IAEA
International Atomic Energy Agency

IAEA ACTIVITIES ON SYNERGIES IN TECHNOLOGY DEVELOPMENT BETWEEN NUCLEAR FISSION AND FUSION FOR ENERGY PRODUCTION

Nicole Virgili, Vladimir Kriventsev, Sehila Gonzalez De Vicente, Luigi Di Pace, Lorenz Gaertner

Technical Meeting on Synergies Between Nuclear Fusion Technology Developments and Advanced Nuclear Fission Technologies

6-10 June 2022
IAEA, Vienna
Webex

Fission and Fusion Timeline

Fukushima

Three Mile Island

Chernobyl

GIF
(Gen IV International Forum)

GEN IV International Forum

IAEA

Fission

Gen I
Early Prototype Reactors

Gen II
Commercial Power Reactors

Gen III
Advanced LWR
Advanced BWR

Gen III+
Evolutionary designs offering improved safety, economics

Gen IV
Highly Economical
Enhanced Safety
Minimal Waste
Proliferation Resistance

1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060

Fusion

JET

ITER

Start of construction
First plasma
Full performance

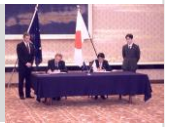
DEMO

Start of construction
First power production

United Nations Conference on the Peaceful Uses of Atomic Energy

"Controlled fusion for peaceful purposes" – Gorbachev & Reagan

Broader Approach Agreement



JT-60SA

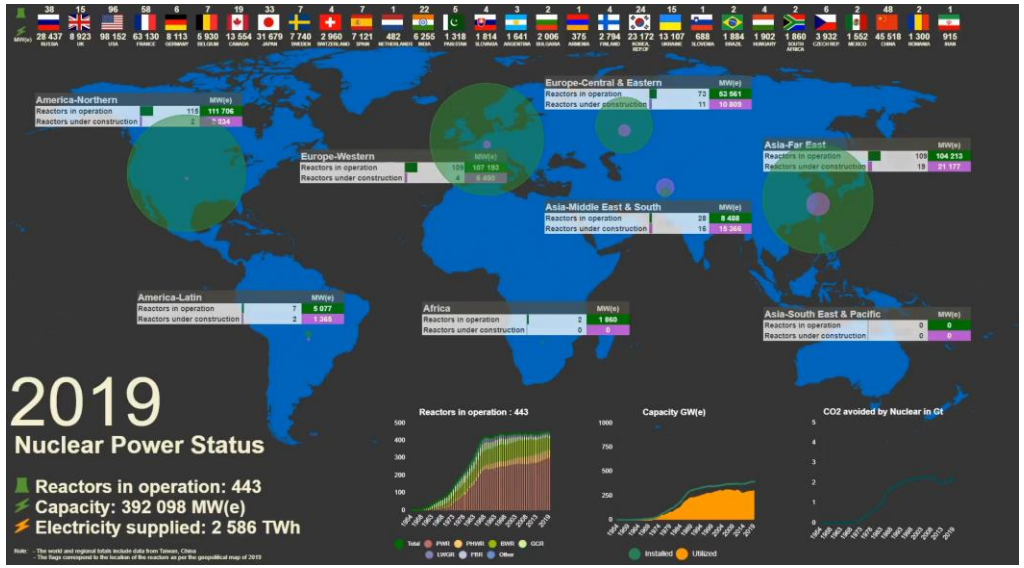
IFMIF/EVEDA **IFMIF/DONES**

Fusion still in R&D phase,
No production of electricity yet

First power production

https://www.iter.org/newsline/-/2323
https://de.wikipedia.org/wiki/Experimental_Breeder_Reactor_I

