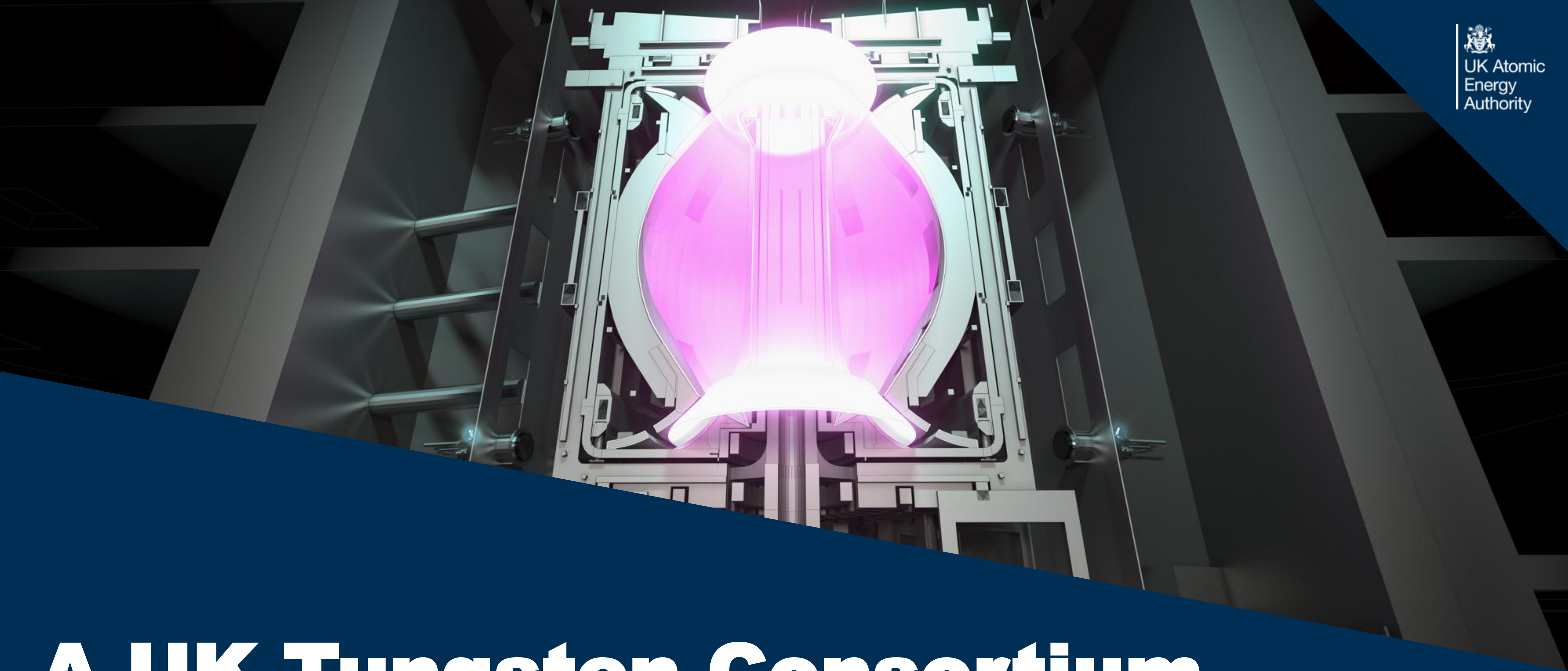


UK Atomic Energy Authority

A UK Tungsten Consortium

Dr Benjamin Evans
Senior Materials Engineer

Agenda for the day

UK Atomic Energy Authority

Time	Title	Presenter
10.00 – 10.05	Welcome & Introduction	Amanda Quadling, Executive Director of Materials, Blankets and Research, UKAEA
10.05 – 10.30	Introduction to the day, UKAEA & Fusion and proposal of UK tungsten consortium	Benjamin Evans, Senior Materials Engineer UKAEA
10.30 – 10.45	Supply and demand at fusion power plant fleet scale, and Oxford Sigma areas of interest	Alasdair Morrison, CTO Oxford Sigma
10.45 – 11.00	Li corrosion of W coatings for future fusion breeder blanket applications	Hazel Gardner, Senior Materials Scientist UKAEA
11.00 – 11.15	Break & Networking	
11.15 – 11.30	Existing W alloy manufacture and an outlook on development for industrial fusion	Tom Galvin, Innovation and Technical Support Manager, M&I Materials
11.30 – 11.45	Irradiation-driven Structure and Property Evolution in Tungsten Materials	Prof Felix Hofmann, Department of Engineering, University of Oxford
11.45 – 12.00	In-situ maintenance and repair for fusion	Yao Ren & Ben Quirk, RACE, UKAEA
12.00 – 12.45	Lunch & Networking	
12.45 – 14.15	Breakout Rooms	
14.15 – 14.30	Break & Networking	
14.30 – 15.30	Feedback from Breakout Sessions	
15.30 – 16.00	Tours of UKAEA facilities for pre-registered attendees	

What does UKAEA do?

UK Atomic Energy Authority

- We lead the delivery of sustainable fusion power and maximise scientific and economic benefits
- We deliver high-impact research, partnering with companies and the international research community
- We own UK Industrial Fusion Solutions on behalf of UK government

RESEARCH
building the knowledge base of fusion

- Generate and curate knowledge from our technical centres of excellence
- Solve challenges across the full lifecycle of fusion
- Integration of technologies for fusion
- Operate world-leading facilities
- Analyse what is needed for the widespread use of fusion

DELIVER
fusion powerplants

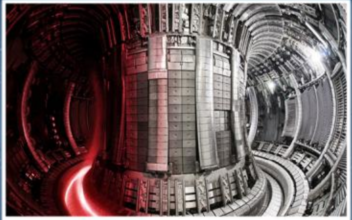
- Use our skills, facilities and expertise to help partners deliver fusion powerplants
- Work with major industrial partners in a national programme to deliver the STEP prototype fusion powerplant

ENABLE
the fusion community

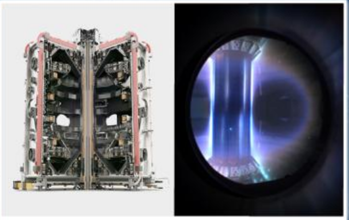
- Grow a fusion cluster
- Support a fusion industry
- Develop skilled people #fusiongeneration
- Support the regulation of fusion
- Seek out growth opportunities for fusion technology
- Communicate the opportunities

UK Programme has unique breadth

UK Atomic Energy Authority

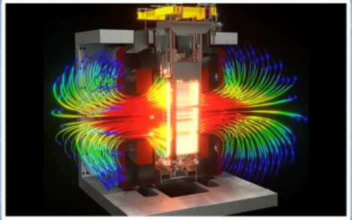


HIGH PERFORMANCE FUSION



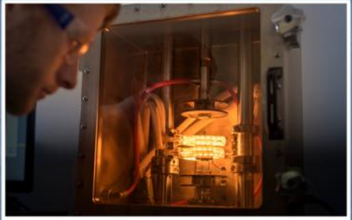
SPHERICAL TOKAMAKS

MATERIALS RESEARCH



FUSION TECHNOLOGY

ROBOTICS



TRITIUM

ADVANCED DIGITAL COMPUTING

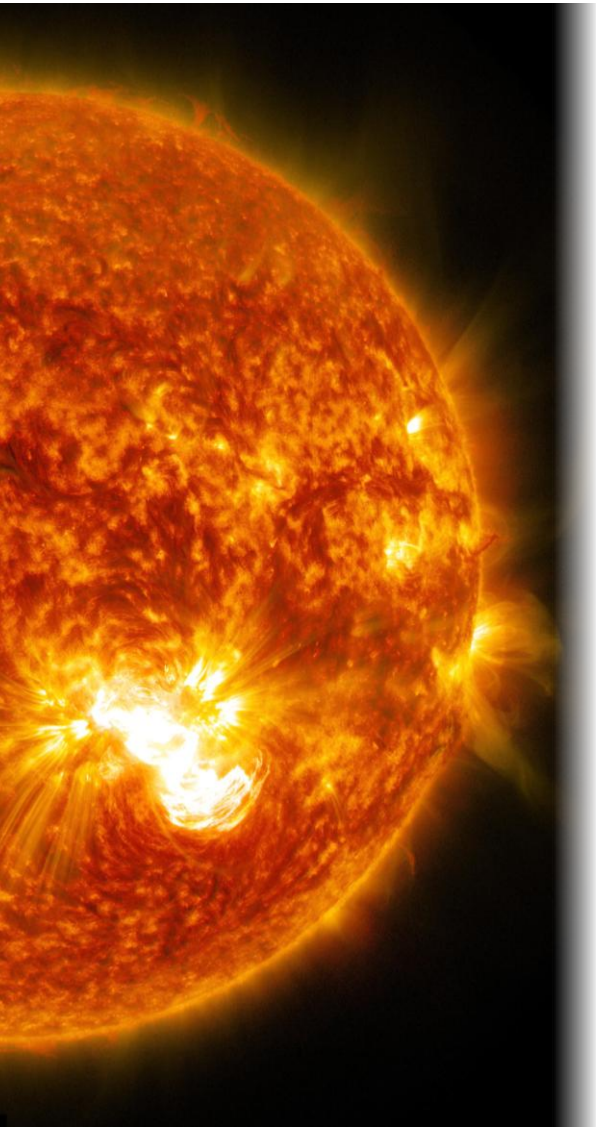
POWERPLANT DESIGN

INDUSTRY DEVELOPMENT

SKILLS DEVELOPMENT

TECHNOLOGY TRANSFER

What is fusion energy?

