TANDEM Technical workshop on Modelling and optimization tools to assess hybrid energy systems integrating nuclear reactors

February 20-21, 2025
“Le Benedettine “ Congress Centre, Pisa, Italy

“Status of Design and Technology Development of Advanced Reactors, including SMRs, and their Applications”

Frederik Reitsma

Section Head

Nuclear Power Technology Development

International Atomic Energy Agency (IAEA)

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The International Atomic Energy Agency

The International Atomic Energy Agency is the world's central intergovernmental forum for scientific and technical cooperation in the nuclear field. It works for the safe, secure and peaceful uses of nuclear science and technology, contributing to international peace and security and the United Nations' Sustainable Development Goals.

Total Membership: 180 (as of 15 November 2024)

6 Departments

ORGANIZATIONAL STRUCTURE

- Offices Reporting to the Director General
- Management
- Technical Cooperation
- Nuclear Energy
- Nuclear Safety and Security
- Nuclear Sciences and Applications
- Safeguards

Department of Nuclear Energy (NE)

Nuclear Fuel Cycle and Waste Management

Nuclear Power

Planning, Information and Knowledge Management

Fosters sustainable nuclear energy development by supporting existing and new nuclear programmes around the world.

Provides technical support on the nuclear fuel cycle and the life cycle of nuclear facilities, and builds indigenous capability in energy planning, analysis, and nuclear information and knowledge management.

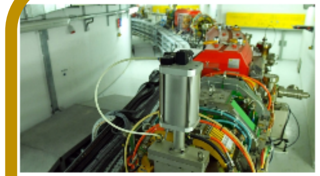
Division of Nuclear Power

Nuclear Power Engineering Section

The Section supports countries operating nuclear power plants or expanding their existing programmes to improve engineering, performance, management systems, human resource management, stakeholder involvement and technical infrastructure. It shares best engineering practices and innovations consistent with the global objectives of nuclear safety, security and non-proliferation. Read more →

Nuclear Infrastructure Development Section

This Section is responsible for coordinating IAEA assistance to Member States considering or embarking on nuclear power programmes. It supports capacity-building, conducts review missions and offers guidelines, standards and workshops on developing the infrastructure for a safe, secure and sustainable nuclear power programme. Read more →



Nuclear Power Technology Development Section

Fostering information exchange and collaborative research and development for advanced nuclear reactor technologies, this Section provides information to the IAEA's Member States on technology status and development trends for advanced reactor systems and their applications. Read more →

International Project on Innovative Nuclear Reactors and Fuel Cycles Section

The Section coordinates the activities of the membership-based International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) to increase international cooperation on global nuclear energy sustainability, long term strategies and institutional and technical innovations for nuclear energy development and deployment. Read more →

Nuclear Power Technology Development Section

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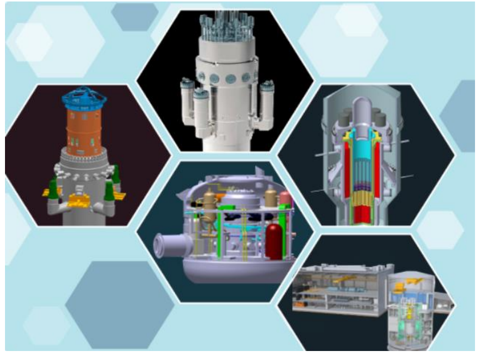
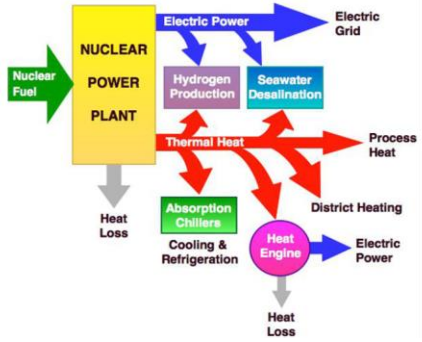
Advanced Water-Cooled Reactors



SMRs

Advanced Technology for Fast Reactors



Non-Electric Applications

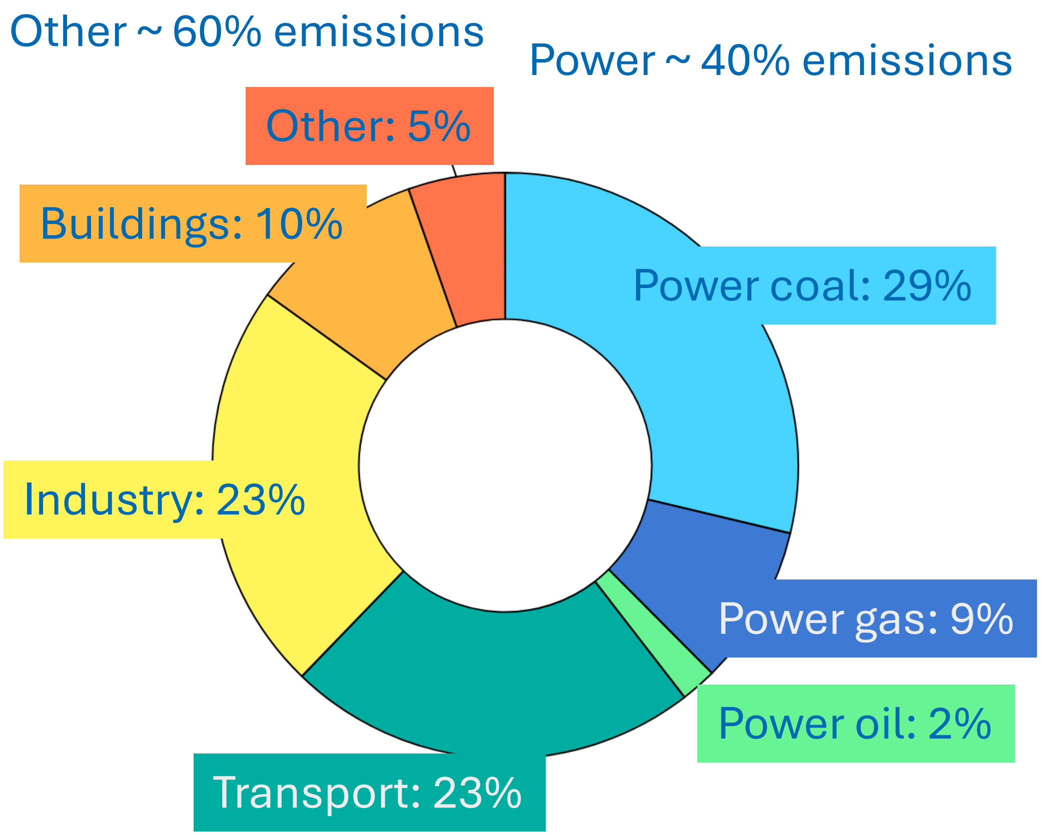
Fusion Technology

OUTLINE

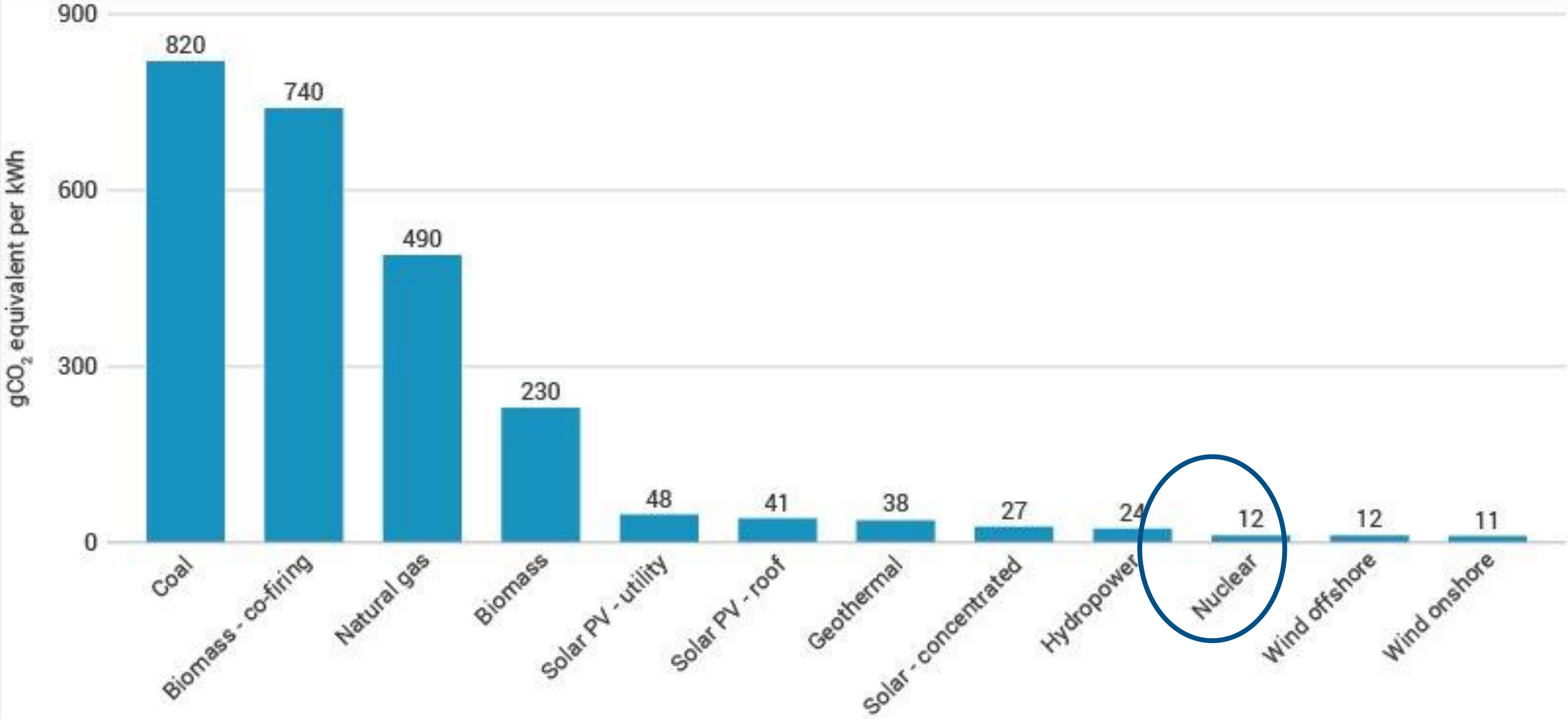
- Energy outlook and role of Nuclear
- Advanced Reactors Outlook
- SMR and Applications
- Highlights of available IAEA resources
- Summary

Towards Net-zero Emissions

- Decarbonising **the power sector** will not be sufficient to reach climate goals
- Need to decarbonize other sectors, representing 60% of emissions
  - **Electrification** whenever possible: increased demand for clean electricity
  - **Low Carbon heat sources**
  - **Low Carbon fuels**, including hydrogen, produced from clean electricity



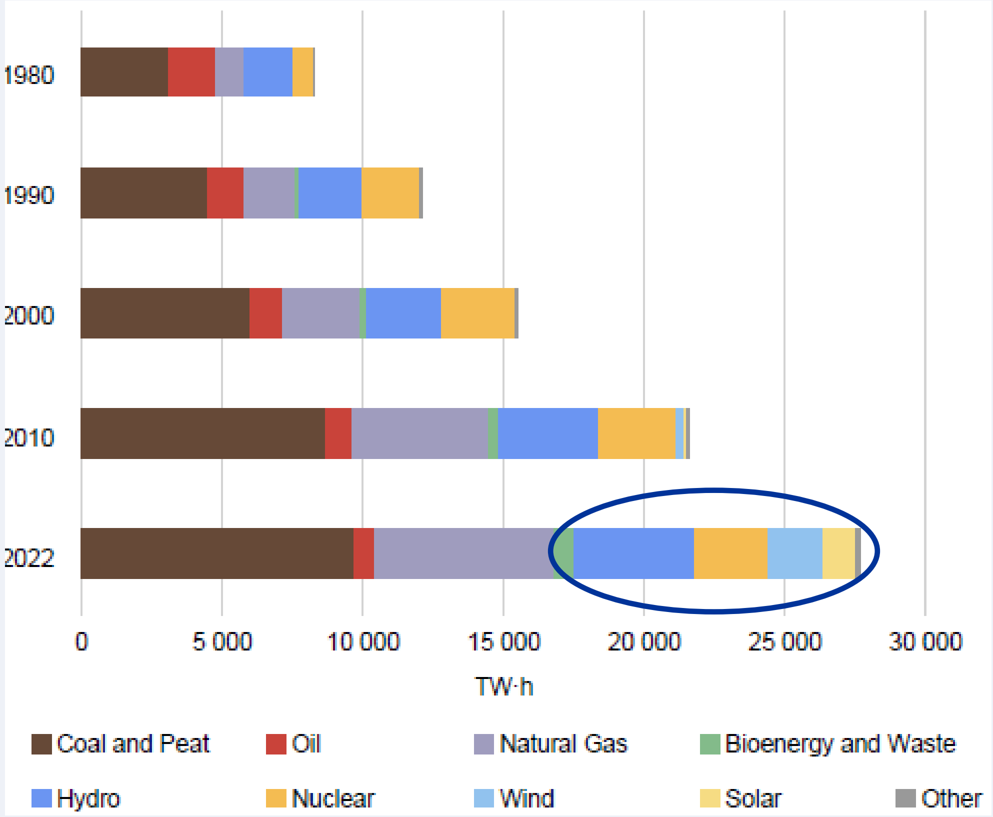
Life Cycle CO2 emissions from various primary energy sources



Average life-cycle carbon dioxide-equivalent emissions for different electricity generators, IPCC

World Electricity Production by Energy Source

- **Final energy consumption** from electricity: 20% (2022), 30% (2050)
- 16, 12 and 9% of **electricity** was produced by hydro, solar/wind, and **nuclear**, respectively, in 2022
- **Nuclear Power reactors**
    - 417 in operation
    - 377 GWe total installed capacity
    - 62 under construction



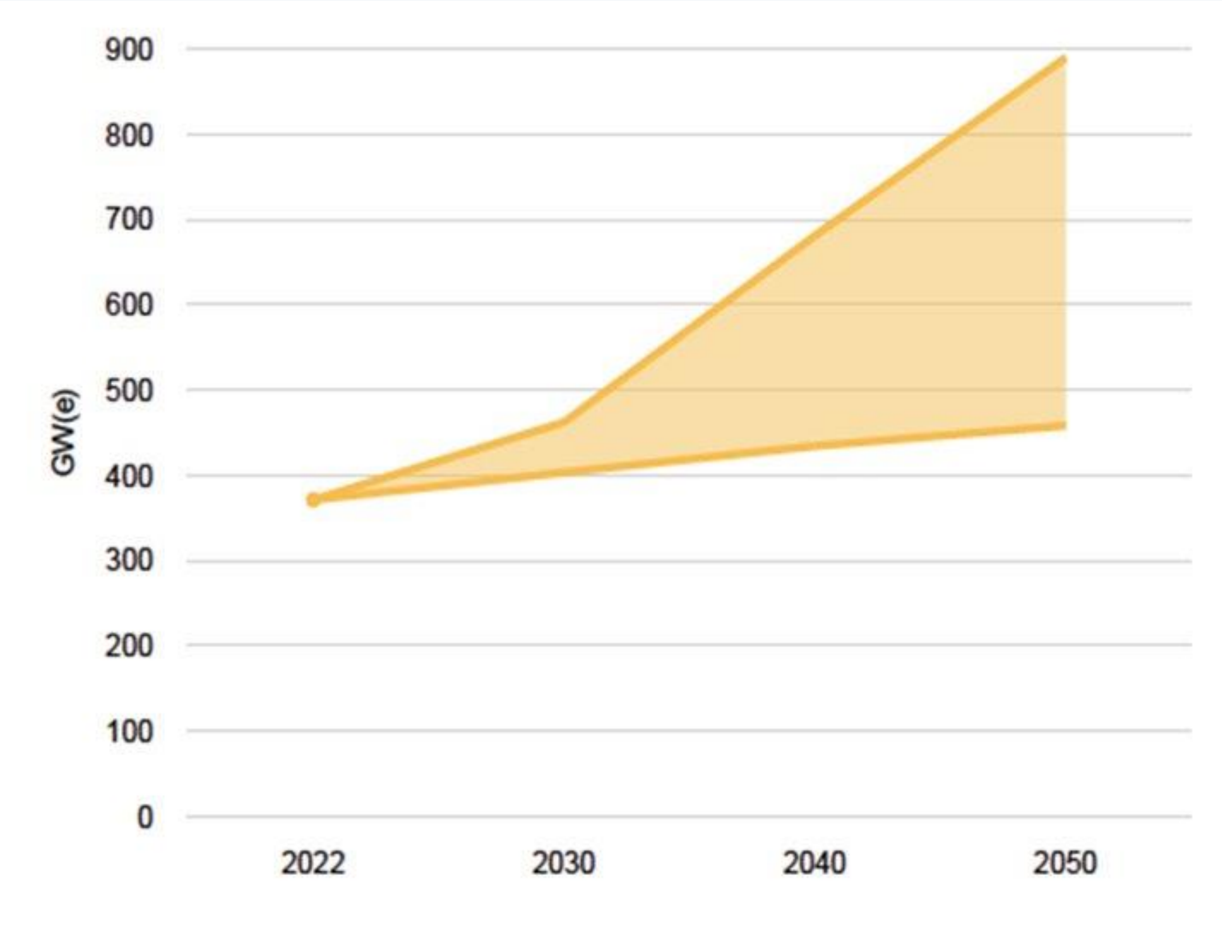
IAEA RDS 1, 2023
Energy, Electricity and Nuclear Power
Estimates for the Period up to 2050

Expanded role of Nuclear

Technical Innovation:

Key to expanded role in clean energy transition and for energy security

- **Advanced Reactors, Small Modular Reactors**
- **Non-electric Applications**
- **Integrated Energy Systems**