Fission reactors in operation

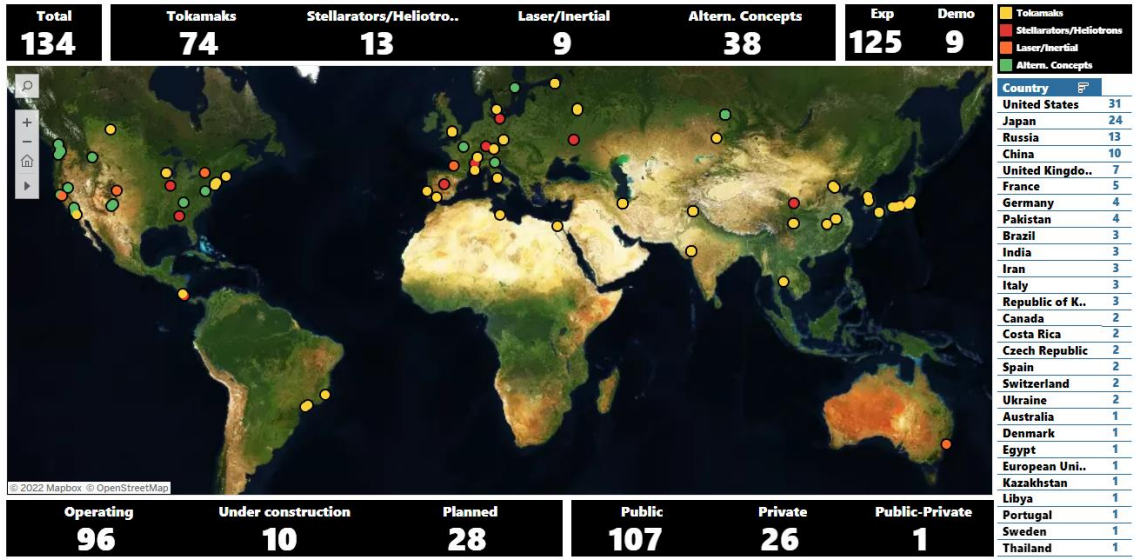


https://pris.iaea.org/PRIS/home.aspx

- 443 Reactors in operation
- 392 GW Capacity
- 2586 TWh Electricity supplied
- 30 countries (+2 in 2020)

Nuclear Power Plants
for industrial deployment

Experimental studies for fusion facilities



https://nucleus.iaea.org/sites/fusionportal/Pages/FusDIS.aspx

- 134 Fusion projects
- 28 countries

Still experimental level

R&D needed to verify physics and technology

Fusion Development Challenges

ITER

Designed

- to produce burning plasma
- to test systems and elements needed in a fusion machine
- to setup the fusion supply chain

DEMO

- Demonstration of electricity generation
- Qualification of components and processes
- Test self-production of fuel, closed fuel cycle
- Licensing

Support facilities

- R&D on materials and components
- Plasma performance

New private enterprises

- Advanced technologies
- New approaches and concepts

Challenges

- Confining the plasma at T~10 times hotter than the center of the Sun
- Neutrons damaging the structural materials
- Exhausting extreme heat fluxes
- Breeding and handling Tritium
- Need for remote handling and maintenance
- Waste management

Fusion Power Plant

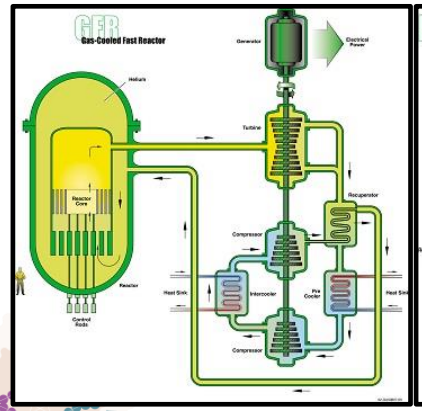
Generation IV reactor designs under development by GIF

Goals

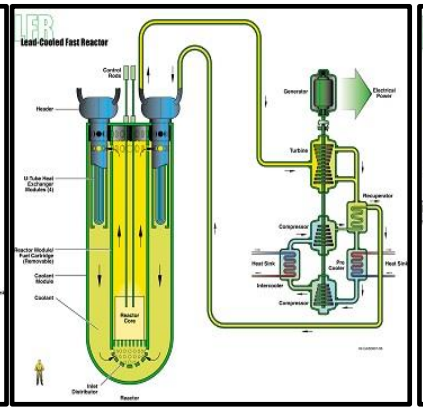
- Highly Economical Competitiveness
- Enhanced Safety
- Minimal Waste
- Proliferation Resistance
- New applications (process heat, hydrogen production)

Reactor type	Neutron spectrum	Coolant	Temp. (°C)	Fuel cycle	GW(e)	Use
Gas-cooled fast reactors	fast	helium	850	closed, on site	1200	electricity & hydrogen
Lead-cooled fast reactors	fast	lead or Pb-Bi	480-570	closed, regional	20-180** 300-1200 600-1000	electricity & hydrogen
Molten salt reactors	thermal or fast	fluoride salts	700-800	open/closed	1000-1500	electricity & hydrogen
Sodium-cooled fast reactors	fast	sodium	500-550	closed	50-150 600-1500	electricity
Supercritical water-cooled reactors	thermal or fast	water	510-625	open (thermal) closed (fast)	300-700 1000-1500	electricity
Very high temperature gas reactors	thermal	helium	900-1000	open	250-300	hydrogen & electricity

