

# Futuri reattori a fusione

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Università degli Studi di Bologna, Dipartimento di Fisica, 28 marzo 2024

SECRET

SUMMARY OF NOTES ON LECTURES  
BY E. FERMI.

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F. B. Moon.

\*These notes and any others on this topic .....  
must continue to be classified as SECRET until  
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with the greatest discretion.

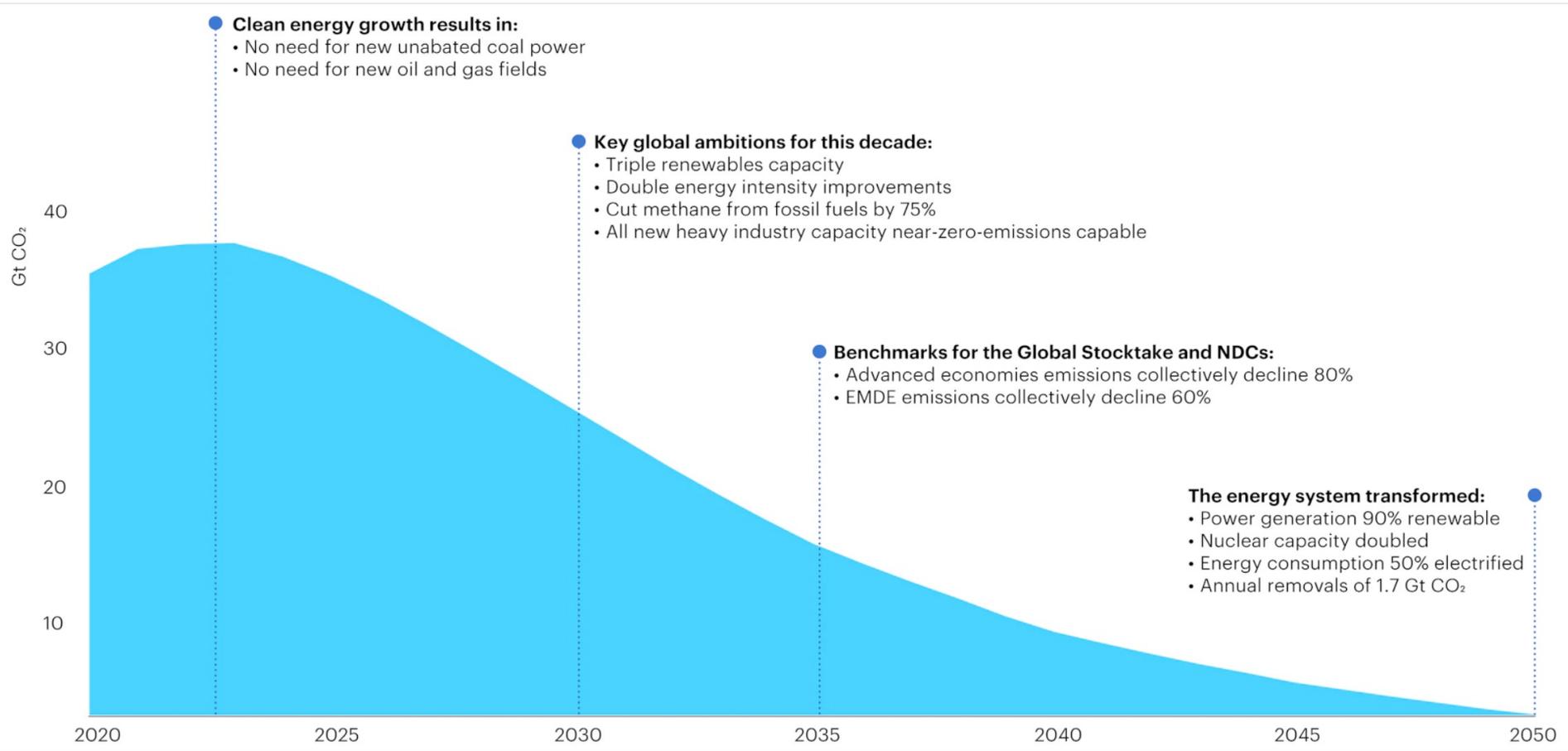
J. Chadwick.\*

Churchill Archives Centre, Churchill College, Cambridge.

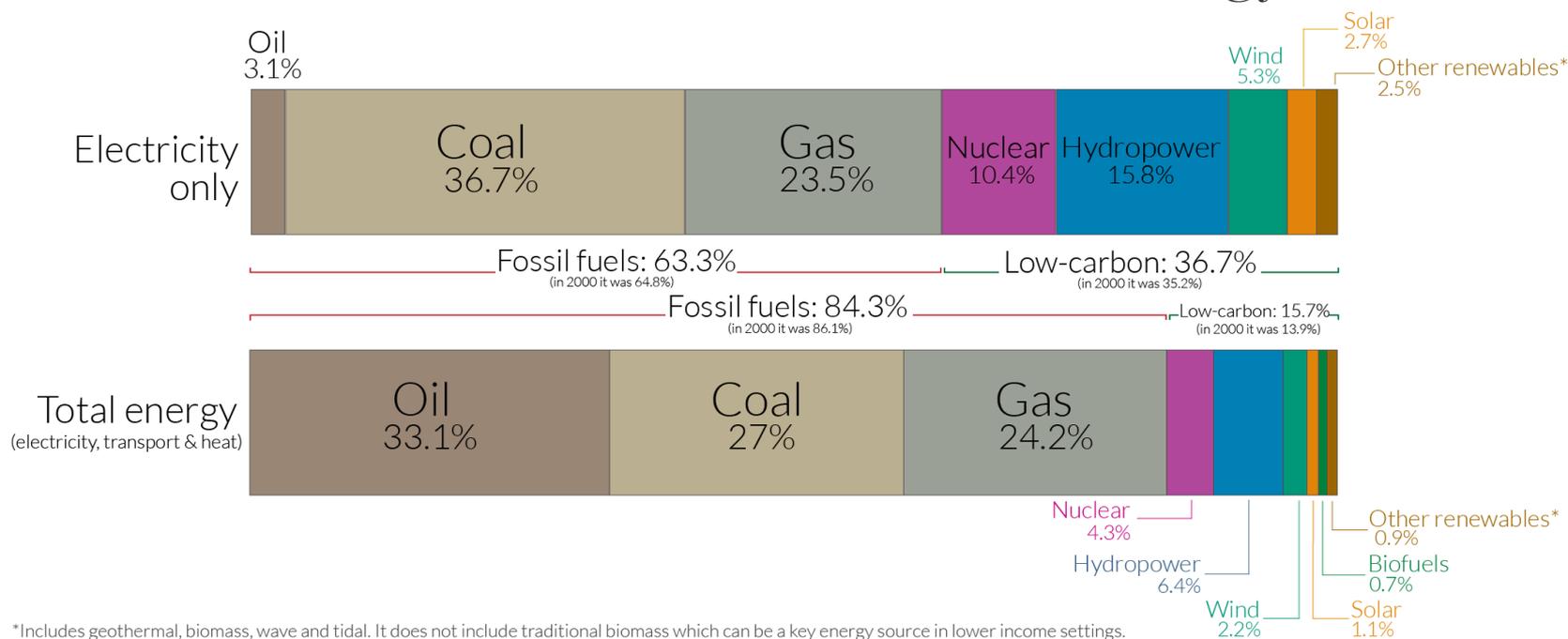
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# A roadmap to net zero by 2050



# More than one-third of global electricity comes from low-carbon sources; but a lot less of total energy does



\*Includes geothermal, biomass, wave and tidal. It does not include traditional biomass which can be a key energy source in lower income settings.

OurWorldinData.org – Research and data to make progress against the world's largest problems.

