IAEA
International Atomic Energy Agency
Atoms for Peace and Development

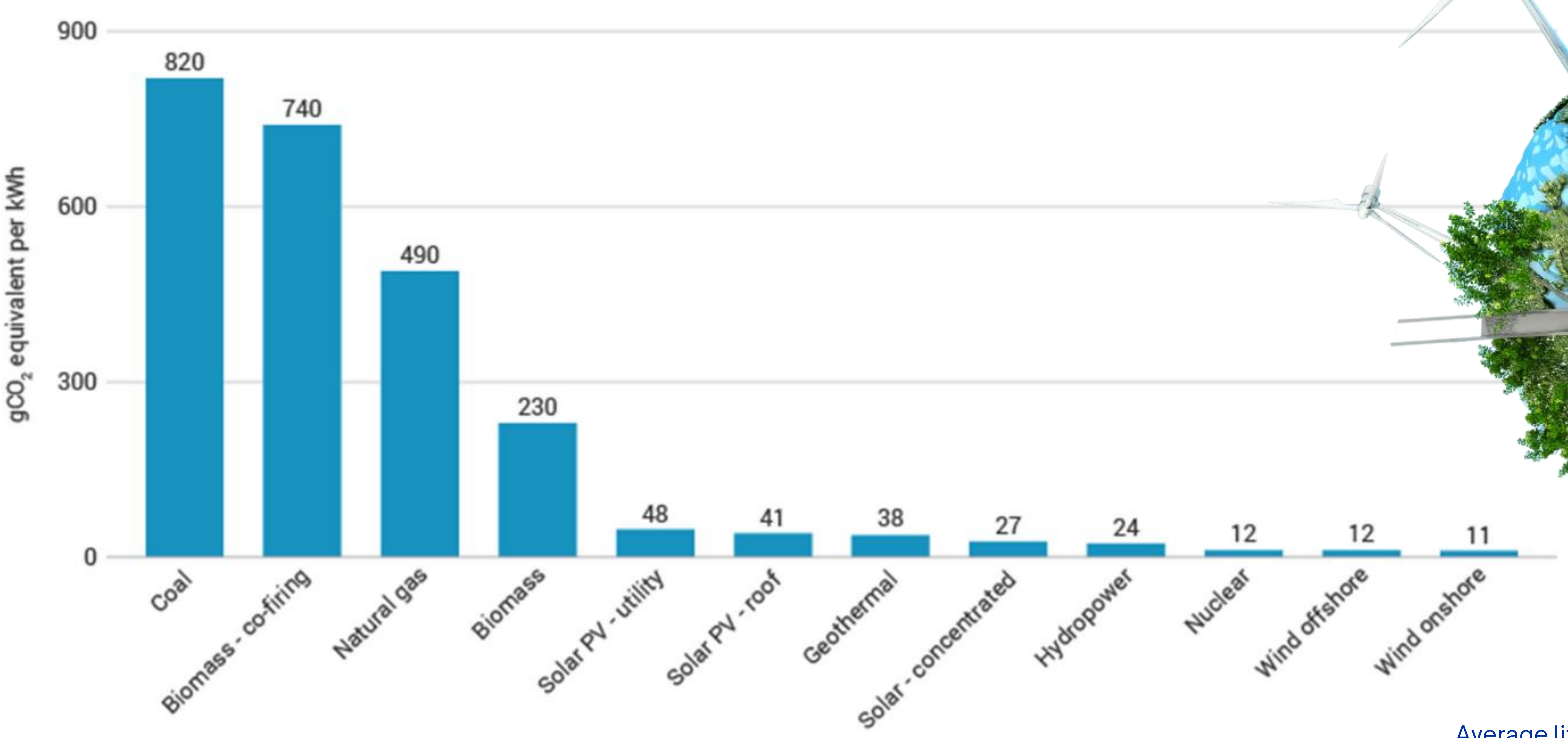
Nuclear Power: Global Prospects and IAEA Support

Aline des Cloizeaux
Director of the Division of Nuclear Power

University of Warsaw
Warsaw, Poland
April 2024

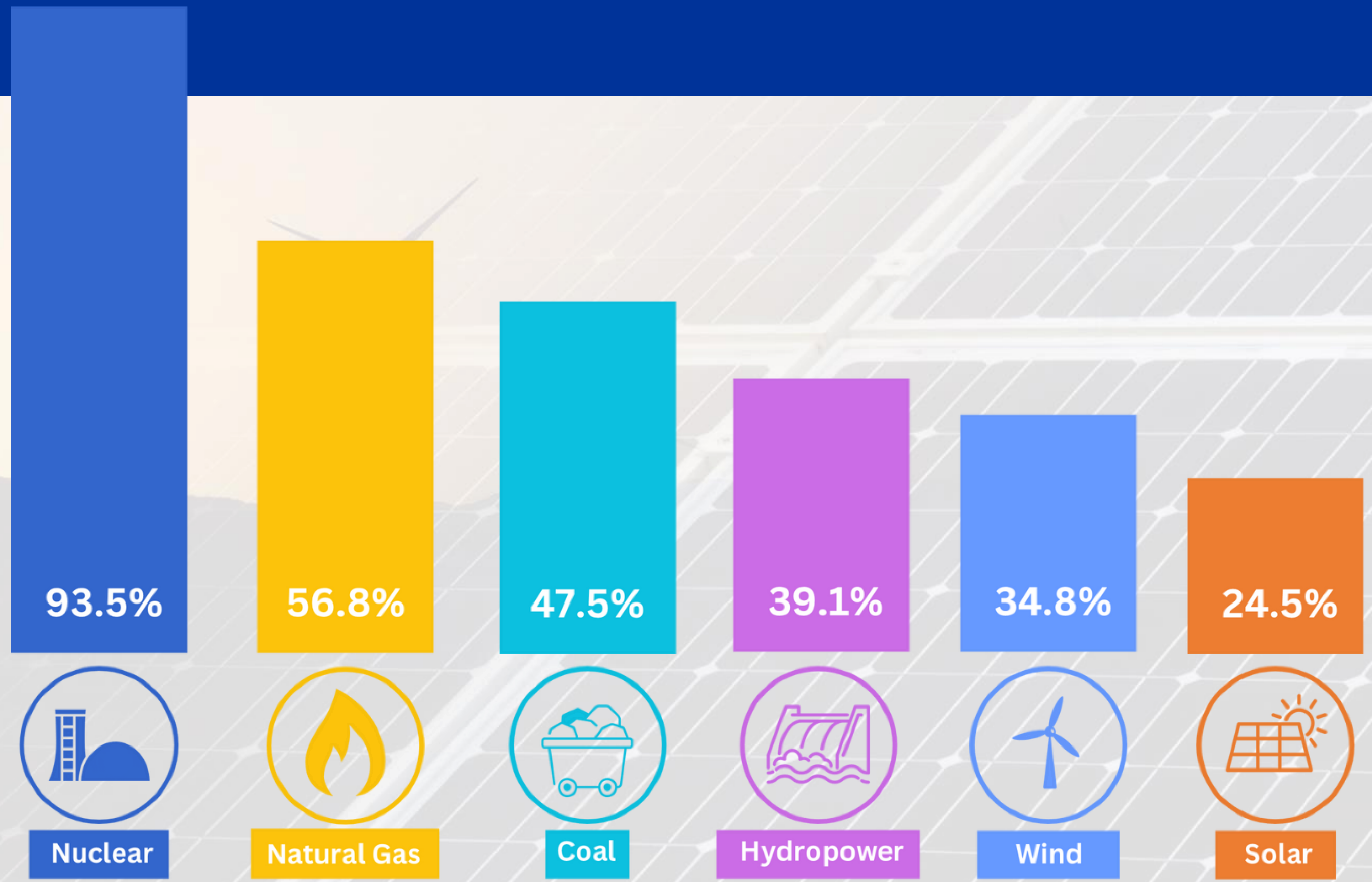
Energy access & climate change

Life cycle GHG emissions

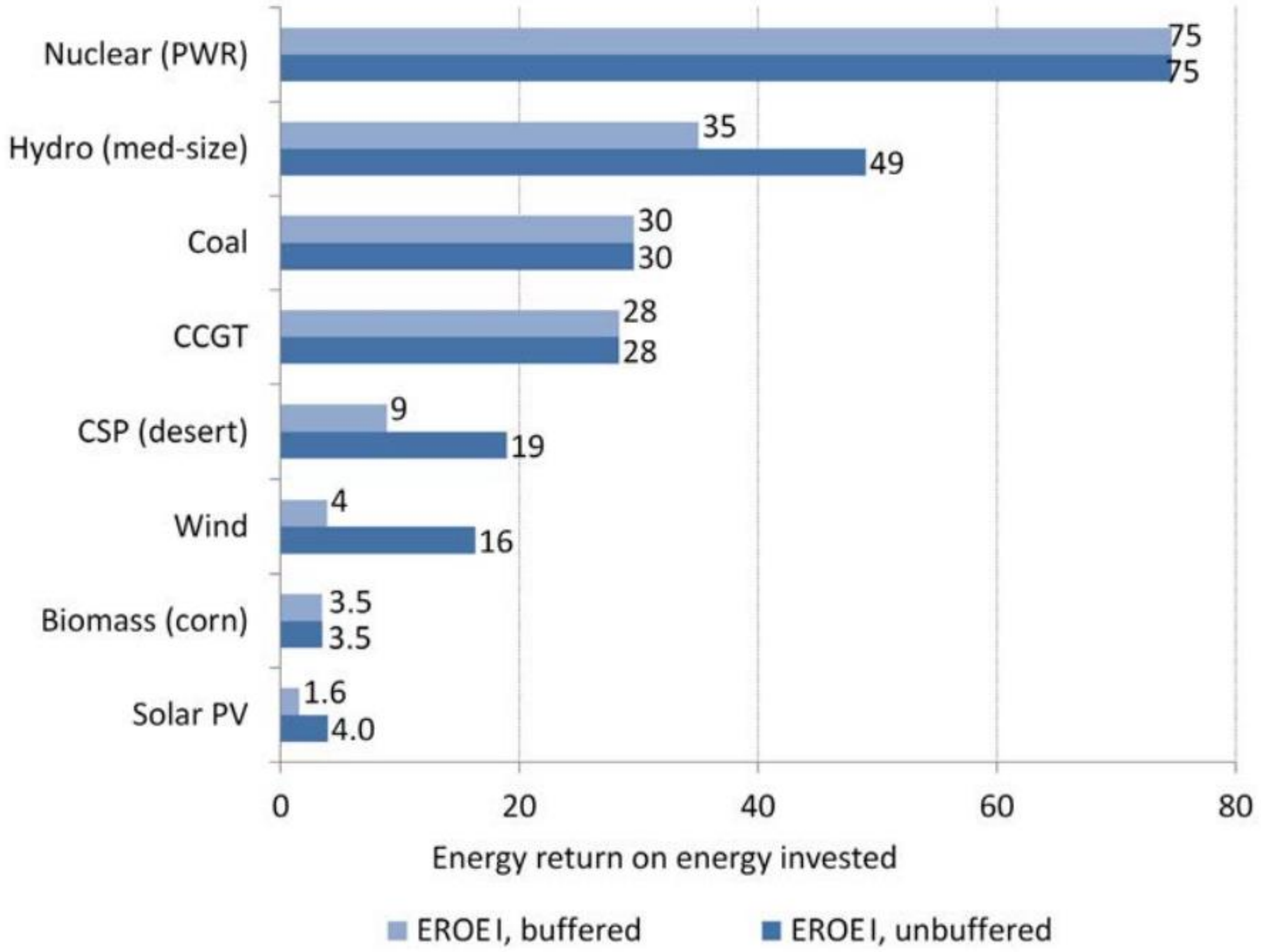


Average life-cycle CO2 equivalent emissions (source: IPCC)

Capacity Factor by Energy Source



Energy return on investment



Nuclear power today

as of April 2024

IAEA

Reactors

416 nuclear power reactors in **31** countries

Capacity

~**370** GW(e) capacity

Electricity

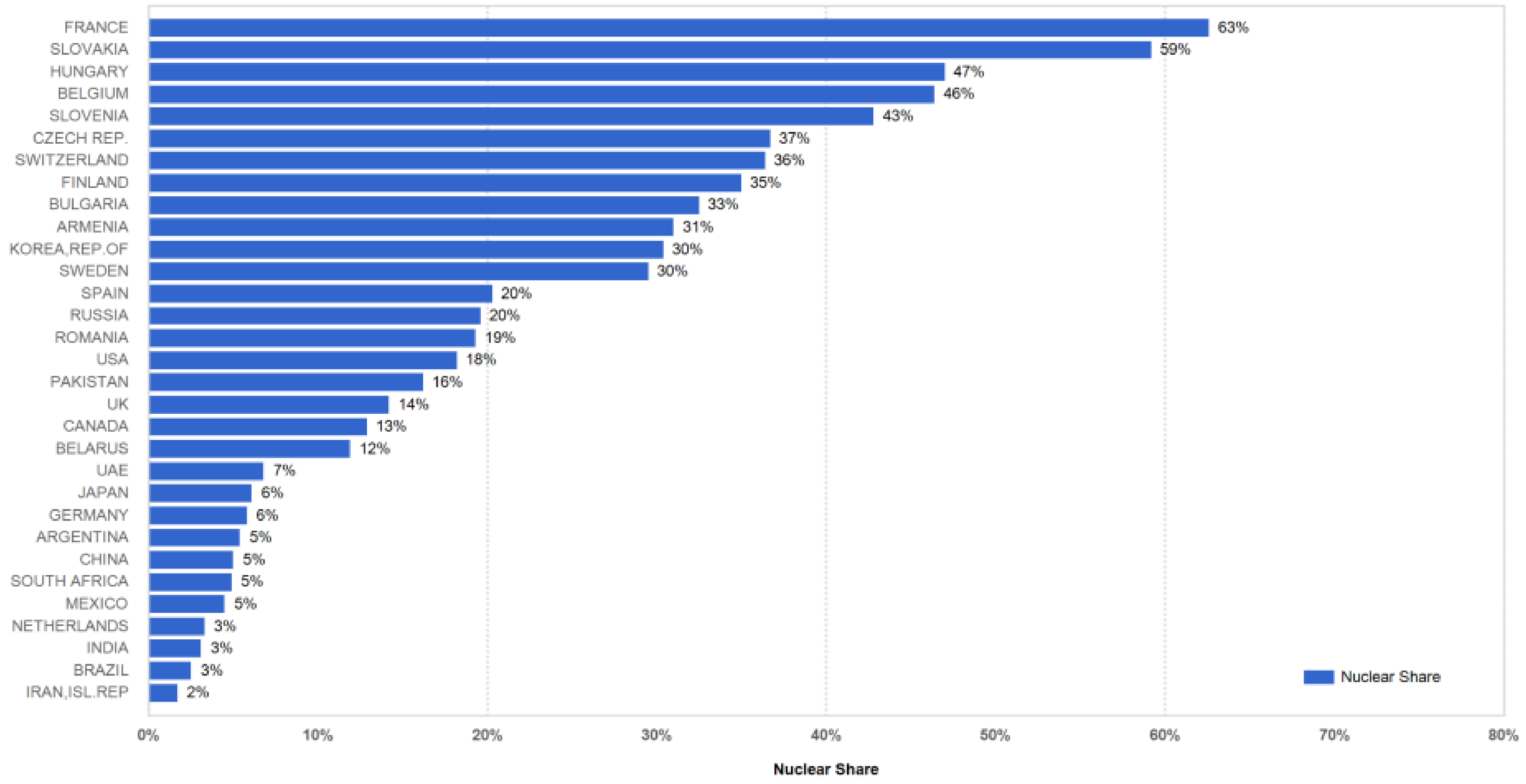
~ **10%** world's electricity

1/4

low carbon electricity

Electricity production share from nuclear

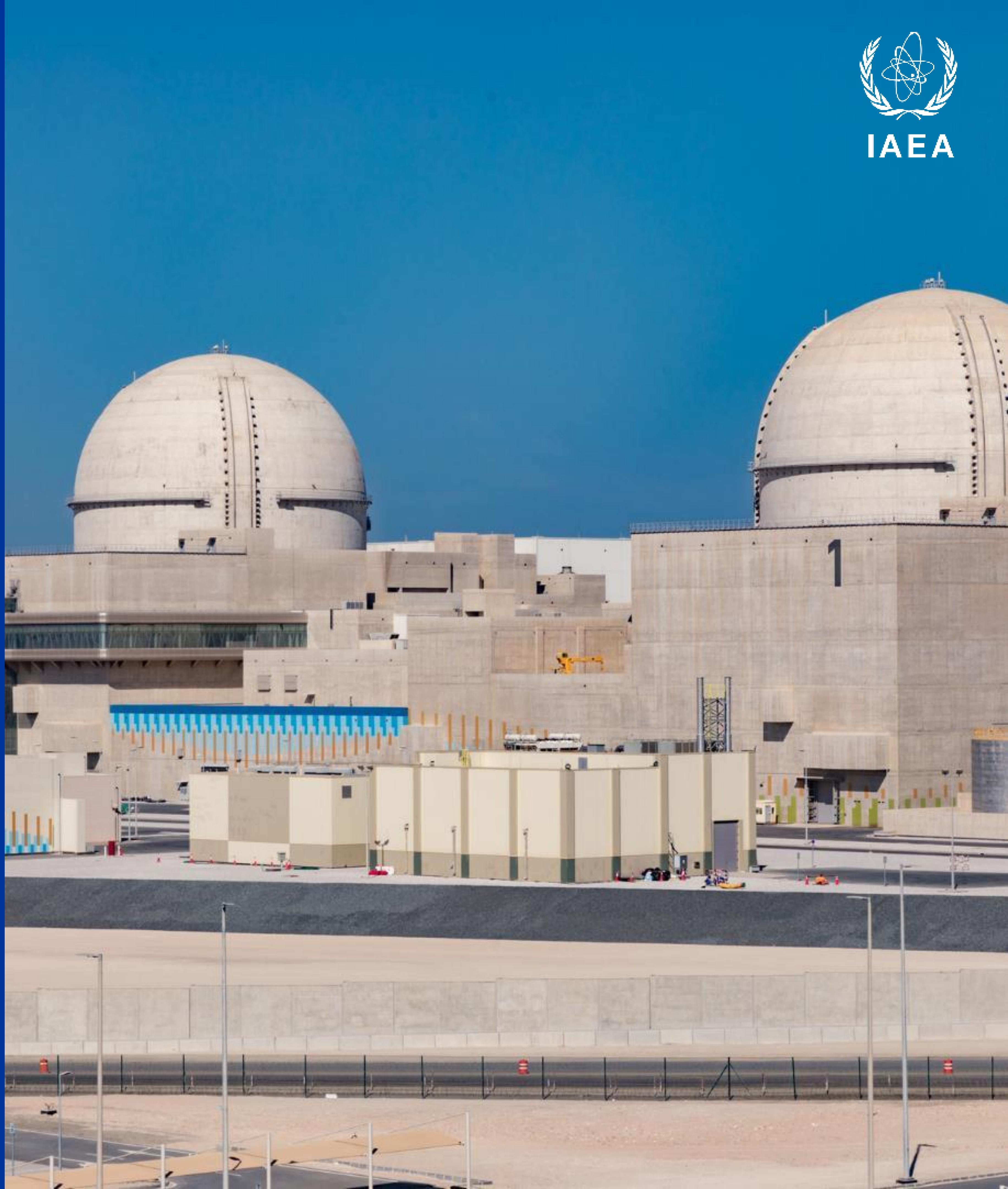
Figure 3. Nuclear share of electricity generation (as of 31 Dec. 2022)



