The Fork in the Road to Electric Power From Fusion

Spherical Tokamak for Energy Production (STEP)

Peter Lobner, 1 February 2021

STEP is a compact spherical tokamak fusion power reactor project led by the UK Atomic Energy Agency (UKAEA). The program's goals are to design a commercially viable fusion power plant and build a 100 MWe UK prototype by 2040. The program is being conducted in three phases (tranches):

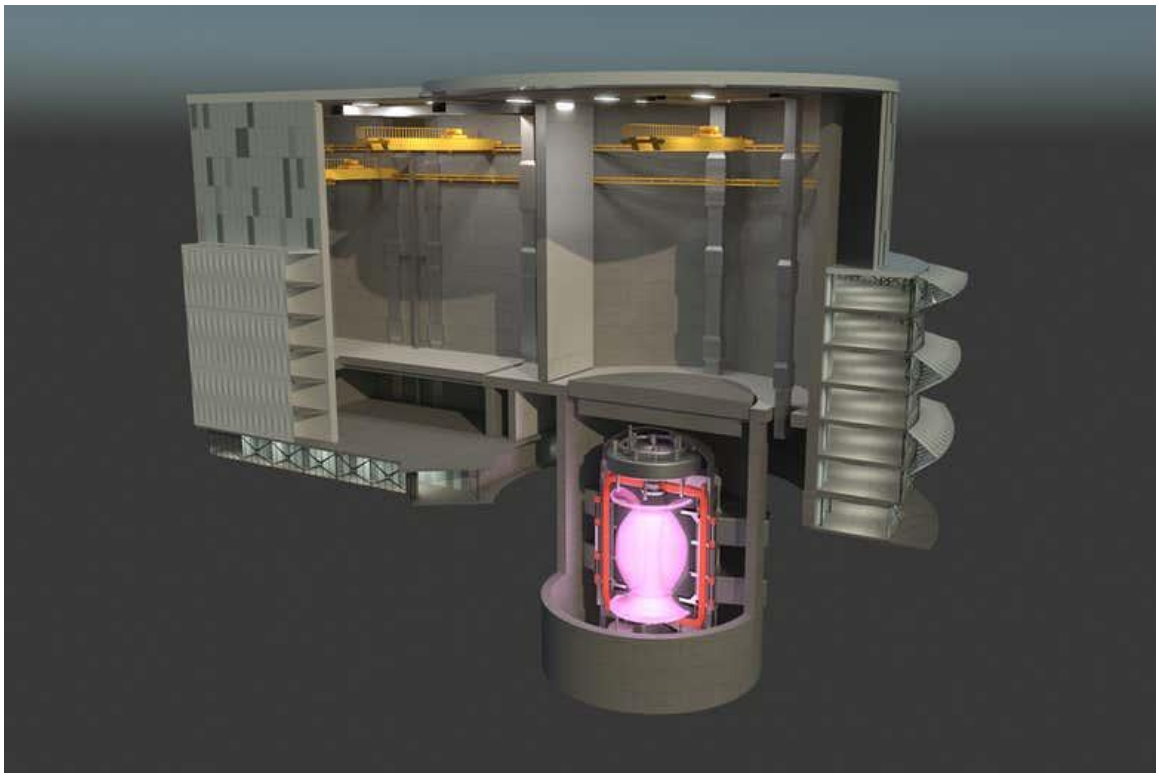
- Tranche 1, 2019 – 2024: Concept design, site selection & definition of the future commercial model
- Tranche 2, 2024 – 2032: Engineering design & infrastructure planning
- Tranche 3, 2032 – 2040: Construction

The goal is for grid-connected power operation to start after 2040.

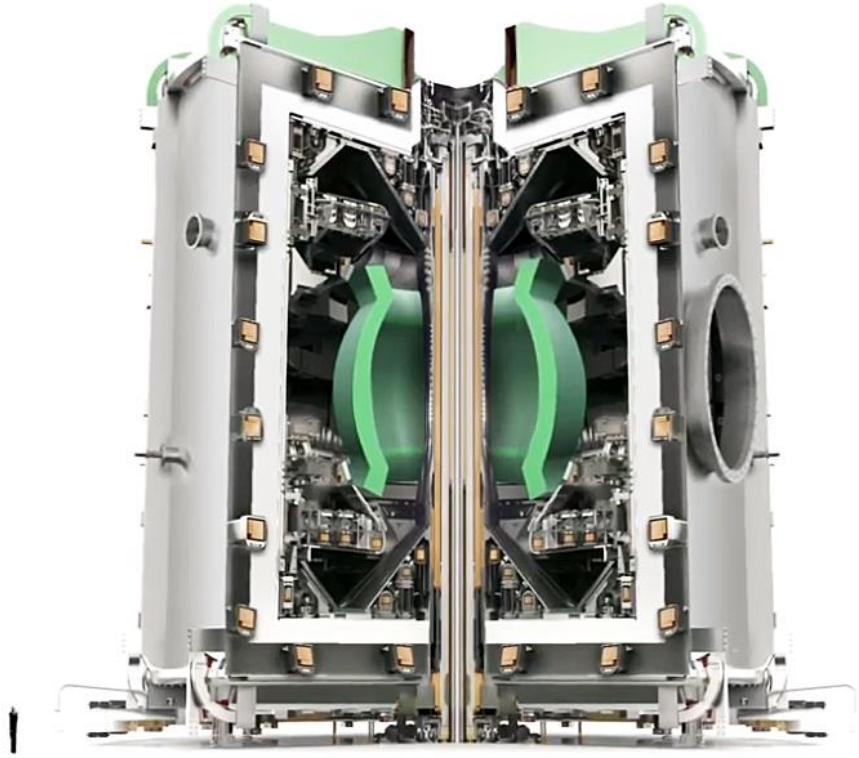
The UKAEA's STEP website is here: https://step.ukaea.uk