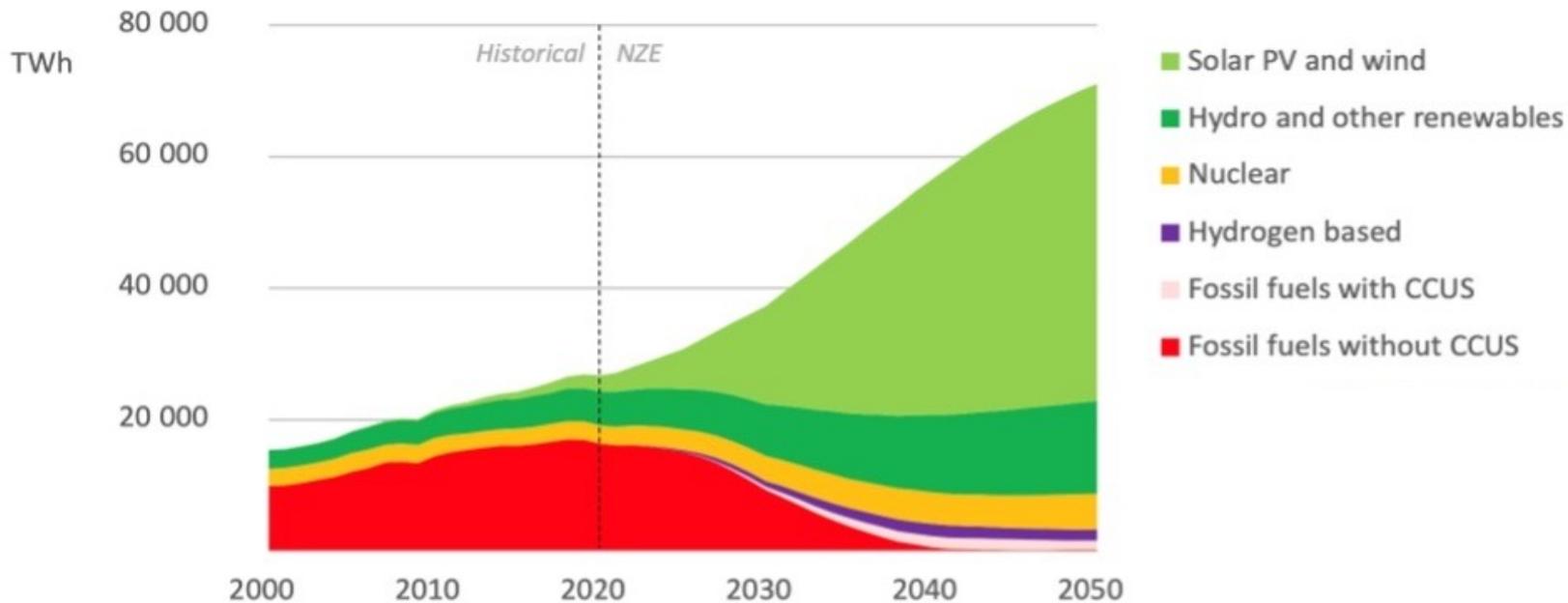
Source: Our World in Data based on BP Statistical Review of World Energy (2020). Based on the primary energy and electricity mix in 2019.

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# Energy transition needs nuclear electricity

Global electricity supply, NZE scenario

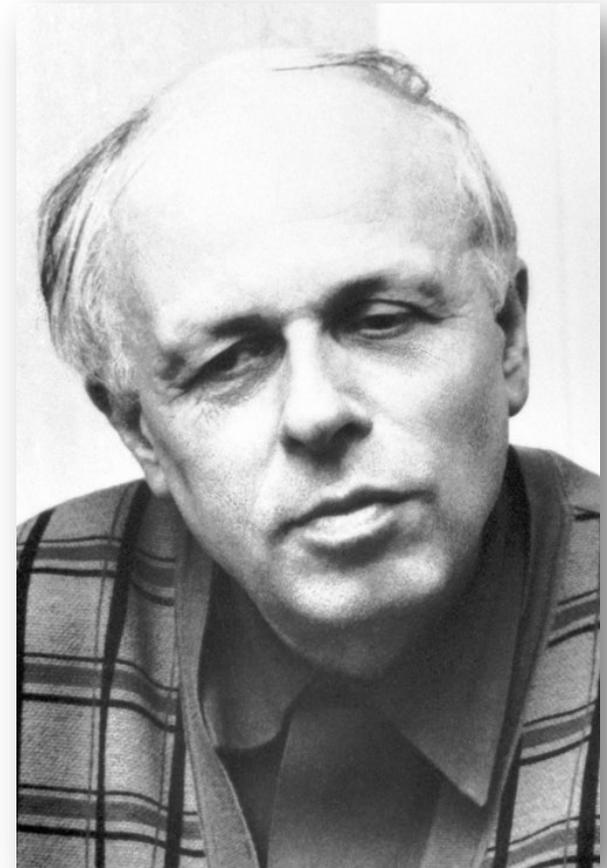
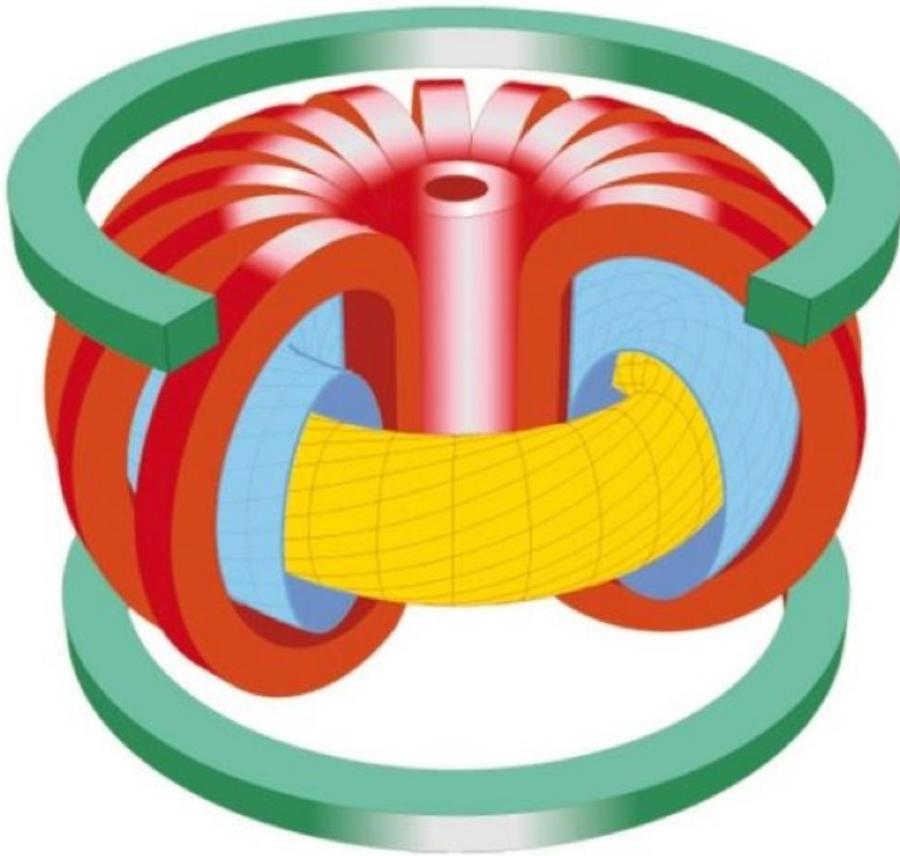


Fusion can contribute to it



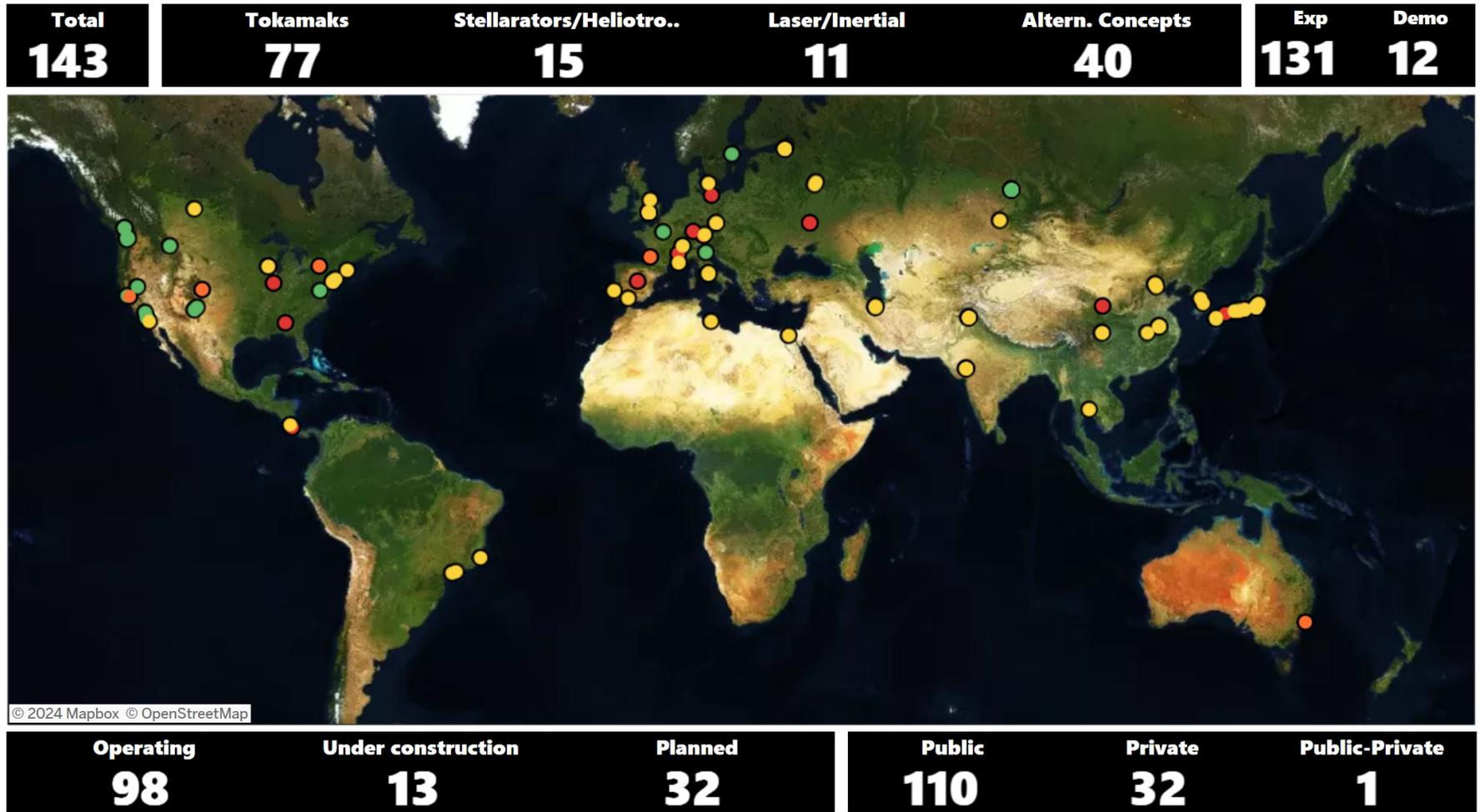
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# The tokamak concept