Energy, Electricity and Nuclear Power Estimates for the Period up to 2050

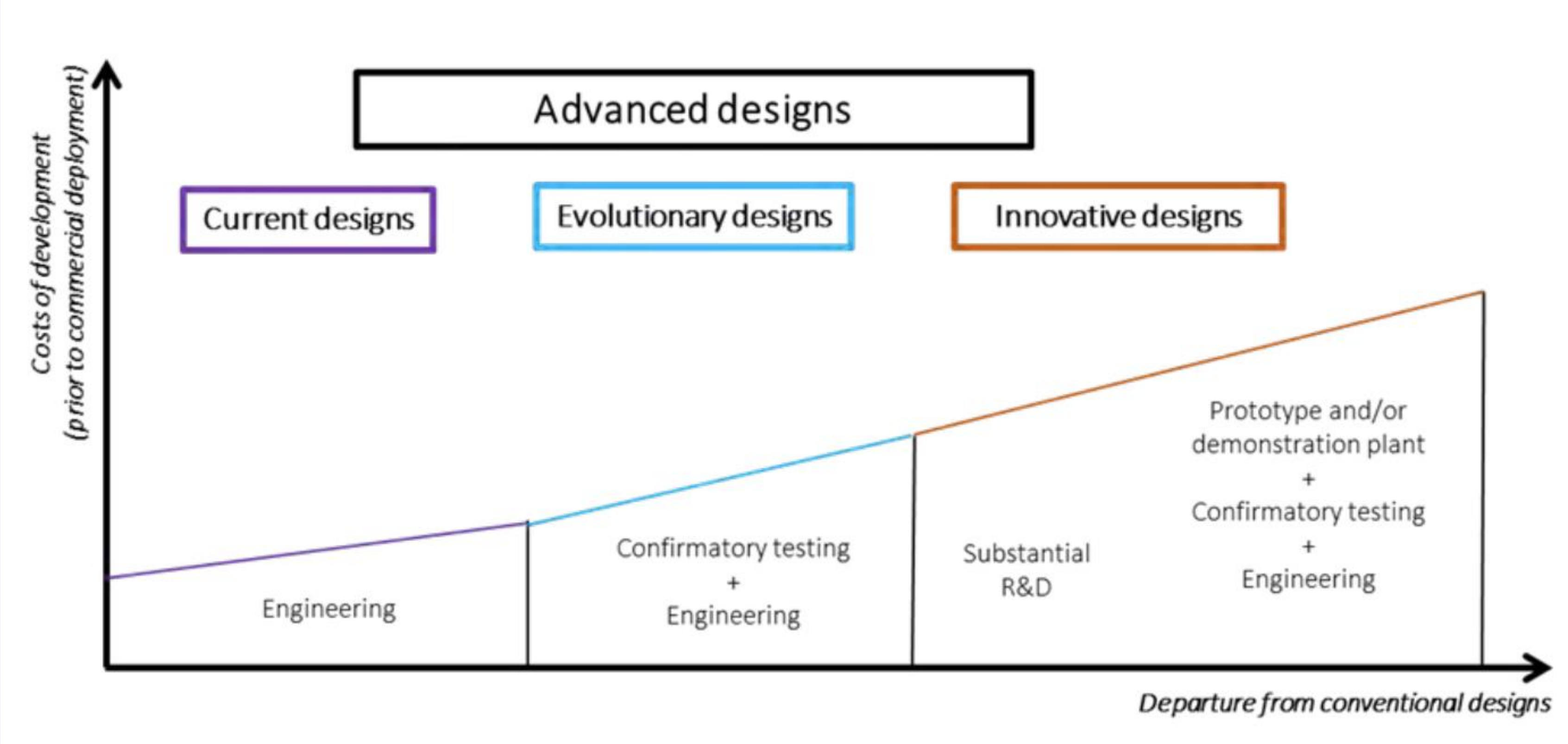
IAEA RDS-1 2023

Advanced Reactors Outlook

Advanced Reactors: Evolutionary and Innovative

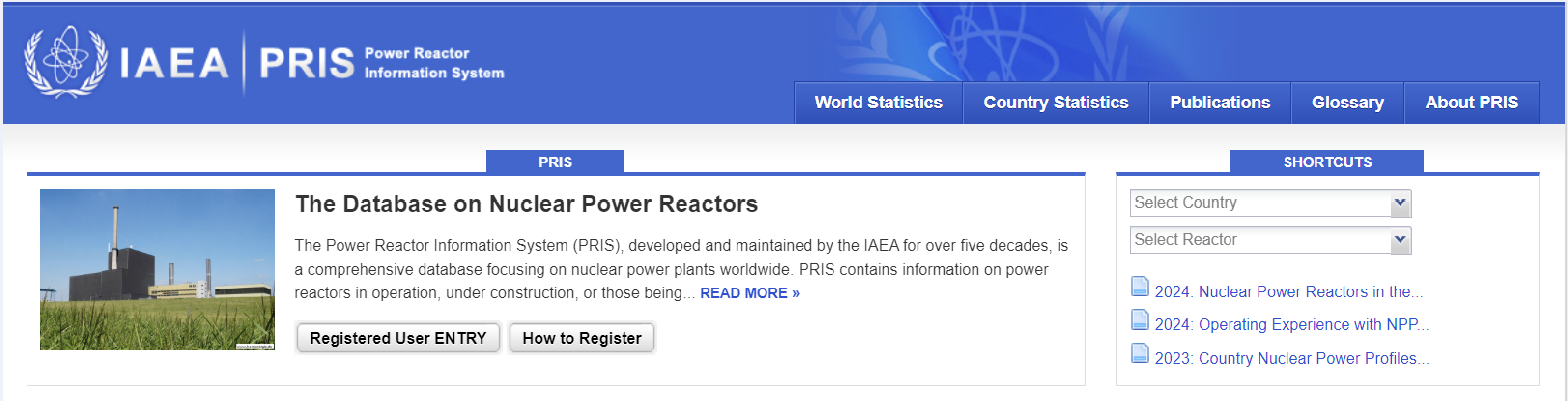
- **Evolutionary Designs** - an advanced design that achieves improvements over current designs throughsmall to moderate modifications, with a strong emphasis on maintaining proven design elements to minimize technological risks.

- **Innovative Designs** - an advanced design which incorporates conceptual changes in design approaches or system configuration in comparison with existing practice



(As defined in IAEA “Terms for Describing Advanced Nuclear Power Plants” NR-T-1.19)

NPP currently in operation and Advanced reactors



- PRIS - Home (iaea.org)
- **Commercial Advanced Nuclear Power Reactors for Near Term Deployment**

CURRENT STATUS – 16 February 2025

IAEA PRIS Power Reactor Information System

CURRENT STATUS

417 NUCLEAR POWER REACTORS IN OPERATION

377 046 MW_e TOTAL NET INSTALLED CAPACITY

23 NUCLEAR POWER REACTORS IN SUSPENDED OPERATION

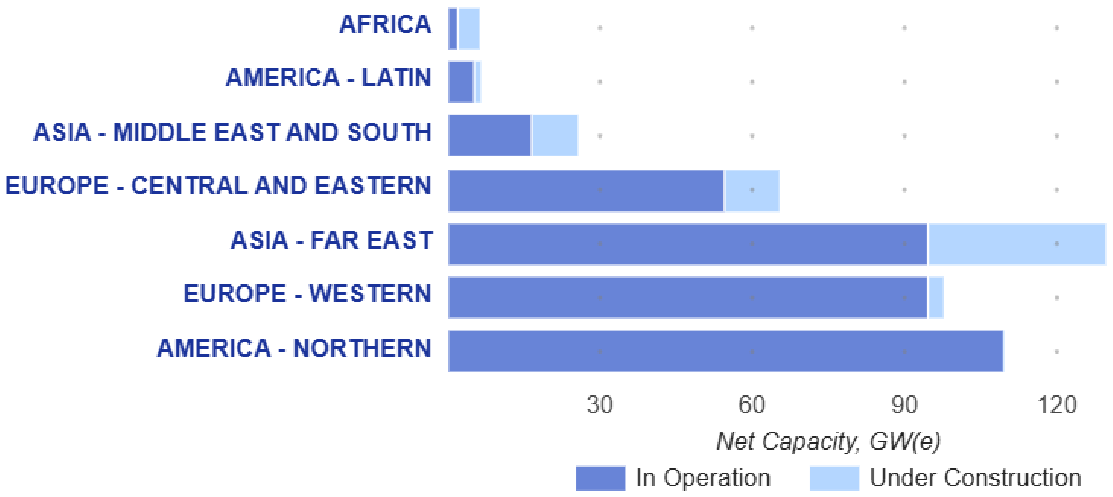
19 687 MW_e TOTAL NET INSTALLED CAPACITY

62 NUCLEAR POWER REACTORS UNDER CONSTRUCTION

64 461 MW_e TOTAL NET INSTALLED CAPACITY

20 174 REACTOR-YEARS OF OPERATION

REGIONAL DISTRIBUTION OF NUCLEAR POWER CAPACITY



Restart after suspended operations

ONAGAWA-2	(796 MW(e), BWR, JAPAN) on 15 November
SHIMANE-2	(789 MW(e), BWR, JAPAN) on 12 December

HIGHLIGHTS of 2024

New connections to the grid

Nuclear Power Plants	Power and Type	Country	Design / Technology	Date
BARAKAH-4	1310 MW(e), PWR	United Arab Emirates	**APR1400 (Korea)**	23 March
FANGCHENGGANG-4	1000 MW(e), PWR	China	**HPR1000 (China)**	9 April
FLAMANVILLE-3	1630 MW(e), PWR	France	**EPR (France)**	21 December
KAKRAPAR-4	630 MW(e), PHWR	India	PHWR700 (India)	20 February
VOGTLE-4	1117 MW(e), PWR	United States of America	**AP1000 (United States)**	6 March
ZHANGZHOU-1	1126 MW(e), PWR	China	**HPR1000 (China)**	28 November

Construction starts

Nuclear Power Plants	Power and Type	Country	Design / Technology	Date
CHASNUPP-5	1117 MW(e), PWR	Pakistan	**HPR1000 (China)**	30 December
EL DABAA-4	1100 MW(e), PWR	Egypt	**VVER1200 (Russia)**	23 January
LENINGRAD 2-3	1150 MW(e), PWR	Russian Federation	VVER1200 (Russia)	14 March
LIANJIANG-2	1224 MW(e), PWR	China	**CAP1000 (China)**	26 April
NINGDE-5	1200 MW(e), PWR	China	**HPR1000 (China)**	28 July
SHIDAOWAN-1	1116 MW(e), PWR,	China	**HPR1000 (China)**	28 July
XUDABU-2	1000 MW(e), PWR	China	**CAP1000 (China)**	17 July
ZHANGZHOU-3	1129 MW(e), PWR	China	**HPR1000 (China)**	22 February
ZHANGZHOU-4	1129 MW(e), PWR	China	**HPR1000 (China)**	27 September

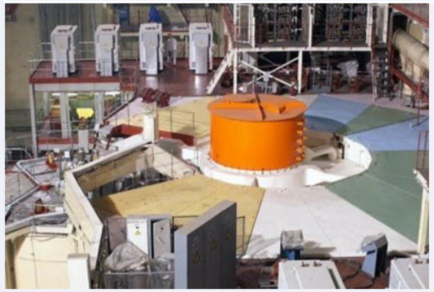
Key Commercial Designs - 2024

Large Light-water cooled reactors

Countries	Design / Technology	Rated Power (gross)	Companies, Vendors	User Countries
China	**HPR1000**	1180 MW(e)	**CNNC, CGN**	China, Pakistan
	CAP1000	1224 MW(e)	**SNERDI**	China
France	**EPR**	1660 MW(e)	**EDF**	France, China, Finland, and United Kingdom
	EPR2	1200 MW(e)	**EDF**	France
Japan	**ABWR**	1400 MW(e)	**Hitachi GE Nuclear Energy**	5 all in Japan
Republic of Korea	**APR1400**	1417 MW(e)	**Korea Hydro and Nuclear Power (KHNP)**	South Korea and United Arab Emirates
	APR1000	1000 MW(e)	**KHNP**	South Korea and Czech Republic
Russian Federation	**VVER1200 / VVERTOI**	1200 MW(e)	**ROSATOM**	**Russia, China, India, Belarus, Bangladesh, Turkey, Egypt, etc.**
United States of America	**AP1000**	1117 MW(e)	**Westinghouse**	United States and China

Fast Reactors in Operation & under Commissioning

Country	Name	Coolant	Fuel	Purpose	Power (th/e) MW	Year (Op.)	Status
Russia	BOR-60	sodium	UO_2/MOX	experimental	**60/10**	1969	operating
	BN-600	sodium	UO_2	prototype	**1470/600**	1980	operating
	BN-800	sodium	UO_2/MOX	commercial	**2100/880**	2015	operating
China	CEFR	sodium	UO_2	experimental	**65/20**	2011	operating
	CFR600-1	sodium	UO_2/?	prototype	**1500/600**	~2024	commissioning
India	FBTR	sodium	(Pu,U)C	experimental	**40/13**	1985	operating
	PFBR	sodium	MOX	prototype	**1250/500**	~2024	commissioning
Japan	JOYO	sodium	UO_2/MOX	experimental	**150/--**	1978	lic renew (2024?)



BN-600
Russia, 1980

BN-800
Russia, 2015

CEFR, 20 MW(e)
China, 2011

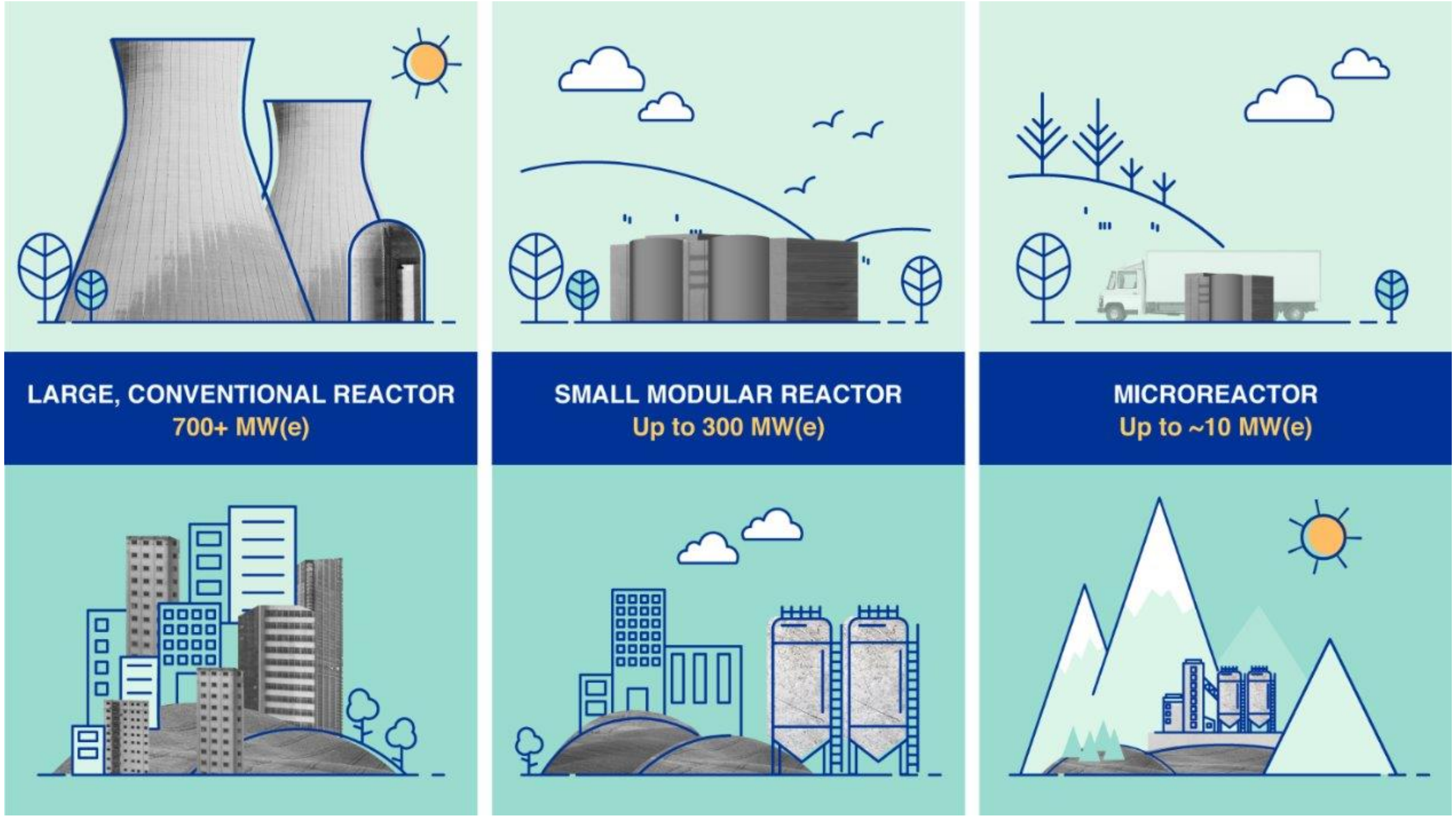
FBTR, 13 MW(e)
India, 1985

PFBR, 500 MW(e)
India, 2024

SMR and Applications

Small Modular Reactors

Advanced Reactors that produce typically **up to 300 MWe**, built in factories and transported as **Modules** to sites for installation as demand arises.



Small: in size, compared to traditional reactors.

Modular: factory-manufactured, installed onsite.

Reactor: energy generation via nuclear fission.

SMR Key Attributes and Driving Factors

Cost Affordability

- Small power
- Lower upfront capital cost
- Economy of serial production

Shorter Construction Span

- Design simplification
- Modularization
- Standardization
- Multi-module
- Smaller footprint

Energy Resilience

- Flexibility
- Ensured energy supply
- Smaller grids
- Remote regions

Reduced CO_2 Production

- Replacement of aging fossil-fired plants
- Almost zero emissions

Energy Sustainability

- Cogeneration
- Hydrogen production
- Integration with Renewable to form Hybrid Energy Systems

Small Modular Reactors are designed and developed to be versatile with enhanced safety and reduced waste.

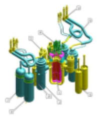
Technology Categorization

SMR Technology Lines

Water Cooled (Land based)

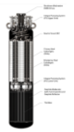
PWRs, BWRs and HWR type SMRs

Marine-based Reactors



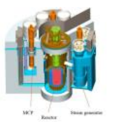
Mainly PWRs; Some are non-water-cooled reactors with capacity less than 100 MWe

Molten Salt Reactors



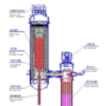
Can operate at high temperature under atmospheric pressure

Liquid Metal Cooled Fast Reactors



Better utilization of uranium resources with lower radioactive waste

High Temperature Gas Cooled Reactors



Suitable for cogeneration purposes due to high exit temperatures

Microreactors

A subset of small modular reactors with the power up to 10 MWe

Microreactors are intended for another niche market such as off-grid remote regions, small islands, and as power source for mining industries

More than 90 SMR Technology Developers in 18 Member States

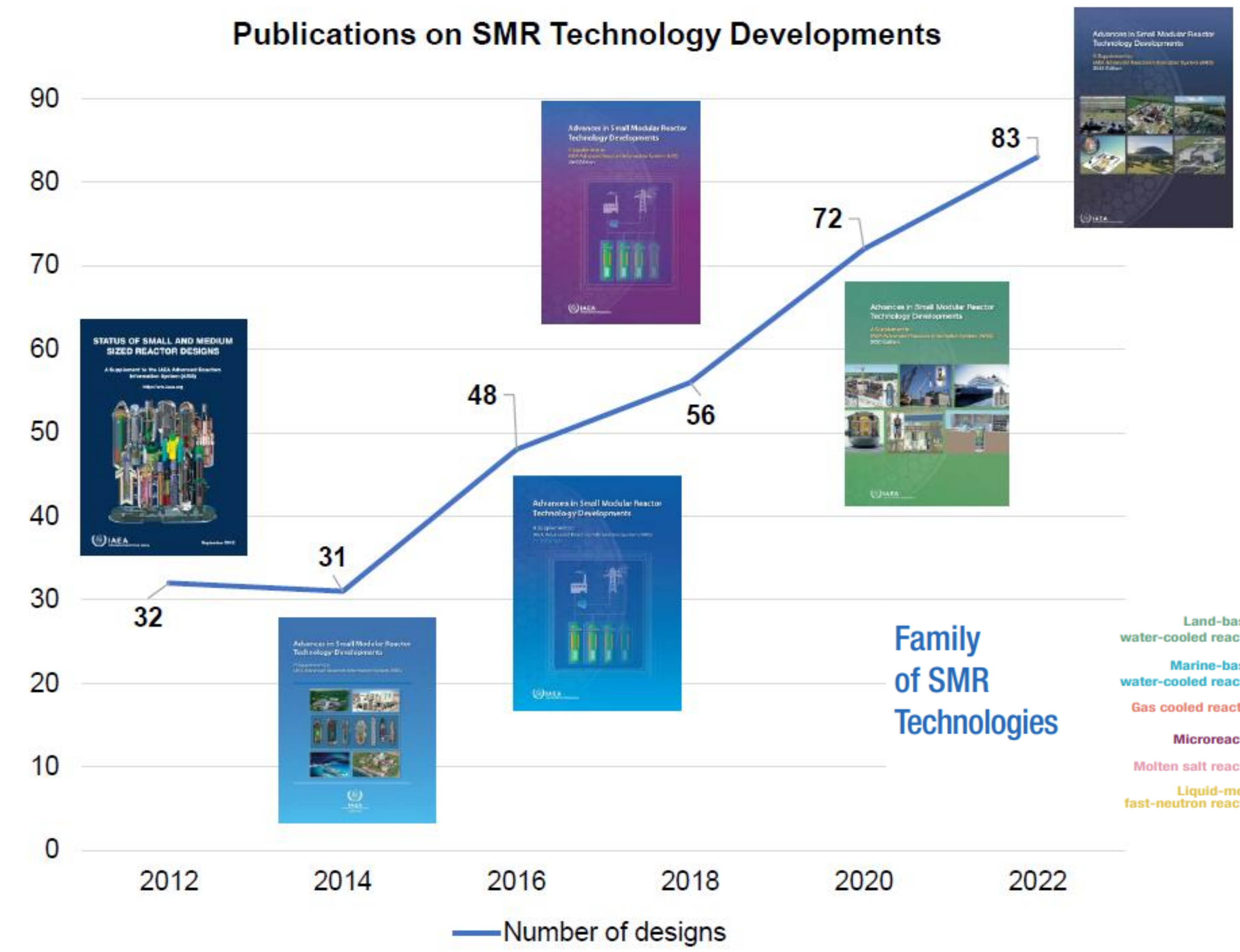
Growing Interest in SMRs

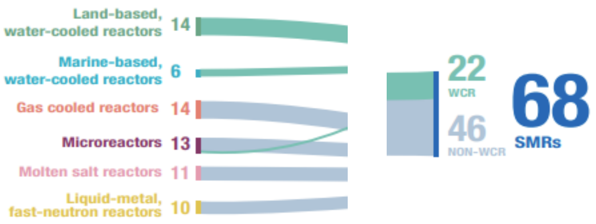
2022 - Number of SMR designs under development: 83