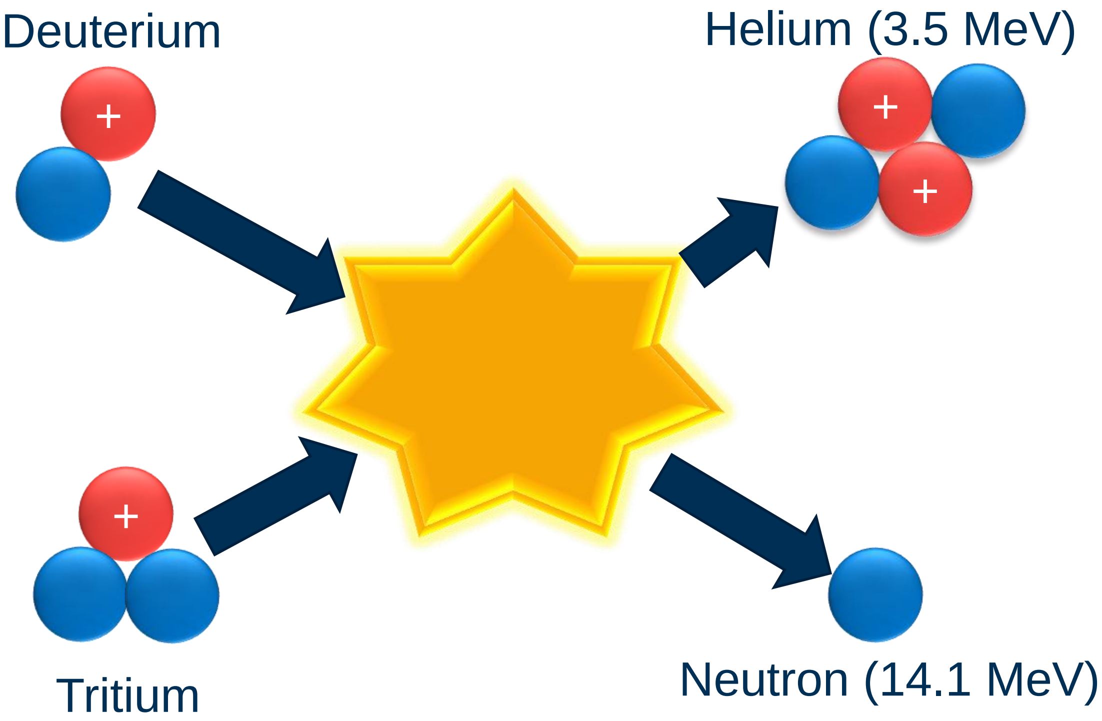


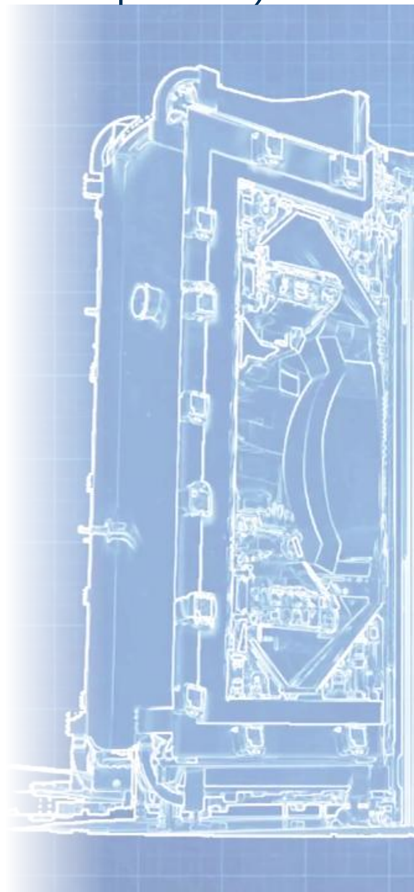
In the sun:

- Core temperature of 15,000,000°C.
- Fuse hydrogen isotopes to form He. Stellar fusion continues all the way up to iron!
- Uses gravity to enable fusion.

In a fusion power plant:

- Plasma at 150,000,000°C.
- Fuse hydrogen isotopes; deuterium and tritium.
- Generate 17.6MeV energy per fusion reaction.
- Uses a combination of high temperature and pressure (confinement) to enable fusion (other methods possible).





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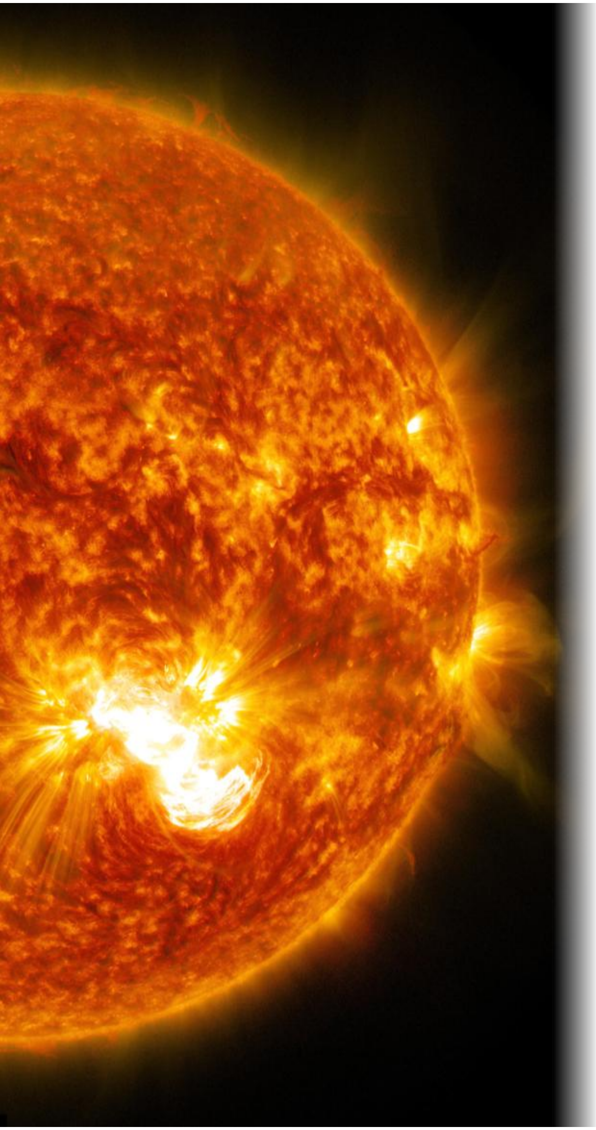

