Joint IAEA-ICTP Workshop on Reactor Physics, Thermal-hydraulics and Plant Design Engineering for SMRs, Trieste, Italy, 13 – 17 April 2026

Advances in SMR Design and Technology Development and their Applications

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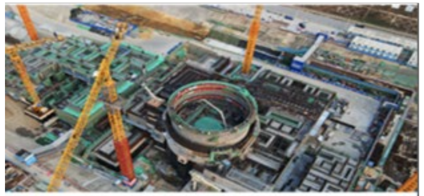
SMR Fundamentals: Advances in Technology Development and Applications

Definition, Rationale for Development

- SMRs: Advanced reactors to generate typically up to 300 MWe, built with modularity in factory setting, transportable as modules to shorten construction schedule thus reduce cost
- Designed for lower capital cost, flexible siting & operation, scalability and non-power applications

Categorization by Technology, Siting & Size

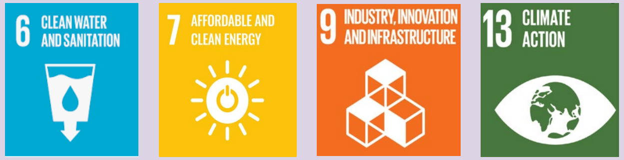
- Water-cooled reactors (land based, stationary)
- Marine-based reactors (WCRs and Non-WCRs)
- High Temperature Gas-cooled Reactors
- Liquid-metal cooled reactors, with fast neutron spectrum
- Molten salt fuelled and cooled reactors
- Microreactors (≤ 10 MWe) of diverse technologies



Advances in Design Development

- ~ 71 designs of major lines technology with active development projects in 20 Member States
- Four (4) units in operation: 2 PWR units (70 MWe) in Floating NPP, 2 HTGR units for 200 MWe) NPP
- Four (4) units under construction. > 50 designs in conceptual, basic and detail design stages

Cogeneration & Non-Electric Applications



- **Higher Efficiency**
- **Less Environmental Impacts**
- **Better Use of Energy**
- **Enhanced Flexibility**

Issues and Prospects of Deployments

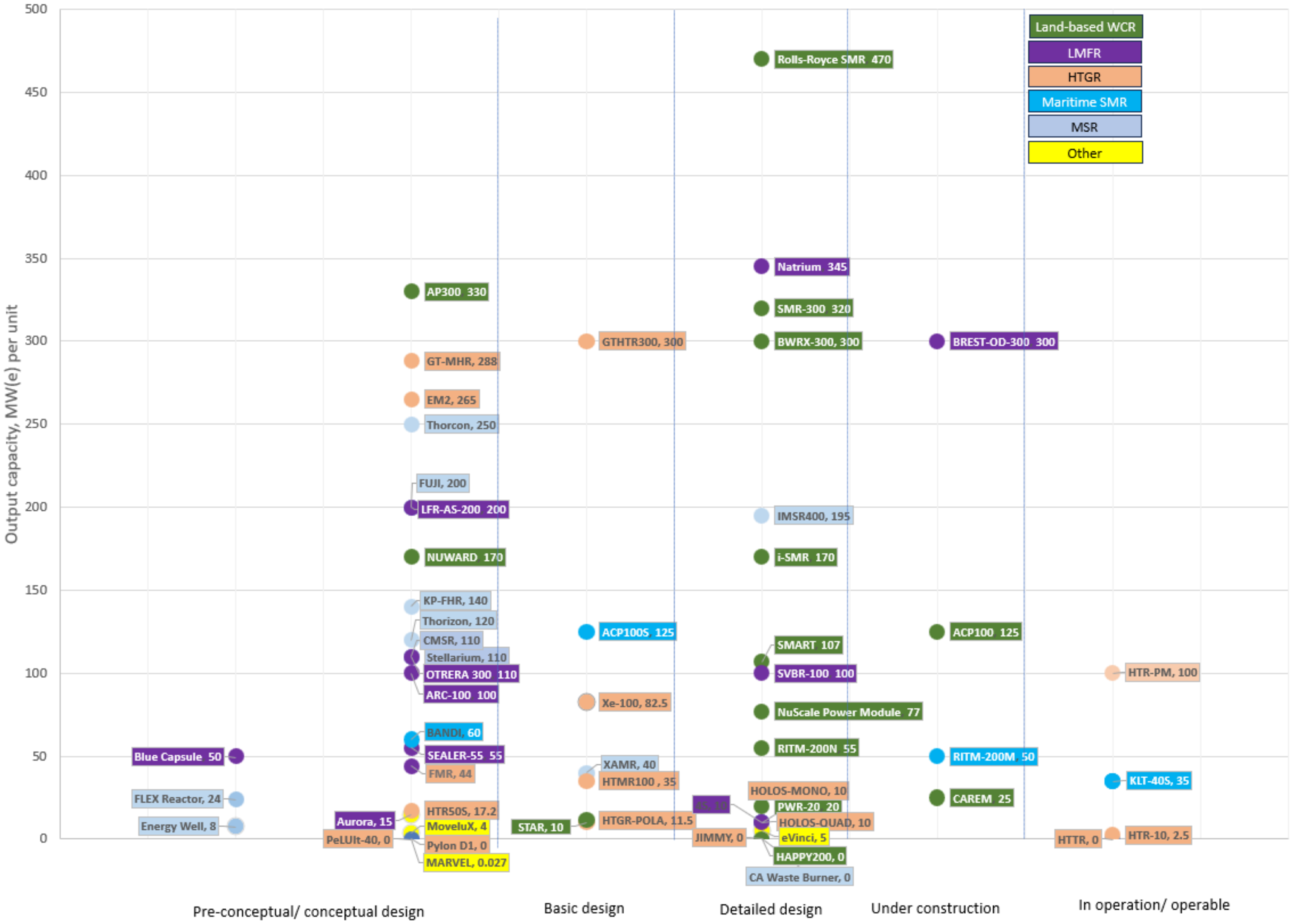
- Demonstration of safety and operational Performance of FOAK, novel designs & technologies, until mid 2030s
- Continuity of Orders, cost competitiveness against alternatives, robust supply chain, and viable financing Option
- Regulatory framework, licensing pathways: global deployment, the need of harmonization and standardization
- Development of nuclear infrastructure for near-term deployment particularly in embarking countries

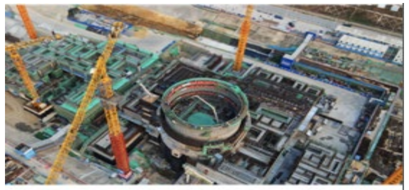
IAEA

IAEA Methodology: Nuclear Reactor Technology Assessment for Near Term Deployment, NE Series No. **NR-T-1.10 (Rev. 1)**

Status of SMR Development and Deployment

Based on updates from technology developers to IAEA in 2024





More than 90 SMR Technology Developers in 18 Member States

CURRENT STATUS – April 2026

Source:
IAEA Power Reactor Information System (**PRIS**), the database of nuclear power reactors,
https://pris.iaea.org/PRIS/home.aspx

