



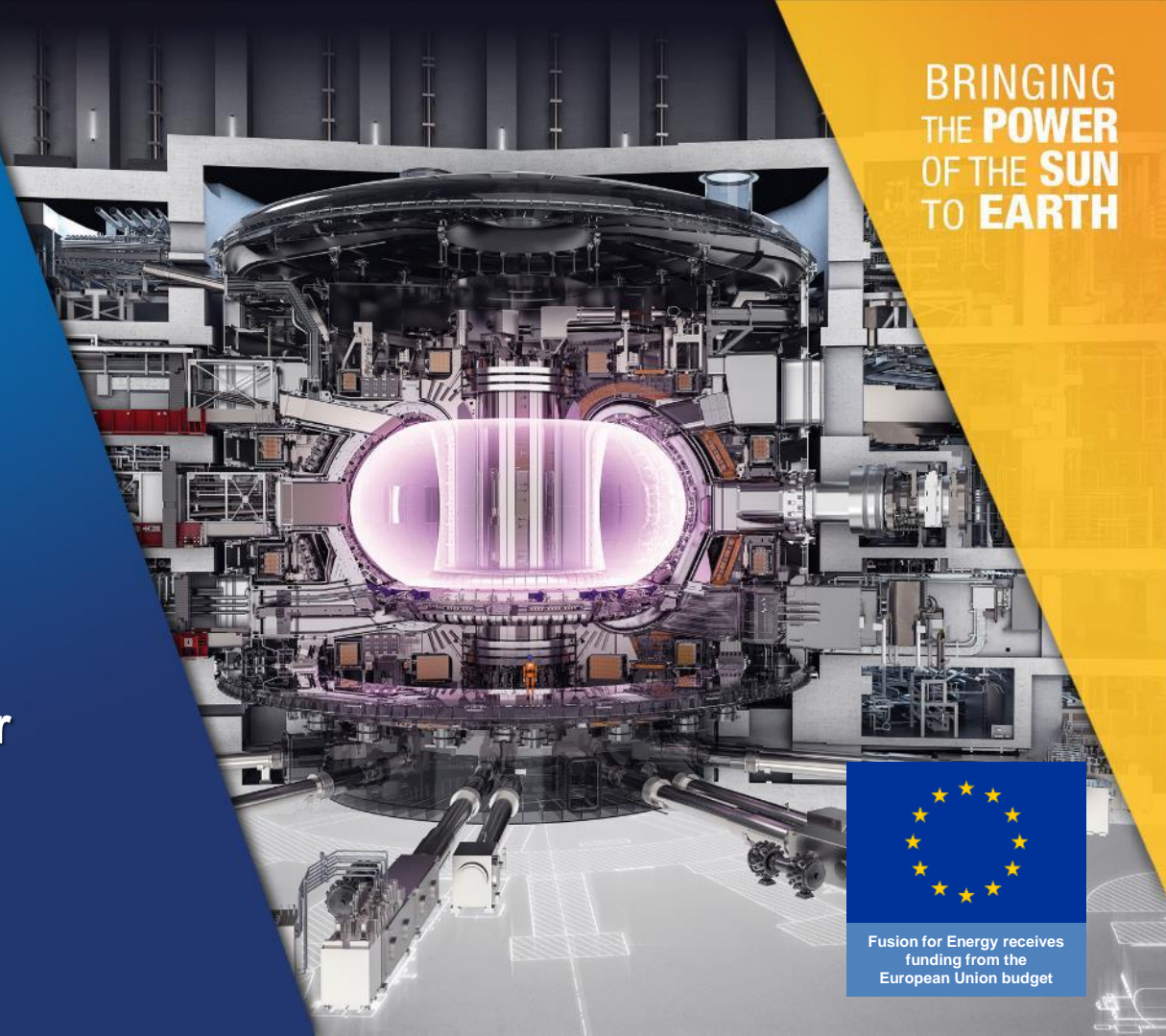
**FUSION
FOR
ENERGY**

ITER ... Die Zukunft

Johannes P. Schwemmer

KIT, 17/5/2022

BRINGING
THE **POWER**
OF THE **SUN**
TO **EARTH**



Fusion for Energy receives
funding from the
European Union budget

Dr Bernard Bigot

24th January 1950 – 14th May 2022

ITER Director-General 2015-2022



Why is fusion energy attractive?



Abundant

**Fuels are plentiful
and available all
over the world**



Sustainable

**No greenhouse
gas (CO₂)
emissions**



Safe

**No long-lived
radioactive waste**

**Reactors can not
run out of control**

Large amounts of energy for little fuel



280 liters of Earth crust
(50 g lithium)

+ 400 liters of water
(12 g deuterium)

=



300 tonnes of oil

=



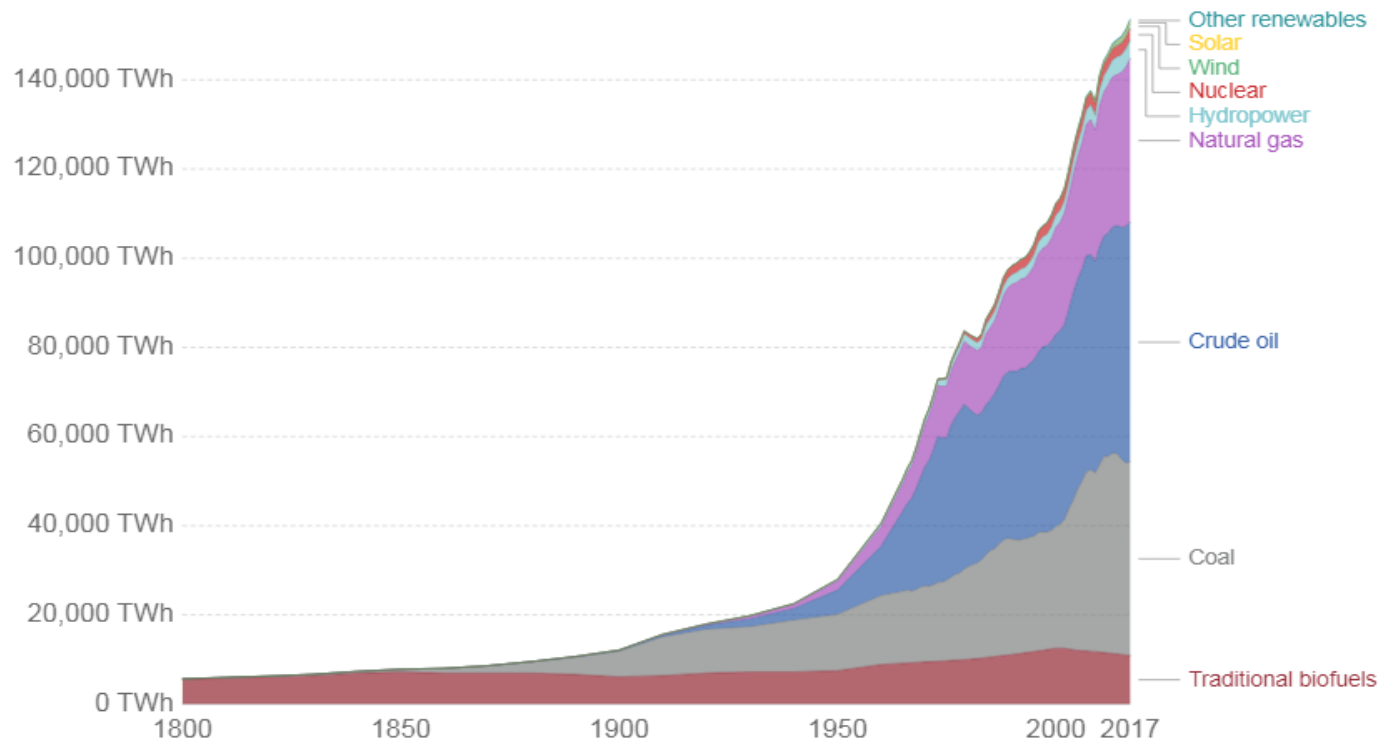
**Total energy consumed
by average EU citizen
during whole life**

A long way to replace fossil fuels

Global primary energy consumption

Global primary energy consumption, measured in terawatt-hours (TWh) per year. Here 'other renewables' are renewable technologies not including solar, wind, hydropower and traditional biofuels.

