EUROfusion

Why do we need IFMIF-DONES?

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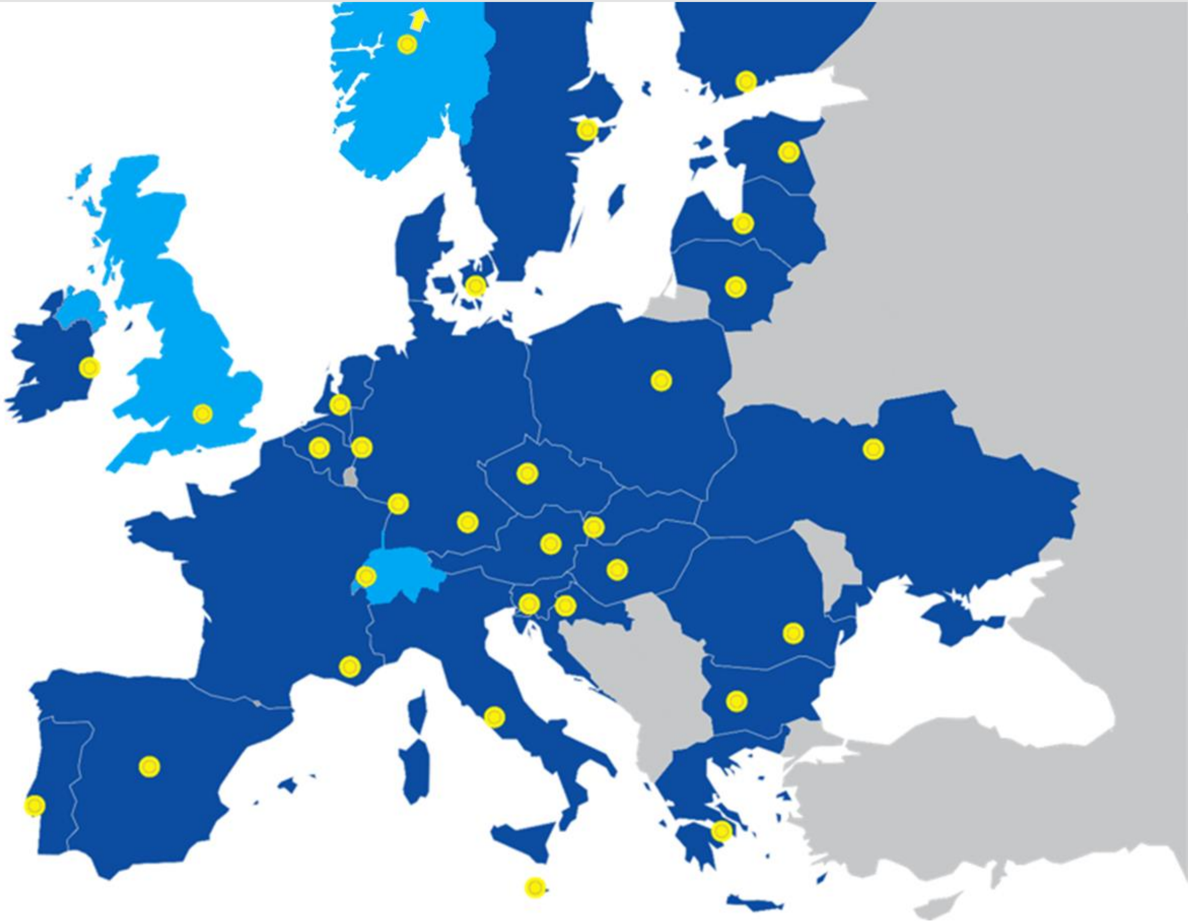
EUROfusion 2022