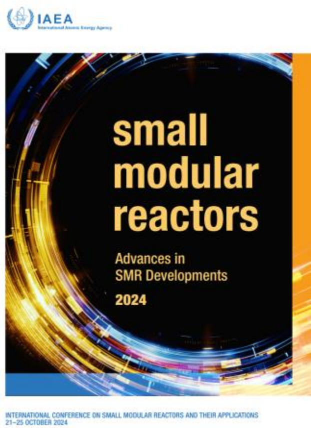
83 Designs

- Land-based Light Water: 27
- Maritime reactors: 8
- High Temperature Gas: 22
- Molten Salt: 14
- Liquid Metal: 12

Comprehensive Collections of Designs

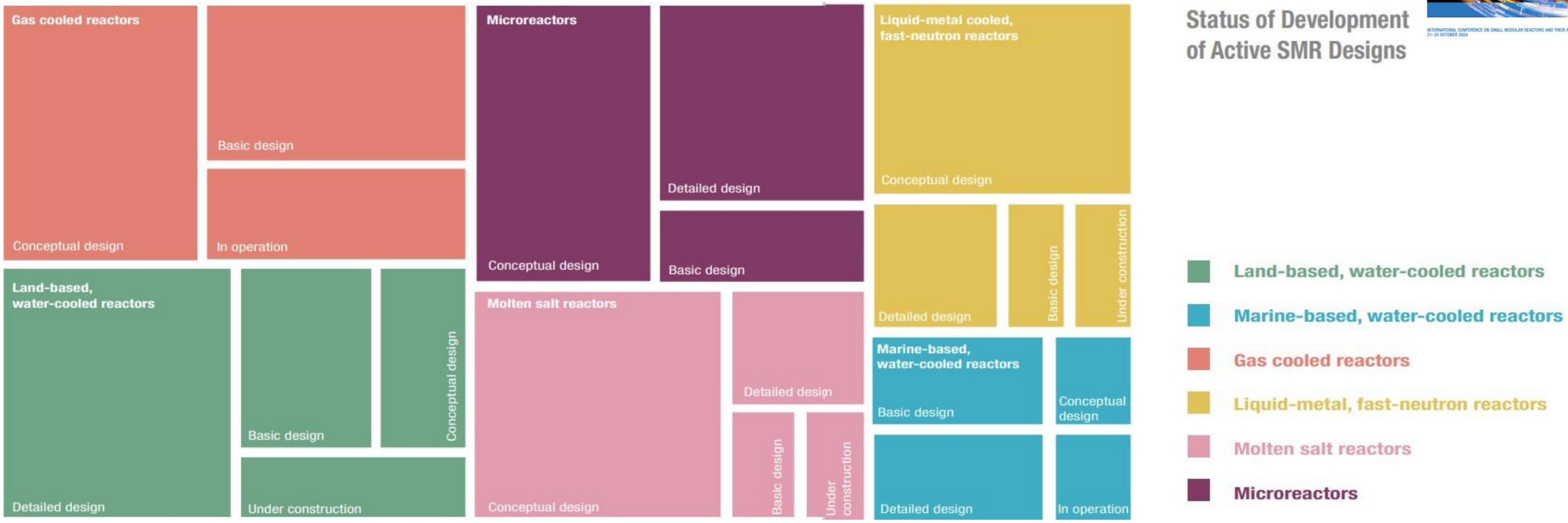






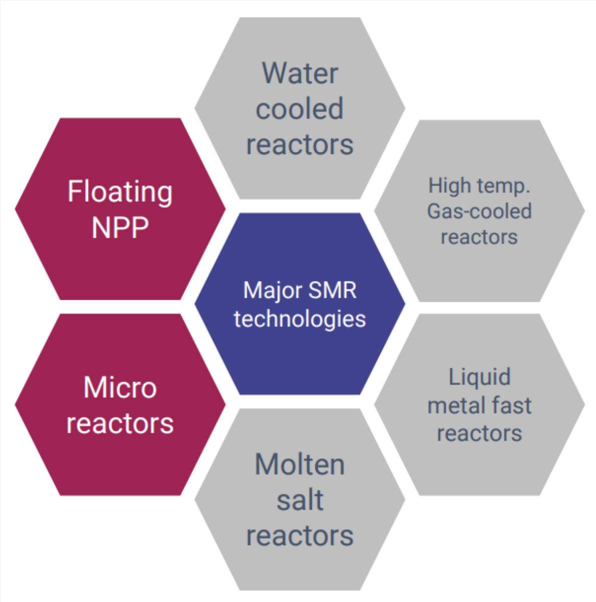
Recent SMR Highlights

Small Modular Reactors are advanced nuclear reactors with typical power up to 300 MW(e) of major lines of technology; whose systems and structures can be modularized in factory setting to shorten construction schedule thus reduce cost.

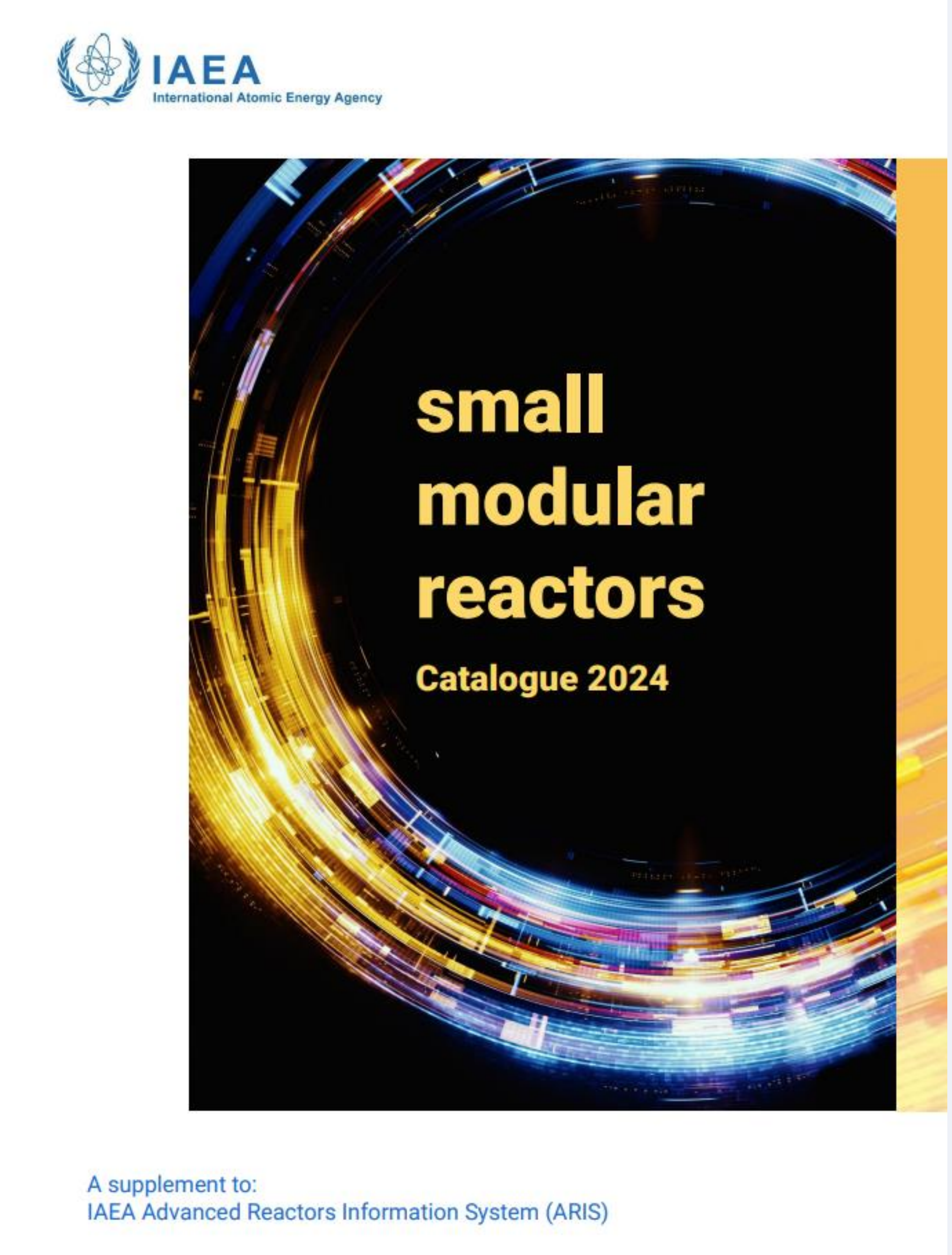


In Operation = 2 units (+2 research/prototypes)	**Under Construction = 4 units**
Basic/detailed design stage = 32 designs	**Conceptual design stage = 28 designs**

ARIS SMR Catalogue 2024



- **Available for download from this link:** https://aris.iaea.org/publications/SMR_catalogue_2024.pdf
- A supplement to ARIS Database, published biannually since 2012 with the objective to provide Member States with a concise overview of the latest status of SMR designs.
- The content is provided by the responsible institute or organization and is reproduced, with permission.
- For the 2024 SMR Catalogue, although close to 100 designs could have been listed, only active designs with demonstrated sustained development were reported in the catalogue.



SMRs details captures in ARIS

57 Designs from 15 Countries

Land based water cooled	14
Marine based	2
High Temperature Gas Cooled	10
Liquid Metal Cooled FR	16
Molten Salt	9
Microreactors	6

ARIS DB, 12 August 2024

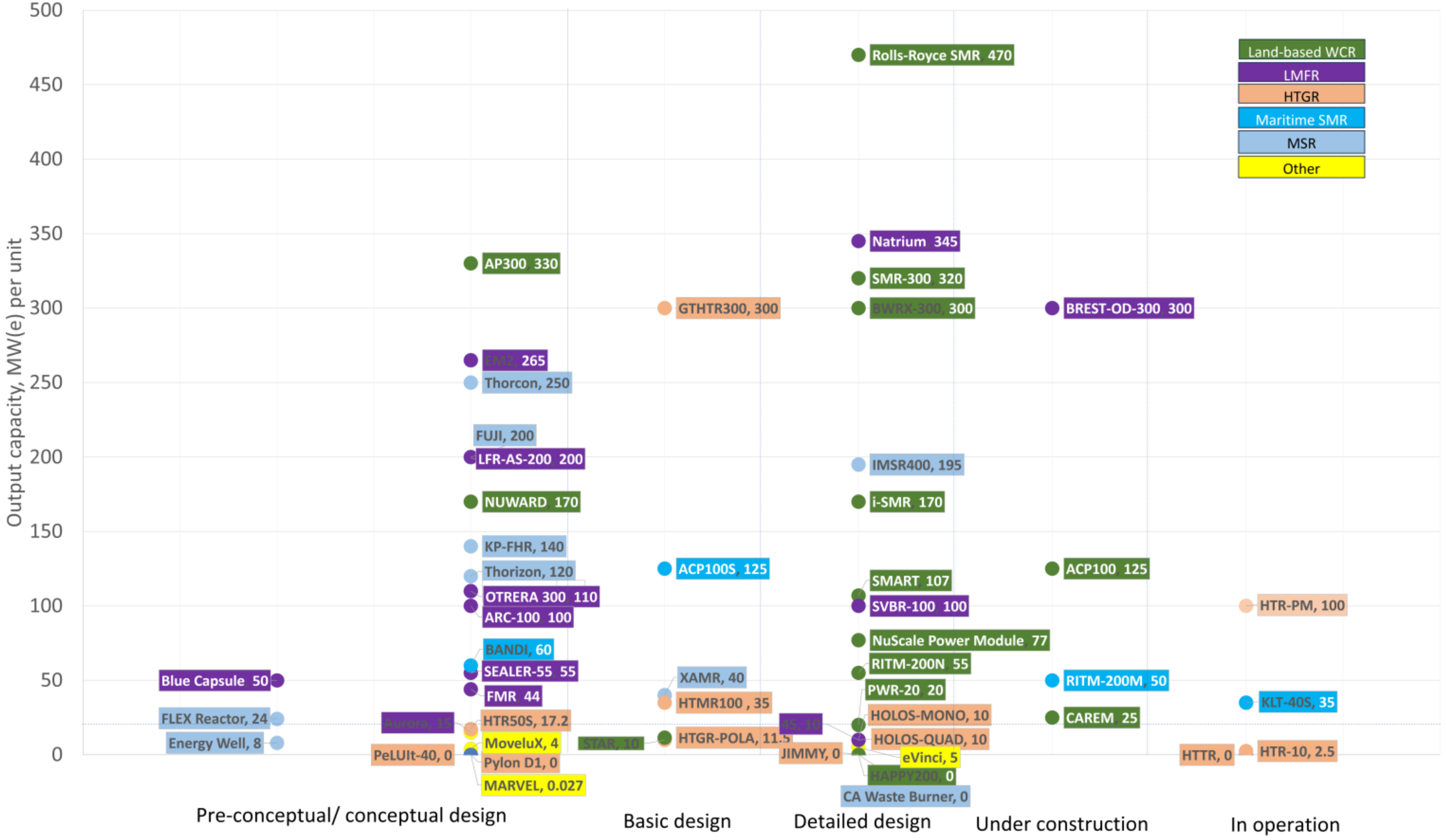
Key Commercial Designs - 2024

Small Modular Reactors

Countries	Design / Technology	Rated Power (gross)	Companies, Vendors	User Countries
China	**HTR-PM**	200 MW(e)	**INET**	China in operation
	ACP100	125 MW(e)	**CNNC/NPIC/CNPE**	China under construction
France	**NUWARD**	2 x 170 MW(e)	**EDF**	France, under development, status unclear
Republic of Korea	**iSMR**	170 MW(e)	**i-SMR Agency**	South Korea, under development
Russian Federation	**RITM-200**	55 MW(e)	**ROSATOM**	Russian Federation, 6 units ordered by Uzbekistan, 6 units in operation in icebreakers
United States of America	**VOYGR**	6 x 77 MW(e)	**NuScale Power Inc.**	United States and potentially for Romania
	BWRX-300	300 MW(e)	**GE Hitachi Nuclear Energy**	Under licensing for Canada OPG Darlington site
	Xe-100	80 MW(e)	**X-Energy**	Construction permit to be submitted to NRC for a 4-unit 320MWe with Dow at Seadrift, Texas (2026 – 2030)
	KP-FHR	140 MW(e)	**Kairos Power**	2024 Construction begins on the Hermes demonstration reactor in Oak Ridge, Tennessee
	SMR-300	300 MW(e)	**Holtec International**	Under licensing in the U.S.
	AP300	300 MW(e)	**Westinghouse**	Under development in the U.S.

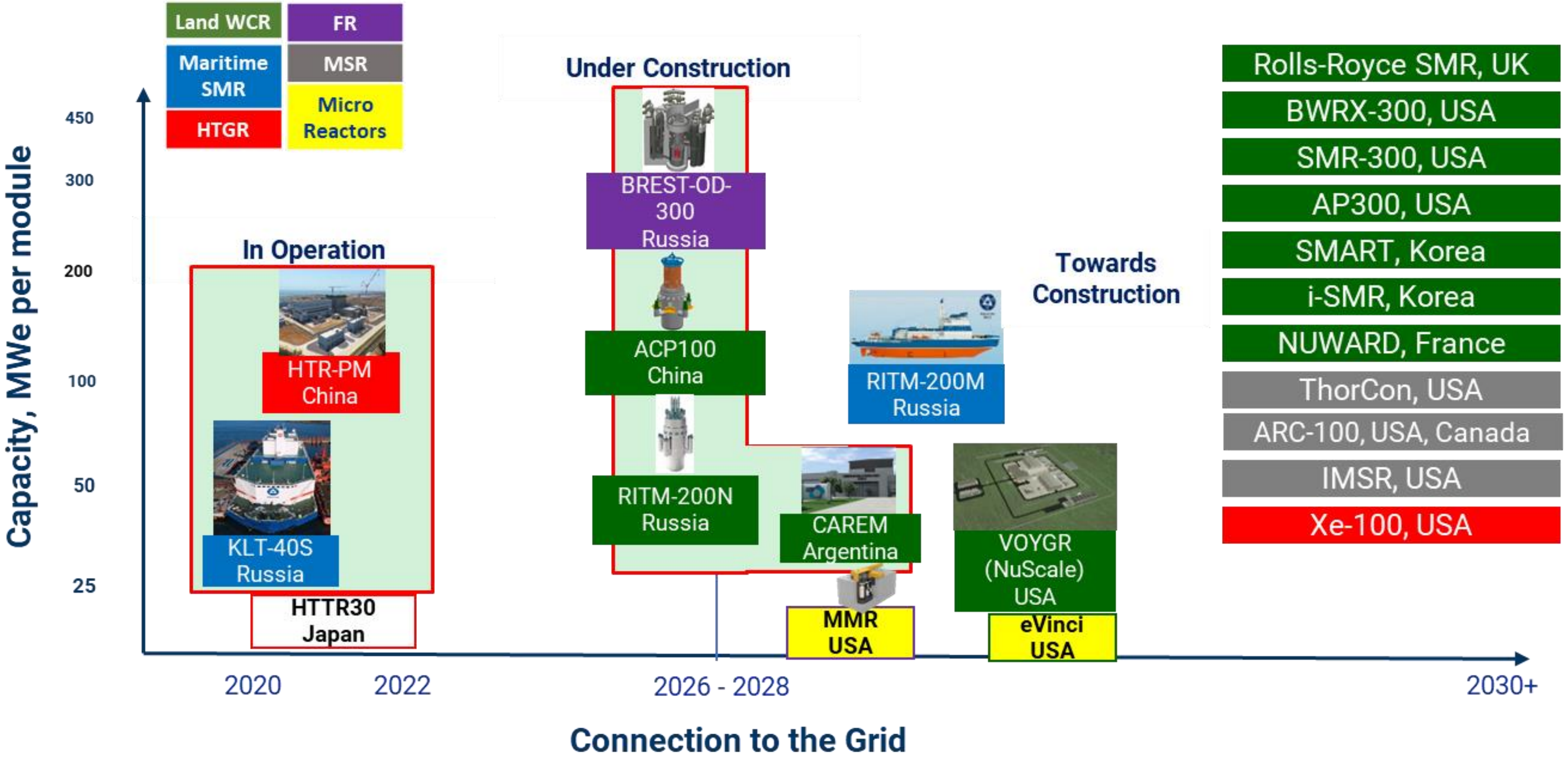
Status of SMR Development and Deployment