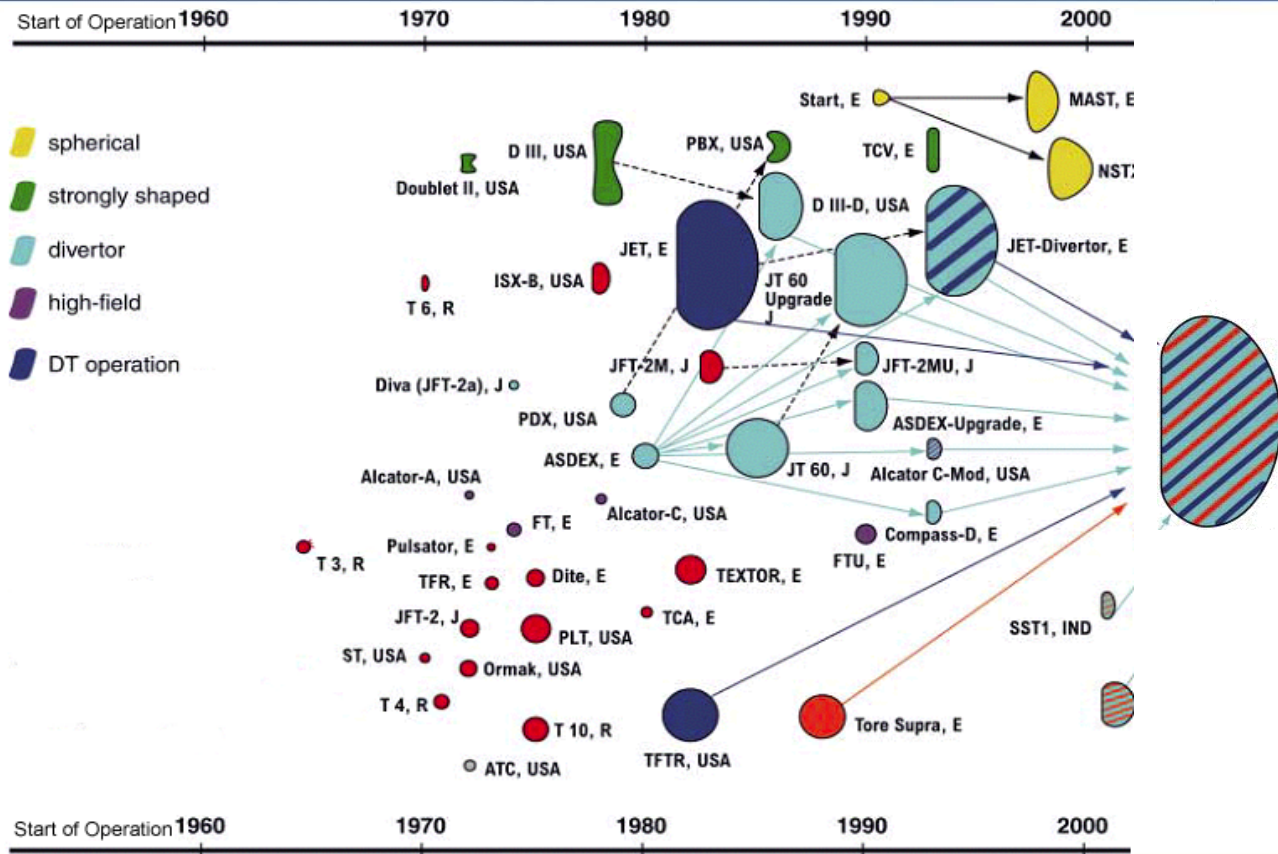
Our World
in Data



Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

CC BY-SA

Since 1960's many different fusion experiments

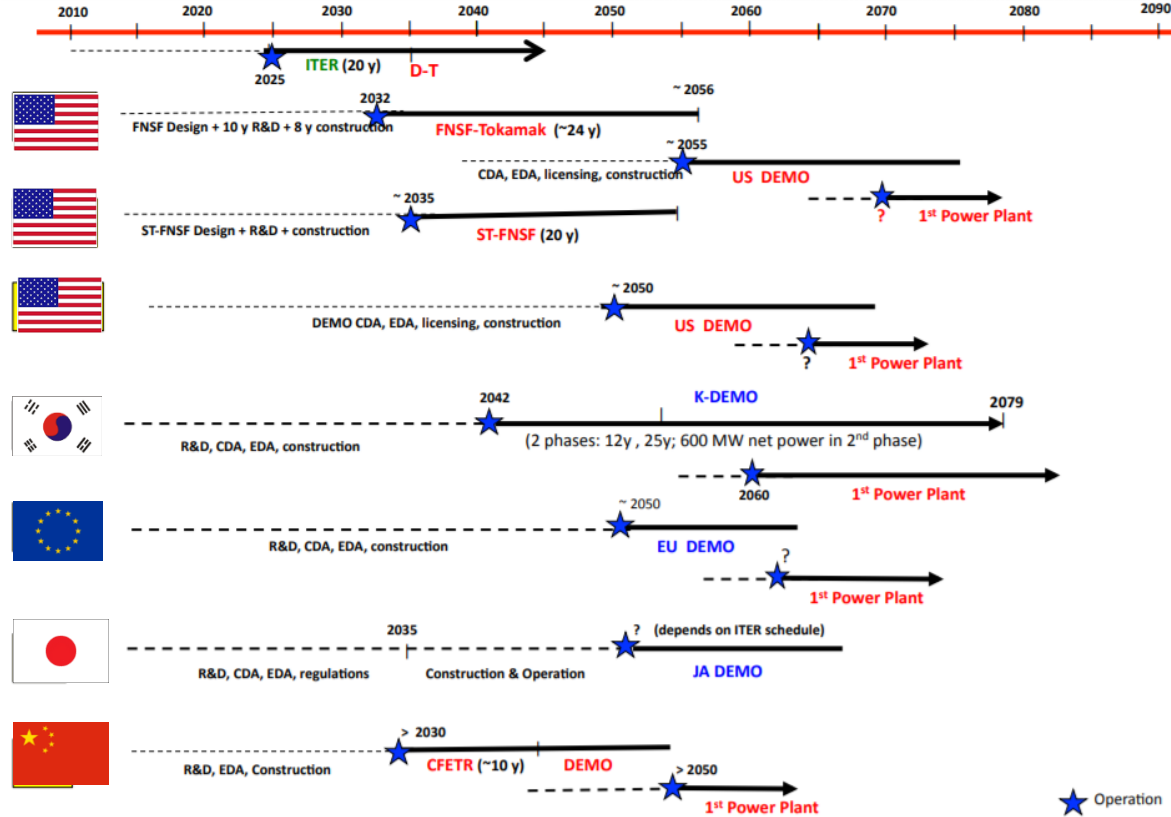




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**What is the roadmap to
fusion energy?**

Worldwide roadmaps to electricity generation

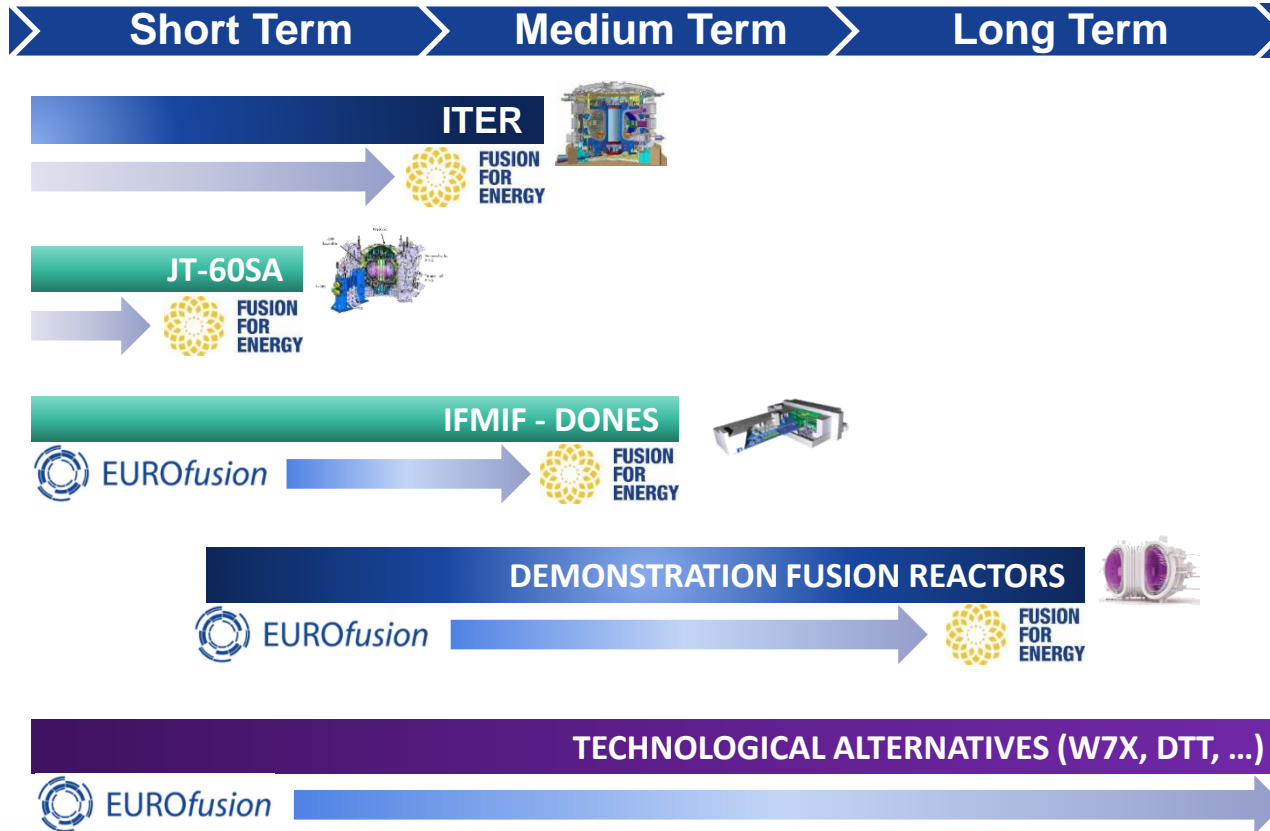


Europe: two main pillars



- ▶ F4E is a EU public organisation set up in 2007 for 35 years
- ▶ Headquarters: Barcelona, Spain
- ▶ Offices: Cadarache, France
Garching, Germany
Naka & Rokkasho, Japan
- ▶ Staff: 460+ (mostly engineers)
- ▶ Budget
 - ▶ 2007-2020 ~€6.8bn (2008 values)
 - ▶ 2021-2027 ~€5bn (2018 values)







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What is ITER?

ITER will create “burning” plasmas under conditions close to those in future power plants



