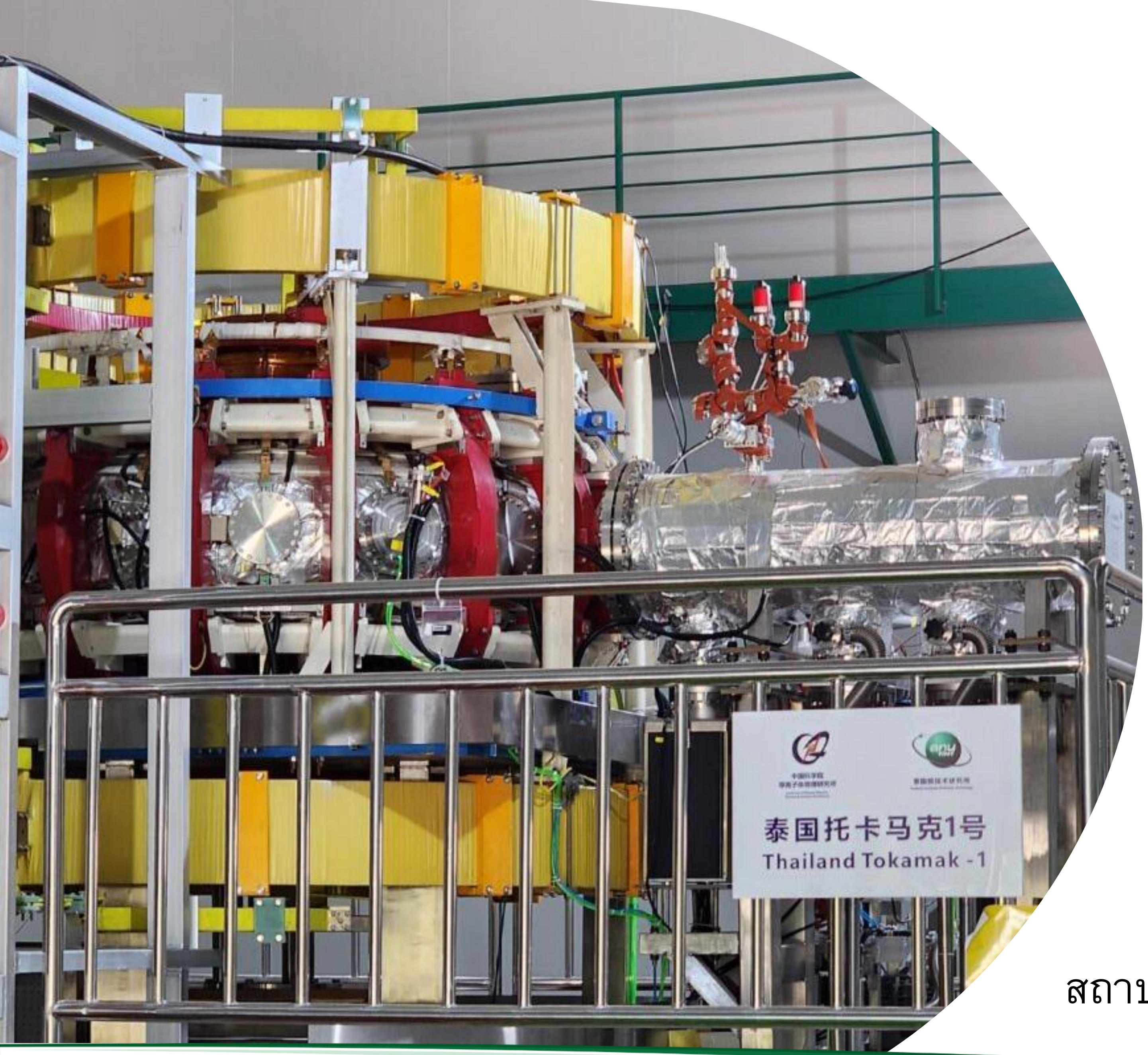


เทคโนโลยี SMR และฟิวชัน

พลังงานสะอาดแห่งอนาคต

ดร.นพพร พูลยรัตน์

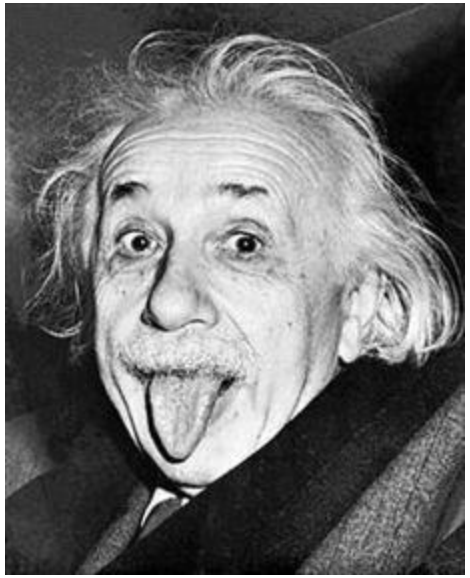
หัวหน้าฝ่ายนิวเคลียร์ฟิวชันและพลาสมา

สถาบันเทคโนโลยีนิวเคลียร์แห่งชาติ (องค์การมหาชน)