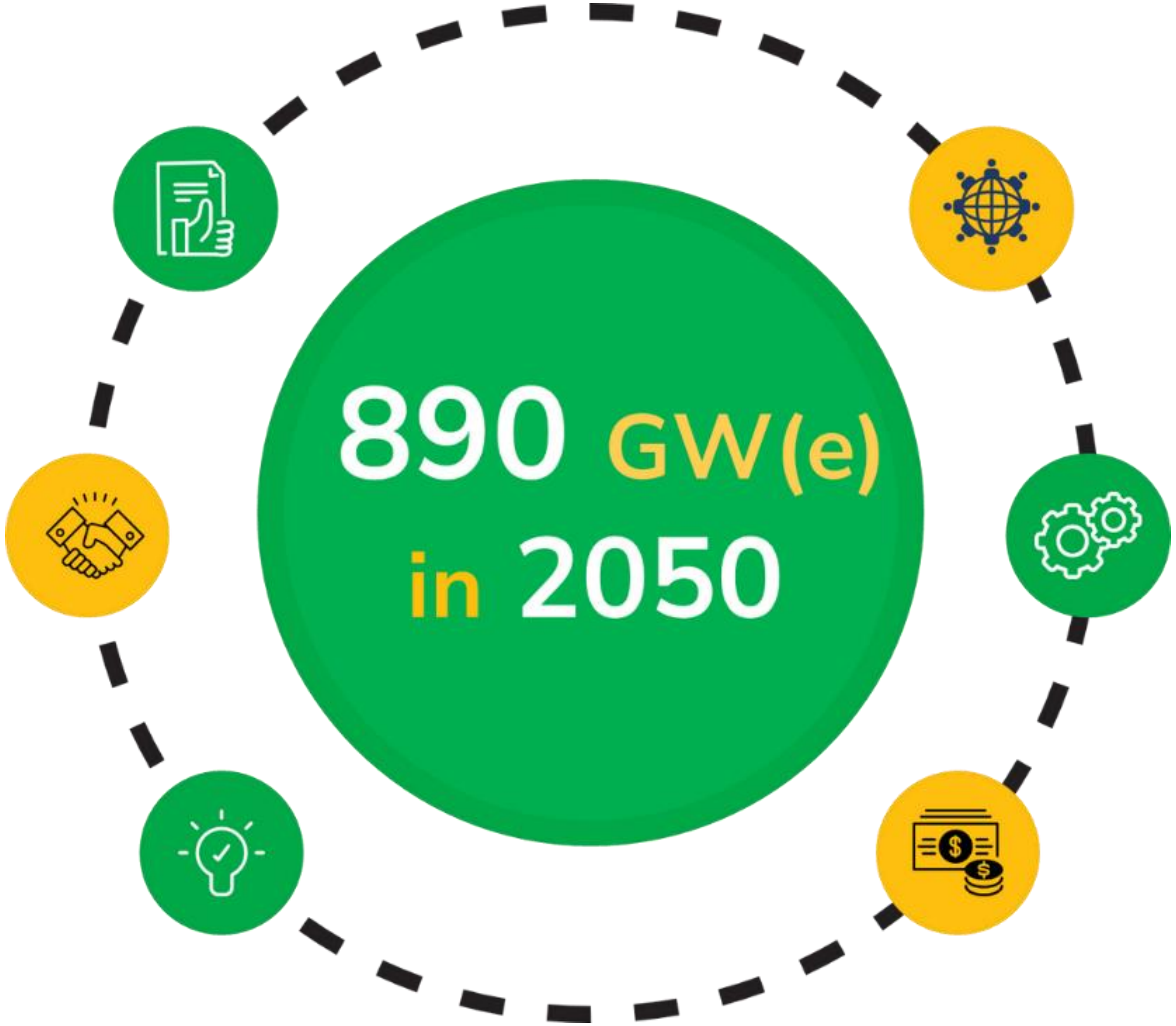
Note: The nuclear share of electricity supplied in Taiwan, China was 9.1% of the total.

Nuclear power prospects as of April 2024

- **59**
  under construction
- **~30**
  'newcomers'



IAEA projections for nuclear power



Advanced reactors & fusion

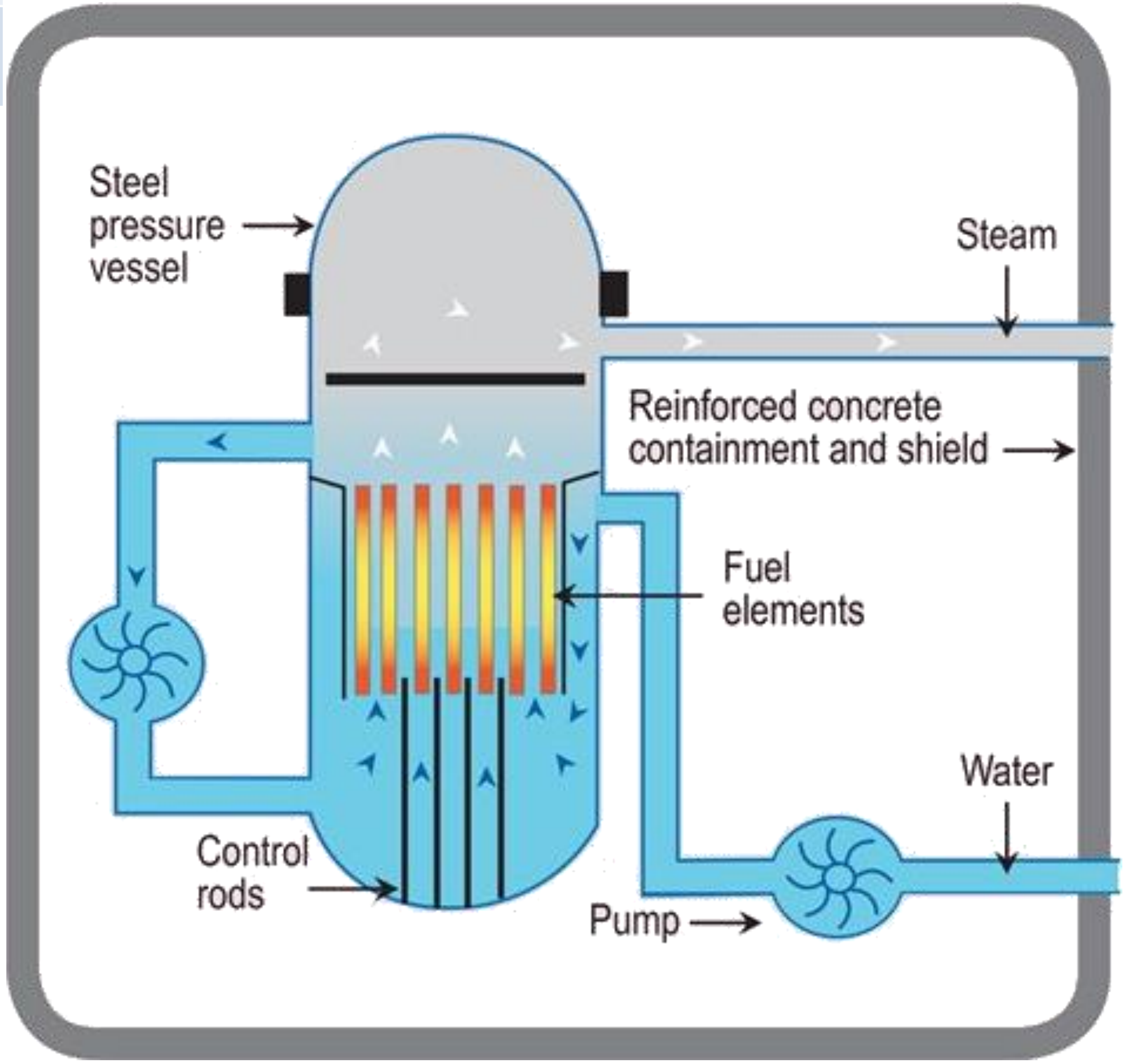
IAEA

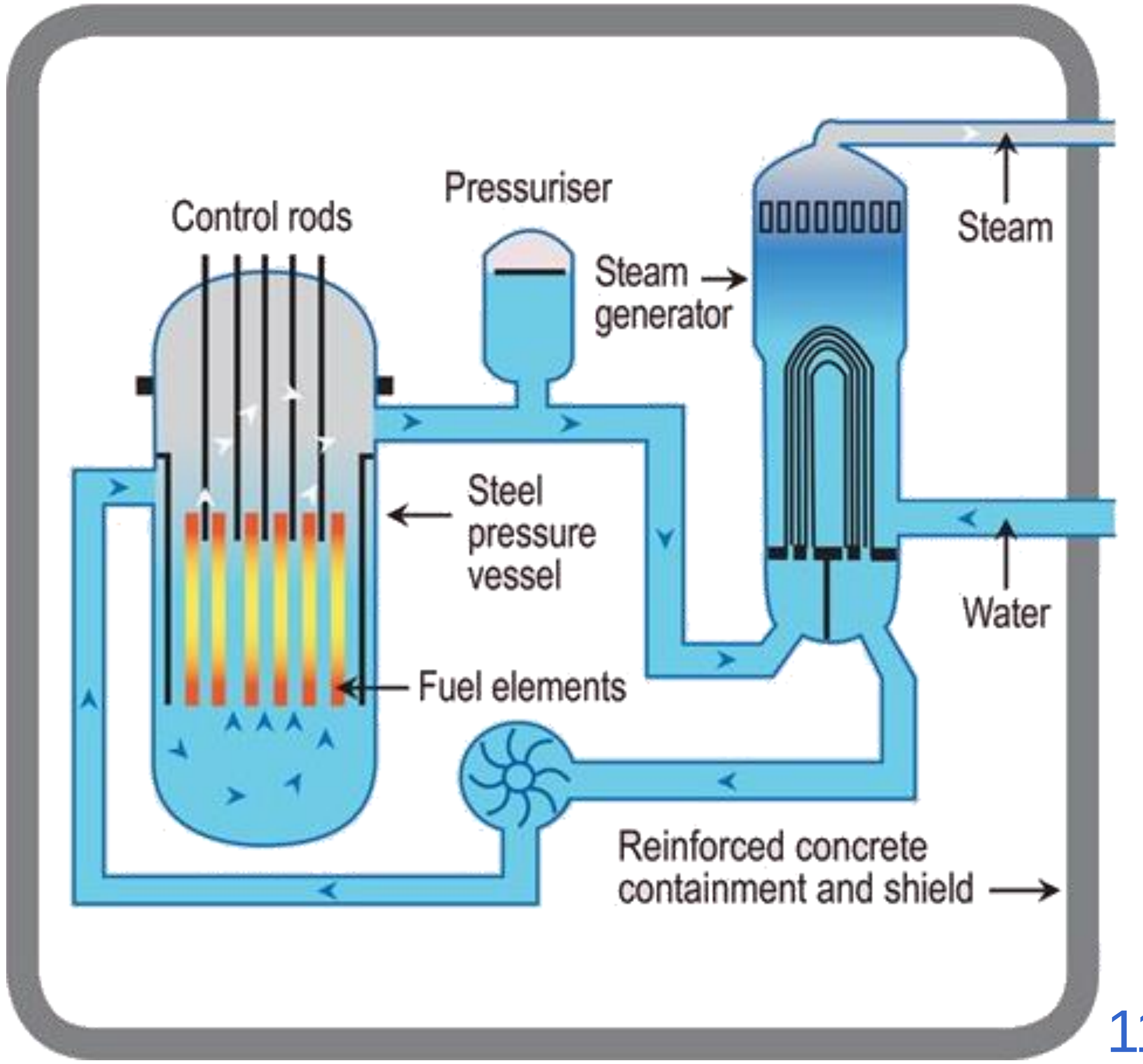
- Innovation
- Non-electric applications
- Fast reactors
- SMRs & MRs
- Nuclear Fusion

Water Cooled Reactors

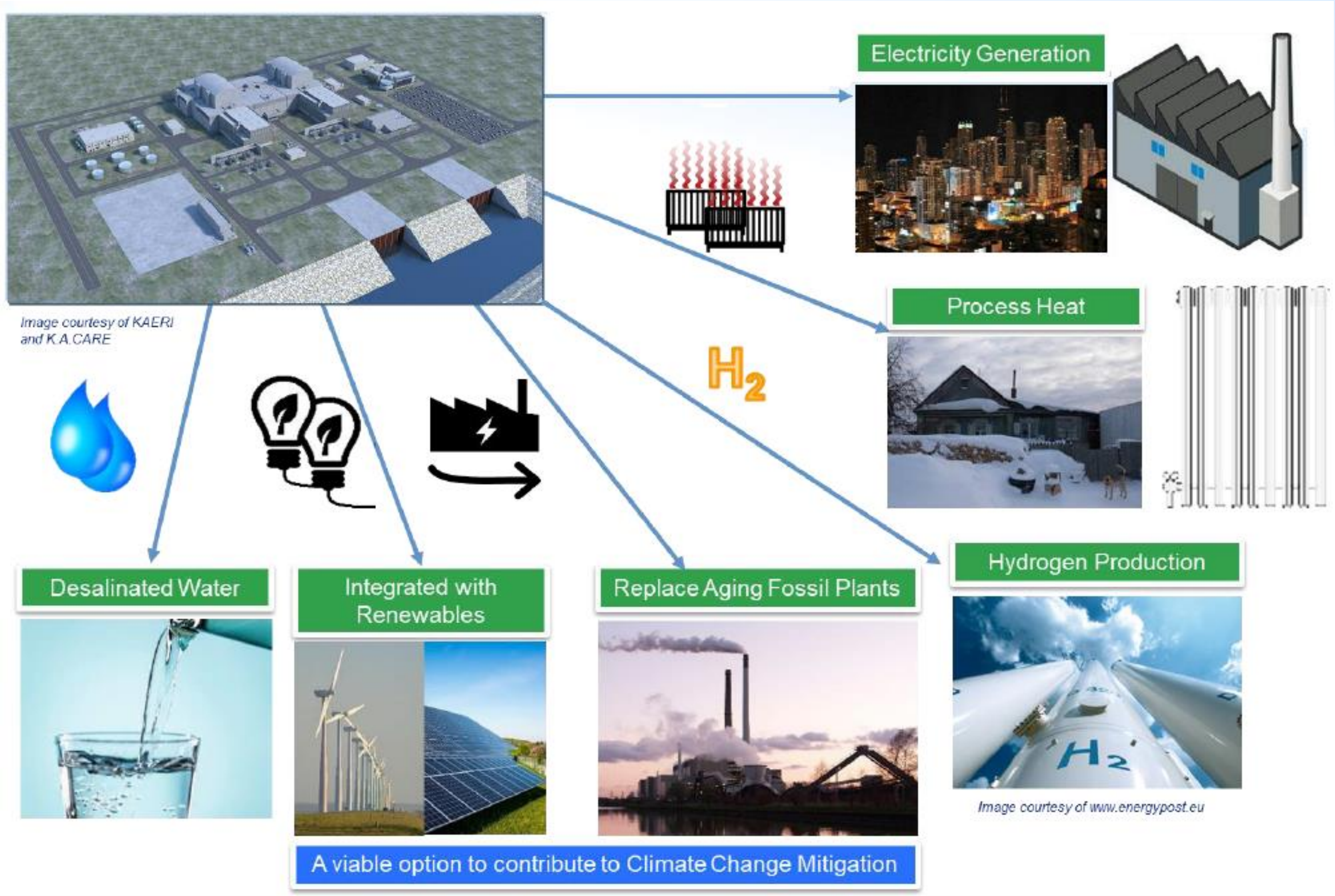
	WCR
coolant	H_2O
outlet T, C	288-329
efficiency, %	35
max P, MPa	7-17
spectrum	thermal

- *Mature Technology*
- *Low T => Low Efficiency*
- *High Pressure => safety issues*
- *Only thermal spectrum => not sustainable*