EUROfusion integrates R&D in fusion science and technology

29	Countries
31	Research Institutions
150	Universities
800	MSc and PhD students
4000	Fusion Researchers & Support Staff

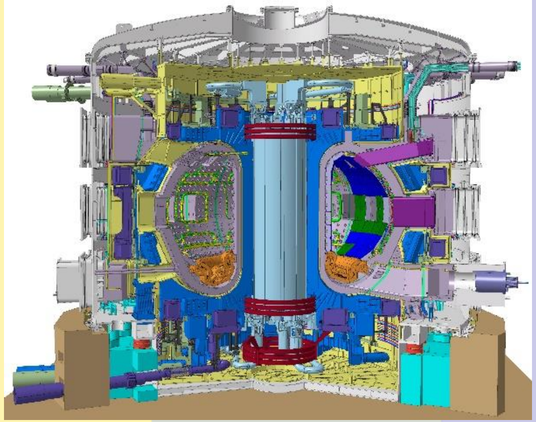


EUROfusion research is prioritised along the Fusion Roadmap

Short-term | Medium-term | Long-term

ITER

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



◆ Milestone

Fusion Power Plants

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

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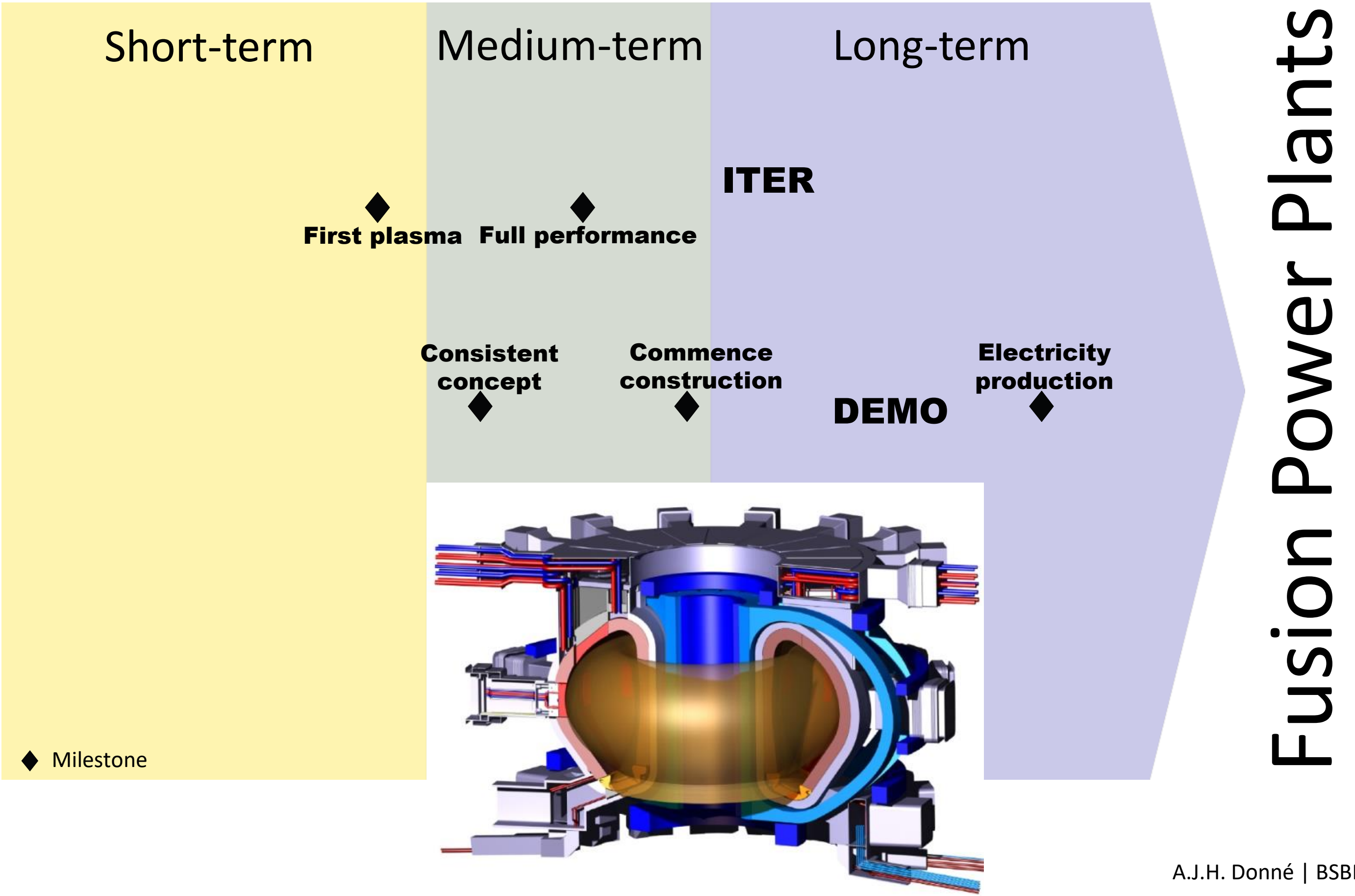
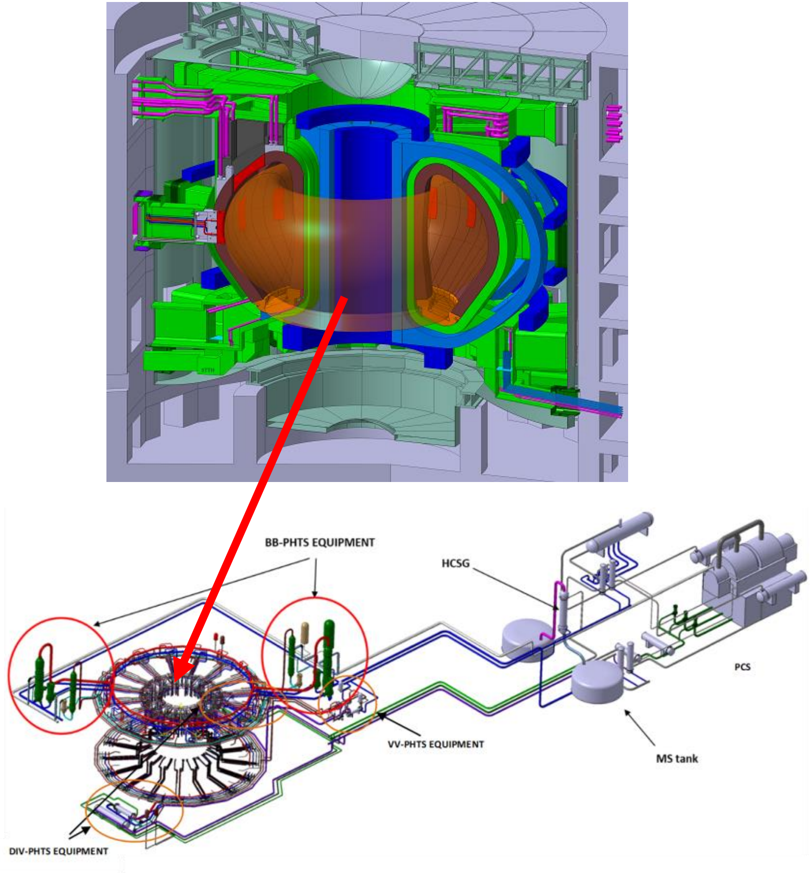


DEMO Preconceptual design finished

Preconceptual DEMO design activities from H2020 will soon be published in a special issue of Fusion Engineering and Design