Based on updates from technology developers to IAEA in 2024

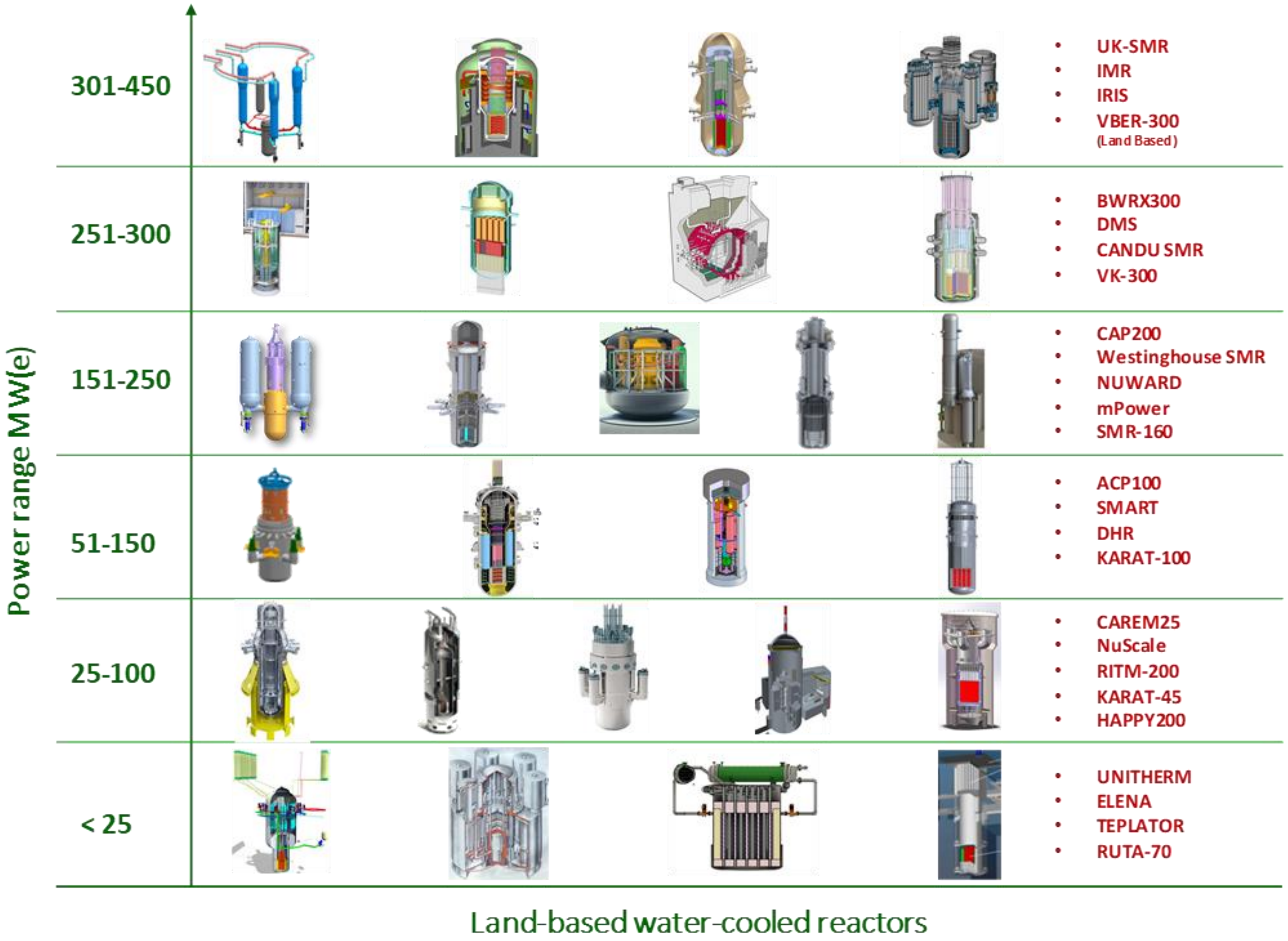


Note: The value displayed with the design refers to the output capacity in MW(e) per unit.

Timeline of Near-Term Deployment of some SMRs

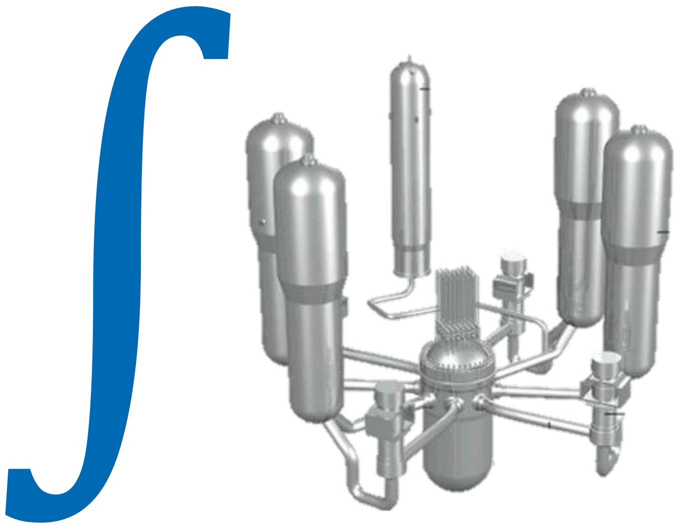


Power range of water-cooled type SMRs



Majority of designs have power less than 300 MW(e), only some have power above 300 MW(e)
Power definition remains the same at the IAEA.

Design Approach of the Integral PWRs



(2000 – 4500) MWth

(100 – 1000) MWth

Advantages
No large piping connected to RPV → No Large-LOCA
Coolant Pumps connected to RPV → Reduced leakage probability
Internal Control Rod Drive Mechanism → No CRD ejection accident
Wide use of Passive Safety Systems → Independence of power source
Modularization and NSSS components integration → compact reactor building

Issues / Challenges
Increased numbers of small-bore piping connections to the RPV
Structural strength of RPV and joints; mechanical vibration; flow stability
In-service inspection approach for in-vessel components
Passive system has lower driving heads; ADS reliability is critical
Larger and taller RPV to house NSSS components: steam generators, etc.

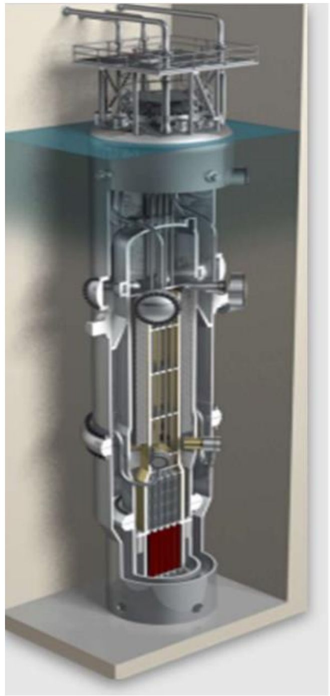
VOYGR™

NuScale Power Inc.

NUSCALE

Status:
Certified design by U.S NRC for construction in USA and Europe

Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Integral PWR	Natural circulation, gravity driven	Light Water/Light Water	255 MW_{th} / 77 MW_e
Design Life	**Reactivity Control**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
60 yrs.	Control rod drive	249°C/316 °C	13.8 MPa/4.3 MPa
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
18 months	< 4.95 %	> 45 GWD/tonnes	UO_2 / 17× 17 Square



Unique Features: Unlimited time of core cooling without AC or DC power or water addition or operator action

Target Application: The NuScale design is a modular reactor for electricity production, with the capability for flexible operations to load follow, and for non-electrical process heat applications, including the cogeneration of heat and electricity.

Design Philosophy: The NPM is designed to operate efficiently at full-power conditions using natural circulation as the means of providing core coolant flow, eliminating the need for reactor coolant pumps

RITM200

JSC OKBM Afrikantov

Status:
4 Units of RITM200N are in operation for Icebreaker ship (Nuclear Propulsion) to start construction of 2 units in Russian Federation and 6 Units in Uzbekistan

Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Integral PWR	Forced, Pumps	Water/Water	190 MW_{th} / 55 MW_e
Design Life	**Reactivity Control**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
60 yrs.	Control rod, boron…	283 °C/321 °C	15.7 MPa/3.83 MPa
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
60-72 months	< 20 %	---	UO_2 pellet hexagonal

Unique Features	Modular design; integral reactor; in vessel corium retention in severe accidents
Target Application	The RITM-200N reactor plants may be used to generate electricity, cogenerate electricity and heat, and to desalinate sea water.
Design Philosophy	The design is developed in compliance with the requirements of federal standards and regulations in nuclear energy use for NPPs. Modularity is adopted for design and transport. An industrial large-unit installation process is used for construction.

ACP100, China

NPIC, CNNC

Status:
Under construction in China for grid connection in mid 2026

Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Integral PWR	Forced, Pumps	Light Water/Light Water	385 MW_{th} / 125 MW_e
Design Life	**Reactivity Control**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
60 yrs.	Control rod, …	286.5 °C/319.5 °C	15 MPa/4.6 MPa
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
24 months	< 4.95 %	<52 GWD/tonnes	UO_2 / 17× 17 Square

Unique Features
Integrated Reactor with tube-in-tube once through steam generator, and underground nuclear island

Target Application
The ACP100 is a multipurpose power reactor designed for electricity production, district heating, steam production or seawater desalination and is suitable for remote areas that have limited energy options or industrial infrastructure

Design Philosophy
The ACP100 realizes design simplification by integration the primary cooling system and enhanced safety by means of passive safety systems

i-SMR

KHNP, KAERI

Status:
Standard design in progress

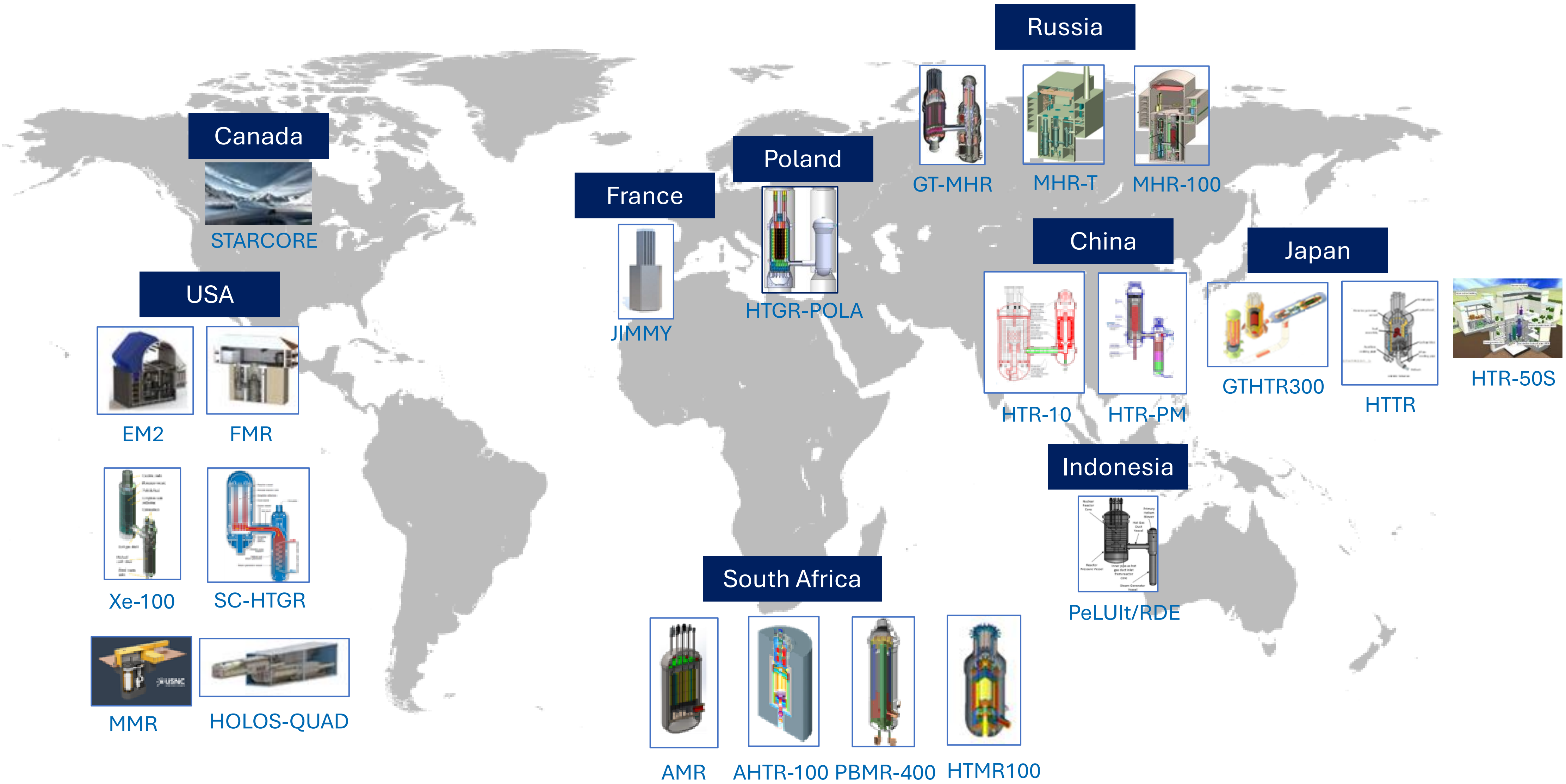
Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Integral PWR	Forced	Light Water/Light Water	520 MW_{th} / 170 MW_e
Design Life	**Reactivity Control**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
80 yrs.	Control rods, burnable rods and MTC	286°C/321 °C	15.5 MPa/--
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
24 months	< 5 %	~ 62 GWD/tonnes	UO_2 / 17× 17 Square

Unique Features: Boron free operation, at least 72 hours of core cooling without AC/DC power

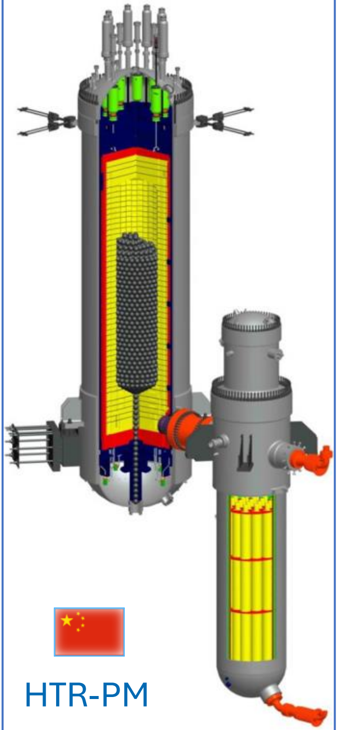
Target Application: It is a multi-purpose reactor for electricity production, heat supply for industries, seawater desalination and hydrogen production.

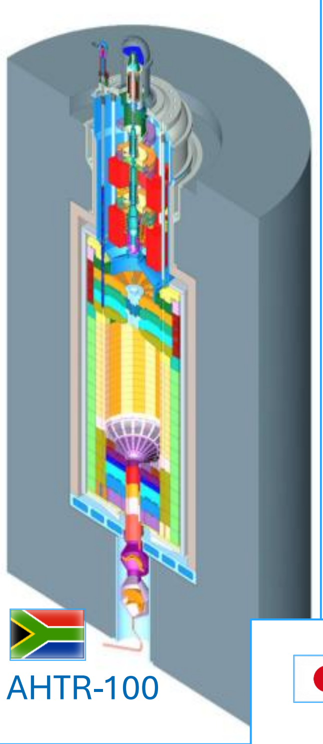
Design Philosophy: This implements design simplification and elimination of large break LOCA by integrating the primary coolant system and also incorporates boron free operation enhancing safety and economics.

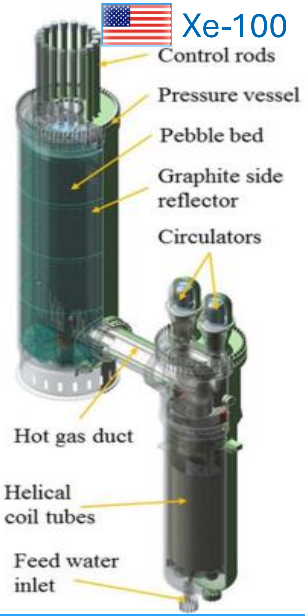
Global Activities on HTGR-SMR development

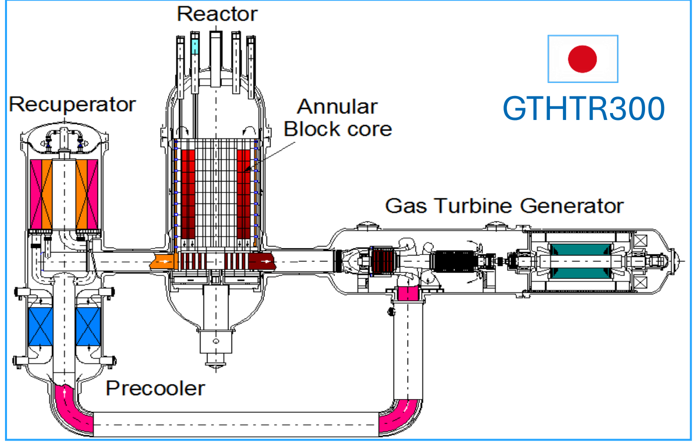


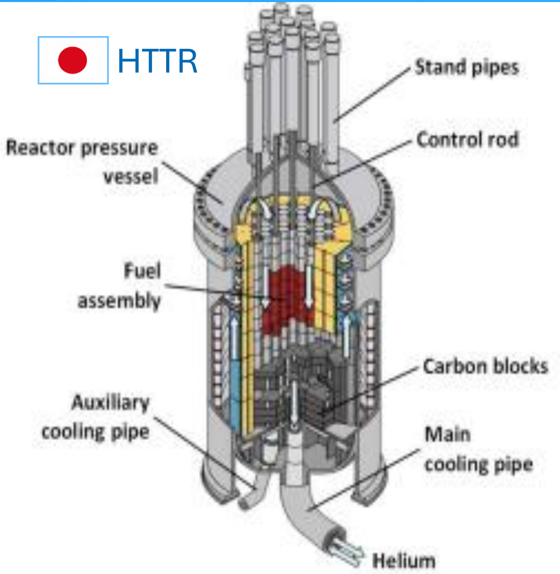
Multiple designs from Member States

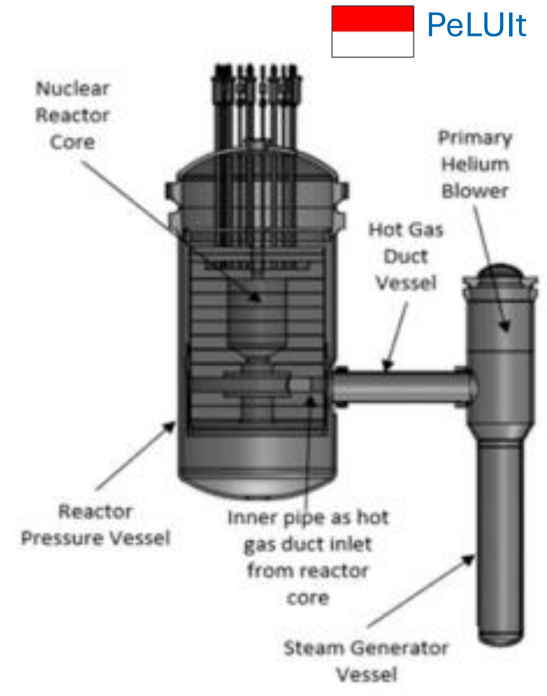


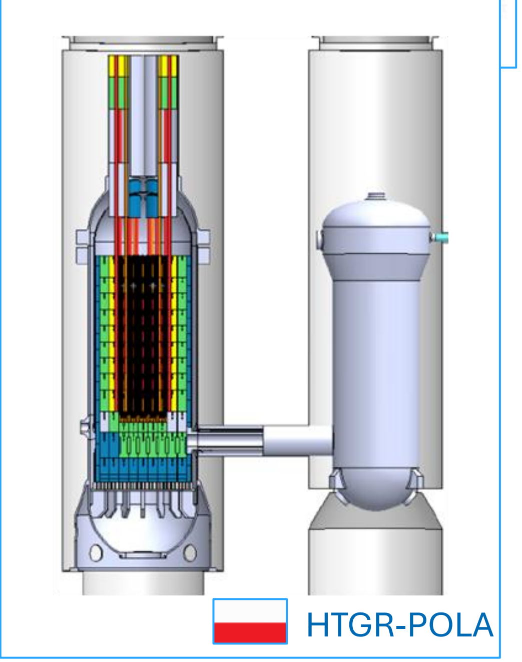












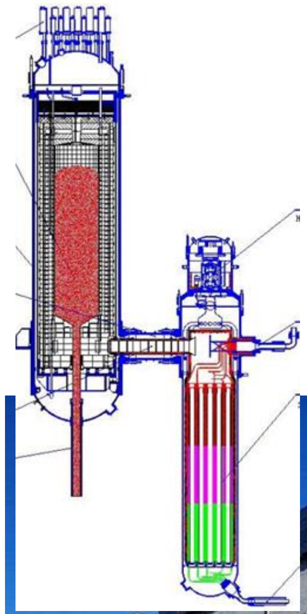
Number of SMR designs under development (2022)

- 38 Water-cooled
- 45 Non-water cooled
  - HTGR 21
  - MSR 13
  - LFR 8
  - SFR 3

HTR-PM, China

INET, Tsinghua University | CHINA HUANENG

Status:
In operation since December 2022



Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Modular HTGR	Forced, Pumps	Helium/Graphite	2 x 250 MW_{th} / 210 MW_e

Design Life	Reactivity Control	Core Inlet/Outlet Temperature	NSSS Operating Pressure Primary/Secondary
40 yrs.		250 °C/750 °C	7 MPa/13.25 MPa

Refuelling Cycle	Fuel Enrichment	Core Discharge Burnup	Fuel Type / Assembly Array
Online Refuelling	< 8.5 %	90 GWD/tonnes	Spherical elements with coated TRISO particle fuel

Unique Features
420 000 spherical elements with coated TRISO particle fuel, online refuelling, helium gas cooled, graphite moderated.