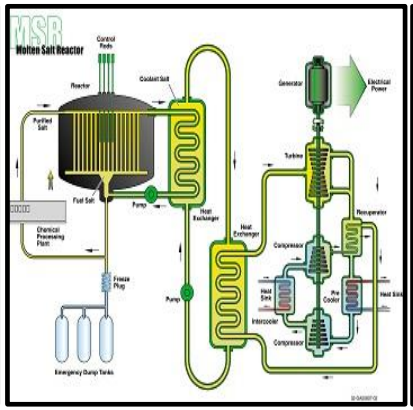
GFR



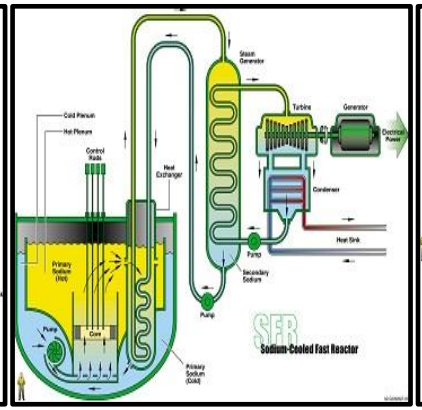
LFR



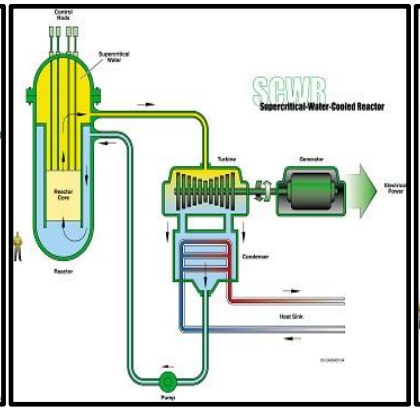
MSR



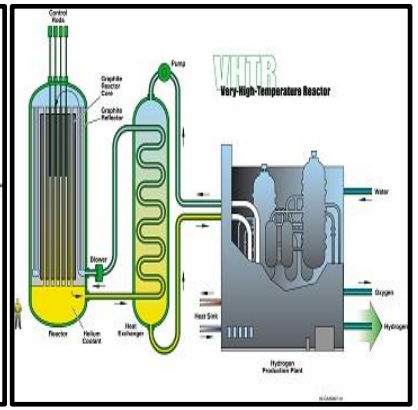
SFR



SCWR

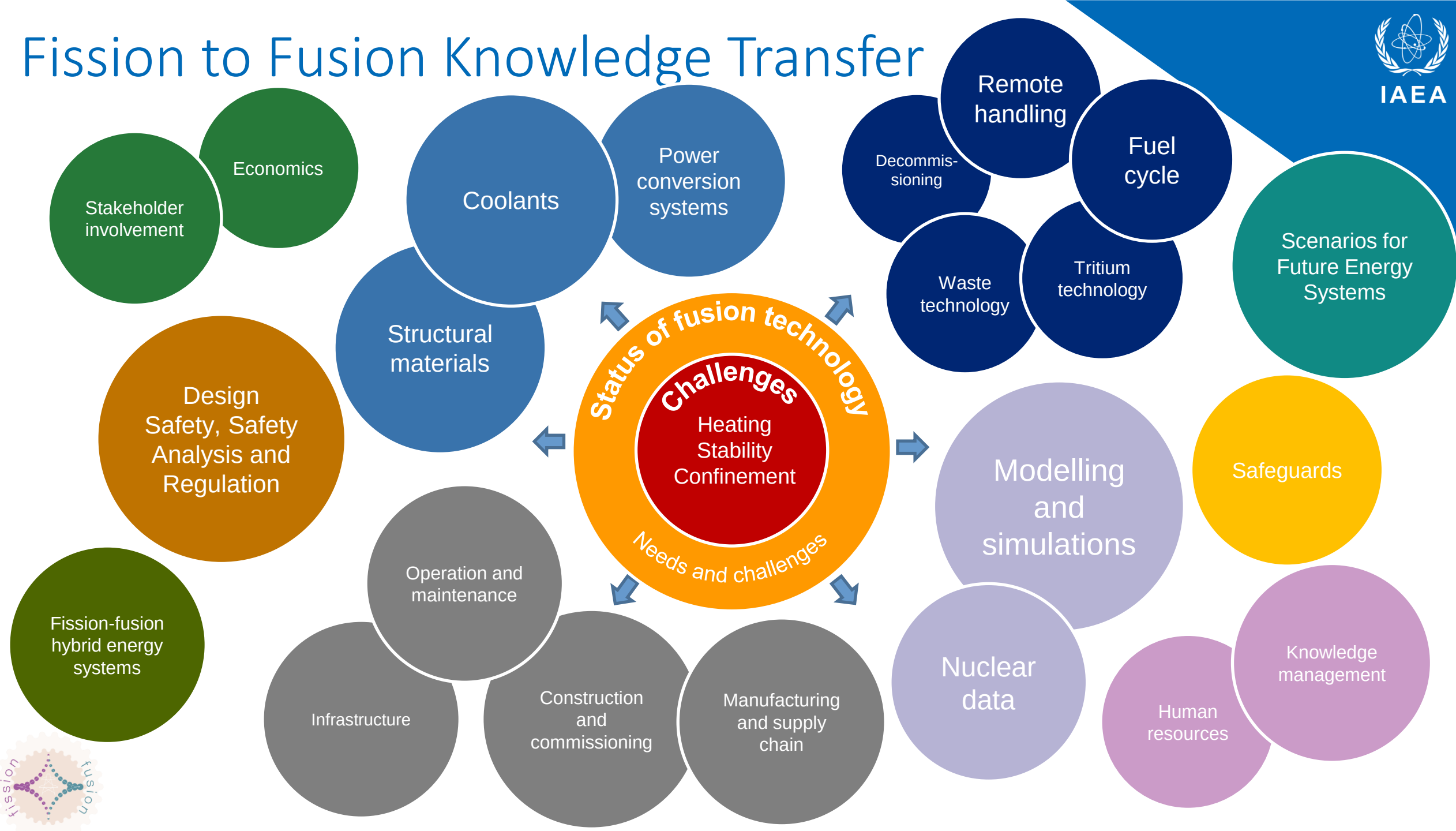


VHTR

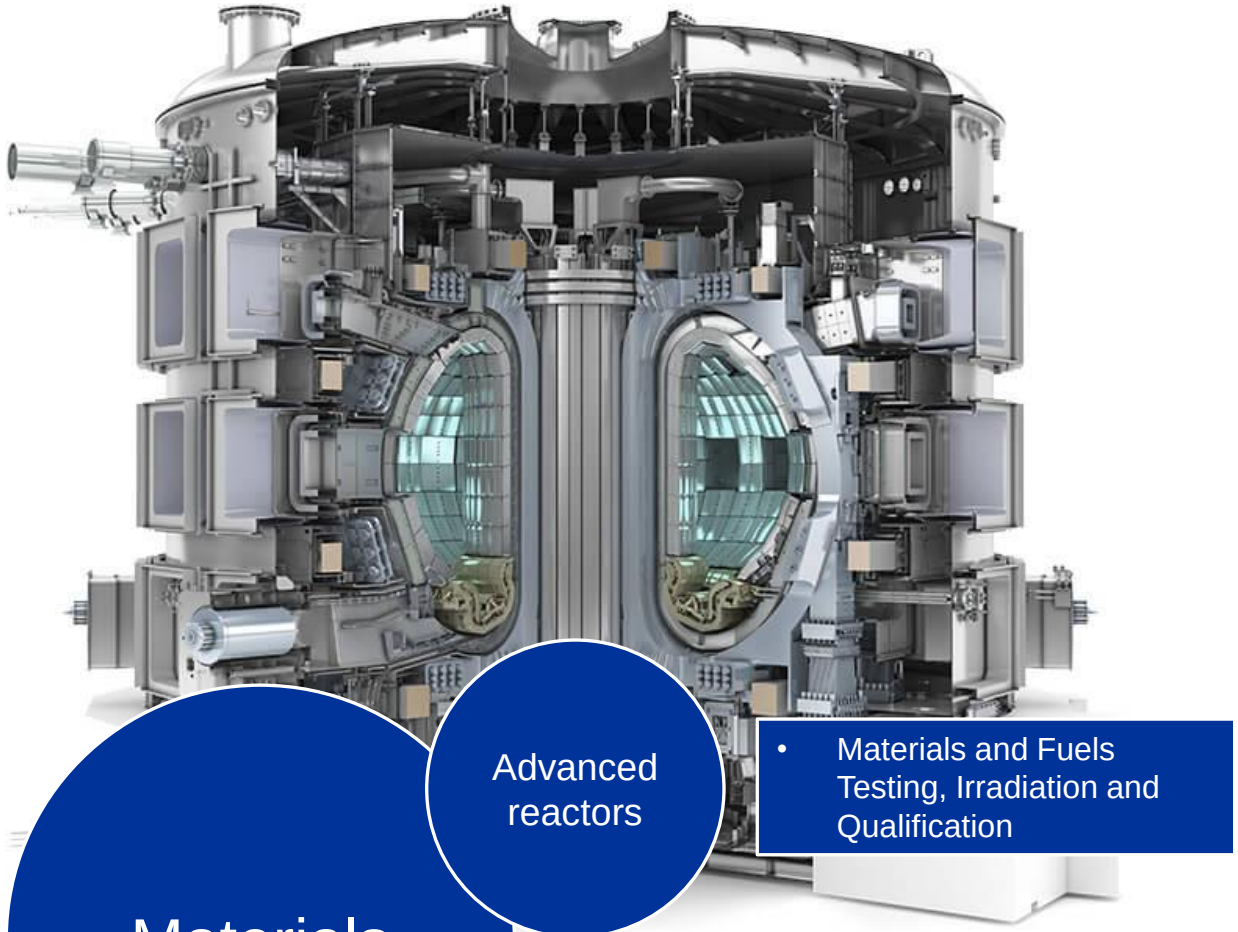