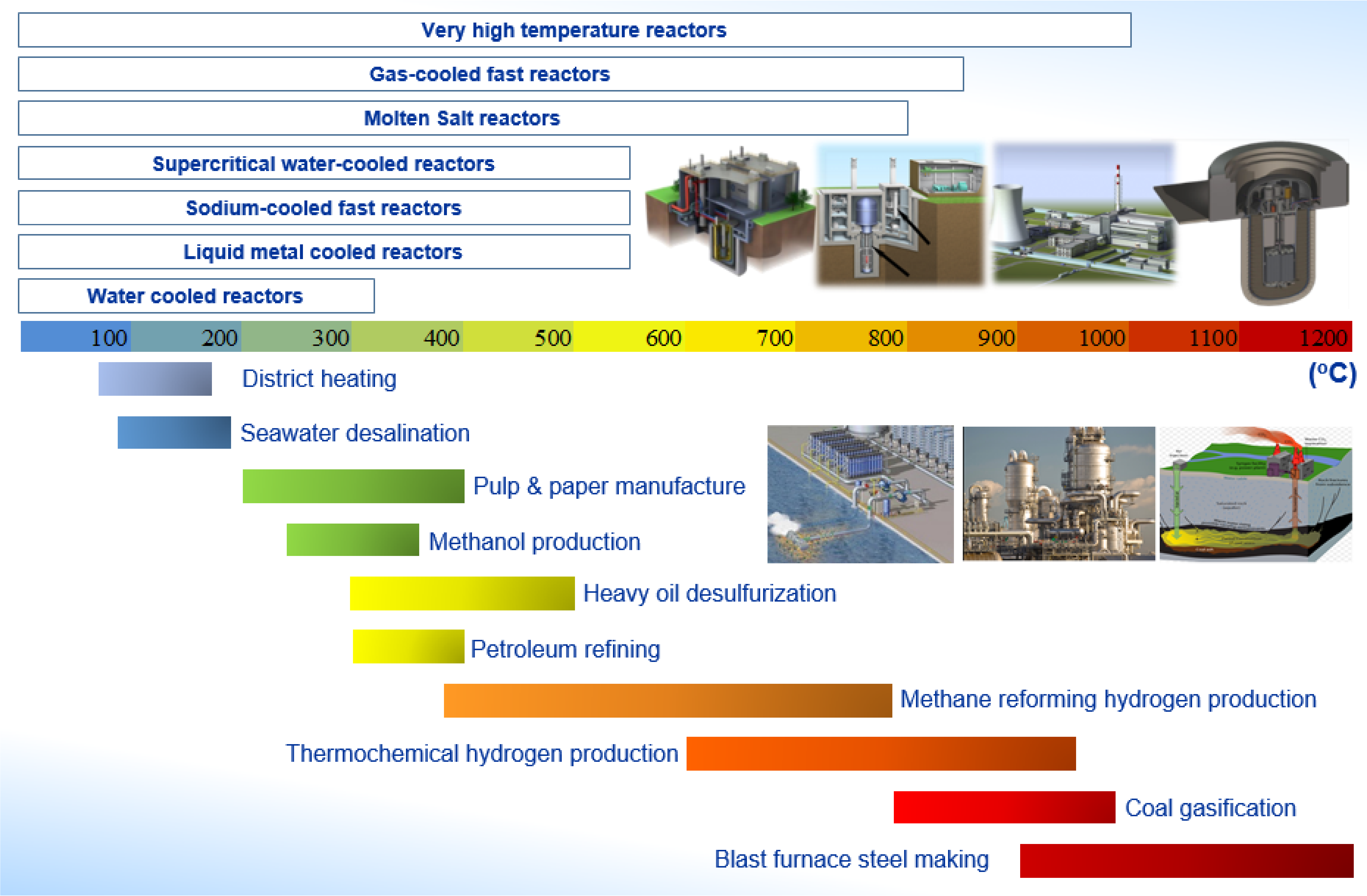




Reactor Technologies for Non-electric Applications



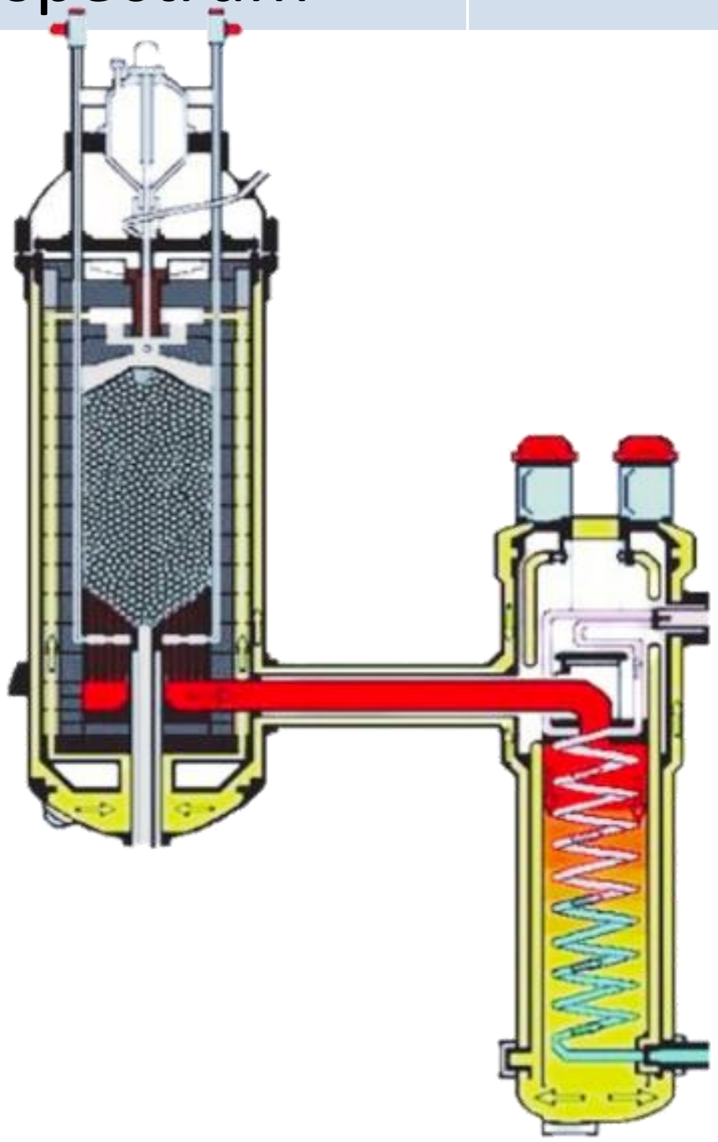
Reactor Technologies for Non-electric Applications



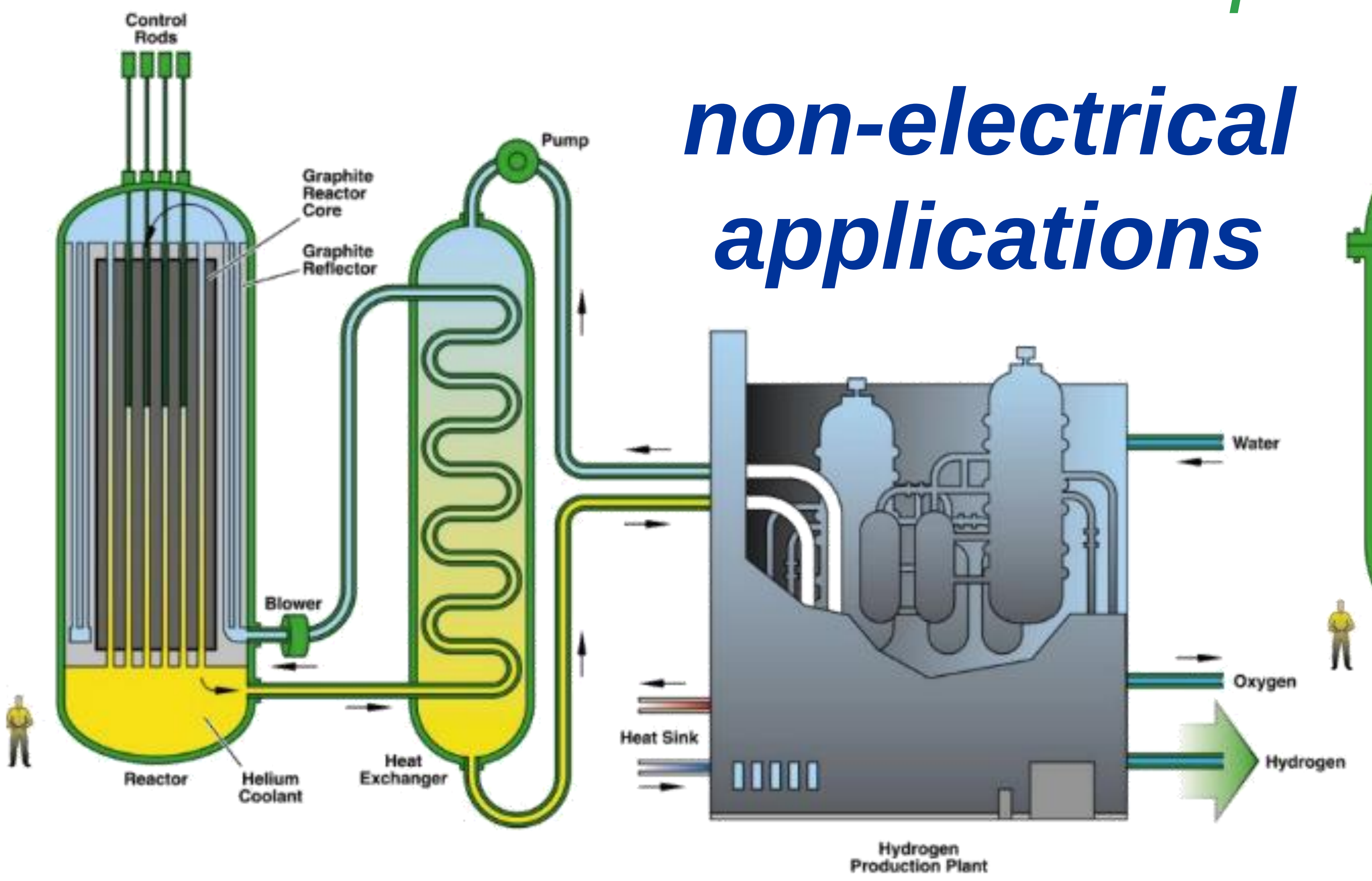
Gas cooled Reactors (HTGR, VHTR, GFR)

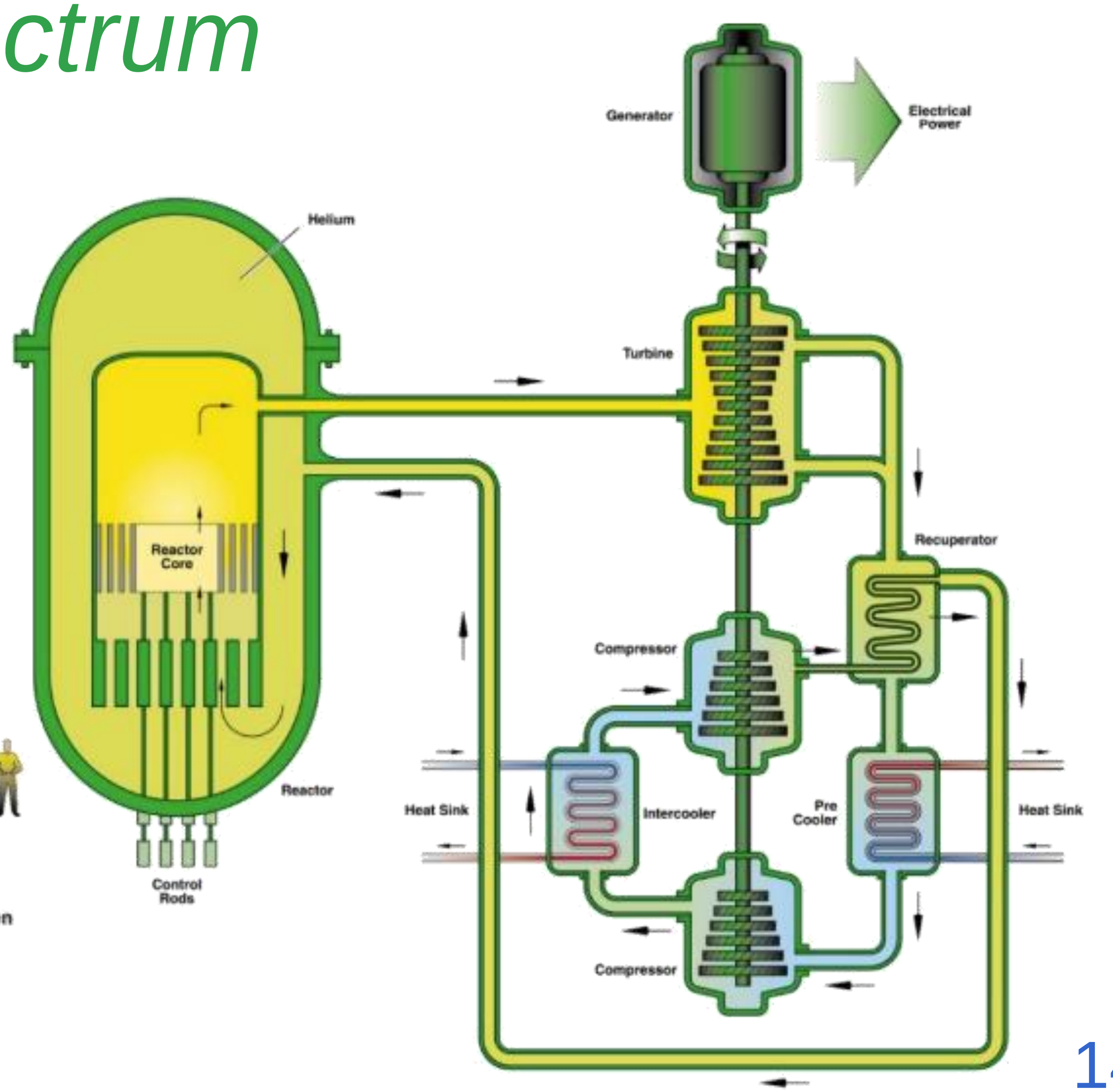
	WCR	SCWR	HTGR	GFR
coolant	H_2O	H_2O	He	He
outlet T, C	288-329	500	750	750
efficiency, %	35	45	50	50
max P, MPa	17	25	7	7
spectrum	thermal	thermal/fast	thermal	fast

- *New Technology*
- *Hight T => High Efficiency*
- *High Pressure => safety issues*
- *Sustainable if works in fast spectrum*