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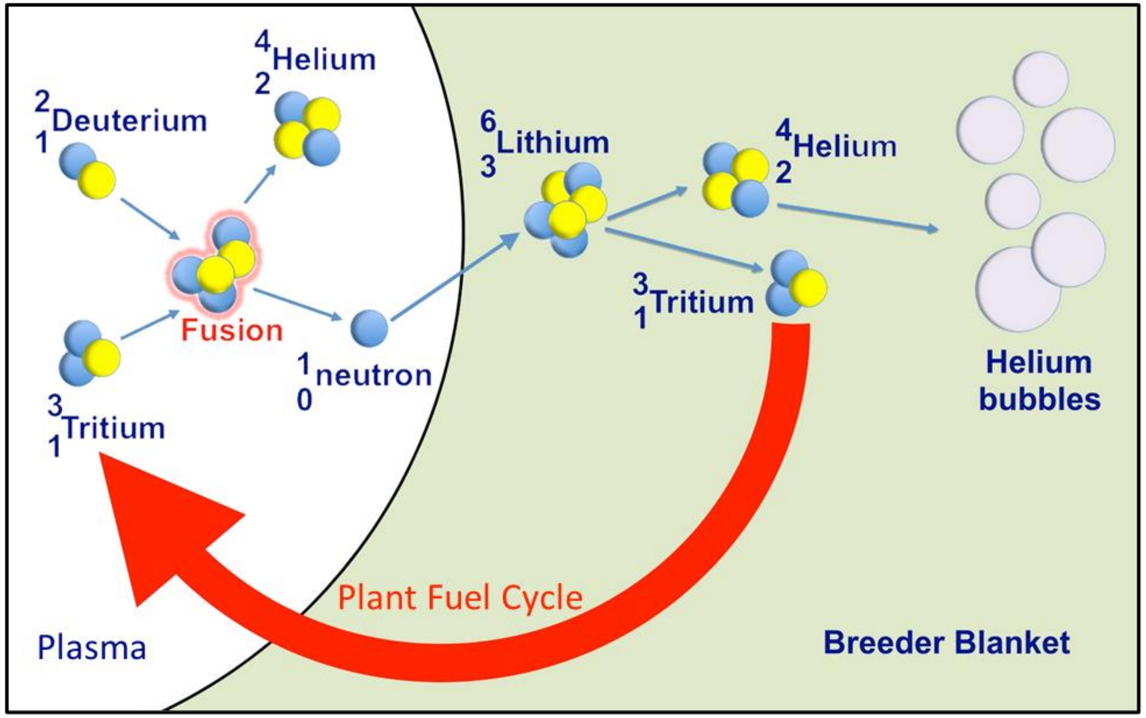
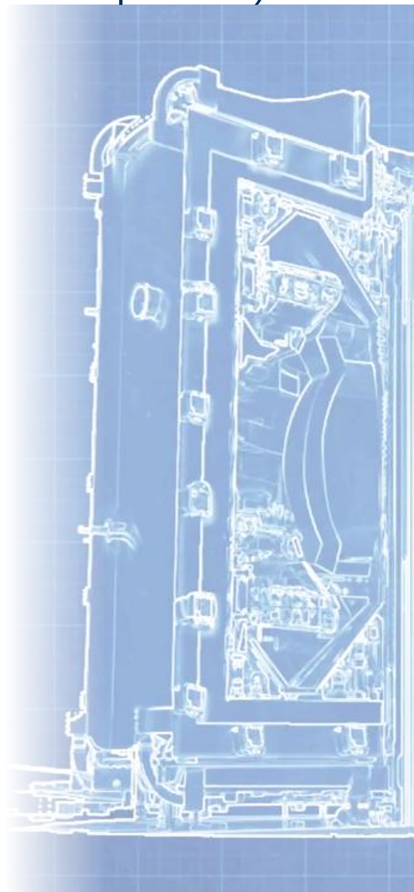


Coal-fired plant (1GW) = 2.7 MT coal p/a

Fusion plant = 250 kg DT p/a



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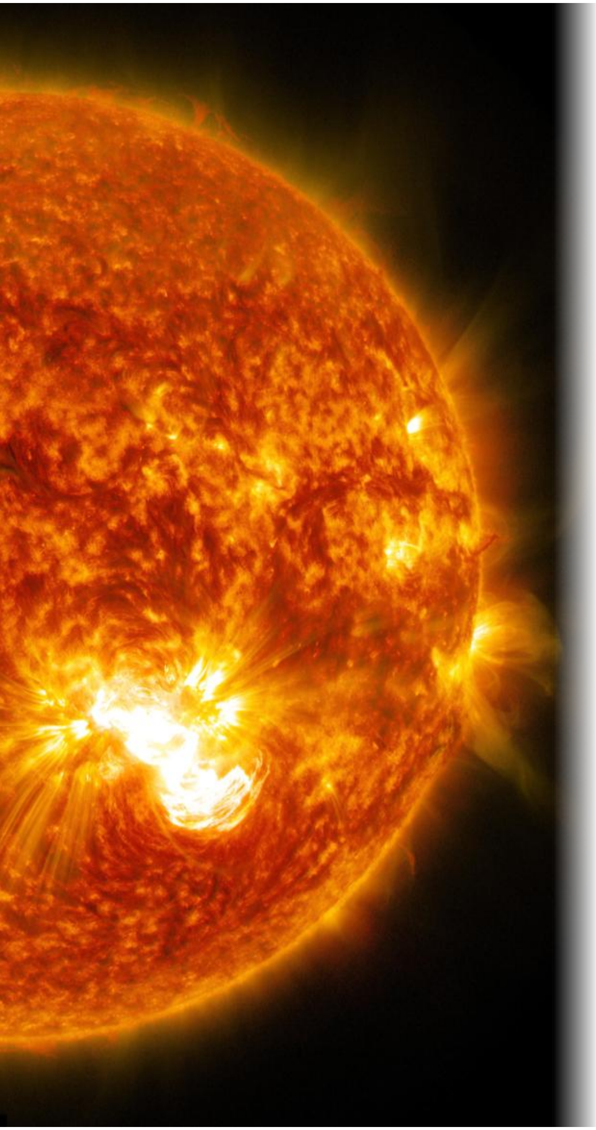

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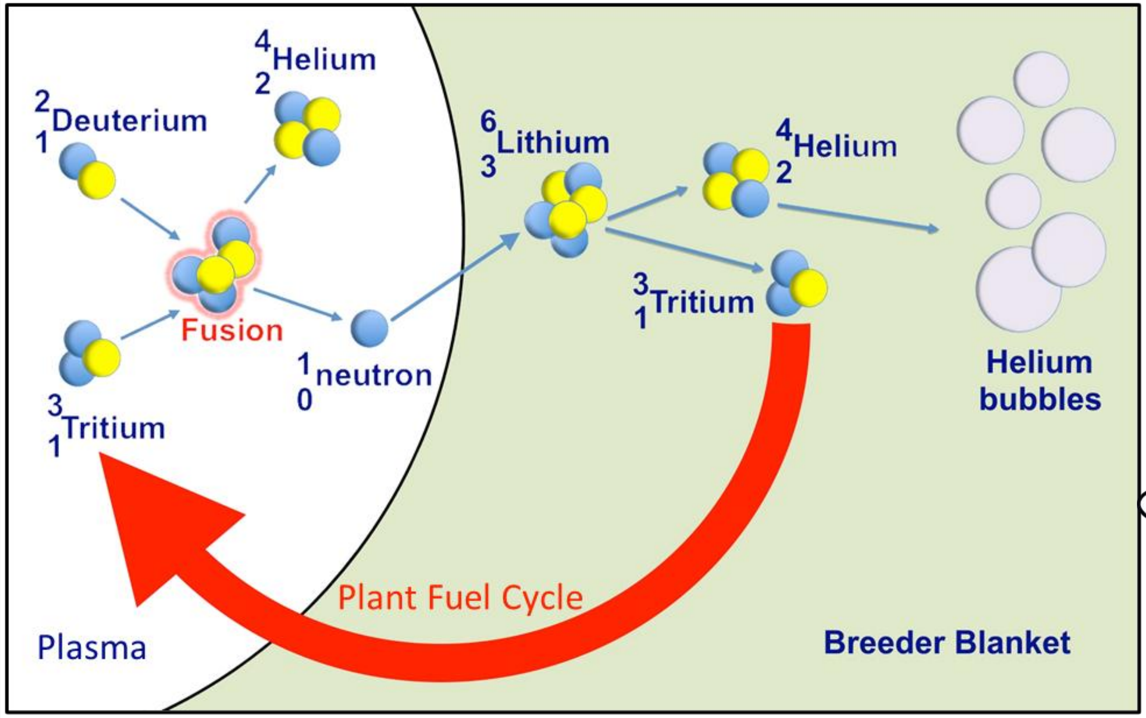
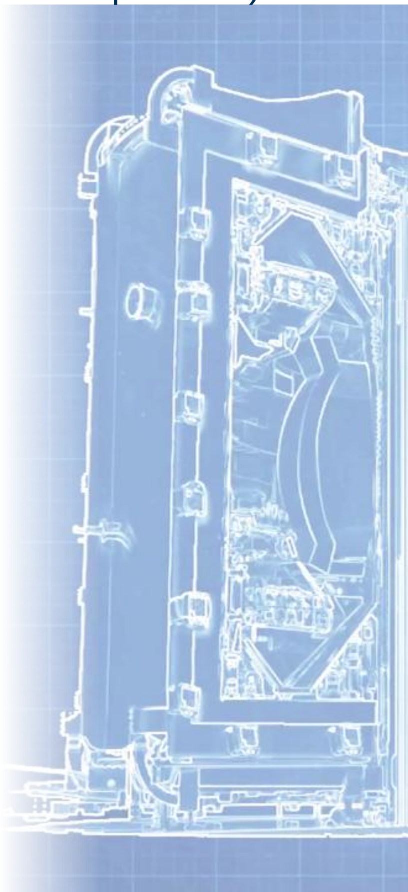