Tore Supra

25 m³

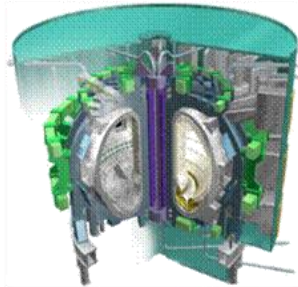
~ 0 MW_{th}



JET

80 m³

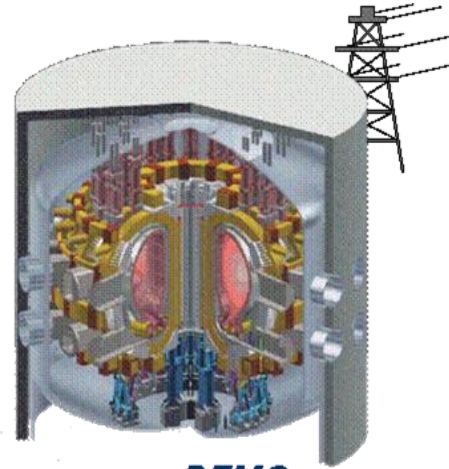
~16 MW_{th}



ITER

800 m³

~ 500 MW_{th}



DEMO

~ 1000 - 3500 m³

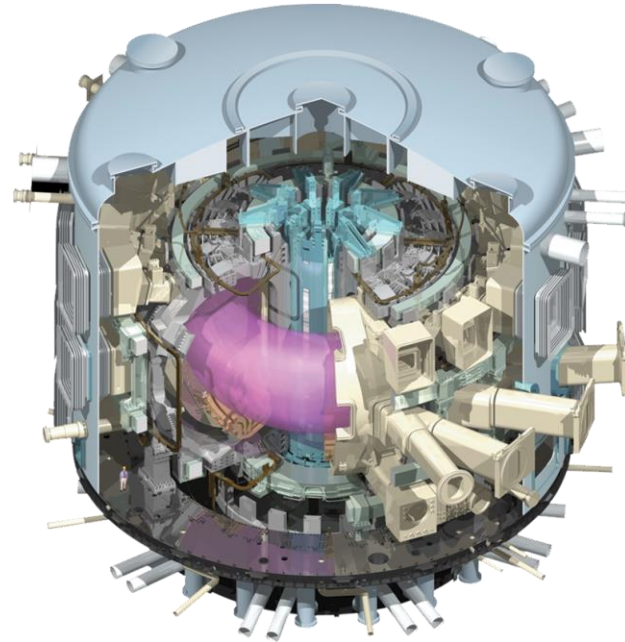
~ 2000 - 4000 MW_{th}

Fusion energy released
on large scale

10 times more energy
generated than consumed

Study of “burning
plasma” and its long
operation

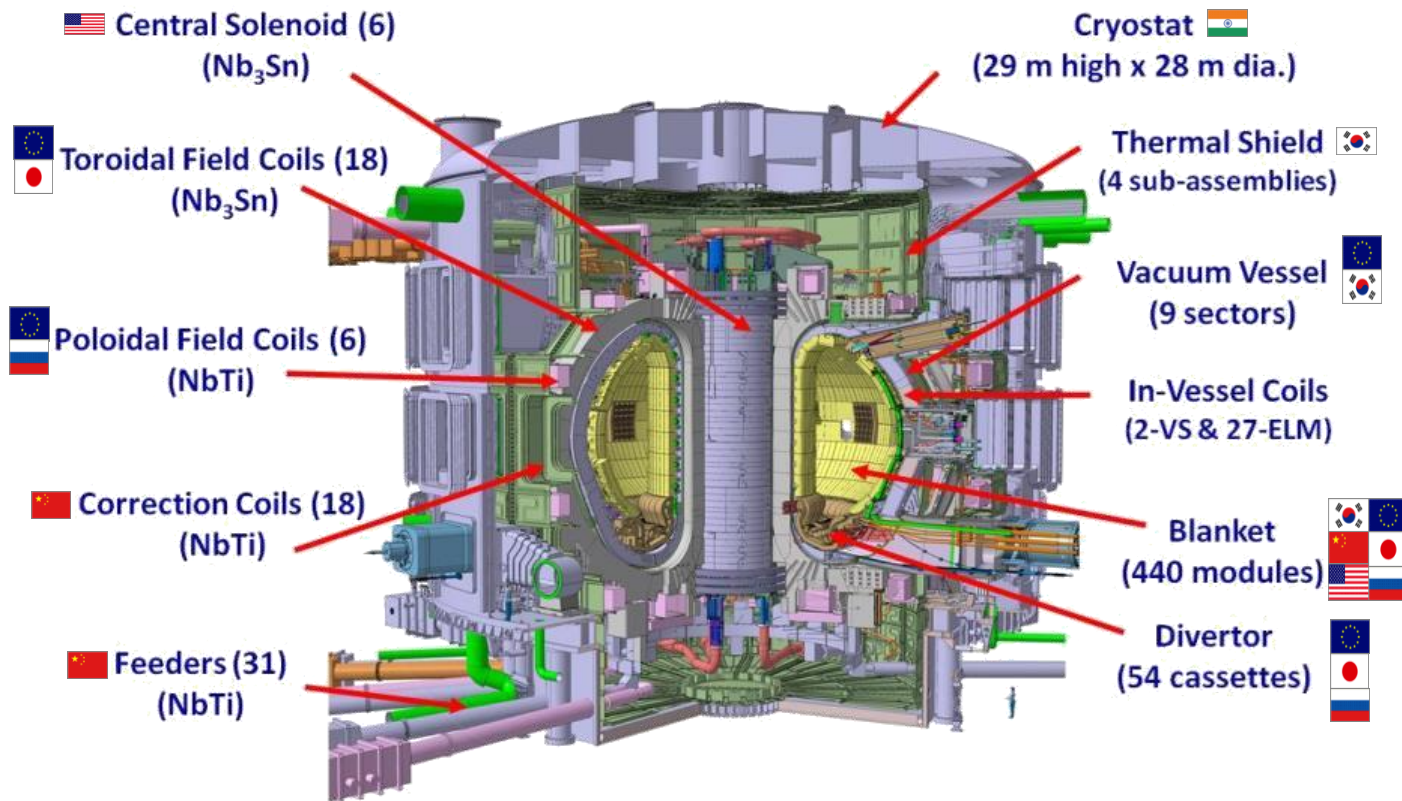
Testing key technologies
for future fusion reactors



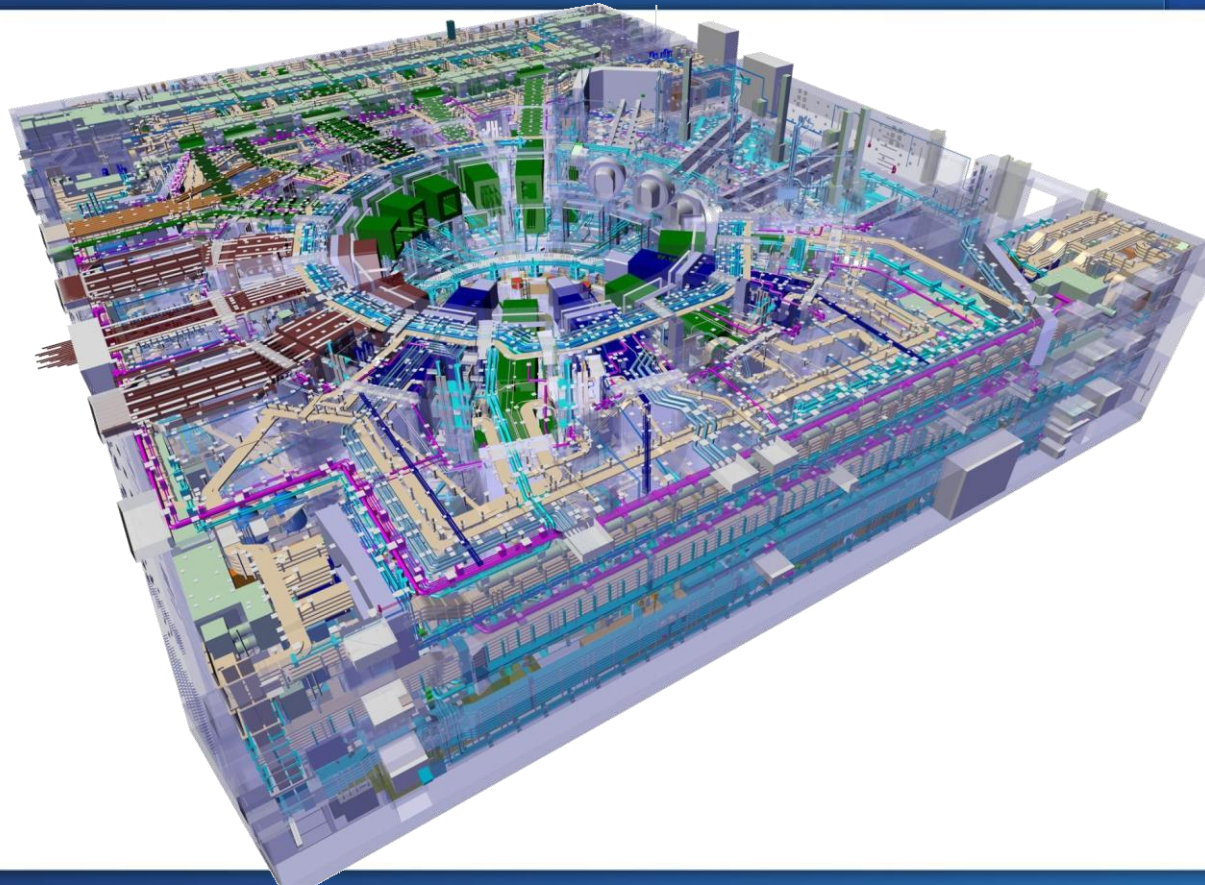
ITER is a truly international project



Sharing knowledge through in-kind



Systems with unprecedented complexity

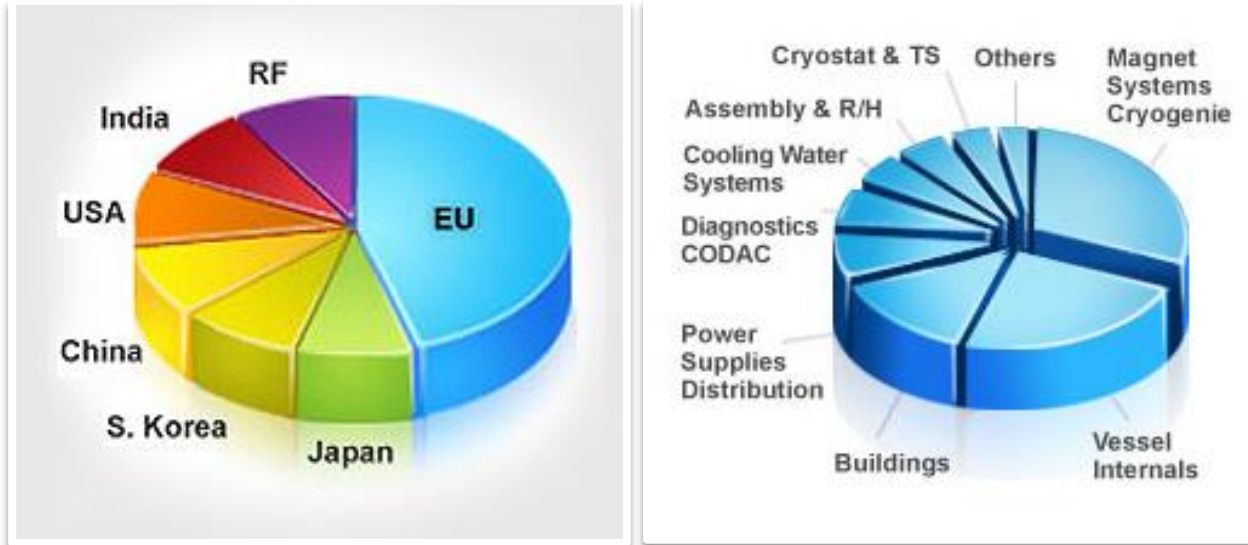




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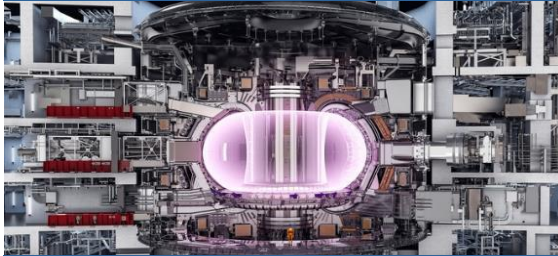
What is Europe's role in ITER?

Pooling resources from around the world



F4E developing fusion through four main projects

ITER: Burning Plasma



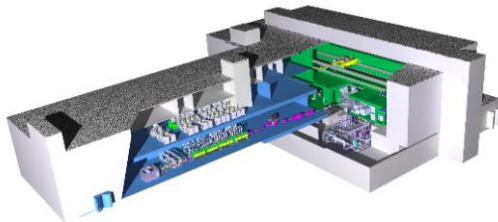
Responsible for Europe's contribution to **ITER**

BROADER APPROACH



Working with Japan on satellite fusion projects

DONES: Materials Testing



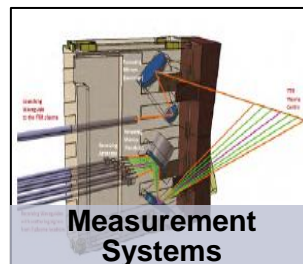
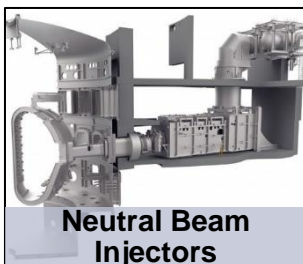
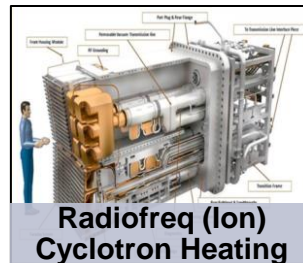
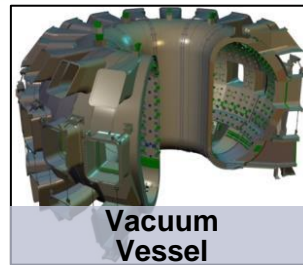
Responsible for the design & construction of **DEMO Orientated Neutron Source**

