IAEA
International Atomic Energy Agency
Atoms for Peace and Development

The status of different SMR technologies and the role of the IAEA to support its Member States in SMR Technology Development

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Nuclear Power Technology Development Section
Division of Nuclear Power, Department of Nuclear Energy

Outline

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- Definition, motivation and target application
- SMRs for immediate & near term deployment
- Prospects for SMRs
- Cogeneration and Integration with Renewables
- SMR design characteristics
- Perceived advantages and potential challenges
- IAEA Activities

SMR: definition & rationale of developments

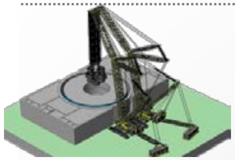
Advanced Reactors to produce up to 300 MW(e), built in factories and transported as modules to sites for installation as demand arises.

A nuclear option to meet the need for flexible power generation for wider range of users and applications

Economic

- Lower Upfront capital cost
- Economy of serial production

Better Affordability



Modularization

- Multi-module
- Modular Construction

Shorter construction time

Flexible Application

- Remote regions
- Small grids

Wider range of Users

Smaller footprint

- Reduced Emergency planning zone

Site flexibility

Replacement for aging fossil-fired plants

Reduced CO_2 production

Potential Hybrid Energy System

Integration with Renewables

SMRs for immediate & near term deployment

- SMR designs overview
- Selection of SMRs considered ready for near term deployment

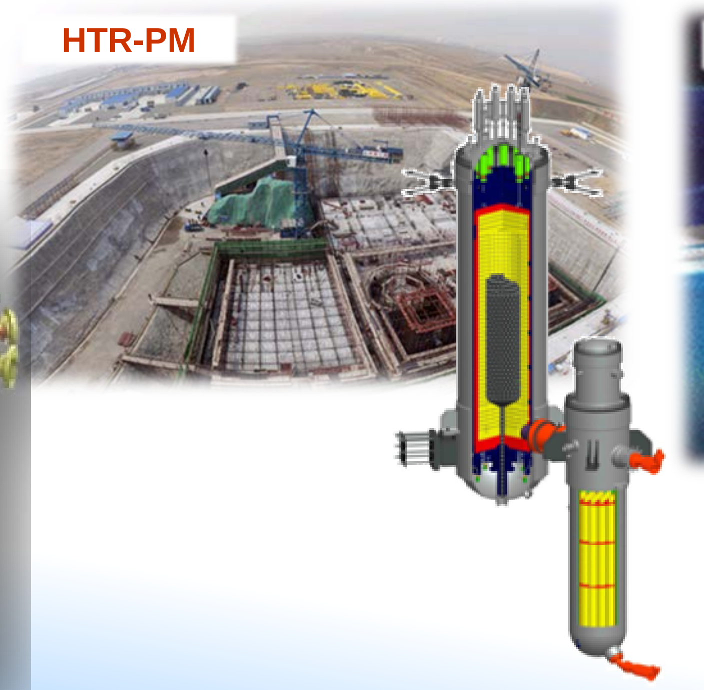
IAEA SMR Booklet 2018 Edition

- Main Features
  - Design description and main features of 56 SMR designs
  - SMRs are categorized in six(06) types based on coolant type/neutron spectrum:
    - ➢ Land Based WCRs
    - ➢ Marine Based WCRs
    - ➢ HTGRs
    - ➢ Fast Reactors
    - ➢ MSRs
    - ➢ Others

➢ MANY designs not included / not submitted

SMRs Under Construction for Immediate Deployment – the front runners …

Country	Reactor Model	Output (MWe)	Designer	Number of units	Site, Plant ID, and unit #	Startup Commissioning
Argentina	CAREM-25	27	CNEA	1	Near the Atucha-2 site	2022
China	HTR-PM	210	INET, Tsinghua	2 mods, 1 turbine	Shidaowan unit-1	2019
Russian Federation	KLT-40S *(ship-borne)*	70	OKBM Afrikantov	2 mod x 35 MWe	Akademik Lomonosov units 1 & 2	2019
	RITM-200 *(Icebreaker)*	50	OKBM Afrikantov		RITM-200 nuclear-propelled icebreaker ship	2019



SMRs: Under Construction

CAREM

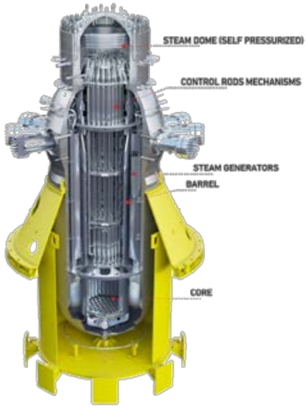


Image Courtesy of CNEA, Argentina

Under Construction

Integral PWR type SMR

Naturally circulation

- 30 MW(e) / 100 MW(th)
- Core Outlet Temp: 326°C
- Fuel Enrichment: 3.1% UO_2
- In-vessel control rod drive mechanisms
- Self-pressurized system
- Pressure suppression containment system
- First Criticality: 2022

KLT-40S

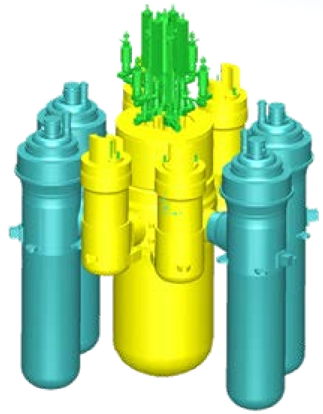


Image Courtesy of Afrikantov, Russia

Under Commissioning

Floating PWR type SMR

Forced circulation

- 35 MW(e) / 150 MW(th)
- Core Outlet Temp: 316°C
- Fuel Enrichment: 18.6% UO_2
- Floating power unit for cogeneration of heat and electricity; onsite refuelling not required; spent fuel take back to the supplier
- Commercial Start-up: 2019-20

HTR-PM

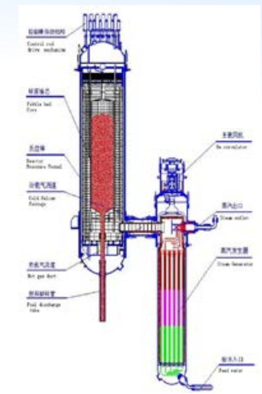


Image Courtesy of Tsinghua University, China

Under Construction

HTGR type SMR

Forced circulation

- 210 MW(e) / 2x250 MW(th)
- Core Outlet Temp: 750°C
- Fuel Enrichment: 8.5% TRISO coated particle fuel
- Inherent safety, no need for offsite safety measures
- Multiple reactor modules can be coupled with single steam turbine
- Commercial operation: 2019
- The HTR-PM 600 (6 modules) are under design and several potential sites identified