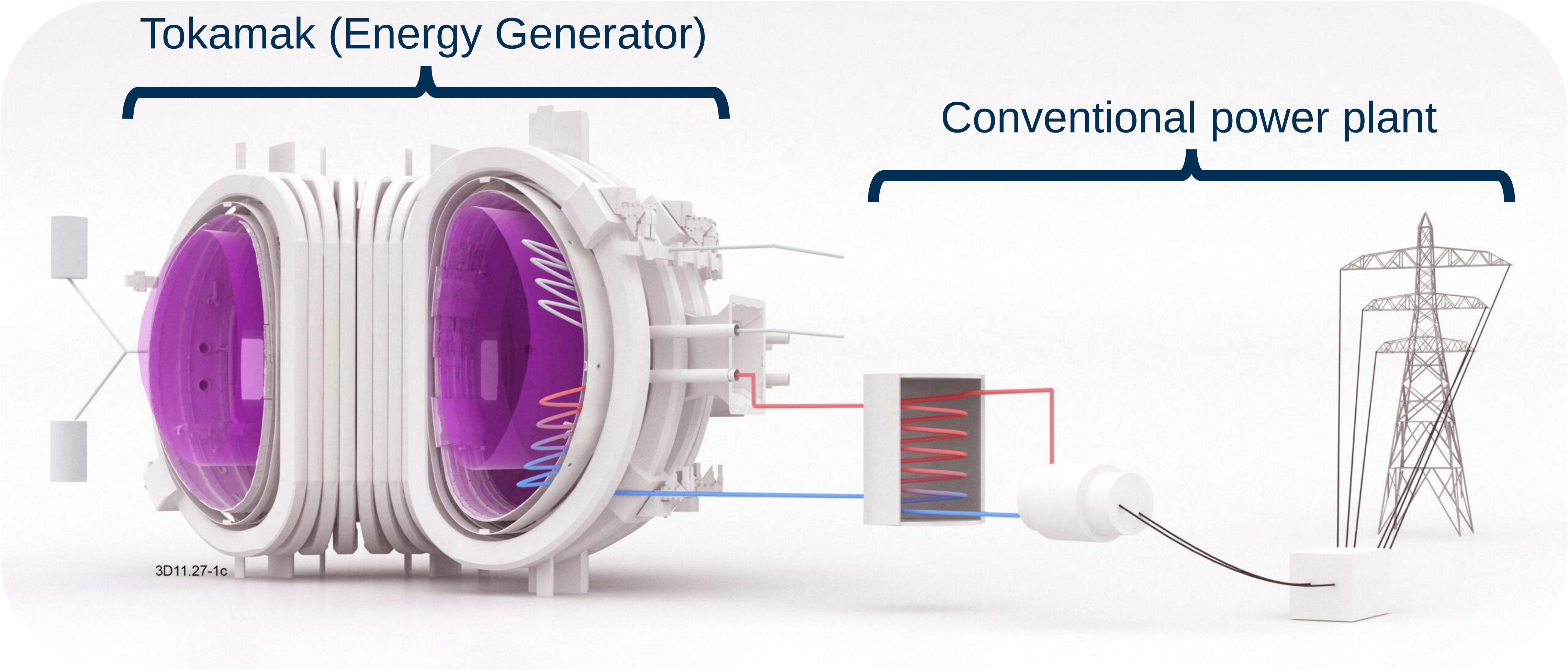
2 Laptop batteries

Bathtub of seawater

Enough fusion energy for 1 person's lifetime



Fusion power plant design



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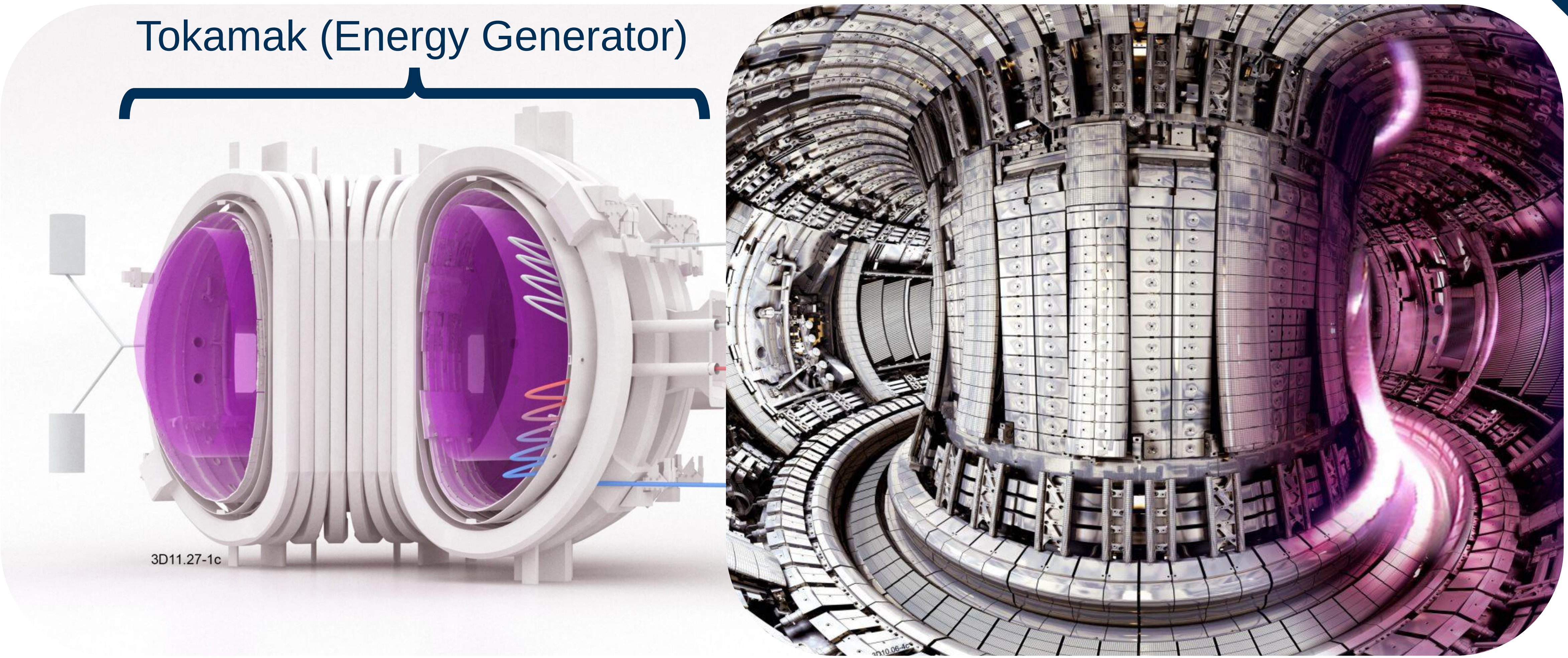