DEMO: Continuous Power

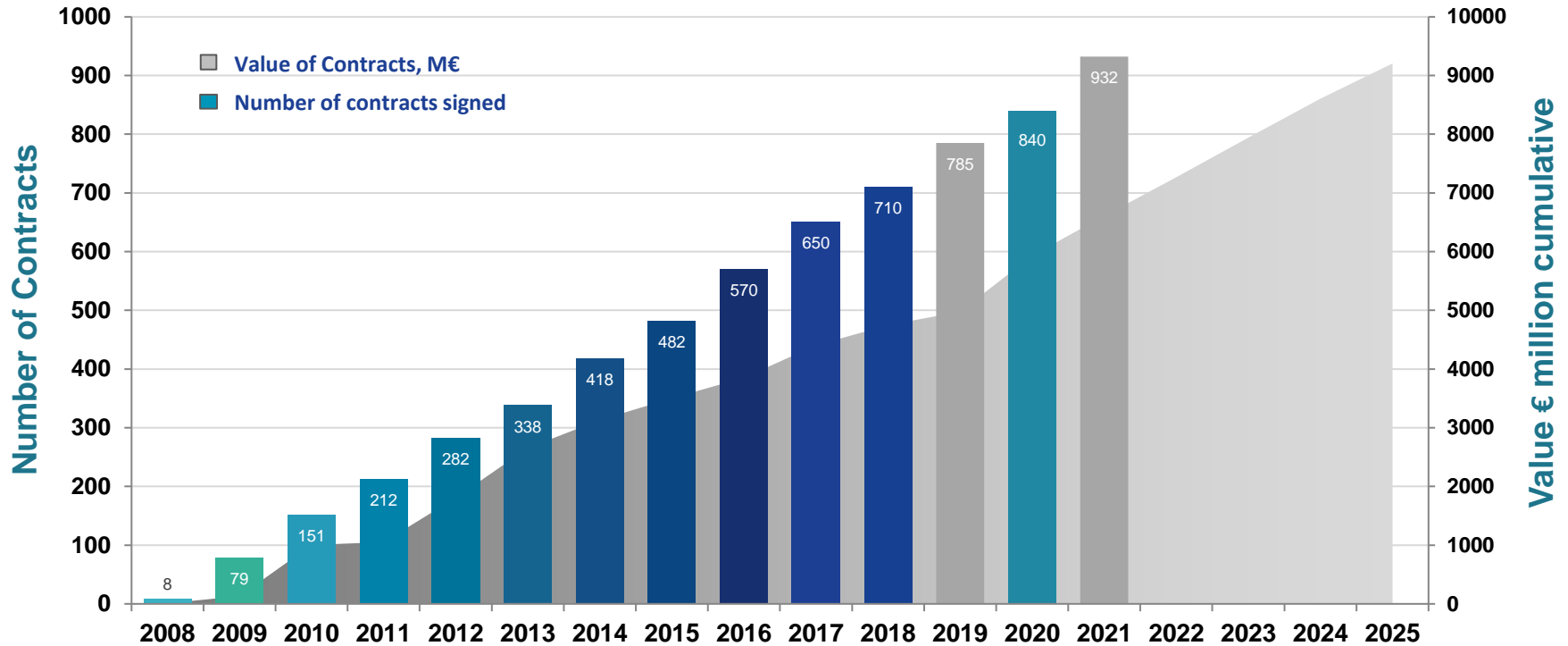


Preparing to build power-generating **Demonstration Fusion Reactor**

European contributions to ITER



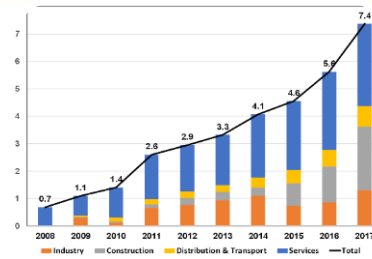
We have placed ~€6bn of contracts with industries & research labs all over Europe



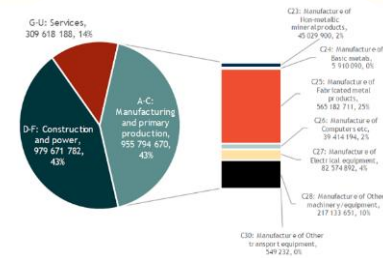
ITER impact on European economy



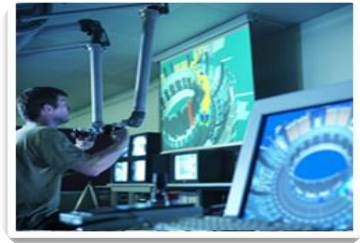
€8 billion to European industry and laboratories by 2021



Approx. 40,000 job years created 2008-2020 (78,000 more until 2035)



Net value added of 12% on EU investment in ITER



Development of new cutting edge industrial technologies

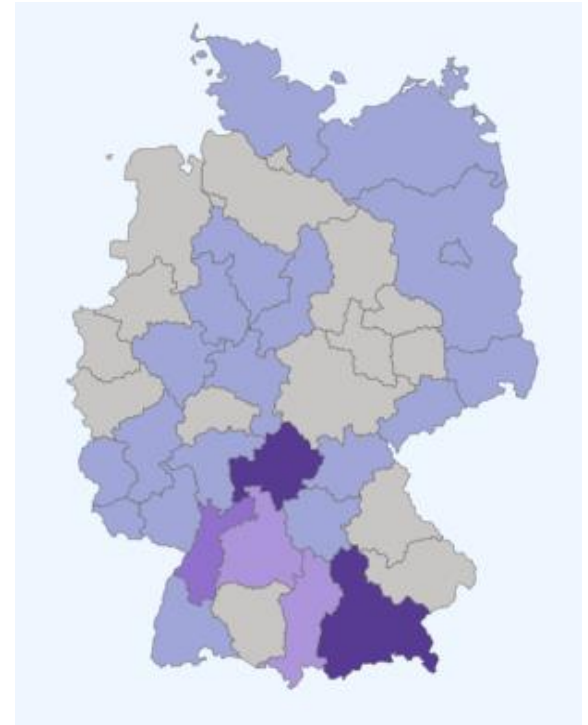


Cases of spin-out technologies from ITER work emerging

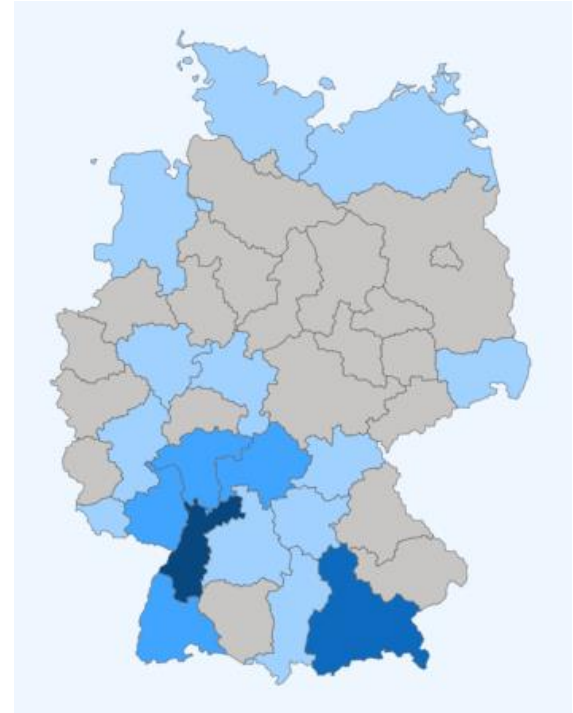


Companies are expanding into new markets from ITER work

- **350** participations to **pre-procurement** activities:
 - 230 in market surveys
 - 120 in information days



- **Tier-1** contracts won:
 - 50+ companies and research centers
 - 202 million EUR awarded by F4E
(as of Dec 2021)
 - 25 million EUR awarded by IO
(as of Dec 2020)
- **Tier-2** contracts won:
 - 60+ companies and research centers
 - 160 million EUR under F4E contracts
(as of Dec 2021)



Who subcontracts entities from GERMANY?



| Contractor Country | Contractors |
|--------------------|-------------|
| GERMANY | 8 |
| ITALY | 7 |
| SPAIN | 7 |
| FRANCE | 6 |
| UNITED KINGDOM | 3 |
| AUSTRIA | 1 |
| SWITZERLAND | 1 |

33

Contractors

Who do contractors from GERMANY subcontract?

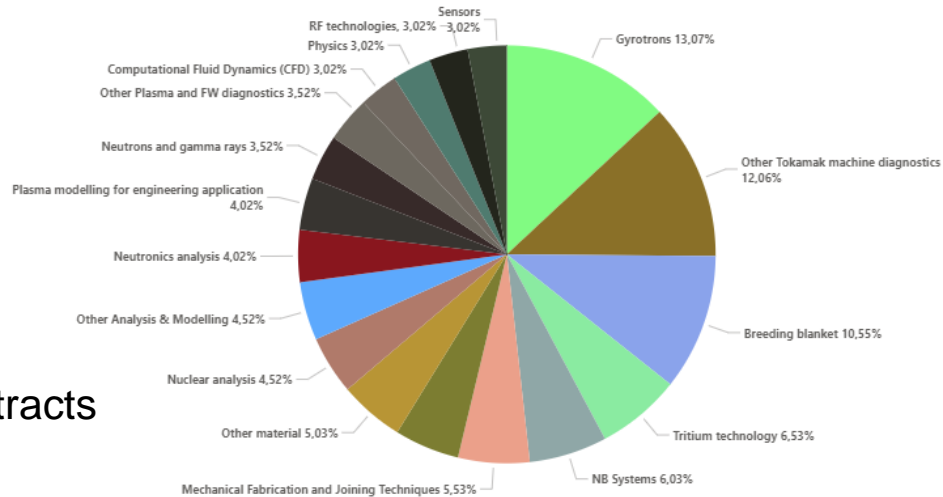


| Subcontractor Country | #Entities |
|-----------------------|-----------|
| GERMANY | 32 |
| FRANCE | 12 |
| AUSTRIA | 4 |
| ITALY | 4 |
| BELGIUM | 3 |