https://www.gen-4.org/gif/jcms/c_40486/technology-systems
https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/generation-iv-nuclear-reactors.aspx

Fission to Fusion Knowledge Transfer



Fission-Fusion Synergy: Materials



Materials

Advanced reactors

Fusion Facilities

- Materials and Fuels Testing, Irradiation and Qualification

- Materials-coolants compatibility
- Efficient energy generation problems related to coolants

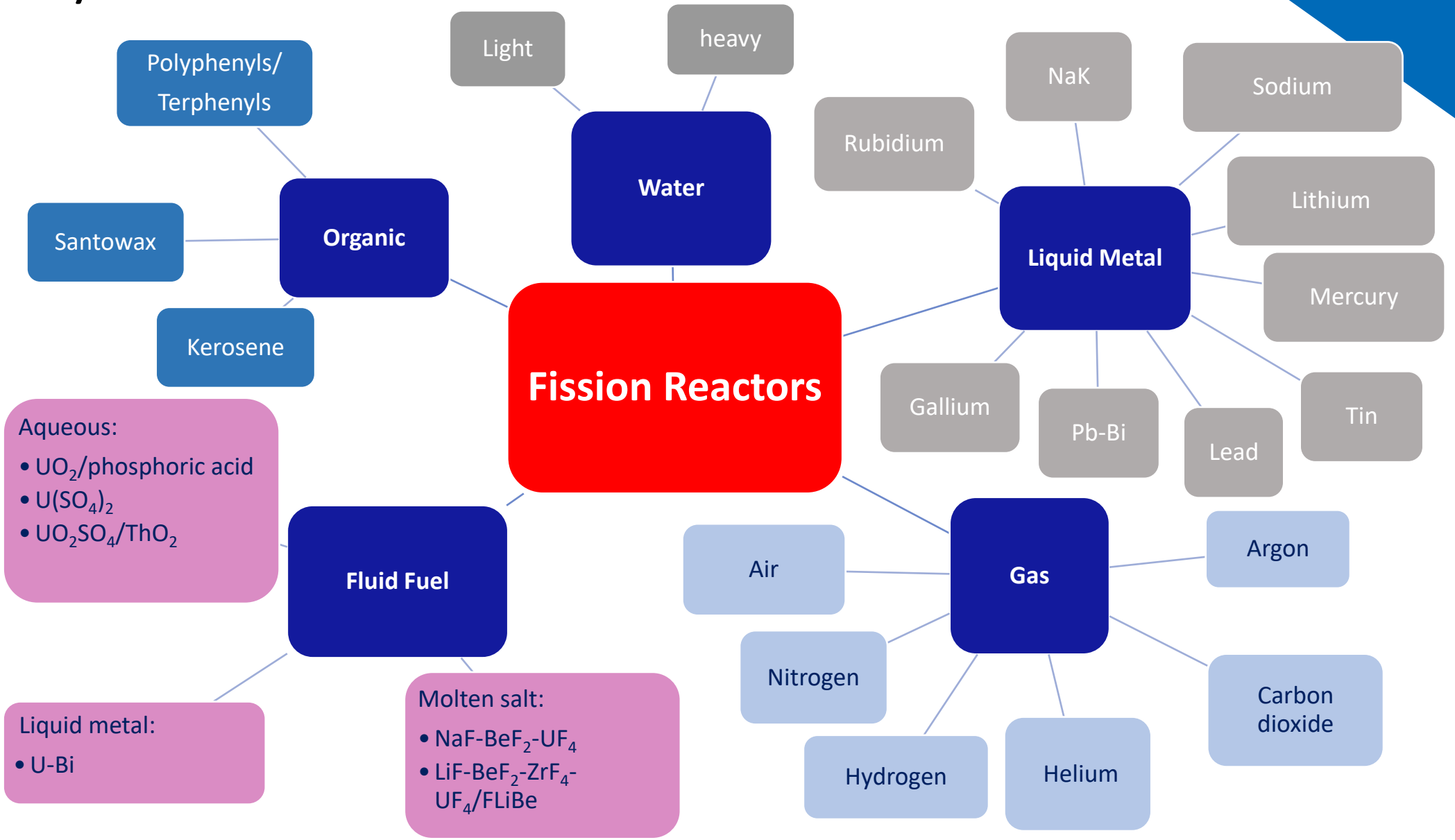
https://fusionforenergy.europa.eu/the-device/