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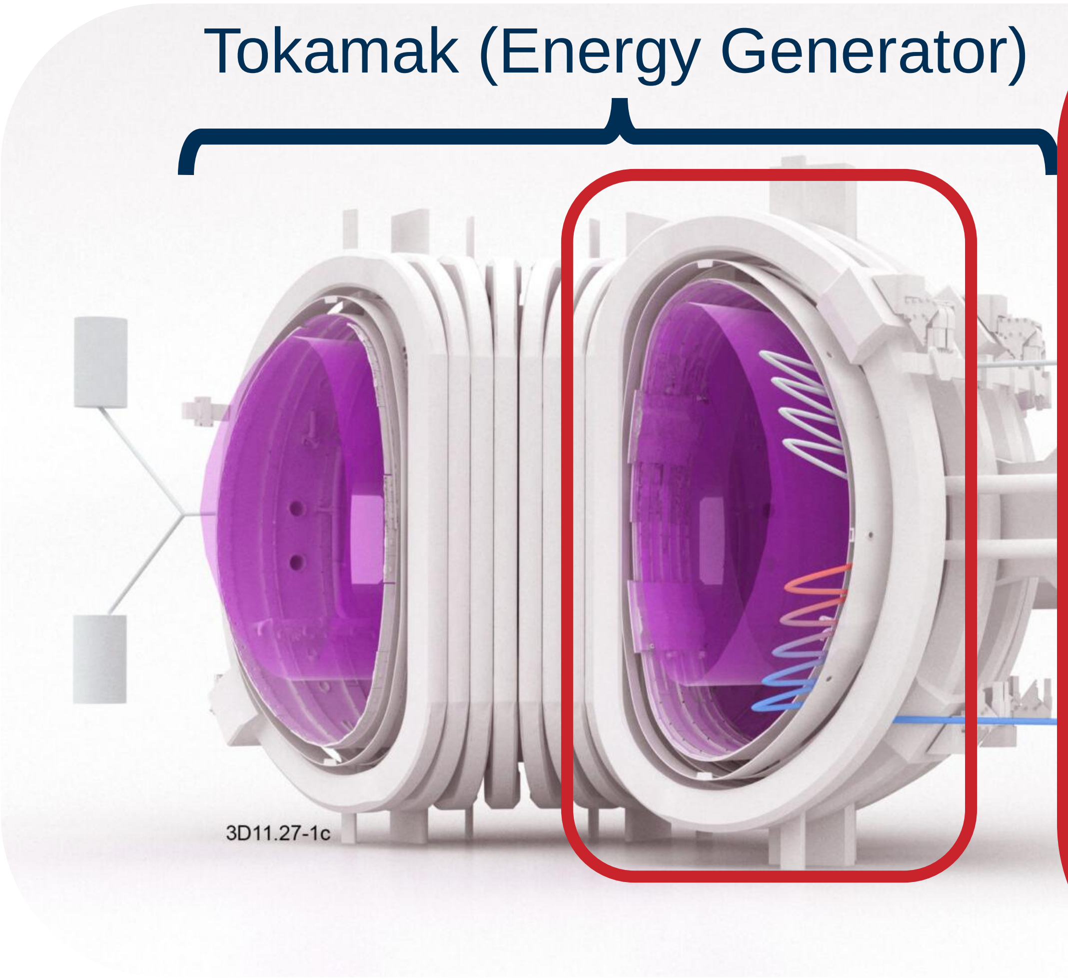
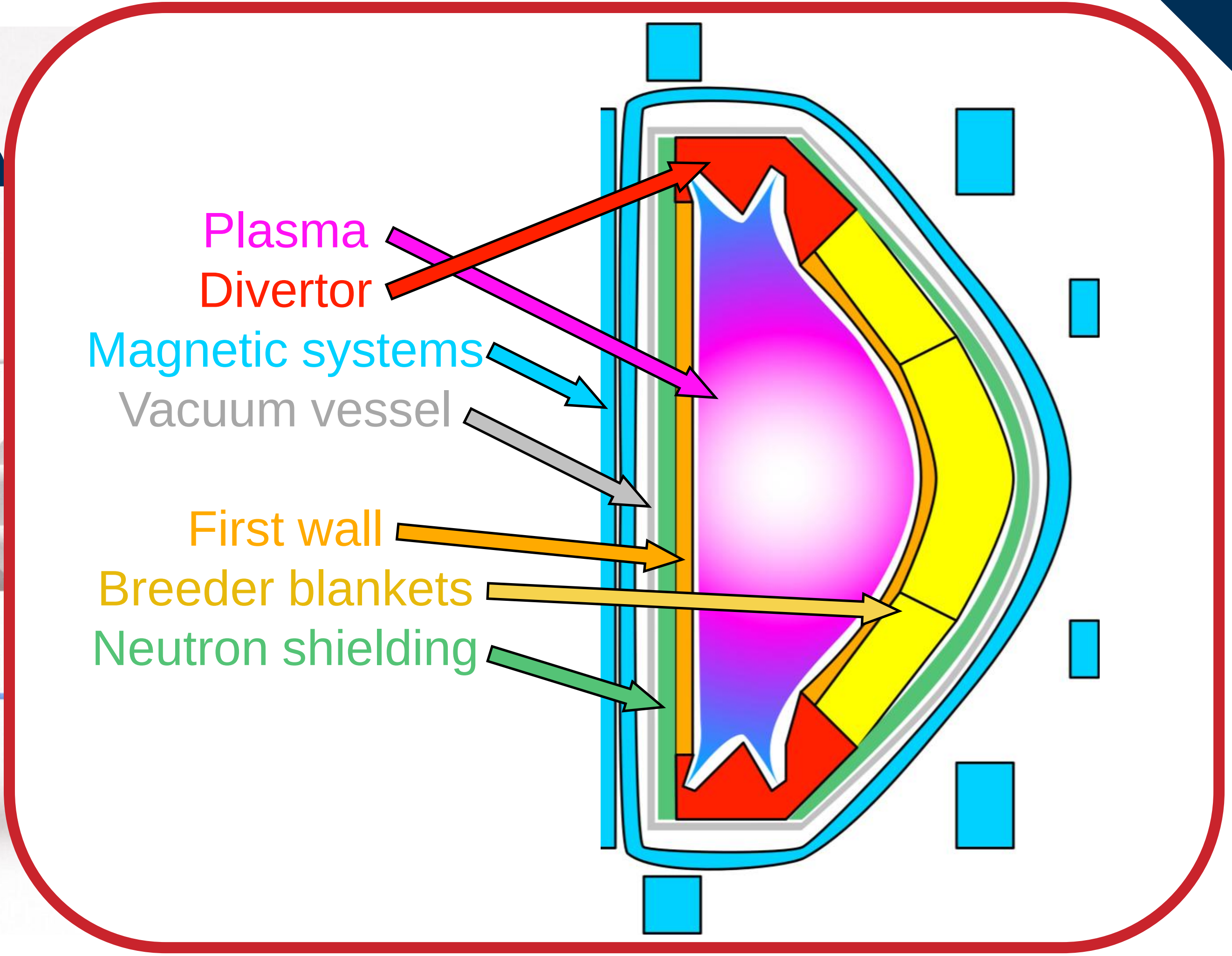




Metals are at the heart of fusion

UK Atomic Energy Authority

Functional

Key technology for power plant operation

- Breeder Material (Lithium)
- Neutron Multipliers (Lead & Beryllium)
- Magnets (REBCO, NbTi/NbSn & Copper alloys)

Survival

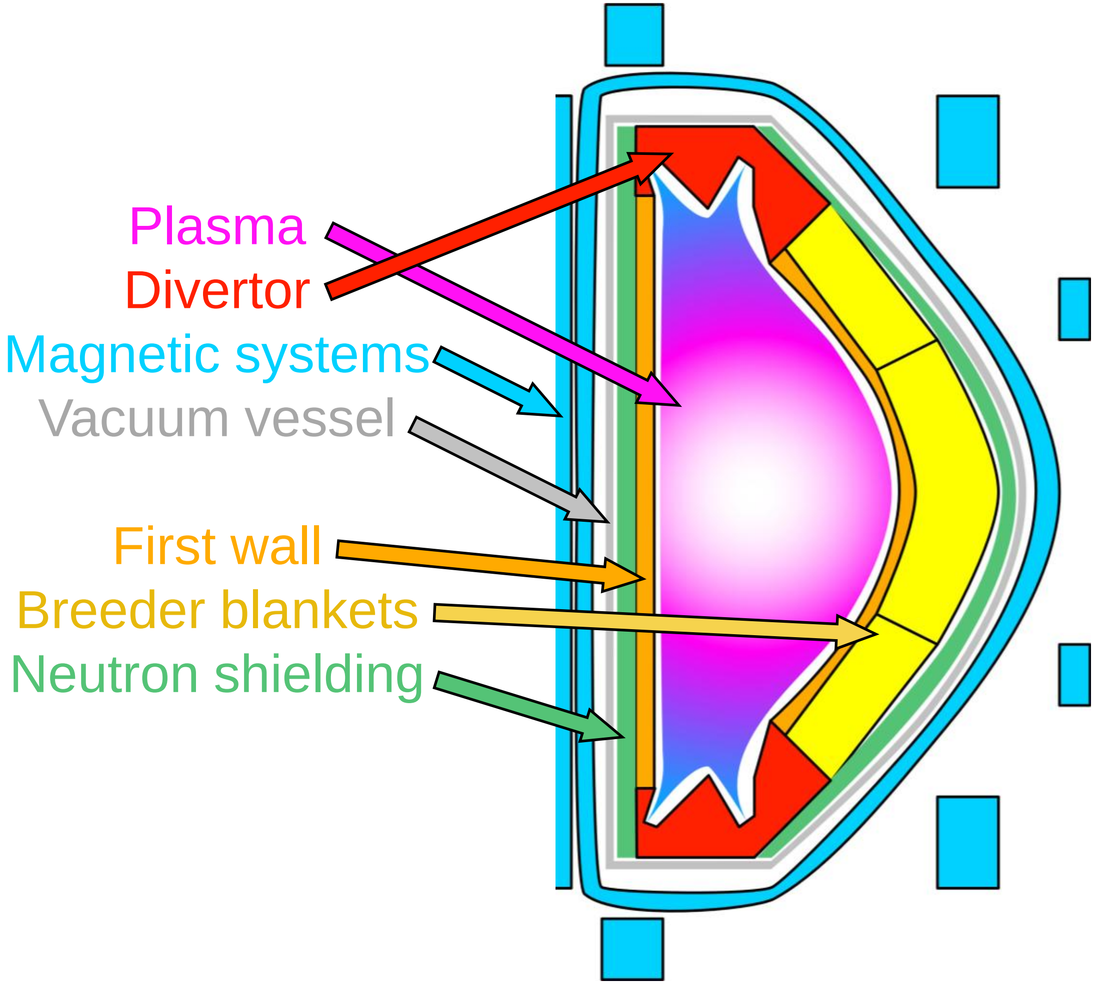
Protection from hostile environment

- Plasma Facing Components (**Tungsten**)
- Neutron Shielding (**Tungsten** carbides/borides)
- Coatings (**Tungsten**, Vanadium & Metal Oxides)