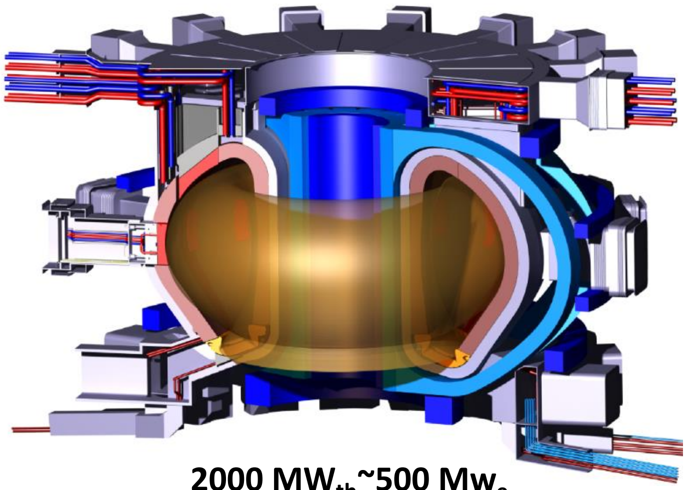
https://www.sciencedirect.com/journal/fusion-engineering-and-design/special-issue/10KZQ5JW058

An extensive Gate Review process was organised to agree on the starting point of the Conceptual Design Stage



G. Federici et al., Nucl. Fusion 59 (2019) 066013.

General design features current baseline (evolving!)



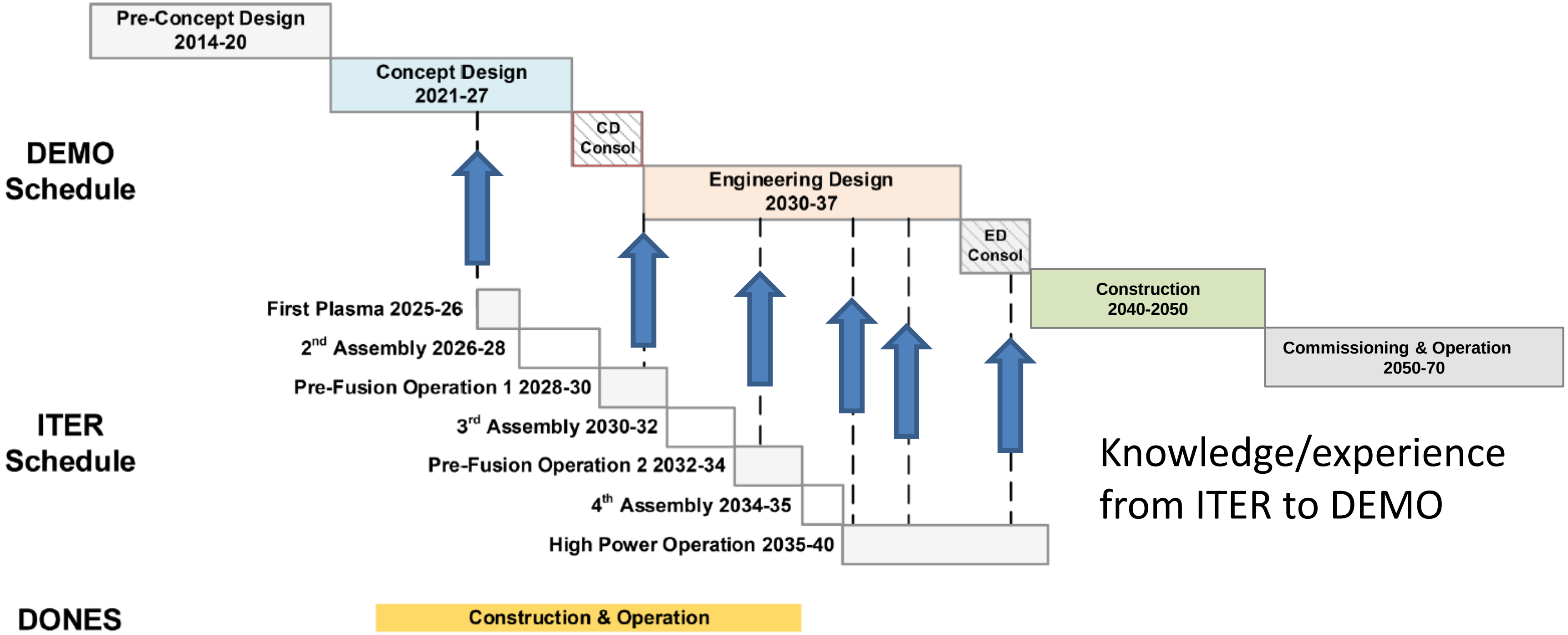
2000 MW_{th}~500 Mw_e

Open Choices:
- Plasma operating scenario
- Breeding blanket design concept
- Primary Blanket Coolant/ BoP
- Divertor configurations

R_0 = 9 m; a= 2.9m
B_0 = 5.9 T, I_0 = 18 MA; q_{95} = 3.6
κ_{95} = 1.66; δ_{95} = 0.33
H=1.1
P_{fus}=2000 MW, P_{aux}=<100 MW, P_{el}=500 MW
NWL = 1 MW/m^2
Still exploring the available design space !!