SMRs: Near Term Deployable

NuScale

Image Courtesy of NuScale Power, USA

Under regulatory review

Integral PWR type SMR

Naturally circulation

- 50 MW(e) / 160 MW(th) per module - upgraded to 60 MW(e)
- Core Outlet Temp: 314°C
- Fuel Enrichment: <4.95% UO_2
- 0.5g peak ground accelerations
- Modules per plant: 12
- Containment vessel immersed in reactor pool that provide unlimited coping time for core cooling
- Multi-purpose Energy use: Electricity and process heat applications

SMART

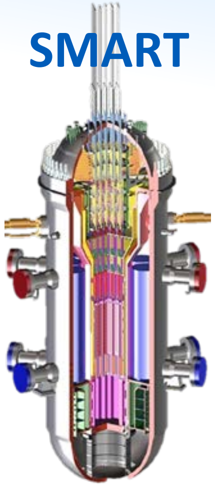


Image Courtesy of KAERI, Republic of Korea

Standard design approval (2012)

Integral PWR type SMR

Forced circulation

- 100 MW(e) / 330 MW(th)
- Core Outlet Temp: 323°C
- Fuel Enrichment: <5% UO_2
- Coupling with desalination and process heat application
- Pre-project engineering agreement between Korea and Kingdom of Saudi Arabia for the deployment of SMART in the Gulf country
- Design update (increased power and more passive safety features) to be submitted for design approval

ACP-100

Image Courtesy of CNNC(NPIC/CNPE), China

Basic Design Completed

Integral PWR type SMR

Forced circulation

- 125 MW(e) / 385 MW(th)
- Core Outlet Temp: 319°C
- Fuel Enrichment: <4.95% UO_2
- In-vessel control rod drive mechanisms
- nuclear island underground
- Preliminary safety assessment report (PSAR) finished
- An industrial demonstration plant with one 385 MW(t) unit is planned in Hainan Province
- IAEA conducted a generic safety review

SMRs: Generation-IV Designs

SEALER

Image Courtesy of LeadCold, Sweden

Conceptual Design

Small lead-cooled battery

Forced circulation

- 3 MW(e) / 8 MW(th)
- Core Outlet Temp: 432°C
- Fuel Enrichment: <20% UO_2
- Non-pressurized
- The primary market for SEALER is constituted by Arctic communities and mining operations which today depend on diesel generators for production of power and heat

EM2

Image Courtesy of General Atomics, USA

Conceptual Design

Modular high temperature gas-cooled fast reactor

Forced cooling with helium

- 265 MW(e) / 500 MW(th)
- Core Outlet Temp: 850°C
- Fuel Enrichment: 14.5% UO_2
- Silicon carbide composite cladding and fission gas collection system
- Use a combined power conversion cycle - direct helium Brayton cycle and a Rankine bottoming cycle
- Modules per plant: 4

IMSR

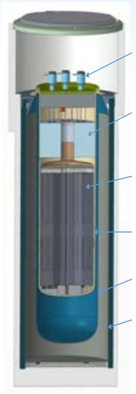


Image Courtesy of Terrestrial Energy Inc., Canada

Conceptual / Basic Design

Molten Salt Reactor

Forced circulation

- 190 MW(e) / 400 MW(th) per module
- Core Outlet Temp: ~700°C
- Fuel Enrichment: < 5%
- Completely sealed reactor vessel with integrated pumps, heat exchangers and shutdown rods; core-unit is replaced completely as a single unit every seven years
- Conceptual design complete – basic engineering in progress

Water Cooled SMR Designs for district heating

DHR-400

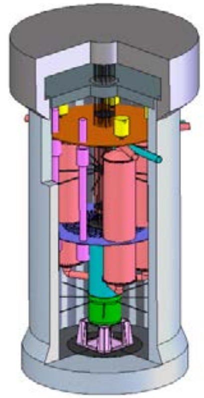


Image Courtesy of CNNC, China

Basic Design

Pool Type SMR

Forced circulation

- 0 MW(e) /400 MW(th)
- Core Outlet Temp: 98^{o}C
- Fuel Enrichment: <5% UO_2
- Designed to replace traditional coal plants for district heating
- Multi-purpose applications including district heating, sea water desalination & radioisotope production
- Seeking a construction license in 2019
- First plant that is expected to be built in Xudapu, Liaoning, China.

RUTA-70

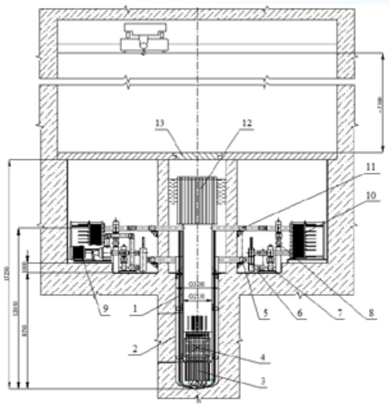


Image Courtesy of , NIKIET, Russian Federation

Conceptual Design

Pool type SMR

Natural / Forced circulation

- 0 MW(e) / 70 MW(th)
- Core Outlet Temp: 102^{o}C
- Fuel Enrichment: 3% UO_2
- Designed for low temperature process heat, coupling with desalination system, radioisotope production or other applications

