33rd International Meeting on Reactor Noise

Advanced Reactors: Navigating the Noise Towards Deployment Reality

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Menu of the day

What is Innovative reactor technology?

Expansion expectations: Navigating the Noise

Main challenges to Nuclear deployment

Opportunities and Challenges for Advanced Small Modular Reactors (SMRs)

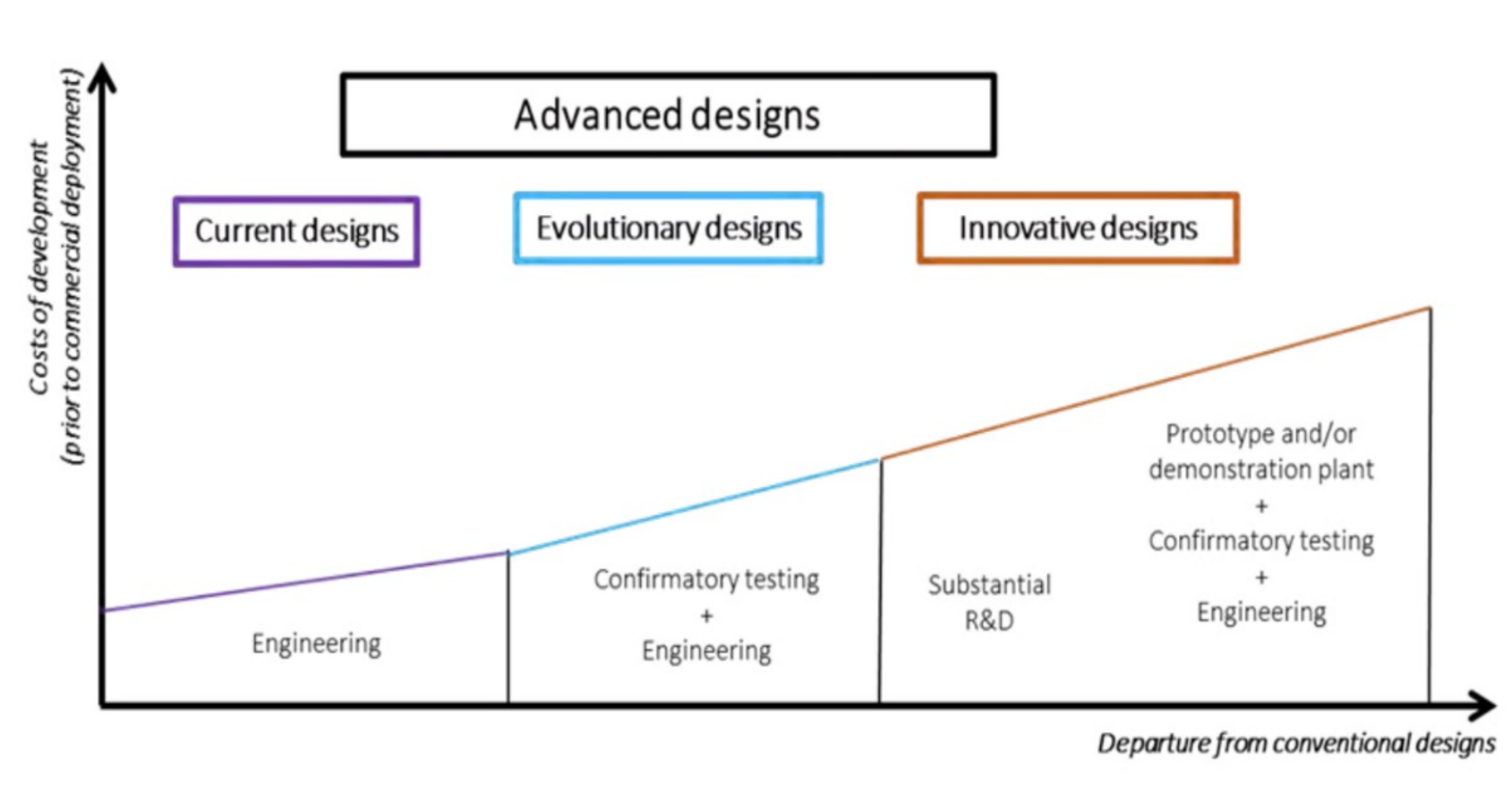
Back to Noise Analysis – Some thoughts

Advanced Reactors: Evolutionary and Innovative

What is Innovative reactor technology?

- **Evolutionary Designs** - an advanced design that achieves improvements over current designs through small 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

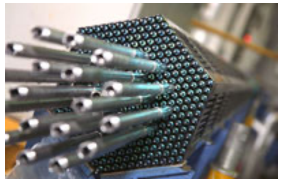


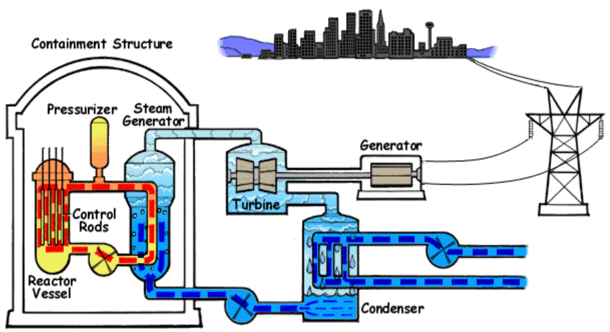
(As defined in IAEA "Terms for Describing Advanced Nuclear Power Plants" NR-T-1.19)

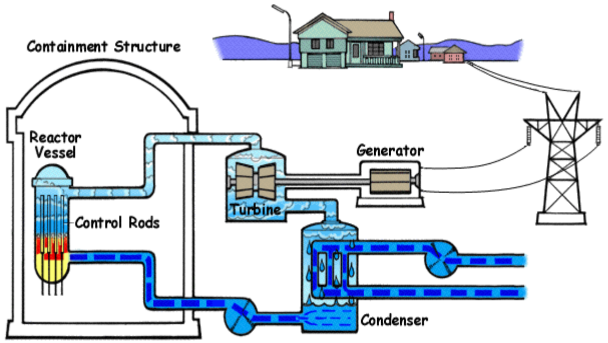
Commercial Reactors (Gen-II and III)

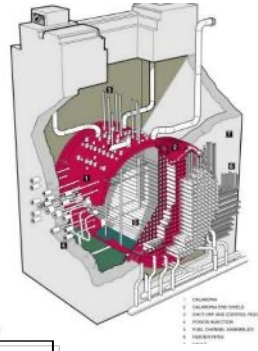
Most Common Technologies

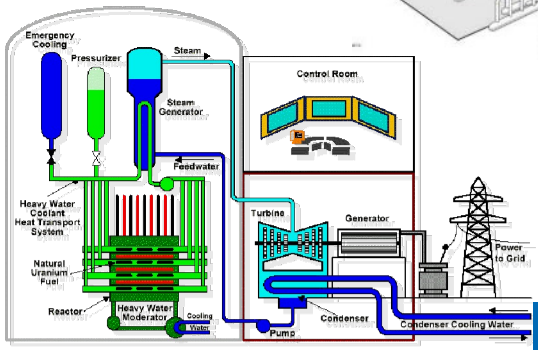
	PWR	BWR	PHWR
- **Moderator & coolant** - **Fuel** - **Operating Pressure** - **Characteristics**	- Light water - Enriched Uranium - ~15MPa (~6-7MPa steam) - Most common NPP technology	- Light water - Enriched Uranium - ~7MPa - Direct cycle: steam from drives from the reactor to the turbines	- Heavy water - Natural Uranium - ~10MPa - Pressure-tube design: pressure tubes within the calandria
- **Examples**	- Westinghouse and Combustion Engineering (USA) - Framatome (AREVA/EDF) (France) - KONVOI (Germany) - VVERs (Russia)	- General Electric BWRs (USA) - ABB Atom BWRs (Sweden) - Toshiba Hitachi BWRs (Japan)	- Bruce, Pickering, CANDU-6 (Canada) - Indian PHWR-220 & 540 MWe (India) - Atucha (Germany/Argentina)







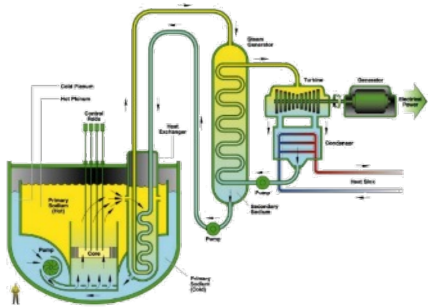




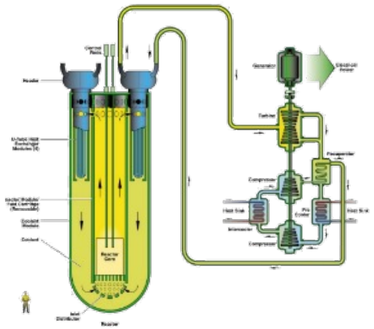
IAEA and GIF Terminology: Innovative Gen-IV Reactors

- **Early Prototypes and Demonstration Plants Gen-I**
- **Current Fleet Gen-II/III**
- **Advanced Nuclear Reactors**
  - *Evolutionary designs*
    Gen-III and Gen-III+
  - *Innovative designs*
    Gen-IV
  - SMRs can be either *evolutionary* or *innovative*
  - *Innovative SMR*
    Advanced Modular Reactor (AMR)

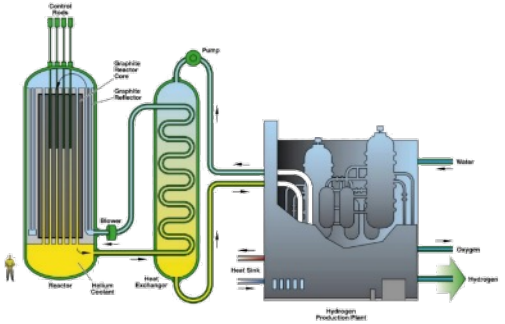
Sodium cooled Fast Reactor (SFR)

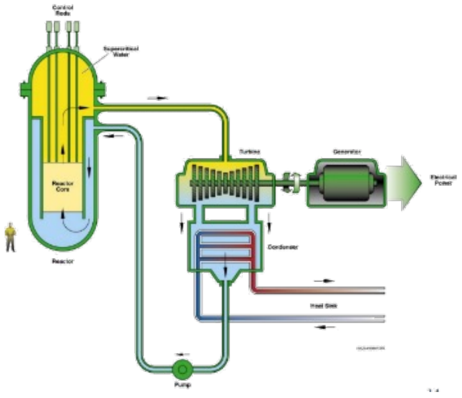


Lead cooled Fast Reactor (LFR)

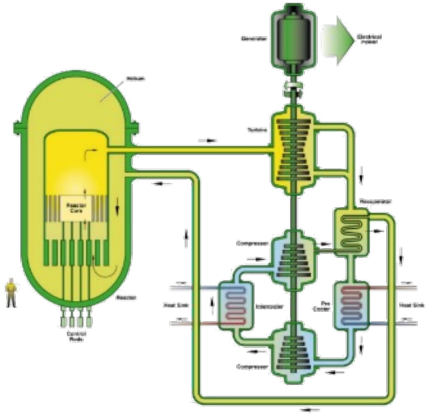


Very-High-Temperature Reactor (VHTR)

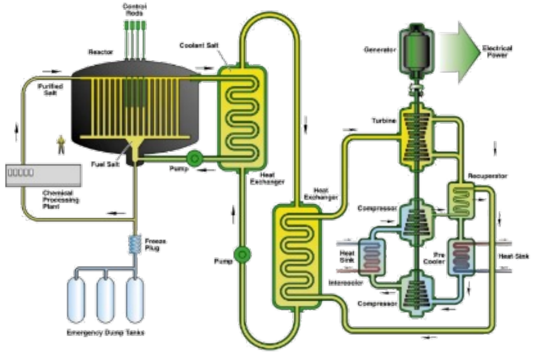




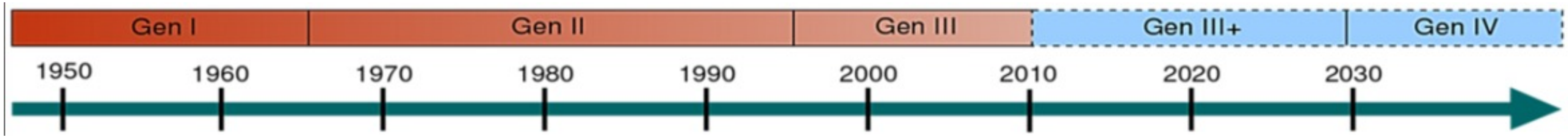
Supercritical Water cooled Reactor (SCWR)



Gas cooled Fast Reactor (GFR)



Molten Salt Reactor (MSR)



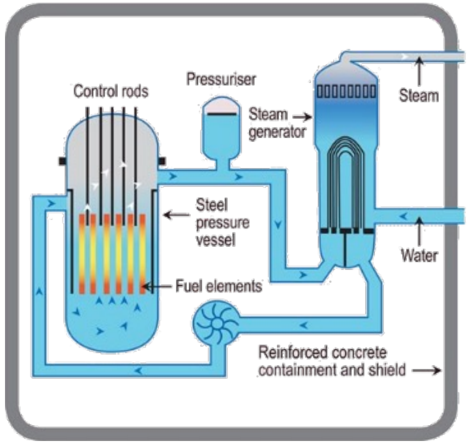
Key Commercial Designs Available Today GEN III +