Andrej Dmitrievič Sacharov (1921-1989)

# Worldwide fusion program





# Renaissance of worldwide activity, e.g. US

THE WHITE HOUSE 

DECEMBER 02, 2023

## International Partnerships in a New Era of Fusion Energy Development

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COP28

## US envoy Kerry launches international nuclear fusion plan at COP28

By Valerie Volcovici

December 6, 2023 6:21 PM GMT+1 · Updated 2 months ago

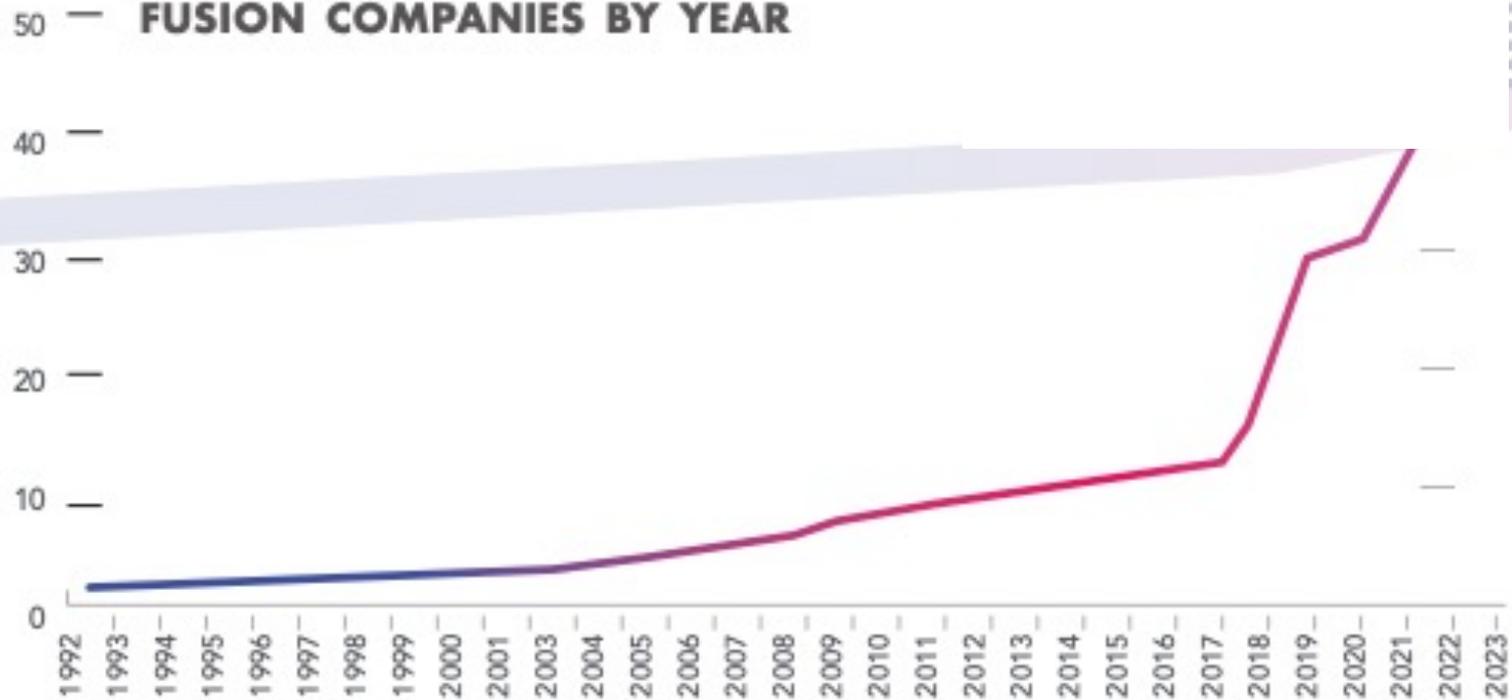
  



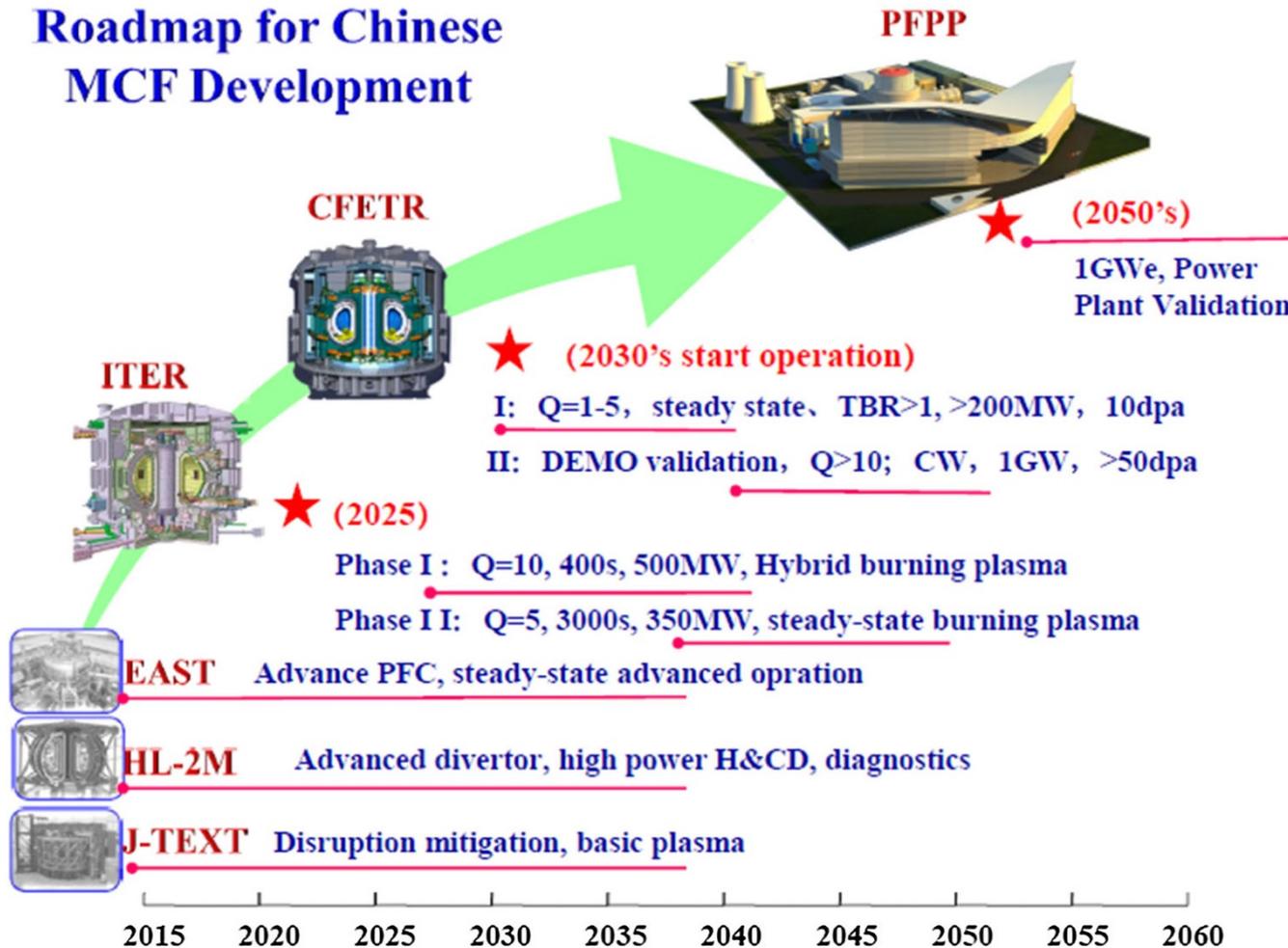


# Growing interest in fusion from private companies

**15. TOTAL NUMBER OF PRIVATE FUSION COMPANIES BY YEAR**



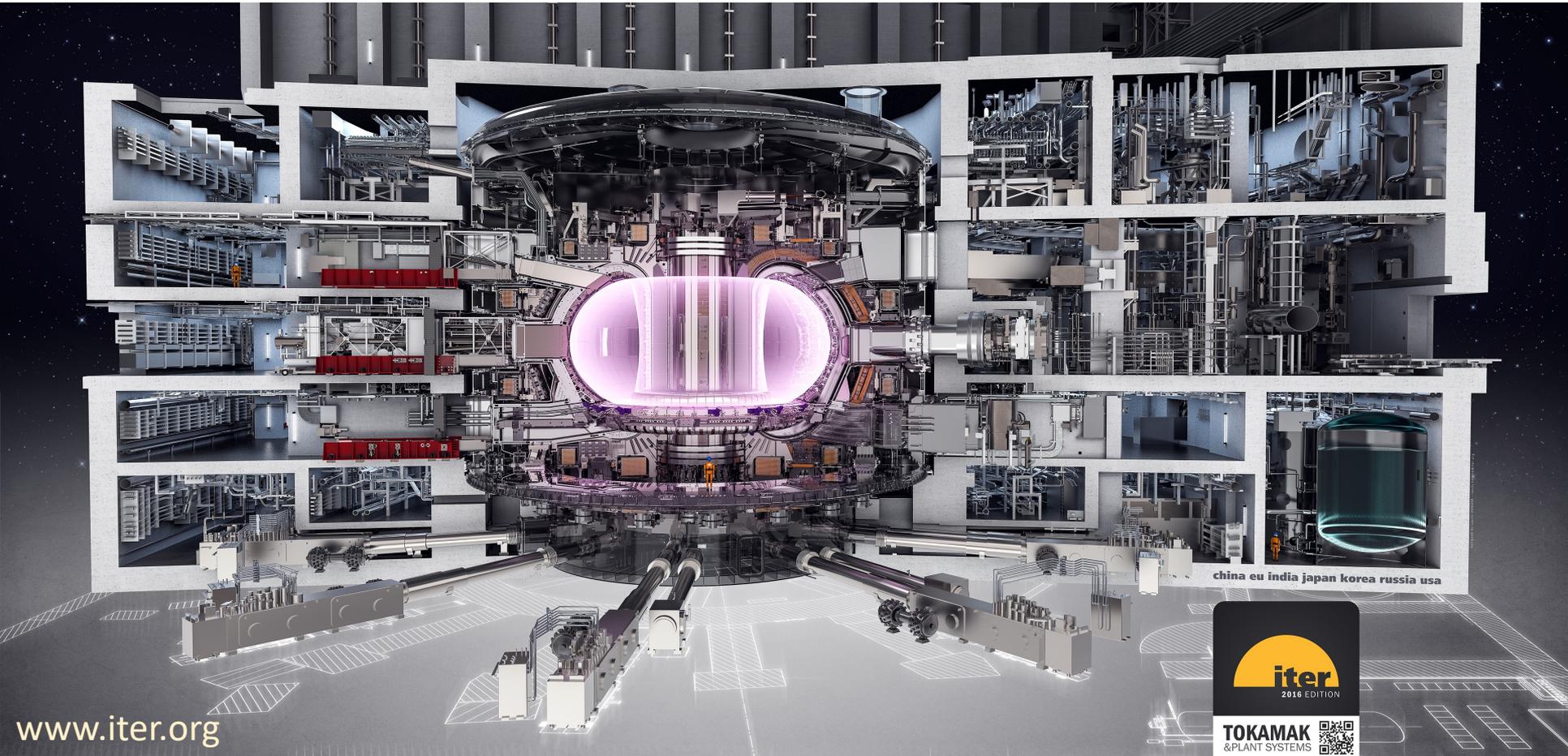