CURRENT STATUS

415 NUCLEAR POWER REACTORS IN OPERATION

379 471 MW_e TOTAL NET INSTALLED CAPACITY

23 NUCLEAR POWER REACTORS IN SUSPENDED OPERATION

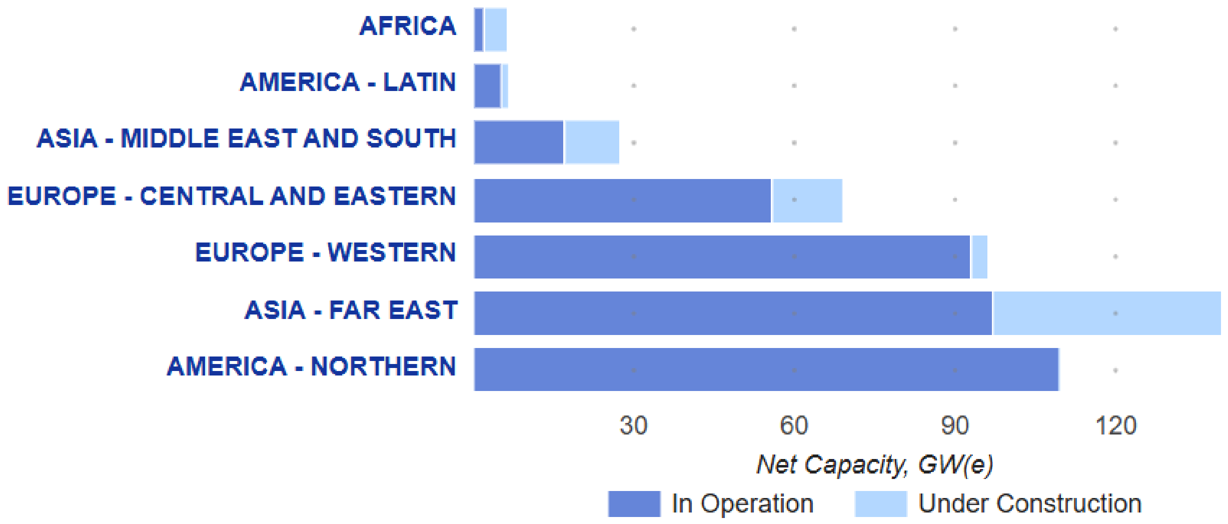
19 687 MW_e TOTAL NET INSTALLED CAPACITY

72 NUCLEAR POWER REACTORS UNDER CONSTRUCTION

75 474 MW_e TOTAL NET INSTALLED CAPACITY

20 648 REACTOR-YEARS OF OPERATION

REGIONAL DISTRIBUTION OF NUCLEAR POWER CAPACITY



The operating reactors, include two (2) SMR NPPs in China and Russian Federation
NPPs under constructions, include four (4) SMR NPPs in Argentina, China, and Russia

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

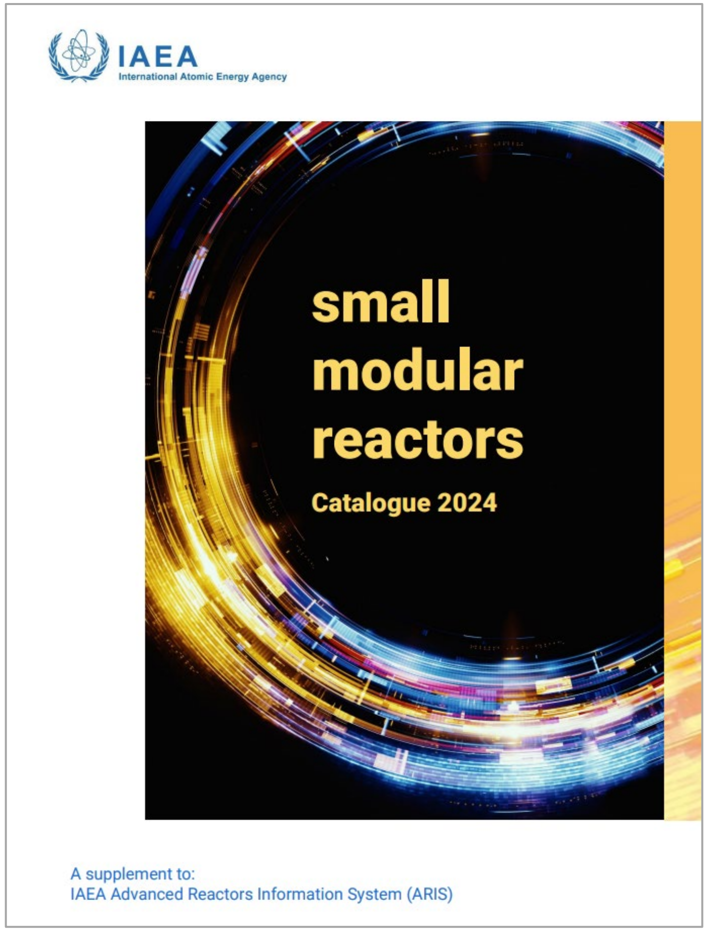
Energy Sustainability

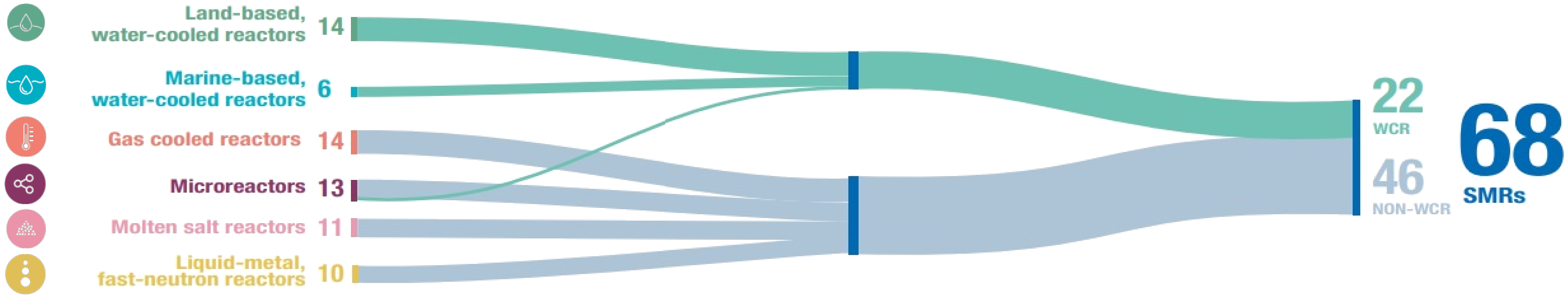
- Cogeneration
- Hydrogen production
- Integration with Renewable to form Hybrid Energy Systems

Small Modular Reactors are advanced reactors that produce typically up to 300 MWe, built in factories and transported as *modules* to sites for installation to shorten construction span thus reduce the cost.