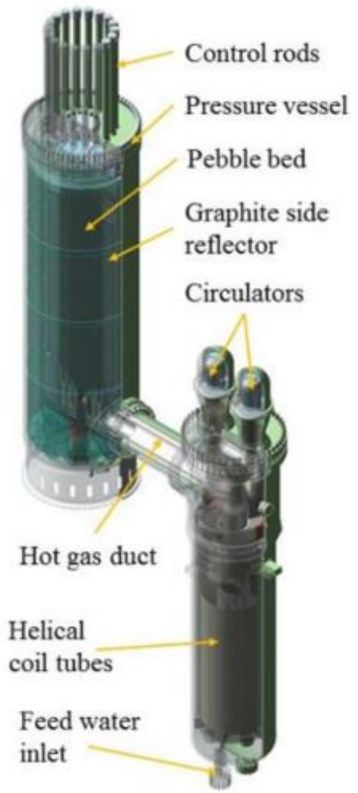
Target Application
The HTR-PM is a commercial demonstration unit for electricity production. The twin reactor modules driving a single turbine configuration.

Design Philosophy
HTR-PM consists of two NSSS modules coupled with a 210 MW(e) steam turbine. Each module includes reactor pressure vessel; a steam generator; a main helium blower; and a hot gas duct. The thermal power of each reactor module is 250 MW(t)

Xe-100

X Energy

Status:
Basic Design



Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Modular HTGR	Forced helium	Helium/Graphite	200 MW_{th} / 82.5 MW_e
Design Life	**Reactivity Control**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
60 yrs.	Control rods and thermal feedback	260°C/750 °C	6.0 MPa/16.5 MPa
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
Online	15.5 %	165 GWD/tonnes	UCO TRISO/pebbles

Unique Features: Online refuelling, core cannot melt and fuel damage is minimized by design, independent radionuclide barriers, potential for advanced fuel cycles

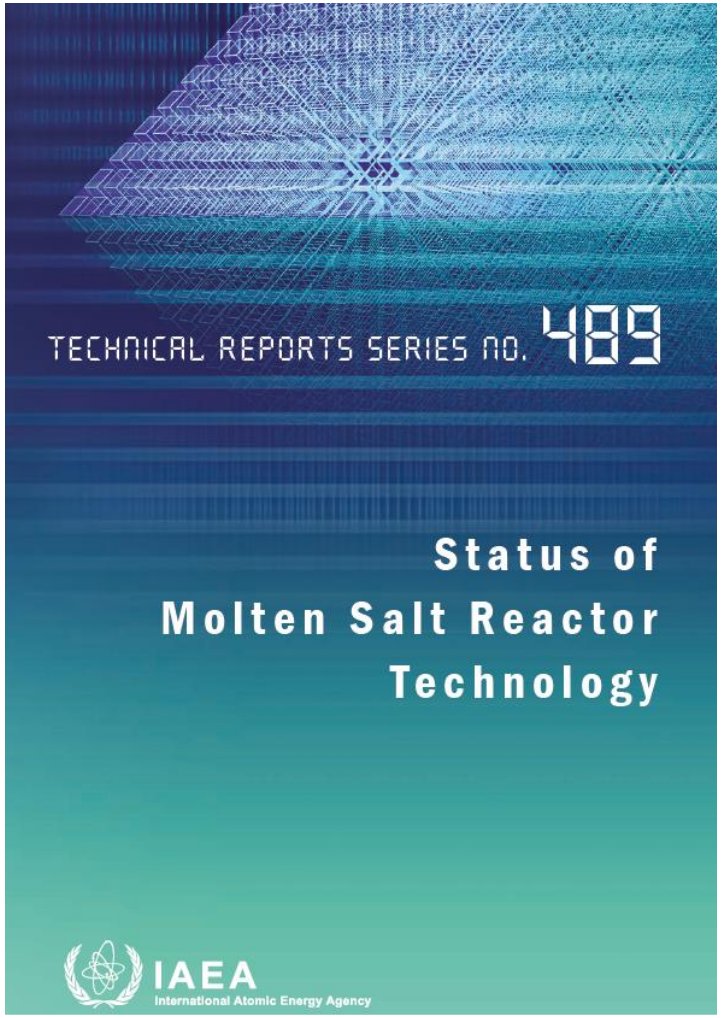
Target Application: Process heat applications, desalination, electricity and cogeneration.

Design Philosophy: A major aim of the Xe-100 design is to improve the economics through system simplification, component modularization, reduction of construction time and high plant availability.

Advances in Molten Salt Reactors
(examples)

Power range of MSRs

IAEA Publication on MSR Technology (2023)



220 pages

Section 1: Introduction	• Background, Objective, Scope, Structure
Section 2: History of MSR technology	• Development efforts of several member states on MSR technologies since the 1940s
Section 3: Advantages and technical challenges of MSR technology	• Potential safety and economic advantages of MSRs and technical challenges for deploying MSRs
Section 4: Classification of MSRs	• Taxonomy of MSRs based on the major reactor types and technological similarities: Classes, Families, Types
Section 5: Research and Development activities	• R&D activities in Member states with major programmes for MSR technology
Section 6: Current challenges to deploying MSRs	• Non-technical challenges associated with the deployment MSRs and potential solutions to these challenges
Section 7: Summary and conclusions	• Summary and main conclusions regarding the status of the MSR technology

KP-FHR

Kairos Power

Kairos Power

Status:
Conceptual Design

Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Modular, salt cooled reactor	Forced circulation	Li_2BeF_4 Flibe/Graphite	320 MW_{th} / 140 MW_e

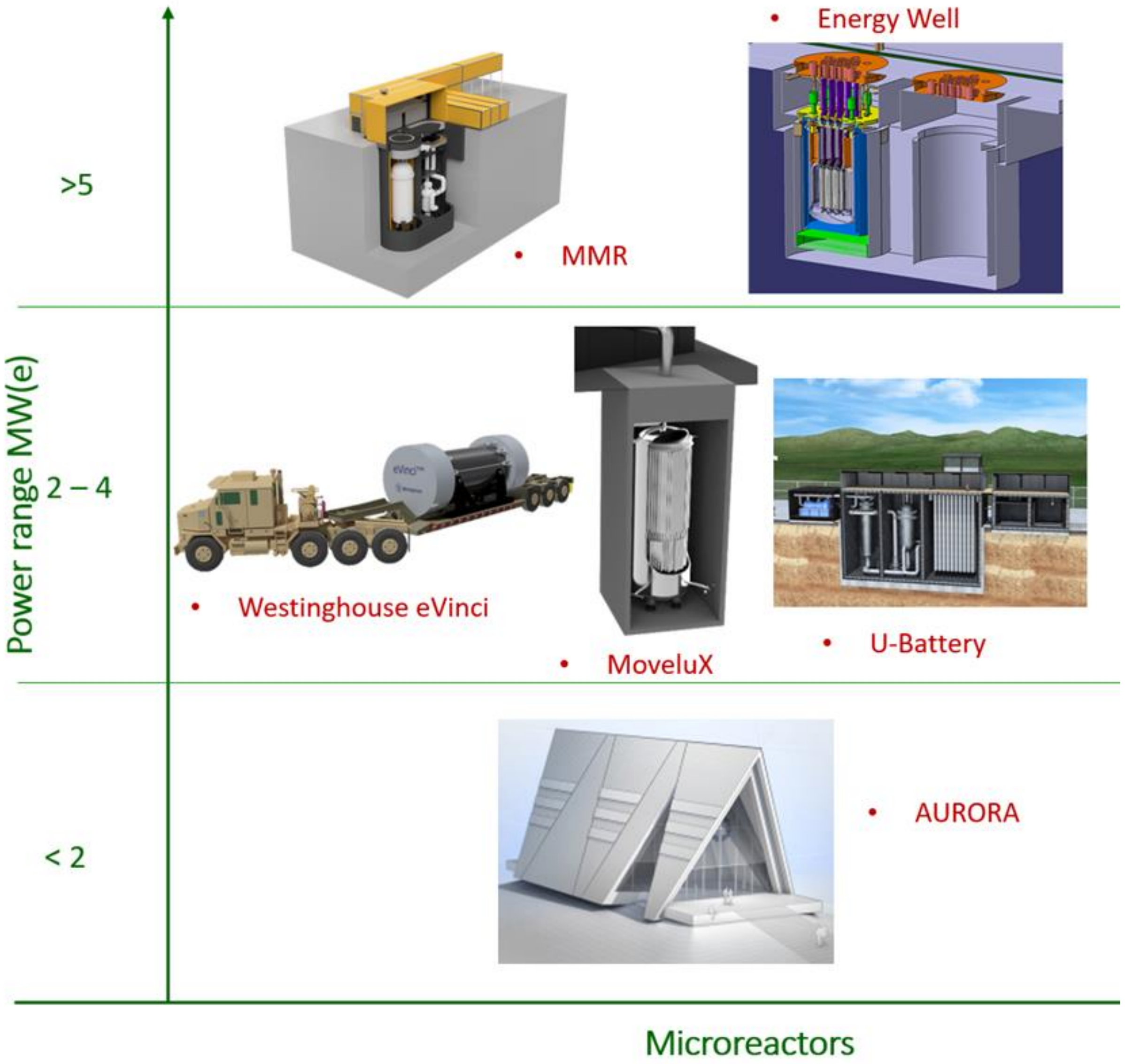
Design Life	Reactivity Control	Core Inlet/Outlet Temperature	NSSS Operating Pressure Primary/Secondary
80 yrs.	Control elements and boron	550°C/650 °C	<0.2 MPa/--

Refuelling Cycle	Fuel Enrichment	Core Discharge Burnup	Fuel Type / Assembly Array
Online	19.75 %	--	TRISO in graphite pebble / Pebble bed

Unique Features	Longer than 72-hour coping time for core cooling without AC or DC power, or operator action
Target Application	Dispatchable power to improve grid resilience and security. The KP-FHR aims to be cost competitive with natural gas
Design Philosophy	Combination of TRISO particle fuel coupled with molten fluoride salt coolant (2LiF:BeF2, Flibe) to result in a high temperature, low-pressure reactor with robust, passive safety systems.

Emerging: Microreactors

Micro Reactors



- Several countries are developing Microreactors technology for potential deployment by 2030;
- *Typically* to generate from 1 to 10 MWe; designed for enhanced transportability to site by modularity;
- To supply power at remote sites with mining operations, island communities, oil platforms and maritime shipping.
- Deployment opportunities in remote areas in North America, Middle East, Africa, and the South-East Asian archipelagos.

44

MMR

Ultra Safe Nuclear Corporation

USNC / NANO Nuclear Energy Inc.

KRONOS MMR™

Status:
Preliminary Design, Licensing in Canada

Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
HTGR	Forced (1 Circulators)	Helium/Graphite	45 MW_{th} / 15 MW_e
Design Life	**Reactivity Control**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
40 yrs.	Control rods and negative coefficient	300°C/660 °C	1.3-6 MPa/0.3 MPa
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
18-24 months / livetime	9.9-19.75 %	50-150 GWD/tonnes	TRISO in FCM / Hexagonal

Unique Features	Micro-reactor, off-grid power potential, modular design, designed for remote/off-grid locations, passive safety systems
Target Application	An MMR Energy System can be configured for a number of applications, such as electricity generation, process heat, hydrogen production, district heating, etc.
Design Philosophy	The design embraces the separation principle, the nuclear plant is physically separate from the adjacent plant, which reduces the nuclear footprint of the overall facility

Microreactors (others, in organizations' website)

Technology Category
• Subcritical power modules in ISO container
• UCO TRISO fuel with gas/steam turbine generator
• Self cooling heat pipe
• Sodium Potassium eutectic-cooled, UZrH, HALEU
• lightweight fission power system to fuel deep-space exploration

Specificities of Microreactors

Westinghouse's eVinci micro reactor schematic (Image: SMR Booklet edition 2020)

04

Heat-pipe technology
proven by LANL for space application

03

Transportability
Within standard shipping containers

05

Compact and simplified

02

Multi-applications
- Energy generation; or
- Production of heat and electricity

06

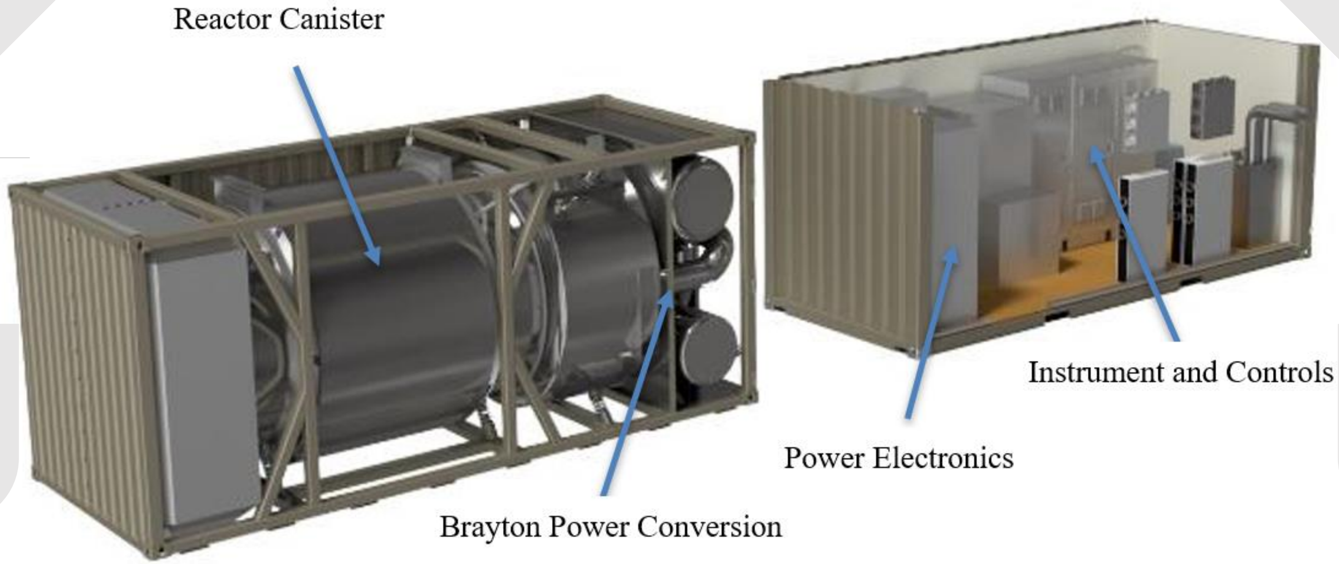
Manufactured and fueled in a factory

01

Specifically designed to serve
- Remote communities;
- Mining operations; or
- military installations.

07

Packageable
in standard transport containers



Comparison of Main Characteristics among Microreactors SMR Designs

Designs	AMR	Aurora	ELENA	Energy Well	eVinci	HOLOS-MONO	HOLOS-QUAD	Jimmy	MMR	MoveluX	Pylon D1	SHELF	Unitherm
Designers	Power Cell Micro Reactor Pty	OKLO, Inc.	NRC “Kurchatov Institute”	Centrum výzkumu Řež	Westinghouse Electric Company, LLC.	HolosGen	HolosGen	Jimmy Energy SAS	Ultra Safe Nuclear Corporation	Toshiba Corporation	Ultra Safe Nuclear Corporation	NIKIET	NIKIET
Country of Origin	South Africa	USA	Russian Federation	Czech Republic	USA	USA	USA	France	USA	Japan	USA	Russian Federation	Russian Federation
Thermal Output MW(t)	10	50	3.3	20	15	22	22	10	45	10	1	35	30
Electrical Output MW(e)	3	1.5	0.068	8	5	10	10	10	15	3	0	10	6.6
Reactor Type	HTR, Advanced Prismatic Type	LMFR	PWR	Fluoride high temperature reactor	Micro-modular reactor	HTGR	HTGR	HTGR	HTGR	Heat-Pipe cooled and calcium-hydride moderated reactor	HTGR	Integral PWR	PWR
Primary Circulation	Forced Circulation	0	Natural Circulation	Forced Circulation	Natural Circulation	Helium	Helium	Forced Circulation	Forced Circulation	Natural Circulation	Forced Circulation	Natural Circulation	Natural Circulation
Fuel Type	TRISO particles/ LBE eutectic/ SiC tubes	Metal Fuel	UO_2, MOX (option)	TRISO	TRISO in fuel compacts	Qualified TRISO-UCO Compacts	Qualified TRISO-UCO Compacts	UCO TRISO particles packed into pellets	TRISO coated particles inside FCM matrix	Silicide (U_3Si_2)	FCM™ TRISO	Cermet (UO_2 + metallic silumin)	UO_2 in a metallic silumin or zirconium matrix, metal-ceramic
Assembly Array	0	N/A	N/A	N/A	N/A	Hexagonal	Hexagonal	N/A	Hexagonal	Hexagonal	Hexagonal	Hexagonal	54 / 55
No. of fuel assembly	420	N/A	109	25	N/A	Monolithic graphite-fuel matrix	Multiple layers of hexagonal graphite-fuel elements	N/S	150	66 (fuel), 72 (CaH_2)	150	N/S	265
Coolant	Helium	Liquid Metal	Light Water	Molten salt FLiBe	Heat pipes (Na)	Helium	Helium	Helium	Helium	N/A	Helium and sCO_2	Light water	High purity water
Moderator	Graphite	N/A	Light Water	N/A	Graphite	Graphite	Graphite	Graphite	Graphite	Calcium hydride (CaH_2)	Zirconium Hydride	Light water	High purity water
Core Inlet Temp, °C	450	N/A	311	650	N/A	590	590	300	300	680	327	271	249
Core Outlet Temp, °C	750	N/A	328	700	N/A	855	855	700	660	685	727	308	330
Enrichment %	10 - 20	N/A	15.2	15	19.75	19.95	19.95	9.8 - 19.75	9.9 - 19.75	4.8 - 5	9.9	19.7	19.75
Refuelling Cycle, months	96	120 - 240	300	84	8 full-power years	96 at EFPY operating conditions	96 at EFPY operating conditions	No refuelling	18 months to 27 years	Continuous	N/A	96	200
Reactivity Control	Control and shutdown rods in core, and the reflector	N/A	Control rods & absorber rods	Control rods	Control drums and rods DiD	Drums and shutdown rods	Drums and shutdown rods	B_4C Control rods	Control rod, negative temperature coefficient	In-Ga Expansion Module (IGEM)	Drums	CRDM	Soluble boron and control rod
Reactor Vessels													

Factors in Microreactors Development

Rationales

- More specific nuclear portfolios beyond ‘known’ SMRs
- The need for energy resiliency
- Power needs in regions inaccessible by known power generators / plants
- Power needs in cities / techno parks

Pursued Advantages

- New technologies with innovative inherent safety features
- Substantially lower capital cost
- Modularity, Mobility, more of “installation” than construction
- Long refueling interval or no refuel