## Roadmap for Chinese MCF Development





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# ITER



china eu india japan korea russia usa



[www.iter.org](http://www.iter.org)

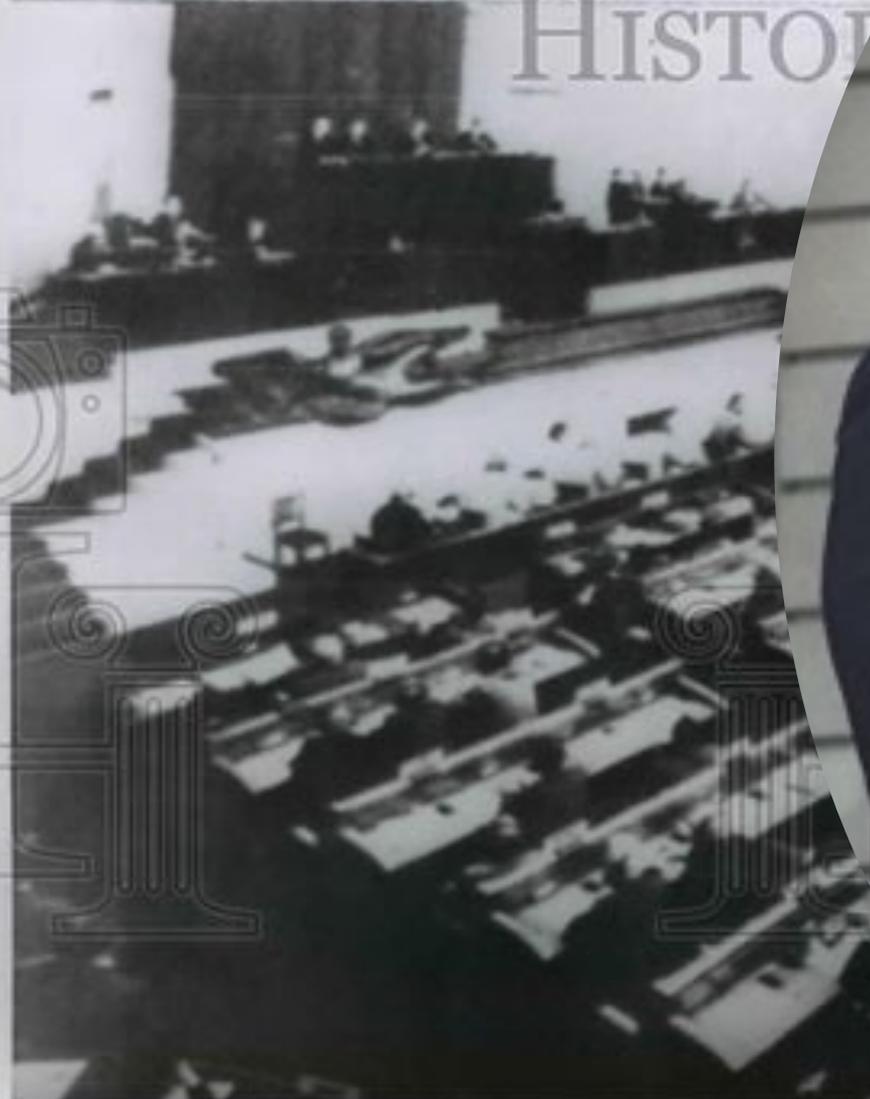


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International Atomic Energy Agency is a general view  
International Atomic Energy Conference 9/1.  
huge atomic power program for the Soviet Union  
pioneering step forward in the use of nuclear

# HISTORY





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“By mutual agreement, President of the United States Ronald Reagan and General Secretary of the Central Committee of the Communist Party of the Soviet Union Mikhail Gorbachev met in Geneva November 19 - 21.