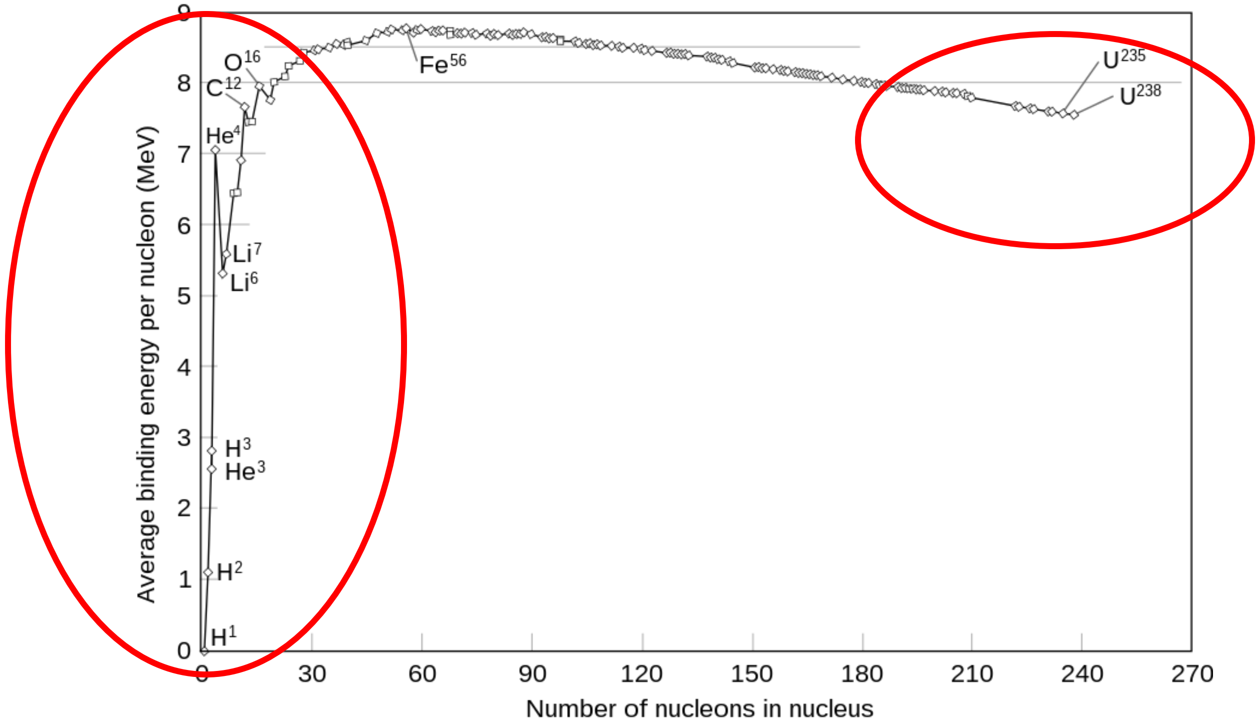
Nuclear Energy

- Nuclear energy is a form energy released from nucleus.
- A released energy is equivalent to mass defect × [speed of light]^2

$$E = mc^2$$



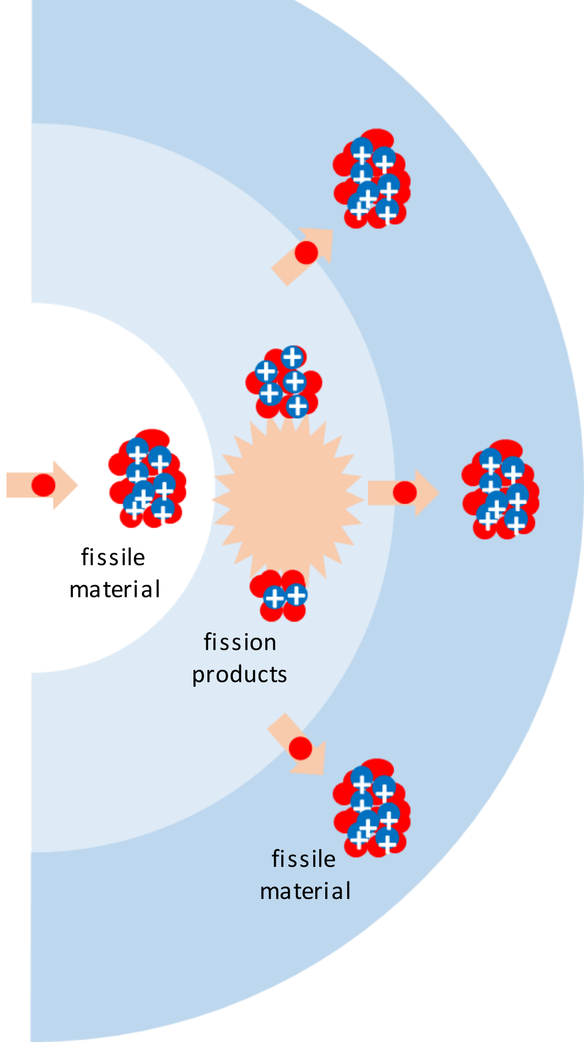
Nuclear Binding Energy



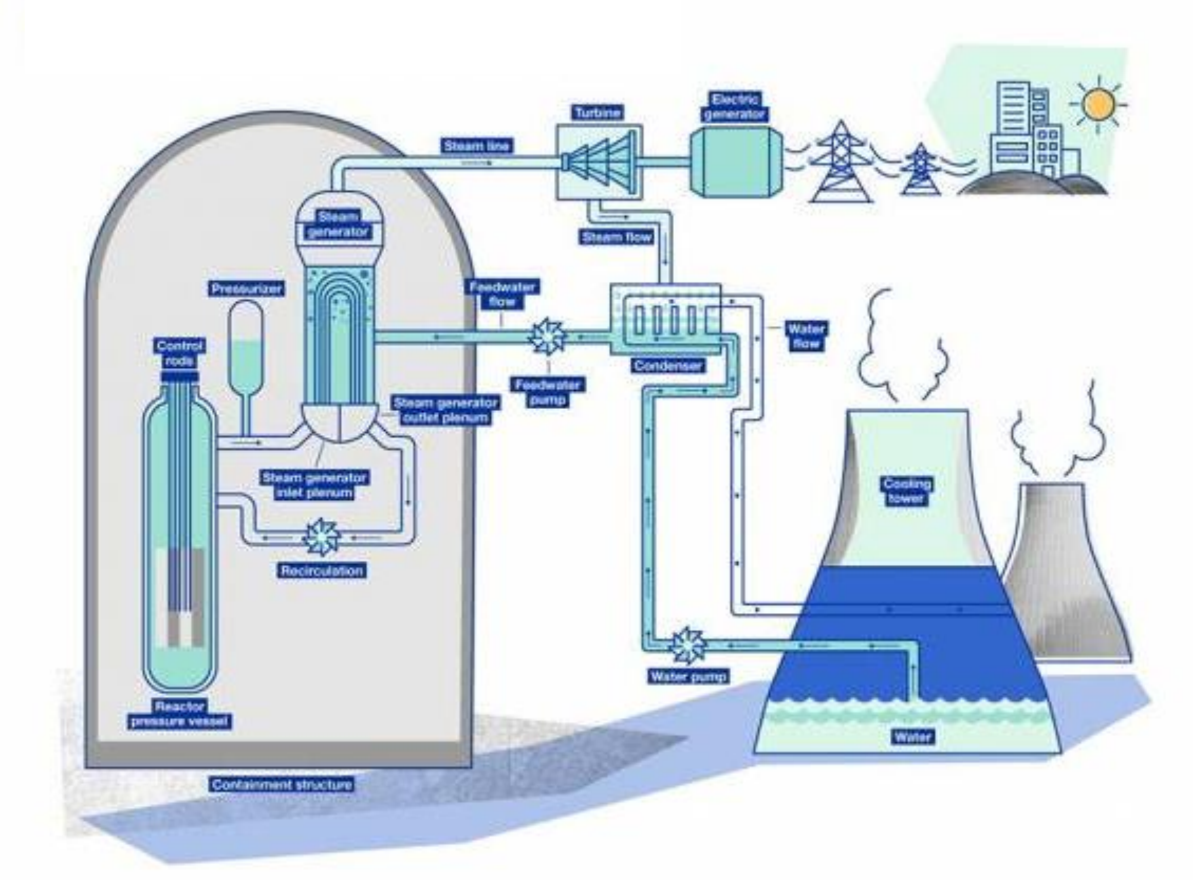
https://en.wikipedia.org/wiki/Nuclear_binding_energy