74

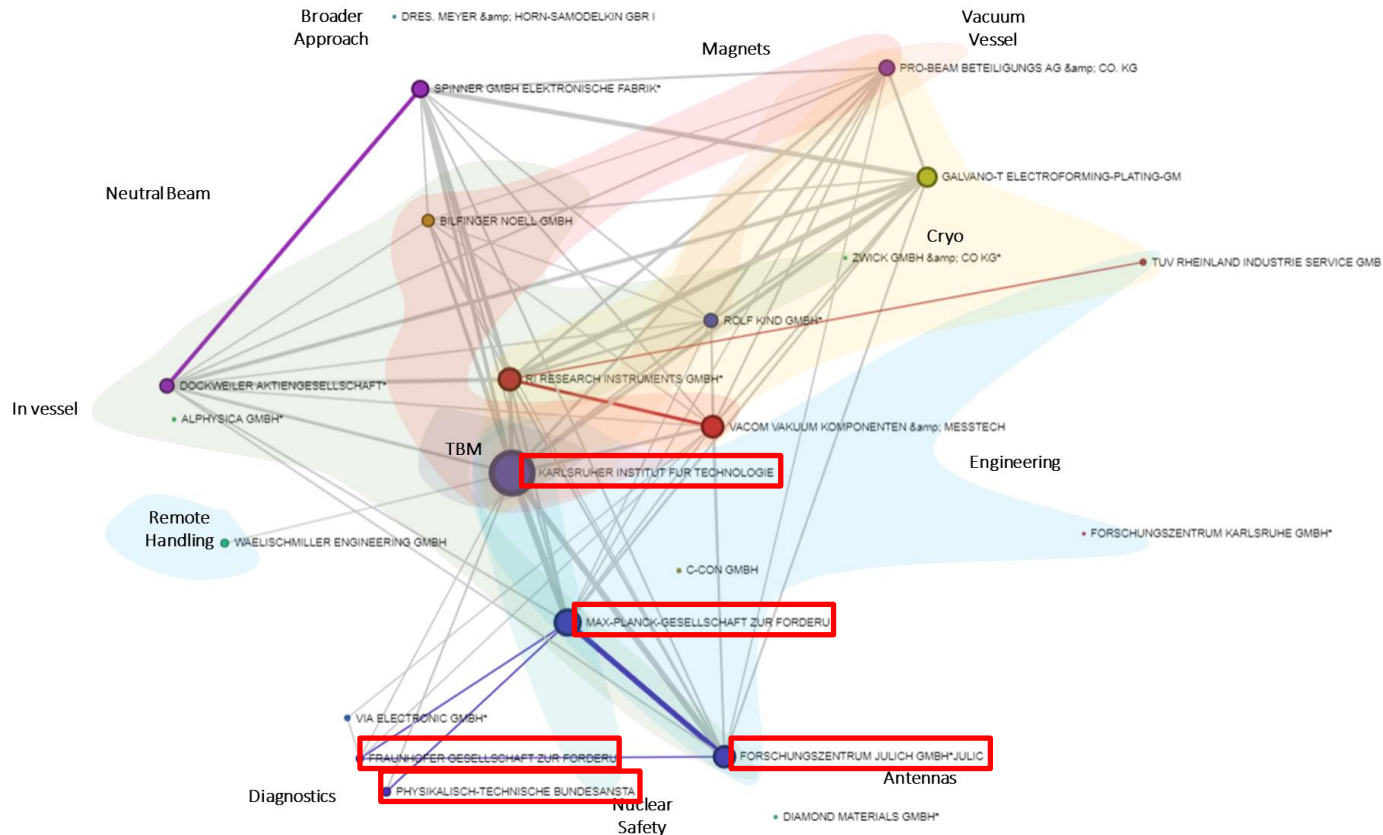
Subcontractors

Distinct IPs per PT



- **112 new IP items** developed under F4E contracts in Germany:
 - Average 1 new IP every 2 contracts
 - Owned by 17 companies and research centers

German research centers are tech hubs





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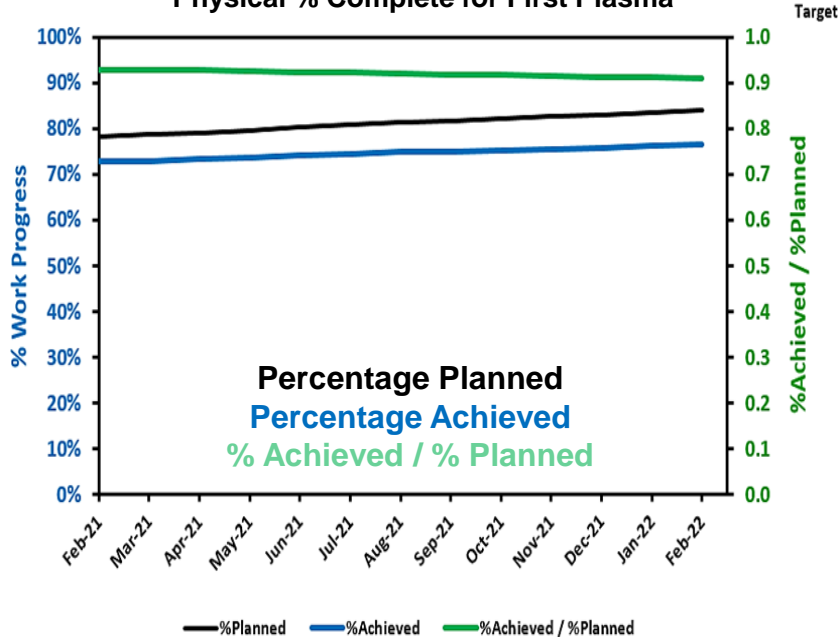
**What is the current
status of ITER?**

ITER now >75% complete to First Plasma

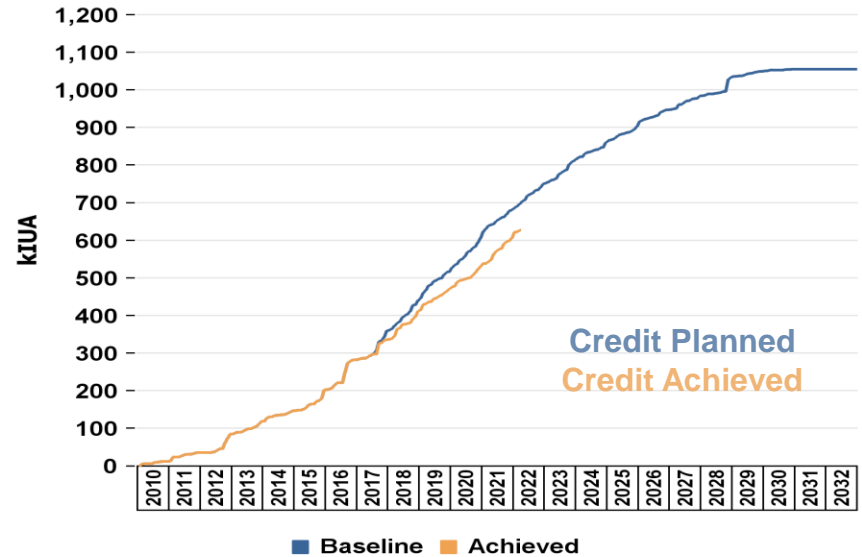
F4E has delivered 59% of its in-kind contributions



Physical % Complete for First Plasma



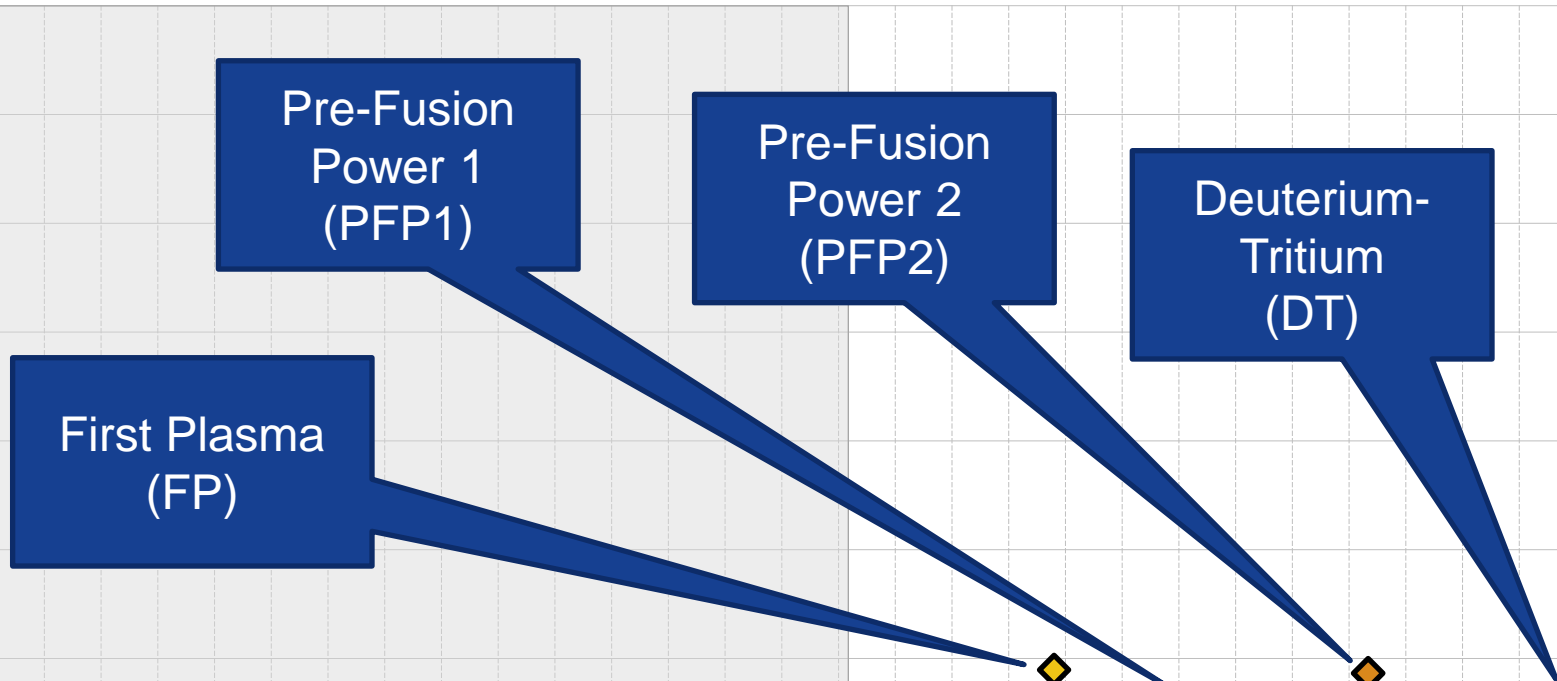
Earned ITER credit for all EU contributions