SMR development in 2024 -2026

- **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 developer and is reproduced with permission.
- For the 2024 SMR Catalogue, although over than 100 designs could have been listed, only
  68 active designs with demonstrated sustained development were reported in the catalogue.





Status of development of SMRs (2024 snapshot)

Near-term and mid-term deployment (March 2026)

(year : connection to the grid)

In operation

KLT-40S (2020)

HTR-PM (2022)

Under construction

CAREM (20??)

Natrium (2031)

Aurora (2028)

BWRX-300 (2030)

RITM-200N (2028)

BREST-OD300 (2028)

ACP-100 (2026)

Towards construction

Xe-100
Construction permit pending
Dow to take FID in 2028

e-Vinci
Test reactor could be built in 2026
Commercialization in 2029

Post 2030 construction

Rolls-Royce SMR

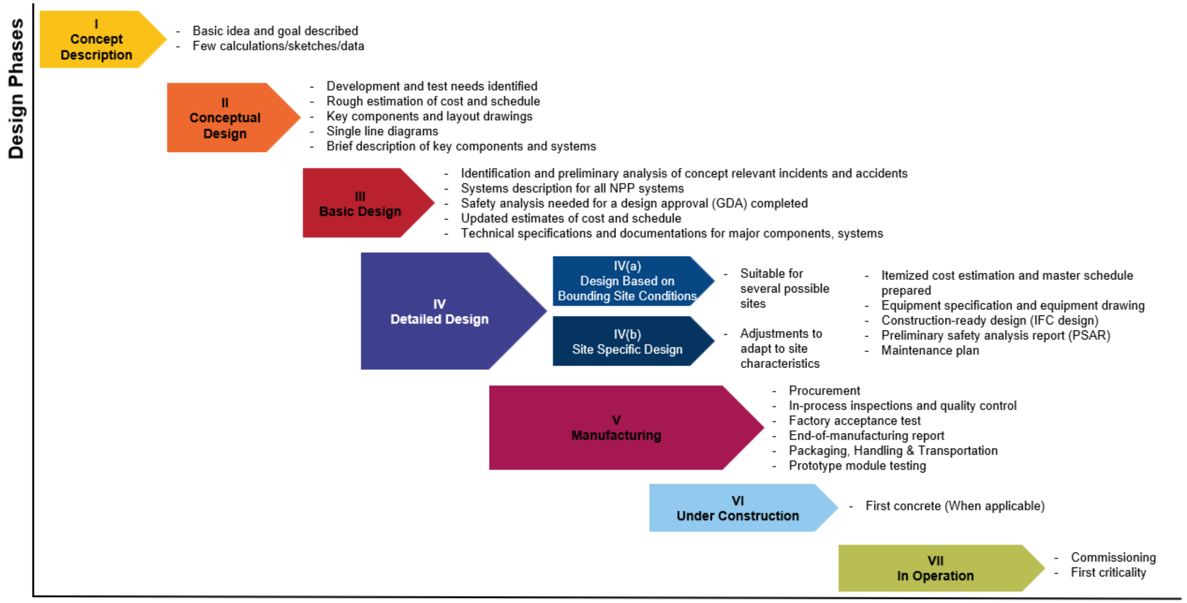
i-SMR

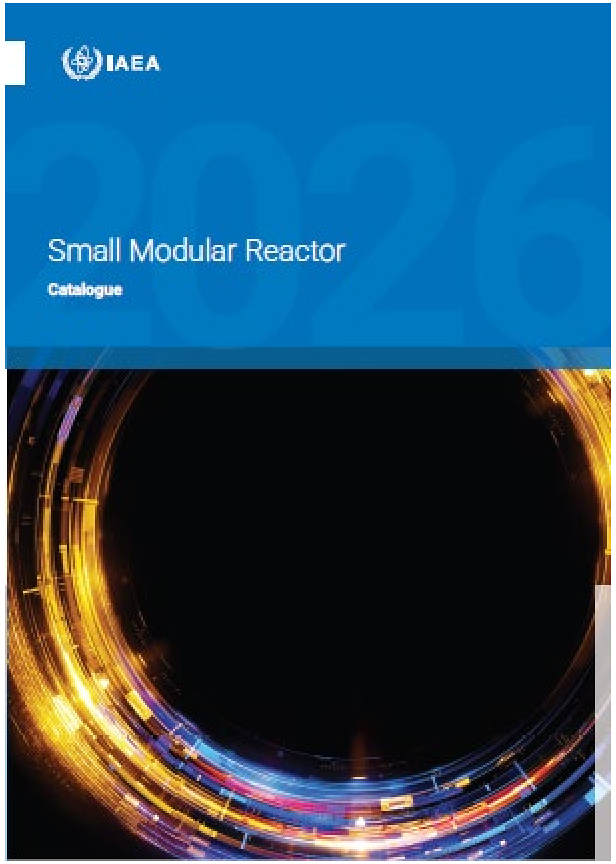
NUWARD

VOYGR

SMR development is still booming in 2026

- **The SMR catalogue is being updated in 2026**
- Difficult to assess which designs are active (not the IAEA's role to discriminate)
- But many more designs appear, while other seem to stall. The 2026 catalogue will list them all and clearly indicate:
  - Their stage of design, based on objective criteria
  - Whether design information has evolved since the 2024 catalogue
- More than a hundred designs are anticipated.





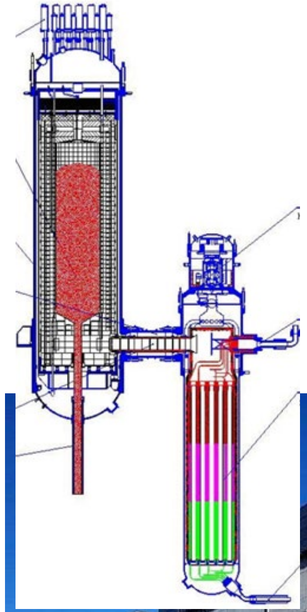
Examples of SMRs for Near Term Deployment

HTR-PM, China

INET, Tsinghua University

CHINA HUANENG

Status:
In operation since December 2022



Reactor Type	Modular HTGR
Primary Circulation	Forced, Pumps
Coolant/Moderator	Helium/Graphite
Thermal/Electric Power	2 x 250 MW_{th} / 210 MW_e
Design Life	40 yrs.
Reactivity Control	
Core Inlet/Outlet Temperature	250 °C/750 °C
NSSS Operating Pressure Primary/Secondary	7 MPa/13.25 MPa
Refuelling Cycle	Online Refuelling
Fuel Enrichment	< 8.5 %
Core Discharge Burnup	90 GWD/tonnes
Fuel Type / Assembly Array	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)