Fission

Nuclear Fission

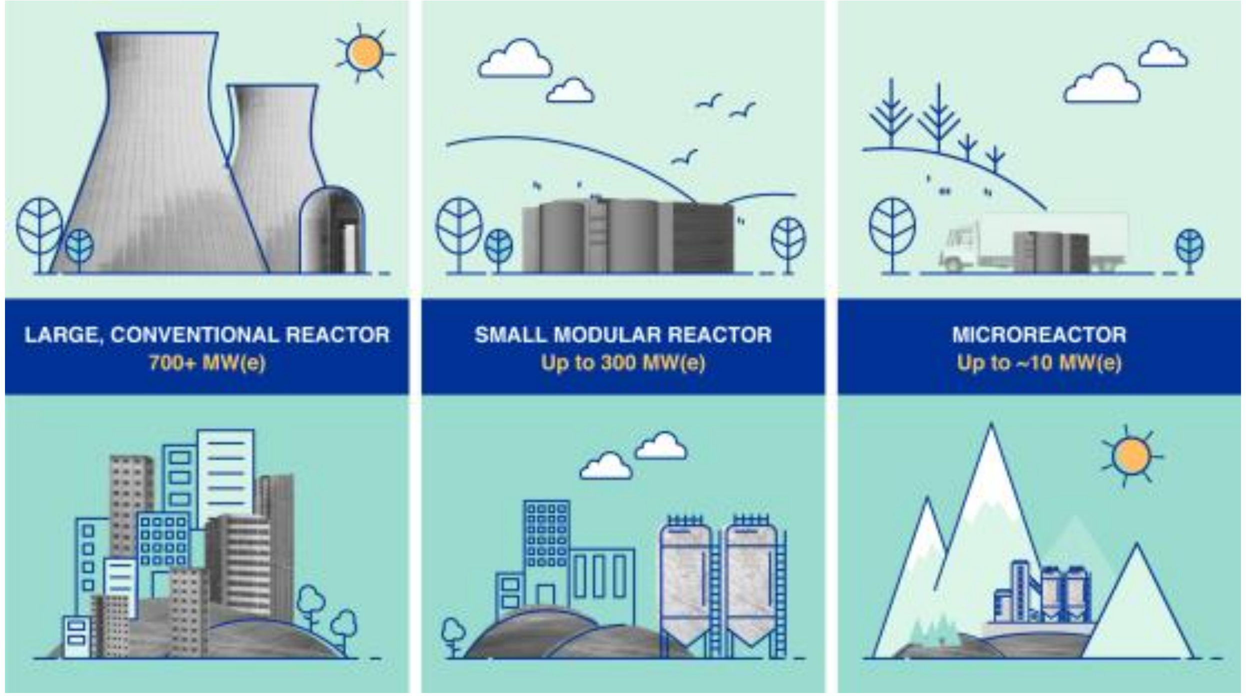


Nuclear Power Plant



https://www.iaea.org/newscenter/news/what-is-nuclear-energy-the-science-of-nuclear-power

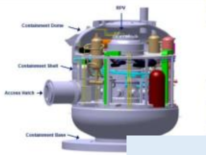
Small Modular Reactor (SMR)



https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs

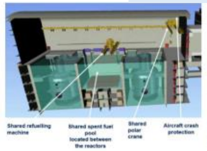
- Small
- Modular
- More affordable to build
- Safety relies more on passive systems
- >80 commercial designs being developed around the world

NUWARD™ (EDF, France)

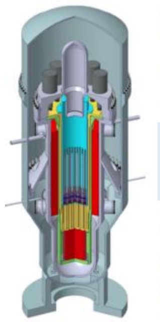


MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	EDF, France with major contributions from CEA, Naval Group, Framatome, TechnicAtome, and Tractebel-Engie
Reactor type	Integral PWR
Coolant/moderator	Light water / light water
Thermal/electrical capacity, MW(t)/MW(e)	2 x 540 / 2 x 170
Primary circulation	Forced circulation
in the core	
Fuel enrichment (%)	<5
Refuelling Cycle (months)	24 (half core)
Reactivity control	Control rod drive mechanism (CRDM), solid burnable poisons
Approach to safety systems	Passive
Design life (years)	60
Plant footprint (m^2)	3500, nuclear island including fuel storage pool
RPV height/diameter (m)	15 / 5
RPV weight (metric ton)	310
Seismic Design (SSE)	0.3g
Distinguishing features	Integrated NSSS with pool submerged containment, boron-free in normal operation and in all Design Basis Conditions (DBC), semi-buried nuclear island

340 MWe



i-SMR (KHNP & KAERI, Republic of Korea)



MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	KHNP&KAERI Republic of Korea
Reactor type	Integral PWR
Coolant/moderator	Light water / Light water
Thermal/electrical capacity, MW(t)/MW(e)	540 / 170
Primary circulation	Forced circulation
NSSS operating pressure (primary/secondary), MPa	15.0
Core inlet/outlet coolant temperature (°C)	295.5 / 320.9
mechanism	moderator temperature
Approach to safety systems	Fully passive
Design life (years)	80
Plant footprint (m^2)	NA
RPV height/diameter (m)	23 / 5
RPV weight (metric ton)	650
Seismic design (SSE)	0.5g
Fuel cycle requirements/approach	Conventional LWR requirements applied
Distinguishing features	At least 72 hours for core cooling without AC/DC power
Design status	Conceptual design

170 MWe

CAP200 (SPIC/SNERDI, China)

MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	SPIC/SNERDI, China
Reactor type	PWR
Coolant/moderator	Light water / Light water
Thermal/electrical capacity, MW(t)/MW(e)	660 / >200
Number of fuel assemblies in the core	89
Fuel enrichment (%)	4.2 (Average)
Refuelling cycle (months)	24
Core discharge burnup	37 (Average)
Reactivity control mechanism	Control rod drive mechanism and soluble boron
Approach to safety systems	Passive
Design life (years)	60
Plant footprint (m^2)	–
RPV height/diameter (m)	8.845 / 3.280
RPV weight (metric ton)	200
Seismic design (SSE)	0.30 g
Fuel cycle requirements/approach	UO_2 fuel and low-leakage core design
Distinguishing features	Compact layout; Passive safety; Underground containment
Design status	Basic design

200 MWe

IMR (Mitsubishi Heavy Industries, Japan)