SMR Designs Based on Power Range

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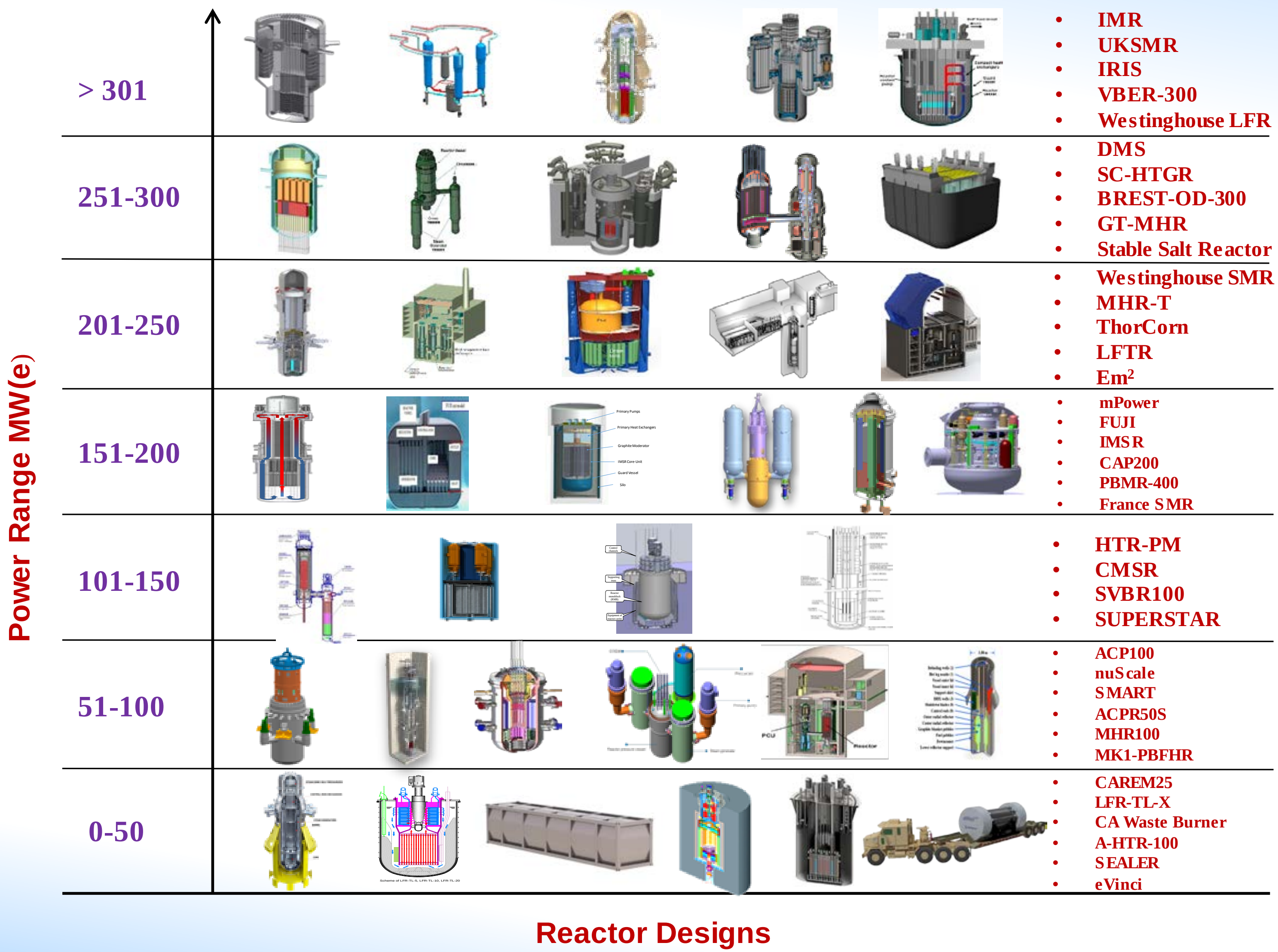
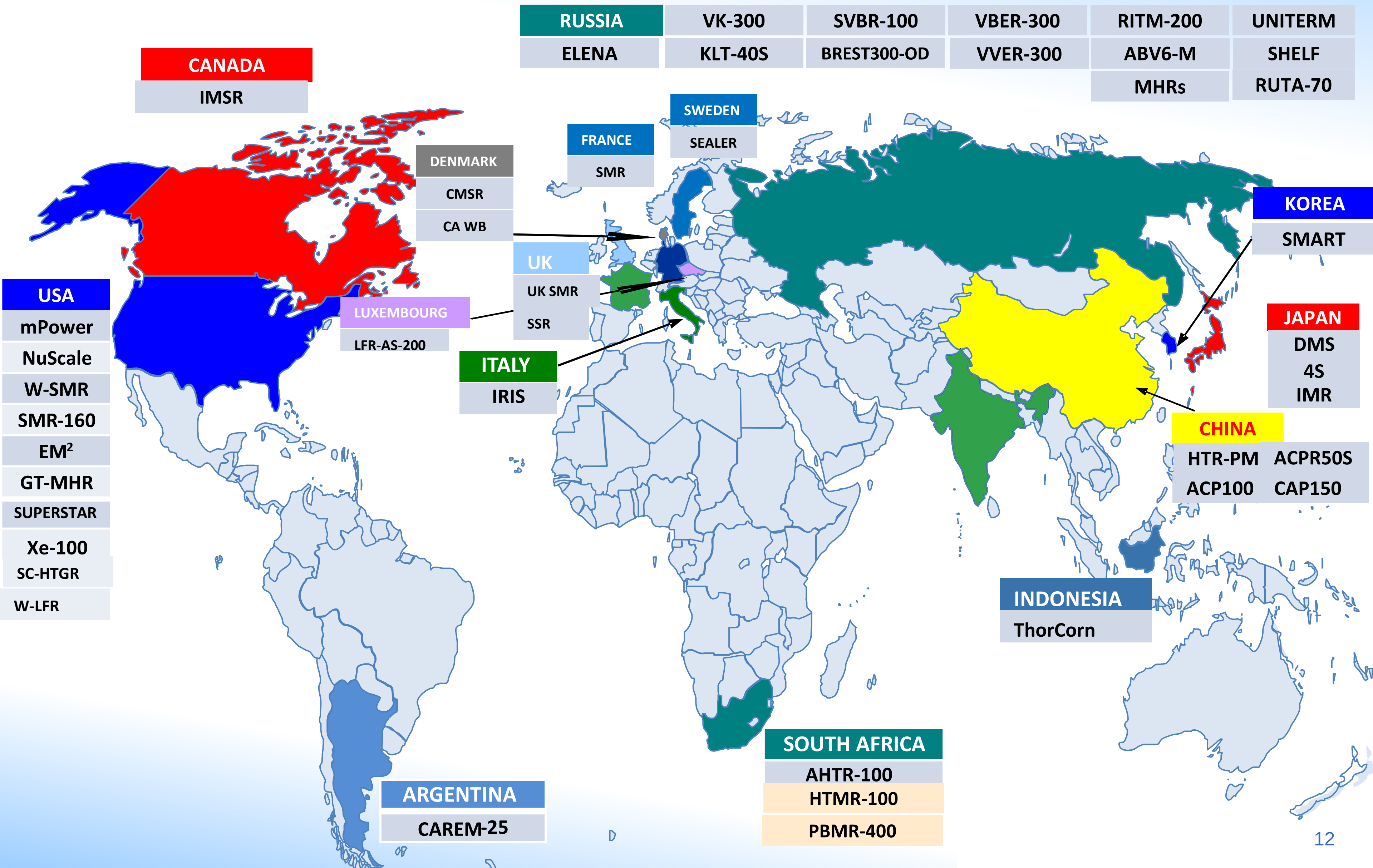


