fusion Power Plant

European Fusion Roadmap

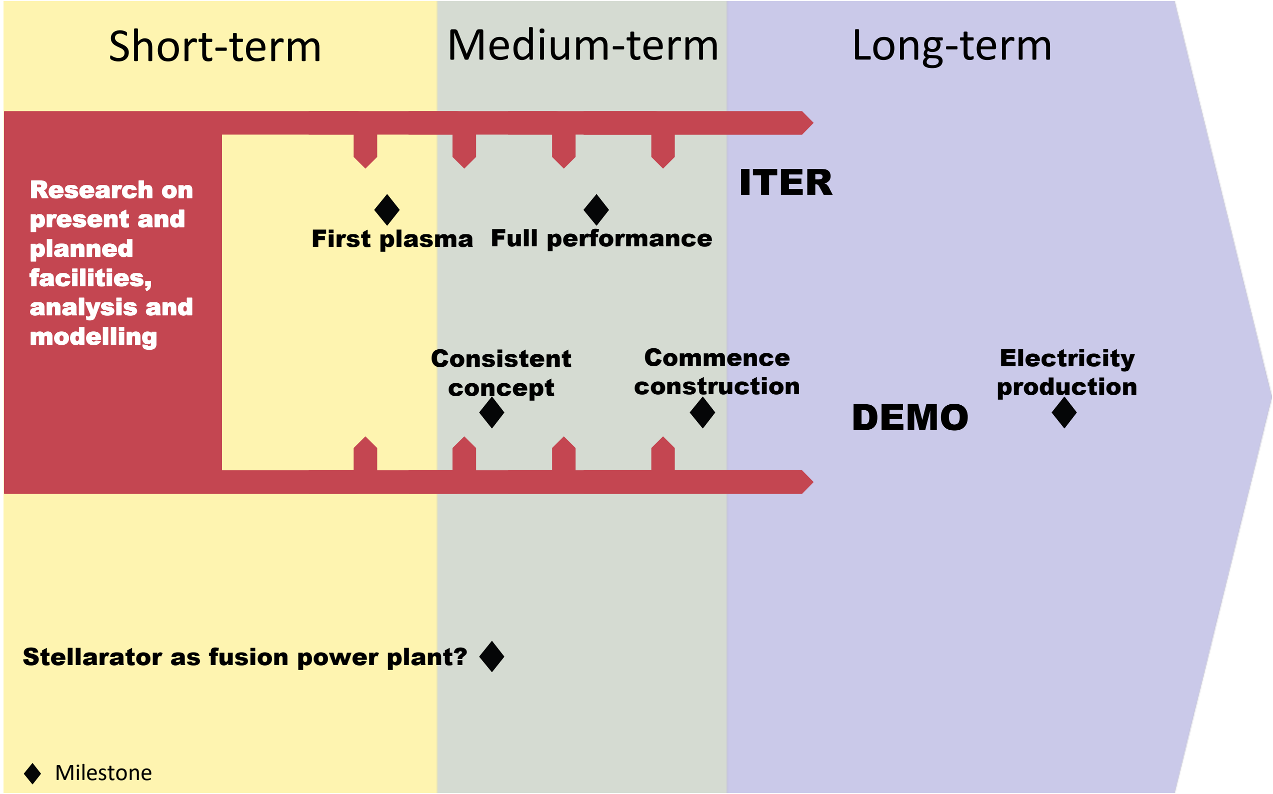


European Fusion Roadmap

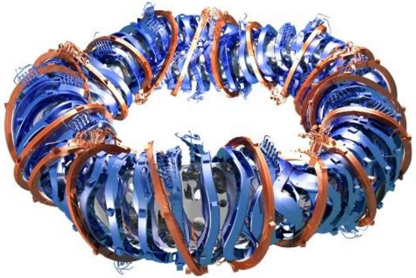


Fusion Power Plants

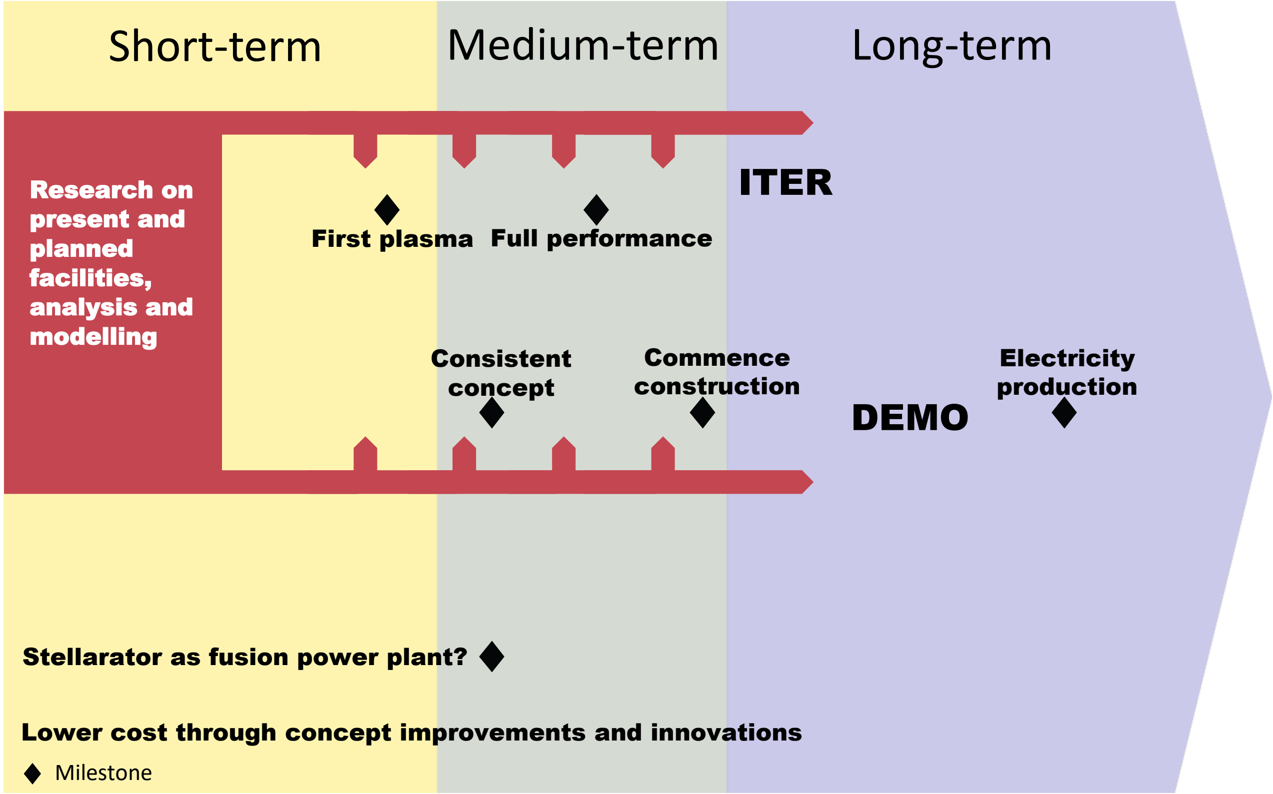
European Fusion Roadmap



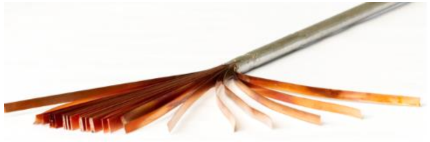
Fusion Power Plants