....

### Fusion Research

The two leaders emphasized the potential importance of the work aimed at utilizing controlled thermonuclear fusion for peaceful purposes and, in this connection, **advocated the widest practicable development of international cooperation in obtaining this source of energy**, which is essentially inexhaustible, for the benefit for all mankind.”

*From the Joint statement after the meeting*

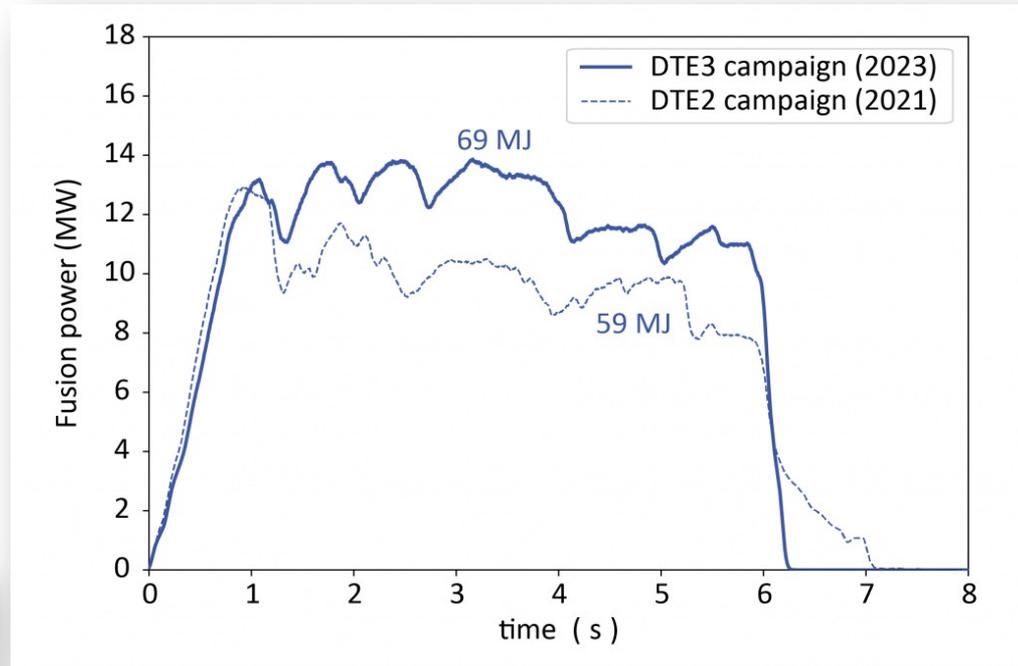
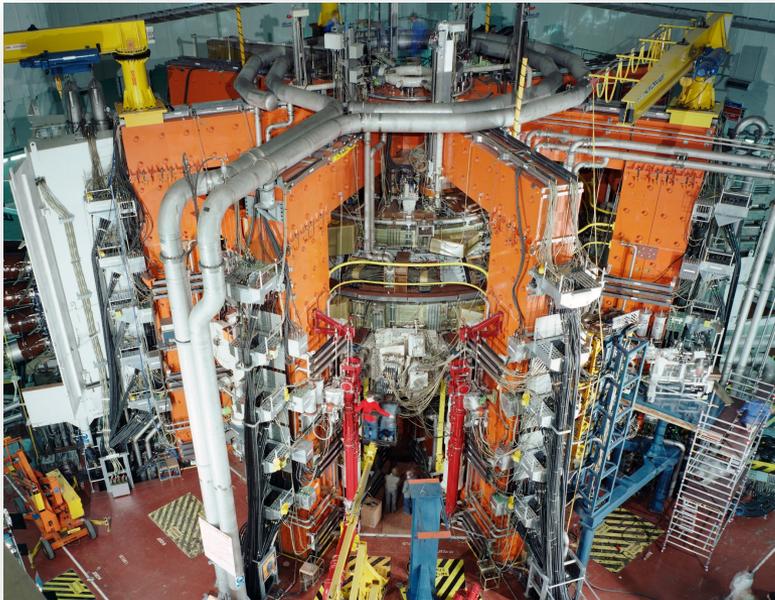
# 1985 Geneva





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# JET

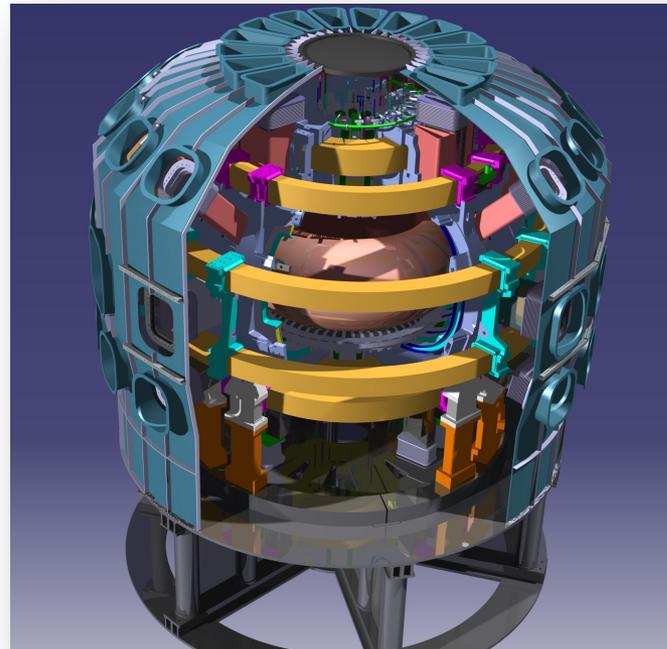




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# Made in Italy: Divertor Tokamak Test facility (DTT)

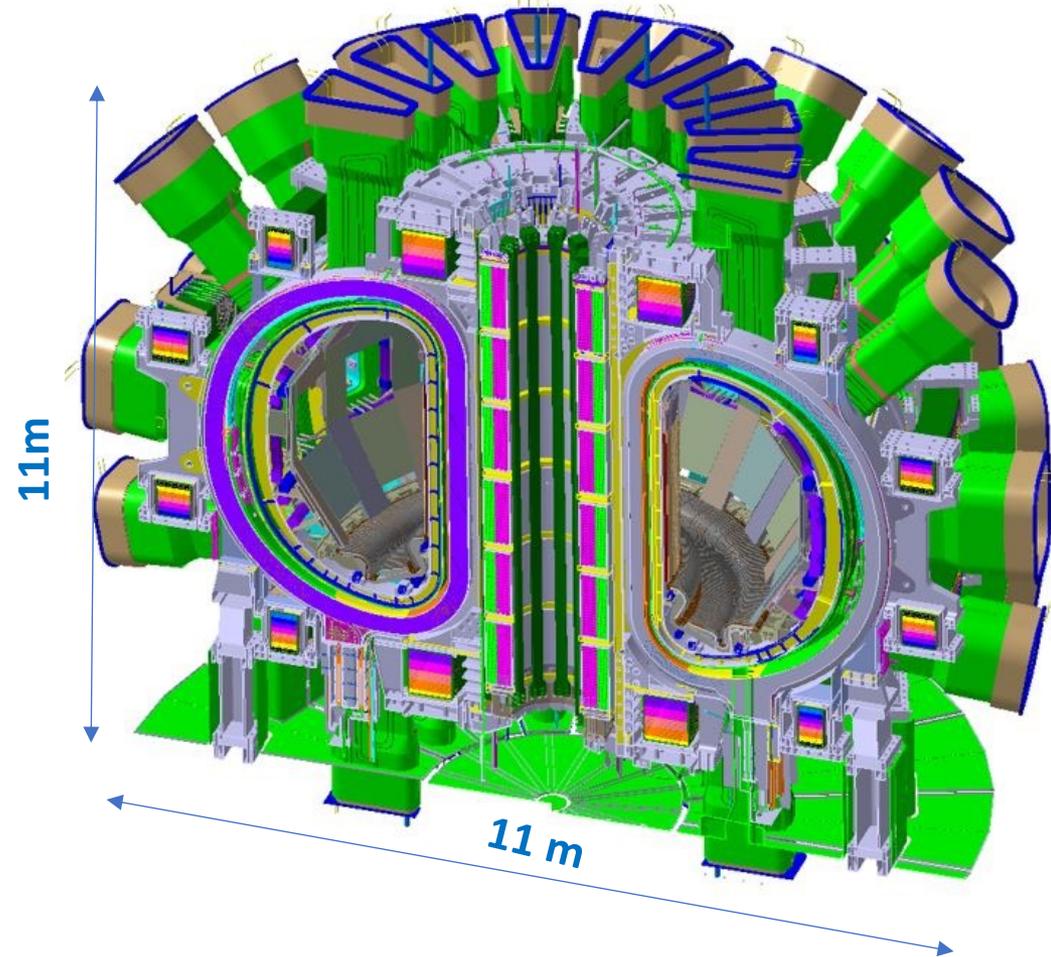
Under construction in the Enea Frascati site  
Public-private enterprise  
first of its kind