SMR Technology Development



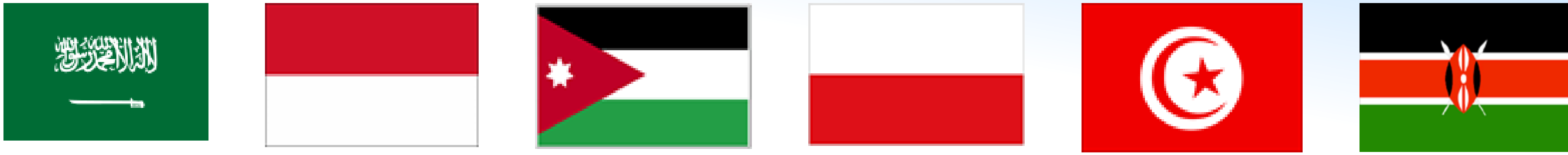
Prospects for SMRs

- Some Technology Developer Member State activities
- New-comers interest

Status and major accomplishment in Technology Developer Countries

Countries	Recent Milestone
Argentina	**CAREM25** is in advanced stage of construction. Aiming for fuel loading & start-up commissioning in 2019
Canada	**CNSC** is performing design reviews for several innovative SMR designs, mostly non-water cooled, including molten salt reactors (MSR)
China	• **HTR-PM** is in advanced stage of construction. Commissioning expected in 2018. • **ACP100** completed IAEA generic reactor safety review. CNNC plans to build **ACP100** demo-plant in **Hainan Provence** in the site where NPPs are already in operation. • China has 3 floating SMR designs (**ACP100S**, **ACPR50S** and **CAP-F**)
France	• Propose a new French SMR design (Consortium of TechnicAtome, CEA, EDF, Naval Group, Investir L`Avenir)
Republic of Korea	**SMART** (100 MWe) by KAERI certified in 2012. • SMART undertakes a pre-project engineering in Saudi Arabia, for near-term construction of 2 units. • Updated design with increased power and more passive safety features developed • New design will be submitted for certification in Korea in parallel with KSA licensing application
Russian Federation	• Akademik Lomonosov floating NPP with 2 modules of **KLT40S** is in advanced stage of construction and commissioning. Aiming for commissioning in 2019. • AKME Engineering will develop a deployment plan for **SVBR100**, a eutectic lead bismuth cooled, fast reactor.
United Kingdom	• **Rolls-Royce** recently introduced **UK-SMR**, a 450 MW(e) PWR-based design; many organizations in the UK work on SMR design, manufacturing & supply chain preparation • Identifying *potential* sites for future deployment of SMR; • Government supporting 8 advanced designs (Phase I) to determine its feasibility
United States of America	• The US-NRC has started design review for **NuScale** (600 MW(e) from 12 modules) from April 2017, aiming for FOAK plant deployment in Idaho Falls. • **TVA** submitted early site permit **(ESP)** for Clinch River site, design is still open.

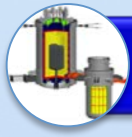
Status and major accomplishment in Embarking Countries



Countries	Recent Milestone
Saudi Arabia	• **Vision 2030 → National Transformation Program 2020: Saudi National Atomic Energy Project:** • **K.A.CARE** performs a PPE with **KAERI** to prepare a construction of 2 units of **SMART** • An MOU between K.A.CARE and CNNC on **HTGR** development/deployment in KSA
Indonesia	• Through an open-bidding, an experimental 10 MW(th) **HTR-type SMR** was selected in March 2015 for a concept design aiming for a deployment in mid 2020s • Site: R&D Complex in Serpong where a 30 MW(th) research reactor in operation • MoU with INET and considering commercial deployment in future in the eastern region
Jordan	• Jordan decided to deploy a SMR and is down-selecting on 3 possible designs / vendors
Poland	• **HTGR** for process heat application to be implemented in parallel to large LWRs • **10 MW(th) experimental HTGR at NCBJ** proposed possibly with EU cooperation
Tunisia	• STEG, the National Electricity and Gas Company is active in performing technology assessment for near-term deployable **water-cooled SMRs**
Kenya	• Requested support on human capacity building for Reactor Technology Assessment that covers **SMRs** through **IAEA-TC Project**

Status of SMR pre-licensing in Canada

Vendor	Name / cooling type	(MWe)	Applied for	Review start date	Status
Terrestrial Energy Inc.	IMSR Integral Molten Salt Reactor	200	Phase 1	April 2016	Phase 1 complete
			Phase 2	December 2018	Phase 2 assessment in progress
NuScale Power, LLC	NuScale Integral Pressurized Water Reactor	50	Phase 2*	April 1, 2019	Service agreement signed. Assessment pending
Ultra Safe Nuclear Corporation / Global First Power	MMR-5 and MMR-10 High Temperature Gas	5-10	Phase 1	December 2016	Phase 1 complete
			Phase 2	Pending	PHASE 2 Service Agreement in place – Project start pending
Westinghouse Electric Company, LLC	eVinci Micro Reactor Solid core and heat pipes	up to 25 MWe	Phase 2*	Pending early 2019	Service agreement under development
LeadCold Nuclear Inc.	SEALER Molten Lead	3	Phase 1	January 2017	Phase 1 on hold at vendor's request
Advanced Reactor Concepts Ltd.	ARC-100 Liquid Sodium	100	Phase 1	Fall 2017	Assessment in progress
URENCO	U-Battery High-Temperature Gas	4	Phase 1	To be determined	Service agreement under development
Moltex Energy	Moltex Energy Stable Salt Reactor Molten Salt	300	Series Phase 1 and 2	December 2017	Phase 1 assessment in progress
SMR, LLC. (A Holtec International Company)	SMR-160 Pressurized Light Water	160	Phase 1	July 2018	Assessment in progress
StarCore Nuclear	StarCore Module High-Temperature Gas	10	Series Phase 1 and 2	To be determined	Service agreement under development