Structural

Management of thermal and mechanical loads

- Breeder Blankets (Advanced fusion steel)
- Coolant Pipes (Copper alloys)
- Vacuum Vessel (Steel)



Highlighted in UK Fusion Materials Roadmap:
https://ccfe.ukaea.uk/wp-content/uploads/2025/09/uk-materials-roadmap-2-0.pdf

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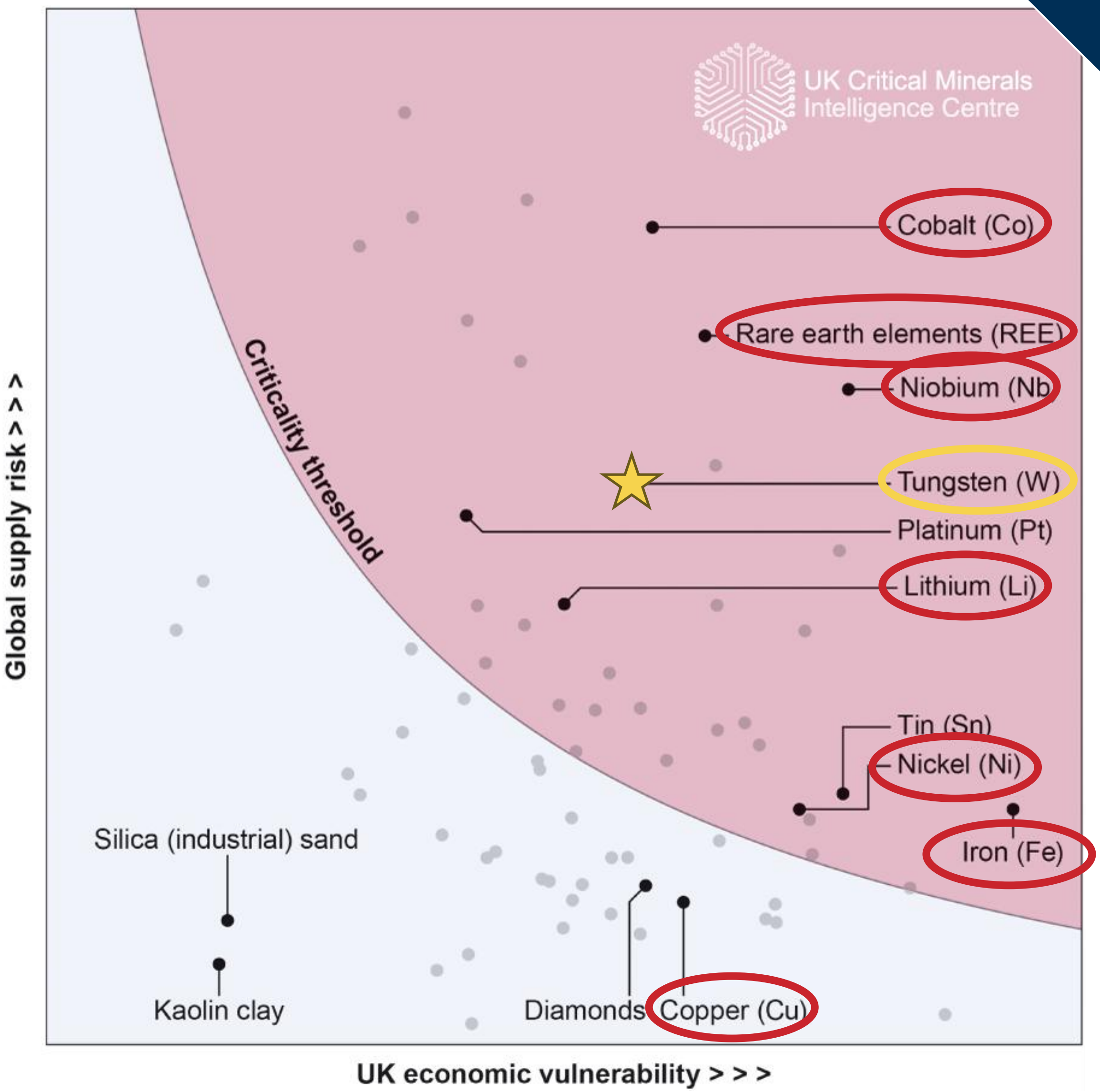

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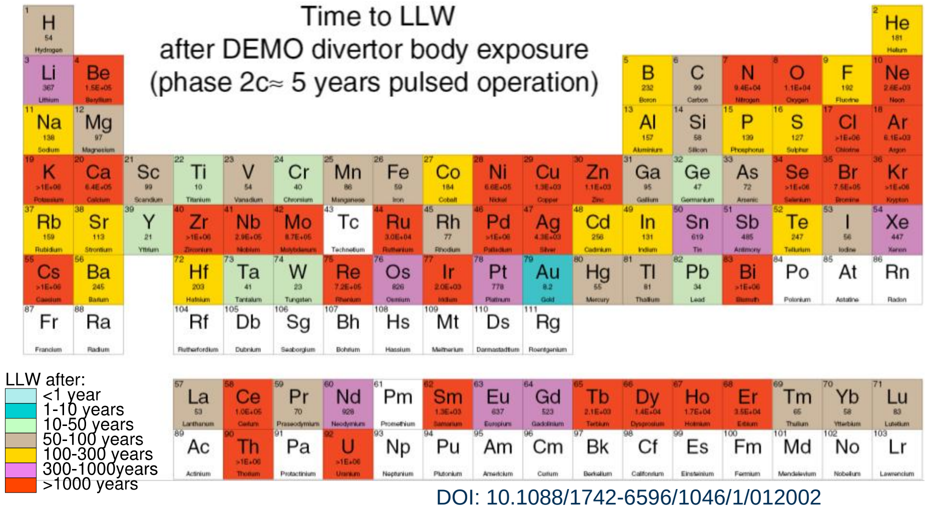
The need for advanced tungsten



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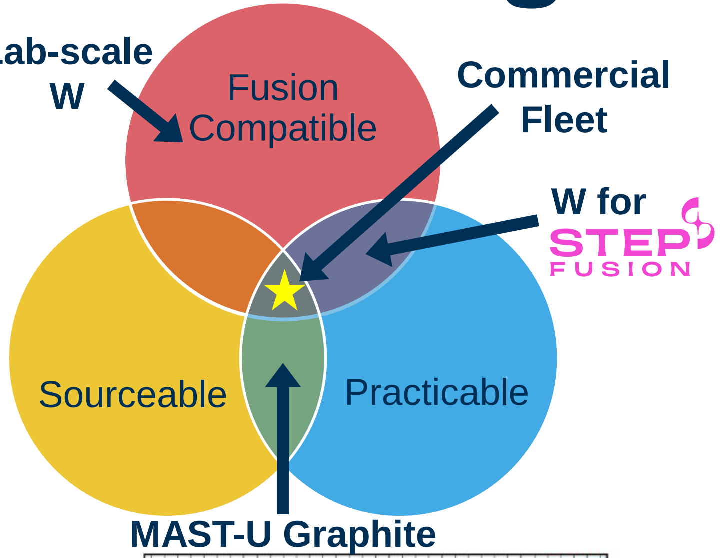
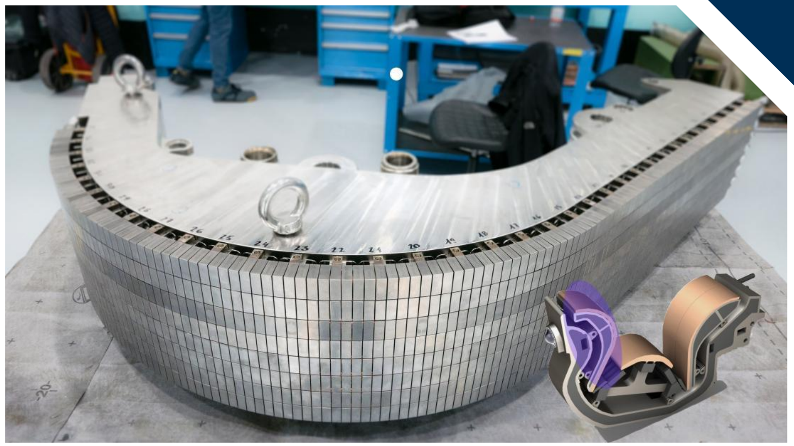
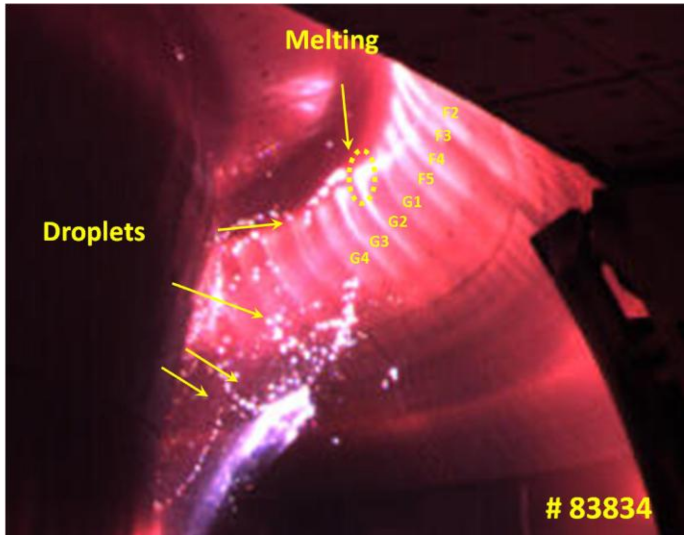