Target Applications

- Microgrids for critical infrastructures
- Remote off-grid areas, minings
- Emergency power supply
- Wide spectrum non-electric apps
- Space and Naval applications (UUV)

Potential Issues and Key Challenges

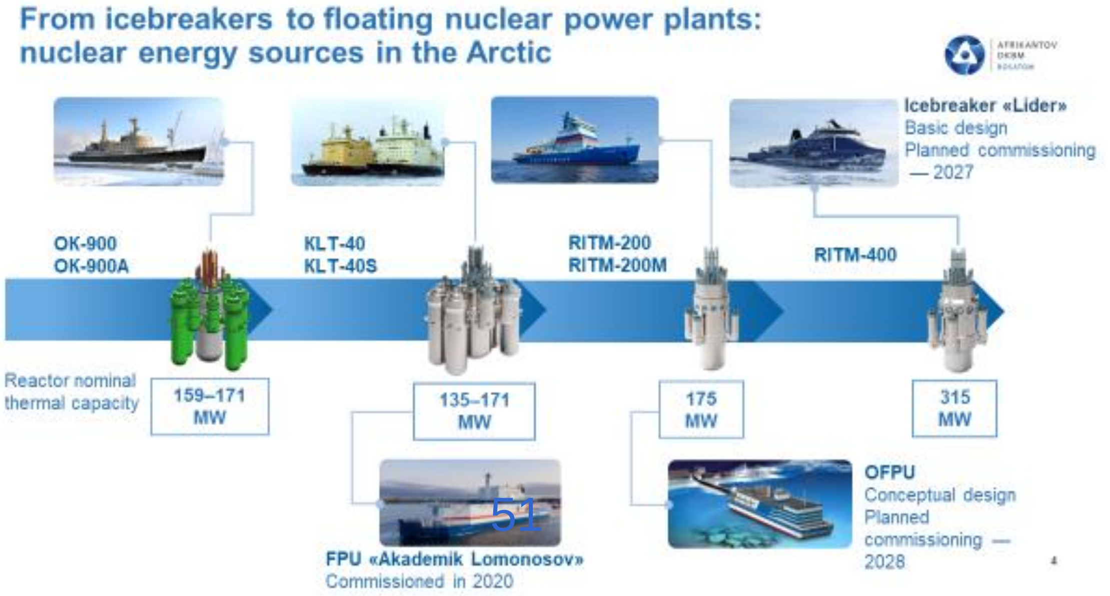
- Safeguards: *factory-sealed cores, new configs.*
- Security: *remote off grid areas, attractive theft target of new fuels / higher enrichment*
- Strategies for waste treatment and disposal
- Operator requirements, oversights / inspections

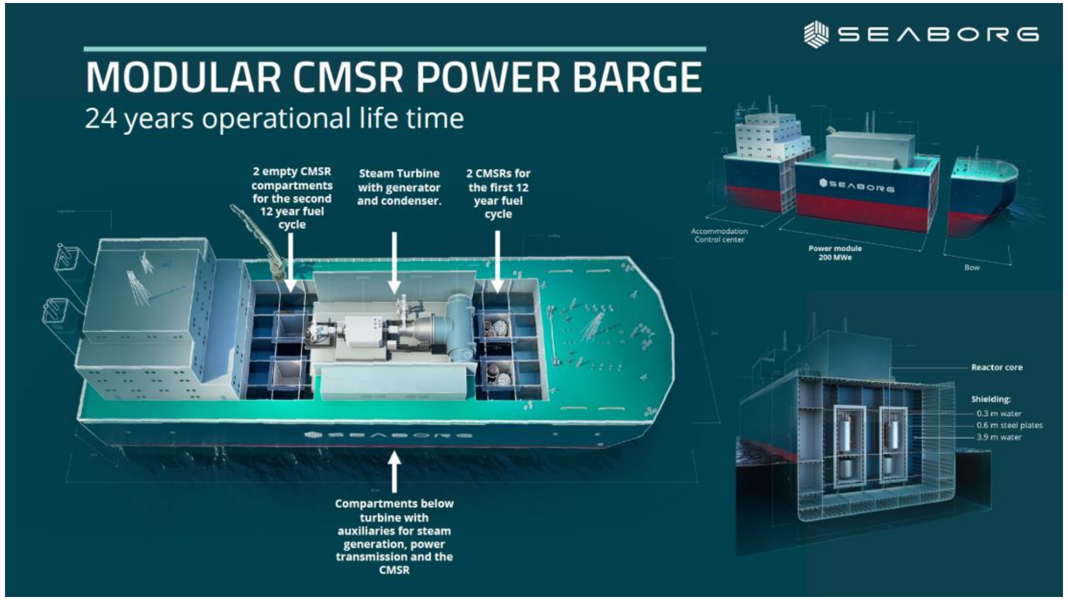
Floating Nuclear Power Plants and Maritime Applications

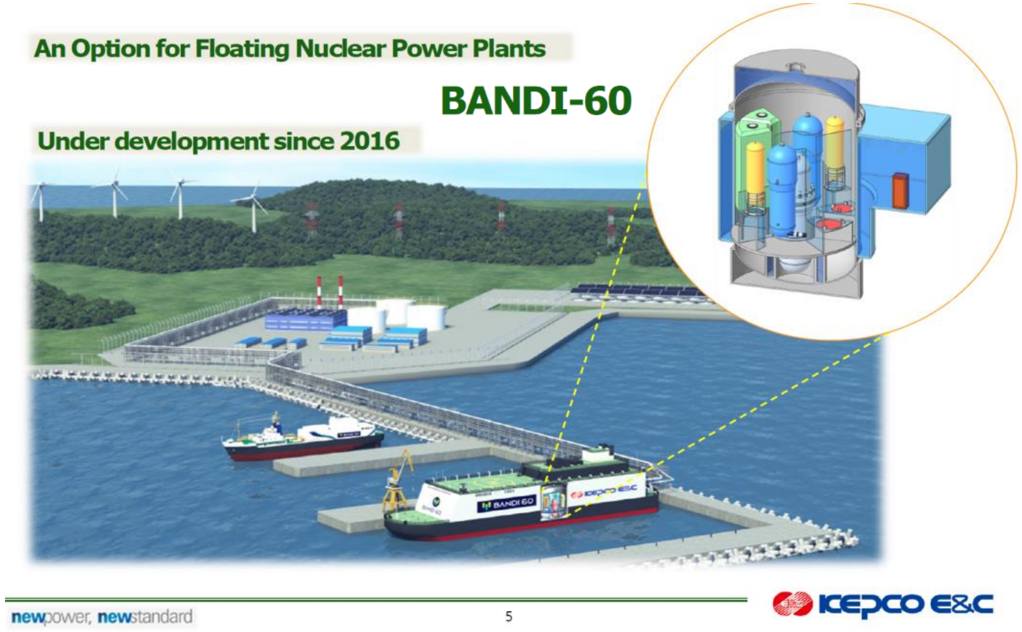
Maritime Applications

- Floating nuclear power plants (FNPPs) serve as mobile sources of clean energy, with the capability to provide power as needed to coastal electric grids.
- The Akademik Lomonosov, the world's first FNPP, entered commercial operation in 2020.
- INPRO is assisting Member States in coordinating key stakeholders to make FNPP technology available to meet global clean energy needs.
- INPRO is working with reactor developers and shipping companies to enable economic serial production of FNPPs in shipyards and integrate nuclear quality and standards into the existing shipyard model.
- The IAEA's groundbreaking International Symposium on the Deployment of Floating Nuclear Power Plants, held in Vienna in November 2023, explored current and future designs of FNPPs and their applications as well as challenges in the areas of licensing, regulation, transportation and safeguards.

FNPP R&D and deployment progress







Prospects and Actions for Deployments

Demonstration of Safety and Operational Performance of
FOAK, Novel Designs & Technologies

Continuity of Orders, cost competitiveness against alternatives, robust supply chain, and viable financing Option

SMR Deployment Competitiveness

Regulatory framework, licensing pathways: global deployment, need of harmonization?

Development of Nuclear Infrastructure for near-term deployment particularly in Embarking countries

Advantages, Issues & Challenges

Technology aspects
- Shorter construction period (modularization)
- Potential for enhanced safety and reliability
- Design simplicity
- Suitability for non-electric application (desalination, etc.).
- Replacement for aging fossil plants, reducing GHG emissions

Non-Techno aspects
- Fitness for smaller electricity grids
- Options to match demand growth by incremental capacity increase
- Site flexibility
- Reduced emergency planning zone
- Lower upfront capital cost (better affordability)
- Easier financing scheme

Technology issues
- Licensing of FOAK designs, particularly non-LWR technologies
- Prove of operability and maintainability
- Staffing for multi-module plant;
- Supply chain for multi-modules
- Optimum plant/module size
- Advanced R&D needs

Non-technology issues
- Time from design-to-deployment
- Highly competitive budget source for design development
- Economic competitiveness: affordability & generation cost
- Availability of *off-the-shelf* design for newcomers
- Operating scheme in an integration with renewables

Benefits of Cogeneration and Non-Electric Applications

01

Higher Efficiency

- Up to 80% overall energy efficiency
- Opens new sectors for nuclear power

02

Less Environmental Impacts

- Reduce the waste heat dumped to environment
- Additional heat sink

03

Better Use of Energy

- Optimize energy efficiency
- Match industrial application needs at the right temperature

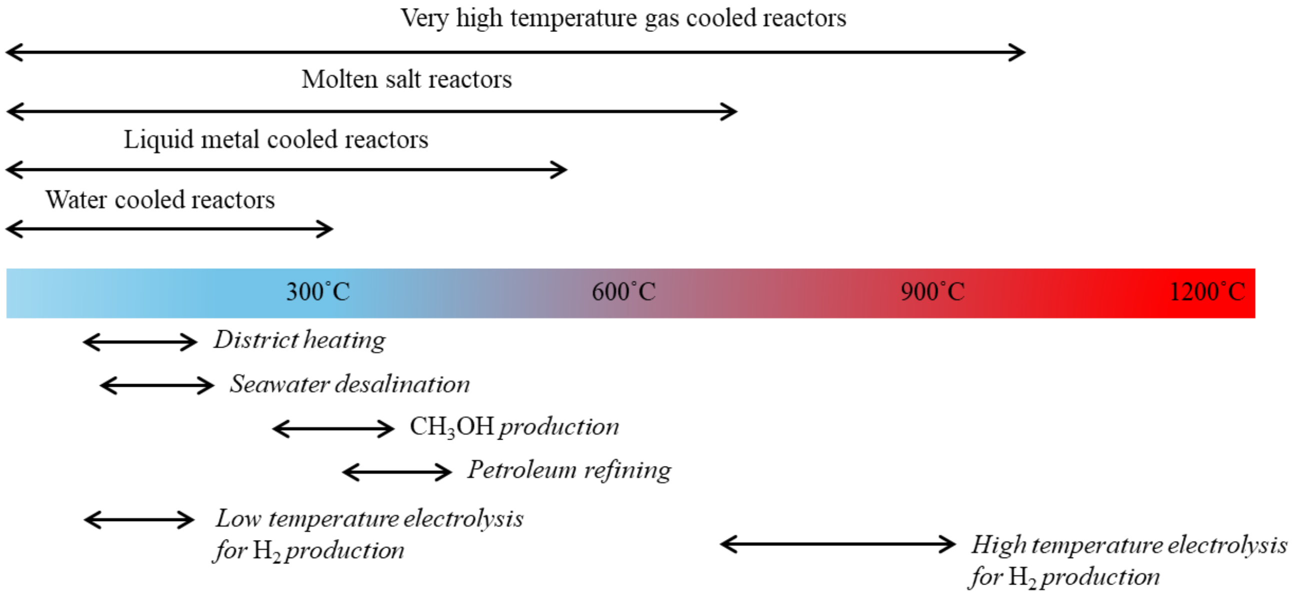
04

Enhanced Flexibility

- In future energy planning
- In operating NPPs & Grid
- In diversifying energy outputs

The need of non-electric applications using nuclear power is inevitable for the future diversified energy market

SMR: MSR and HTRs – serving the complete energy market



- **50% of the users for industrial processes require less then 10 MWt capacities.**
- **40% require between 10 and 50 MWt.**
- **99% of the users are included in the 1 to 300 MWt range, which accounts for about 80% of the total energy consumed.**
- **Large market can be served NOW with 580ºC steam**
- **More (material) development for T_{out} > 850ºC -> VHTRs**

- Decarbonising **the power sector** will not be sufficient to reach climate goals
- **Need to decarbonize other sectors, representing 60% of emissions**
- Cogeneration and high temperature process heat application
  - Process steam for petro-chemical industry
  - Potential for higher T in future addressing the complete heat market

Latest developments - Cogeneration

Jimmy submits an application for authorization to build a thermal generator on the Cristanol site.

Jimmy submits a request for authorization (DAC) for a thermal generator project which, if it passes all

Jimmy

FRANCE 2030

Hatch and X-energy partner on project to reshape energy systems in Alberta

A potential, first-of-a-kind nuclear project in Alberta to transform a thermal power plant with the use of small modular nuclear reactor technology

June 11, 2024

Nuclear

Nuclear Milestone: China's HTR-PM Demonstrates Inherent Safety

POWER

Chinese researchers have confirmed the first of two units of the 200-MWe high-temperature modular pebble bed (HTR-PM) demonstration project at the Shidao Bay site in Rongcheng, Shandong Province, successfully achieved inherent safety during loss-of-cooling tests. The tests demonstrated, for the first time, a commercial-scale high-temperature reactor's (HTR's) ability to remove decay heat without active intervention, the researchers from the Institute of Nuclear and New Energy Technology (INET) at Tsinghua University in Beijing said in a July 2024 article

China / Shidao Bay HTR-PM Nuclear Energy Heating Project Begins Operation

NUCNET

By David Dalton
4 April 2024

… the project can meet the clean heating needs of 1,850 households, replacing 3,700 tonnes of coal every winter.

Latest developments - Cogeneration

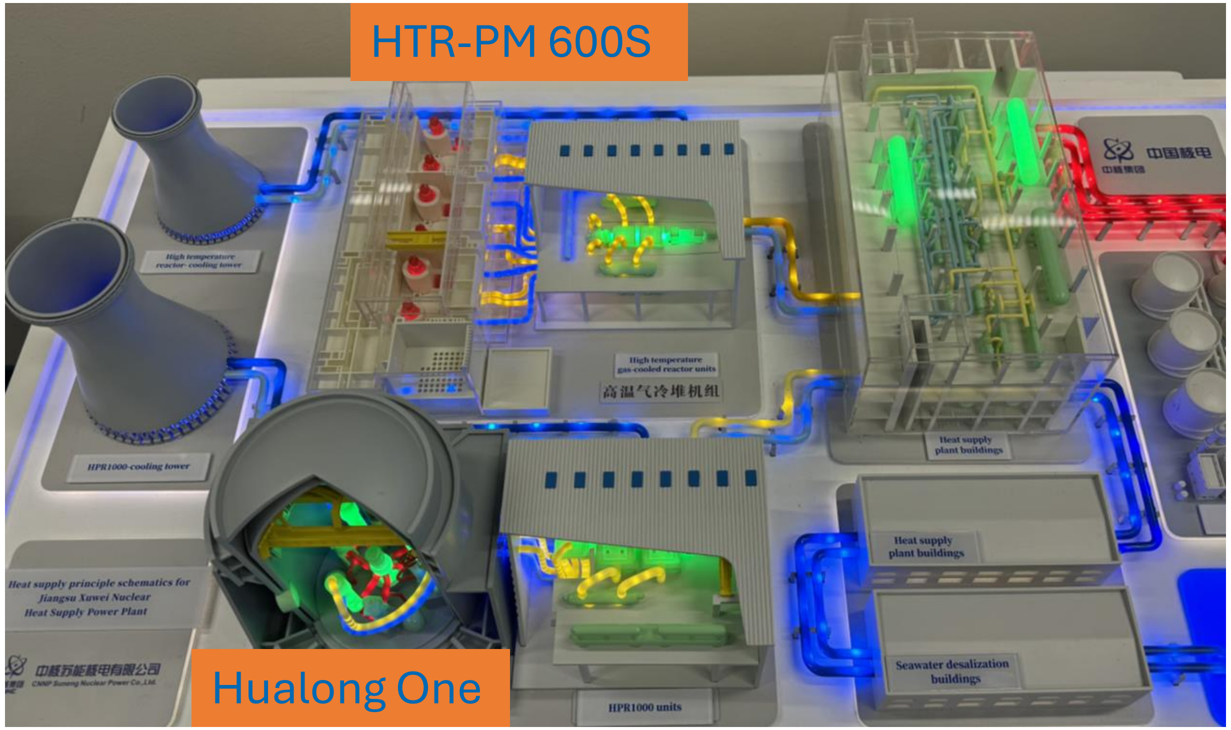
China National Nuclear Power: The Phase I project of the Xuwei Nuclear Heating and Power Plant in Jiangsu has been approved by the State Council for nuclear energy.

Breakings · Aug 19 14:01

文/A

SH China National Nuclear Power +1.36%

China National Nuclear Power announced that its subsidiary, China Nuclear Su Power Nuclear Power Co., Ltd., as the owner unit, is responsible for the investment, construction, and operation management of the Phase I project of the Xuwei Nuclear Heating and Power Plant in Jiangsu. The project plans to build two Hualong One pressurized water reactor nuclear power generators and one set of high-temperature gas-cooled reactor nuclear power generators, with a



2x Hualong One (FCD expected Aug2025
+ HTR-PM 600S (FCD Feb 2026) with 6x250MWt units

Steam supply: 4082 t/h
460°C at 4.9MPa
340°C at 3.8 and 2.8 MPa

Generation capacity: 1653 MWe

Serving the Lianyungang Petrochemical park

Steam supply ~ Oct 2030

Summary

Nuclear energy can provide

- Zero-carbon electricity
- Zero-carbon heat
- Complementary to intermittent renewables (hourly, daily, seasonal) with integration in heat storage an option of some advanced SMR technologies
- Supporting decarbonization of complete energy sector - green steel, mining, industrial heat, H_2 production, cogeneration, district heating, water desalination, ammonia (fertilizer and maritime propulsion), fossil fuel replacement (from captured CO_2), etc…

Challenges

- Stakeholder and Public Support
- Demonstration Plants (FOAK vs NOAK)
- Economic viability and business model selection by utilities and industry for process heat.
- Site selection including the transport of electricity, heat and products.
- The ability to license including cogeneration with ensured safety.
- Timing of technology availability (also other such as H2 production) to reach commercialization and climate goals.