- Pulsed tokamak: pulses > 2 hrs
- Divertor coolant: water
- PFC armour: W
- LTSC magnets Nb_3Sn (grading)
- B_{max} conductor > 12 T (depends on A)
- RAFM (EUROFER) as blanket structure
- VV made of AISI 316
- Blanket vertical RH /
- Lifetime: starter blanket: 20 dpa (200 appm He); 2nd blanket 50 dpa; divertor: 5-10 dpa (Cu)

DEMO design in parallel to ITER construction and operation



Knowledge/experience from ITER to DEMO

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)

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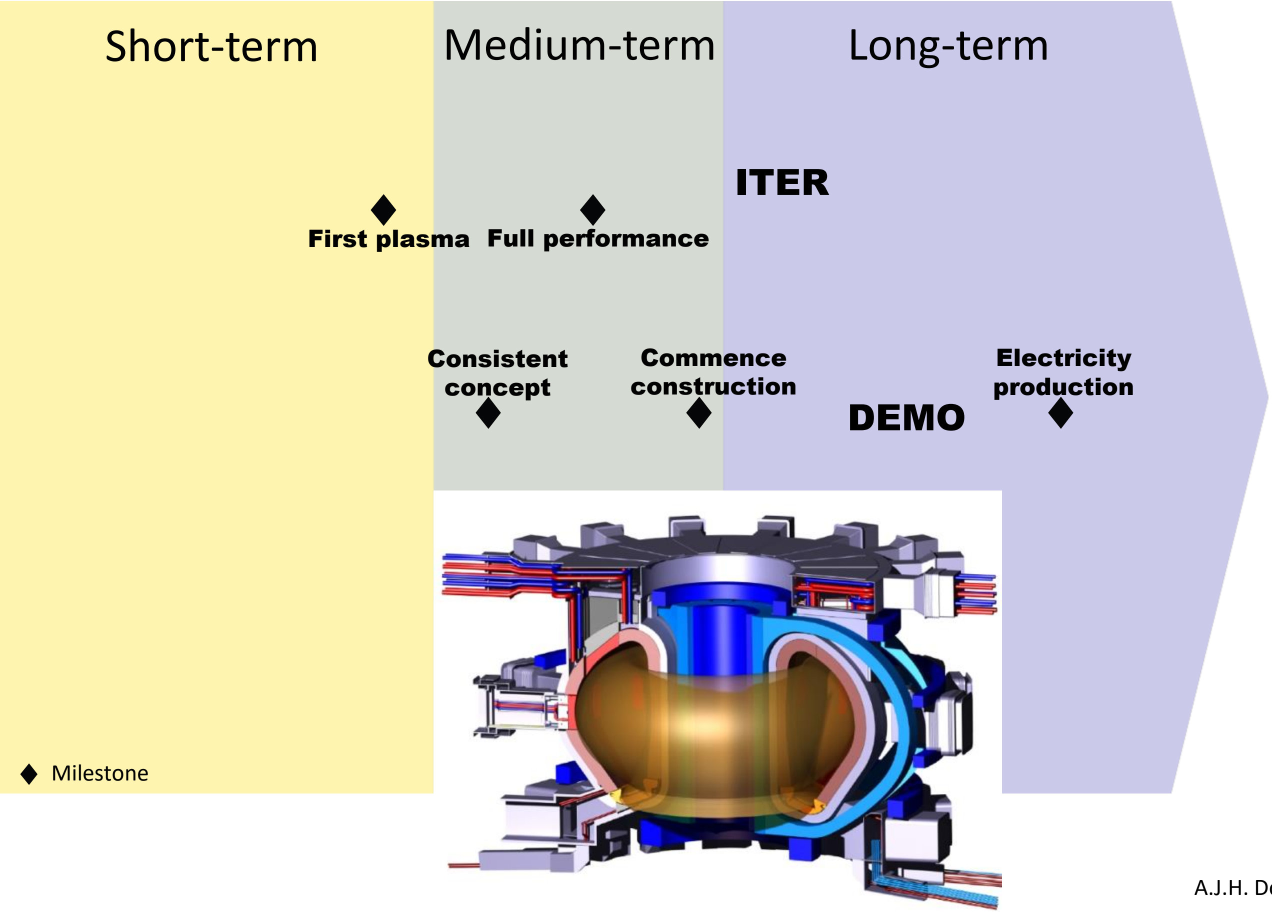