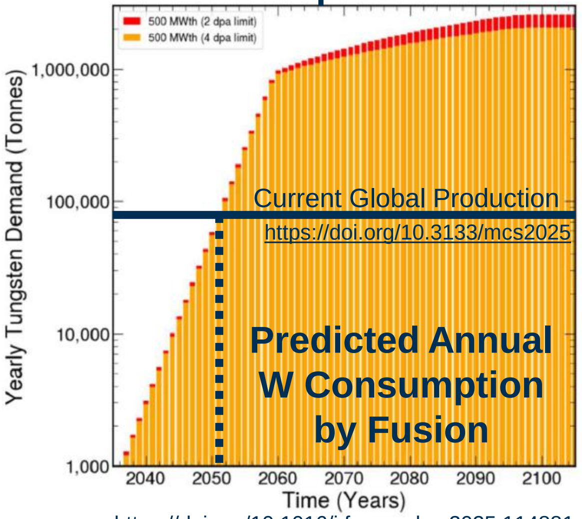
Consistent Precision



ITER Newsline 2018

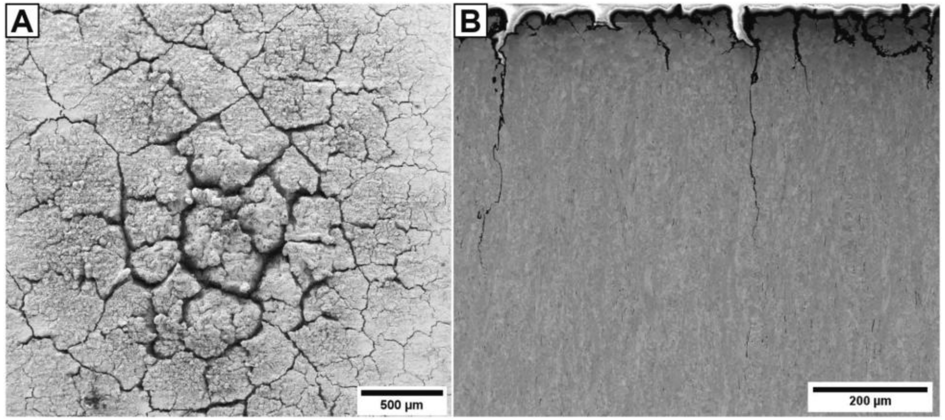


https://doi.org/10.1016/j.nme.2020.100847



https://doi.org/10.1016/j.fusengdes.2025.114881

In-situ Repair



https://doi.org/10.1016/j.nme.2024.101787

Fusion Compatible → **Sourceable** → **Practicable**

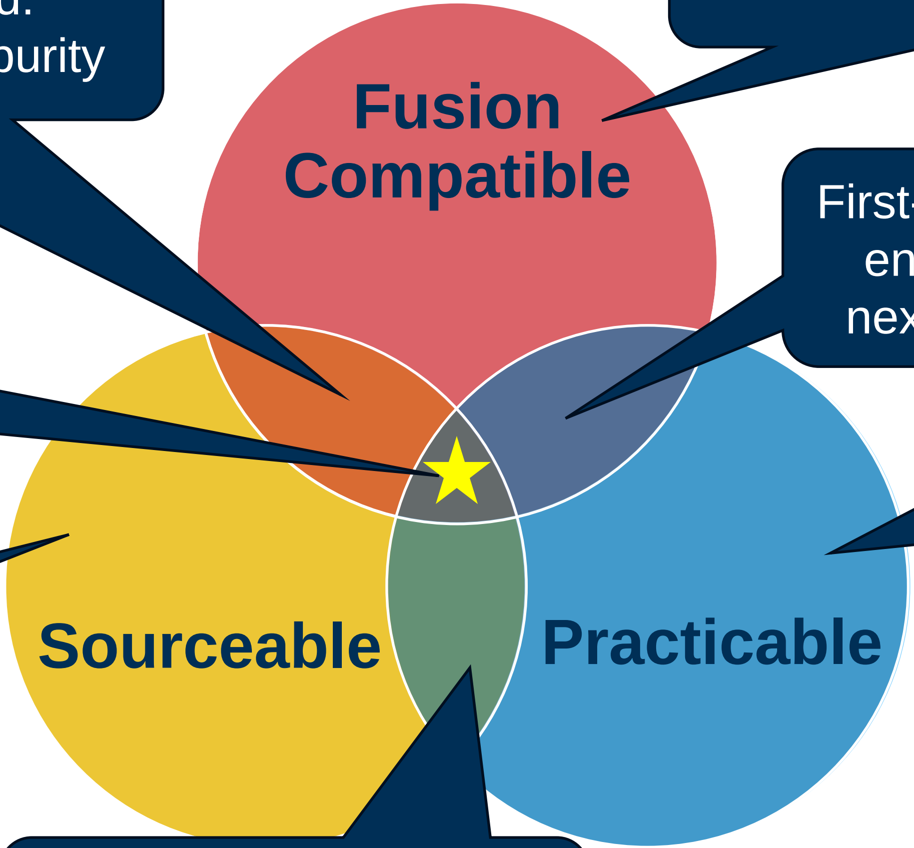
Key challenges for tungsten

Compositional control needed: improved refinement → higher purity

Novel microstructures for advanced functionality

Commercial fleet: maintainable, affordable, profitable

First-of-a-kind fusion plants: Aggressive environments + larger machines → next-generation components needed



Easily manufacturable, machinable and maintainable

100+kT annual demand in 2050s

Recyclable to reduce environmental impact

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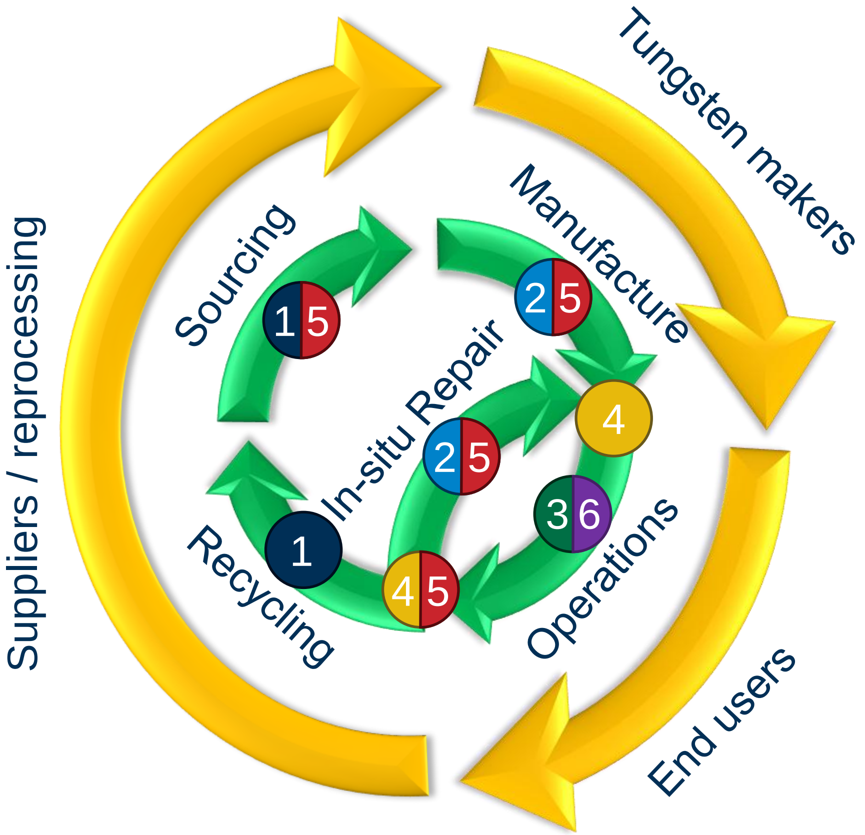
Tungsten life cycle → informs programme