	Present Generation		Next Generation	
	Fission (Gen II&III)	**Fusion (ITER)**	**Fission (Gen IV)**	**Fusion (Reactor)**
Structural material	**Austenitic steels, Zircaloy**	**Austenitic steels**	**Ferritic steels, Superalloys? SiC-SiC?**	**Ferritic martensitic steels, SiC-SiC?**
T_{max} (structural material)	<300 °C	<300 °C	**500 – 1000°C**	**550-1000°C**
DPA max (internal components)	~1 dpa	~3 dpa (TBM)	**~30-100 dpa**	**~150 dpa**
He Production	~ 0.1 appm	~30 aapm	~3-10 appm	~1500 appm

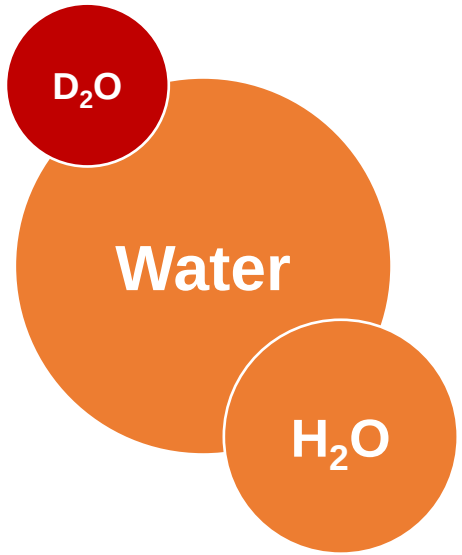
Comparable service conditions:
high temp. (>500 °C) & **high dpa** (>100 dpa)

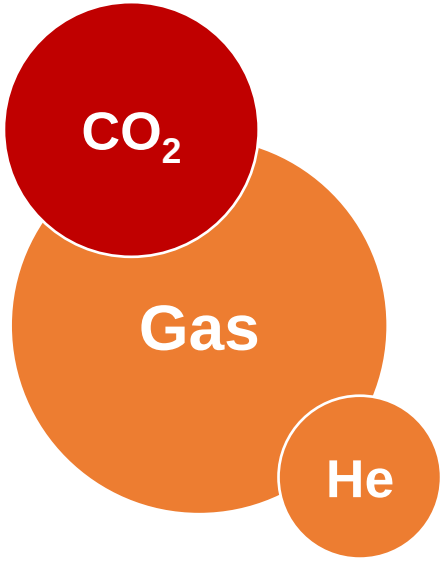
Growing synergies between fission and fusion research towards demonstration plants, F. Carré, Ph. Magaud