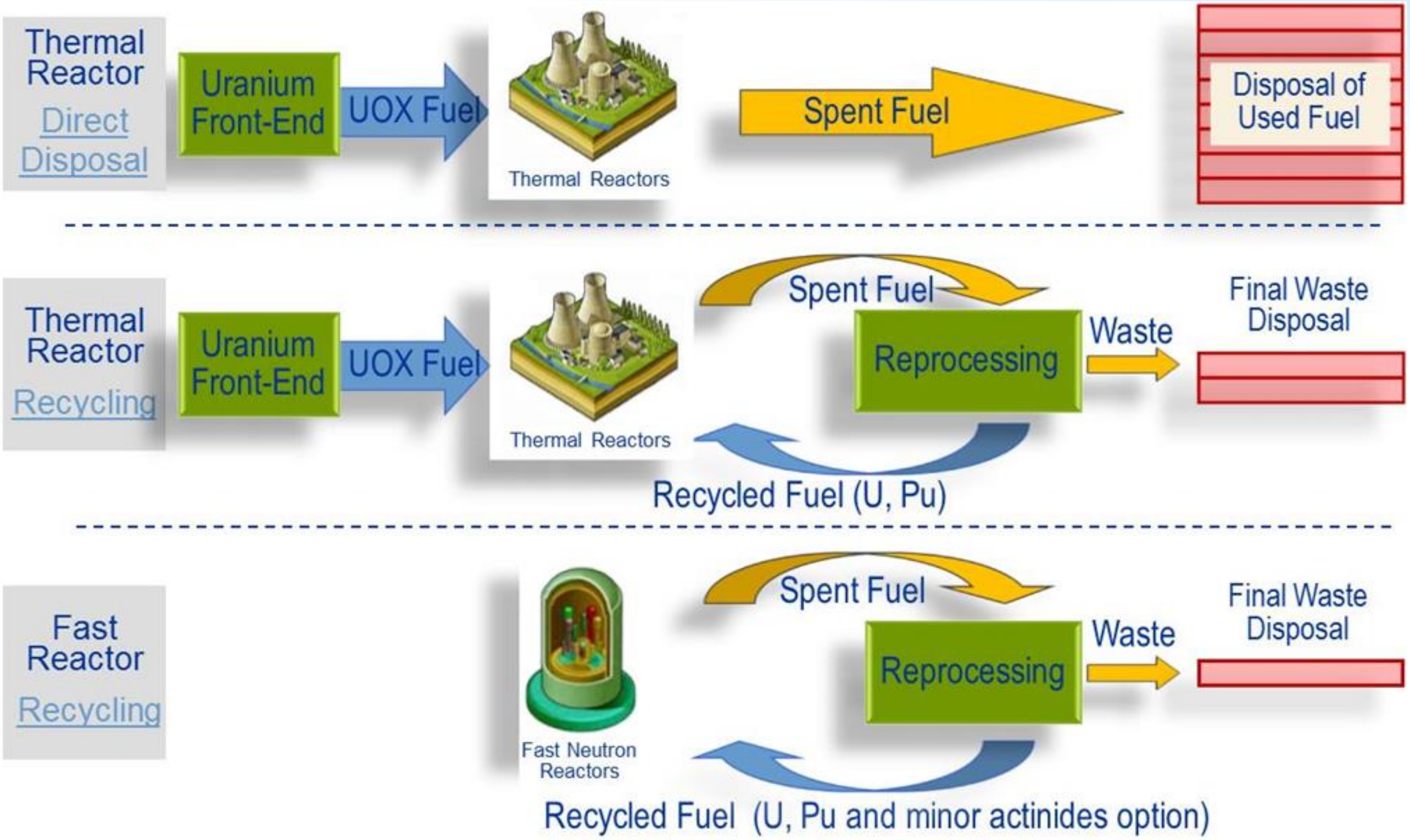


non-electrical applications

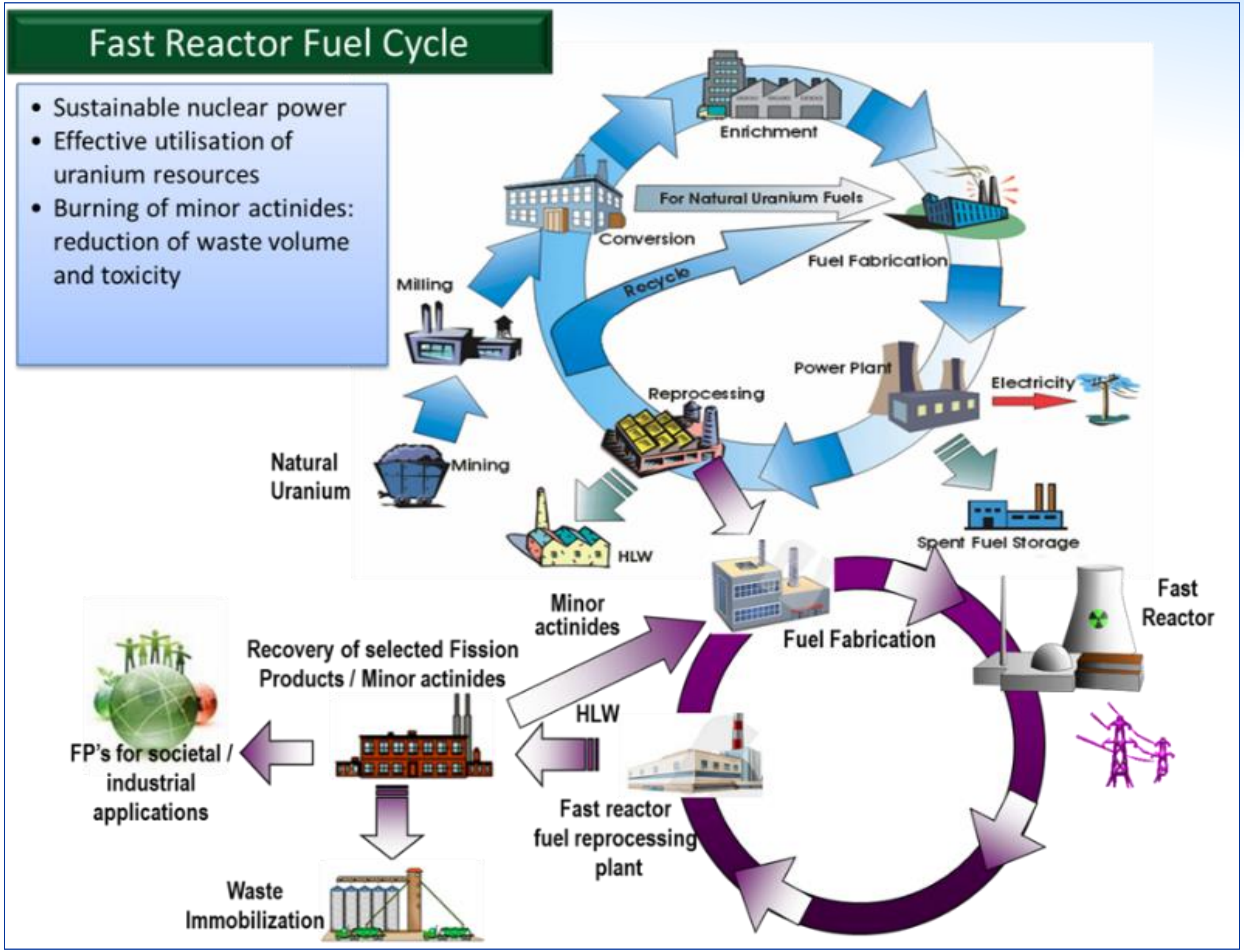




Fuel Cycles

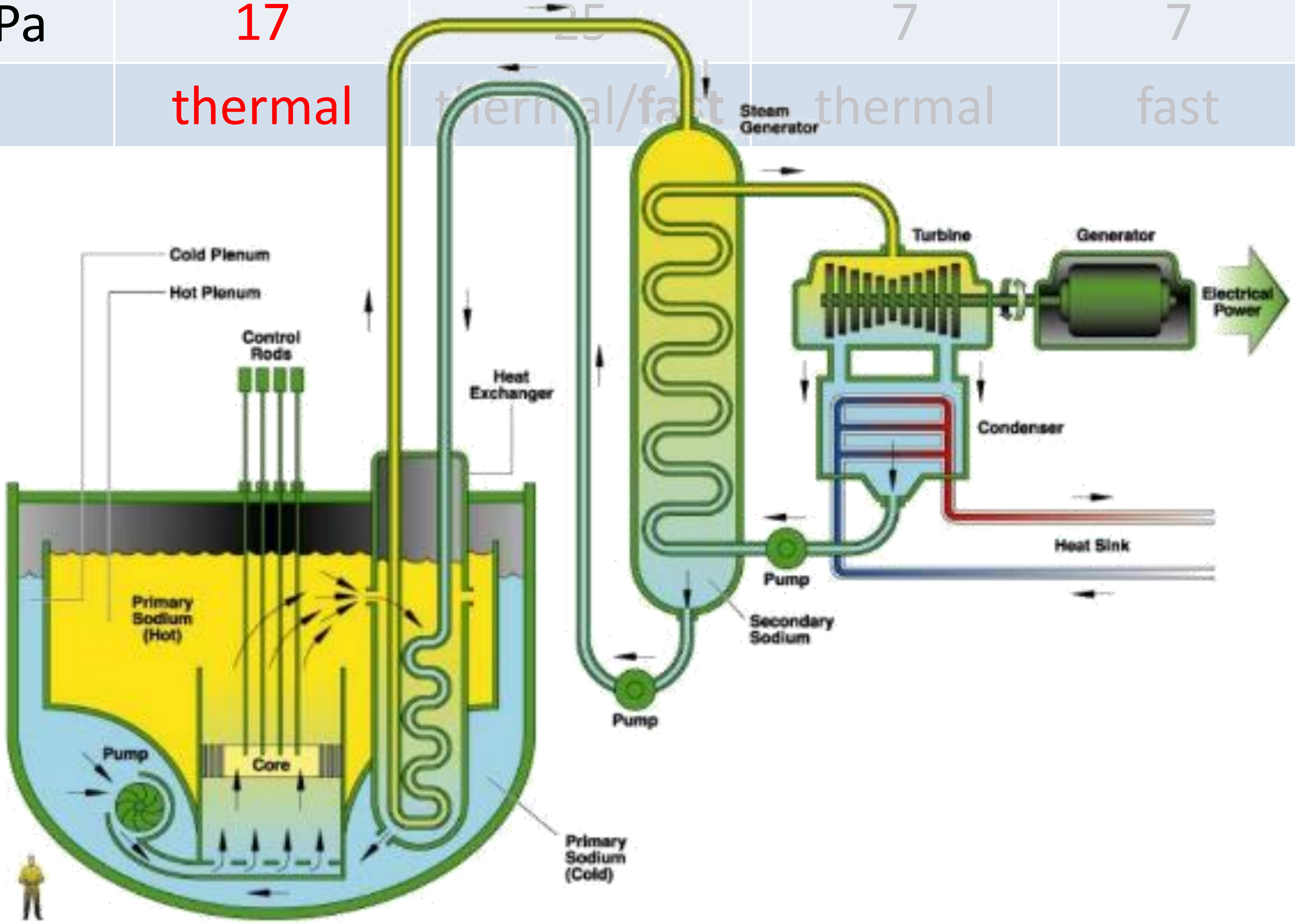

Thermal Reactor
Direct Disposal
Uranium Front-End
UOX Fuel
Thermal Reactors
Spent Fuel
Disposal of Used Fuel
Thermal Reactor
Recycling
Uranium Front-End
UOX Fuel
Thermal Reactors
Spent Fuel
Reprocessing
Waste
Final Waste Disposal
Recycled Fuel (U, Pu)
Fast Reactor
Recycling
Fast Neutron Reactors
Spent Fuel
Reprocessing
Waste
Final Waste Disposal
Recycled Fuel (U, Pu and minor actinides option)

Fast Neutron Reactors



Sodium cooled Fast Reactor

	WCR	SCWR	HTGR	GFR	SFR
coolant	H_2O	H_2O	He	He	Na
outlet T, C	288-329	500	750	750	550
efficiency, %	35	45	50	50	45
max P, MPa	17	25	7	7	~0.2
spectrum	thermal	thermal/fast	thermal	fast	fast

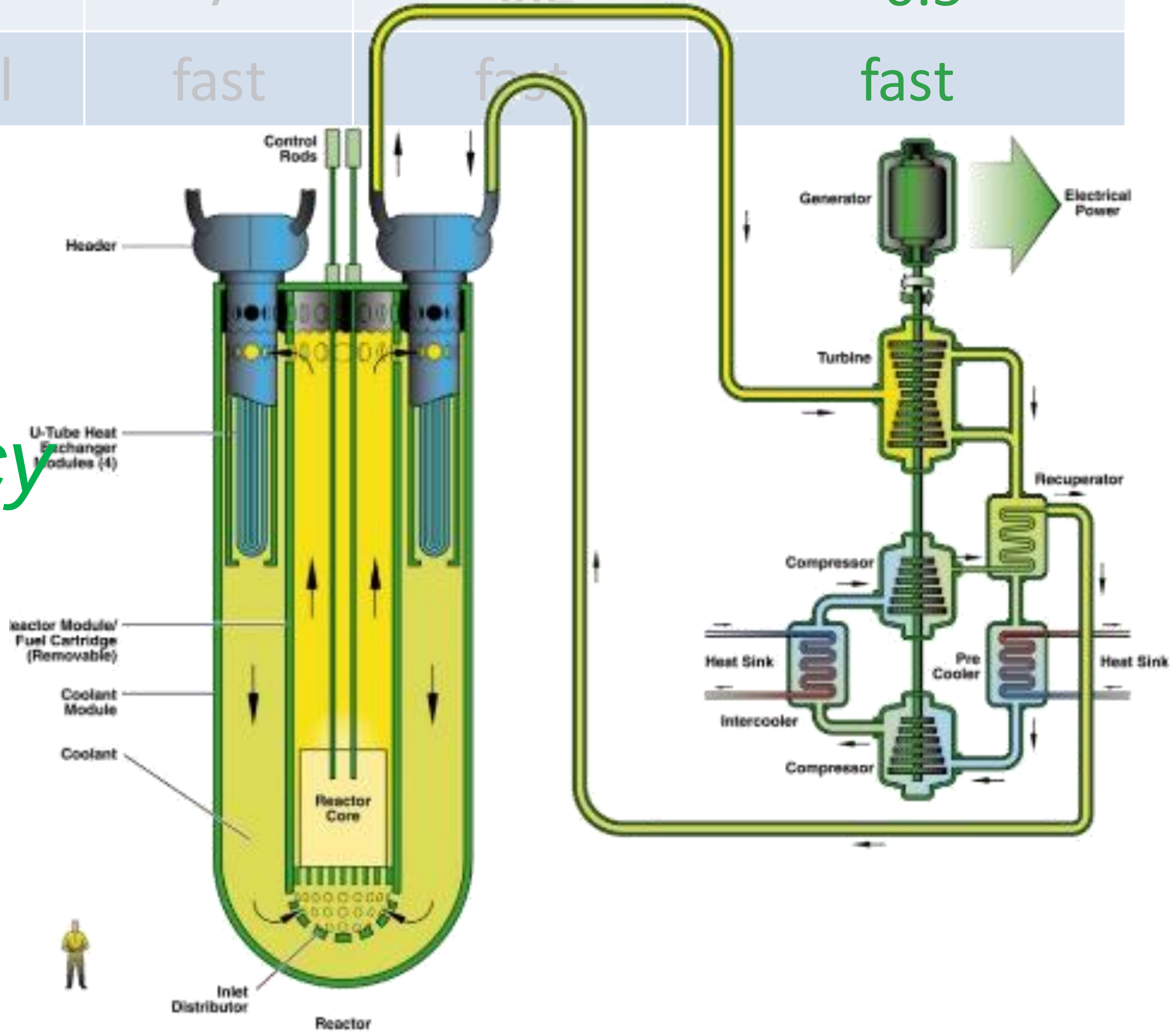


- *Mature Technology*
- *Hight coolant T => High Efficiency*
- *Low Pressure*
- *Fast spectrum*
- *Na violently reacts with water and air*

Heavy Liquid Metal cooled Fast Reactors

	WCR	SCWR	HTGR	GFR	SFR	LFR
coolant	H_2O	H_2O	He	He	Na	Pb/LBE
outlet T, C	288-329	500	750	750	550	500
efficiency, %	35	45	50	50	45	43
max P, MPa	17	25	7	7	~0.2	~0.5
spectrum	thermal	thermal/fast	thermal	fast	fast	fast

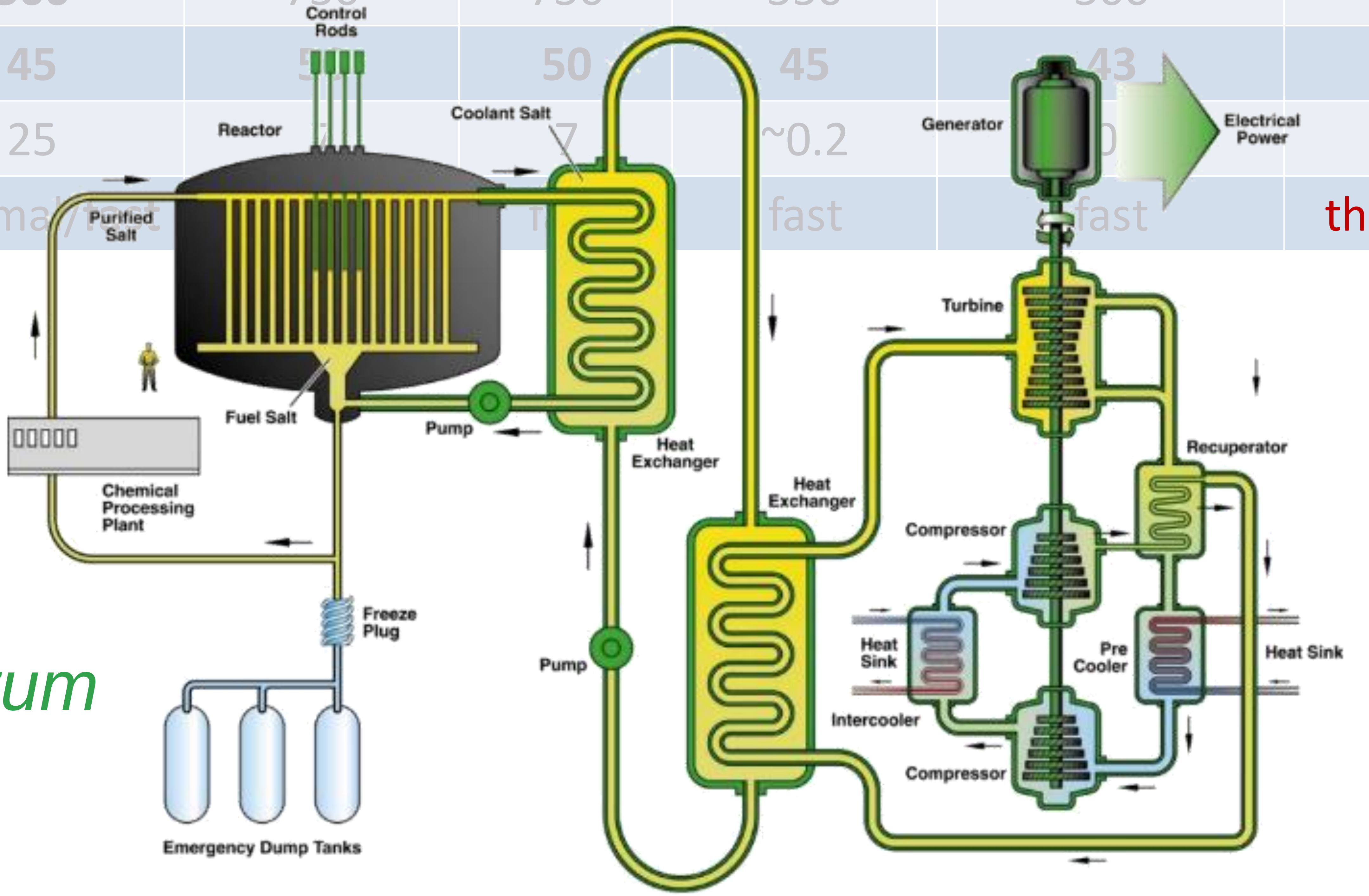
- *New Technology*
- *Pb/LBE material issues*
- *Hight coolant T => High Efficiency*
- *Low Pressure*
- *Fast spectrum*
- *No intermediate circuit*



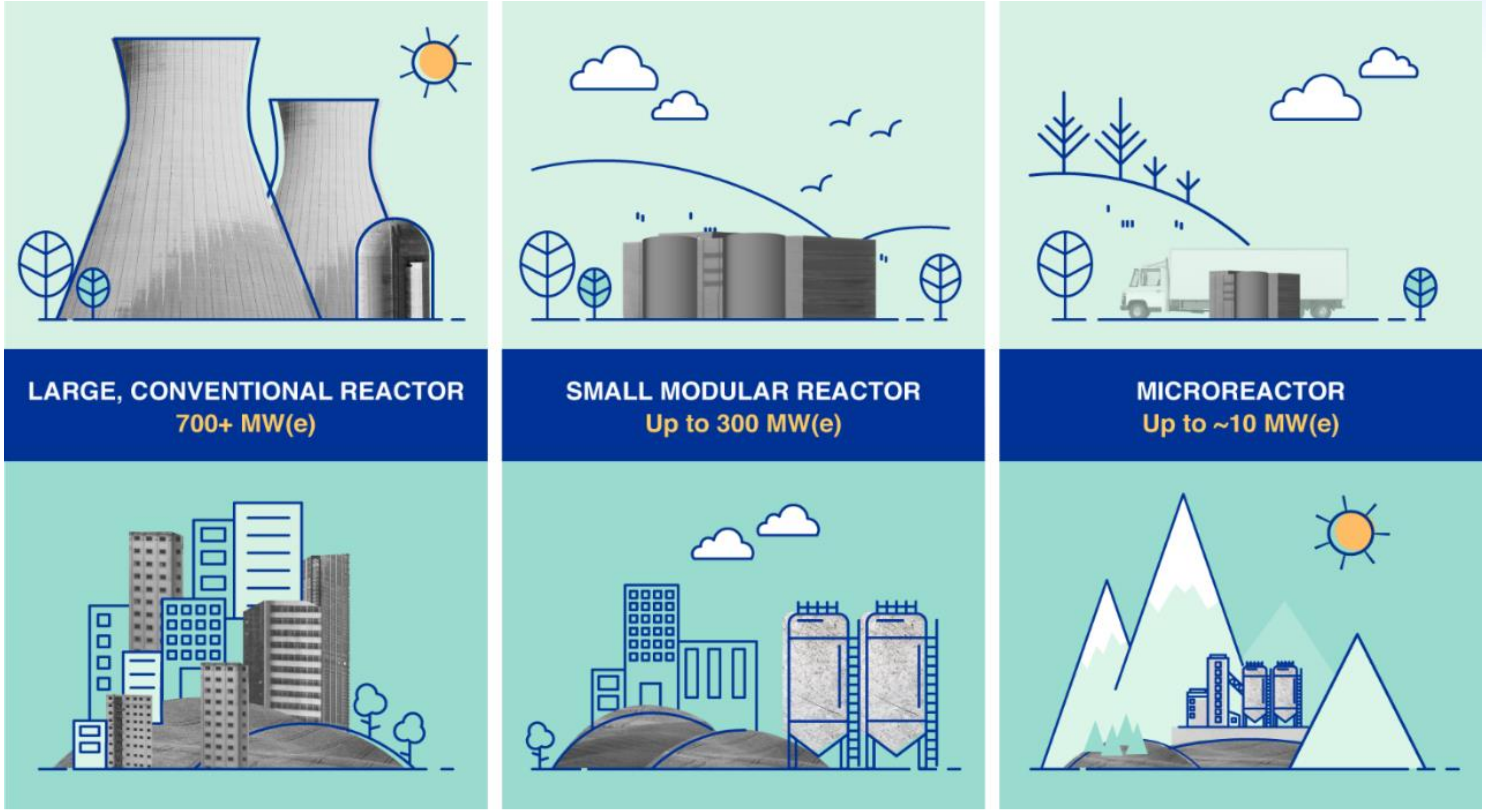
Molten Salt Reactors

	WCR	SCWR	HTGR	GFR	SFR	LFR	MSR
coolant	H_2O	H_2O	He	He	Na	Pb/LBE	Fluoride/Chloride
outlet T, C	288-329	500	750	750	550	500	800
efficiency, %	35	45	[illegible]	50	45	43	48
max P, MPa	17	25	[illegible]	7	~0.2	[illegible]	~0.2
spectrum	thermal	thermal/fast	[illegible]	[illegible]	fast	fast	thermal/fast