- WP1 – **Mining, Refining & Recycling**
- WP2 – **Microstructural Design & Manufacture**
- WP3 – **Operational Testing**
- WP4 – **Characterisation & Properties**
- WP5 – **Component Engineering**
- WP6 – **Hierarchical Modelling**

UK Tungsten Consortium

UK Atomic Energy Authority

Develop a cradle-to-cradle tungsten supply chain to deliver and validate advanced fusion components at commercial scale

Mining, Refining & Recycling

Develop refining and recycling techniques to maximise W circularity

1.1 Mining

1.2 Refining

1.3 Recycling

Microstructural Design & Manufacture

Develop microstructures for next-generation fusion systems (PFCs, Shielding & Coatings)

2.1 Plasma Facing Components

2.2 Neutron Shielding

2.3 Protective Coatings

Operational Testing

Quantify efficacy of microstructural strategies using international testing facilities

3.1 High Heat Flux & Plasma

3.2 Irradiation

3.3 Liquid Metal

Characterisation & Properties

Identify and understand successful microstructures to inform future developments of manufacturing strategy

4.1 Microscopy

4.2 (Micro)Mechanics

4.3 Thermal Properties

Component Engineering

Establish rigorous engineering standards, with simple joining and remote maintenance instructions for engineers

5.1 Joining

5.2 Qualification

5.3 Remote Maintenance

Hierarchical Modelling

Develop existing modelling capability to predict lifetime performance and inform maintenance schedules of W components

6.1 Tritium Transport

6.2 Microstructural Stability

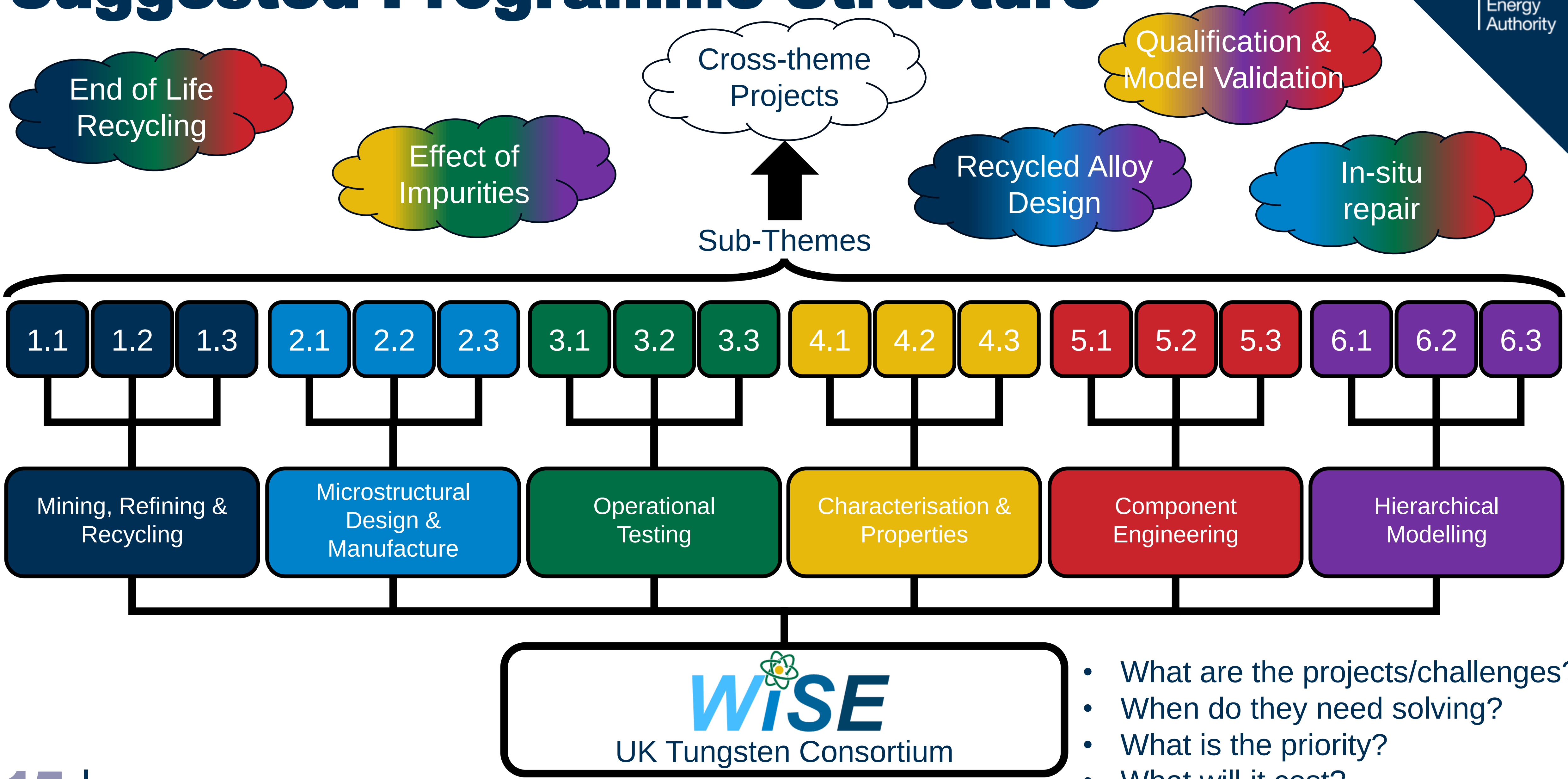
6.3 Multiscale Modelling

Components

Lifecycle

Suggested Programme Structure

UK Atomic Energy Authority



- What are the projects/challenges?
- When do they need solving?
- What is the priority?
- What will it cost?

Proposed Objectives

Theme	Sub-Theme 1	Sub-Theme 2	Sub-Theme 3
Mining, Refining & Recycling: “Develop refining and recycling techniques to maximise W circularity”	**Mining:** “Identify and develop W-containing deposits to maximise extraction efficiency”	**Refining:** “Develop refining technology to reduce energy consumption and maximise purity of W extracted”	**Recycling:** “Develop capability to reprocess used W (inc. activated W) into new fusion feedstock”
Microstructural Design & Manufacture: “Develop microstructures for next-generation fusion systems (PFCs, Shielding & Coatings)”	**Plasma Facing Components:** “Develop manufacture techniques to produce improved microstructures resilient to thermal excursions”	**Neutron Shielding:** “Develop shielding materials and manufacturing processes to improve efficacy of neutron shielding (volume/weight reduction)”	**Protective Coatings:** “Develop manufacture methods of W and ceramic coatings to optimise microstructure for liquid metal coolants”
Operational Testing: “Quantify efficacy of microstructural strategies using international testing facilities”	**High Heat Flux & Plasma:** “Develop tiered testing strategy, to increase down-selection efficacy to determine successful microstructure-manufacture combinations”	**Irradiation:** “Develop irradiation standard, to facilitate comparison between different irradiation campaigns/facilities. Assess neutron capture/resilience”	**Liquid Metal:** “Develop testing facilities and procedures representative of fusion environments, with standardised metrics for susceptibility to corrosion”
Characterisation & Properties: “Identify and understand successful microstructures to inform future developments of manufacturing strategy”	**Microscopy:** “Utilise existing expertise and develop new techniques to assess and screen microstructures”	**(Micro)mechanics:** “Establish high-throughput micromechanical testing methodologies to screen samples before and after irradiation” “Establish relevant testing standards for functional in-vessel components”	**Thermal Properties:** “Establish relevant testing standards for functional in-vessel components”
		“Produce material property handbook suitable for fusion machine design engineers for successful material-manufacture pairings”	
Component Engineering: “Establish rigorous engineering standards, with simple joining and remote maintenance instructions for engineers”	**Joining:** “Identify and develop joining methodologies for W to other relevant material systems: Cu-alloys, steel, SiC, V”	**Qualification:** “Establish relevant testing standards for functional in-vessel components” “Establish acceptance protocols for part manufacture and repair”	**Remote Maintenance:** “Develop in-situ NDT inspection techniques” “Develop in-situ tile stripping and replacement methodologies” “Establish acceptance protocols for part repair”
Hierarchical Modelling: “Develop existing modelling capability to predict lifetime performance and inform maintenance schedules of W components”	**Tritium Transport Modelling:** “Identify probable H^3 trapping sites in W microstructures” “Propose microstructural, processing and maintenance changes to reduce retention and improve release of H^3”	**Microstructural Stability:** “Identify relative stability under irradiation of proposed microstructures (matrix, precipitates, fibres, etc.)” “Inform microstructural development strategy”	**Multiscale Modelling:** “Establish multi-scale modelling to match micromechanical testing to bulk mechanical performance” “Predict and validate microstructural performance under irradiation”