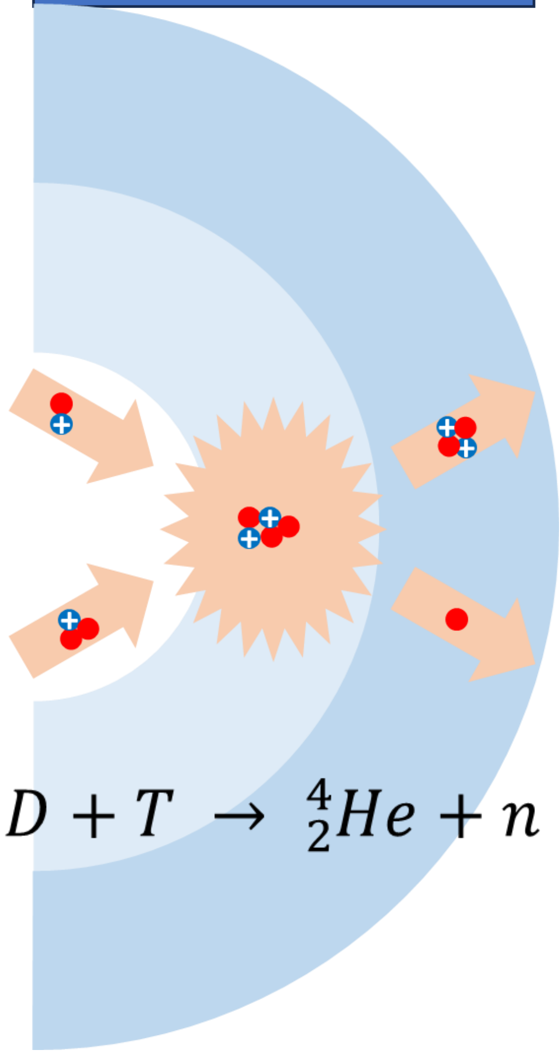
MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	Mitsubishi Heavy Industries, Ltd. (MHI), Japan
Reactor type	Integral PWR
Coolant/moderator	Light water / light water
Thermal/electrical capacity, MW(t)/MW(e)	1 000 / 350
in the core	
Fuel enrichment (%)	4.8
Core Discharge Burnup (GWd/ton)	> 40
Refuelling Cycle (months)	26
Reactivity control mechanism	Control rods drive mechanism
Approach to safety systems	Hybrid (Passive + Active) system
Design life (years)	60
Plant footprint (m^2)	4900
RPV height/diameter (m)	17 / 6
RPV weight (metric ton)	–
Seismic Design (SSE)	0.3g
Fuel cycle requirements / Approach	Similar to existing PWR plants
Distinguishing features	Integral PWR with natural circulation; employs two types of in-vessel steam generator
Design status	Conceptual design completed

350 MWe

Source: Advances Small Modular Reactor Technology Development, IAEA 2022 eds.