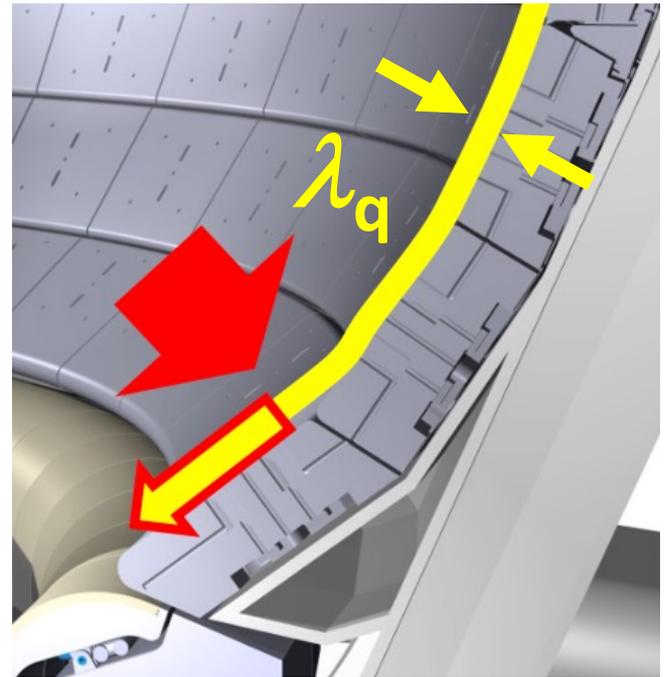
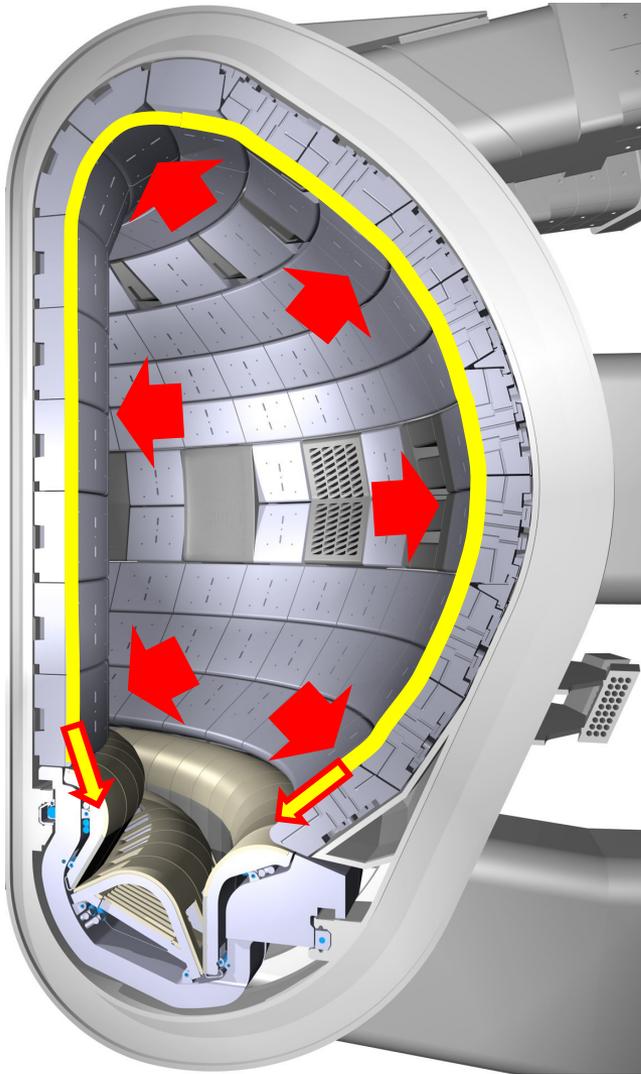




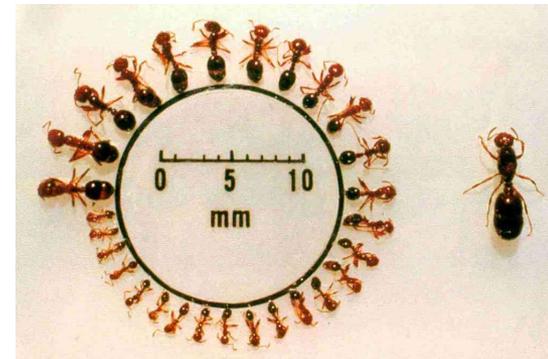
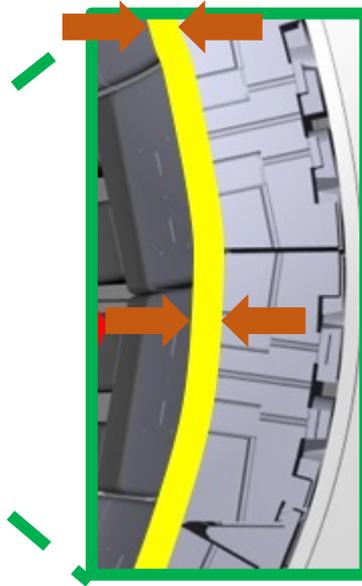
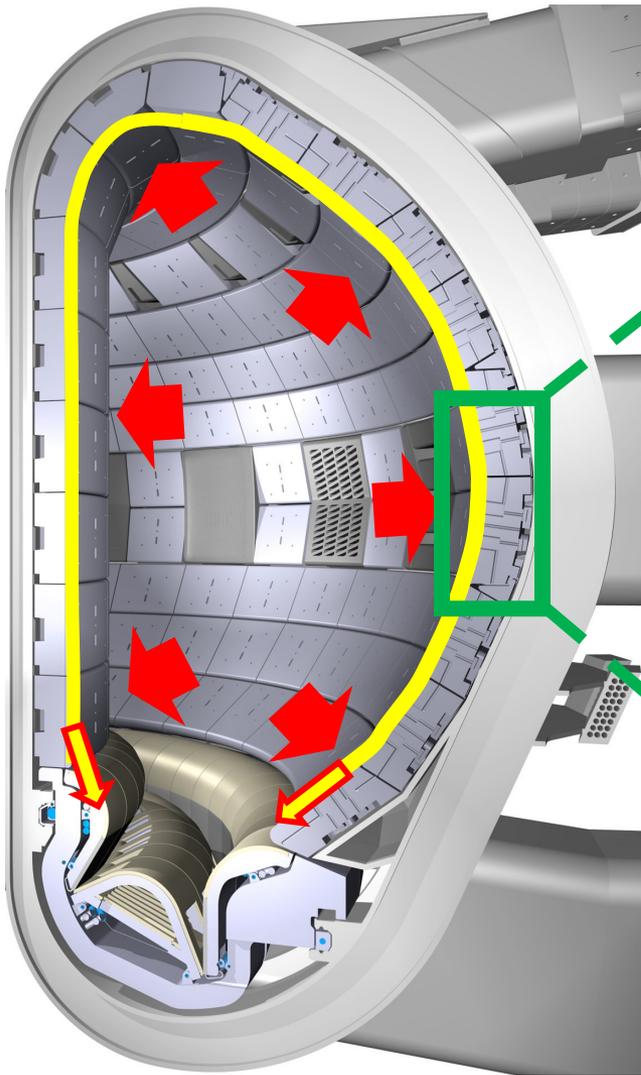
# DTT under construction in Frascati, Italy

	DTT
R (m)	2.19
$\alpha$ (m)	0.7
$I_p$ (MA)	5.5
B (T)	6
Heating P (MW)	45
$P_{sep}/R$ (MW/m)	15
$\lambda_q$ (mm)	0.7
Pulse length (s)	100