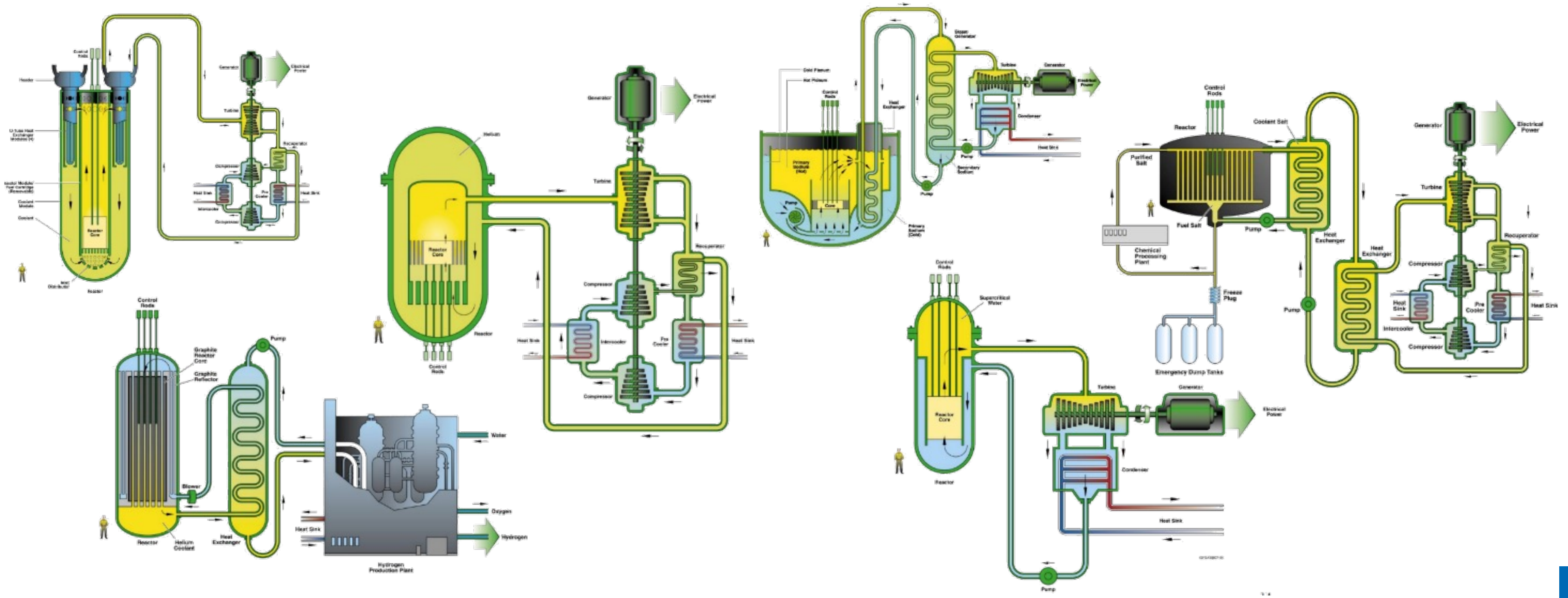
Large Light-water cooled reactors

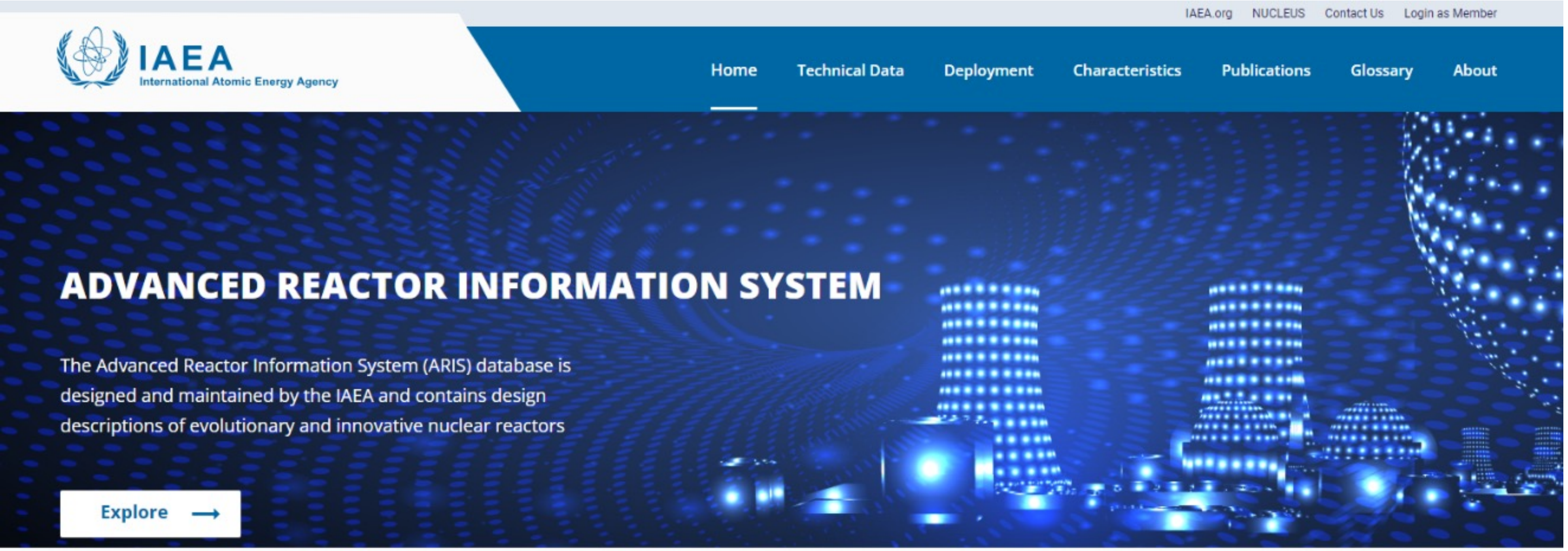
Countries	Design / Technology	Rated Power (gross)	Companies, Vendors	User Countries
China	**HPR1000**	1180 MW(e)	**CNNC, CGN**	China, Pakistan
	CAP1000	1224 MW(e)	**SNERDI**	China
France	**EPR**	1660 MW(e)	**EDF**	France, China, Finland, and United Kingdom
	EPR2	1200 MW(e)	**EDF**	France
Japan	**ABWR**	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

Comparing Innovative Reactor Concepts

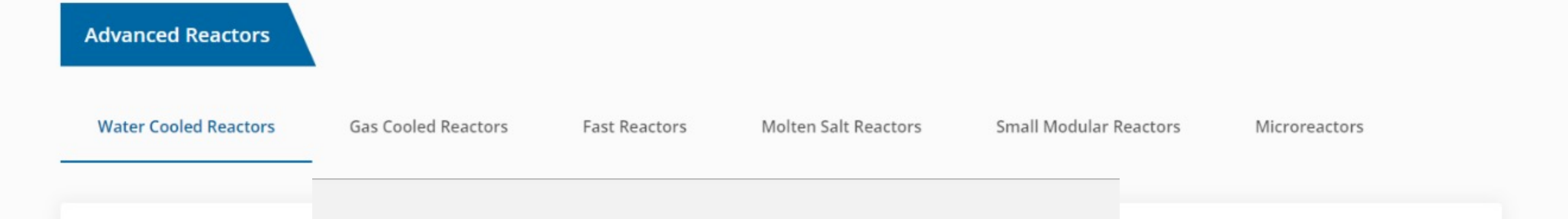
	WCR	SCWR	HTGR	GFR	SFR	LFR	MSR
coolant	H_2O	H_2O	He	He	Na	Pb/LBE	Fluoride/Chloride
outlet T, C	288-329	**500**	750	750	550	500	**800**
efficiency, %	35	**45**	**50**	**50**	**45**	**43**	**48**
max P, MPa	17	25	7	7	~0.2	~0.5	~0.2
spectrum	thermal	thermal/**fast**	thermal	fast	fast	fast	thermal/fast

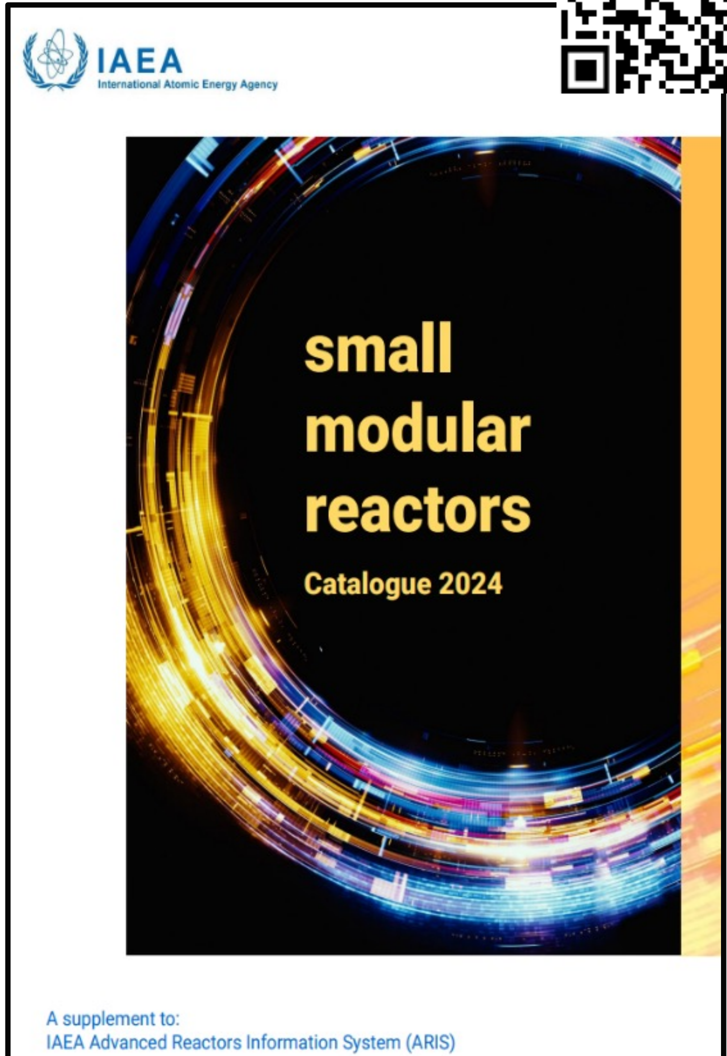






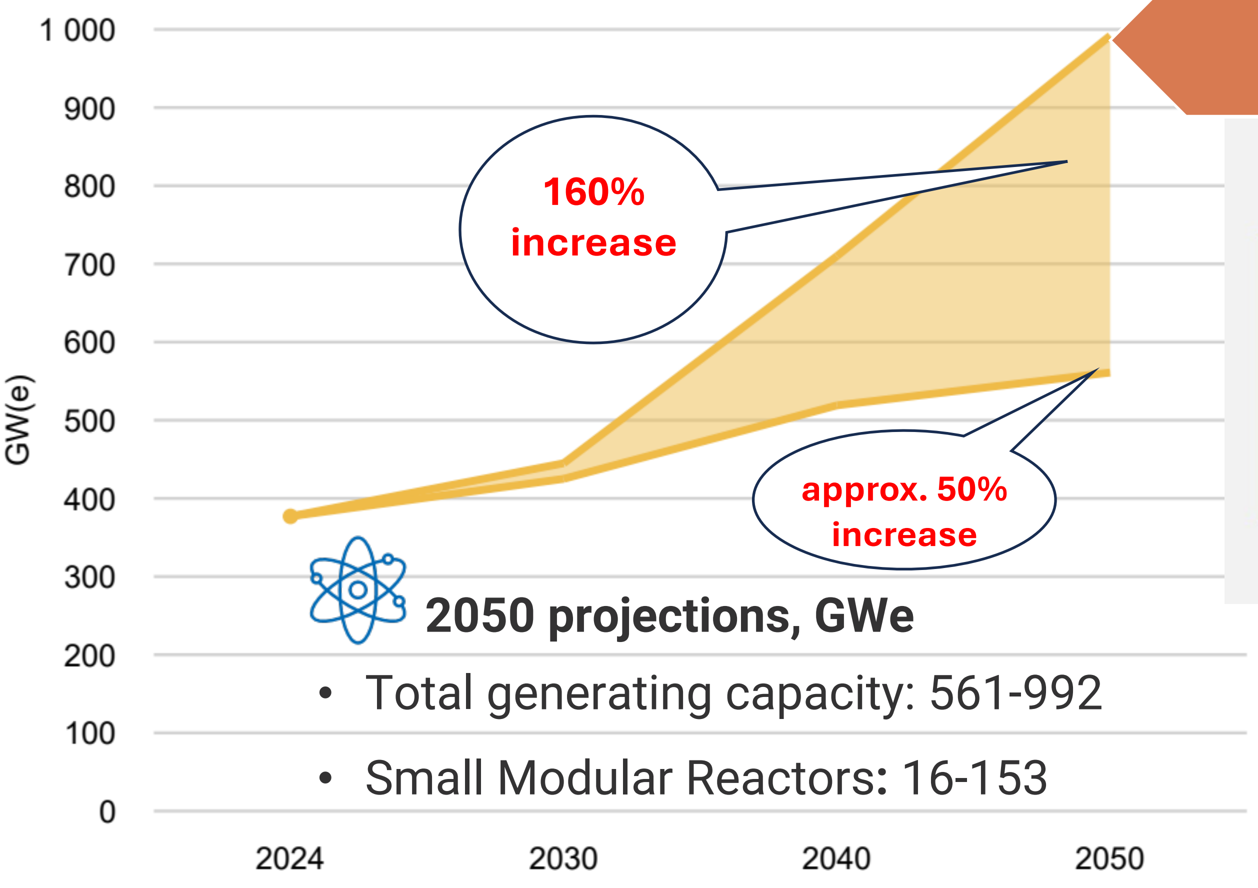
Currently 126 designs, including SMRs and microreactors