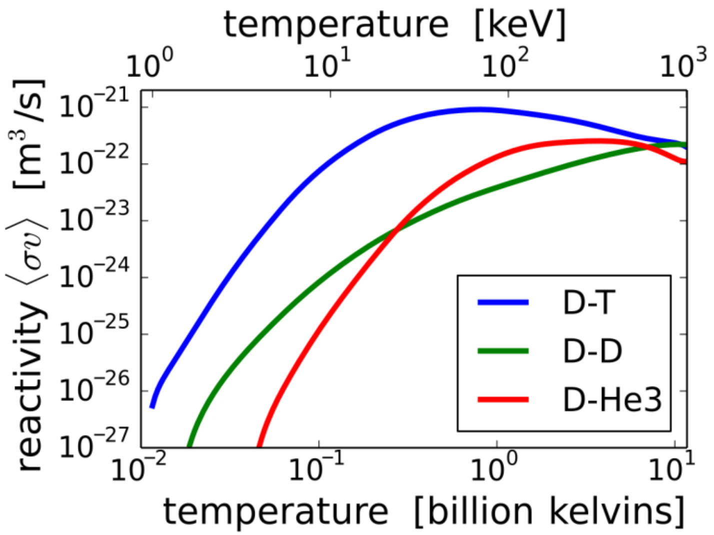
Fusion

Nuclear Fusion



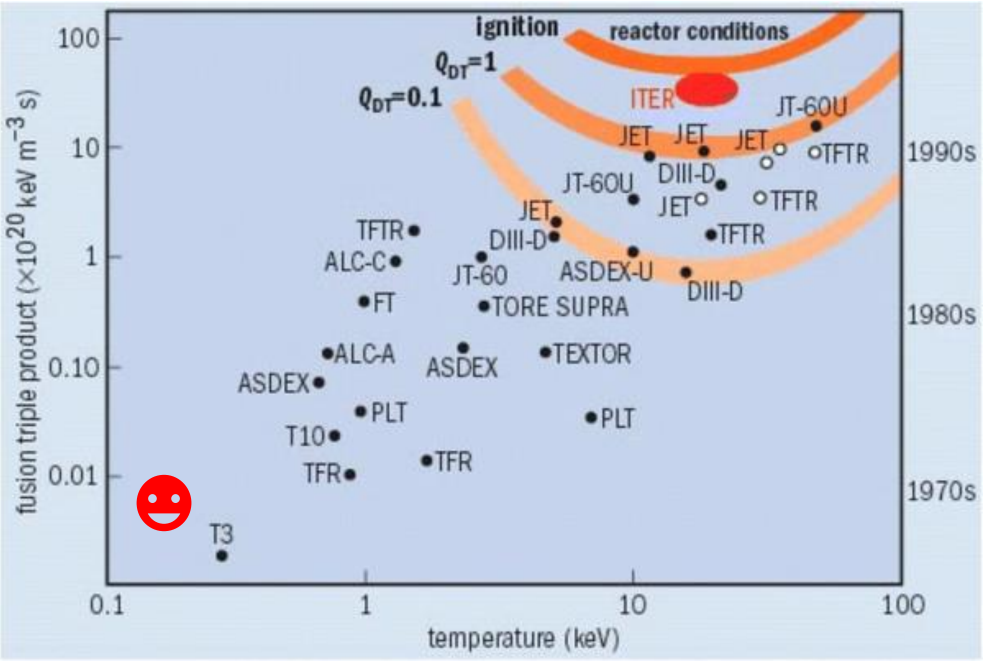
$$D + T \rightarrow {}^{4}_{2}He + n$$

Fusion Cross section



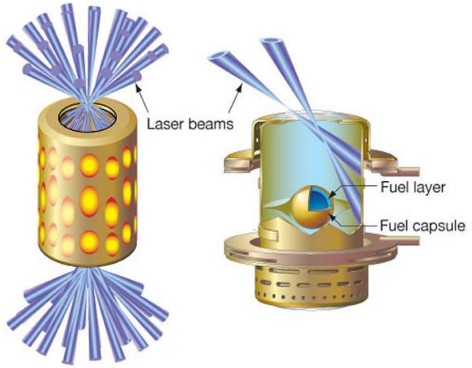
Lawson Criterion

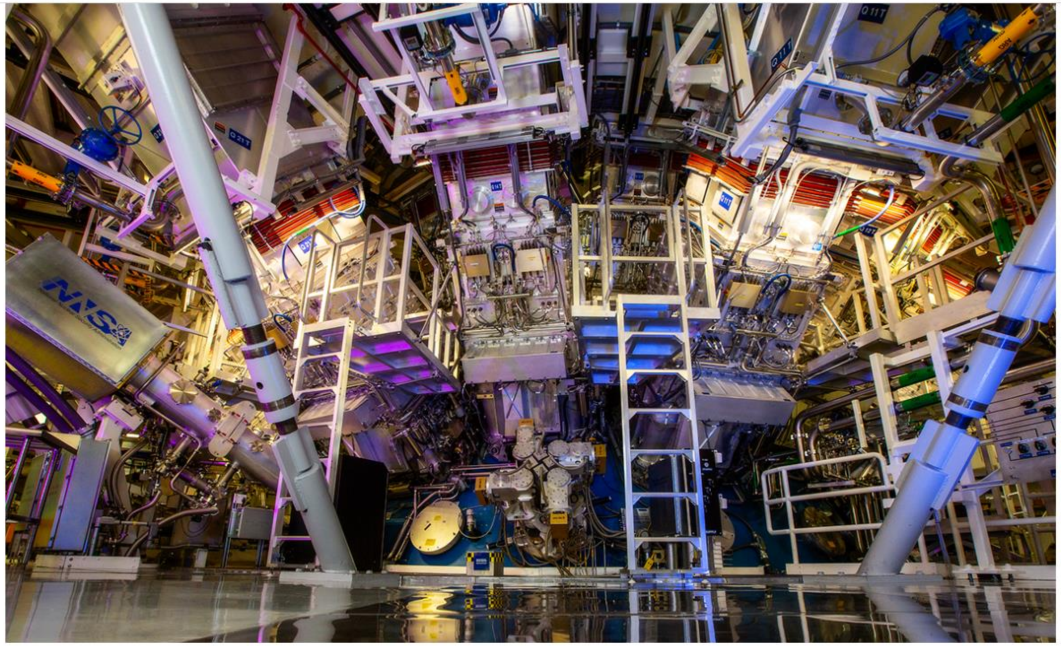
$$nT\tau \geq 3 \times 10^{21} keV\ s/m^3$$



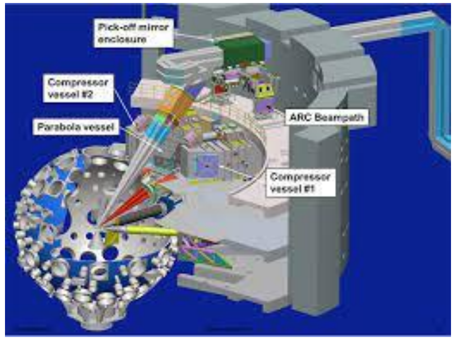
Inertial Confinement Fusion

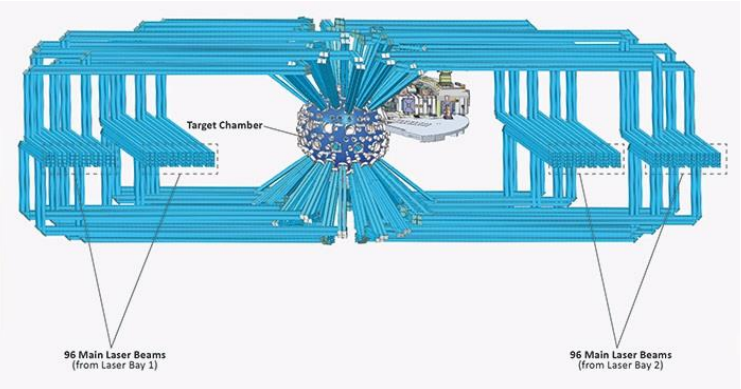
- National Ignition Facility (NIF), Lawrence Livermore National Laboratory (LLNL)
- Achieved Q=1.5 (Output 3.15 MJ/Input 2.05 MJ)
- Based on pulsed laser





THE WORLD'S LARGEST AND HIGHEST-ENERGY LASER



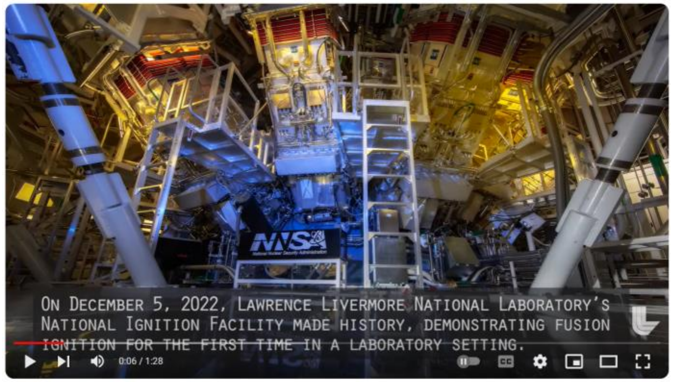


12 DEC, 2022 Print Read the latest published articles

Congratulations!

ITER APPLAUDS NIF FUSION BREAKTHROUGH

ITER scientists hailed the latest experimental results at the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory in California: the achievement of "breakeven" fusion energy. "When future generations look back on the evolution of fusion energy research, I believe this will be recognized as a historic milestone," said ITER Director-General Pietro Barabaschi. NIF's experiment used 2.05 megajoules of laser energy to produce 3.15 megajoules of fusion energy, reaching a Q value of 1.5.

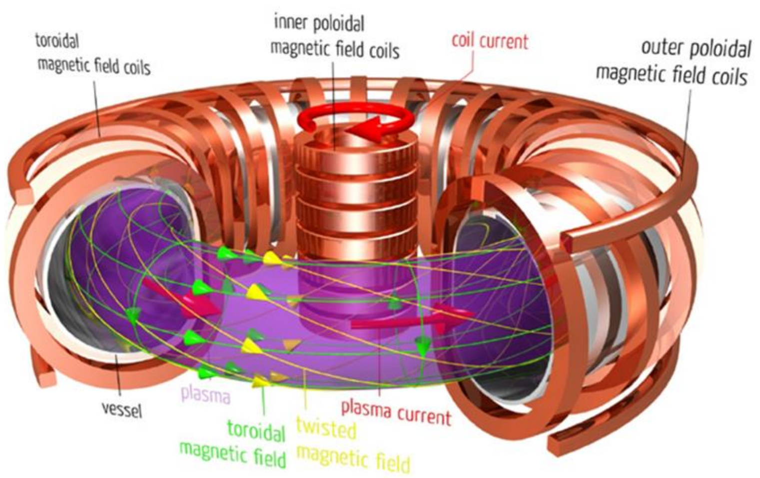


https://www.youtube.com/watch?v=71gqaFoix1w&t=8s

Magnetic Confinement Fusion

Tokamak

- Confine hot plasma in toroidal chamber with magnetic field
- Auxiliary Heating: ECRH, ICRH, NBI