Highlights of relevant available IAEA resources

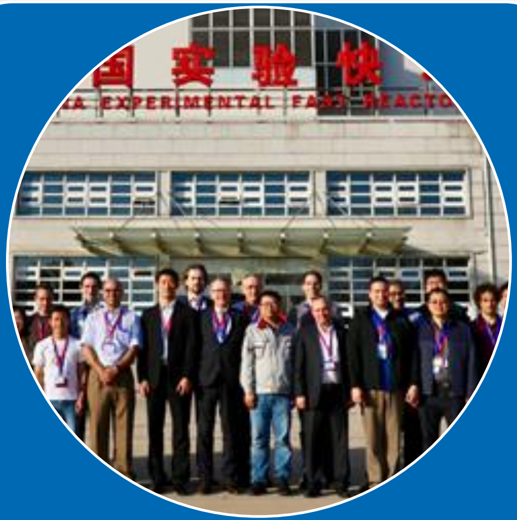
Main IAEA Activities on Advanced Reactor Technology

Knowledge Sharing

Publications

Conferences

TMs



Technology Development

Coordinated Research Projects (CRPs)

Capacity Building

Training Courses

Workshops

TECDOCs

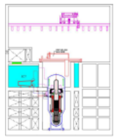
Key IAEA Activities on SMR

Technology Development and Deployment
- TWG-SMR/GCR
- ARIS Database SMR Booklet

Reactor Technology Assessment
- Method incorporates SMR

Fuel, Safe management of Spent Fuel, Radioactive Waste and Decommissioning

Approaches to Commissioning and Operation
- Issues on the conduct of operation, OLC and MCR for multi-unit plant



Economics
- Economic Appraisal of SMR Projects: Methodologies and Applications

IAEA Platform on SMRs and their Applications

Nuclear Harmonization and Standardization Initiative

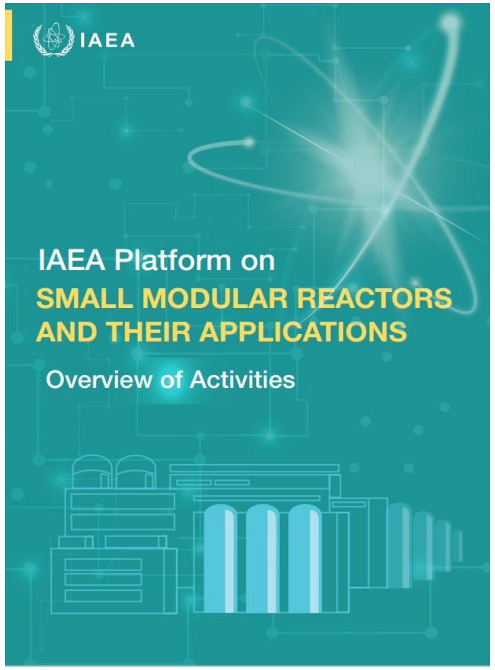
Legal Frameworks for safety, security, safeguards and civil liability for nuclear damage

Safety & Security
- Applicability of Safety Standards and Security Guides
- Emergency Preparedness and Response

Safeguards-by-Design
- Facilitation of safeguards inspection early in reactor design stage

Infrastructure Development
- IAEA Milestones Approach applicable to SMR
- New deployment models

Technical Cooperation
- Capacity Building

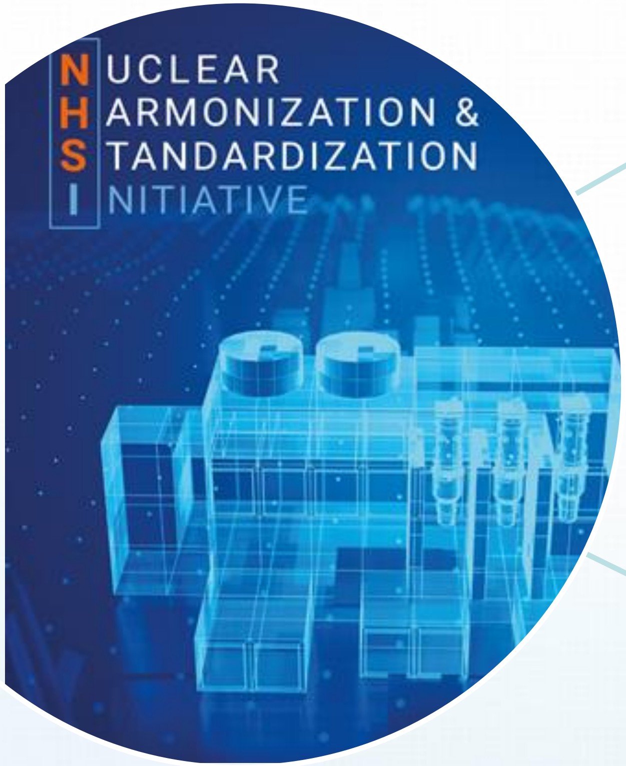


New publication available (launched at GC68)

See SMR Portal (https://smr.iaea.org)

Background: NHSI Industry Track

Effective Global Deployment of **Safe and Secure** Advanced Nuclear Reactors



Harmonization of Regulatory Approaches Track

- **WG1:** Framework for information exchange
- **WG2**: International pre-licensing regulatory reviews
- **WG3:** Leveraging other regulatory reviews

IAEA as facilitator

within and between the tracks

Harmonization and Standardization of Industrial Approaches Track

- **Topic 1:** Harmonization of high-level user requirements
- **Topic 2**: Information sharing on Codes and Standards
- **Topic 3:** Experimental Testing and Validation for Design and Safety Analysis Computer Codes
- **Topic 4:** Acceleration of nuclear infrastructure implementation for SMR

Regulators

Governments

Technology Holders

Operators and other end-users

International Organisations and Associations

NHSI Industry Track Vision

Together, let's make nuclear simpler

Near & Medium-Term Objectives

- Map pathways and reduce timelines and costs to both vendors and customers
- Facilitate common approaches for regulatory approvals
- Gather lessons learned from SMR deployment models

Long Term Goal

- Prepare industry, end-users and MSs for large-scale SMR deployment

Continuous Engagement Strategy

- Establish and maintain a strong and consistent interface mechanism with industry and with regulatory tracks

Topic Group 1 (TG1):
Harmonization of High-Level User Requirements

Topic Group 2 (TG2):
Common Approaches on Codes and Standards

Topic Group 3 (TG3):
Experimental Testing and Validation for Design and Safety Analysis Computer Codes

Topic Group 4 (TG4):
Considerations to Facilitate the Accelerated Deployment of SMRs - Concept

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Technology Development and Operations

ARIS and the SMR Catalogue (booklet)

- Innovative research on SMRs and other advanced reactors and non-electric applications continues to speed ahead.
- The TWG-SMR released the Technology Roadmap for Small Modular Reactor Deployment – It outlines the R&D and regulatory activities needed to deploy SMRs in the near future based on a step-by-step approach.
- The Advanced Reactor Information System (ARIS) compiles information including technical data, design characteristics and relevant publications on all advanced reactor designs (NEW RELEASE) and supported by new SMR booklet 2024 and catalogue of active SMR designs
- Reactor Technology Assessment methodology and Toolkit for countries to do the self-assessment based on ten key elements
- Learning from new operating experience and advancements such as capability for semiautonomous operation.

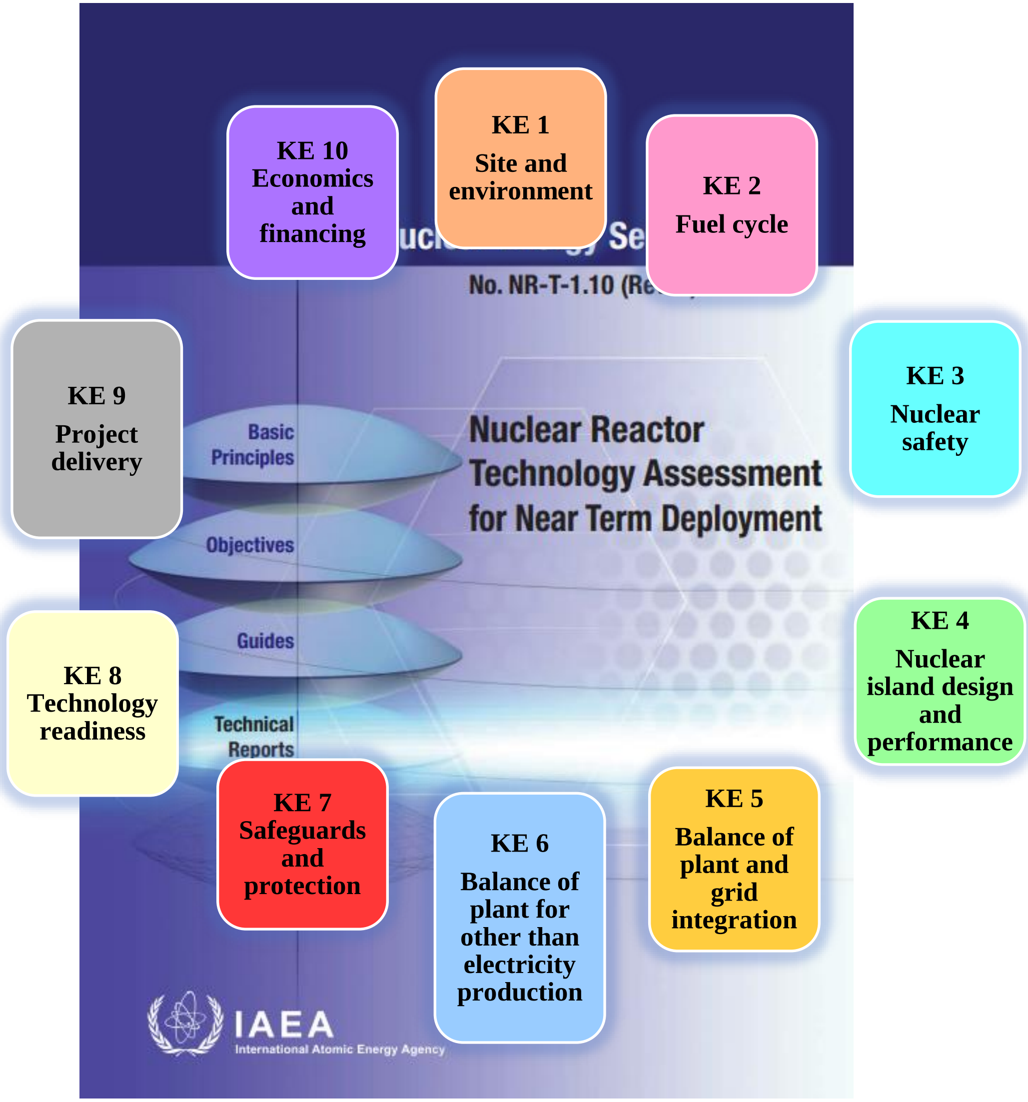
RTA supports the process of identifying, assessing and selecting available technology options. It can be applied to:

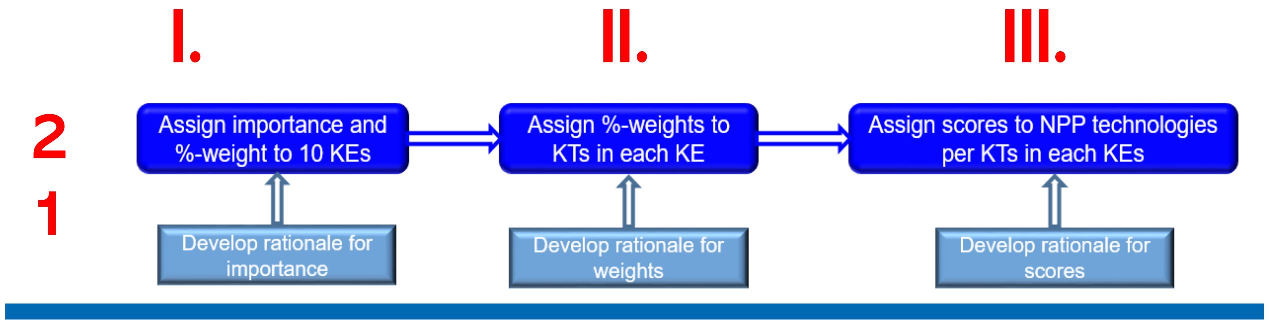
01 Large water cooled reactors (WCRs)

02 Small and medium sized or modular reactors (SMRs)

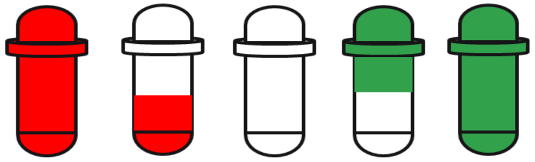
03 and their broad applications (electricity production, non-electric applications, hybrid energy systems)

IAEA Methodology for Reactor Technology Assessment





- A key challenge for Member States deploying SMRs is identifying and assessing suitable technologies that align with national objectives. The IAEA launched the **SMR Platform** to coordinate its SMR-related activities and offers tools such as the **RTA methodology**. This event demonstrated SMR assessment using the RTA methodology and the ARIS database.



NPP design satisfies the KEs/KTs to:

Little extent / not acceptable	Lesser than medium extent, but greater than a little extent	Medium extent	Greater than medium extent, but not to a large extent	Large extent
5 – point scoring system				
1	2	3	4	5
9 – point scoring system				
1	3	5	7	9

- Supported by eLearning material, Workbook and TOOLKIT
- Training example: International Workshop on the IAEA Methodology for Reactor Technology Assessment for Near Term Deployment, 28–31 August 2023, Denmark
- **Highlighted at GC 67 (2023) Side Event SMR Platform Activity: Reactor Technology Assessment using ARIS Database.**

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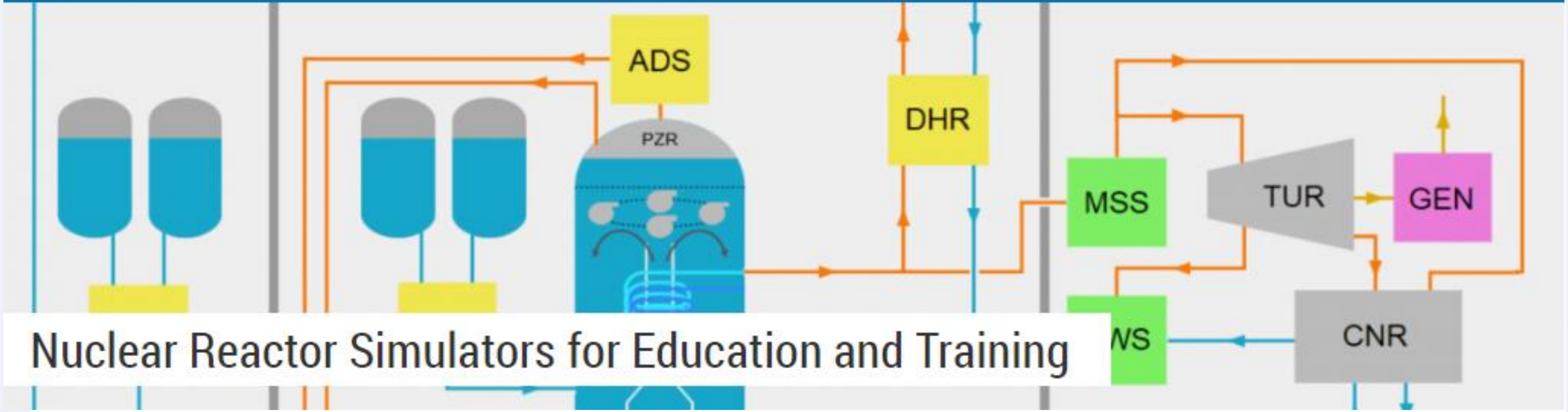

Nuclear Reactor Simulators for Education and Training

Pressurized Water Reactor (PWR) Simulators

- Advanced PWR: Two-Loop Large PWR (Korean-OPR 1000)
- Russian-type PWR (VVER-1000)
- Advanced Passive PWR (AP-600)
- Integral Pressurized Water Reactor (SMR)

Boiling Water Reactor (BWRs) Simulators

- Conventional Boiling Water Reactor with Active Safety Systems (BWR)
- Advanced BWR with Passive Safety Systems (ESBWR)

Pressurized Heavy Water Reactor (PHWR)

- Conventional Pressurized Heavy Water Reactor (PHWR)
- Advanced PHWR (ACR-700)

Part-Task Simulator

- Micro-Physics Nuclear Reactor Simulator

Under Development

- High Temperature Gas Cooled Reactor (HTGR)
- Sodium Cooled Fast Reactor (SFR)

- Used for educational purposes and aid in the understanding of reactor plant fundamentals of a NPP, operational characteristics and various approaches to reactor designs.
- The IAEA sponsors training courses and workshops on a regular basis, and would also be willing to support additional training events on this topic at the request of Member States.

Designed and maintained by Nuclear Power Technology and Development Section (NPTDS) since 2009

The IAEA has recently launched a fully redesigned version of ARIS

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ADVANCED REACTOR INFORMATION SYSTEM

The Advanced Reactor Information System (ARIS) database is designed and maintained by the IAEA and contains design descriptions of evolutionary and innovative nuclear reactors

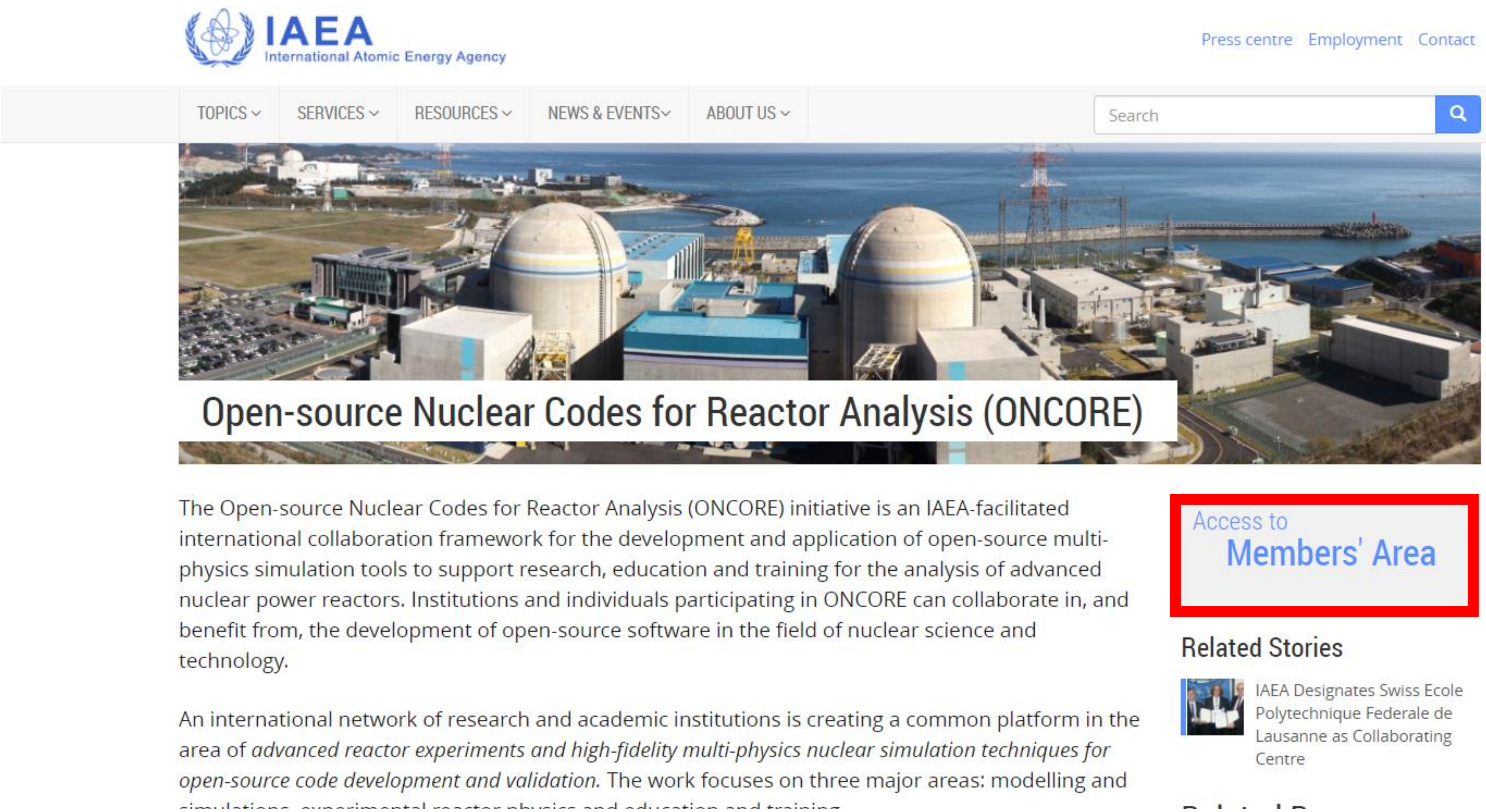
Explore ⟶

Currently 126 designs, including SMRs and microreactors

Advanced Reactors

Water Cooled Reactors | Gas Cooled Reactors | Fast Reactors | Molten Salt Reactors | Small Modular Reactors | Microreactors

IAEA ONCORE initiative



Technical Meeting on
Development and Application of Open Source Modelling and Simulation Tools for Nuclear Reactors, 20-24 June 2022 Milano, Italy

In Publishing
Technical Report Series (TRS)
Development and Application of Open-Source Modelling and Simulation Tools for Nuclear Reactor Analysis