World Nuclear Electrical Generating Capacity

Expectations for nuclear expansion



2050 projections, GWe

- Total generating capacity: 561-992
- Small Modular Reactors: 16-153

IAEA Energy, Electricity and Nuclear Power Estimates for the Period up to 2050, RDS-1 2025 Edition

Navigating the Noise

Nuclear Power Projections

Depending on the level of global electrification, the share of nuclear power could represent

up to 12.7%

of the electricity mix, up from 8.7% today

In the low case, the installed nuclear capacity by 2050 would slowly increase to

561 GW

but the share of nuclear electricity could drop to 7.2%

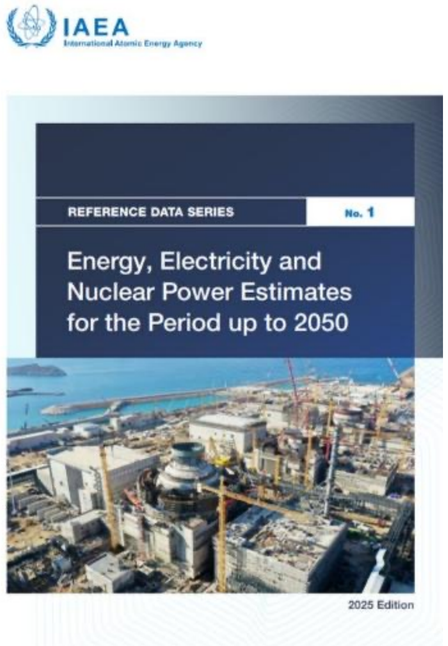


TABLE 3. WORLD TOTAL AND NUCLEAR ELECTRICAL GENERATING CAPACITY, GW(e)

Electrical Capacity	2024	2030		2040		2050	
		Low	High	Low	High	Low	High
Total	9 581	11 215	11 215	14 727	14 727	21 140	21 140
Nuclear	377	425	445	519	710	561	992
Nuclear as % of Electrical Capacity	*3.9%*	*3.8%*	*4.0%*	*3.5%*	*4.8%*	*2.7%*	*4.7%*

Countries Interested in Nuclear Power Energy

Expressed interest 23

Decision making phase 28

Post-decision-making phase including 3 countries which are under construction 14

Progress with Advanced Reactor Deployment – In the News

India has a nuclear reactor that can make more fuel than it burns. Science explained

India's Prototype Fast Breeder Reactor at Kalpakkam has attained a historic milestone. The 500 MWe reactor, which produces more fuel than it consumes, puts India on course to harness its vast thorium reserves.

Date: 6 April 2026 : 500 MWe pool type sodium-cooled fast breeder reactor (FBR) using MOX fuel

Why it matters

- Marks **India's formal entry into Stage II** of the **three-stage nuclear programme**.
- Enables large-scale **plutonium breeding** and future **thorium utilisation (Stage III)**.
- One of **very few commercial-scale fast reactors worldwide**.

Critical moment: The 500 MW prototype fast-breeder reactor is located at Kalpakkam, about 70 km south of Chennai. (Courtesy: Department of Atomic Energy)

physicsworld

https://physicsworld.com/wp-content/uploads/2026/04/pfbr-15-04-2026.jpg

Progress with Advanced Reactor Deployment – In the News

The First Advanced Nuclear Reactor in U.S. History Just Got Approved—and Bill Gates Is Behind It The Microsoft co-founder is betting next-generation nuclear reactors can power the AI boom while cutting carbon emissions.

Inc.

Date: 4 March 2026 : 345 MWe sodium-cooled fast reactor + molten-salt energy storage

Why it matters

- First NRC construction permit ever issued for a commercial advanced (non-LWR) reactor. - Regulatory breakthrough for Gen-IV systems.
- Designed to support variable loads → ideal for AI/data-centre demand.

Tech Giants' Interest in advanced SMR

Drivers:

- Multiple-modules
- Behind the meter
- High reliability (the five 9's)
- Deploy close to the end user
- Advanced safety (small EPZ)
- Cooling for datacentres…

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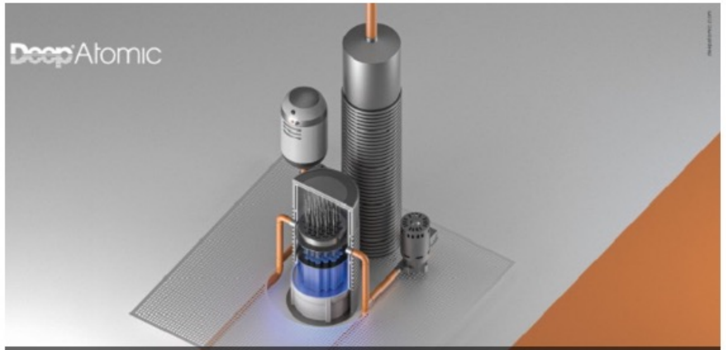
Google and Kairos Power team up for SMR deployments

Tuesday, 15 October 2024

Google has agreed to purchase energy from small modular reactors under a deal that will support the first commercial deployment of Kairos Power's reactor by 2030 and a fleet totalling 500 MW of capacity by 2035.

Powering data centers with SMRs

S. Himmelstein | November 06, 2024



Source: Deep Atomic

A small modular reactor (SMR) has been designed by Switzerland-based Deep Atomic specifically to provide power and cooling to data centers.

wnn world nuclear news

Amazon invests in X-energy, unveils SMR project plans

Wednesday, 16 October 2024

Amazon has announced it has taken a stake in advanced nuclear reactor developer X-energy, with the goal of deploying up to 5 GW of its small modular reactors in the USA by 2039.

- Represent major inroads with SMRs to bring nuclear energy to Data Centres.
- Top hyper-scalers' agreements and investments in could move these technologies to the forefront

Other developments

NUCNET

Deployment of BWRX-300 small modular reactor in Poland takes major step forward with design development

US Kicks Off Advanced Reactor Programme With Criticality Planned For 2026

Final Investment Decision taken for Romanian SMR project

Friday, 13 February 2026

world nuclear news

The shareholders of Romanian nuclear operator Nuclearelectrica have approved the Final Investment Decision for the small modular reactor project in Doicești.

First concrete for Uzbekistan SMR 'well before December'

Wednesday, 28 January 2026

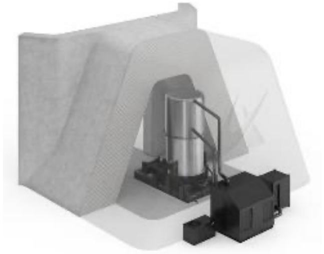
Uzbekistan President Shavkat Mirziyoyev and Rosatom Director General Alexei Likhachev have discussed progress on the project to build a nuclear power plant featuring both large and small reactors.

Commission unveils strategy to bring Europe's first SMRs online by the early 2030s

Accelerated Deployment !

Under President Trump's May 2025 Executive Order 14301 and the DOE Reactor Pilot Program, the target was to have at least three advanced reactors achieve criticality by 4 July 2026.

Company / Reactor	Type / Size	Criticality date	Status
Antares Nuclear Mark-0	Microreactor test unit A sodium heat-pipe-cooled microreactor fuelled by high-assay low-enriched uranium (HALEU) tri-structural isotropic (TRISO) fuel compacts	**4 June 2026**	First reactor in the pilot program to achieve criticality at the Idaho National Laboratory's (INL's) Reactor and Critical Experiment (RACE) facility
Valar Atomics Ward 250	TRISO-fuelled, helium-cooled, graphite-moderated high-temperature gas-cooled microreactor (~5 MWth) The modular Ward250 reactor was transported from California to Utah's via three C-17 Globemaster III military transport aircraft.	**18 June 2026**	Second reactor to achieve criticality; first DOE-authorized reactor built outside a national laboratory. Subsequently operated at low power. Also provide a small amount of electricity to power an Nvidia Blackwell processor (33% power) – 1 July; then went up to 100 kilowatts of heat (full power under the current license) and conducted a LOFC event.
Deployable Energy Unity	"Nuclear battery" microreactor (~1 MWe) Transportable "nuclear battery" concept for remote, military, industrial and data-centre applications. Water-moderated, helium cooled (uses a calandria-style water-moderated geometry)	**30 June 2026** (announced on 1 July)	Third reactor to achieve criticality, satisfying the July 4 target. Will now enter a phased power-ascension testing program.



11 companies selected by the US Department of Energy (DOE) for its Reactor Pilot Program

Status of NPPs today

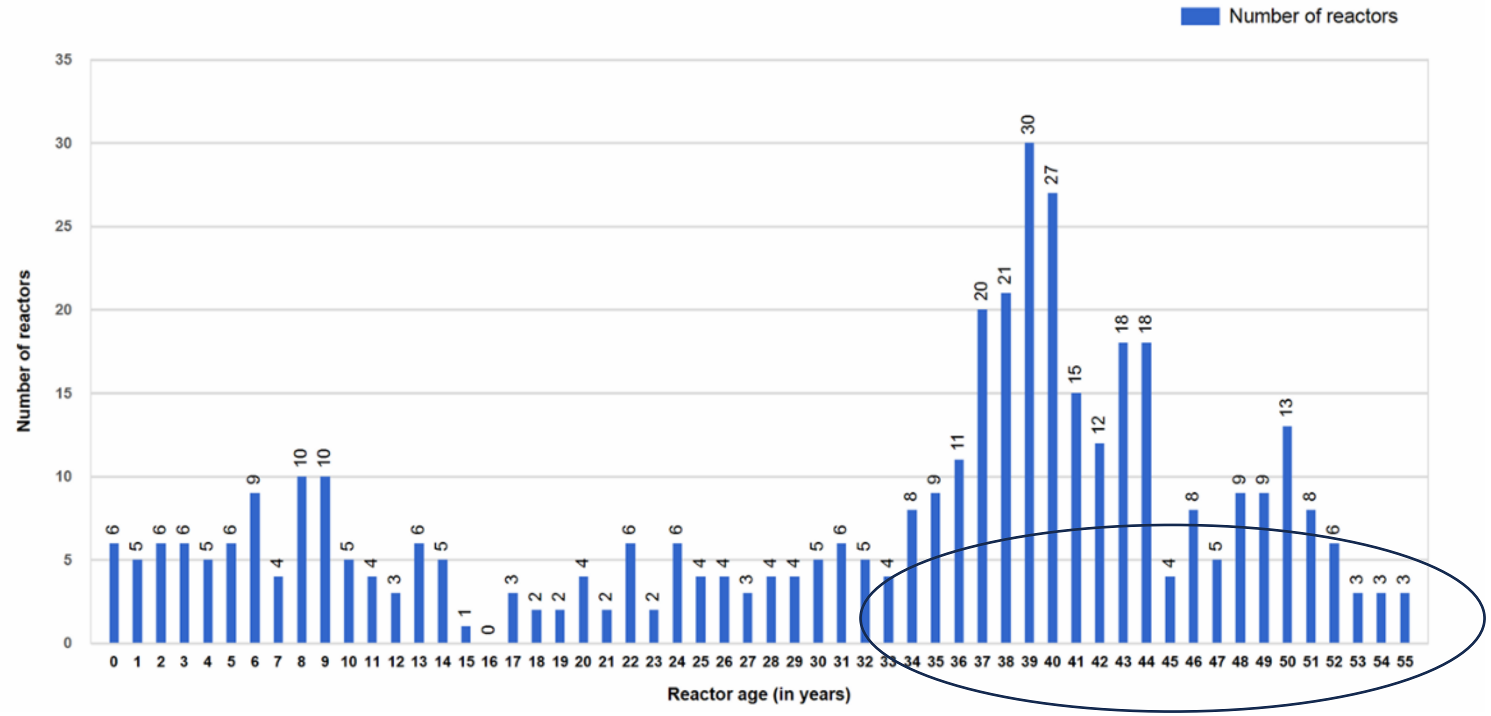
Navigating the Noise: Back to reality...

IAEA | PRIS Power Reactor Information System

CURRENT STATUS

417	NUCLEAR POWER REACTORS IN OPERATION
379 700	MW_e TOTAL NET INSTALLED CAPACITY
21	NUCLEAR POWER REACTORS IN SUSPENDED OPERATION
19 387	MW_e TOTAL NET INSTALLED CAPACITY
77	NUCLEAR POWER REACTORS UNDER CONSTRUCTION
80 720	MW_e TOTAL NET INSTALLED CAPACITY

Figure 5. Number of operational reactors by age (as of 31 Dec. 2024)



Nuclear power reactors today provide ~8.7% of global electricity.
<u>This is actually MORE THAN 20% of the world's LOW CARBON electricity.</u>

Why are we not deploying current large NPPS at a higher rate?