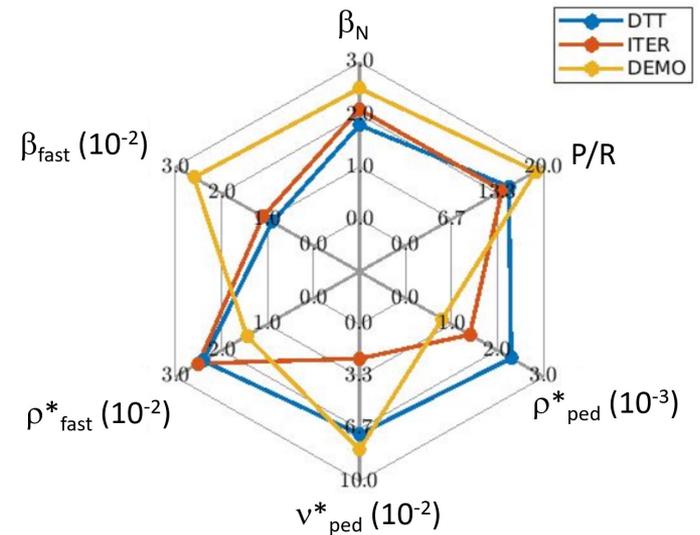
Worst case scenario for divertor  
 $\lambda_q \sim 1$  mm ITER



Wall surface  $\sim 850$  m<sup>2</sup>  $\rightarrow$  Effective surface 1-2 m<sup>2</sup>



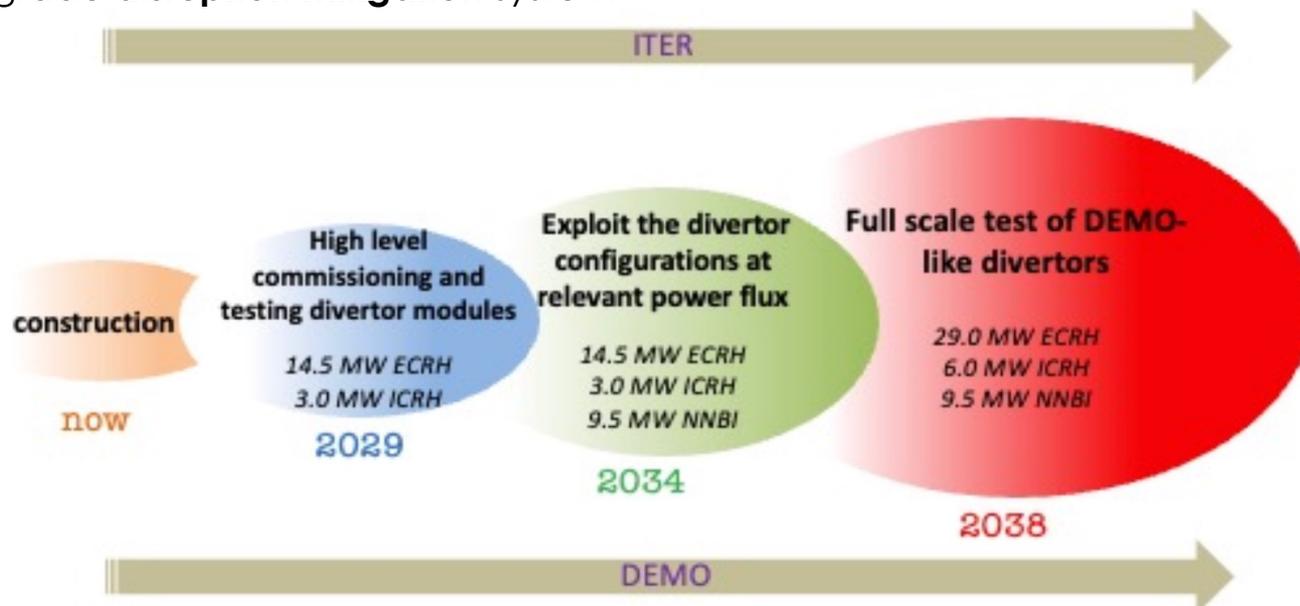
	DTT	ITER	DEMO
R (m)	<b>2.19</b>	6.2	9.1
a (m)	<b>0.7</b>	2	2.93
I <sub>p</sub> (MA)	<b>5.5</b>	15	19.6
<b>B (T)</b>	<b>6</b>	<b>5.3</b>	<b>5.7</b>
<b>Heating P (MW)</b>	<b>45</b>	50	>50
<b>P<sub>sep</sub> /R (MW/m)</b>	<b>15</b>	14	17
λ <sub>q</sub> (mm)	<b>0.7</b>	0.9	1.0
<b>Pulse length (s)</b>	<b>100</b>	400	7600



# DTT design features



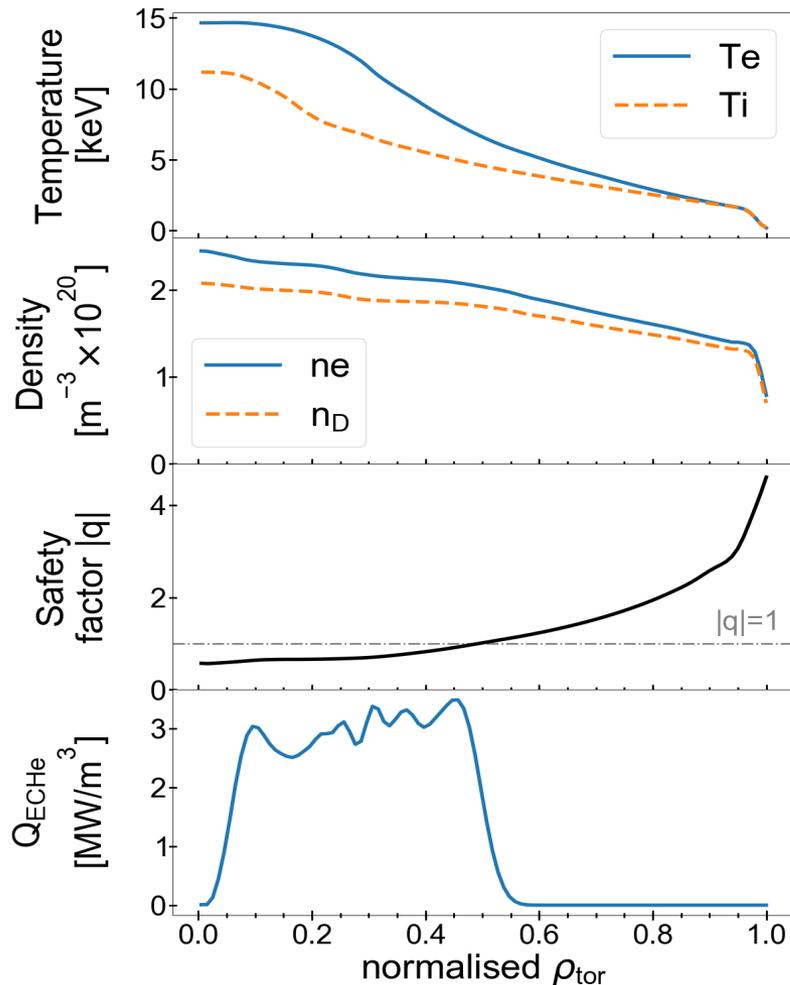
- **full W** plasma facing components
- **flexible divertor**: possibility of operation at vastly different magnetic configurations
- interchangeable **test divertor modules** to study alternative shapings and materials
- **long pulse** capability
- **3 heating systems** (ECRH, ICRH and N-NBI)
- As in a reactor, dominant **electron heating**, **no torque** and relevant **energetic ion population**
- operation and plasma heating at nominal field (**low beta**) and at half field (**high beta, to explore advanced scenarios**)
- **internal magnetic coils** for MHD control
- reactor-grade **disruption mitigation** system





# Simulations of DTT plasma scenarios

E1 scenario (with Ne)