Fusion Power Plants

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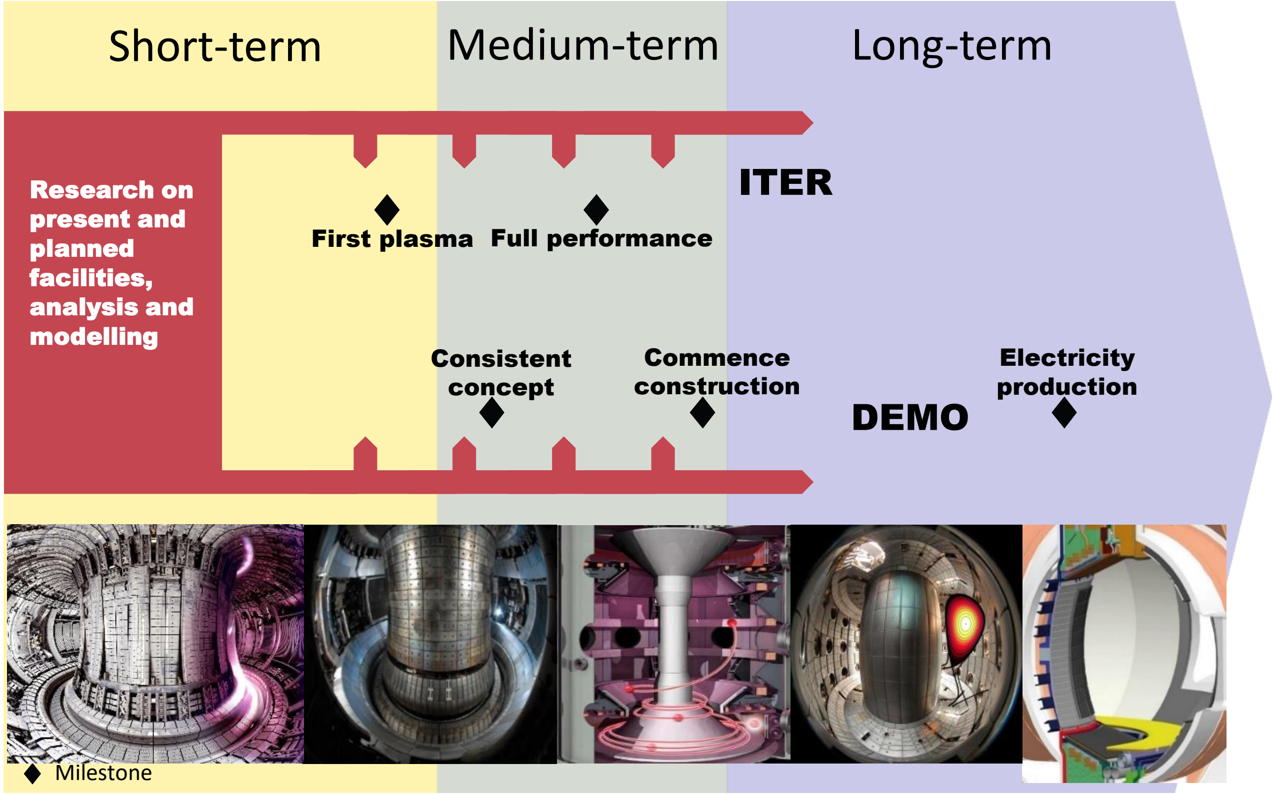

Fusion Power Plants

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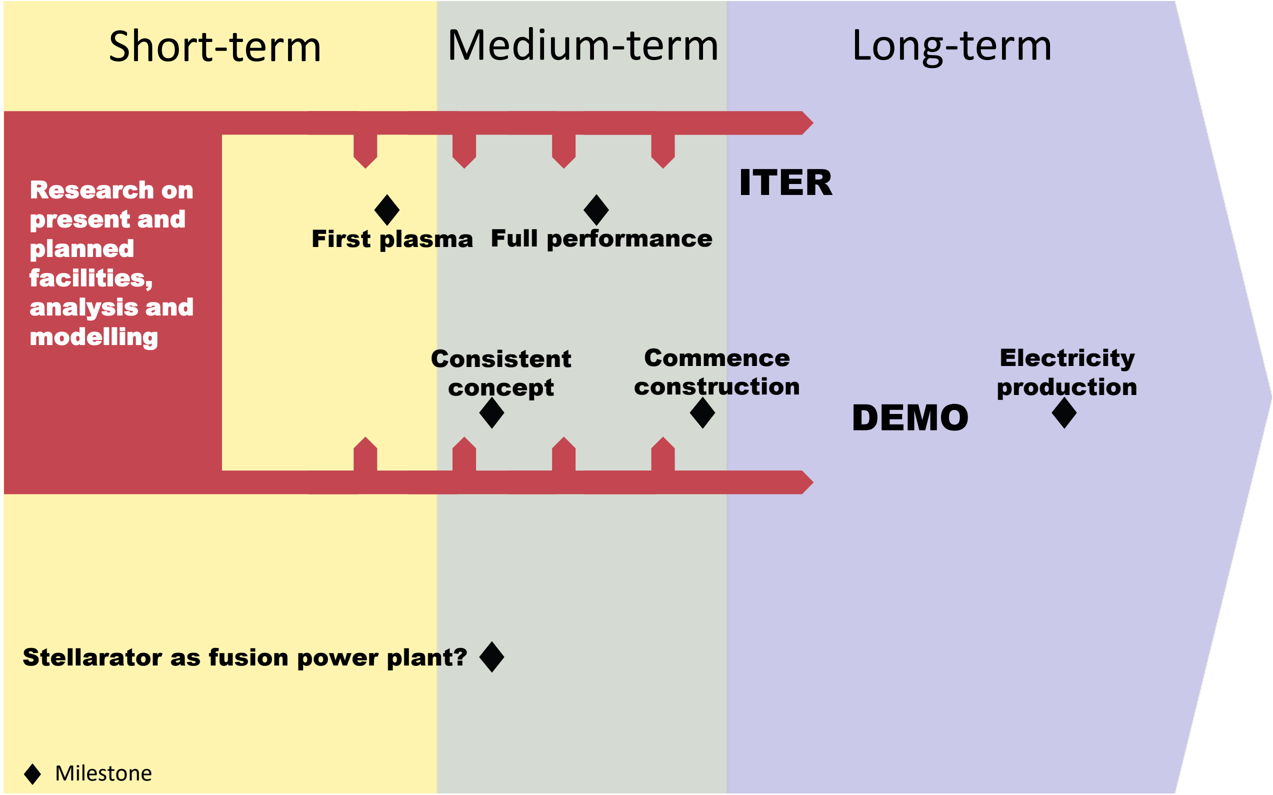
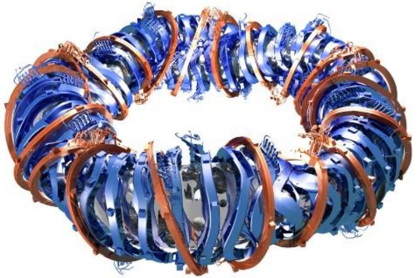