Overall ITER schedule



2008 2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034

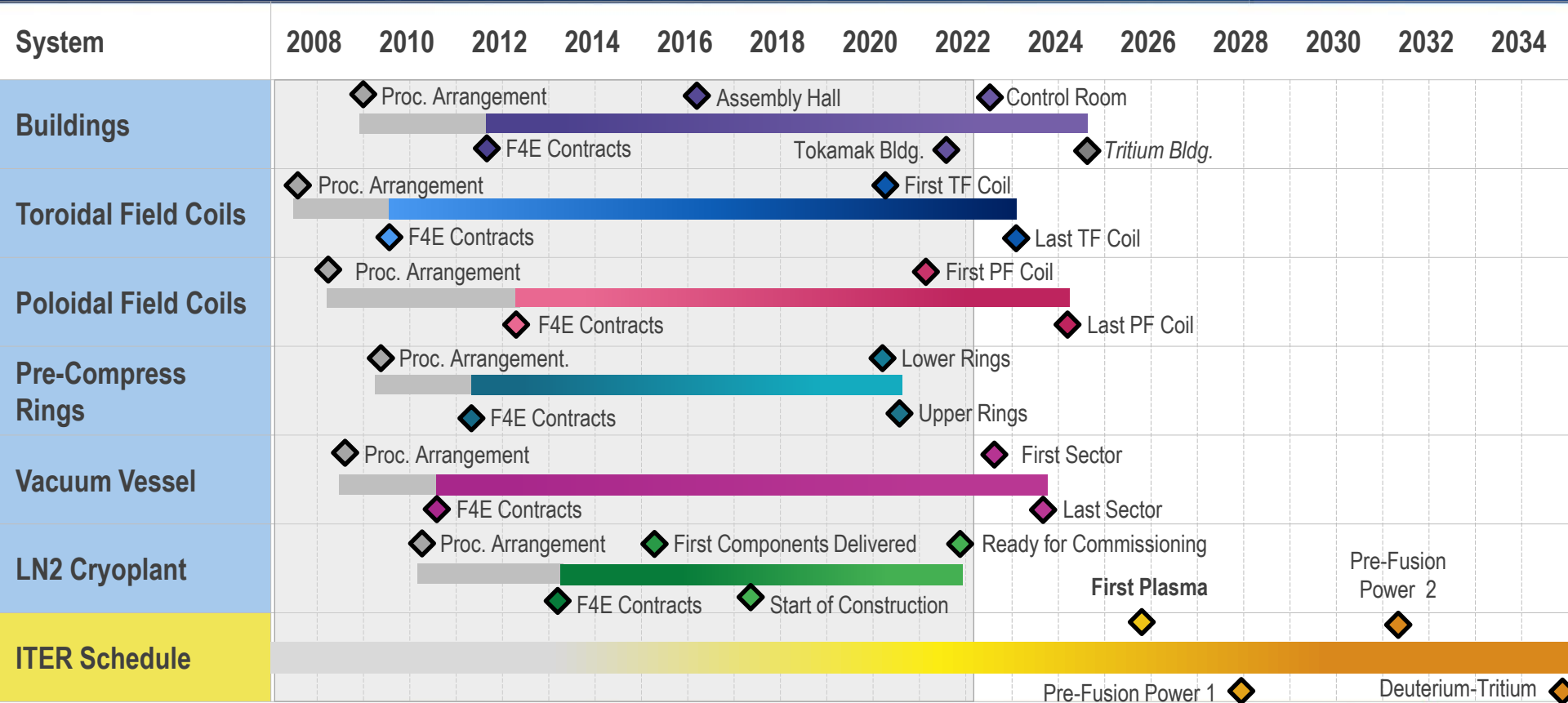


ITER Schedule

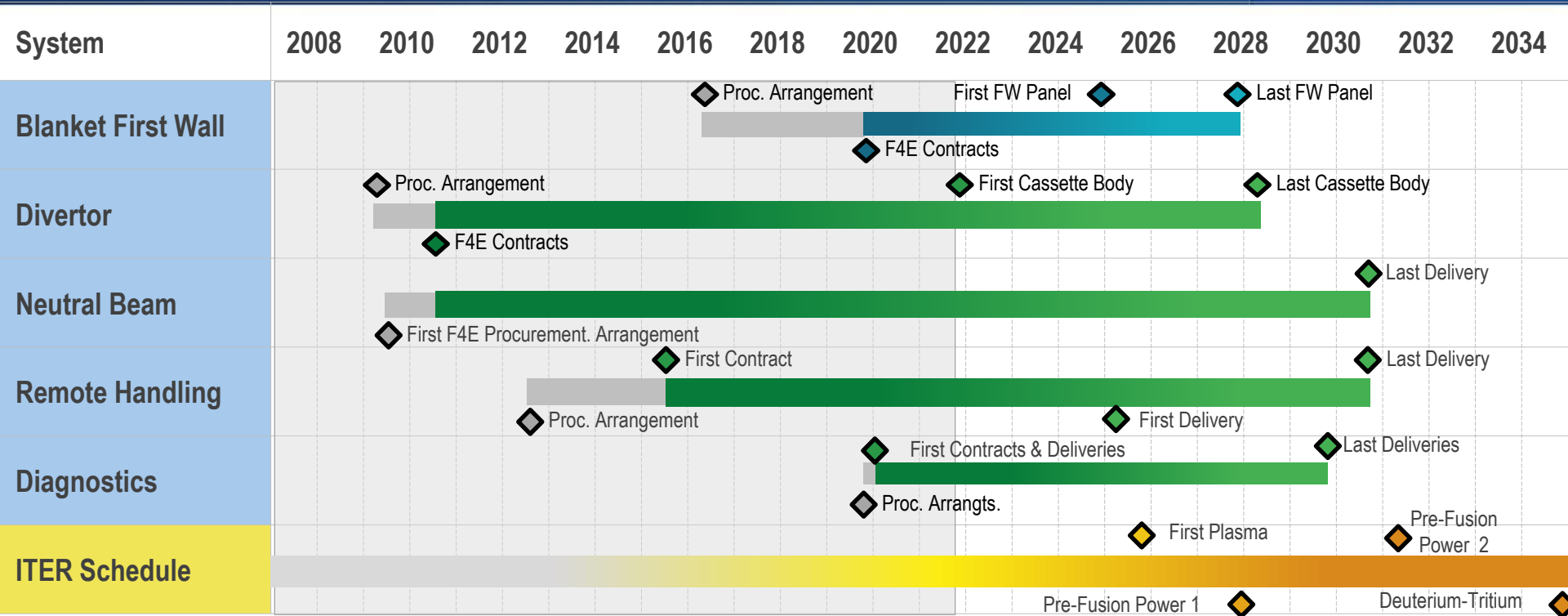
Pre-Fusion Power 1

Deuterium-Tritium

Status of EU First Plasma Systems

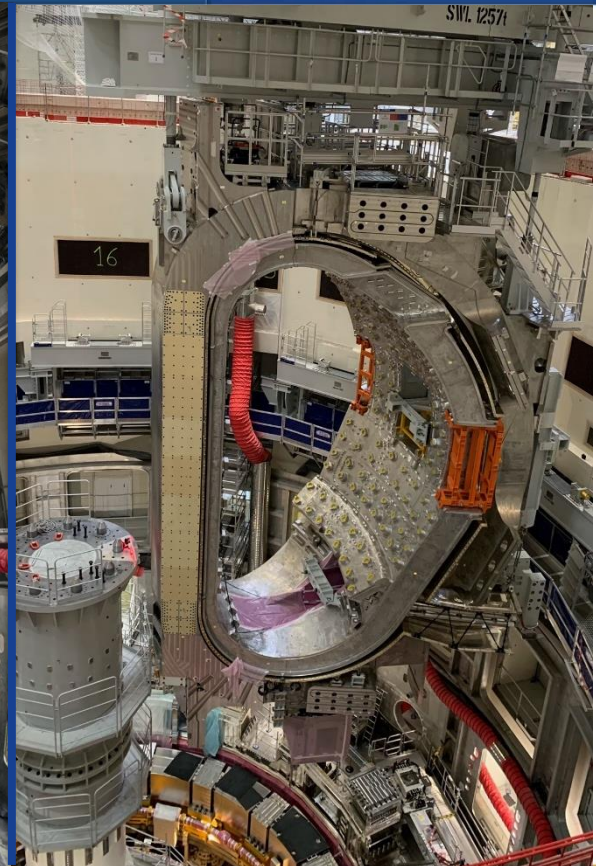


Status of EU PFP1 and PFP2 Systems



Dates under review with IO for schedule re-planning & buildings to be added (Tritium Building & Hot Cell)

Assembly of ITER is in full spin





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The European in-kind contribution



Site infrastructures

B34

B71-N

B37

Magnet Power Conversion Buildings

Cooling Plant

B47

B74

B11

B14

B44

B46

Site Services Building

Site Electrical Power Distribution

B51, B52

B45

B75

Assembly building

B15

Buildings completed & handed over to IO

Cleaning Facility building

Buildings under handing over process

PF Coil Fabrication Building

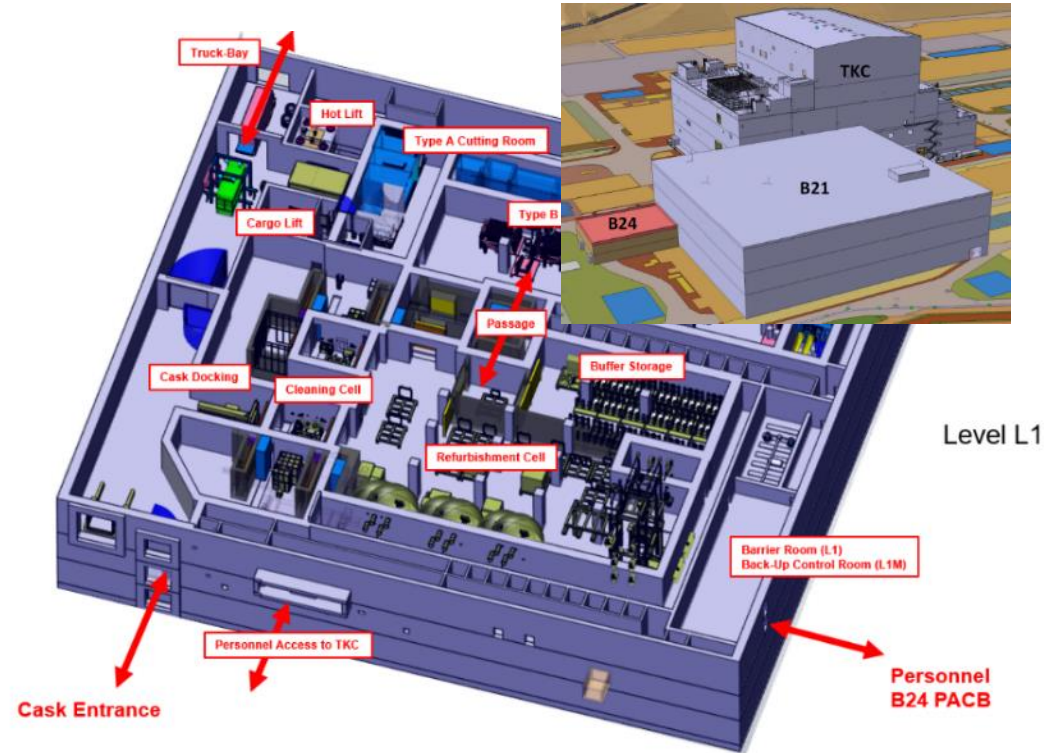
Buildings under construction

B62

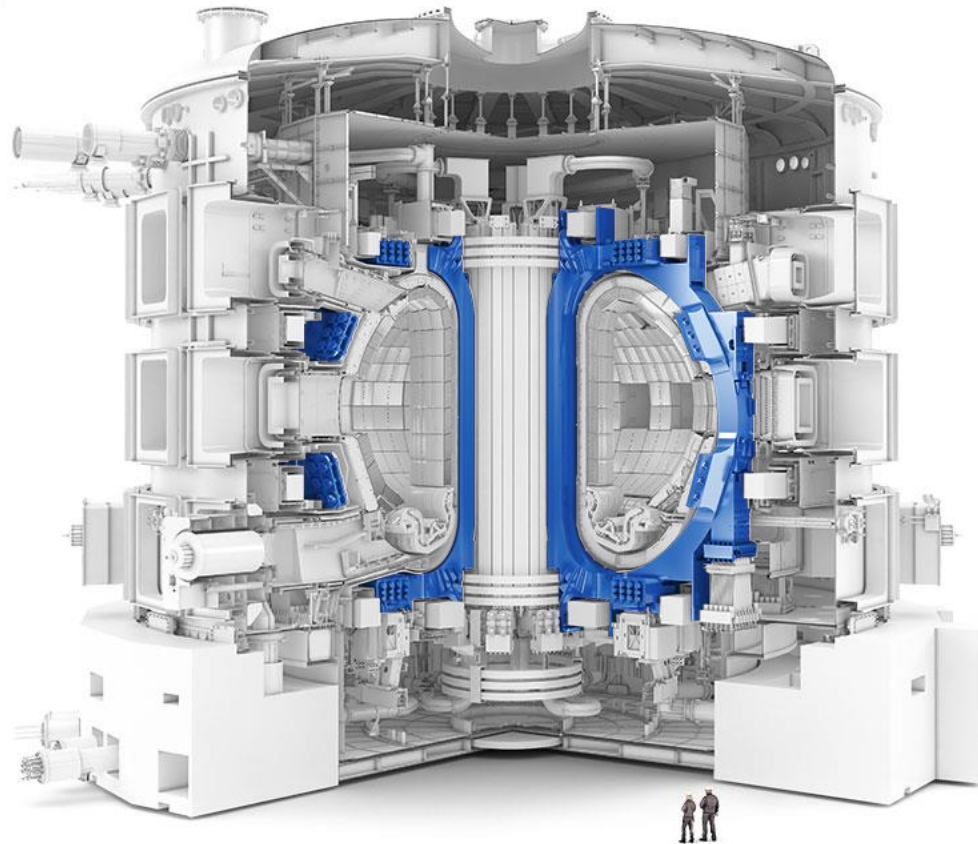
F4E & the IO working to identify optimal design for the Hot Cell Complex