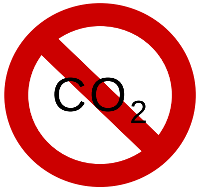


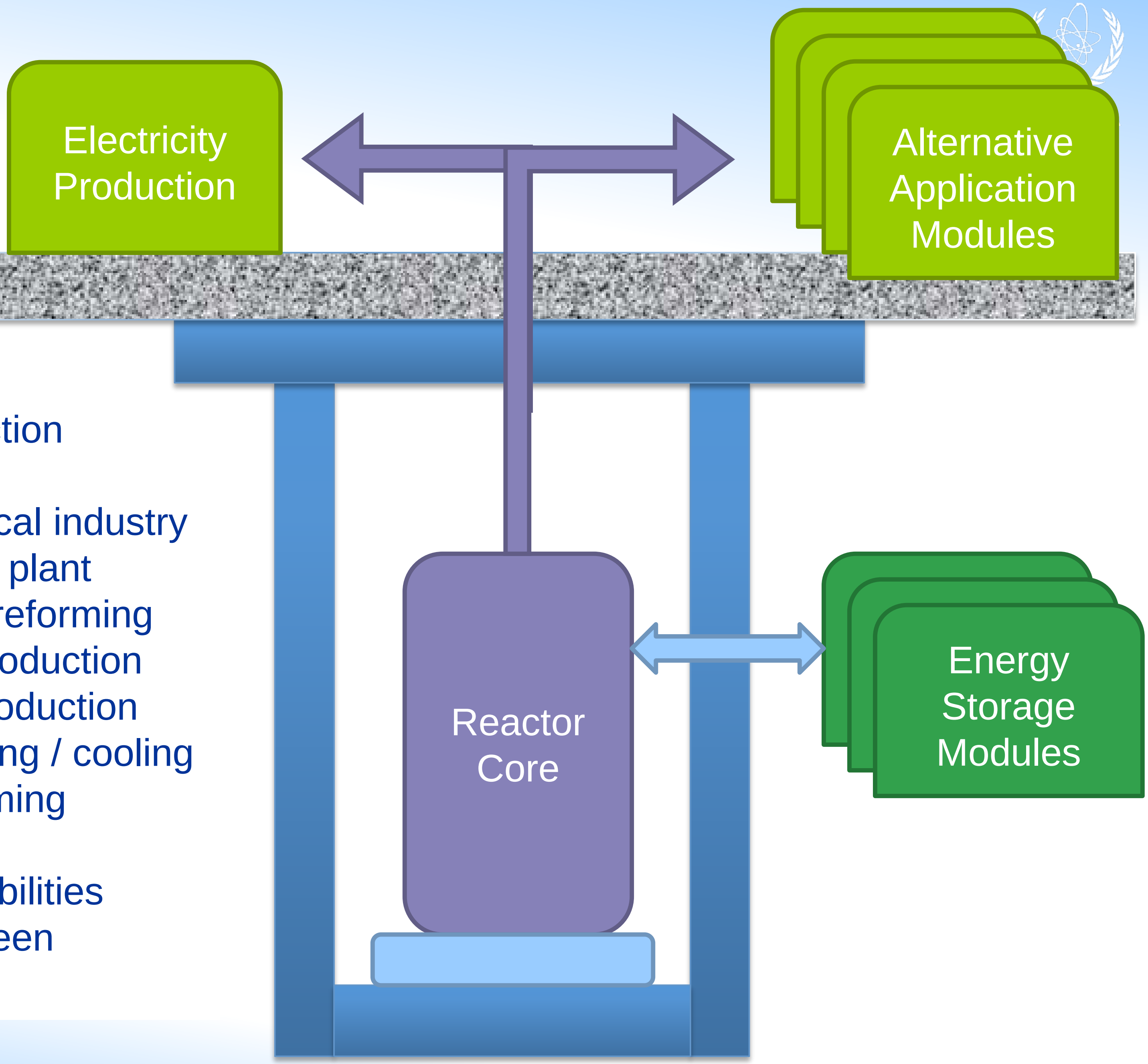
Cogeneration and Integration with Renewables

- **Advantages of cogeneration**
- **A generic flexible cogeneration configuration**
- **Hybrid systems / potential for integration with renewables**

Advantages of Cogeneration

- Improve economics of NPPs (Better Revenue due to):
  - Better utilization of fuel
  - Sharing of infrastructures
  - Production of more than one product
- Improve NPP efficiency (Energy saving):
  - Recycling of waste heat
  - Accommodate seasonal variations of electricity demand
  - Rationalization of power production (use of off-peak)
  - Improve the value of heat (use low-quality steam)
  - Meet demand for energy-intensive processes (desalination, hydrogen, etc.).
- Sustain the environment (keep Clean):
  - Reduce use of fossil fuel
  - Reduce Impacts