Main challenges to Nuclear deployment

- High Capital cost and financial risk
  - High upfront investment – normally needs the backing of governments or load guarantees
  - Long term projects (need to survive government changes)
- Construction time, project delivery and cost over runs
  - Schedule delays and cost overruns remain a key concern.
  - Complex (or non-existing) supply chains, first-time suppliers, and loss of nuclear construction experience exacerbate risks.
  - FOAK effects still material even for "proven" large reactor designs deployed in new countries.
- Regulatory and Licensing Complexity
  - Lengthy, resource-intensive licensing and environmental assessment processes.
  - Differences in national regulations limit standardization across projects.
  - Where regulatory uncertainty may exist, it will increase project risk and cost of capital.
- Market design
  - Nuclear plants struggle to compete against subsidized or short-marginal-cost resources without market reforms or support mechanisms
  - Need to better market its value (security of supply, dispatchable with price certainty)
- Public acceptance
- Human capital and Supply Chain Capacity

Few thoughts on large / mega-projects

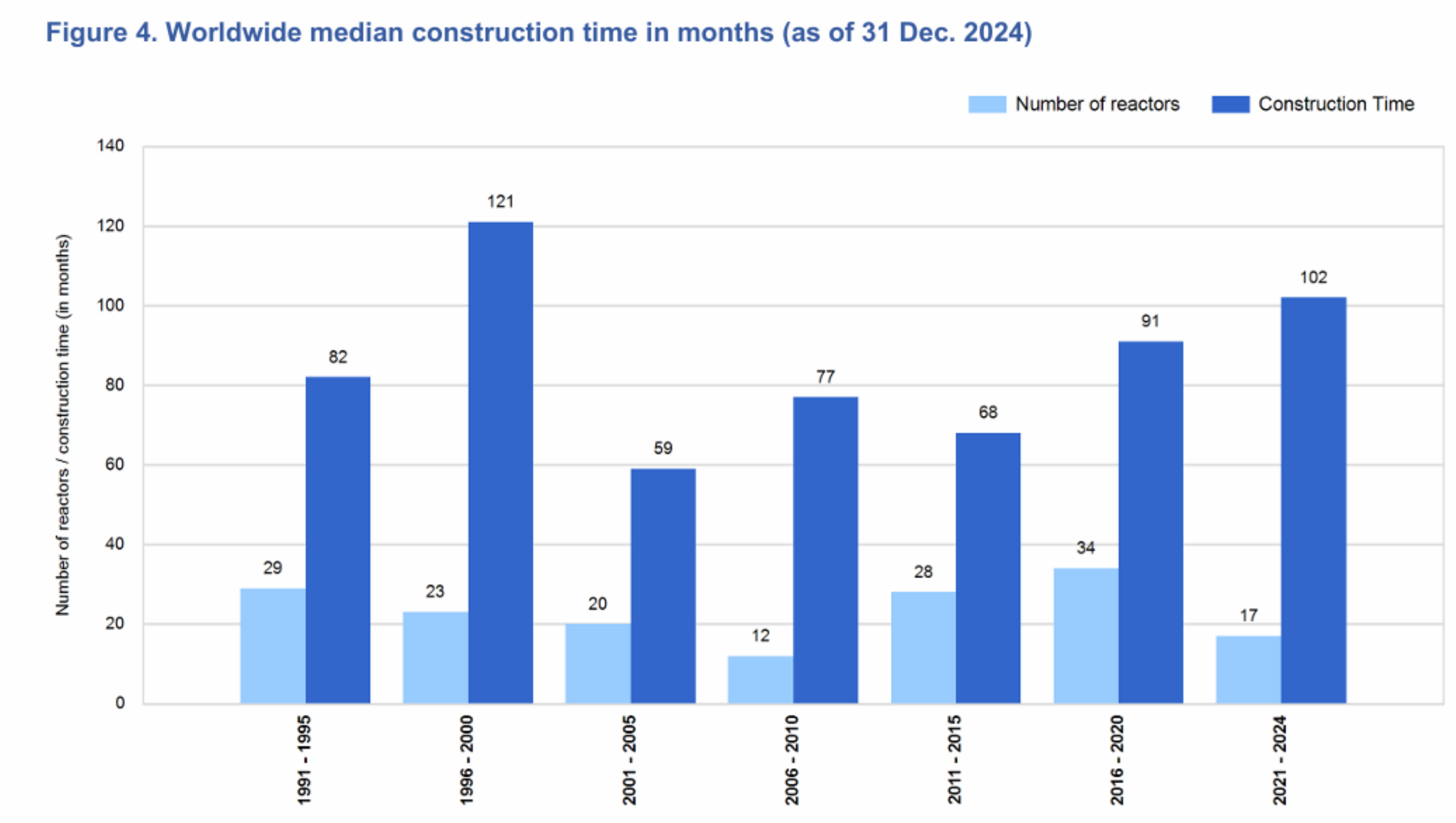
Mega projects is large (> m$500's) and complex
Examples: large infrastructure, refineries, airport projects, aerospace, large NPPs, large offshore wind farms, solar plants, etc.

- **Cost forecasts typically inaccurate and not improving: 44% rail, 33% bridges; 20% roads; 96% dams are over budget**
- **Little learning from the past …**
- **Schedules are systematically biased towards underestimation**
- **Many mega-projects fails …**
- **Large NPPs are mega projects…**

Also experience with many NPPs (increased costs and increased construction times)

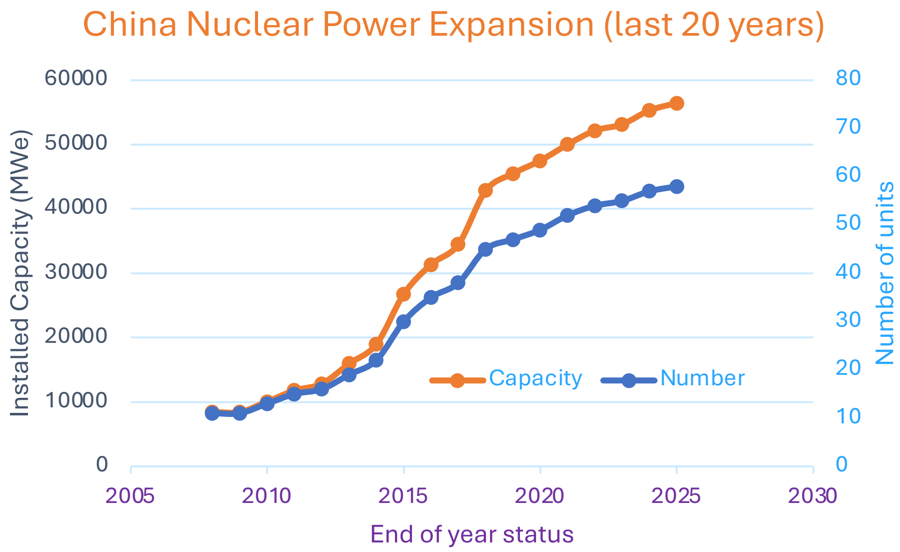
From: Cost-time project performance in megaprojects in general and nuclear in particular, by Dr Giorgio Locatelli

Construction times of new large LWRs



.. but not all bad news

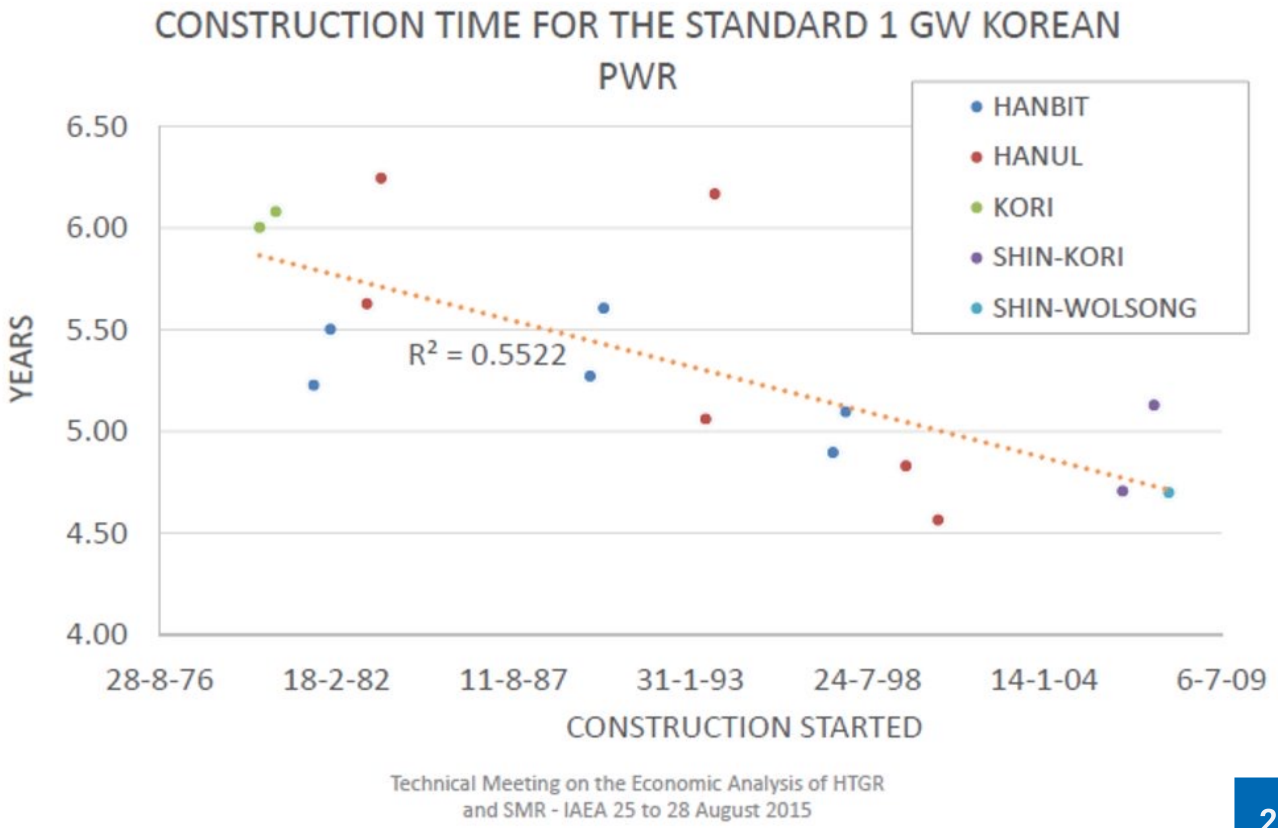
- Need continual construction projects
  - Significant advantage building more than one of the same design
  - Especially advantageous if also built on the same site
  - .. repeat builds on limited sites
- Stable Supply Chain
- Experienced work force
- Construction only after design maturity



Nuclear Energy Content Hub

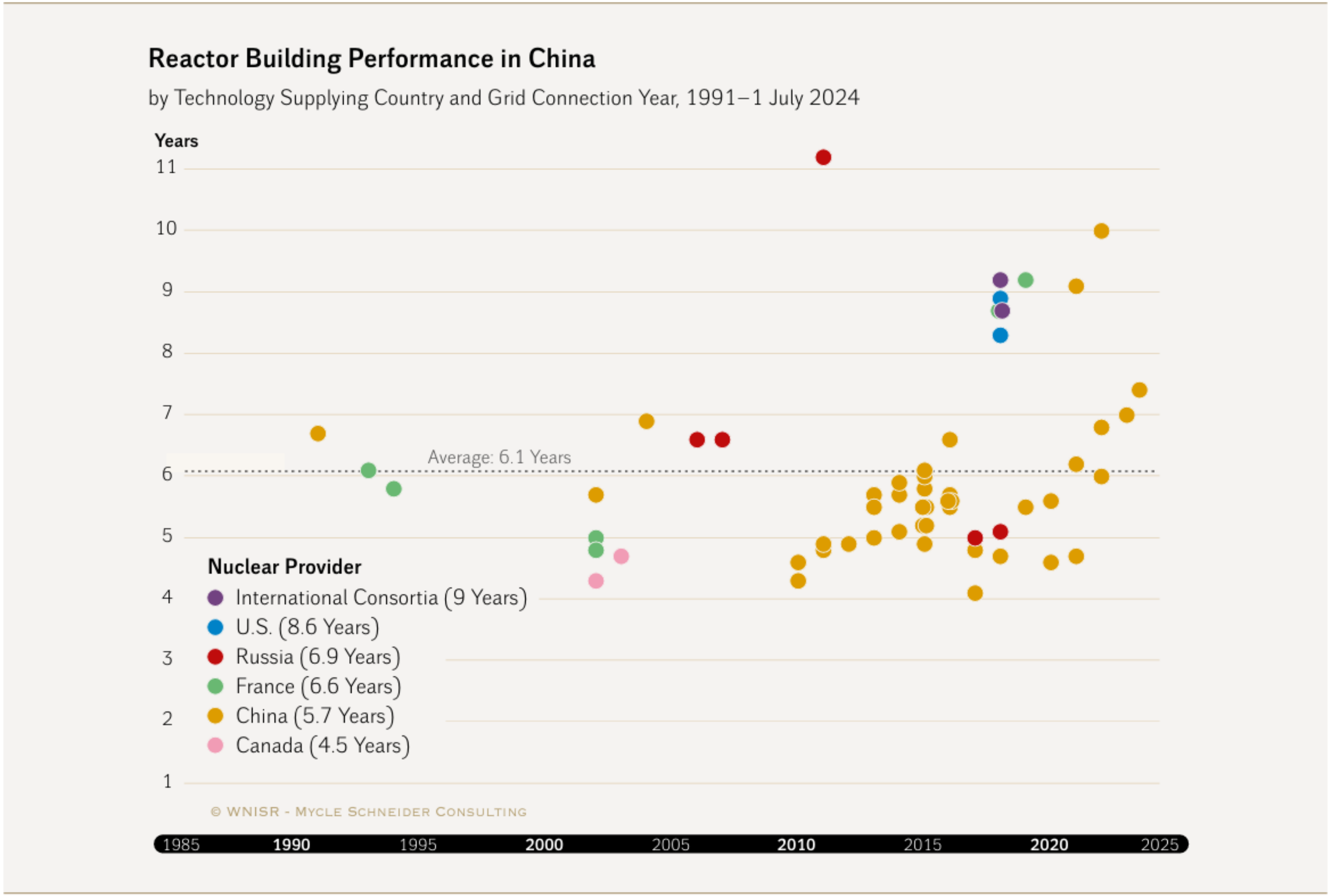
Nuclear Projects Don't Have to Be Late and Over Budget