- *New Technology*
- *Material issues*
- *Hight coolant T*
- *Low Pressure*
- *Thermal/Fast spectrum*
- *Very safe*



Reactor Categorization by Installed Capacity



SMR – Salient Design Characteristics

Simplification by Modularization and System Integration

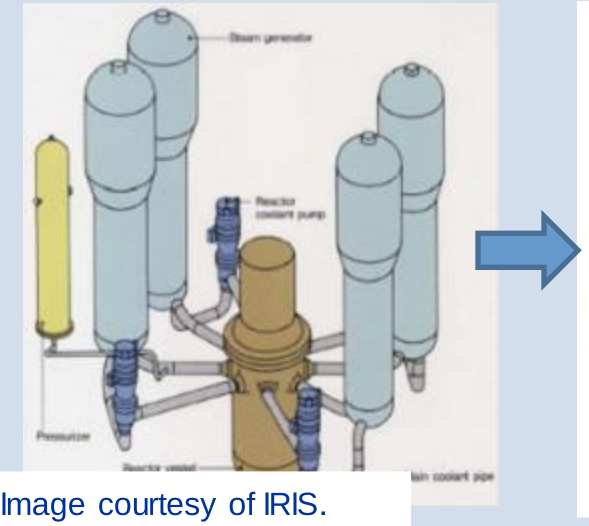
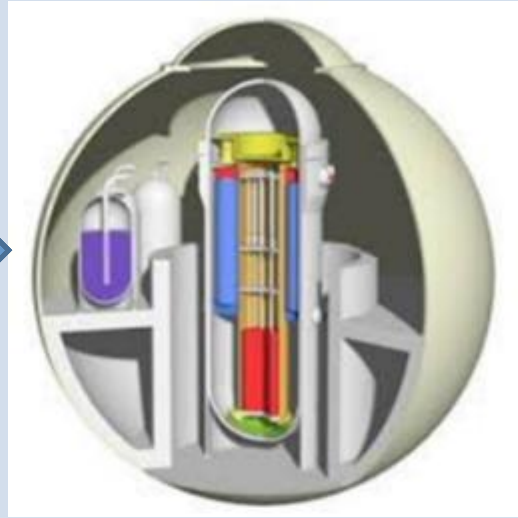
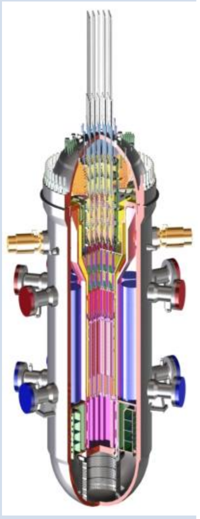




Image courtesy of IRIS.

Multi-module Plant Layout Configuration

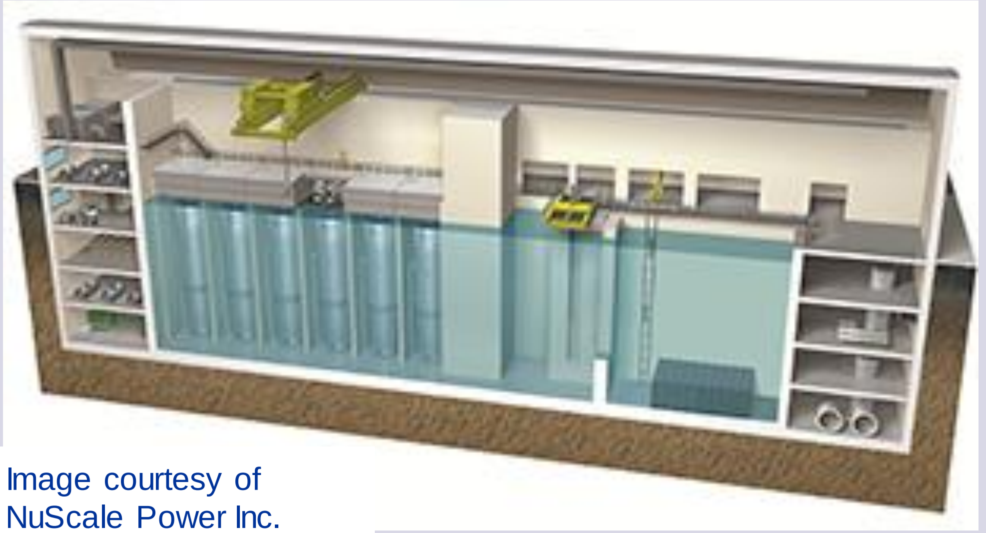
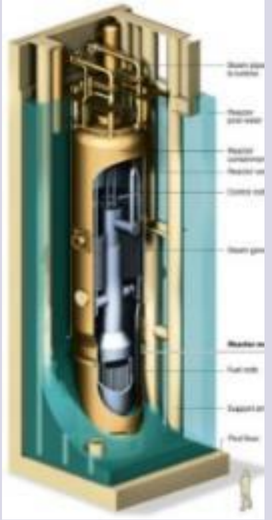



Image courtesy of NuScale Power Inc.

Underground construction for enhanced security and seismic

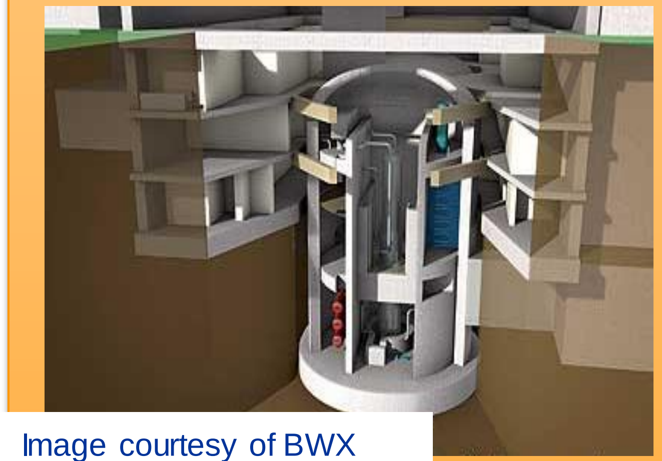
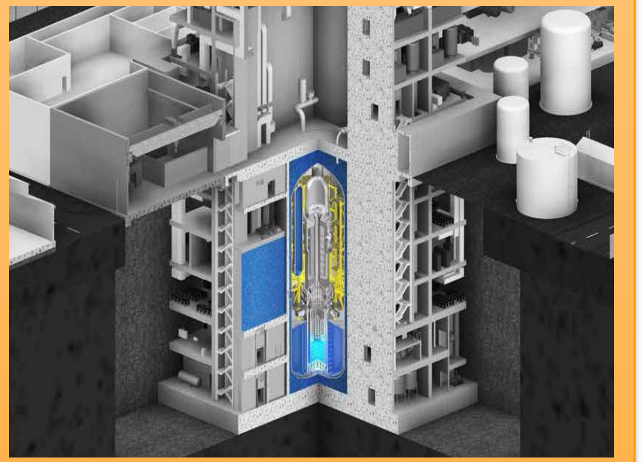



Image courtesy of BWX Technology, Inc.

Enhanced Safety Performance through Passive System

- Enhanced severe accident features
- Passive containment cooling system
- Pressure suppression containment

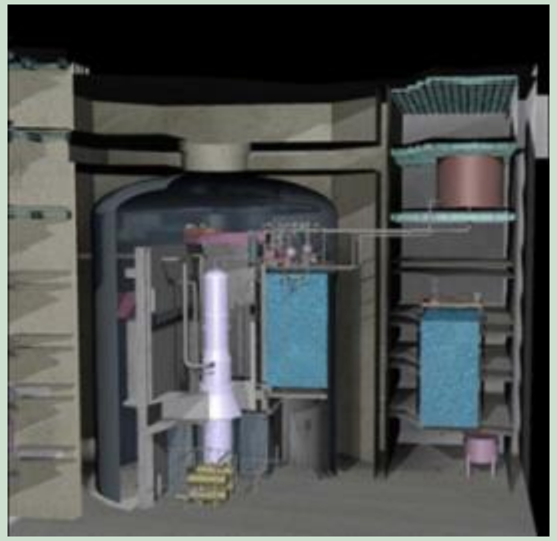


Image courtesy of BWX Technology, Inc.

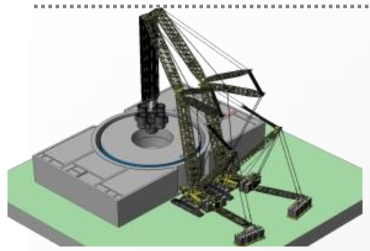
21

SMR – Key Attributes

- Enhanced Safety
- Versatile
- Modular
- Reduced Waste
- Affordable
- Non-electric applications