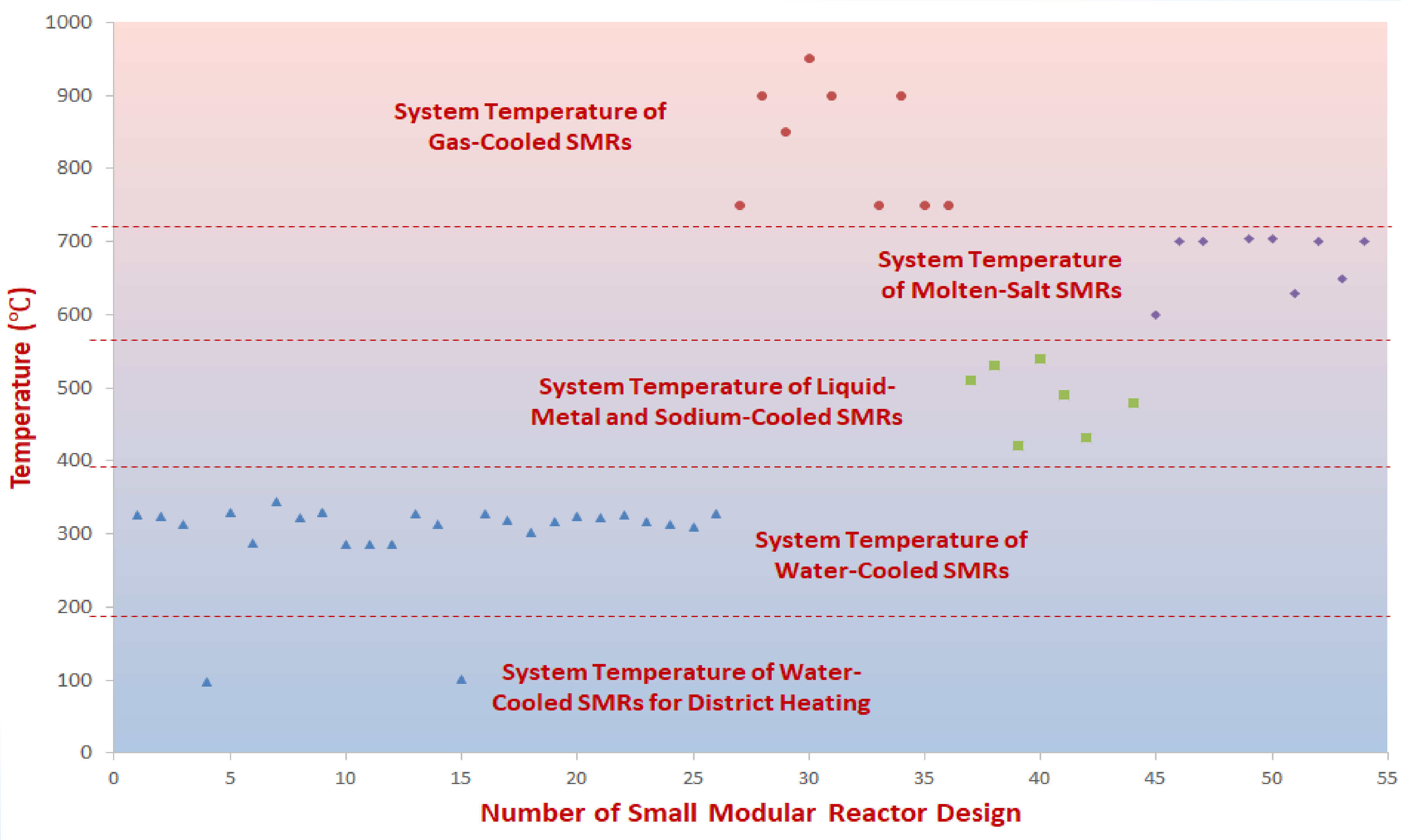




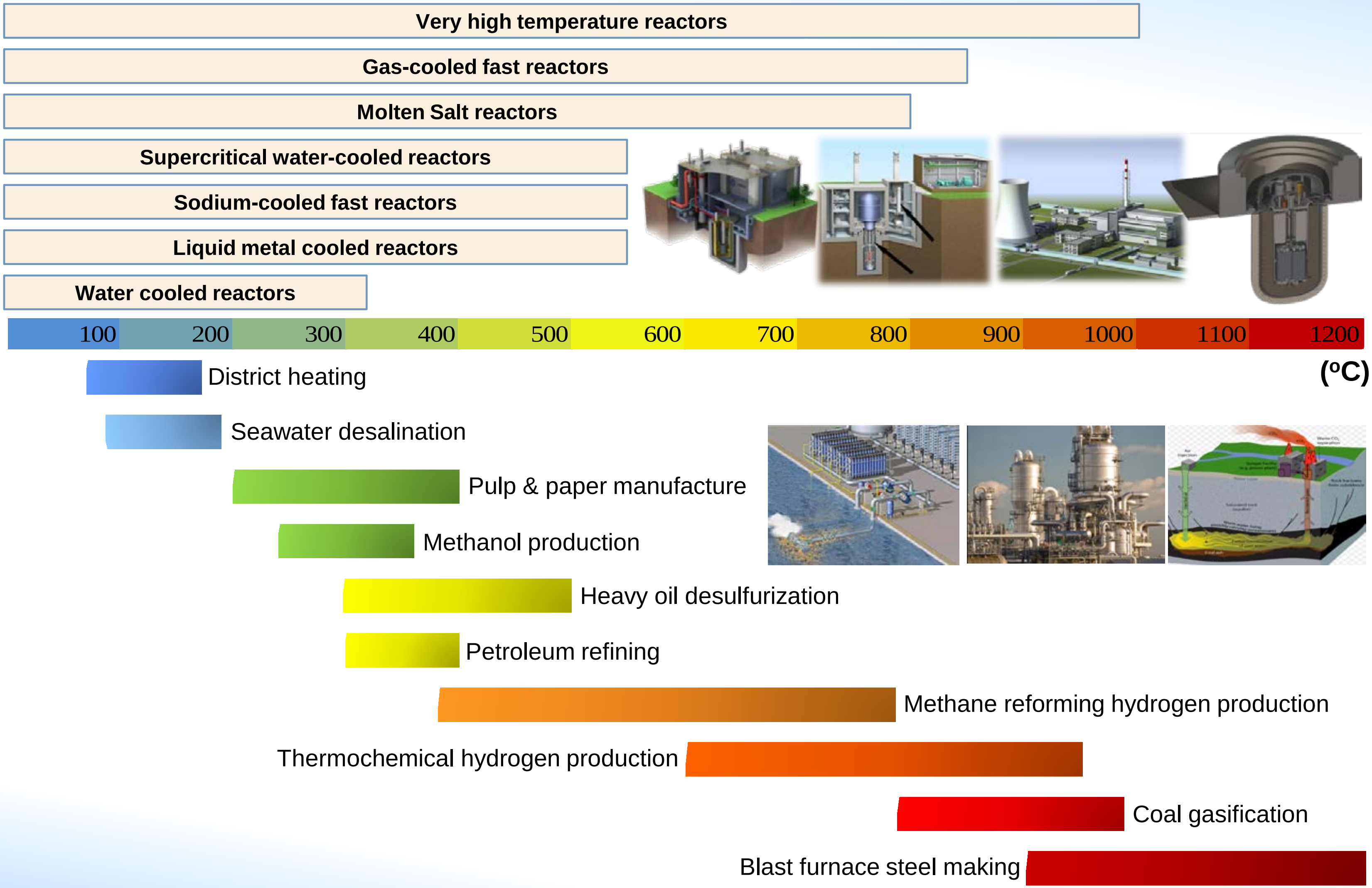
Modules:

- Electricity production
- Process heat
  - Petro-chemical industry
  - Desalination plant
  - Oil and gas reforming
  - Hydrogen production
  - Ammonia production
  - District heating / cooling
  - Waste reforming
- Energy storage
- Load follow capabilities
  - Switch between applications

SMR Designs Based on Core Exit Temperature

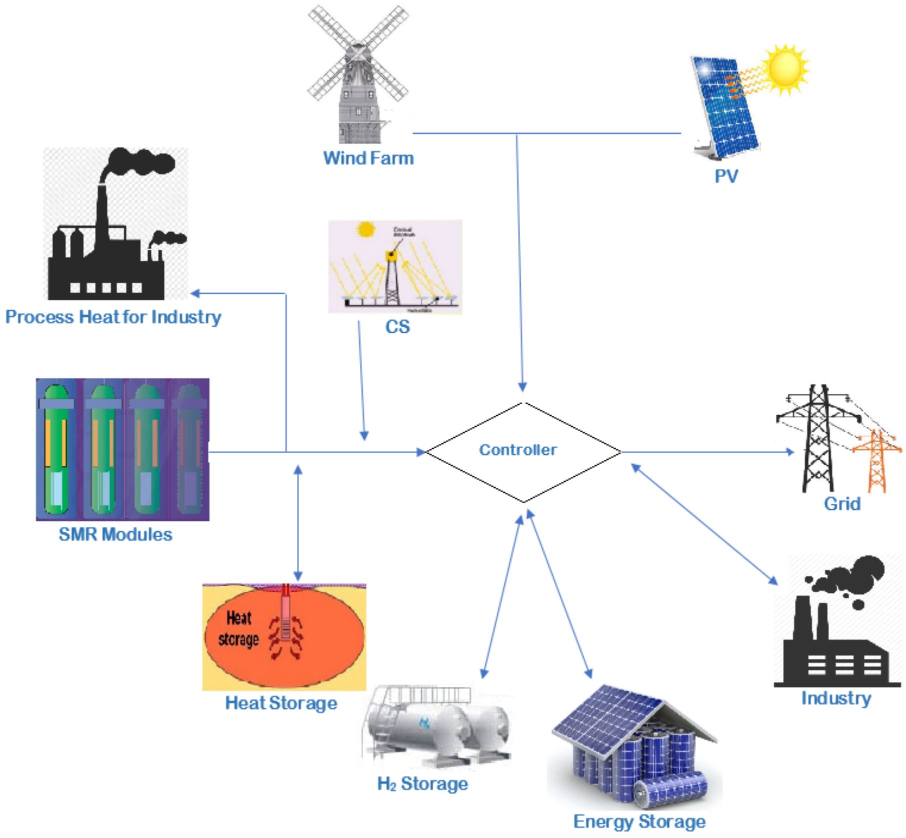


Non Electric Applications of SMRs



Role of SMRs in Climate Change

SMR Renewables Hybrid Energy System to Reduce GHG Emission



TECDOC on Options to Enhance Energy Supply Security using Hybrid Energy Systems based on SMR – Synergizing Nuclear and Renewables; being finalised