ACP100, China

A design by
NPIC, CNNC

中核集团 CNNC

Status:
Under construction in China for grid connection in 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

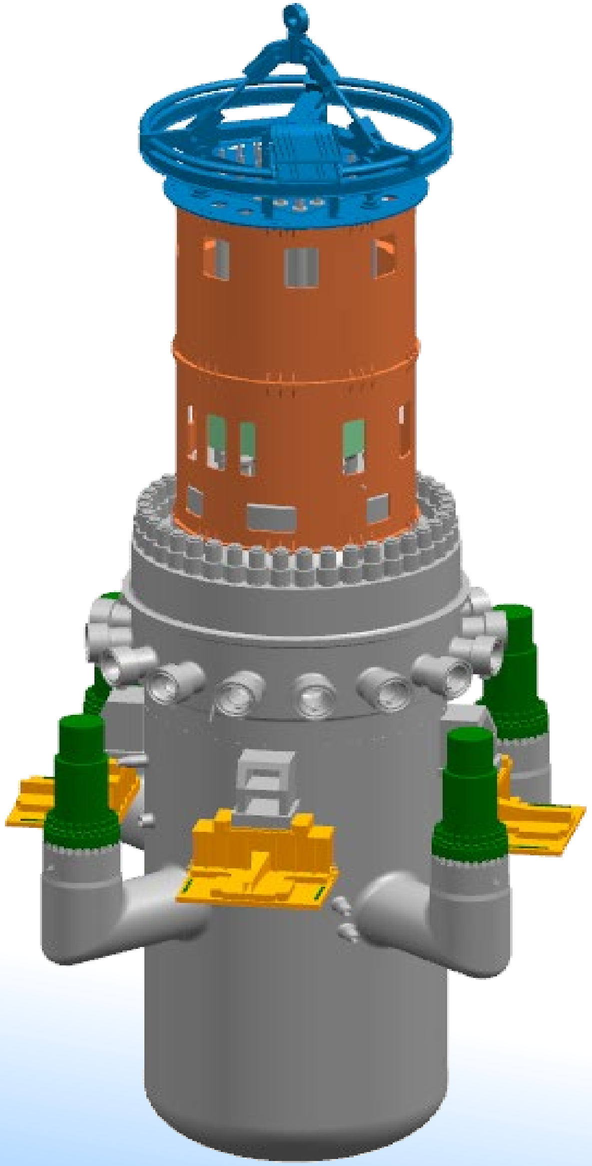
Unique Features	Integrated Reactor with tube-in-tube once through steam generator, and underground nuclear island
Target Application	The ACP100 is a multipurpose power reactor designed for electricity production, district heating, steam production or seawater desalination and is suitable for remote areas 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

Brief Design Description and Key Parameters

MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	CNNC (NPIC), China
Reactor type	Integral PWR
Coolant/moderator	Light water / light water
Thermal/electrical capacity, MW(t)/MW(e)	385 / 125
Primary circulation	Forced circulation
NSSS operating pressure (primary/secondary), MPa	15 / 4.6
Core inlet/outlet coolant temperature (°C)	286.5 / 319.5
Fuel type/assembly array	UO_2 / 17 × 17 square pitch
Number of fuel assemblies in the core	57
Fuel enrichment (%)	< 4.95
Refuelling cycle (months)	24
Core discharge burnup (GWd/ton)	< 52
Reactivity control mechanism	Control rod drive mechanism (CRDM), Gd_2O_3 solid burnable poison and soluble boron acid
Approach to safety systems	Passive
Design life (years)	60

Plant footprint (m^2)	200 000
RPV height/diameter (m)	10 / 3.35
RPV weight (metric ton)	300
Seismic design (SSE)	0.3 g
Fuel cycle requirements/approach	Temporarily stored in spent fuel pools
Distinguishing features	Integrated reactor with tube-in-tube once through steam generator, nuclear island underground
Design status	Construction in progress

Brief Design Description and Key Parameters



Fuel enrichment	*(4.45 - 4.95)%*
Control Rod Drive Mechanism	*Magnetic lifting*
Control rod number	*20*
Reactivity control method	*Control rods, solid burnable poison and soluble boron*
Steam generator type	*Once Through Steam Generator (OTSG)*
Steam generator number	*16*
Main steam temperature	*>290 ℃*
Main steam pressure	*4.5 MPaA*
Main pump type	*canned pump*
Main pump number	*4*
Predicted Core Damage Frequency (CDF)	*<1E-5 per reactor year*
Predicted Large Release Frequency (LRF)	*<1E-6 per reactor year*

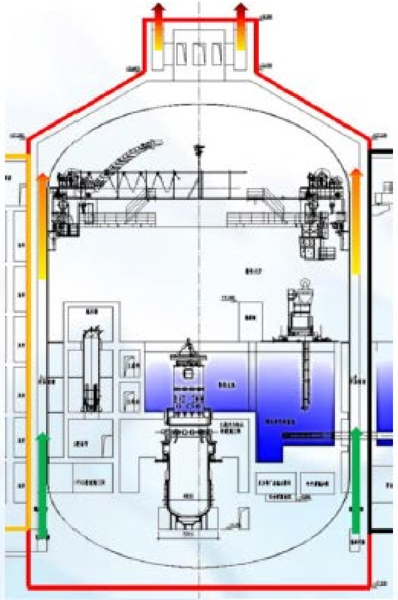
Brief Design Description and Key Parameters

中国核电工程有限公司
China Nuclear Power Engineering Co.,LTD.
中核集团 CNNC

Key features of ACP100

Integrated Design
- Main pump and RPV connected by short pipe
- Steam generator sets in pressure vessel
- Integrated head package

Passive Safety Feature System
- Passive core cooling system
- Passive residual heat removal system
- Automatic pressure release system
- Passive main control room HVAC System
- ***Passive Containment Air cooling System***