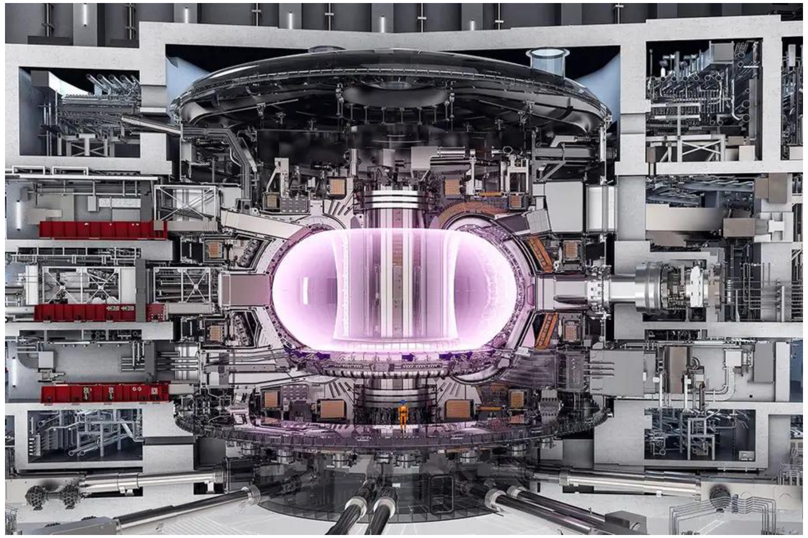


EAST

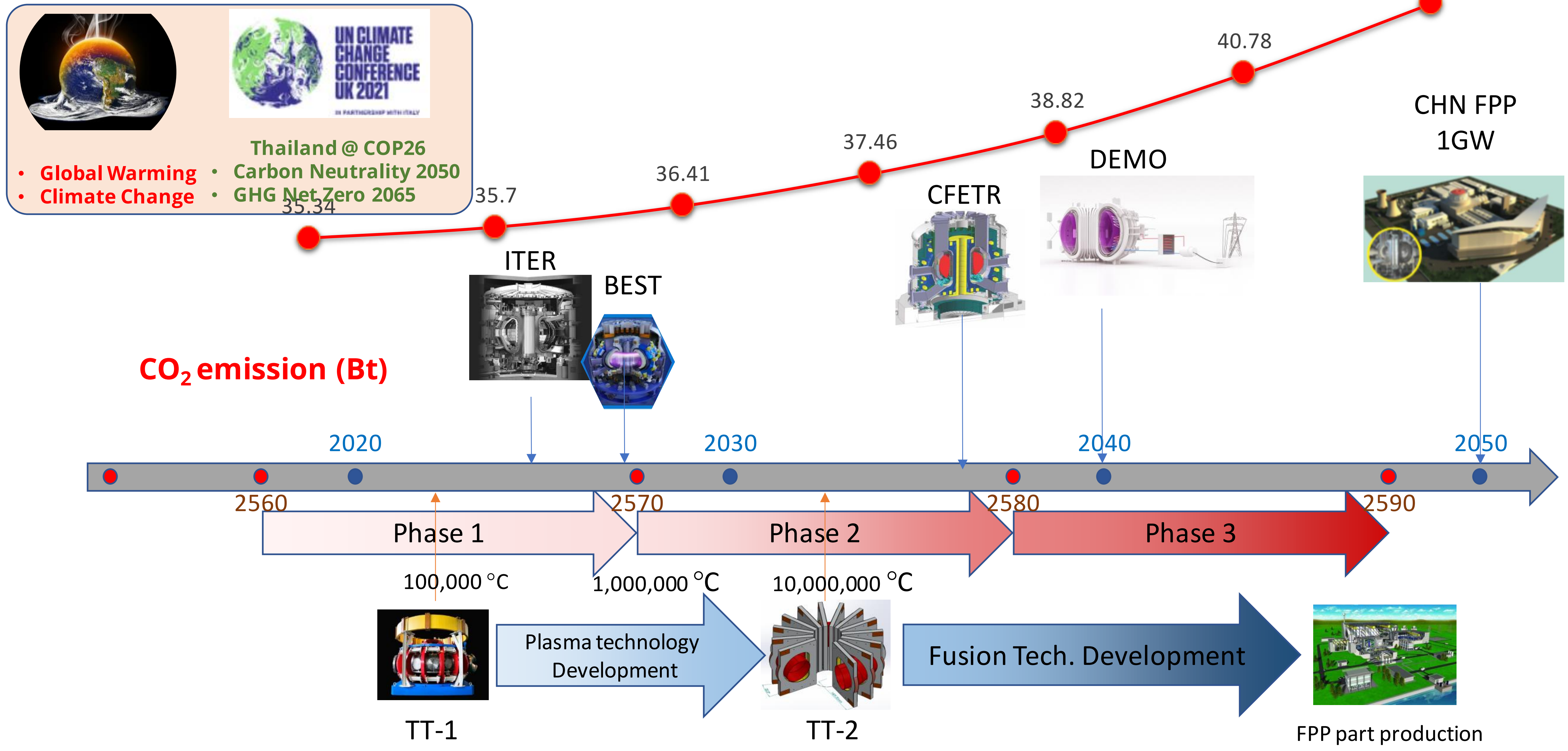
- Longest confinement time (1056 s)

ITER

- Largest tokamak
- 1st plasma : 2025
- Q=10 (output 500 MW/ input 50 MW)



MCF Global timeline

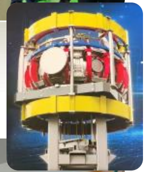


Thailand Tokamak-1

15 Jul 2018
HT-6M Donation Ceremony

TT-1 Building :
Foundation Stone Laying ceremony

Grand Opening Ceremony



Plasma Technology and
Fusion Collaboration
between TINT and EGAT

TT-1 Contract
Signing Ceremony

Thailand Team Onsite @ ASIPP

TT-1 Installation @ TINT Ongkharak

Thailand Tokamak-1

Main machine

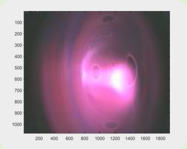
Vacuum Chamber:
- Major Radius : 0.65 m
- Minor Radius : 0.20-0.25 m
- Material : SS 306L

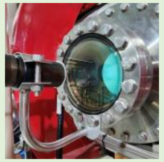
Magnet Coils:

Toroidal Field :	16 coils
Ohmic Heating Field:	5 coils
Vertical Field:	2 coils
Feedback Coils:	1 coils

Diagnostics

- Magnetic Measurement
  - 12x2 Toroidal Positions
  - 12x2 Poloidal Positions
- HCN laser 3 channels
- Hα
- CCD Camera





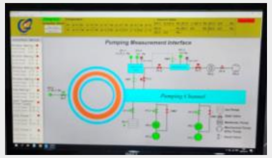
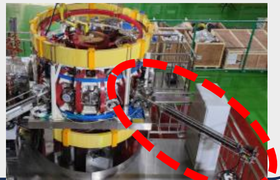
Power Supply