You'll find a short (3:00) overview of the STEP program in the 2020 UKAEA video, "A guide to STEP; UKAEA's compact fusion reactor programme," at the following link:
https://www.youtube.com/watch?v=KHBUuKfCOyU

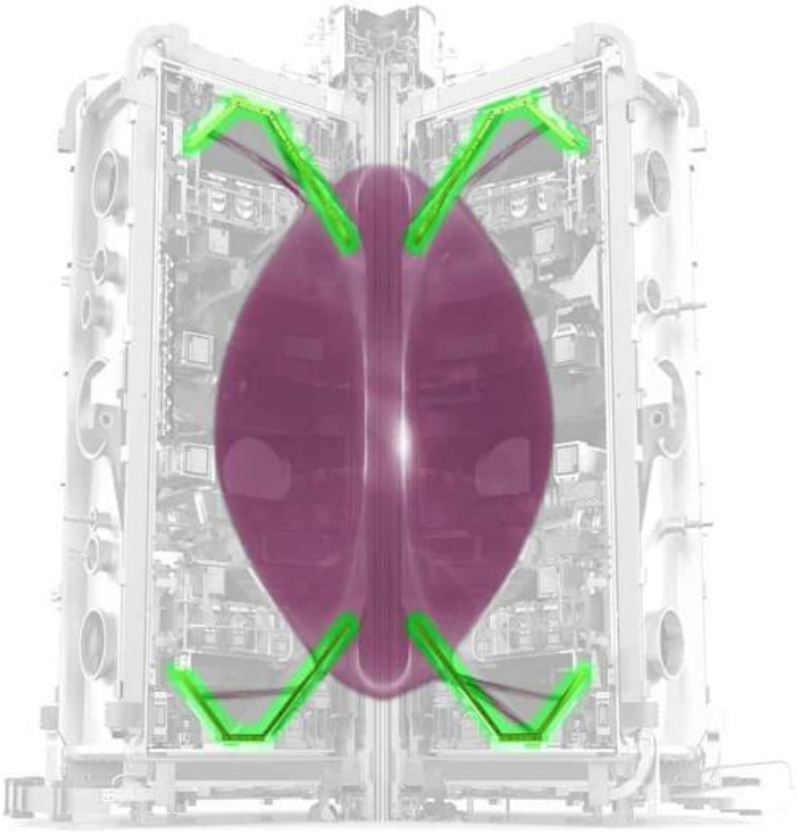
The STEP reactor design is based on the Mast Upgrade (Mega Amp Spherical Tokamak) at the Culham Center for Fusion Energy near Oxford, UK. The Mast Upgrade machine achieved first plasma in October 2020 and will operationally test the "Super-X" magnetic divertor, which is a key new technology that will be implemented in STEP. The Super-X divertors at the top and bottom of the tokamak vessel are designed to safely channel extremely hot edge plasma out of the tokamak vacuum vessel. The approximate tenfold reduction in heat flux arriving at the internal surfaces of the tokamak enables the wall components to last much longer.



Conceptual arrangement of the UK's STEP fusion power station.
Source: UKAEA



Conceptual arrangement of the UK's STEP fusion reactor.
Source: UKAEA



Location of the Super-X divertors (green). Source: UKAEA

To be competitive with a modern, large nuclear fission reactor plant, such as the UK's Hinkley Point C being built now, UKAEA estimates that a commercially viable 100 MWe STEP fusion reactor plant will need to have capital costs on the order of £400 million (about $547 million USD, $5.47/W), an 80% reduction from the cost of the STEP prototype. This is very close to the overnight capital cost target for small fusion power plants recommended in the US by Department of Energy's (DOE Advanced Research Project Agency – Energy (ARPA-E): Overnight capital cost of < US $2 billion and < $5/W.

Funding

In October 2019, the UK Government announced an initial £220 million (about $310 million USD) of funding to produce the concept design by 2024. Total cost of the first-of-a-kind STEP fusion power

plant prototype is expected to be around £2 billion (about $2.74 billion US

For more information

- I.T. Chapman, “UKAEA capabilities to address the challenges on the path to delivering fusion power,” The Royal Society, 4 February 2019: https://royalsocietypublishing.org/doi/10.1098/rsta.2017.0436
- “UK to take a big ‘STEP’ to fusion electricity,” UK Government press release, 3 October 2019: https://www.gov.uk/government/news/uk-to-take-a-big-step-to-fusion-electricity