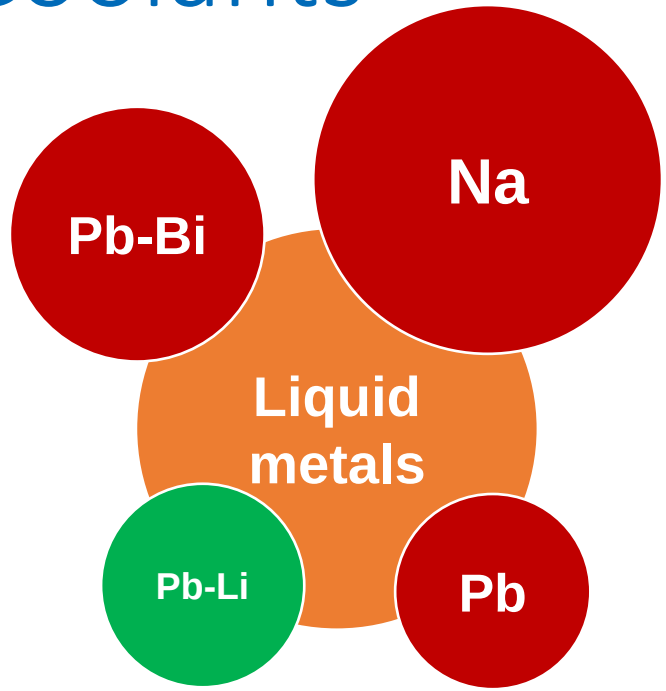
History of Fission Coolants

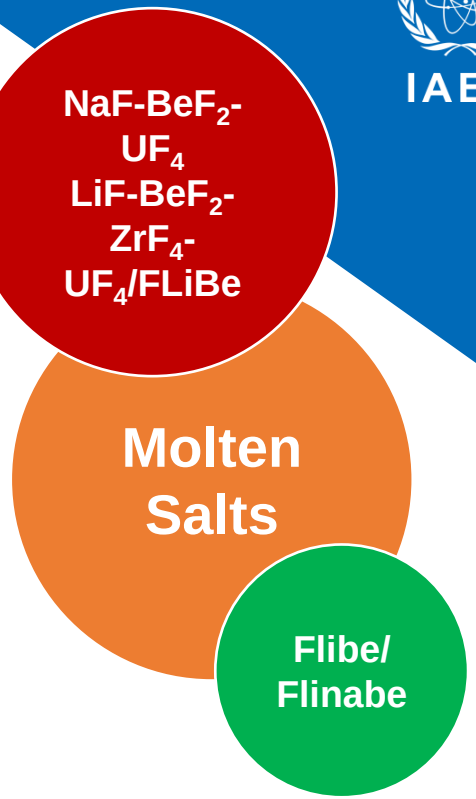


Fission-Fusion Synergy: Coolants

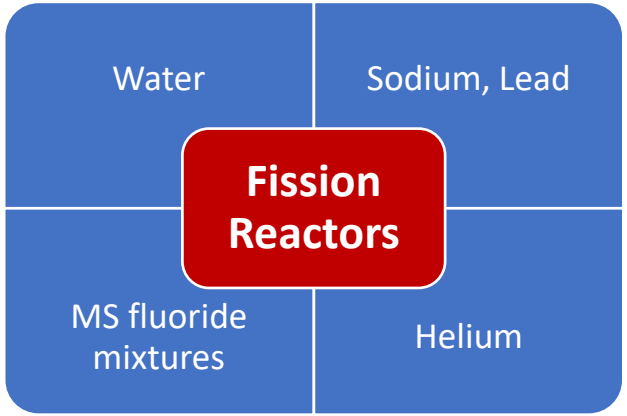


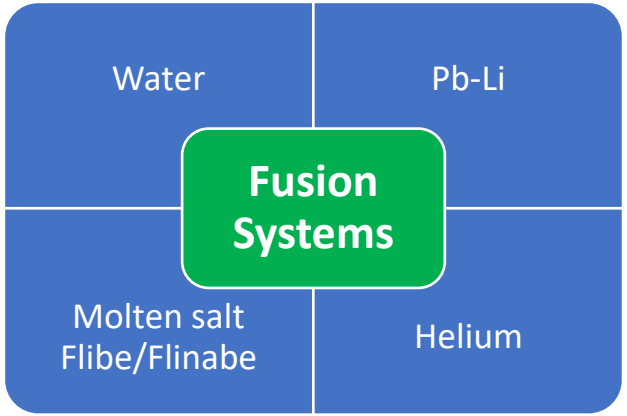






- Coolants in Fission
- Coolants in Fusion
- Common coolants in Fission and Fusion