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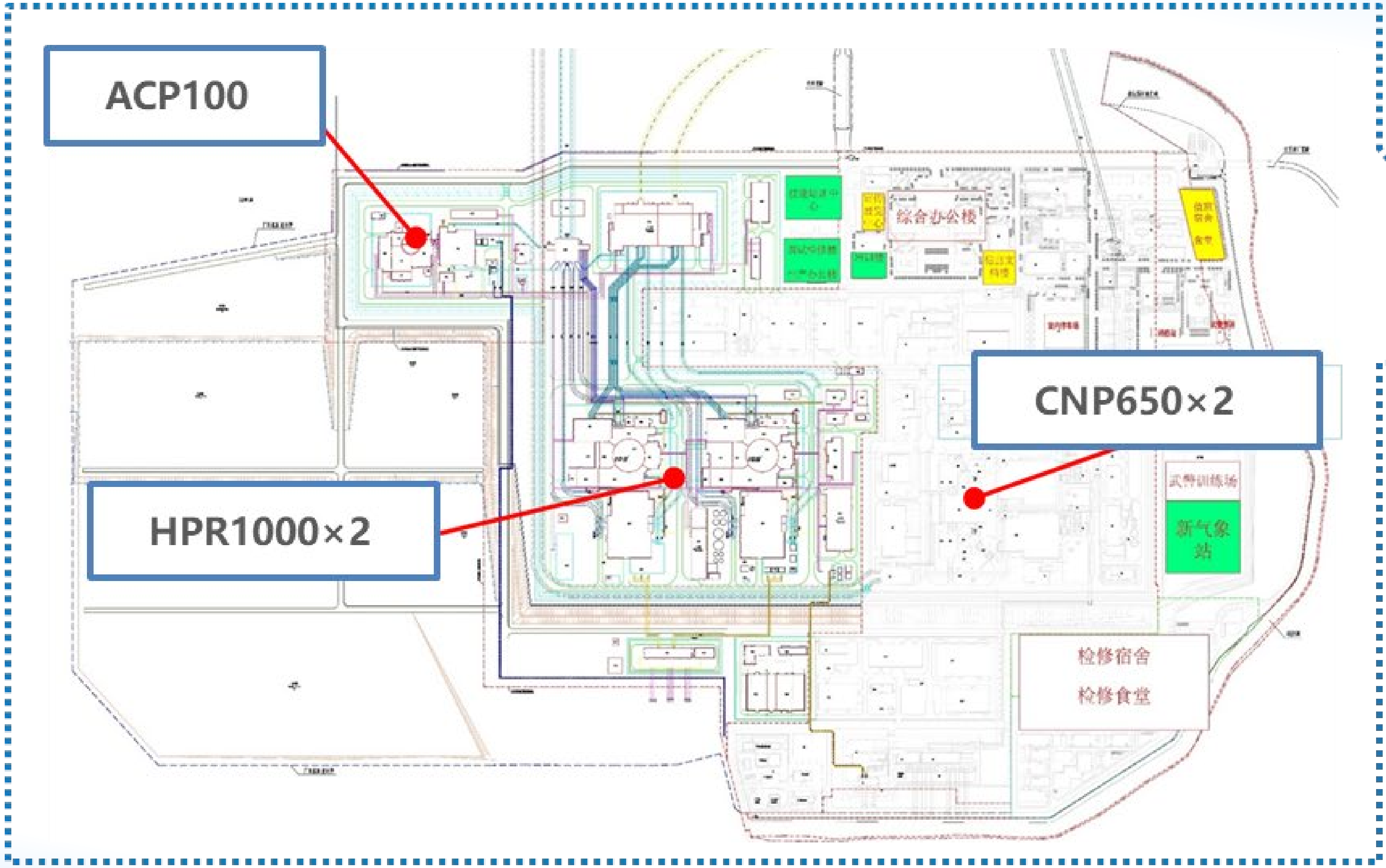
CNNC China National Nuclear Corporation

Siting, Environment and Construction



Siting and Construction

ACP100 Demonstration Power Plant when completed in 2026

Siting and Construction

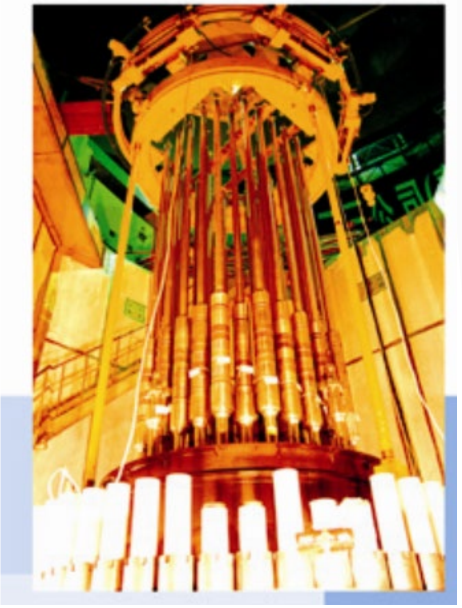
Water consumption of ACP100

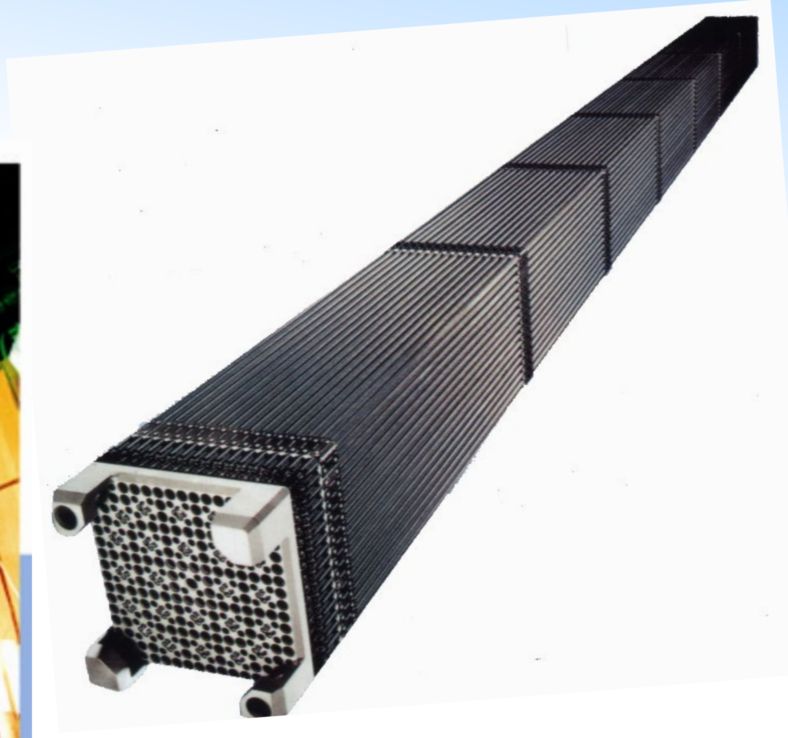
- ACP100 is designed for sites with restricted access to water;
- Air cooling tower [dry] is used for the Circulating Water System
- Mechanical draft [wet] cooling tower is used for the Service Water System
- The water consumption of ACP100 for normal operation is shown in the table below:

Type of site	*Water-deficient site(m^3/d)*	*Coastal site(m^3/d)*
Water consumption for normal operation	*2360*	*794952 (sea water)* *980 (fresh water)*

Fuel Cycle

- ACP100 uses **CF2** shortened fuel assemblies with 17×17 square pitch developed by CNNC
- Height of fuel assembly: 2150 mm
- Number of fuel assemblies: 57
- ACP100 use magnetic lifting type Control Rod Drive Mechanism developed by CNNC