Exploring Synergies between Nuclear and Renewables: IAEA Meeting Discusses Options for Decarbonizing Energy Production and Cogeneration

SMR design characteristics

- Characteristics
- Site considerations / EPZ
- SMR characteristics that may be important to nuclear security discussion

Salient Design Characteristics

Simplification by Modularization and System Integration

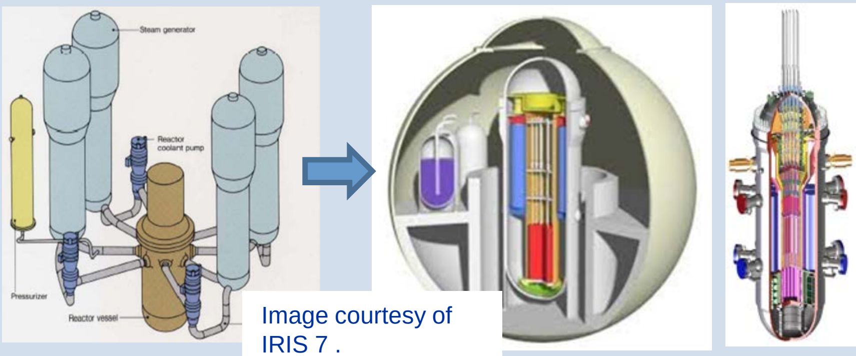


Image courtesy of IRIS 7 .

Multi-module Plant Layout Configuration

Image courtesy of NuScale Power Inc.

Underground construction for enhanced security and seismic

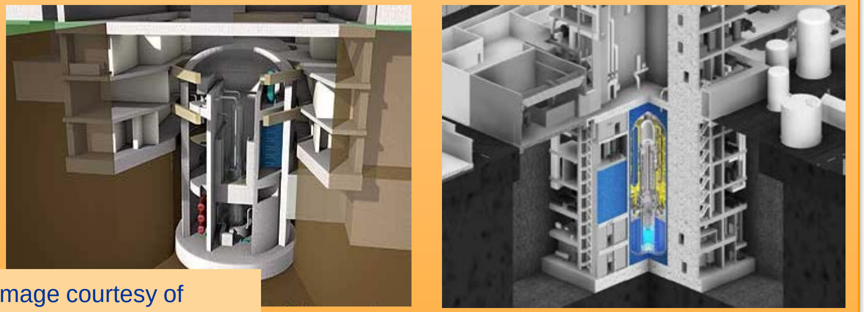


Image courtesy of BWX Technology, Inc.

Enhanced Safety Performance through Passive System

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

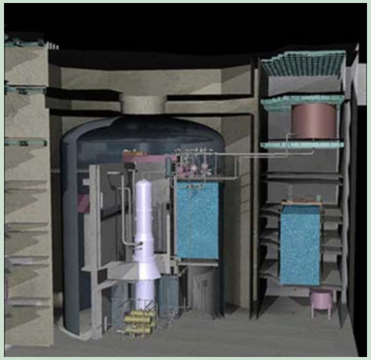
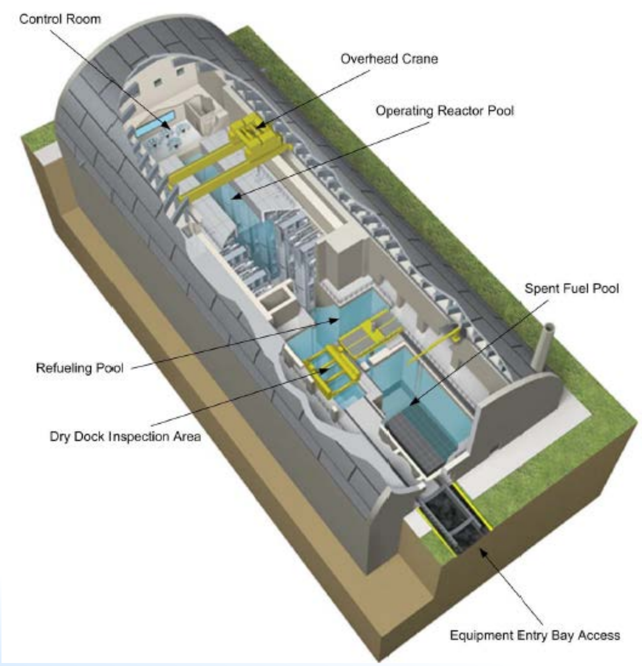
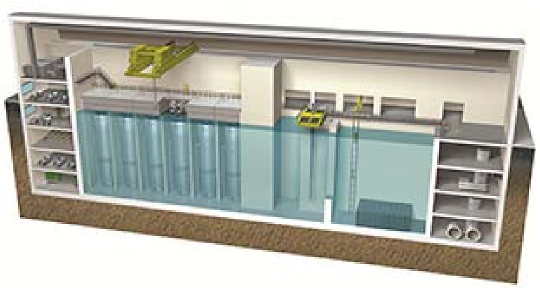


Image courtesy of BWX Technology, Inc.

SMR Key Design Features: Modular

- Multi modules configuration
  - Two or more modules located in one location/reactor building and controlled by single control room
    - → reduced staff
    - → new approach for I&C system





Images reproduced courtesy of NuScale Power Inc. and BWX Technology, Inc., USA.

Progress made in applying a graded approach

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- Nuclear Regulatory Commission staff agreed with the Tennessee Valley Authority that scalable emergency planning zones (EPZs) for small modular reactors are feasible
- …The preliminary finding

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US regulators discuss smaller SMR emergency zones

28 August 2018

Share

CLARIFICATION: NRC staff have concluded the TVA methodology can be used in the future to determine if a reduced emergency planning zones is justified, and has not made a decision on EPZ criteria for small modular reactors.

The US Nuclear Regulatory Commission (NRC) has concluded that Tennessee Valley Authority's (TVA's) methodology can be used in the future to determine if a reduced emergency planning zone is justified for small modular reactors, a spokesman for the Commission told *World Nuclear News* today. It has not yet agreed that an EPZ around small modular reactors can be scaled to reflect their reduced risks rather than the mandatory ten-mile EPZ required for the USA's current light-water reactor fleet.

Characteristics of SMRs that may have an impact on nuclear security considerations….