IAEA Activity on Fission-Fusion Synergies for Energy Production

Nuclear Energy Series on
Synergies in Technology Development between Nuclear Fission and Fusion for Energy Production

- **IAEA 65th General Conference** – ESPACE Event on *Fission Supporting Fusion Technology Development*
- **1st & 2nd Consultancy Meetings** on *Preparing the Technical Meeting on Synergies in Technology Development between Nuclear Fission and Fusion for Energy Production*
- **1st Technical Meeting** on *Synergies in Technology Development between Nuclear Fission and Fusion for Energy Production*

SYNERGIES BETWEEN FISSION AND FUSION NUCLEAR ENERGY

- **Nuclear Design and Technology**
  - Codes and design methods
  - High temperature and neutron resistant materials
  - Gas, water or liquid metal cooled systems technology
  - In service inspection, maintenance in hostile environment
  - Dismantling and waste management
- **Safety approach and licensing**
- **Increased synergies for the Fusion DEMO reactor**
  - Optimization of blanket design for energy and tritium production
  - Demonstration of full tritium breeding and recovery
  - Production of initial tritium load
- **Education in nuclear physics and engineering**
  - Attraction of young scientists in the fields of nuclear energy
  - Stimulation of education and training in nuclear physics and engineering
- **Towards more integrated Fusion and Fission programs**

Context

- Worldwide acceleration towards the early deployment of nuclear fusion for energy production.

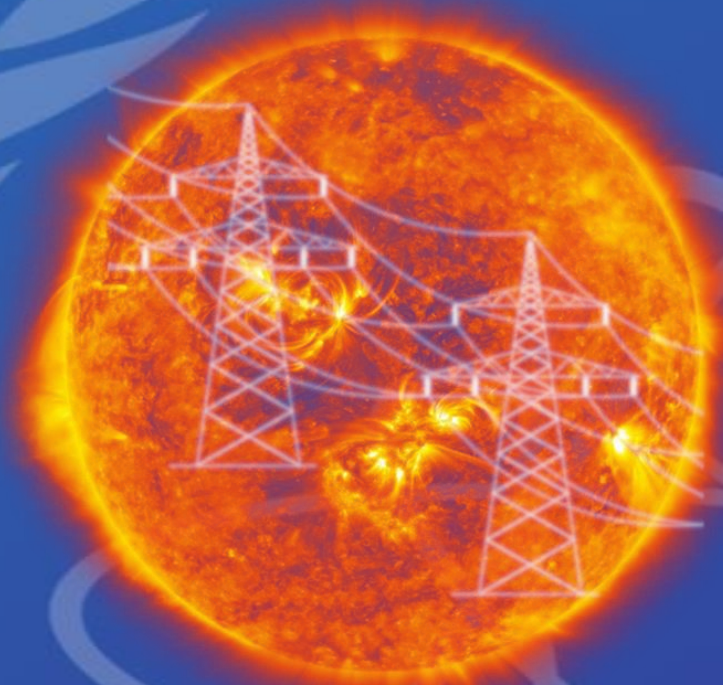
Role of IAEA

- New initiative aimed at addressing the great engineering challenge of fusion, by promoting:
  - Technology development
  - Transfer of knowledge
  - Common infrastructure

  } Fission ⇨ Fusion
- Identifying and analysing **all the possible synergies** on technology development and deployment between nuclear fission and nuclear fusion, **with an international perspective beyond ITER and towards DEMO and industrial deployment of nuclear fusion.**

MSs and Stakeholders

- Will get acquainted of the *synergies in technology development between nuclear fission and fusion for energy production,* status of cooperation between the fission and fusion communities.
- Will receive recommendations on how to enhance relevant technology and knowledge transfers from fission to fusion.



Thank you

Nuclear Power Technology Development Section
Division of Nuclear Power
Department of Nuclear Energy
International Atomic Energy Agency

Website: https://nucleus-new.iaea.org/sites/fr/Pages/fusion.aspx

Email address: FFSynergies@iaea.org