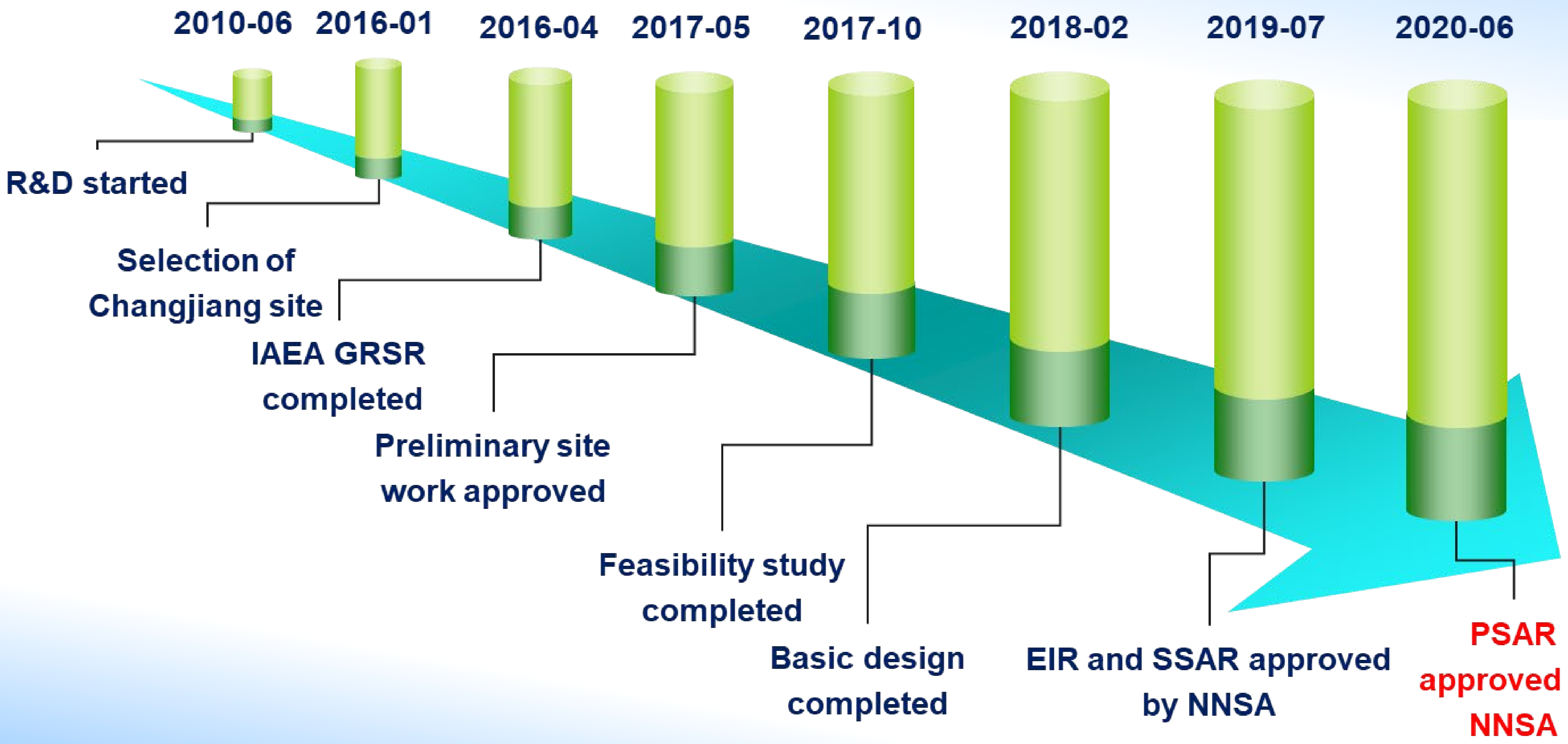




Fuel Cycle Approach, waste management and disposal plan

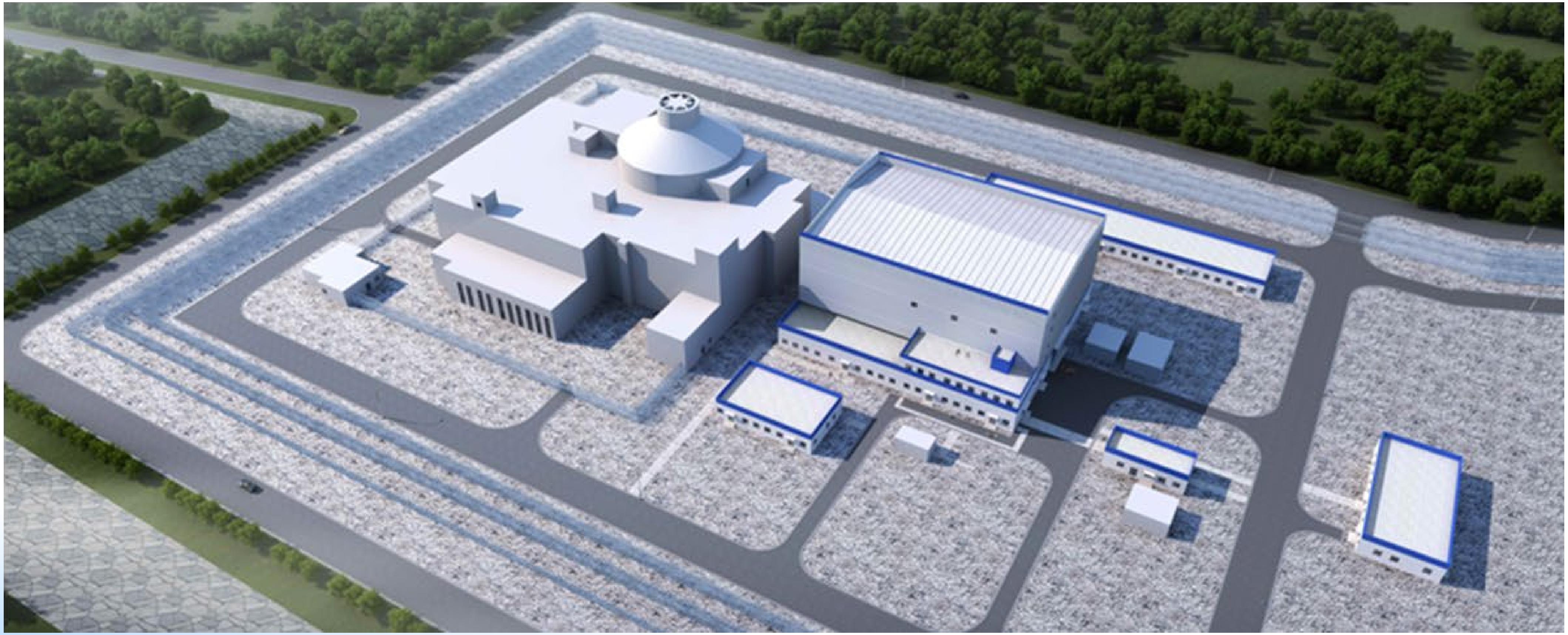
- Open fuel cycle with 24-month refuelling cycle
- Spent fuel processing is similar to conventional NPPs.
- Spent fuels will be temporarily stored in spent fuel pools.
- Waste management approach and disposal plan are also similar to NPPs