## Methodology

Integration with Scrape-Off Layer

—  $n_{e,\text{sep}} = 0.8 \times 10^{20}/\text{m}^3$

—  $T_{\text{sep}} = 130 \text{ eV}$

— Ar or Ne as **seeding gas**

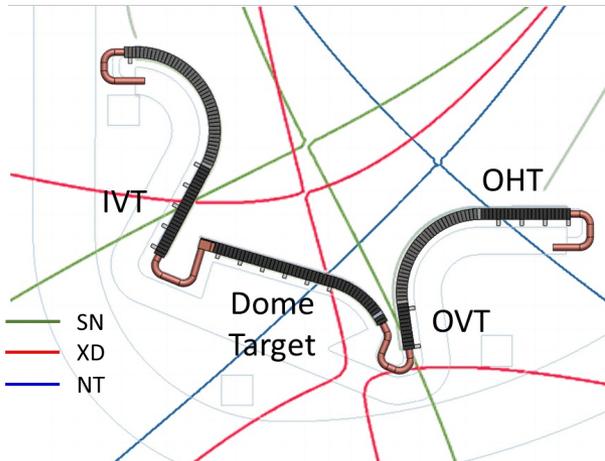
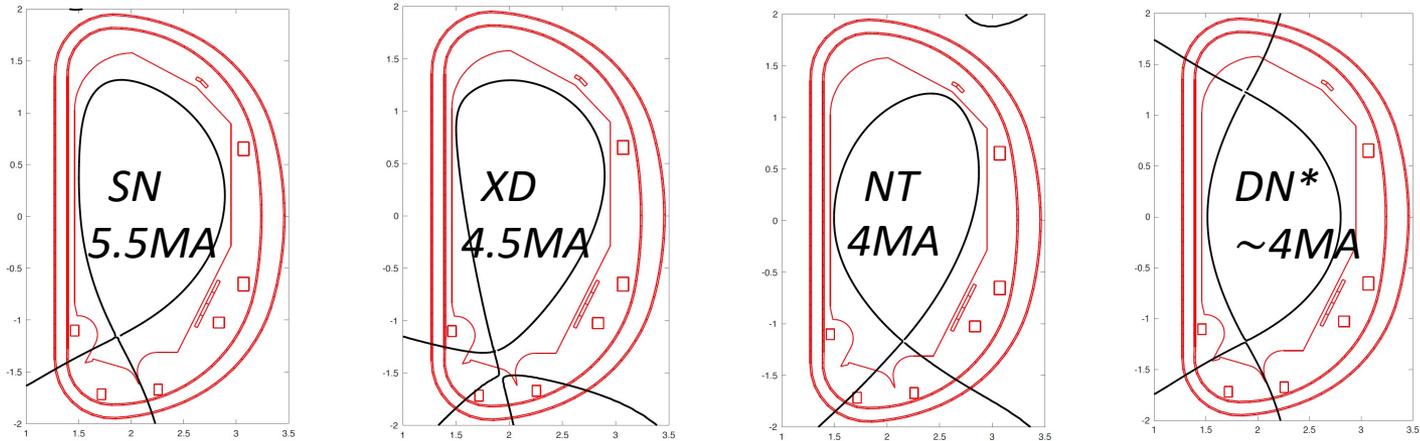
Consistency with control coil system capabilities

Good agreement between the QL models TGLF vs QLK

- **Te > Ti over most of plasma radius**
- **Neutron rate  $\lesssim 1.2 \times 10^{17}$  neutrons/s**
- **$H_{98} = 0.8-1.0$ ,  $\tau_E = (0.41-0.45)\text{s}$ ,  $\beta_{N_{\text{tot}}} = 1.3-1.6$**



# DTT: flexibility is a major guideline



# DTT Research Plan activity



DTT-RP workshop – <b>130 participants</b> (30 non-Italian institutes)	8 July 2022
Call for participation in DTT-RP activity	July-Sept. 2022
Call output: <b>~90 participants</b> (half non-Italian)	
<b>Kick-off</b> meeting of the DTT-RP Team (ROs+coordinators)	Nov. 2022
2nd meeting of the DTT-RP Team (in person)	26-28 Apr. 2023
<b>Report for the EU facility review</b>	June 2023
Drafts of the DTT-RP chapters	Nov. 2023
3rd meeting of the DTT-RP Team (in person)	Nov. 2023
<b>First draft</b> of the DTT-RP	Dec. 2023
4th meeting of the DTT-RP Team (in person)	Feb. 2024
<b>DTT-RP version 1 issued</b>	March 2024

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# Solo una ridotta quota di Italiani è a conoscenza delle nuove tecnologie nel campo del nucleare civile

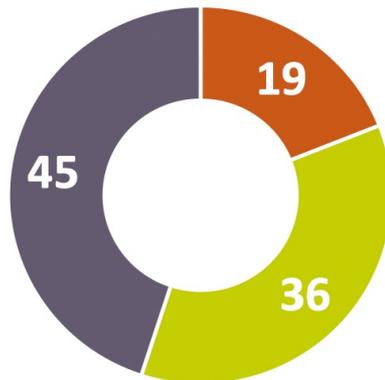
Lei ha sentito parlare delle seguenti tecnologie nel campo della produzione dell'energia?

SÌ, NE SONO A  
CONOSCENZA

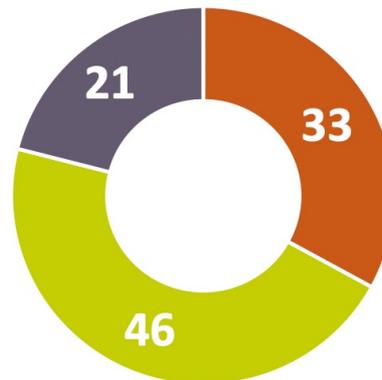
NE HO SENTITO PARLARE MA  
NON SO DI COSA SI TRATTI

NO, NON NE HO MAI  
SENTITO PARLARE

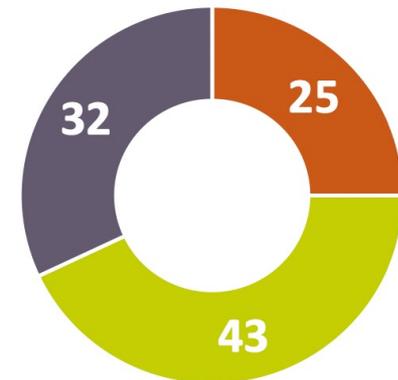
REATTORI SMR



REATTORI NUCLEARI DI  
QUARTA GENERAZIONE

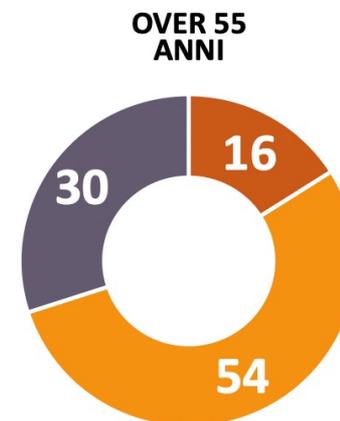
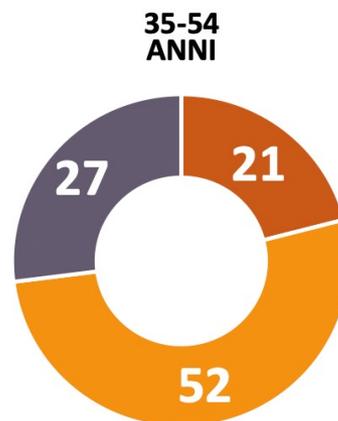
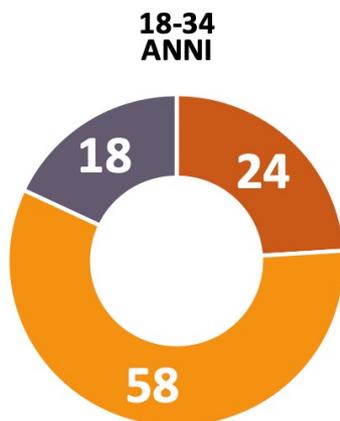
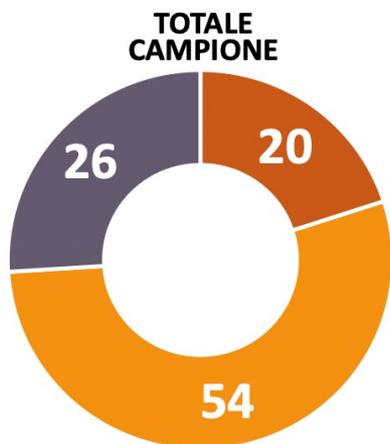


REATTORI A FUSIONE  
NUCLEARE



# Solo 1 italiano su 4 è apertamente contrario alle nuove centrali. I giovani i più favorevoli

Favore o contrarietà alla costruzione di nuove centrali nucleari in Italia per età degli intervistati.





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### Archivio delle notizie

## Indagine conoscitiva su energia prodotta mediante fusione nucleare: in Commissione 8a

12 Marzo 2024

### Sintesi dei lavori in Commissione Ambiente e Lavori pubblici:

[Martedì 20 febbraio](#), approvata proposta di indagine conoscitiva in materia di energia prodotta mediante fusione nucleare.

#### Audizioni:

mercoledì 6 marzo:  
rappresentanti dell'Associazione Italiana Nucleare e dell'ENEA ([video](#)).

martedì 12 marzo:  
rappresentanti di DTT S.C.ar.l. ([video](#))

martedì 26 marzo:  
Piero Martin e rappresentanti del Consiglio nazionale delle ricerche (CNR) ([video](#))

» [Le notizie del giorno](#)



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# Made in Italy: Divertor Tokamak Test facility (DTT)

Under construction in the Enea Frascati site  
Public-private enterprise  
first of its kind