Stacey Morris, CFA November 20, 2025



From: Cost-time project performance in megaprojects in general and nuclear in particular, by Dr Giorgio Locatelli

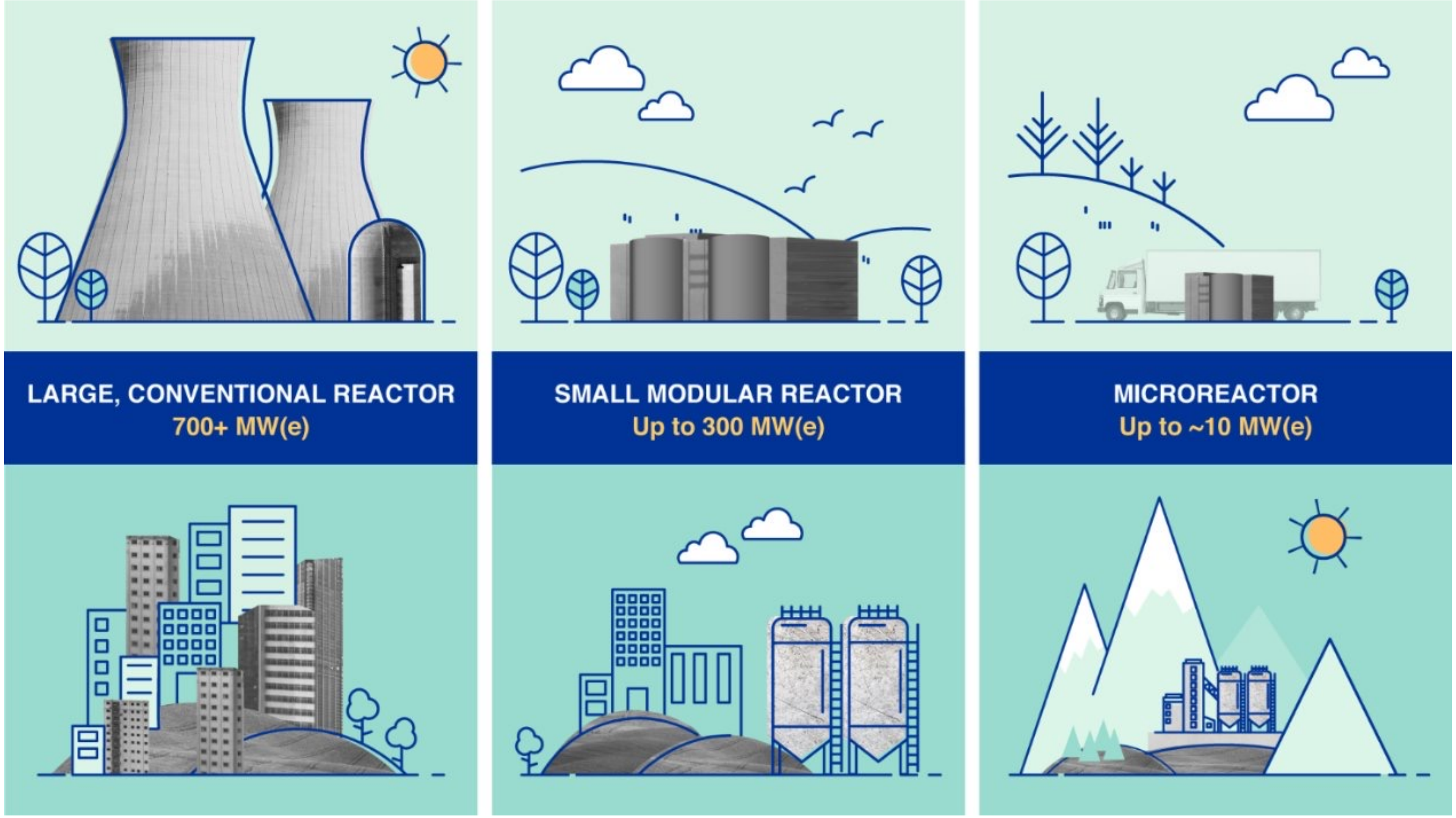
Construction times of commercial NPPs in China



Sources: WNISR with IAEA-PRIS, 2024

Opportunities and Challenges for Advanced Small Modular Reactors (SMRs)

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



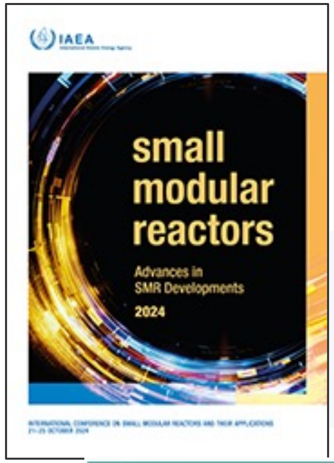
Small: in size, compared to traditional reactors.

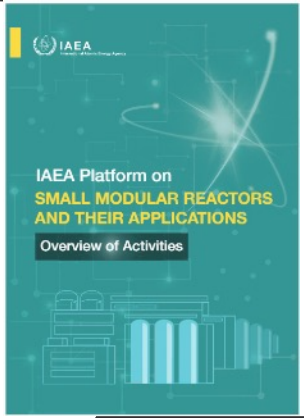
Modular: factory-manufactured, installed onsite.

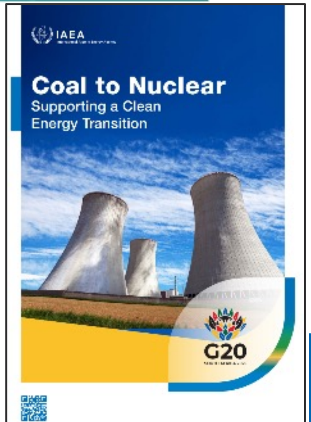
Reactor: energy generation via nuclear fission.

Innovative NPPs and SMR/AMR Advantages & Challenges

	Advantages	Challenges
Technology Issues	• 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	• Licensability (first-of-a-kind structure, systems and components) • Non-LWR technologies • Operability and Maintainability • Staffing for multi-module plant; Human factor engineering; • Post Fukushima action items on design, safety and licensing • Advanced R&D needs
Non-Techno Issues	• 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	• Economic competitiveness • Plant cost estimate • Regulatory infrastructure • Availability of design for newcomers • **Physical Security** • Public acceptance







... but what may be the reality ?

Power point reactors….

UNIVERSITY OF LEEDS

The Rickover Effect

A paper reactor [new reactor concept] has the following characteristics:

- it is simple
- it is small
- it is cheap
- it is lightweight
- it can be built very quickly
- very little development is required and
- it will use off the shelf components; it is in the study phase and not being built now.

By contrast a real reactor has the following characteristics:

- it is complicated
- it is large; it is heavy
- it is being built now
- itis behind schedule
- requires an immense amount of development on apparently trivial items;
- takes a long time to build because of its engineering development problems.

Hyman G. Rickover in pp. 158-159 *The Rickover Effect* (1992) by Theodore Rockwell, Naval Institute Press.

"Those involved with practical reactors, humbled by their experiences, speak less and worry more."
— Hyman Rickover

Technical Meeting on the Economic Analysis of HTGR and SMR - IAEA 25 to 28 August 2015

4

From: Cost-time project performance in megaprojects in general and nuclear in particular, by Dr Giorgio Locatelli

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

(year : connexion to the grid)

In operation

- KLT-40S (2020)
- HTR-PM (2022)

Under construction

- CAREM (20??)
- Natrium (2031)
- Aurora (2028)
- BWRX-300 (2030)
- Hermes2 (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
- **Nuscale PM**: FID taken in Romania; Construction to start 2028-30
- **SMR-300**: Construction to start in 2027; Palisades project

Post 2030 construction

- Rolls-Royce SMR
- iSMR
- NUWARD

SMRs in Commercial Operation

https://fnpp.info/

Russian Federation
2 x KLT-40S reactors (PWR)
70MWe
50 Gcal/h Heat power production
Enrichment: 14,1%
2020, May- Start of commercial operation
3-3.5 yrs operation prior to refuelling
2023, December - refuelled

https://www.world-nuclear-news.org/Articles/HTR-PM-heating-project-commissioned

China
2 x 200 MW units
210 MWe
245,000 spherical fuel elements ('pebbles’),
each 60 mm in diameter and containing
7 g of fuel enriched to 8.5%
2023, December- Start of commercial operation
Refuelling on-line

SMRs Under Construction

NPP under construction

China
ACP-100 (100 MWe)
Operation expected in 2026

https://www.world-nuclear-news.org/Articles/Core-module-installed-at-Chinese-SMR

Russian Federation
BREST-300 (300 MWe)
Operation expected in 2028

https://www.world-nuclear-news.org/Articles/Middle-tier-of-containment-installed-for-Brest-OD

Argentina
CAREM (32 MWe)
Construction suspended

https://www.world-nuclear-news.org/articles/critical-design-review-for-argentina-s-carem-small

New constructions

USA / Canada
BWRX-300 (290 MWe)
Construction license and work started at OPG Darlington site

SMR Momentum Builds at Darlington - NS Energy

USA - TerraPower
Natrium (345-MWe sodium-cooled fast reactor) in Kemmerer, Wyoming

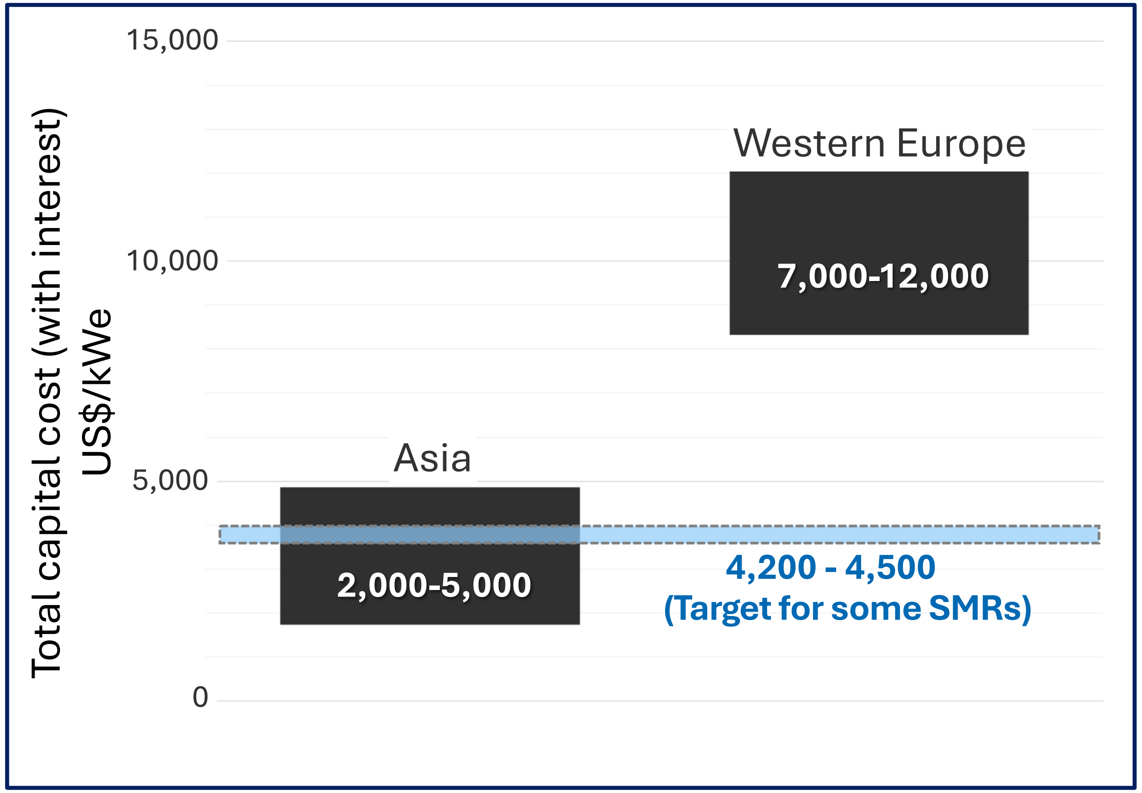
TerraPower begins construction on Natrium power plant in Kemmerer -- ANS / Nuclear Newswire

USA Oklo
Aurora powerhouse (compact, liquid metal-cooled fast reactor) groundbreaking on INL site

Licensing of Oklo pilot reactor facilities advances - World Nuclear News

Economics

It is the economics, stupid...