Objectives:

1. Clarify requirements
2. Design the Hot Cell with the optimum size for the needs & cost effectively
3. Agree with IO & other DAs on the scope for which F4E is responsible
4. Develop a procurement strategy

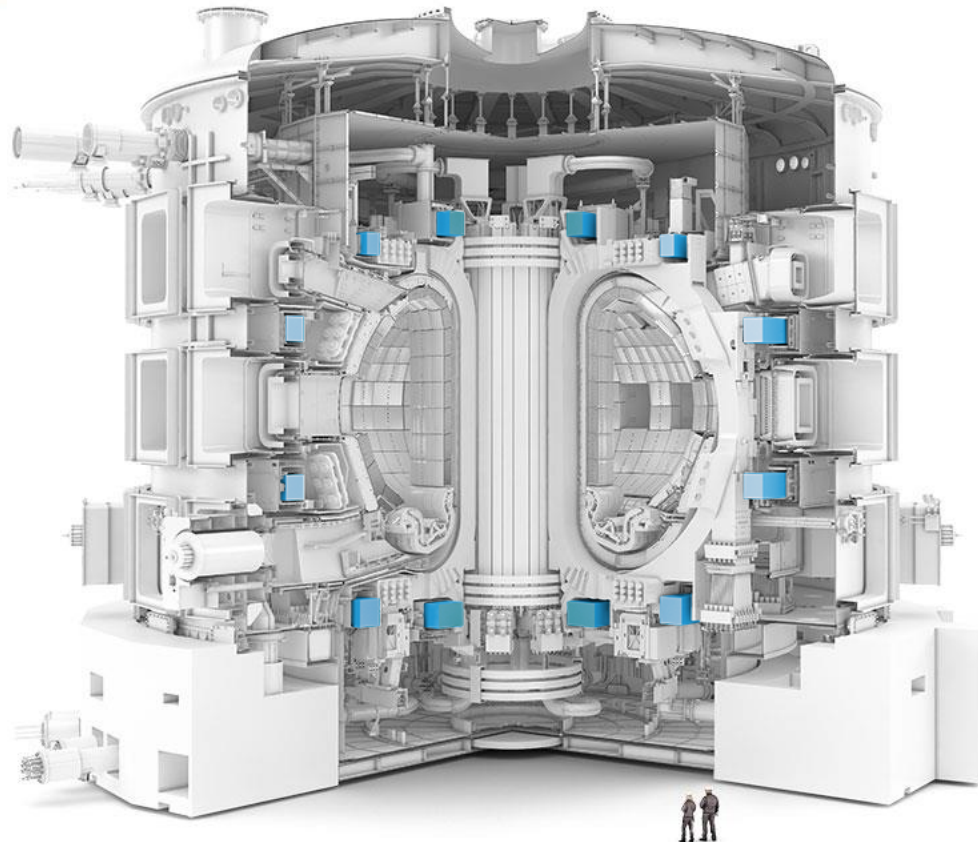


Toroidal Field Coils



Europe has delivered 7 of 10 Superconducting Magnetic Coils to ITER





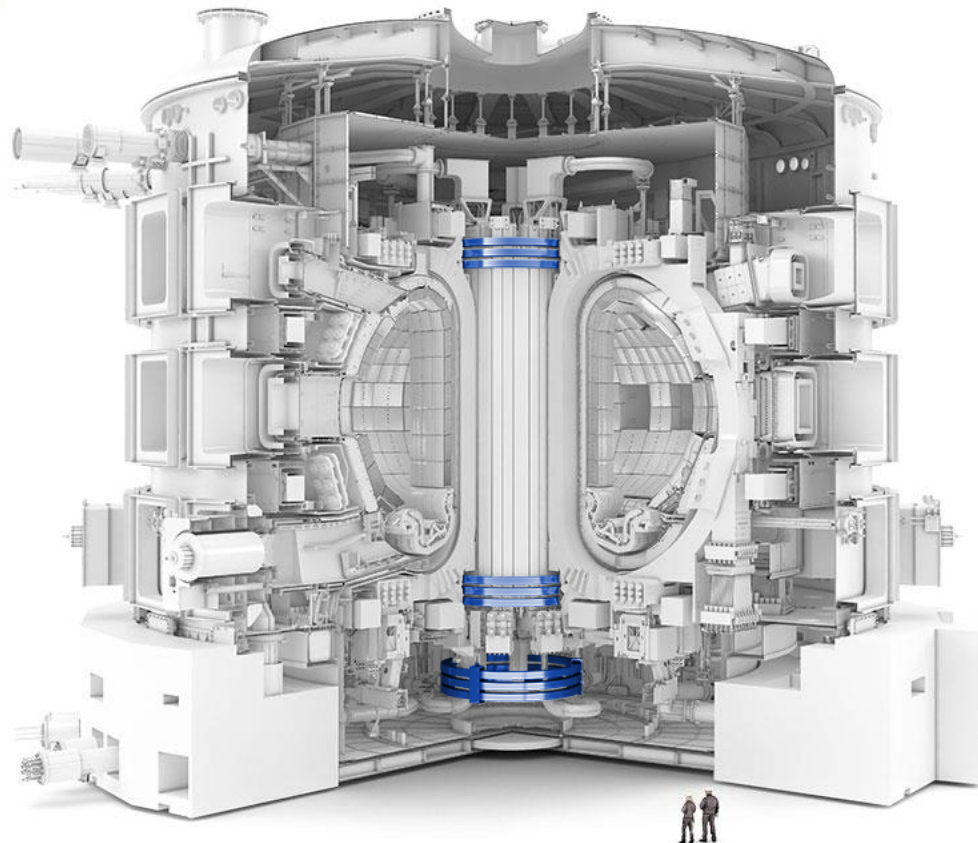
Two EU Poloidal Field Coils (#6 & #5) installed



F4E's Poloidal Field Coil Production Line



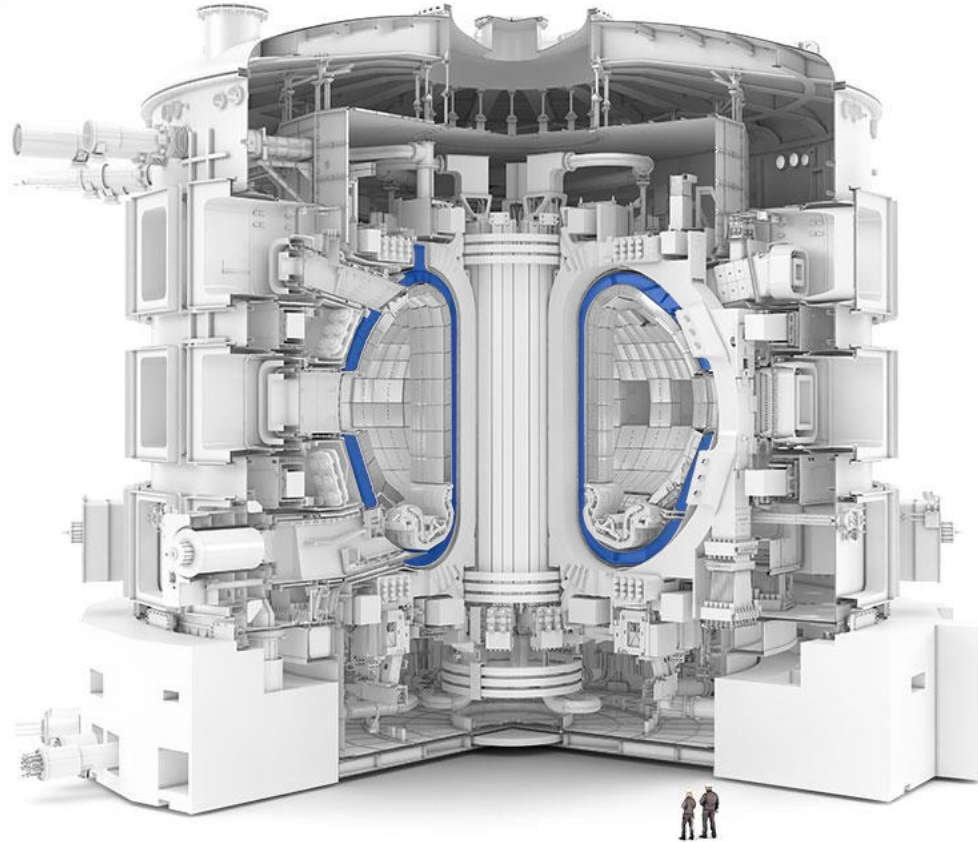
Pre-Compression Rings (PCRs)