Toroidal Field Magnet Coil	7.6 kA
Ohmic Heating	17 kA
Vertical Field Magnet Coil:	4.8 kA
Feedback Coils:	230 A



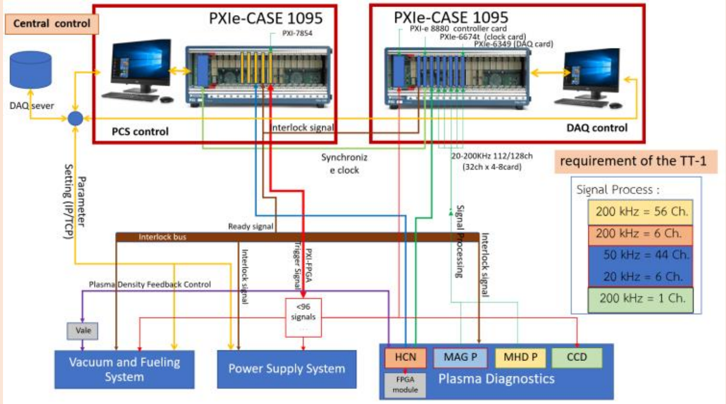
Vacuum System

- Pumping [$1x10^{-6}$ Pa]
  - 2xTMP + 2 Root
  - 1xIon pump
- GIS piezo-electric
- Pre-ionization
- 2xGDC
- Baking
- Boronization
- 2xRGA