Construction cost ranges for recent nuclear newbuild projects in Western Europe and Asia, Climate Change and Nuclear Power 2020, IAEA.

- **Economic competitiveness** of SMR is based upon modularization, reduced construction time, and serial construction
- Some SMR developers have **target overnight construction cost** of about $3,500/kWe
- Approximately $4,200-4,500/kWe **with interest during construction** of 4-5 years

Economy of scale

Economy of multiples

What is the best?

In depends .....

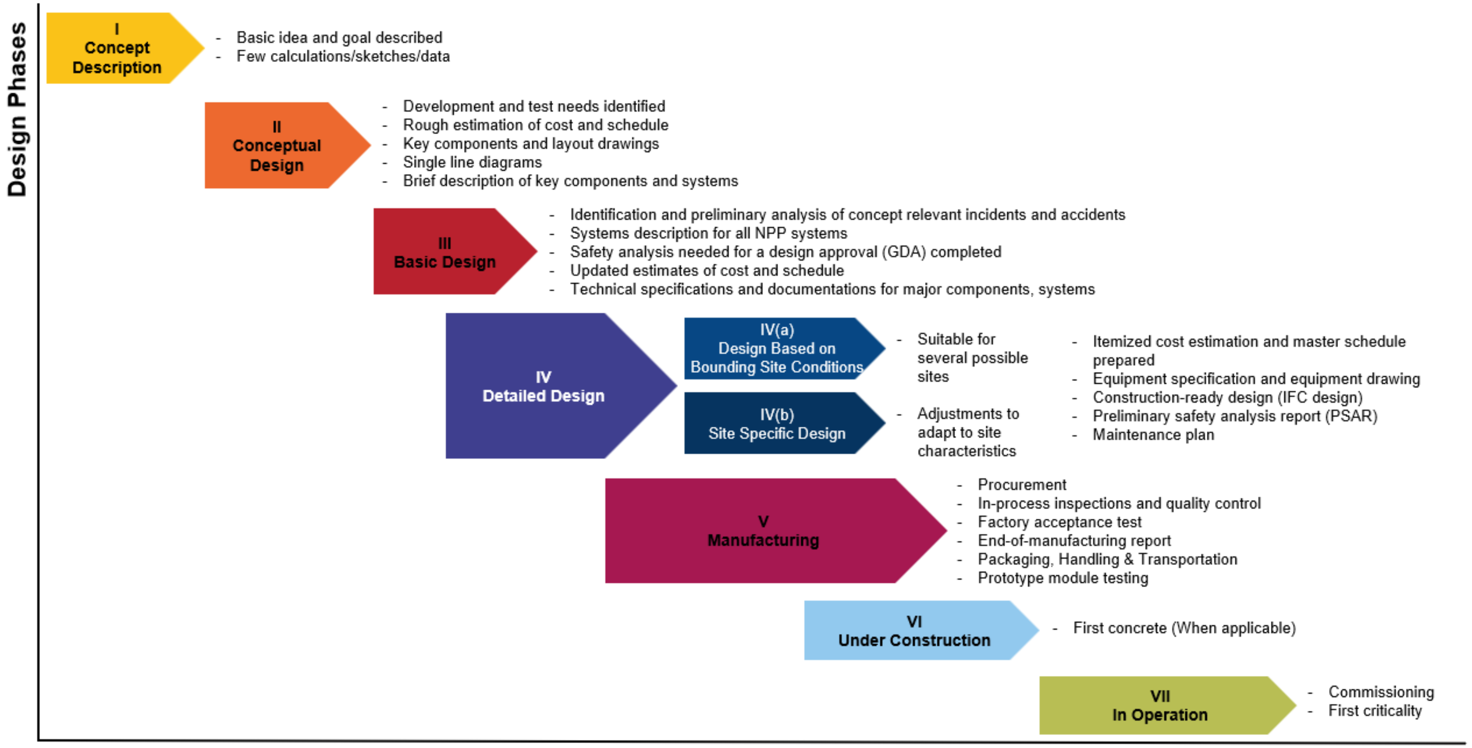
Challenges for new technology deployment (including SMRs / AMRs)

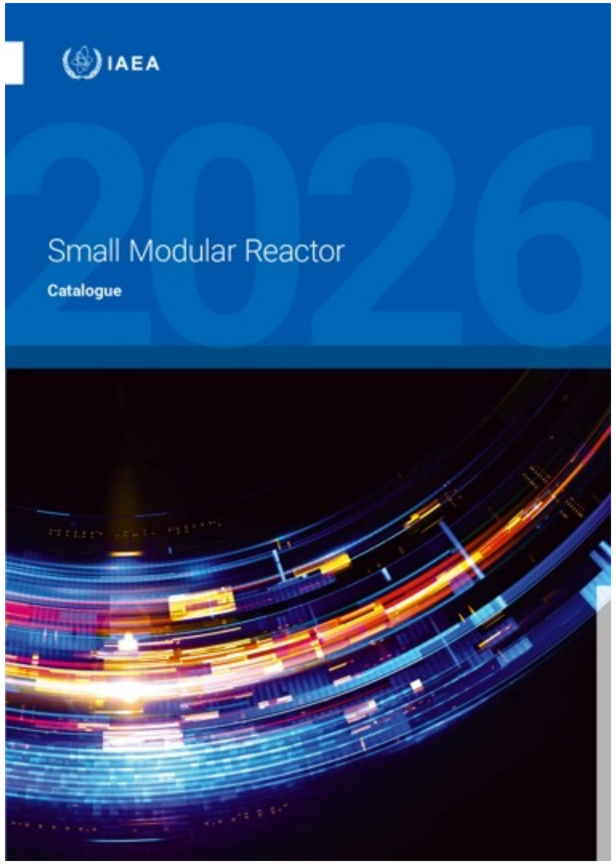
Specific challenges for innovative and Advanced Modular Reactors (SMRs)

- Demonstration of safety and operational performance
  - Technology readiness levels; R&D needs, design and safety codes and validation
  - Testing facilities, prototypes - need to build something (analysis only not enough)
- Need to develop and test new fuel, systems and components
  - Fuel qualification; develop the supply chain, factory for modules
- Demonstration of Economic Competitiveness through Serial Construction
  - Build prototypes or commercial demonstation units
- Harmonization of Regulatory and Industrial Approaches for global deployment
  - Important steps towards joint reviews and considerations of safety reviews / certification
- Newcomer countries deploying NPPs for the first time
  - Establishment of Nuclear Infrastructures – be ready, including human resource development
  - Need a reference design in country of origin…

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.





Reactor Noise Analysis and Advanced Reactor Deployment - I

Even more questions … I am sure you have the answers already.....

- **Can the experience and most R&D done for operating LWRs be transferred unchanged to advanced reactors**
  - New reactor physics, thermal-hydraulic behaviours, perturbation mechanisms => different noise sources
  - We may encounter new phenomena not yet well understood – different noise … and data is not yet available
    - neutron-noise methods will likely need to be extended and adapted
    - advanced reactors introduce new physical phenomena and new sources of perturbations.
  - Future neutron-noise diagnostics may require technology-specific models for different reactor families
- **Can Noise analysis provide insights into reactor behavior and even safety for new advanced reactors?**
  - Direct in-core measurements not available (MSR and pebble bed reactors)
  - Different coolants (helium, molten salt) and neutron spectra OR even the fuel is the coolant / heat transfer fluid
  - HTGRs:
    - The pebble fuel movement (addition, removal, stochastic flow) will add noise signals
    - Helium bypass flows
    - Flow induced vibrations / movement of core structures (oscillations)
    - Control rod movement (coolant flow)
  - Molten Salt Reactors:
    - Fuel-salt flow fluctuations, Pump-induced flow perturbations.
    - Salt temperature and density oscillations, Gas bubble transport,
    - Delayed-neutron precursor drift

Reactor Noise Analysis and Advanced Reactor Deployment - II

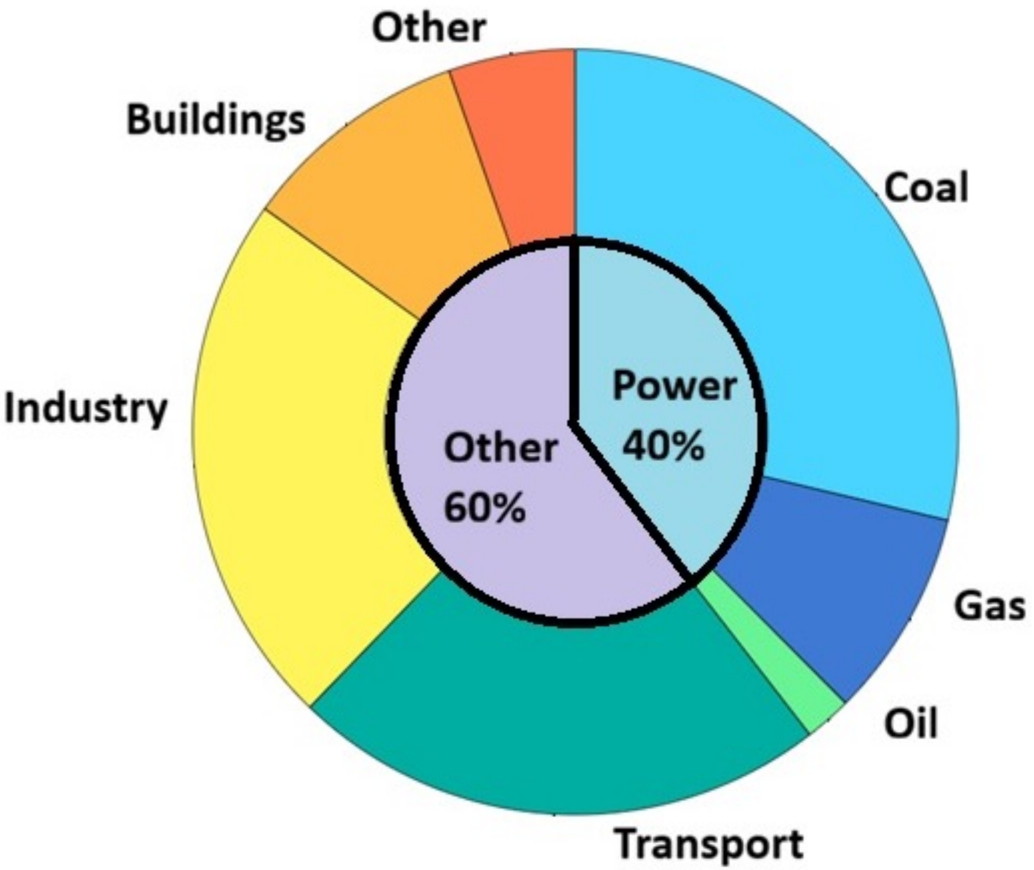
- **Limited operational data available**
  - Can machine learning / AI enrich the data that can be used? – Often already part of the design process
  - Applicable beyond normal operation?, Transients, Startup, Safety, Accident behavior?
  - Feedback to designers from FOAK units
- **SSCs are new with lower TRL and limited operation experience**
  - Increase benefit of noise analysis on equipment to evaluate performance and do preventative maintenance
  - New pump designs, helical coil steam generators
  - IHX (including printed circuit)
  - Gas turbines (Braytin cycle)
  - Helium circulator (with magnetic bearings)
- **Micro reactors**
  - Remote monitoring (and remote operations)
  - Anomaly detection
  - Maintenance planning / replacement of units
- Multiple modules with the same (Identical) design … **accumulation and sharing of data**, learning
  - And what about 12 reactors in the same pool… noise interference?