Fusion Power Plants



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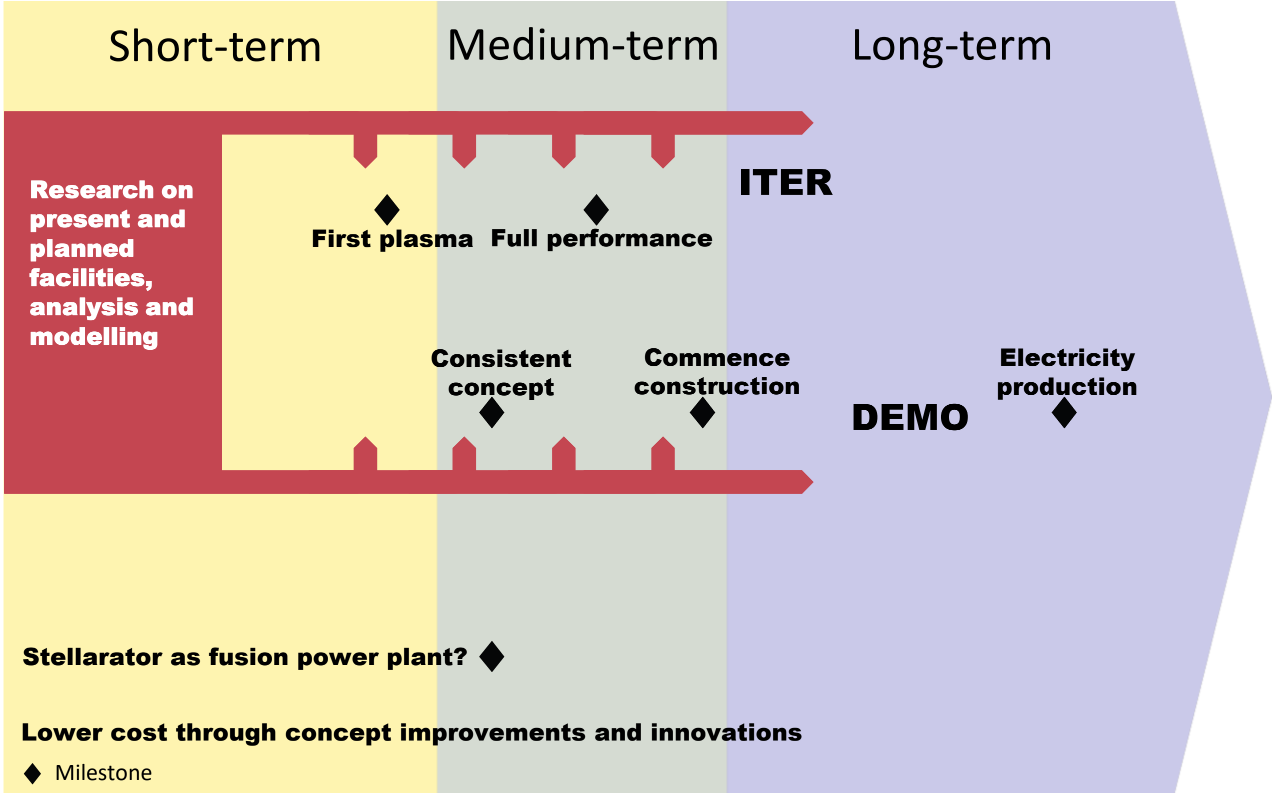

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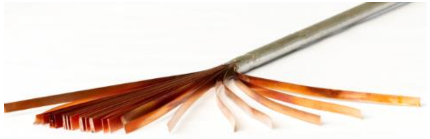


Outcome MAG* fully embedded in the Fusion Roadmap

Emphasising a DEMO concept with a construction decision in the early-2040s gives a sharp focus on materials development issues.

Materials testing with a fusion neutron spectrum is a high priority, but using the ITER precedent, identifying the DEMO vacuum vessel as the primary safety barrier, testable with fission spectra, reduces the burden on fusion spectrum testing.

The EU must accelerate and optimise the fusion spectrum test programme by:
-- early deployment of a less powerful 14 MeV neutron source compared to IFMIF (i.e. IFMIF-DONES);
-- vigorous precursor programmes with isotopically- & chemically-tailored steels and He- ion beams.