Economic
- Lower Upfront capital cost
- Economy of serial production

Better Affordability

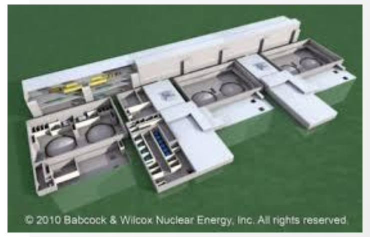


Modularization
- Multi-module
- Modular Construction

Shorter construction time

Flexible Application
- Remote regions
- Small grids

Wider range of Users

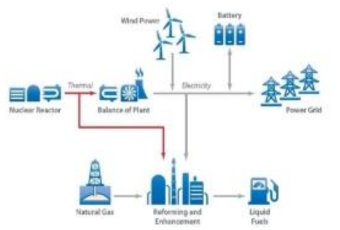


Smaller footprint
- Reduced Emergency planning zone

Site flexibility

Replacement for aging fossil-fired plants

Reduced CO_2 production

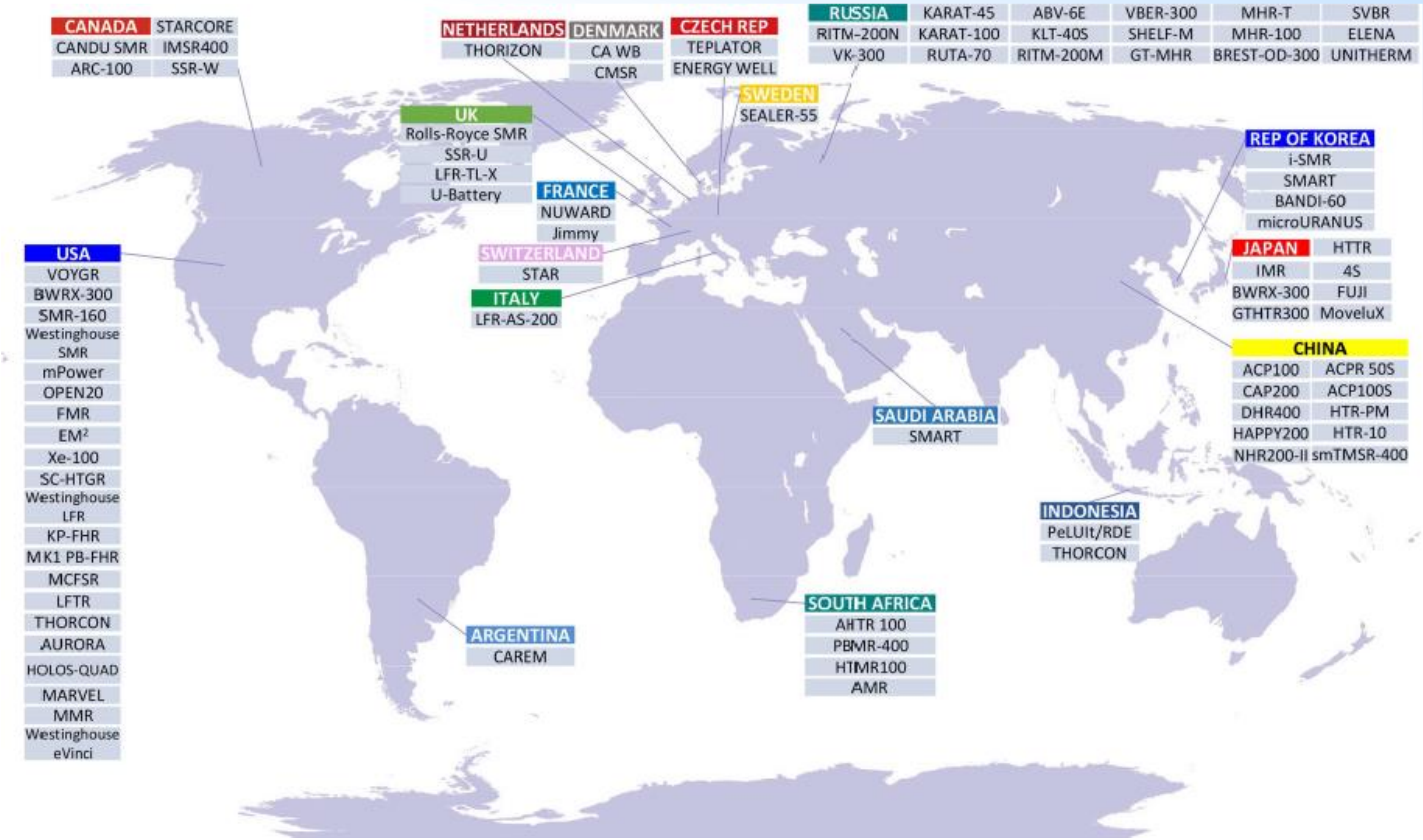


Potential Hybrid Energy System

Integration with Renewables

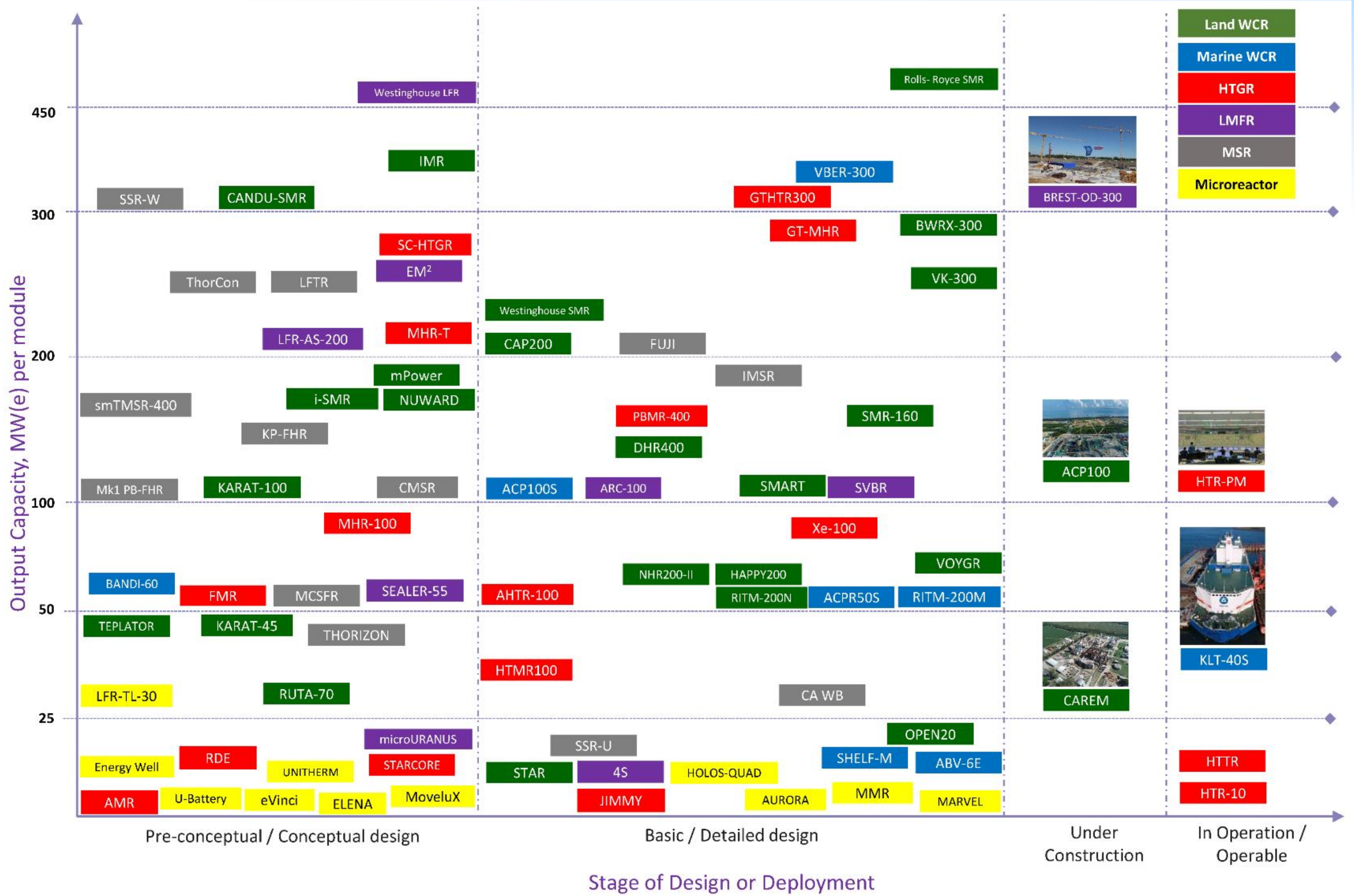
22

Global SMR Technology Development (ARIS 2022) 1/2



23

Global SMR Technology Development (ARIS 2022) 2/2

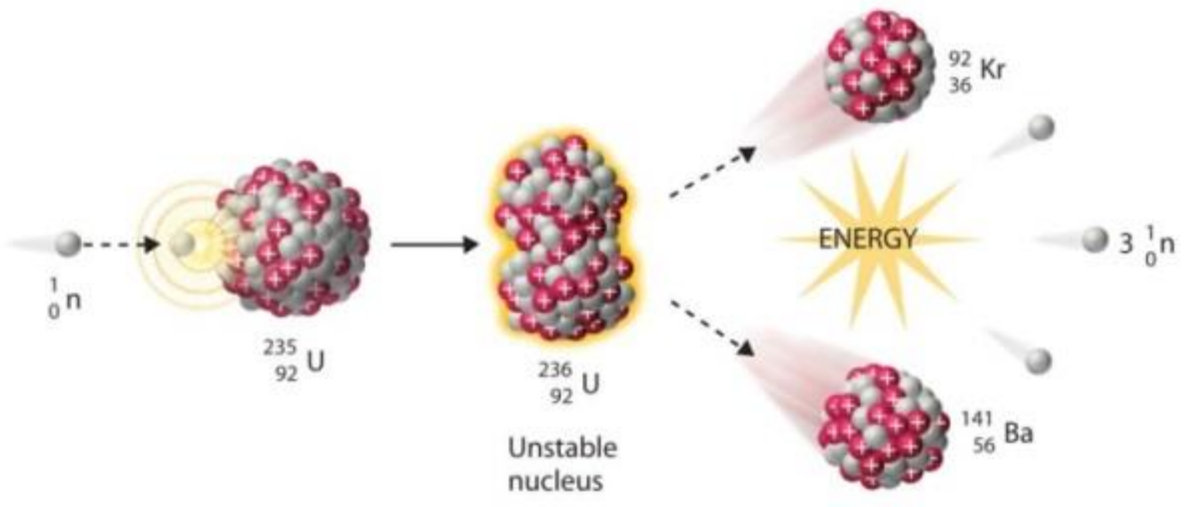


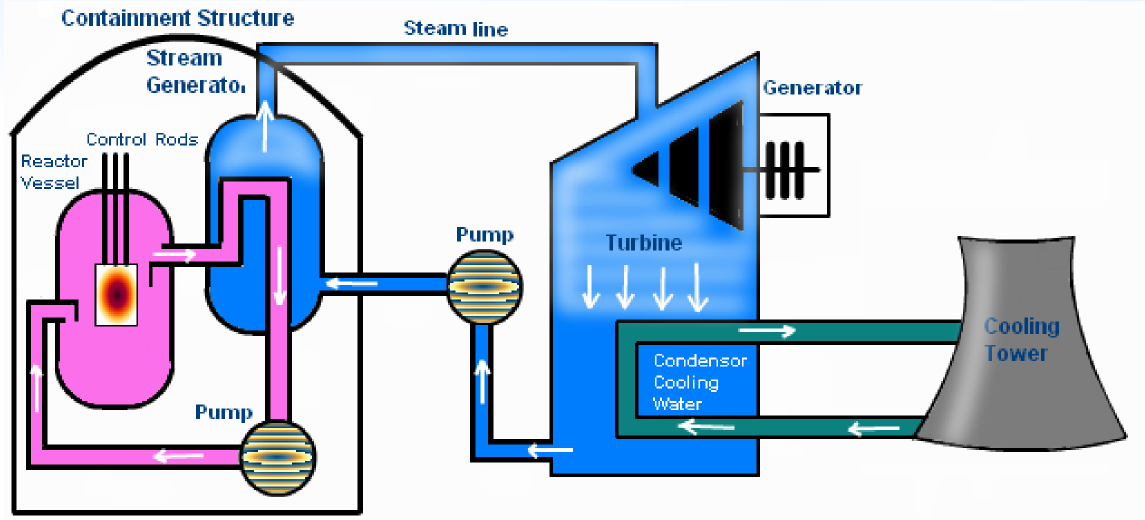
Take Aways on Nuclear Fission Power

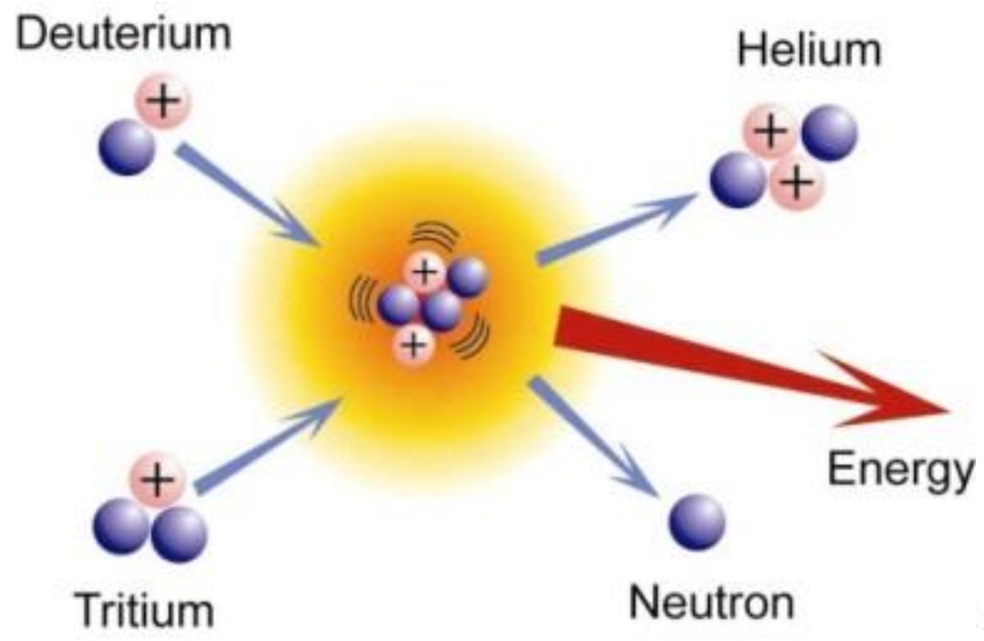
- Nuclear has unique attributes to play a major role in the **transition to Net Zero**:
  - Only technology that can provide **at scale low C electricity, heat and hydrogen**
  - **Reduced land footprint** and **use of critical minerals**, much **higher capacity factors**
- It can complement renewables – dispatchability, flexibility, **security of supply** - and support low carbon H_2 production.
  - It can **lower the costs of the transition** to carbon neutrality.
  - Offers a **less risky pathway** to net zero (*100% renewables would need extremely high deployment rates + massive storage capabilities + higher dependency on critical minerals*)
- For nuclear to fulfill its full role – *i.e. massive production of all major clean energy carriers* – consistently with net zero roadmap there is the **need to quickly advance design and demonstration of advanced reactor technologies, including SMRs**

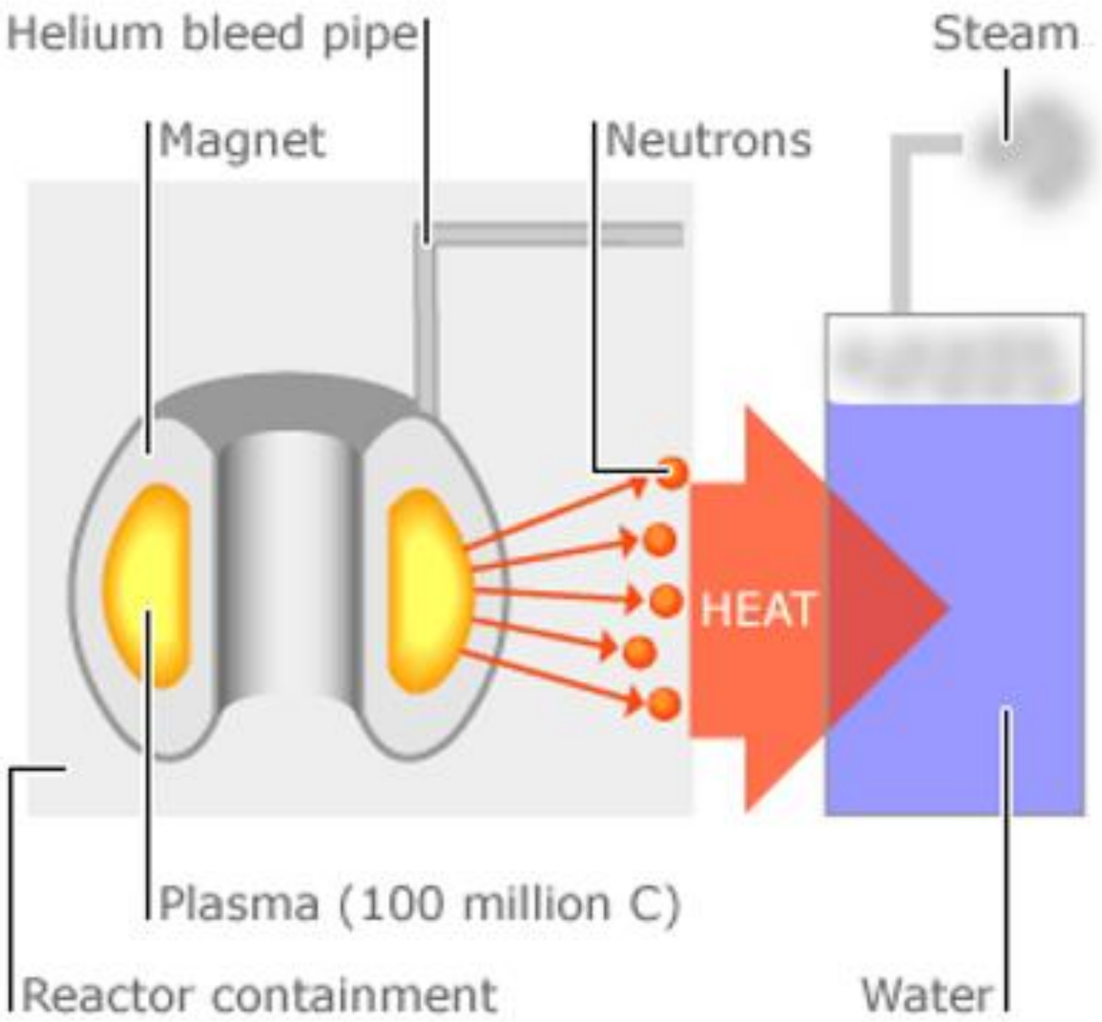
Nuclear Fusion Power

Fission Power Plant









Fusion Power Plant

1 gram of fusion fuel = 8 tons of oil

$^2D^+ + {}^2D^+ \xrightarrow{50\%} T^+$ (1MeV) + p^+ (3MeV)

$^2D^+ + {}^2D^+ \xrightarrow{50\%} {}^3He^{++}$ (0.8MeV) + n^0 (2.5MeV)

$^2D^+ + {}^3T^+ \longrightarrow {}^4He^{++}$ (3.5MeV) + n^0 (14MeV)

$^2D^+ + {}^3He^{++} \longrightarrow {}^4He^{++}$ (3.6MeV) + p^+ (15MeV)

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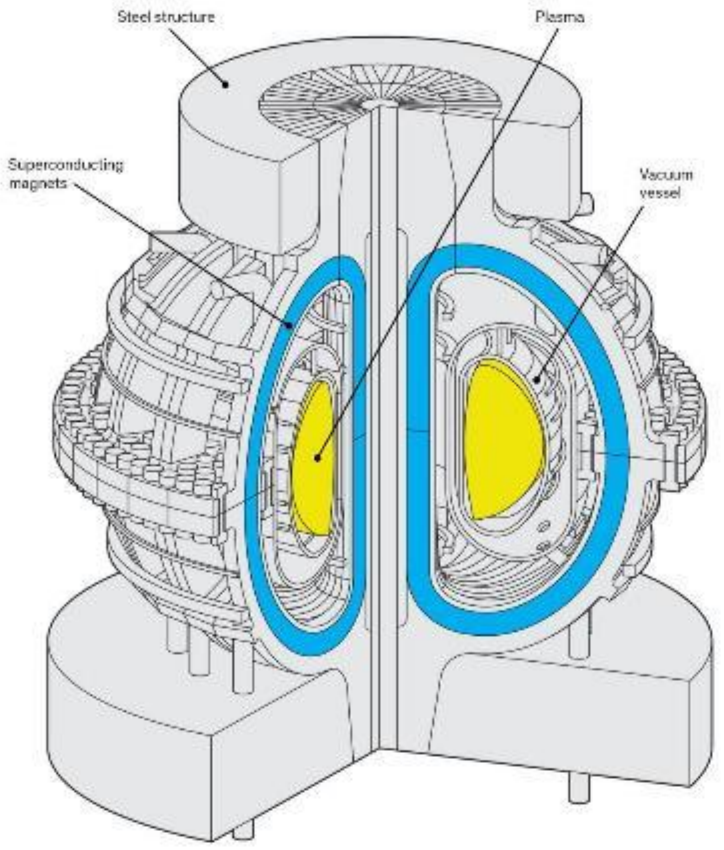
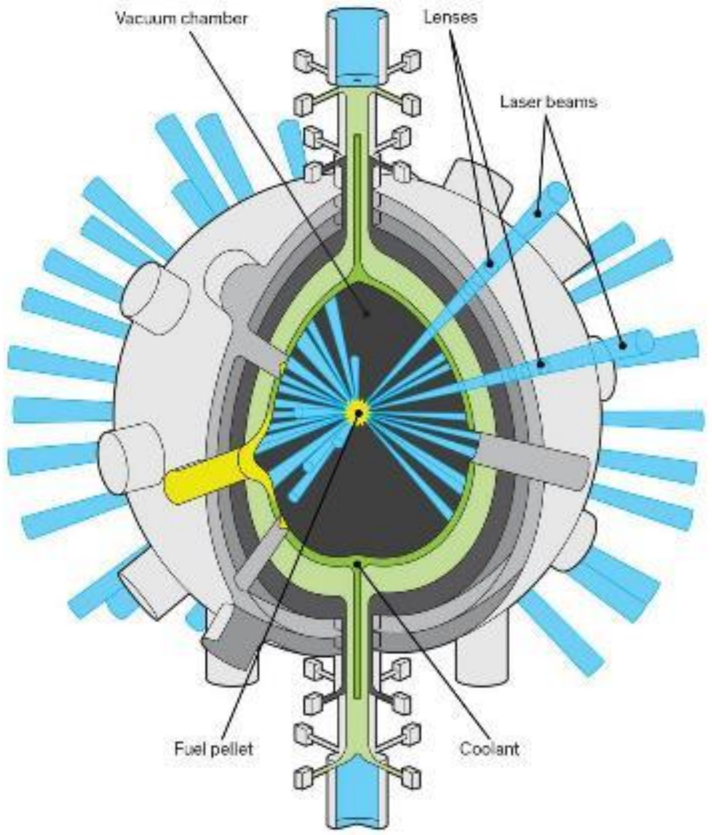
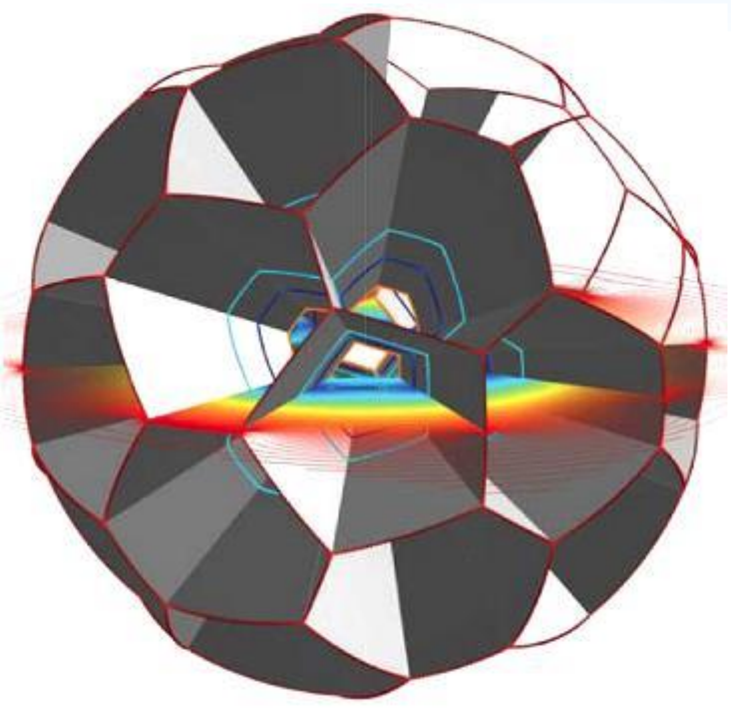
Various Fusion Technologies





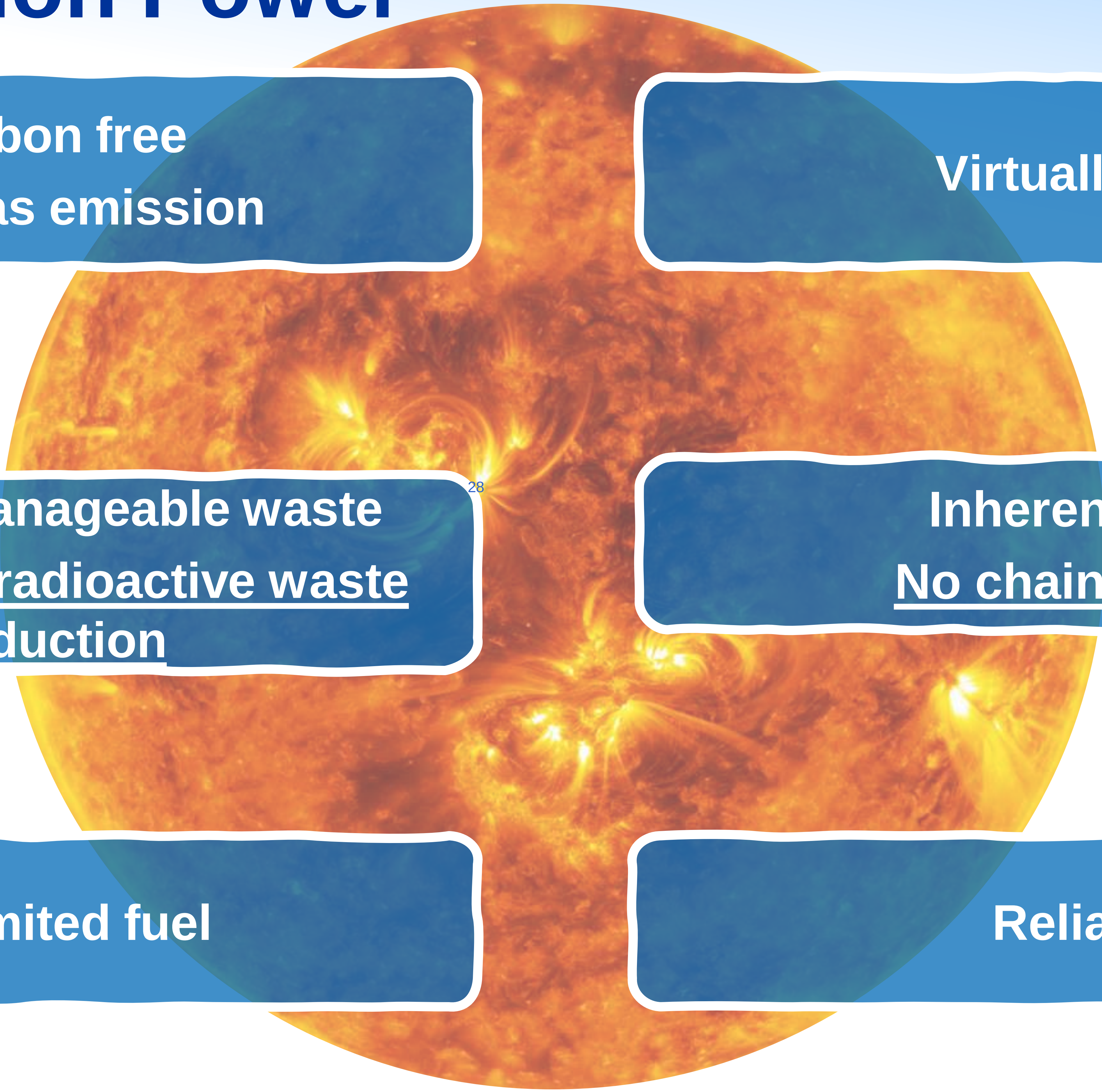


Magnetic confinement
Superconducting magnets confine the fusion fuel in the form of plasma