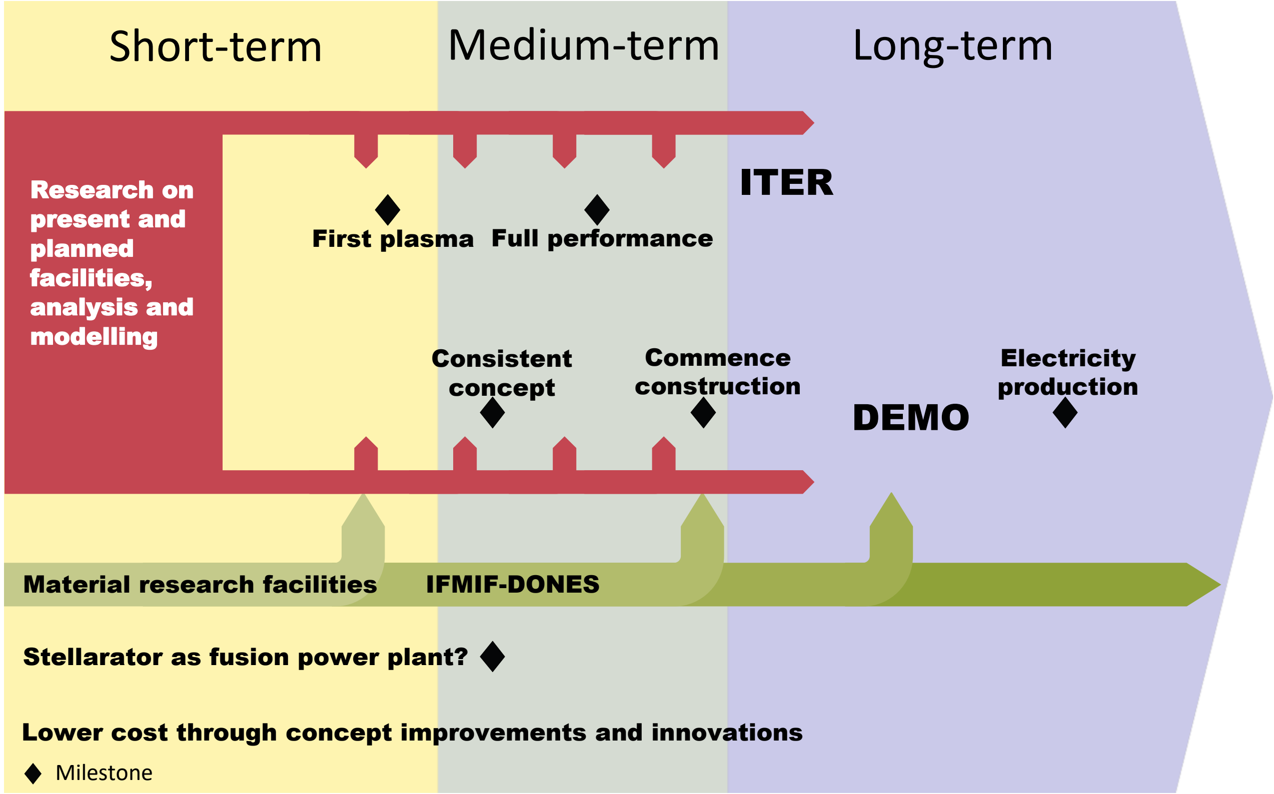
European Fusion Roadmap



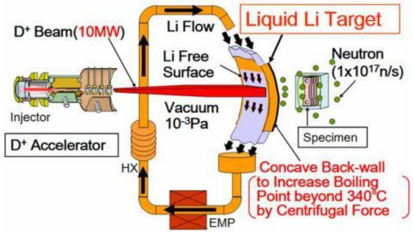
Fusion Power Plants



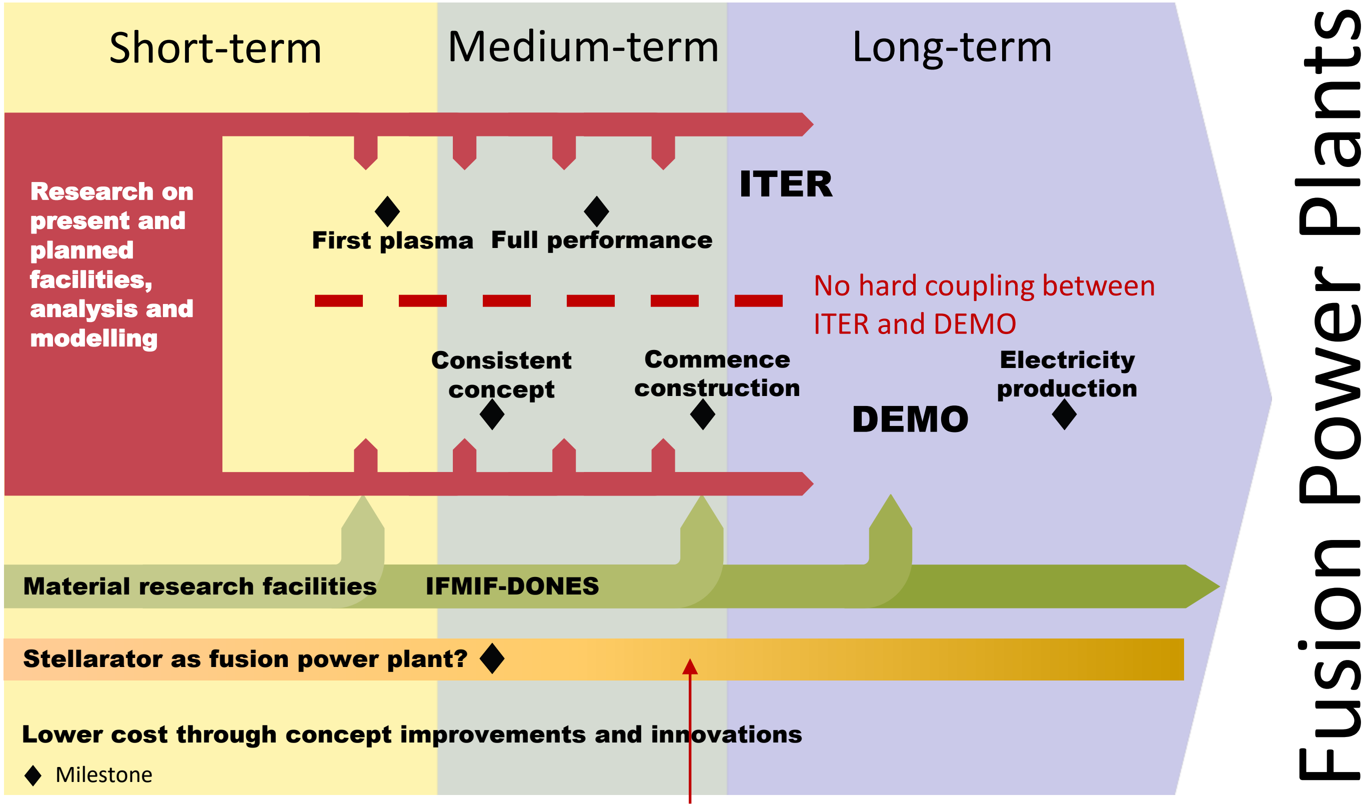
European Fusion Roadmap



Fusion Power Plants



European Fusion Roadmap – revisions under discussion



Continue with the Stellarator FPP as important back-up

Take home message

- European Fusion Roadmap is event-driven and is based on a thorough status and gap analysis of magnetic fusion research
- Elements defining the long time to fusion electricity are
  - Development, testing and validation of materials
  - Development and testing of tritium breeding technologies
- Can we move faster?
  - Decoupling DEMO from ITER
  - By joining venture capitalists' speed with holistic view of public research (incl. working on long-lead items)?
  - Start of DEMO in about 20-25 years from now is possible (provided we have budget)!
  - Risk mitigation by continued focus on Stellarator FPP