I hope I could provide some noise analysis within a world, where nuclear anticipated expansion; SMRs and AMRs deployment expectations are making a lot of noise

THANK YOU

Decarbonization of the Complete Energy Sector – beyond Electricity

- **Decarbonizing the power sector** is essential to reach climate goals
- **Need to decarbonize other sectors**, representing 60% of emissions
  - Electrification with clean electricity
  - Low carbon heat sources
  - Low carbon fuels, including hydrogen, produced from clean energy
  - Maritime applications
  - Green steel, oil and gas, cement



… mostly the harder to abate energy sectors – Innovation needed

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

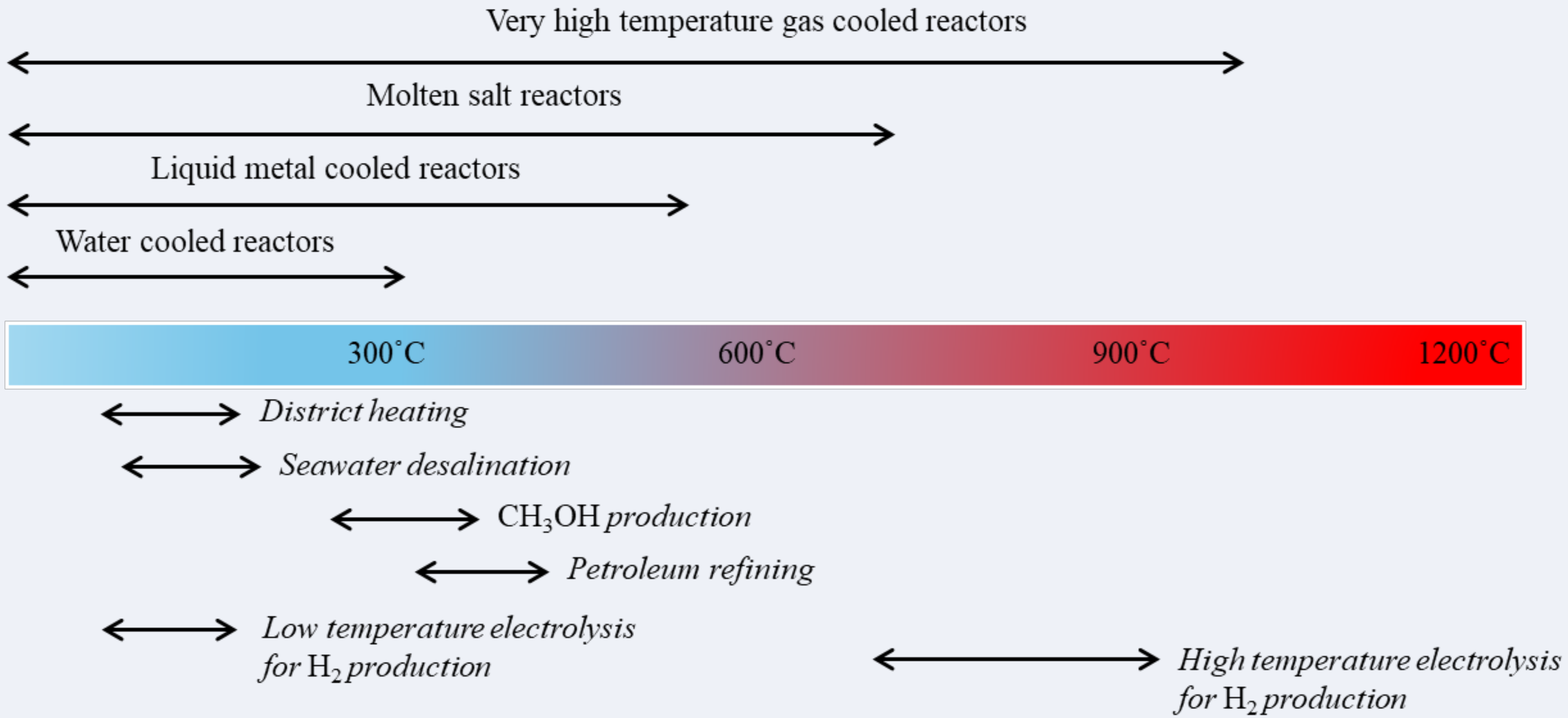
04

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

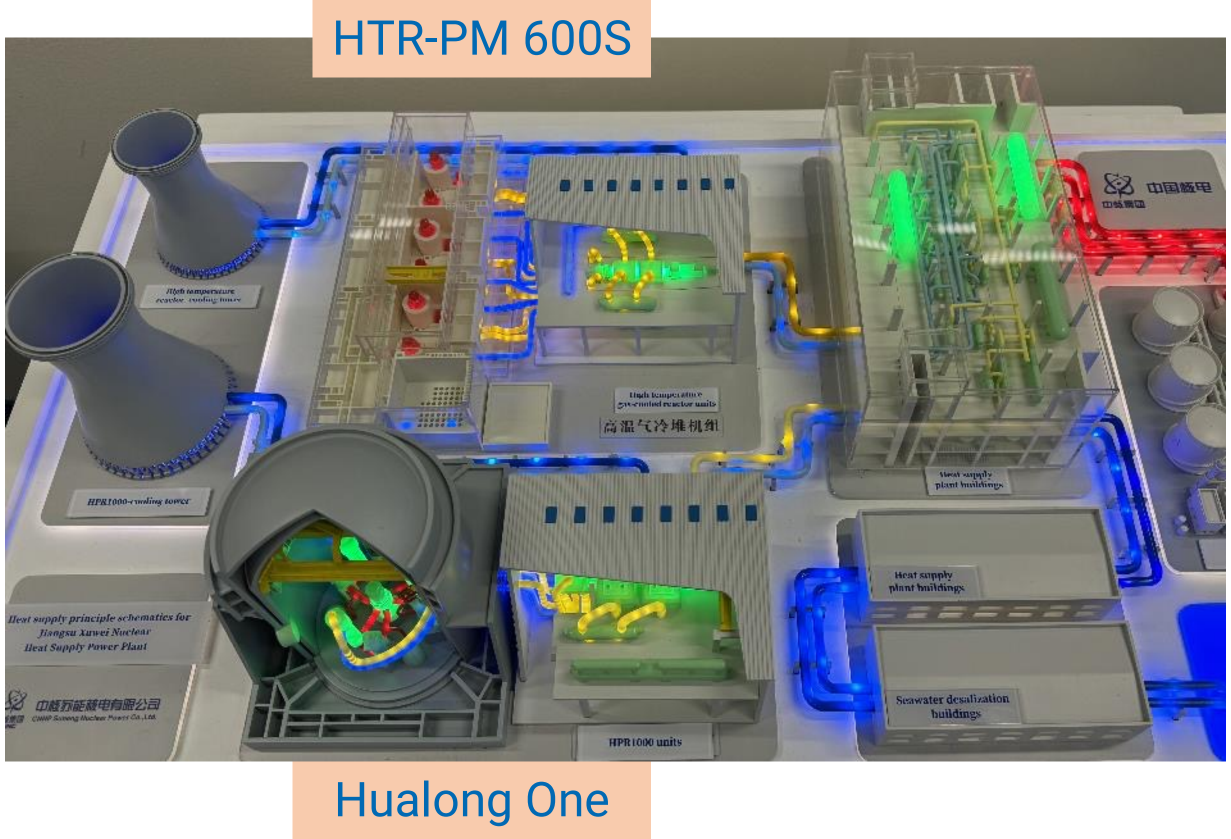
SMRs for Non-Electric Applications



SMRs clearly can play an important role… This market is larger than the existing electricity / power market

Depending on the exit temperature of the coolant there is a huge range of associated non-electric applications

China: Xuwei Cogeneration Plant



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.

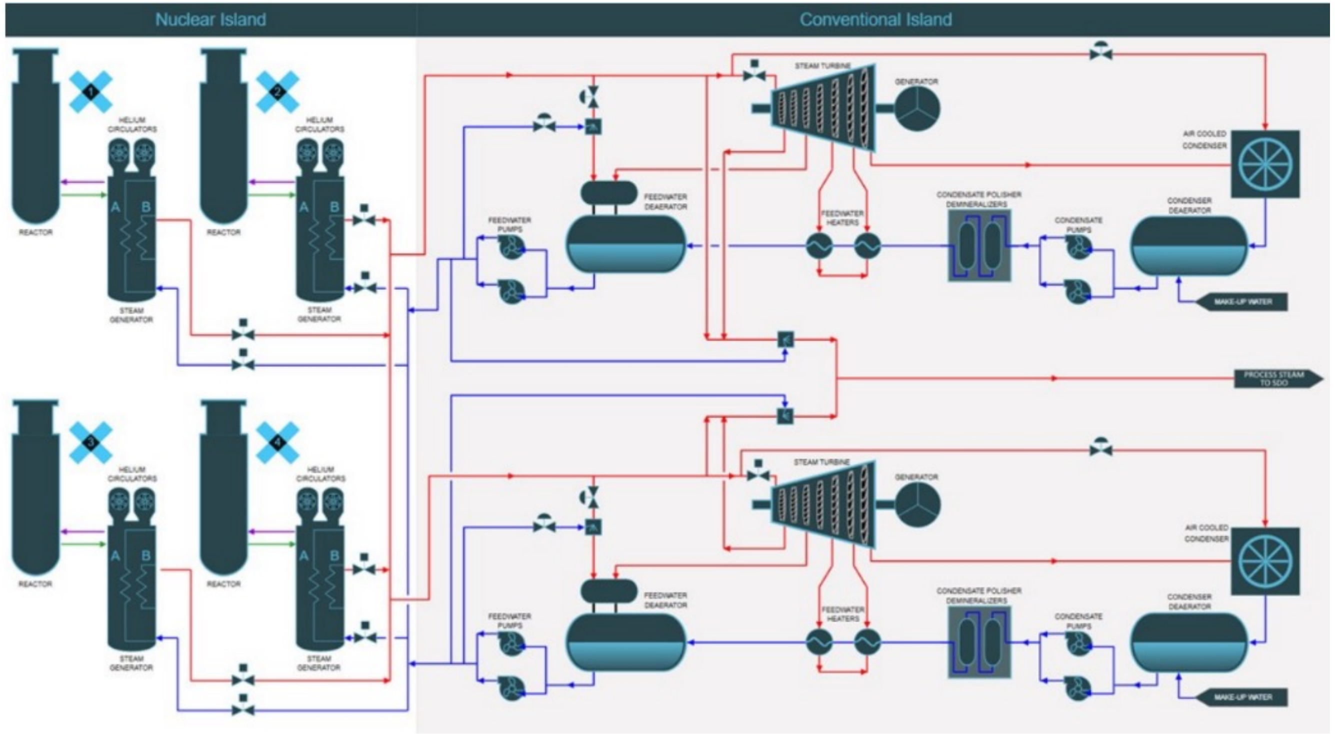
Breakings · Aug 19 14:01

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

USA: Dow and X-energy Industrial Heat

Four Xe-100 pebble-bed HTGR SMRs (200 MWt each) to replace Dow's gas-fired cogeneration facility at their Seadrift, Texas site. The SMRs will provide heat and electricity to the facility. Circulating helium transfers heat to a single steam generator designed to produce high-grade, superheated steam at 565°C. When operating at 100 percent turbine bypass mode, with maximum steam flow sent to the SDO facility, each Xe-100 reactor can generate 601,000 lb/hr (75.57 kg/s) of steam.

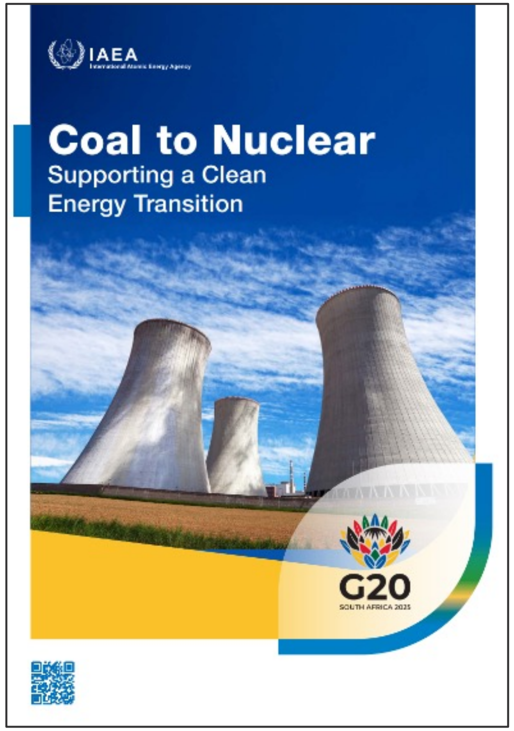
Project Status: Construction Permit Application submitted to the country's nuclear regulator.

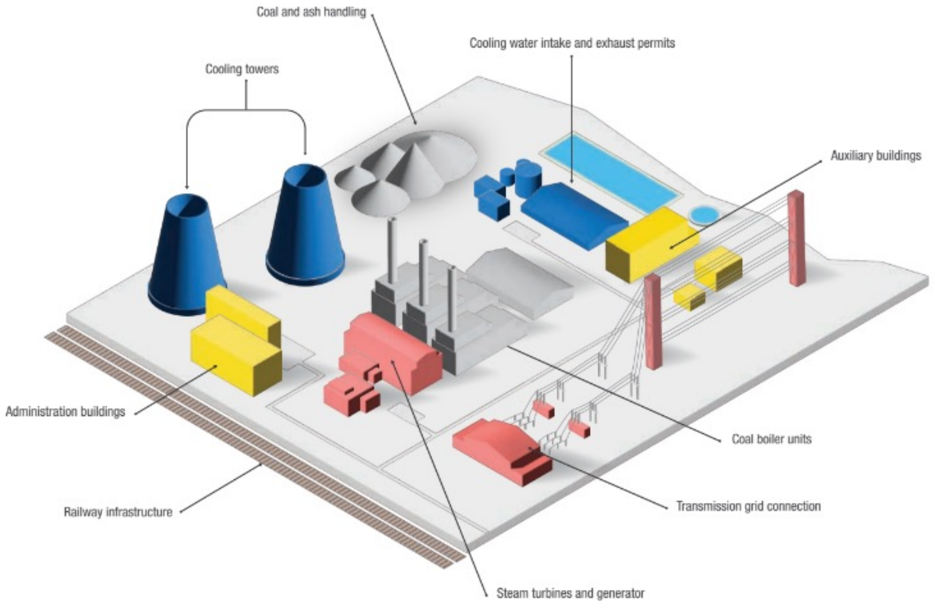


Coal to Nuclear transition : Technical Considerations

Site Selection

- Size of the site needs to be able to accommodate needed NPP infrastructure
- Location of the site must be suitable for an NPP
    - Nearby population density, industrial plants, natural hazards and other aspects of the site could be suitable for a CPP, but not for an NPP
- Cooling water supply is one of the most important site criteria for a C2N transition
    - Rights and permits to both use and discharge the water are also required