Inertial confinement
Compressing fuel pellets with lasers or high energy particle beams

Electrostatic confinement
Plasma is confined using electric fields

Merits of Fusion Power



Carbon free

Zero gas emission

Virtually clean

Low level, manageable waste

No long-lived radioactive waste production

Inherently safe

No chain reaction

Unlimited fuel

Reliable

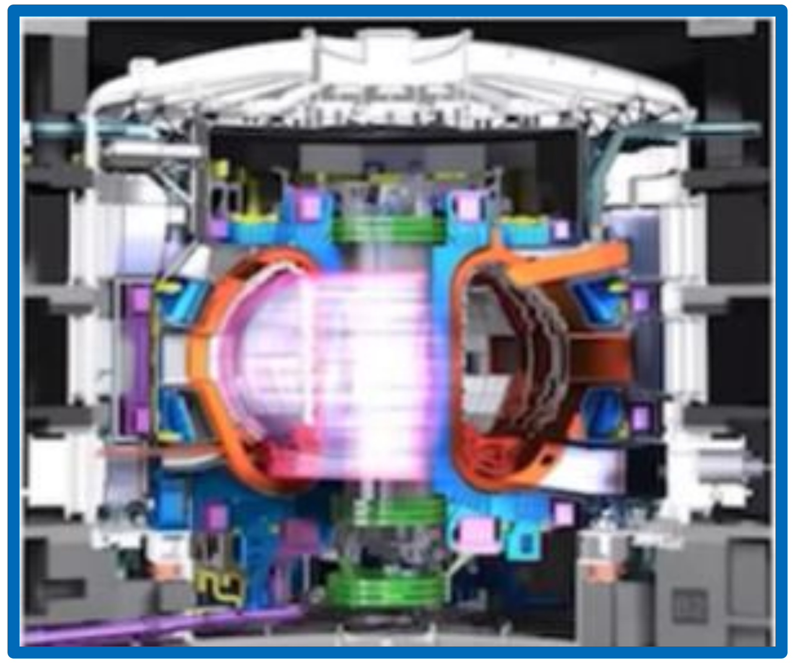
28

Why Fusion now?

Market Conditions Becoming Attractive for Fusion

2 Paths to Fusion

Public



https://www.iter.org/mach/tokamak

Private

Complimentary to one another

Lessons Learned on ITER have contributed to the private investment

Market pull

Climate emergency very high in public consciousness

Technical demonstration

ITER and DEMO will demonstrate the low field path to fusion...

Private investment

>$6.2 Bn invested and committed in 43+ Start-Ups (FIA 2023)

IAEA
International Atomic Energy Agency

IAEA Statute

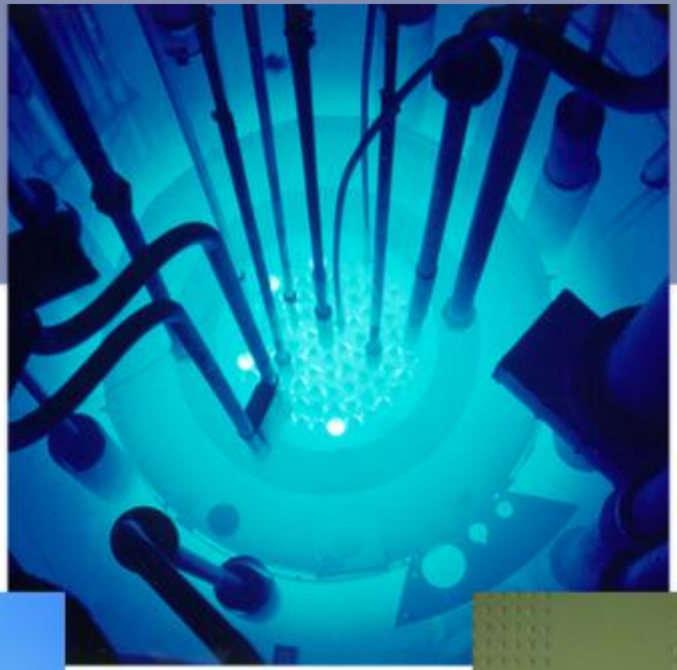
"... to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world."

IAEA Organization

- Director General
- Director General's Office
- Secretariat of the Policy-Making Organs
- Offices of Legal Affairs; Public Information and Communication; and Internal Oversight Services, and
- 6 Departments:

Nuclear Energy	Nuclear Sciences and Applications	Nuclear Safety and Security
Safeguards	Technical Cooperation	Management

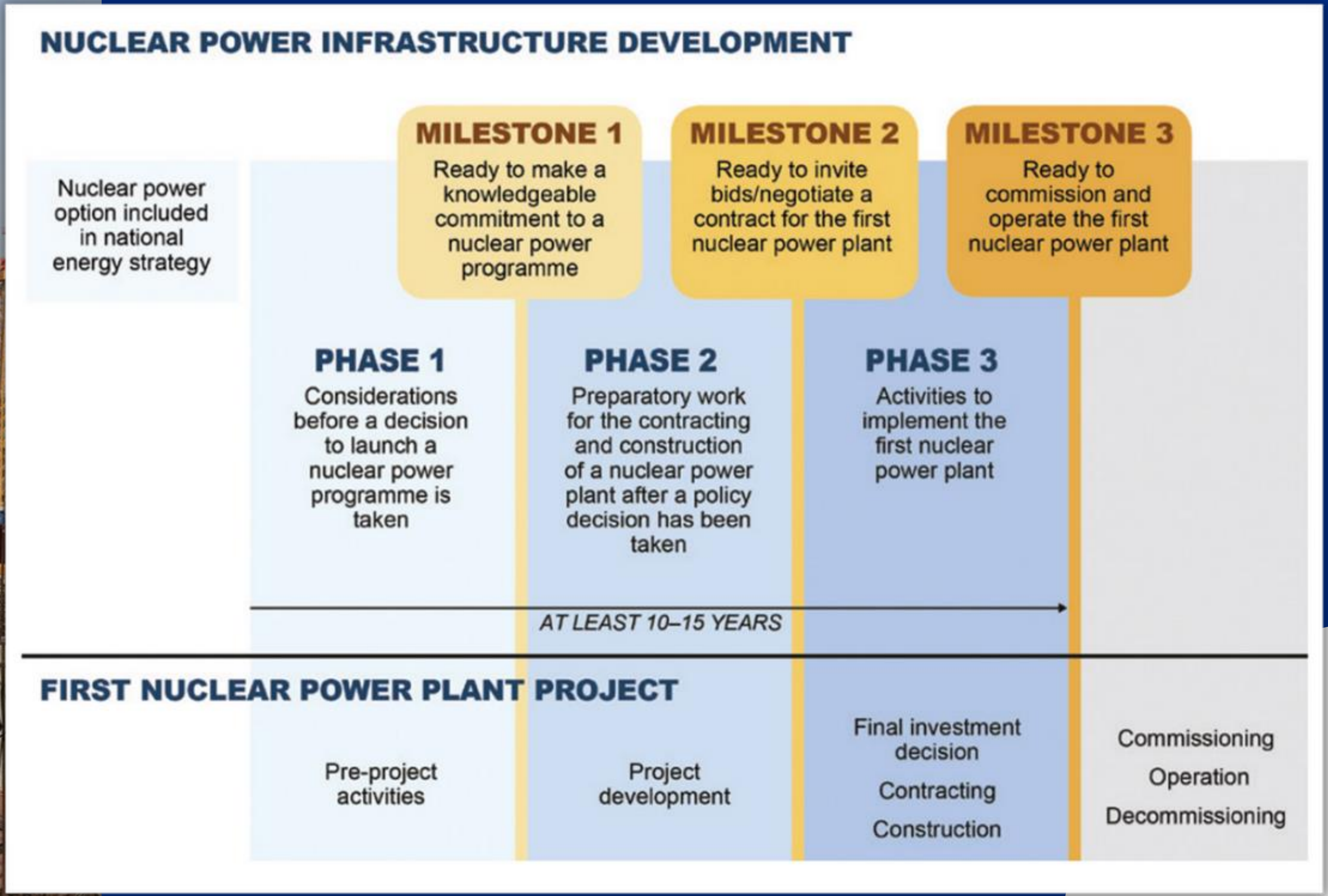
The role of the NE Department

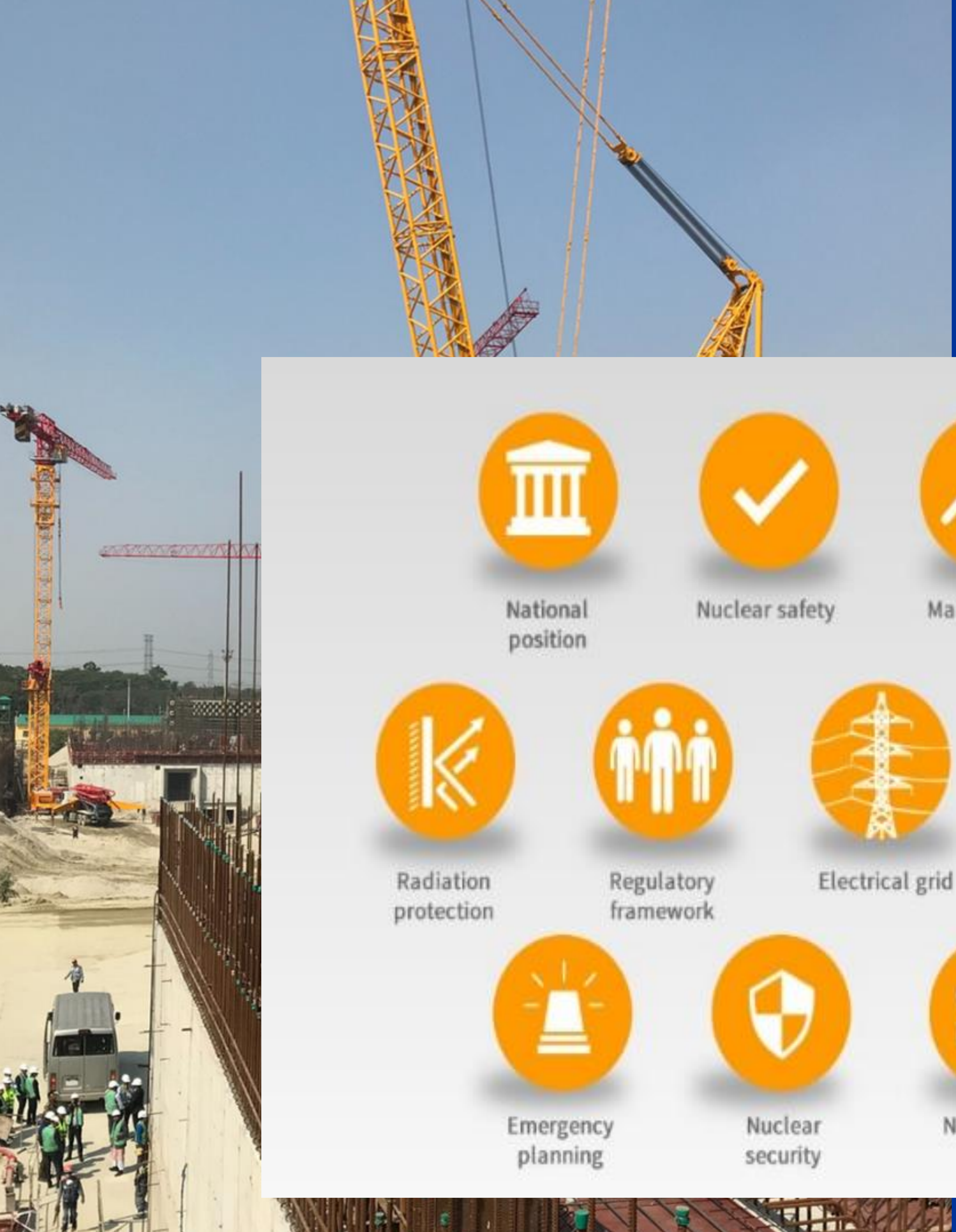

Operators

- Maintenance/outage management
- Instrumentation & control
- Plant life management
- Integrated management & HR development

Newcomers


NUCLEAR POWER INFRASTRUCTURE DEVELOPMENT
Nuclear power option included in national energy strategy
MILESTONE 1
Ready to make a knowledgeable commitment to a nuclear power programme
MILESTONE 2
Ready to invite bids/negotiate a contract for the first nuclear power plant
MILESTONE 3
Ready to commission and operate the first nuclear power plant
PHASE 1
Considerations before a decision to launch a nuclear power programme is taken
PHASE 2
Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken
PHASE 3
Activities to implement the first nuclear power plant
AT LEAST 10–15 YEARS
FIRST NUCLEAR POWER PLANT PROJECT
Pre-project activities
Project development
Final investment decision
Contracting
Construction
Commissioning
Operation
Decommissioning

Nuclear Infrastructure



INIR Missions

36 INIR Missions
(2009-2023)

2024 Missions

27 Newcomers

17
Decision-making phase

Countries considering nuclear power without having made a final decision

- Algeria
- El Salvador
- Estonia
- Ethiopia
- Indonesia
- Kazakhstan
- Mongolia
- Morocco
- Niger
- Philippines
- Senegal
- Sri Lanka
- Sudan
- Thailand
- Tunisia
- Uganda
- Zambia

10
Post-decision-making phase

Countries that have made a decision and are building the infrastructure or have signed a contract and are preparing for or started construction

- Bangladesh
- Egypt
- Ghana
- Jordan
- Kenya
- Nigeria
- Poland
- Saudi Arabia
- Turkiye
- Uzbekistan