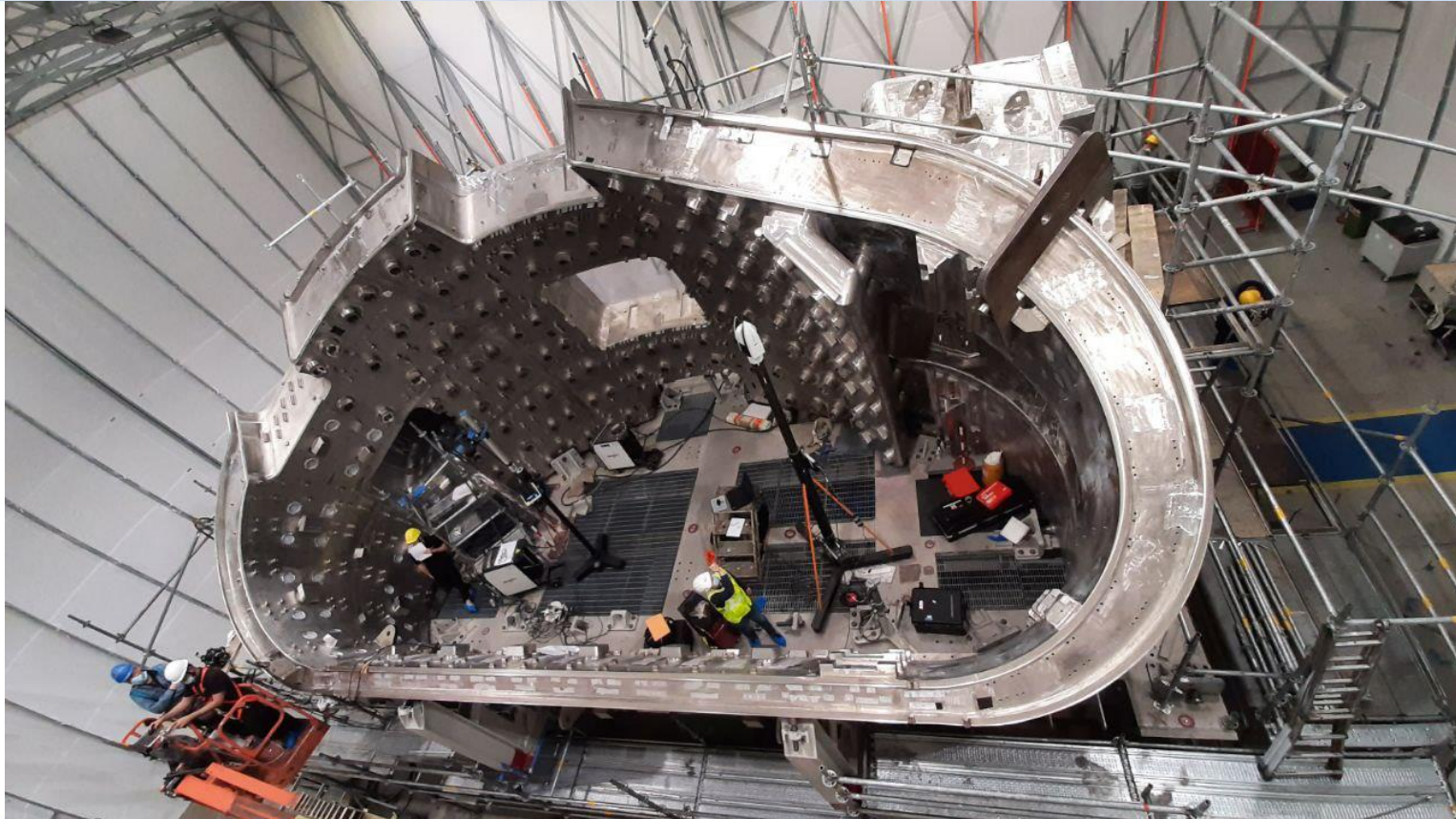
Pre-Compression Rings (PCRs) in central column



Vacuum Vessel (VV)



First EU Vacuum Vessel Sector >95% complete)



Europe completed & is commissioning the largest liquid nitrogen cooling plant in the world



Divertor Inner Vertical Target prototypes



Delivery of the European Full-Scale prototype to IO for assembly trials onto the Divertor Cassette Assembly Full Scale prototype

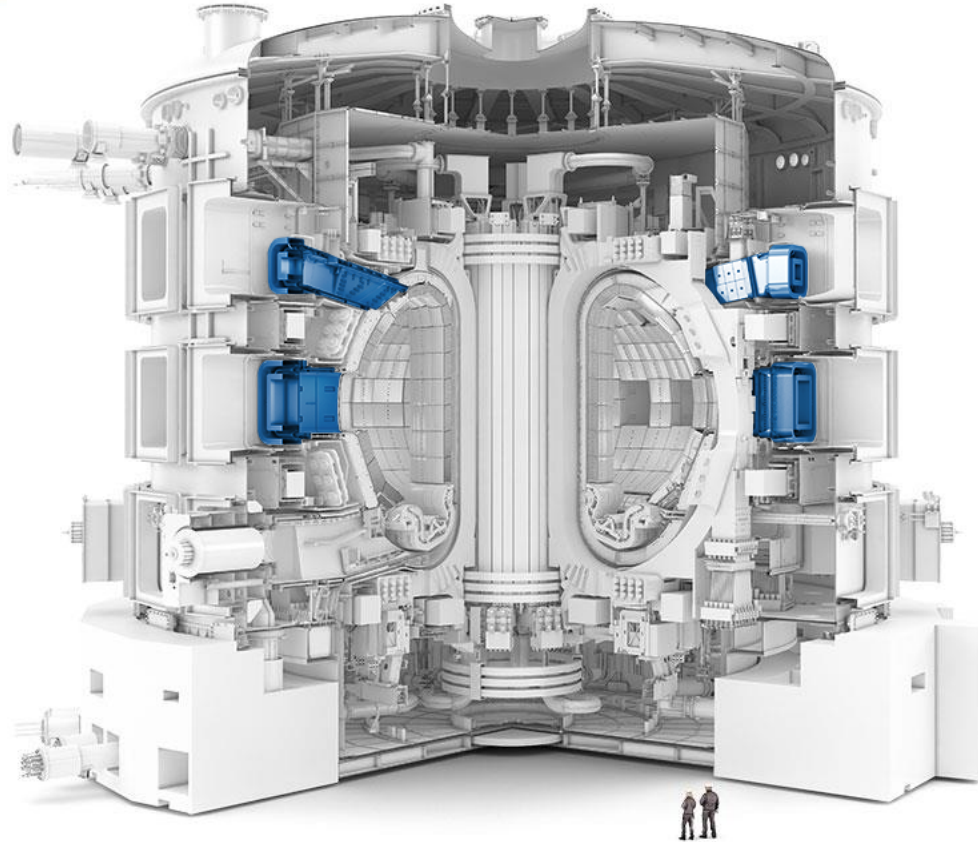


Successful High Heat Flux testing up to 20 MW/m² of the Test Assembly

58 Divertor Cassette Bodies



Neutral Beam Heating



The ITER Neutral Beam Test Facility



Padova, Italy





Grounded grid on the 15tons 90°
tilting assembly structure



Pre-assembly and testing of the grid segments



1st unit of Residual Ion Dump Power Supplies system delivered at NB Test Facility (MITICA)



- Half of the EU Electron Cyclotron Power Supply units delivered to ITER (including all First Plasma units)



Delivered so far:
175 packages,
190 tons, 800 m³



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What are we learning from ITER construction?

Known unknowns

- Technologies
- Materials
- Designs
- Scaling up of manufacturing processes

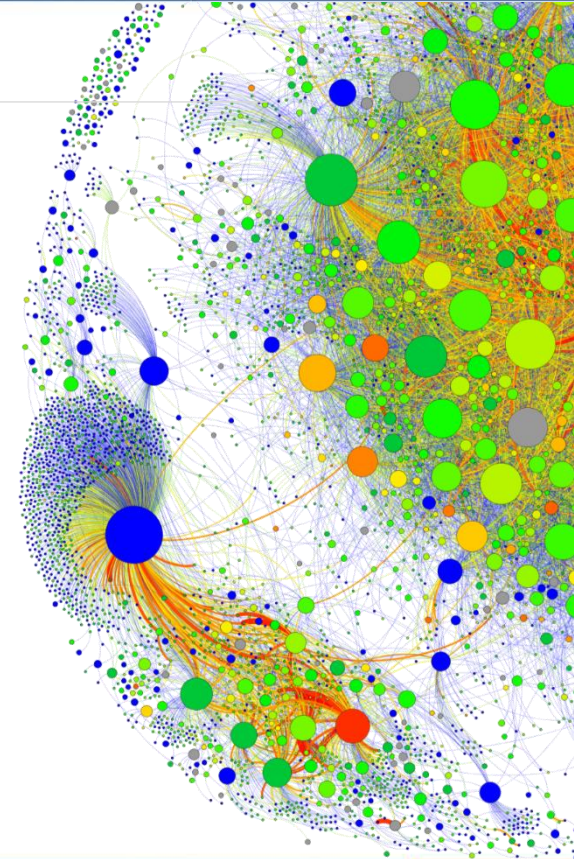


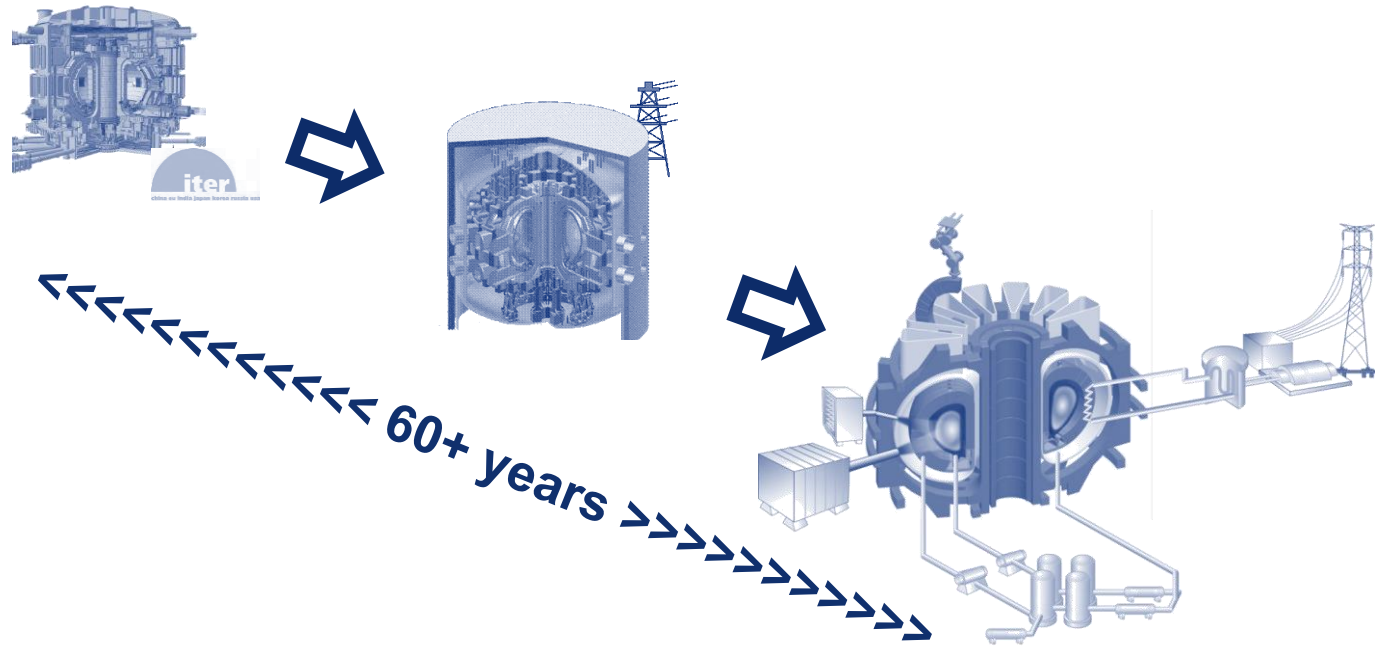
Known unknowns

- Heat loads on plasma facing components, erosion
- Long term material behaviour under neutron bombardment (irradiation at 14.1 MeV)
- Runaway electrons (efficiency and heat losses)
- Reliability/availability of high power density systems (e.g. heating)
- NDT of high thickness, multi-shell nuclear welds
- ...

Unknown unknowns

- Organizational fragmentation
- High system integration
- Nuclear regulatory aspects
- Globally dispersed supply chain





**Strategic view of developments in science,
technology, industry, management,
operations**

A wide-angle photograph of a large-scale construction site at dusk. In the foreground, a worker wearing a blue hard hat and a high-visibility yellow vest with the 'FUSION FOR ENERGY' logo stands on a metal railing, looking out over the site. The background is filled with several tall red tower cranes and a large, partially completed concrete structure. The sky is a mix of blue and orange, suggesting the time is either dawn or dusk. A semi-transparent blue rectangle is overlaid in the center of the image, containing the text 'Thank You' in a bold, yellow, sans-serif font.

Thank You



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