IAEA Webinar Series on Multiphysics Modelling of
Nuclear Reactors using OpenFOAM and its Derivatives

https://www.iaea.org/topics/nuclear-power-reactors/open-source-nuclear-code-for-reactor-analysis-oncore

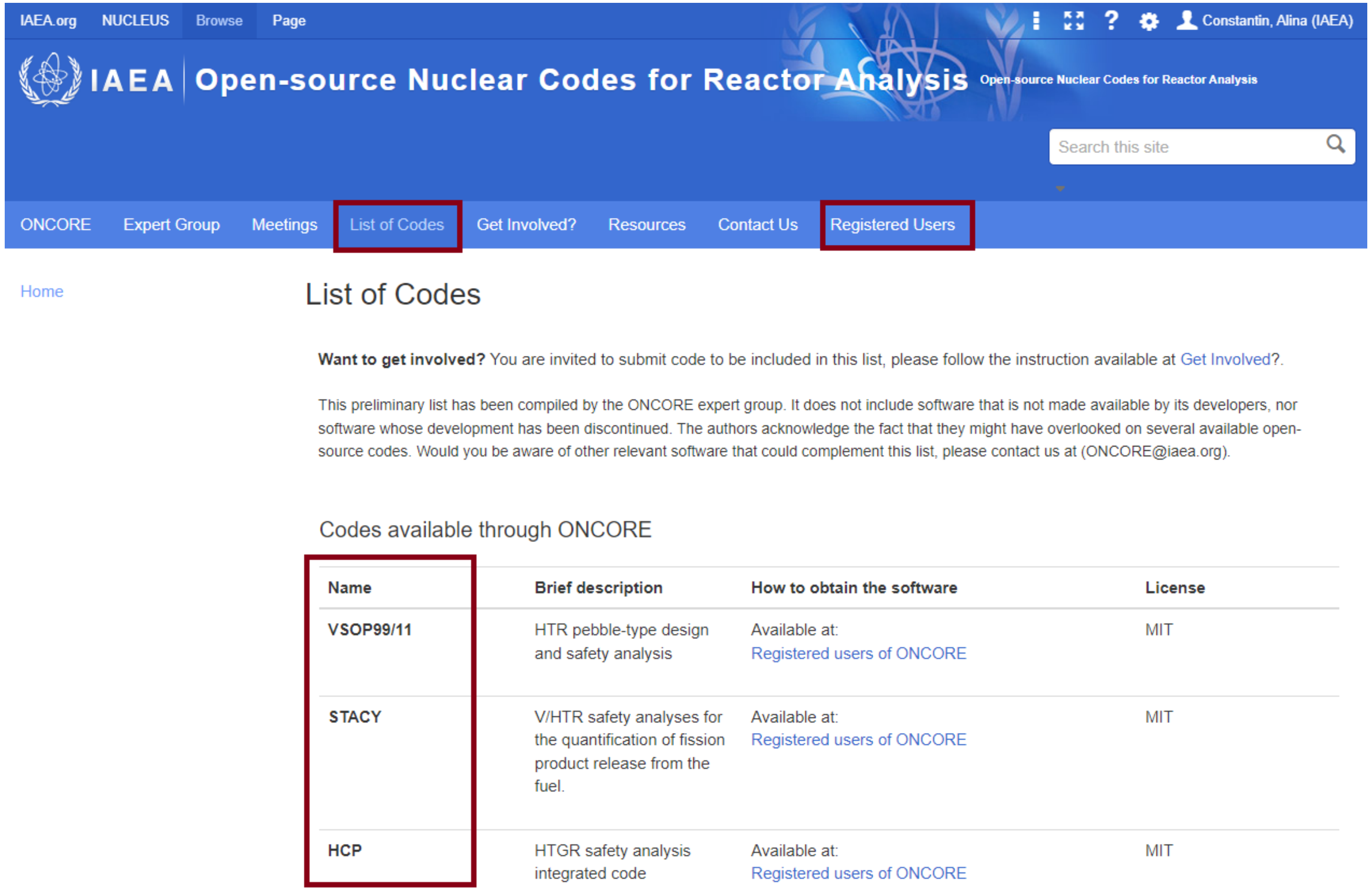
https://nucleus.iaea.org/sites/oncore

ONCORE Objectives

- Build and maintain expertise in open-source simulation codes and data, fostering information exchange in the nuclear science community
- Survey existing open-source codes and data to enhance accessibility
- Establish best practices for collaborative code development
- Identify integration opportunities and gaps in current open-source modules
- Encourage sharing of reference solutions, benchmarks, and input data
- Develop a unified open-source platform, ensuring consistency, verification, and documentation
- Promote the tools and platform for educational and research use
- Organize training and educational activities
- Successful contributions to the Future Global Nuclear Workforce and other IAEA initiatives

HTR Code Package (HCP)

- In 2020, the IAEA, the Jülich Research Centre and German Export Authorities agreed on the release of the high temperature reactor code package (HCP) to the IAEA, so that Member States can use it for design and safety analyses
- The HCP is accessible through the Open-Source Nuclear Codes for Reactor Analysis (ONCORE)
  - ➢ The ONCORE initiative is an IAEA-facilitate international collaboration framework for the development and application of open-source multi-physics simulation tools to support research, education and training for the analysis of advanced nuclear power reactors. Institutions and individuals participating in ONCORE can collaborate in, and benefit from, the development of open-source software in the field of nuclear science and technology.
  - ➢ https://www.iaea.org/topics/nuclear-power-reactors/open-source-nuclear-code-for-reactor-analysis-oncore
  - ➢ https://nucleus.iaea.org/sites/oncore



IAEA.org NUCLEUS Browse Page Constantin, Alina (IAEA)

IAEA | Open-source Nuclear Codes for Reactor Analysis

Search this site

ONCORE Expert Group Meetings List of Codes Get Involved? Resources Contact Us Registered Users

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List of Codes

Want to get involved? You are invited to submit code to be included in this list, please follow the instruction available at Get Involved?.

This preliminary list has been compiled by the ONCORE expert group. It does not include software that is not made available by its developers, nor software whose development has been discontinued. The authors acknowledge the fact that they might have overlooked on several available open-source codes. Would you be aware of other relevant software that could complement this list, please contact us at (ONCORE@iaea.org).

Codes available through ONCORE

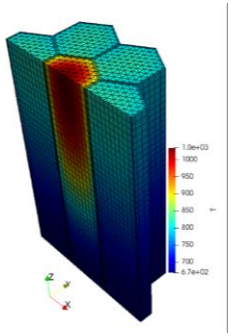
Name	Brief description	How to obtain the software	License
VSOP99/11	HTR pebble-type design and safety analysis	Available at: Registered users of ONCORE	MIT
STACY	V/HTR safety analyses for the quantification of fission product release from the fuel.	Available at: Registered users of ONCORE	MIT
HCP	HTGR safety analysis integrated code	Available at: Registered users of ONCORE	MIT

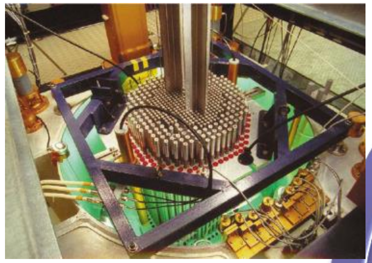
New STACY version developed by USNC available in Github

2025: Workshop on High Temperature Gas Cooled Reactor Technology and Training on the High Temperature Reactor Code Package (2-7 November 2025)

List of ONCORE open source tools

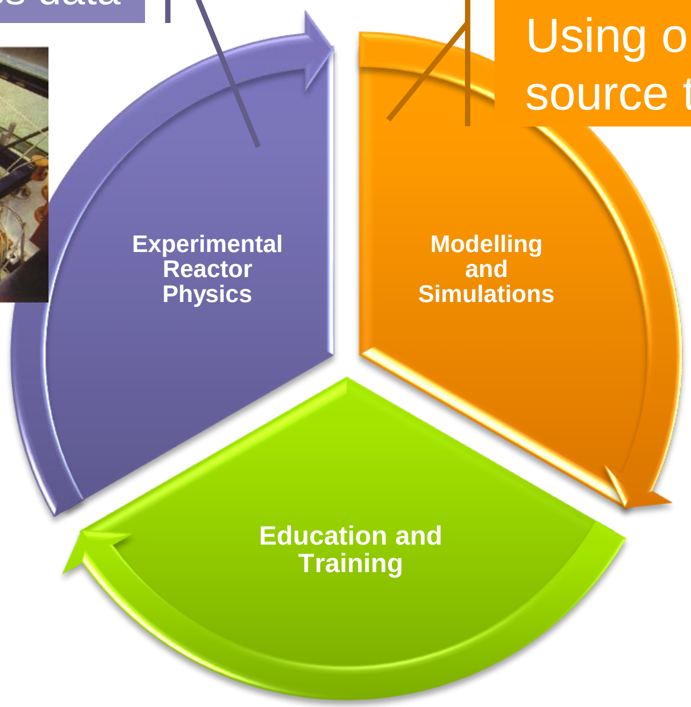
- Links to 35+ Open source tools
  - Neutronics
    - Dragon, FRENDY, NJOY, OpenMC, OpenMOC, SANDY, Scone
  - Thermal-hydraulics, system analysis, containment
    - AeroSolved, code_saturne, containmentFOAM, Fire Dynamics Simulator, Lbh15, Nek5000/NekRS, OpenFOAM, TrioCFD, TRUST,
  - Structural mechanics
    - CALCULIX, code_aster, Mfront, MGIS, OFFBEAT
  - Multi-physics applications and libraries
    - GeN-Foam
    - Elmer, MOOSE, OpenFOAM, OpenModelica, Spheral
  - Data processing, optimization, pre-post processing
    - Dakota, GNU Octave, Raven
  - Application frameworks
    - ARMI, ENRICO, Computational Model Builder (CMB), preCICE
  - Pre- and Post-Processing
    - cfMesh, FreeCAD, Gmsh, MeshLab, paraview, Salome, snappyHexMesh, VisIt





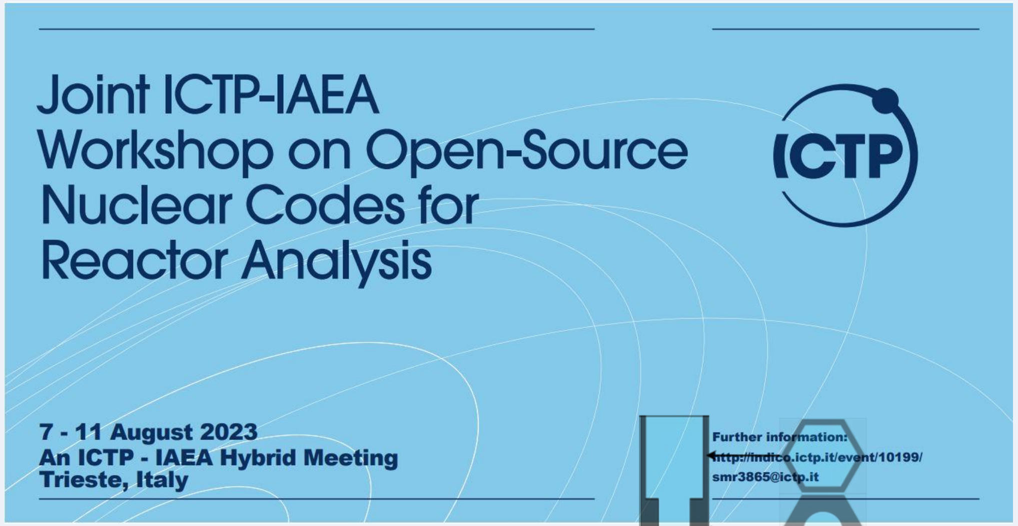
Using open access data

Using open-source tools



https://nucleus.iaea.org/sites/ONCORE

Joint ICTP-IAEA Workshop on
Open-Source Nuclear Codes for Reactor Analysis (IAEA ONCORE Initiative)



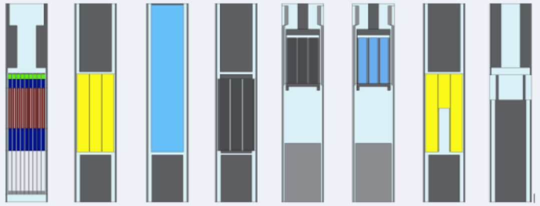
7-11 August 2023 in Trieste, Italy

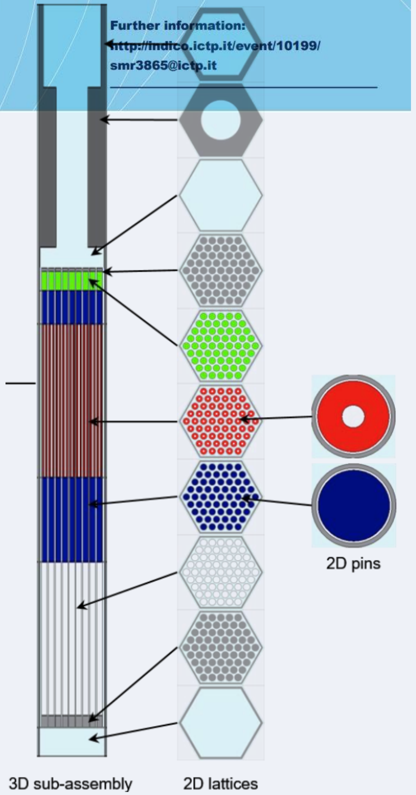
The workshop offers a comprehensive journey in cutting-edge computational techniques for nuclear reactor analysis, providing an in-depth understanding of reactor neutronics, thermal hydraulics and system analysis at different scales.

General overview, theoretical background and practical exercises are offered for

- **OpenFOAM** and its derivatives for CFD simulation of multi-physics and multi-scale problems
- **GenFOAM** for core thermal hydraulics, neutron transport and structural mechanics modelling
- **Offbeat** for fuel performance simulation
- **ContainmentFOAM** for severe accidents simulation
- **OpenMC** Monte-Carlo neutron transport
- **ARMI** Advanced Reactor Modelling Interface

#	2D axial region	
	Content	Snapshot
0	Outside	
1	Head	
2	Upper shield	
3	Upper connector	
4	Top end plug	





2nd Joint ICTP-IAEA Workshop on Open-Source Nuclear Codes for Reactor Analysis | (smr 4103)

22-26 September 2025 (https://indico.ictp.it/event/10868)

International Conference on

small modular reactors

and their applications

21–25 October 2024, Vienna, Austria


IAEA
International Atomic Energy Agency
Atoms for Peace and Development


IAEA
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FELLOWSHIP PROGRAMME
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for more women in nuclear
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Women in Nuclear
International Atomic Energy Agency
Equality
Diversity
Inclusion
Join us and be part
of the change!


IAEA


small
modular


small
modular
reactors


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SMR 2024 – TOPICAL GROUPS DASHBOARD (as of 20/10/2024)

307 Accepted Papers

44 Technical Sessions

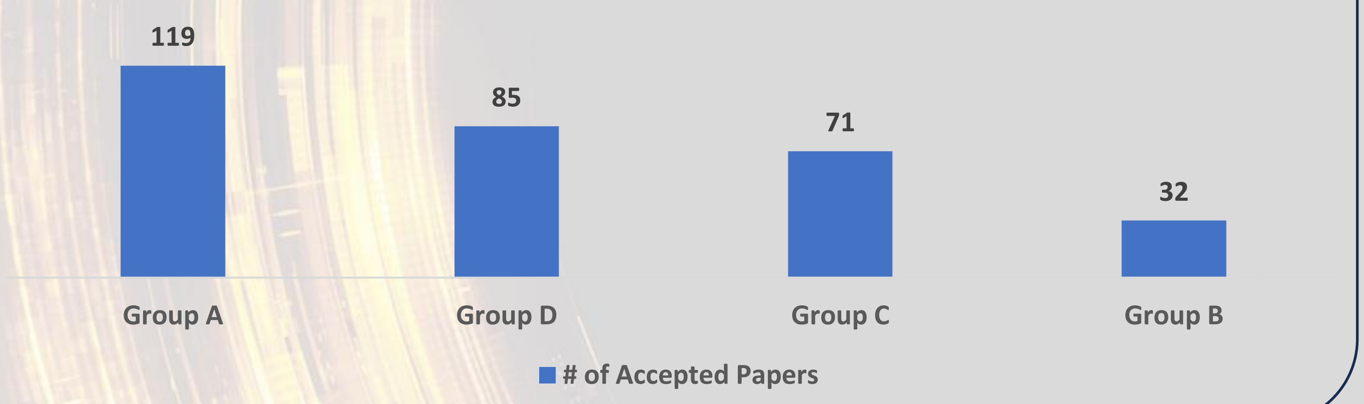
295 Presenters

~ 50 Presenters - Plenary & Side Events

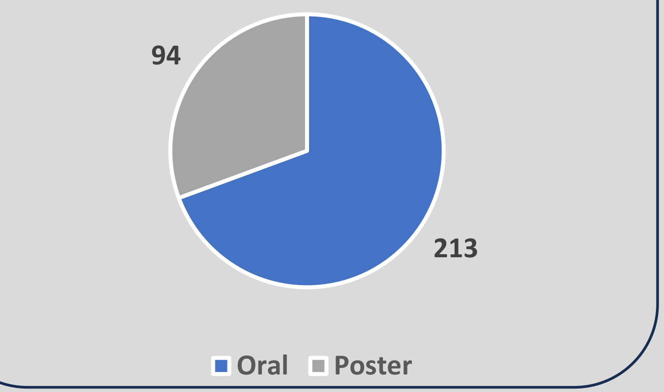
58 Contributing Member States

10 International Organizations

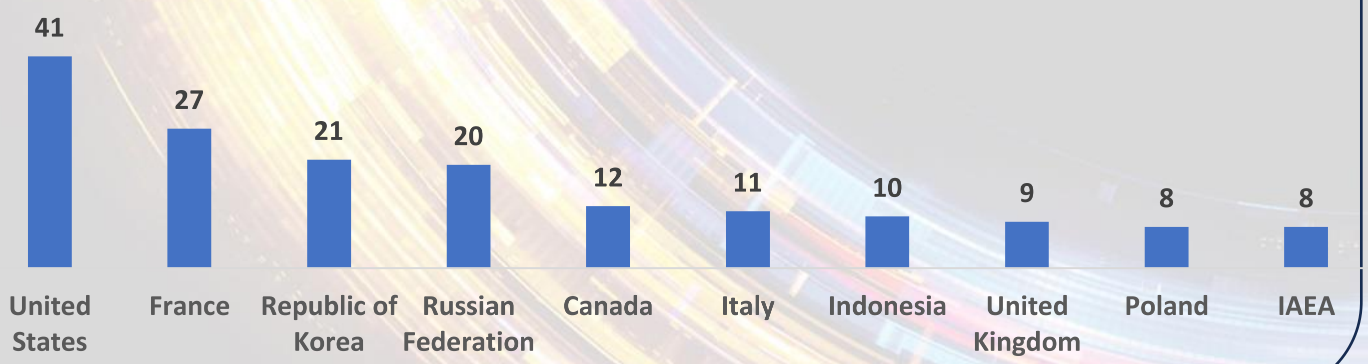
of Accepted Papers for each TG



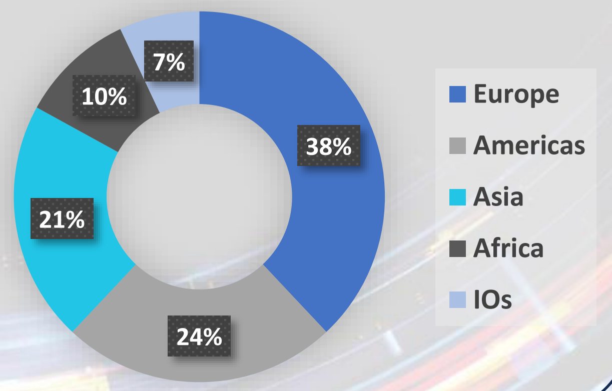
Distribution based on Submission Type



Top 10 Countries and Organizations based on Submissions of Papers



Global Distribution of Accepted Papers



Thank You

f.reitsma@iaea.org