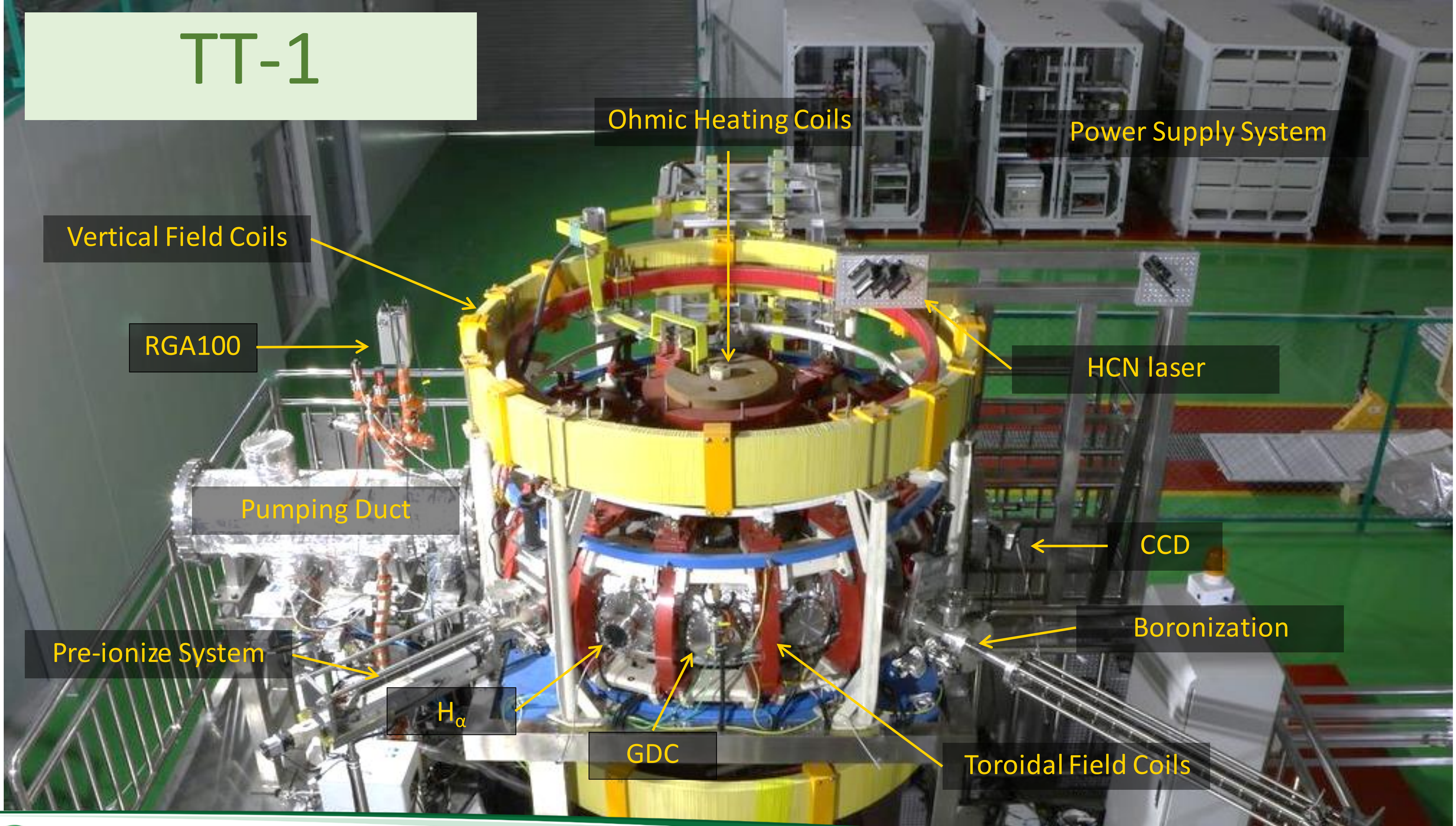



Data Acquisition

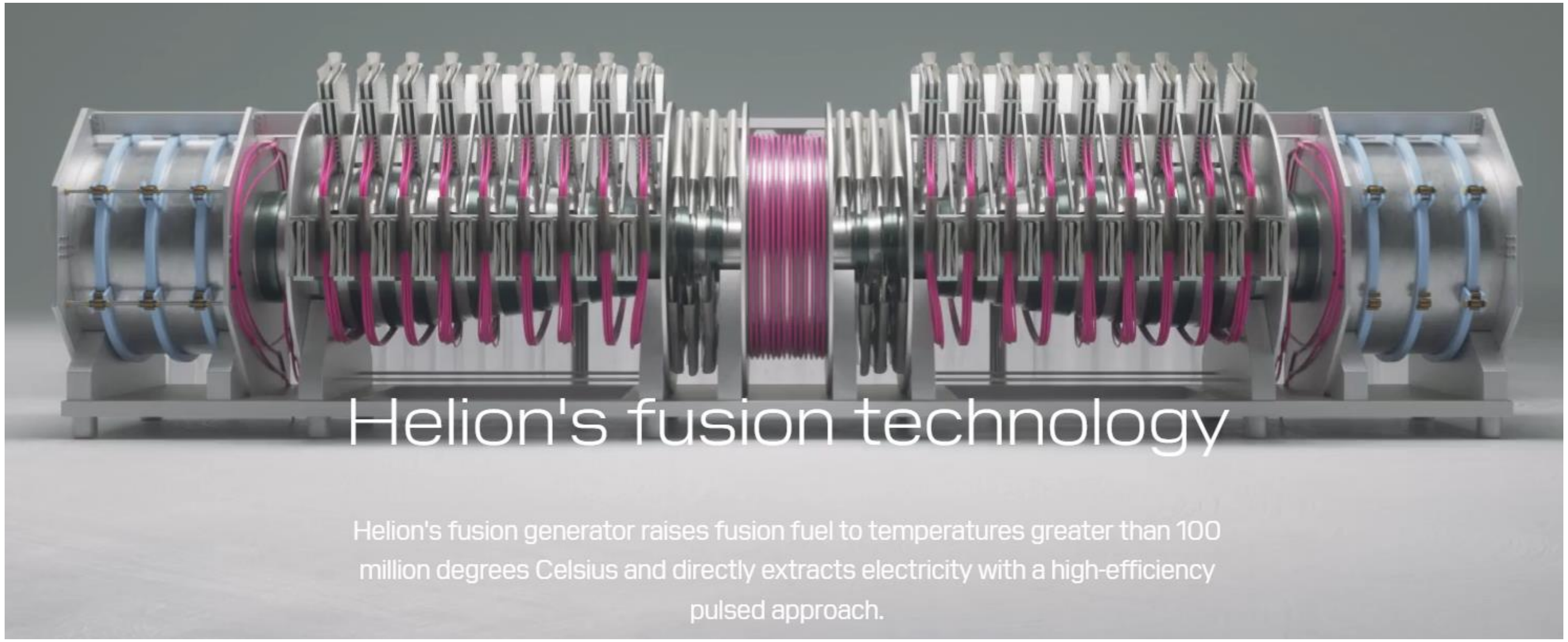
- PXIe / 128 Ch. / 500 kHz

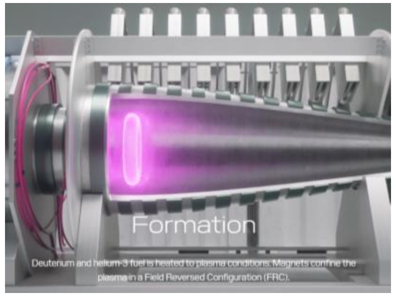


TT-1

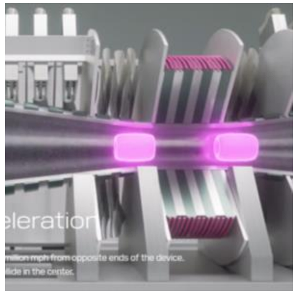

Ohmic Heating Coils
Power Supply System
Vertical Field Coils
RGA100
HCN laser
Pumping Duct
CCD
Boronization
Pre-ionize System
H_α
GDC
Toroidal Field Coils

Helion

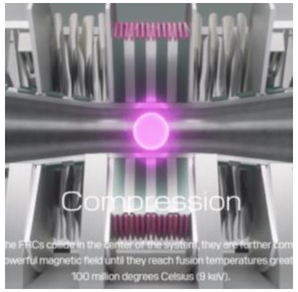




Formation



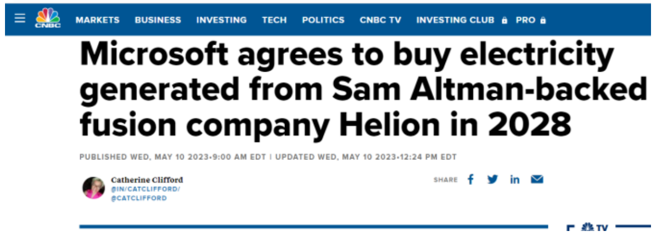
Acceleration



Compression

Electricity Recapture

https://www.helionenergy.com/

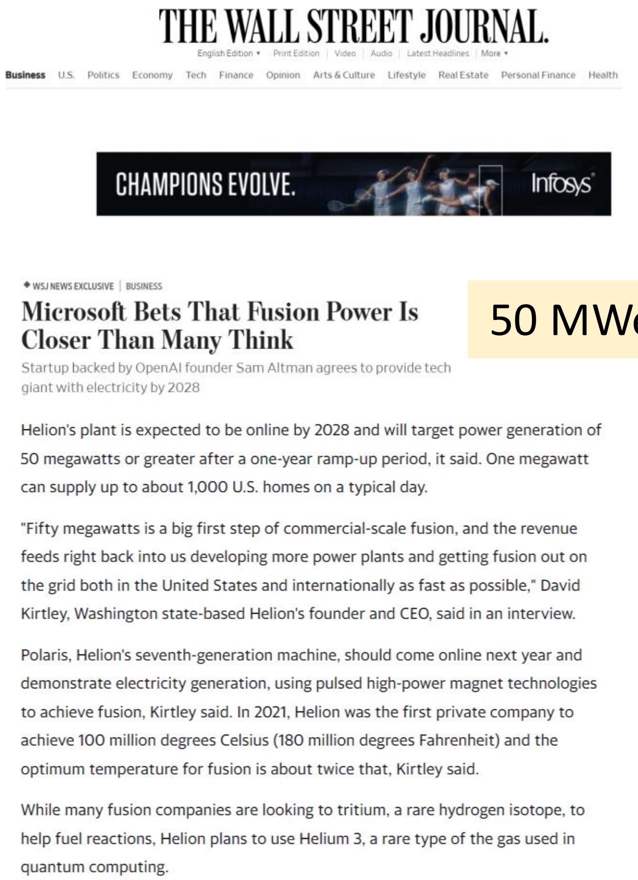


MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV INVESTING CLUB PRO

Microsoft agrees to buy electricity generated from Sam Altman-backed fusion company Helion in 2028

PUBLISHED WED, MAY 10 2023·9:00 AM EDT | UPDATED WED, MAY 10 2023·12:24 PM EDT

Catherine Clifford



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Microsoft Bets That Fusion Power Is Closer Than Many Think

Startup backed by OpenAI founder Sam Altman agrees to provide tech giant with electricity by 2028

Helion's plant is expected to be online by 2028 and will target power generation of 50 megawatts or greater after a one-year ramp-up period, it said. One megawatt can supply up to about 1,000 U.S. homes on a typical day.

"Fifty megawatts is a big first step of commercial-scale fusion, and the revenue feeds right back into us developing more power plants and getting fusion out on the grid both in the United States and internationally as fast as possible," David Kirtley, Washington state-based Helion's founder and CEO, said in an interview.

Polaris, Helion's seventh-generation machine, should come online next year and demonstrate electricity generation, using pulsed high-power magnet technologies to achieve fusion, Kirtley said. In 2021, Helion was the first private company to achieve 100 million degrees Celsius (180 million degrees Fahrenheit) and the optimum temperature for fusion is about twice that, Kirtley said.

While many fusion companies are looking to tritium, a rare hydrogen isotope, to help fuel reactions, Helion plans to use Helium 3, a rare type of the gas used in quantum computing.

50 MWe

Thank you