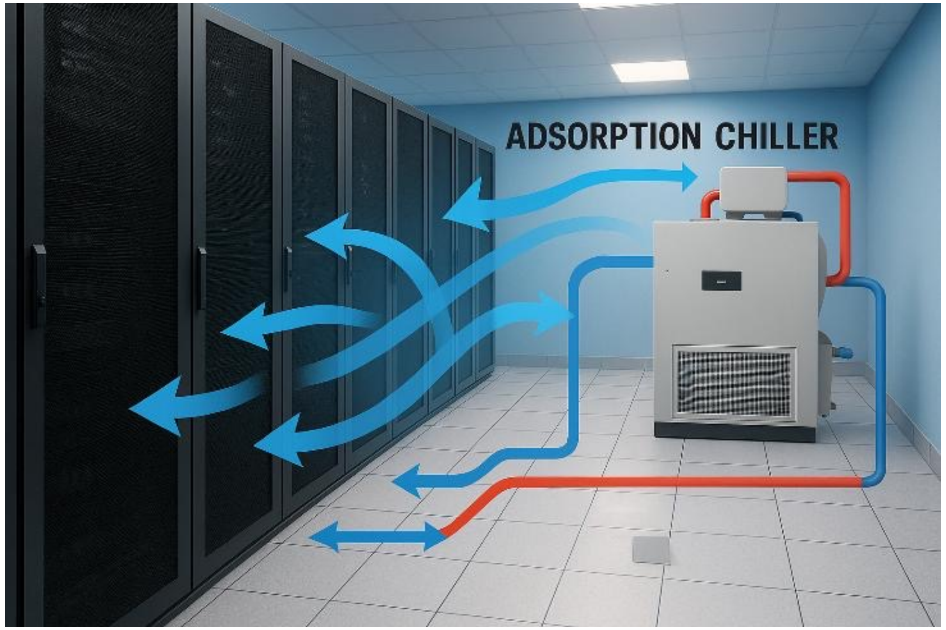


Infrastructure Assessment

- "Repowering" of coal sites generally considers the reuse of existing site infrastructure
- CPP sites include infrastructure and equipment that could be repurposed by NPPs, and reuse of these systems could provide savings on construction costs
- Dependent on several technical and regulatory aspects
- Systems would need to meet the applicable requirements based on each component's safety classification
    - Could require significant regulatory and engineering review

Nuclear energy for cooling AI data centres

- AI data centres require large amount of cooling, roughly matching the IT load:
    - typically, in the tens of MW electrical, up to more than 100 MW for large data centers, >1 GW in the future.
- AI data centres are densely packed and need active cooling – conventional air cooling may not be sufficient for more advanced and dense data centres.
- Nuclear energy, and SMRs, can facilitate data centres cooling
    - Existing access to cooling infrastructure: cooling towers and water usage rights needed by both, nuclear and data centres.
    - Nuclear waste heat can drive adsorption/absorption chillers to provide efficient cooling for data centres.
    - Data centres with advanced cooling will have a competitive advantage, allowing higher workloads.
    - Using nuclear waste heat for cooling will increase the overall efficiency of the combined systems and increase sustainability.



Status of NPPs today

IAEA | PRIS Power Reactor Information System

CURRENT STATUS

417 NUCLEAR POWER REACTORS IN OPERATION

379 700 MW_e TOTAL NET INSTALLED CAPACITY

21 NUCLEAR POWER REACTORS IN SUSPENDED OPERATION

19 387 MW_e TOTAL NET INSTALLED CAPACITY

77 NUCLEAR POWER REACTORS UNDER CONSTRUCTION

80 720 MW_e TOTAL NET INSTALLED CAPACITY

Large Sodium Fast Reactors in Operation today

Country	Name	Fuel	Power MW(th/e)	Year (Op.)
Russia	BN-800	UO_2/MOX	**2100/880**	2015
China	CFR600-1	UO_2/MOX	**1500/650**	2023
India	PFBR	UO_2	**1250/500**	Crit, 04/’26

BN-800
Russia, 2015

CEFR, 20 MW(e)
China, 2011

PFBR, 500 MW(e)
India, 2024

Fast Reactors under Construction

Country	Name	Coolant	Fuel	Purpose	Power, MW(th/e)	Year (Op.)
Russia	MBIR	sodium	MOX	experimental	**150/50**	~2028
	BREST-OD-300	lead	PuN/UN	demonstrator	**700/300**	~2026
China	CFR600-2	sodium	UO_2/MOX	prototype	**1500/650**	~2028

HIGHLIGHTS of 2024 / 2025

New connections to the grid

Nuclear Power Plants	Power and Type	Country	Design / Technology	Date (2024/2025)
BARAKAH-4	1310 MW(e), PWR	United Arab Emirates	**APR1400 (Korea)**	23 March 2024
FANGCHENGGANG-4	1000 MW(e), PWR	China	**HPR1000 (China)**	9 April 2024
FLAMANVILLE-3	1630 MW(e), PWR	France	**EPR (France)**	21 December 2024
KAKRAPAR-4	630 MW(e), PHWR	India	PHWR700 (India)	20 February 2024
VOGTLE-4	1117 MW(e), PWR	United States of America	**AP1000 (United States)**	6 March 2024
ZHANGZHOU-1	1126 MW(e), PWR	China	**HPR1000 (China)**	28 November 2024
KURSK 2-1	1200 MW(e), PWR	Russian Federation	**VVER V-510 (Russia)**	**20 December 2025**
RAJASTHAN-7	630 MW(e), PHWR	India	**PHWR (India)**	**17 March 2025**
ZHANGZHOU-2	1126 MW(e), PWR	China	**HPR1000 (China)**	**22 November 2025**

Nuclear Power Plants	Power and Type	Country	Design / Technology	Date
ONAGAWA-2	796 MW(e), BWR, JAPAN	Japan		15 November
SHIMANE-2	789 MW(e), BWR, JAPAN	Japan		12 December

HIGHLIGHTS of 2024

Construction starts

Nuclear Power Plants	Power and Type	Country	Design / Technology	Date (2024)
CHASNUPP-5	1117 MW(e), PWR	PAKISTAN	Hualong-1 / 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	CAP1000 (China)	28 July
SHIDAOWAN-1	1116 MW(e), PWR	China	CAP1000 (China)	28 July
SHIN-HANUL-3	1340 MW(e), PWR	Korea	APR-1400 (Korea)	12 September
SHIN-HANUL-4	1340 MW(e), PWR	Korea	APR-1400 (Korea)	12 September
XUDAPU-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

HIGHLIGHTS of 2025

Construction starts

Nuclear Power Plants	Power and Type	Country	Design / Technology	Date (2025)
BAILONG-1	1254 MW(e), PWR	China	CAP1000 (China)	22 December
JINQIMEN-1	1233 MW(e), PWR	China	HPR1000 (China)	10 August
KURSK 2-3	1200 MW(e), PWR	Russian Federation	VVER V-510 (Russia)	20 December
LENINGRAD 2-4	1150 MW(e), PWR	Russian Federation	VVER V-491 (Russia)	20 March
LUFENG-1	1250 MW(e), PWR	China	CAP1000 (China)	24 February
LUFENG-2	1250 MW(e), PWR	China	CAP1000 (China)	22 December
NINGDE-6	1117 MW(e), PWR	China	HPR1000 (China)	16 December
SANAO-3	1208 MW(e), PWR	China	HPR1000 (China)	19 November
SHIDAOWAN-2	1134 MW(e), PWR	China	HPR1000 (China)	7 May
TAIPINGLING-3	1209 MW(e), PWR	China	HPR1000 (China)	10 June
ZHAOYUAN-1	1117 MW(e), PWR	China	HPR1000 (China)	18 November

SMRs with Long Lead Items Manufactured

Equipment manufactured

USA
Test unit reactor vessel for Kairos Power

https://www.world-nuclear-news.org/articles/kairos-power-fabricates-and-installs-test-unit-reactor-vessel

Korea
Doosan Enerbility forging production process for a NuScale VOYGR-6 SMR

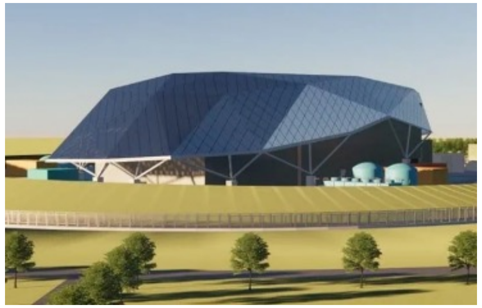
https://world-nuclear-news.org/Articles/Doosan-starts-forging-components-for-NuScale-SMR

Russian Federation – RITM-200
10 reactor units manufactured.
8 installed in icebreakers

https://www.neimagazine.com/analysis/the-ritm-200n-as-a-terrestrial-unit/?cf-view

Progress towards deployment

KP-FHR (USA)
•320 MWt, 140 MWe design
•Hermes demo ORNL (operational in 2027) , Construction permit for the Hermes 2 test plant(2 X 28-MWt)



UK Rolls Royce
Work to start in 2026 on the delivery of three at Wylfa, North Wales.

USA – DOE Reactor Pilot Program to expedite the testing of advanced reactor designs - 11 designs selected
(3 critical before 4th July 2026)

Attractive features of SMRs

Lower capital cost	• Smaller size; Serial construction or assembly • Modularization, reduced construction time • Can used revenue to self-finance later plants
Flexible Siting and Operation	• Close to demand, small or off-the-grid • Load following
Scalability and reliability	• Additional reactor modules to meet increasing demands • More modules – allow for refueling and maintenance
Diverse Products	• Electricity; co-generation • Heat; hydrogen, cooling
Savings through learning	• Building more than one unit especially on the same site • Built in a factory - controlled environment / QA practices

ATLAS (Atomic Licensing at Seas)

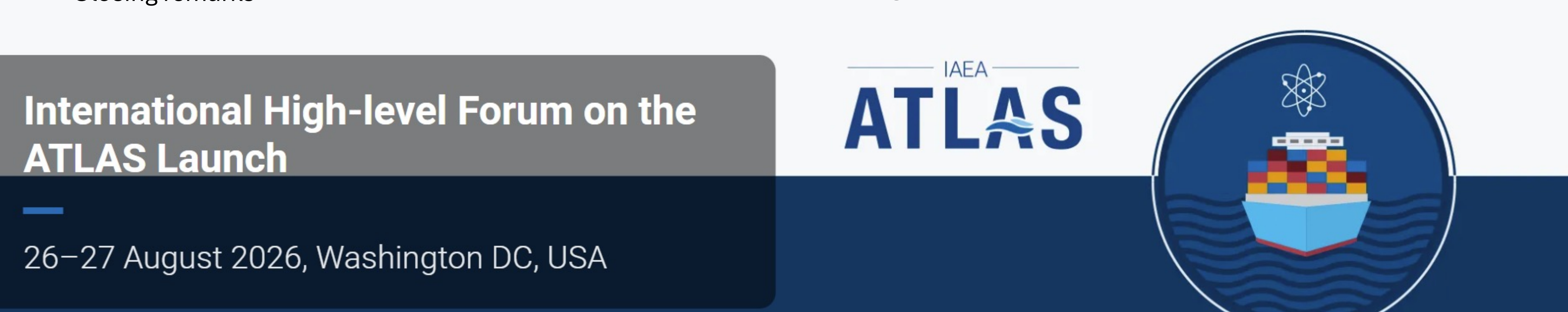
ATLAS is an IAEA initiative intended to create a framework that promotes and supports the safe and secure development and deployment of peaceful forms of nuclear applications at sea, specifically: civil nuclear-powered ships and floating nuclear power plants (FNPPs)

Wednesday, 26 August

- Opening
- Ministerial Statements
- Panel Discussions (afternoon)
  - ✓ "Why Nuclear Maritime Now? Demand, Opportunity, and Strategic Drivers"
  - ✓ "Enabling Maritime Deployment: Law, Regulation, Safety, Security and Safeguards and Liability at Sea"
  - ✓ "Making Nuclear Maritime Happen: How ATLAS can Support Deployment"
- Closing remarks

Thursday, 27 August

- Discussions on ATLAS Project Groups
  - ✓ PG1: International Safety Codes and Standards
  - ✓ PG2: Legal and Regulatory Framework
  - ✓ PG3: Maritime Classification
  - ✓ PG4: Safeguards
  - ✓ PG5: Nuclear Security
  - ✓ PG6: Deployment Roadmap on Technology, Infrastructure and Fuel Cycle
- Discussion / feedback session
- Closing Remarks



Cogeneration (heat and cooling)

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

Steady Energy

August 8, 2025

New Study Confirms Feasibility of SMRs for Urban District Heating — LDR-50 Shown as Profitable Solution

Applied Thermal Engineering, volume 247, pages 123042

Economic optimization and thermodynamic analysis of a novel nuclear district cooling system

Weiqi Liu Liu Weiqi[1], Weiqi Liu[1], Quanbin Zhao[1], Z. M. Sun[2], Zhi-Yong Sun[2], Xingmin Liu[2], Gen Li[3], Gen Li[3], JunJie Yan[1], Jinshi Wang[1]

SHOW AUTHORS AFFILIATIONS: 3 АФФИЛИАЦИИ

Publication type: Journal Article **Publication date**: 2024-06-01

hermaleng.2024.123042 Copy DOI

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.

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

Plans for SMR plant on Svalbard progress

Thursday, 14 August 2025

wnn world nuclear news

An assessment programme has been submitted to the Governor of Svalbard for the construction of a small modular reactor power plant on the Norwegian Arctic archipelago, marking the first formal step towards building the facility.

Status of development of SMRs (2024 snapshot)