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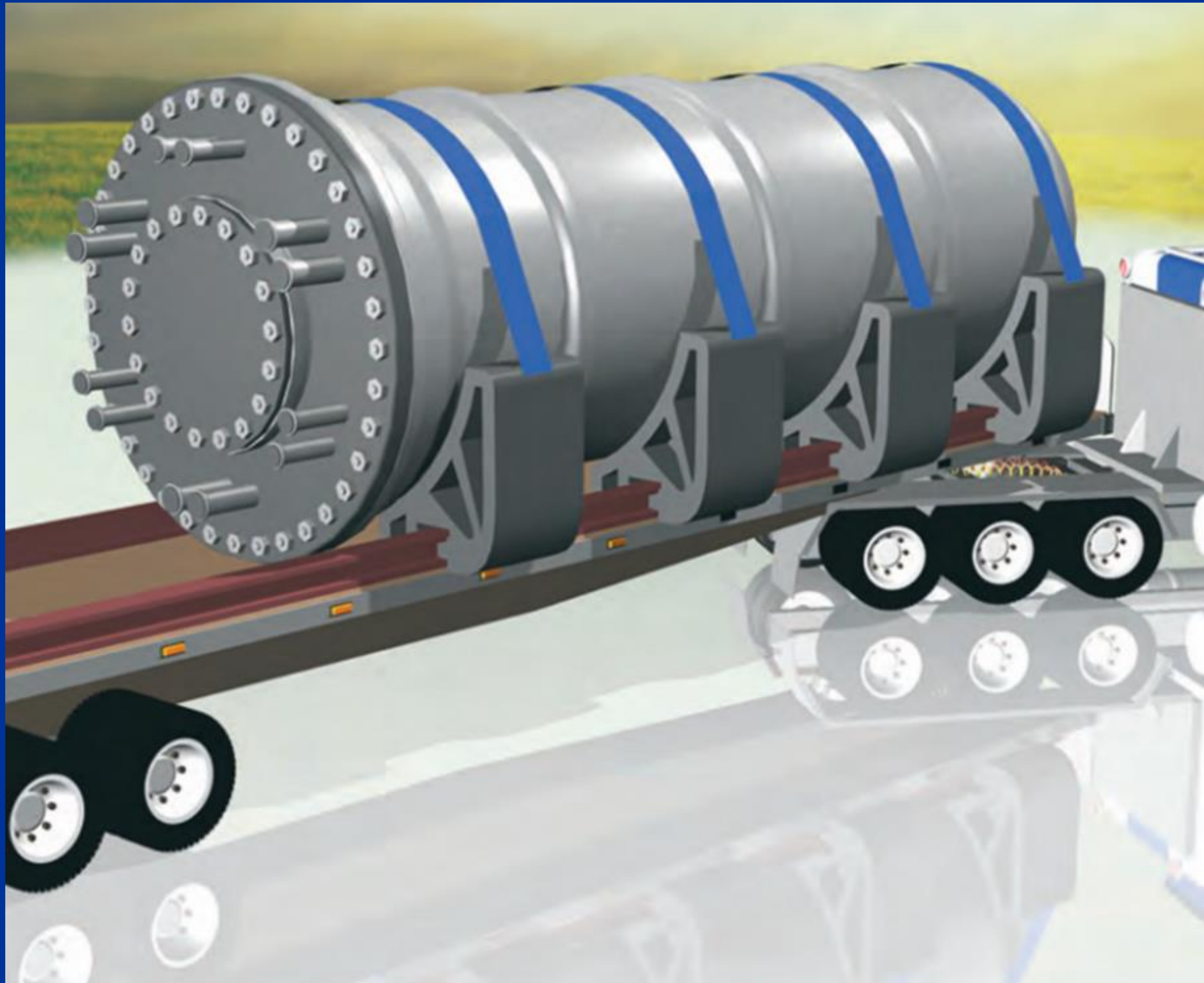
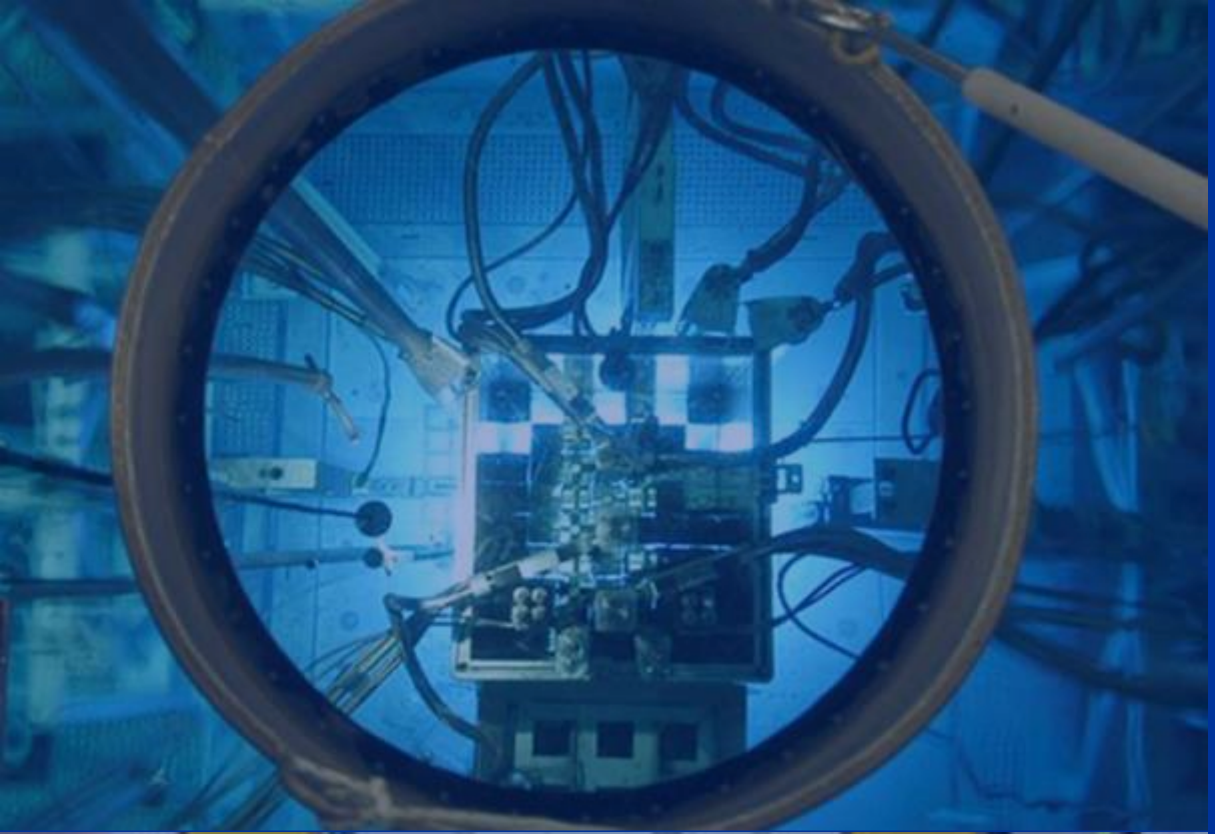
IAEA Platform on SMRs and their Applications

IAEA

- Single access point
- Led & coordinated by NE department
- All Agency services on SMRs - technology development, deployment, safety, security & safeguards



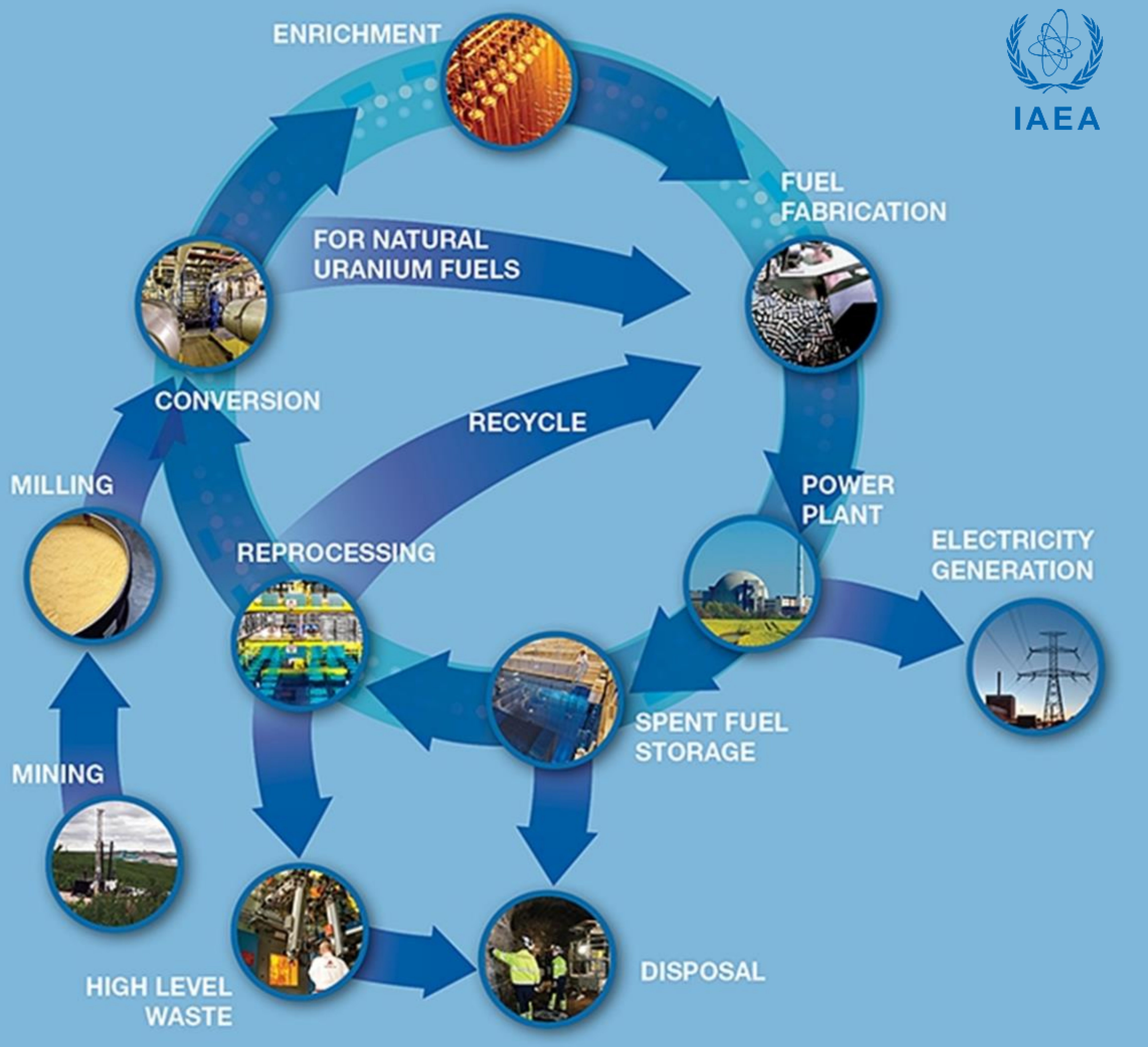


Research reactors, education, HEU removal as of April 2024

IAEA

In operation	Under construction	Planned
226 in 54 countries	7 in 6 countries	13 in 10 countries

NUCLEAR FUEL CYCLE



Radioactive Waste Management

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Decommissioning, environmental remediation

Status in 2022

Power Reactors

182

permanently shut down or undergoing decommissioning

21

decommisioned

Fuel Cycle Facilities

167

permanently shut down or undergoing decommissioning

154

decommisioned

Research Reactors

123

permanently shut down or undergoing decommissioning

448

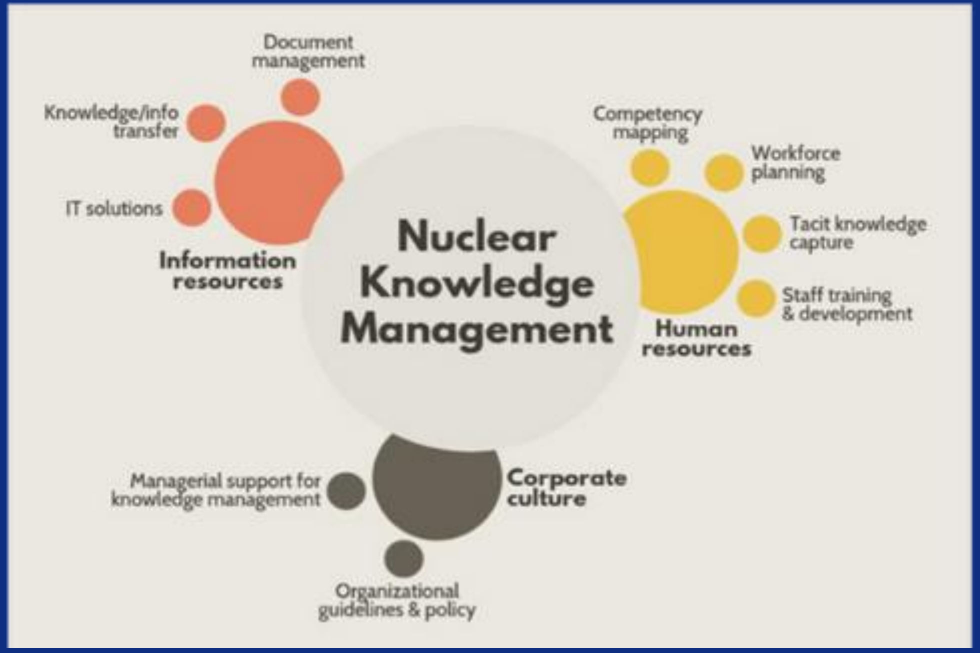
decommisioned

Energy Planning and Systems Analysis

>150 Member States,
21 Regional & Int'l Organizations

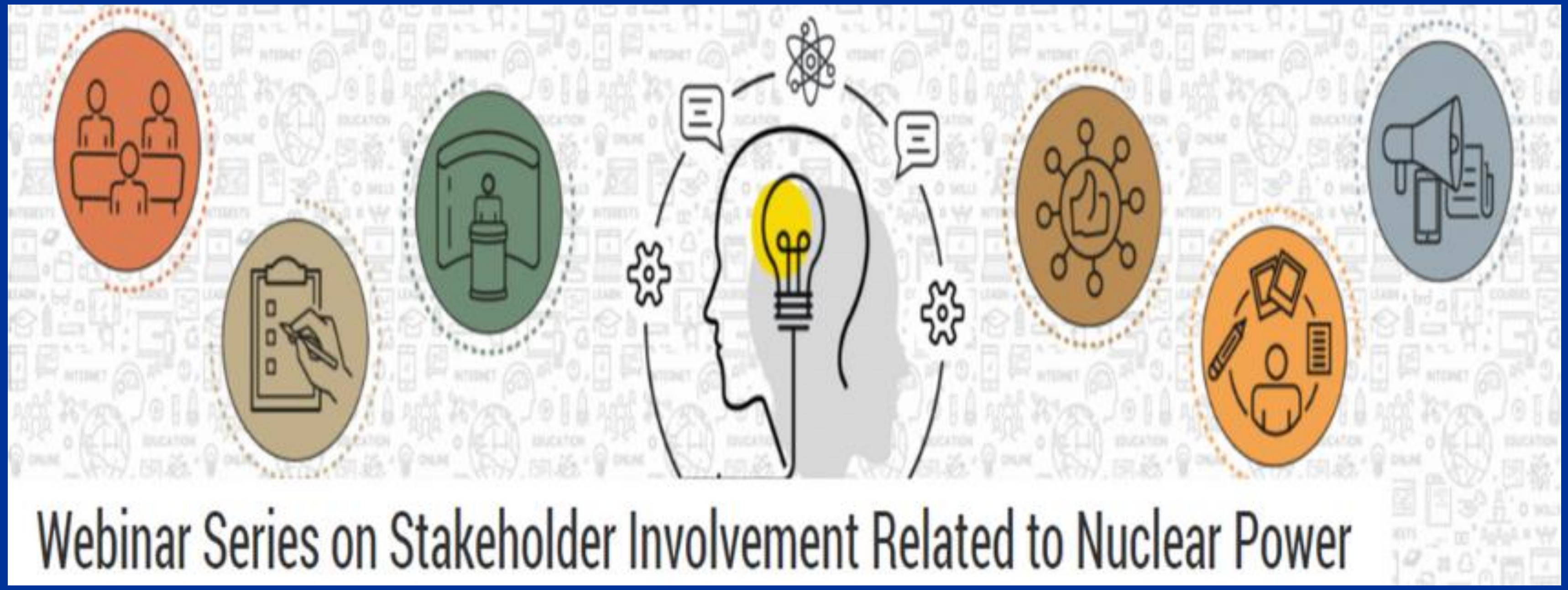
Capacity Building

>1100 on-line training & education courses



~1800 participants from around 80 MS

Stakeholder Engagement



IAEA MARIE SKLODOWSKA-CURIE FELLOWSHIP PROGRAMME

IAEA

Up to 200 scholarships for women studying towards Master's programmes in:

Nuclear Energy
Nuclear Science & Applications
Nuclear Safety & Security
Non-proliferation
Nuclear Law

Selected since 2020

560 from > 121 countries

Application period

Summer-Fall

MSCFP@iaea.org

www.iaea.org/MSCFP

#WomenInScience

IAEA LISE MEITNER PROGRAMME

IAEA

Boosting career development for women professionals in the nuclear field, particularly energy

- 2 – 4 weeks, possibly longer
- 1st and 2nd visit in the USA
- 10 to 15 professionals per cohort
- Onsite lectures and discussions with interactive training

Next LMP visit
Japan, Fall 2024

Application period
Pipeline open

LMP@iaea.org
www.iaea.org/LMP

WOMEN IN NUCLEAR

30 YEARS OF PROMOTING GENDER EQUALITY
AND DIVERSITY IN THE NUCLEAR SECTOR

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IN NUCLEAR
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winpolska@o2.pl

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IAEA

Thank You!

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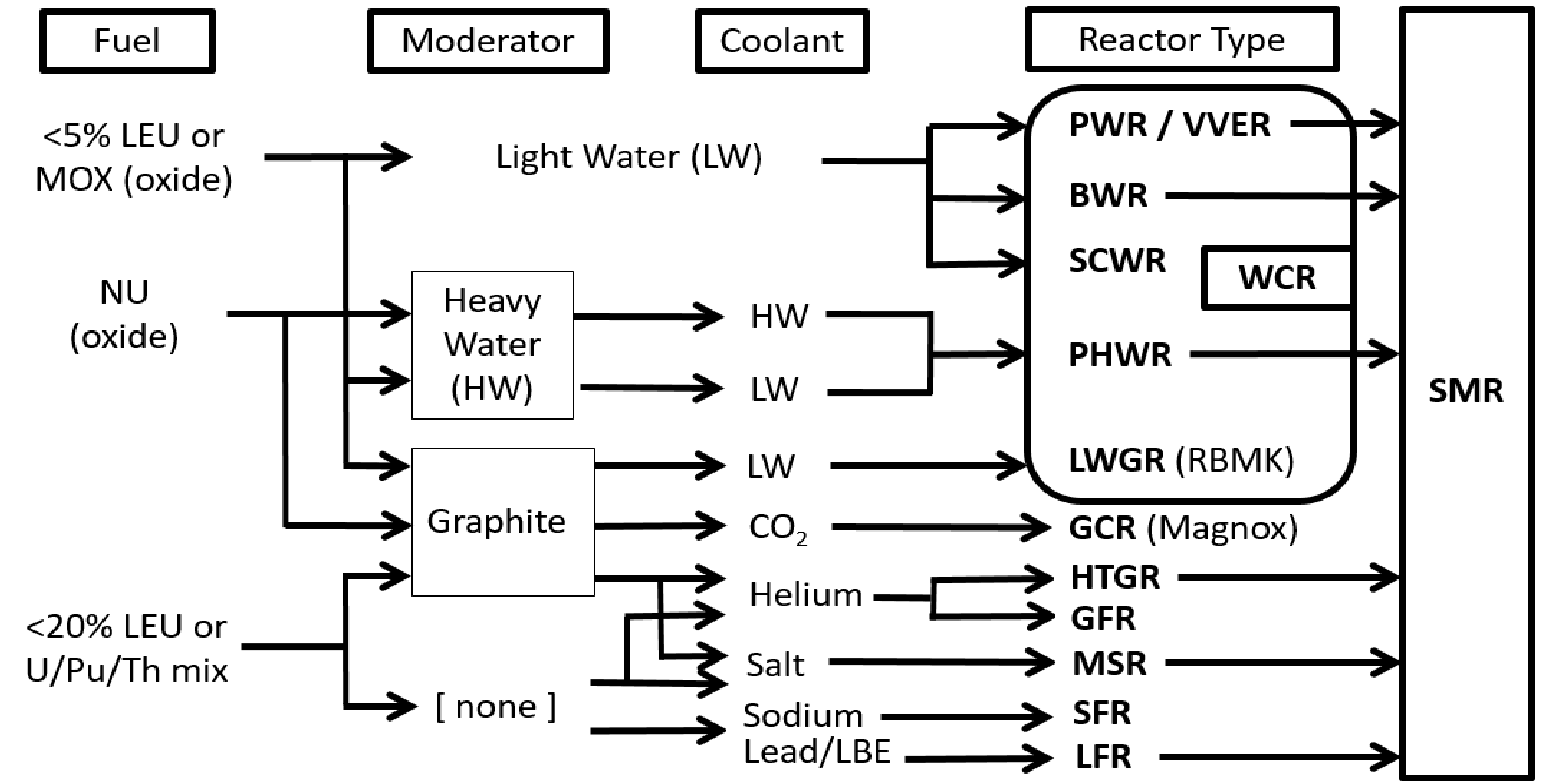
www.iaea.org/ne

Do you have any questions?

Reactor Types



LEU: Lightly enriched uranium
MOX: mixed-oxide containing any combination of U, Pu and Th oxides
NU: Natural uranium

50