Roadmap of ACP100 development



Roadmap of ACP100 deployment

2021.07.13	2022.11	2023.07.	2024.06	2025.04	2025.12	2026.03	2026.05
FCD	FCD+16	1st batch operators in position: FCD+24	Backup PS back energizing: FCD+35	Start of cold test: FCD+45	First fueling: FCD+53	1st grid SYNCH: FCD+56	Temp. accept. FCD+58



BWRX-300

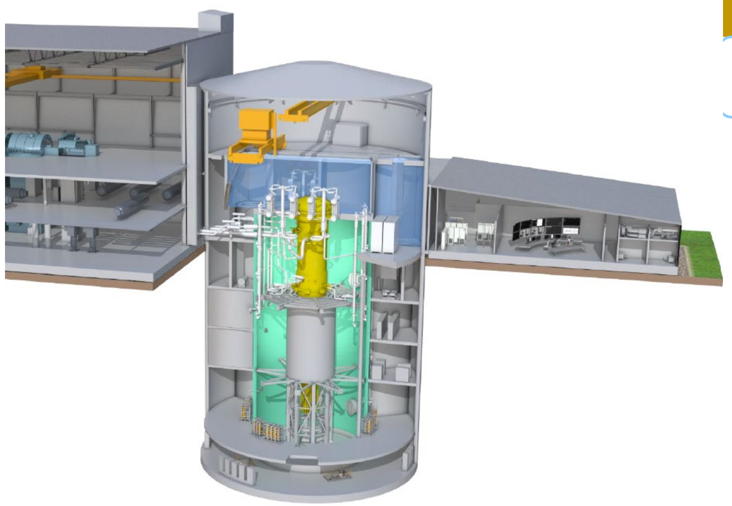
GE-Hitachi Nuclear Energy

HITACHI

Status:
Detailed design with licence permit for construction for 4 units in Darlington site, Ontario, Canada for operation by Ontario Power Generation (OPG)

Site preparation in Darlington site has started with target FCE in a year.

Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Boiling Water Reactor	Natural circulation, gravity driven	Light Water/Light Water	870 MW_{th} / 300 MW_e
Design Life	**Reactivity Control**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
60 yrs.	Control rod drive	270°C/288°C	7.171 MPa (primary side)
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
12 - 24 months	< 4.95 %	~ 55 GWD/tonnes	UO_2 / Square lattice



Unique Features	Simplified BWR design, natural circulation, passive safety features, cost-competitive with natural gas plants
Target Application	Base load electricity generation, load following electrical generation, hydrogen production, synthetic fuel production, district heating and other process heat
Design Philosophy	The BWRX-300 utilizes natural circulation and passive safety systems. It leverages the U.S. NRC-licensed ESBWR design and aims to minimize construction, operation, maintenance, and decommissioning costs.

RITM-200M

A design by OKBM-Afrikantov

Status: Developed for the Optimized Floating Power Unit (OFPU). The OFPU is a compact non-self-propelled vessel having two RITM-200M reactor plants. 6 prototypes were manufactured and installed on icebreakers. 2 reactors are in testing. The OFPU is being developed for commissioning in 2028

Reactor Type	Primary Circulation	Coolant/Moderator	Thermal/Electric Power
Integral PWR	Forced	Water/Water	198 MW_{th} / 50 MW_e
Design Life	**Primary Circulation**	**Core Inlet/Outlet Temperature**	**NSSS Operating Pressure Primary/Secondary**
60 yrs.	Pumps	284°C/321°C	15.7 MPa/3.83 MPa
Refuelling Cycle	**Fuel Enrichment**	**Core Discharge Burnup**	**Fuel Type / Assembly Array**
Up to 120 months	< 20 %	---	UO2 (cermet fuel) pellets / hexagonal

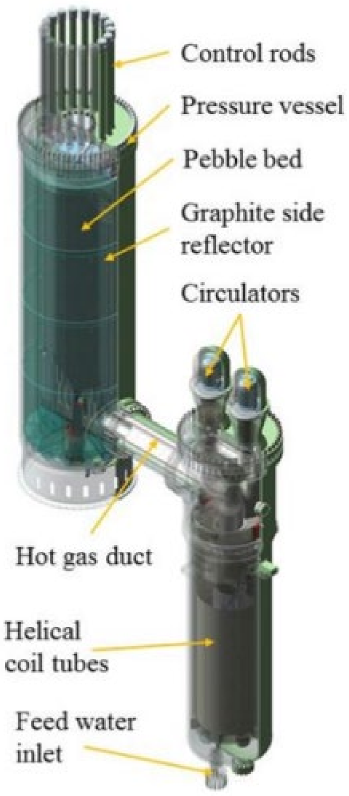
Unique Features	Integral reactor, in-vessel corium retention, double containment
Target Application	The FPUs based on RITM-200M may satisfy the needs of small residentials or industrial facilities. The OFPU can provide electricity to domestic and industrial consumers. Can be also used for water desalination and heat supply.
Design Philosophy	RITM series reactors are the evolutionary development of the reactors (OK-150, OK-900, KLT-40 series) for Russian nuclear icebreakers with a total operating experience of more than 60 years (more than 400 reactor-years).

Xe-100

X Energy

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.

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.

Roadmap of VOYGR deployment

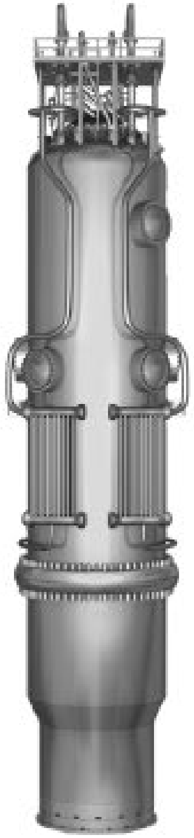
IAEA

6-module VOYGR-6 plant

462 MWe (gross)

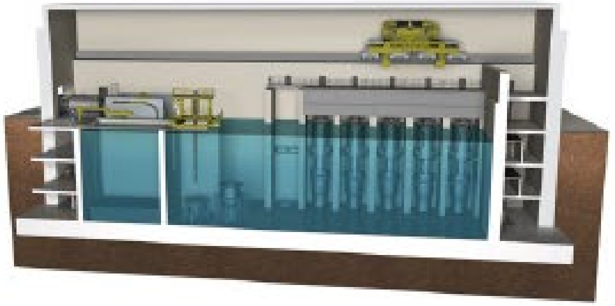
4-module VOYGR-4 plant

308 MWe (gross)



NuScale Power Module™
77 MWe (gross)