*** Material Assessment Group on EU R&D Programme on DEMO Structural and HHF Materials (2012)**

14 MeV neutron testing will validate engineering effects of transmutant products

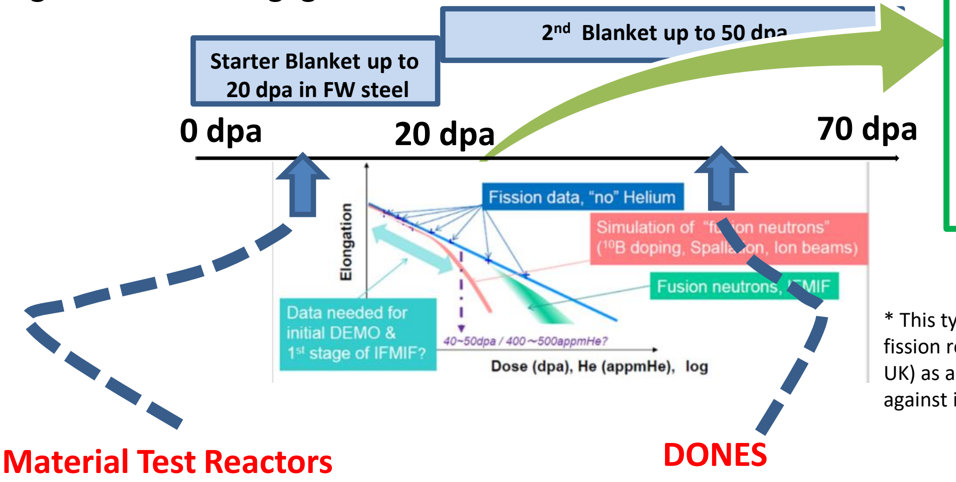
- The MAG confirms that data from irradiation under a "Fusion neutron spectrum" is essential as a precursor to a final engineering decision on DEMO materials
  ☞ not a regulatory requirement as the lightly irradiated Vacuum Vessel is the safety barrier & defence in depth provision – but required is:
  - Design Code input – enabling a robust design & sufficient lifetime (investment protection)
  - A risk reduction strategy
- The Codes and Standards exercise for Fusion Materials has been started in H2020 and is a gradual process that needs to be "completed" by input from 14 MeV neutron irradiation that
  - Must be timely: Codes & Standards milestone for Early DEMO should be in time for the construction decision
  - Can fall short of the full "qualification" of materials envisaged in the full IFMIF project
- Fusion materials development is ongoing, so full-IFMIF realization should be a long-term goal

MAG Recommendations:

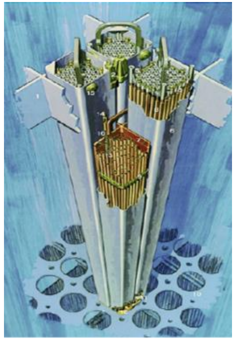
- To fulfil the 14 MeV materials irradiation requirements for a Fusion Power Plant, a dedicated accelerator-driven neutron source is essential … this long-term aim is fulfilled by IFMIF, thanks to the high dose rate and sufficient volume available.
- For Risk Mitigation, minimum 14 MeV neutron data should be provided to the Early DEMO programme. This requires a 14 MeV neutron source capable of irradiating a sufficient mission volume of critical materials of 50 dpa to establish critical properties.

Progressive Approach to Licencing/ Blanket CTF

Obtain licensing approval for operation for the “starter” blanket, while high-dose engineering data is being generated for the 2nd blanket*.



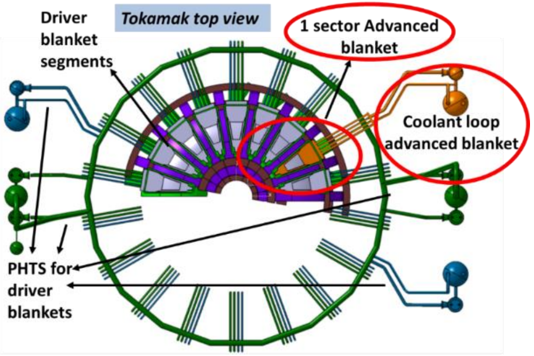
D. Stork, et al., (2014) Materials R&D for a timely DEMO: Key findings and recommendations of the EU Roadmap Mat. Ass. Group, Fus. Eng. Des. 89 (2014) 1586.



* This type of approach has been used for the fuel cladding in fission reactors for many years (e.g., for the MAGNOX in the UK) as a demonstration of the lifetime extension method against increasing technical knowledge of a plant design.

DEMO as a Component Test Facility for the breeding blanket

- a “driver” blanket → **use of available/mature technologies**
- test advanced concepts in ports/segments. → **use of more risky/performant technologies**
- Feasibility of this strategy and design/operation implications must be investigated during the CD phase.



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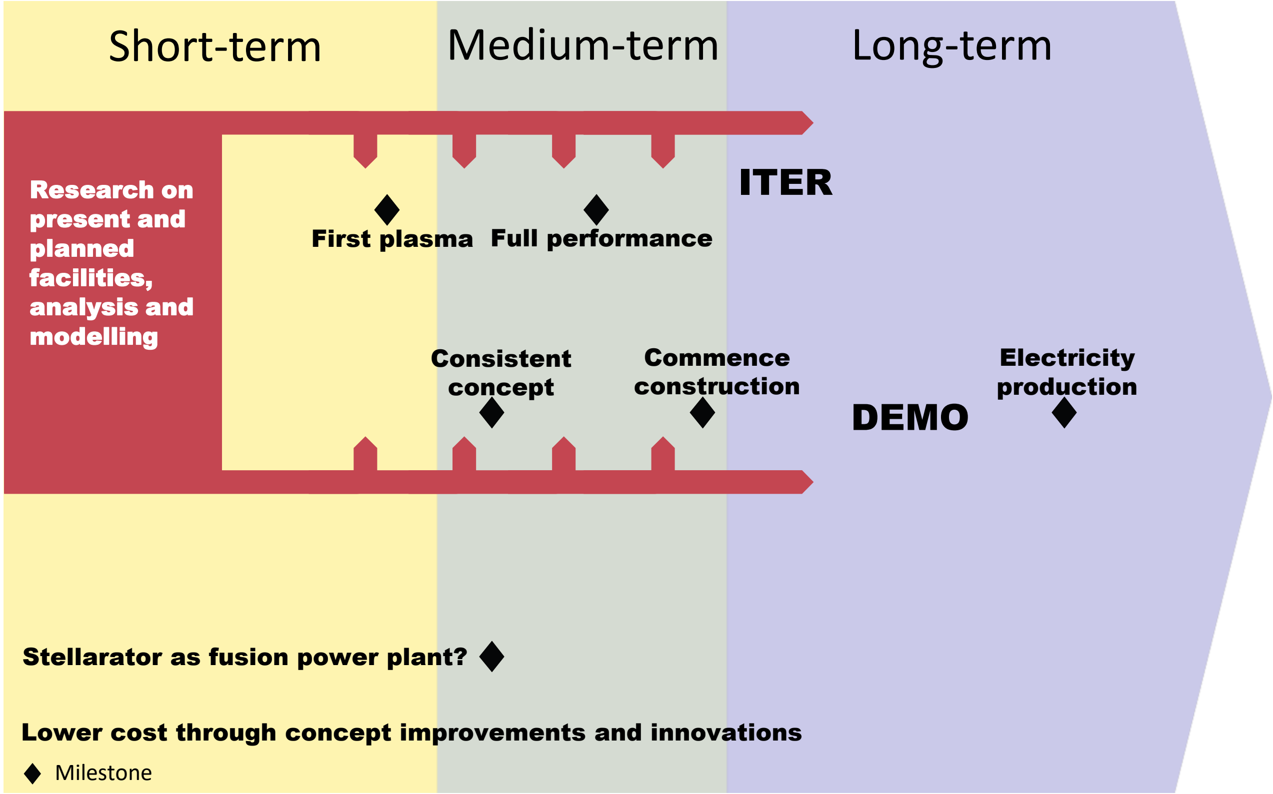

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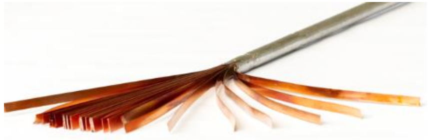

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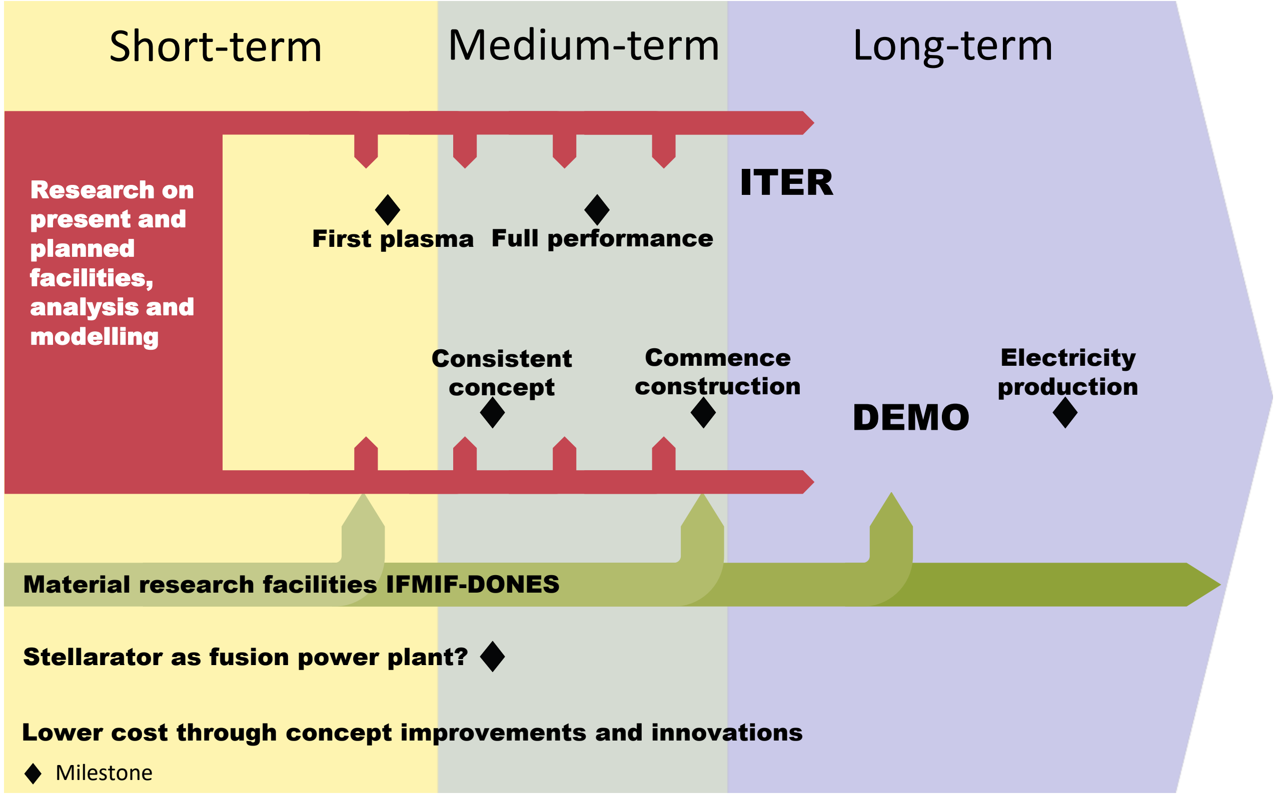

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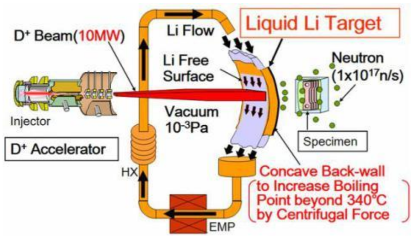

Take home message

- Much of the materials testing for the Early DEMO (reaching a 20 dpa level for the FW materials) can be done presently in fission reactors, later to be confirmed by a dedicated neutron source (IFMIF-DONES)

- For the full DEMO, FW materials will experience up to 50 dpa. Validation and testing of these materials needs to be done under a fusion-relevant neutron spectrum. This requires a dedicated neutron source (IFMIF-DONES and later IFMIF)