12-module VOYGR-12 plant

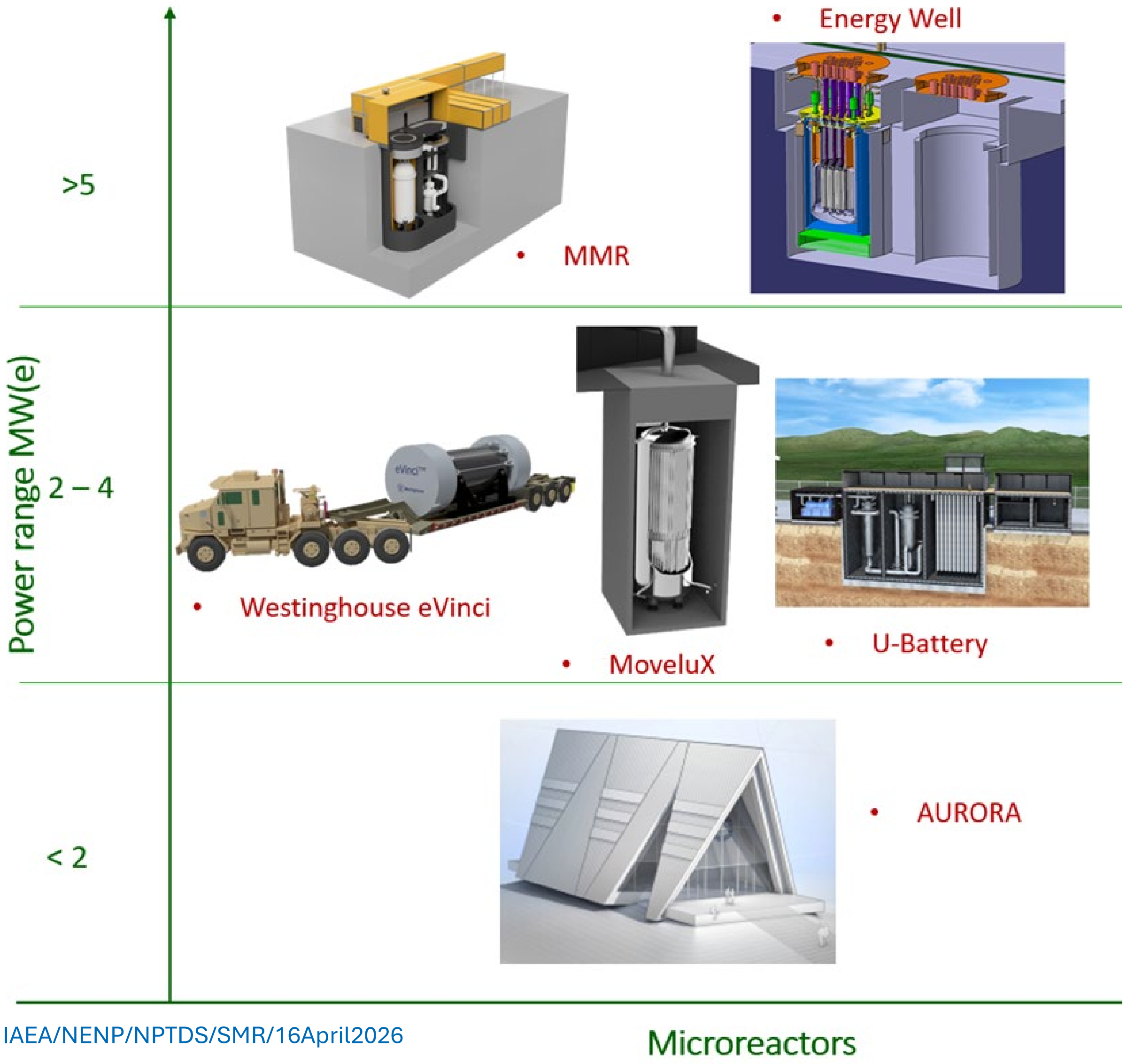


924 MWe (gross)

- Flexibility in size and cost advantages, with the same operational flexibility and unparalleled safety case.
- Each module feeds one turbine generator train, eliminating single-shaft risk.
- Demonstrated resiliency for every configuration (black-start, island-mode, seismically robust, cyber secure, etc.)

NUSCALE
Power for all humankind

Emerging: Microreactors



- 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 Southeast Asian archipelagos.

Specificities of Microreactors

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

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

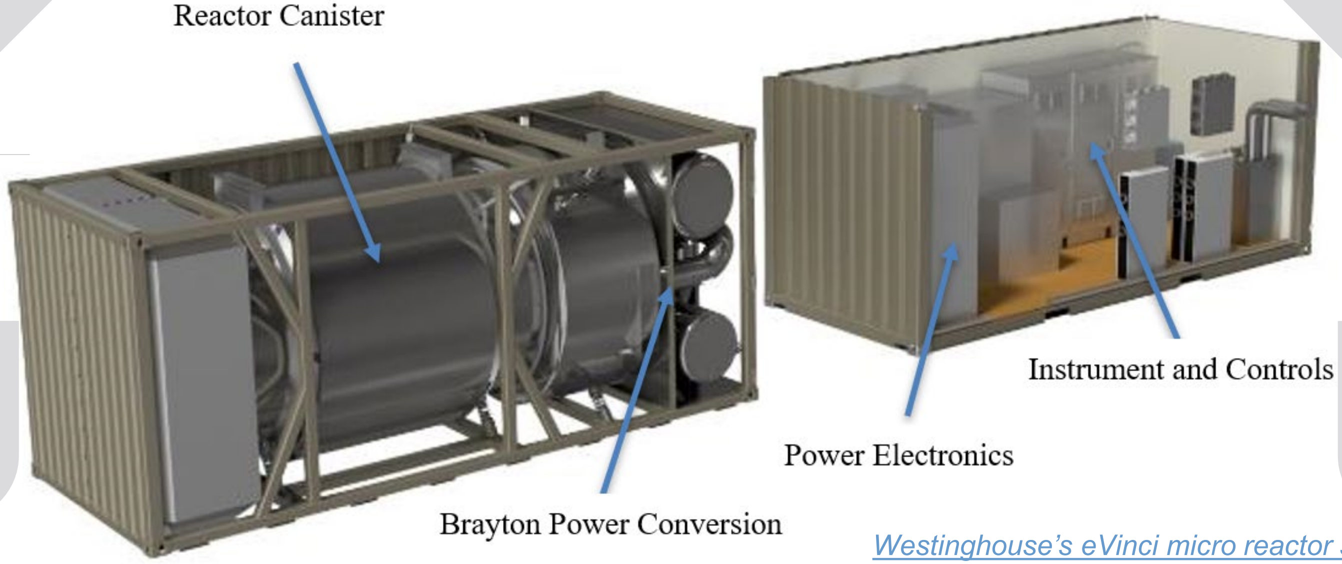
03 **Transportability**
Within standard shipping containers

04 **Heat-pipe technology**
proven by LANL for space application

05 **Compact and simplified**

06 **Manufactured and fueled in a factory**

07 **Packageable**
in standard transport containers



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

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

THANK YOU