- SMR interest in many IAEA Member States, also from many new-comer countries planning to deploy NPP for the first time.
- Modular designs may require construction or installation in close proximity with operating modules
- Fuel types / cycles
  - Increased enrichment (many designs)
  - alternative fuel cycles (waste burners)
  - On-line refueling / lifetime core
- Underground installations / Floating platforms / transportable SMRs
- Factory manufacturing and transport of completed reactor or sub-modules
- Control room staffing for multi-module SMR Plants (one operator may operate more than one reactor module)
- Siting:
  - Smaller sites (reduced EPZ / reduced site boundary)
  - May replace older coal power stations / close to cities
  - Remote areas, northern territories, islands
  - Enhanced potential for non-electric applications so SMRs may be installed close to industrial heat users
- Many designs with enhanced safety characteristics often relying on inherent safety characteristics and/or passive safety systems

Perceived advantages and potential challenges

– **Advantages and challenges**

Advantages, Issues & 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

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

Technology Issues
- Licensability (FOAK designs)
- Non-LWR technologies
- Operability and Maintainability
- Staffing for multi-module plant; Human factor engineering;
- Supply Chain for multi-modules
- Advanced R&D needs

Non-Techno Issues
- Economic competitiveness
- Plant cost estimate
- Regulatory infrastructure
- Availability of design for newcomers
- Physical Security
- Post Fukushima action items on institutional issues and public acceptance

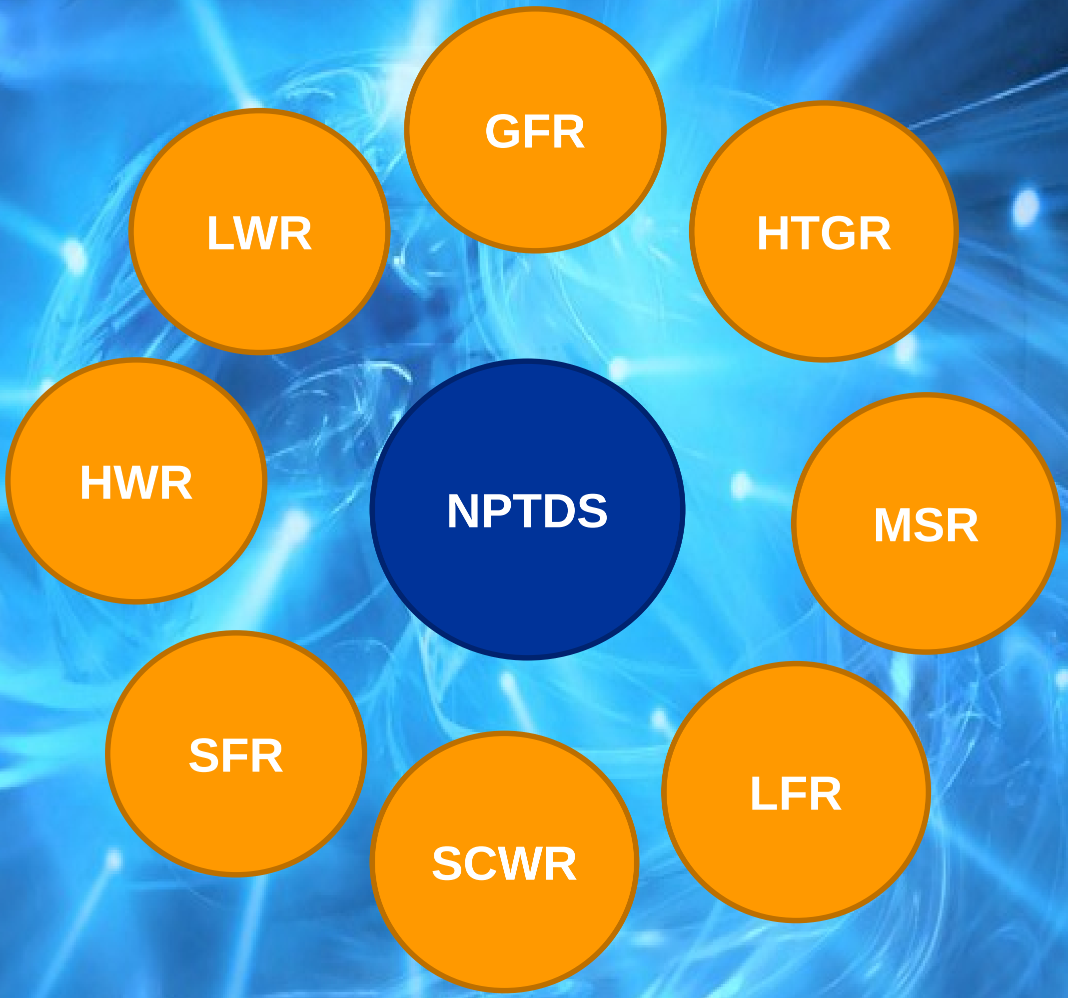
IAEA Activities

- **Technology Development**
- **Main areas and mechanisms available**
- **Coordinated Research Projects**
- **Publications**
- **Future needs**
- **Toolkits, Portals and Training Simulators**

NPTDS

Nuclear Power Technology Development Section

- Department of Energy
- Division Nuclear Power
- NPTDS currently works on all advanced and innovative reactor technologies
- Provides support to member states on all issues related to technology



Programme Activities: TWGs, Conferences, CRPs, International Experts Meetings, TMs

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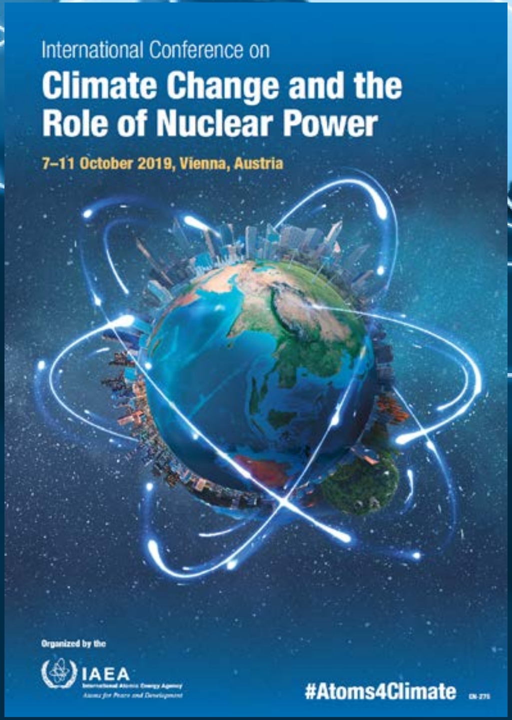
- Collaborating Centers
- Coordinated Research Projects
- Technical Meetings
- Training and Workshops

Conferences



Technical Working Groups

- TWG-SMR: 20
- TWG-LWR: 22
- TWG-HWR: 7
- TWG-FR: 27
- TWG-GCR: 17
- TWG-ND : 14

GC events


Nuclear High Temperature Heat Could Replace Fossil Fuels in Industry, Mitigate Climate Change

Tuesday 19 September 2017 11:30 CEST
Matt Fisher, IAEA Office of Public Information and Communication

International Technical Working Group on SMR

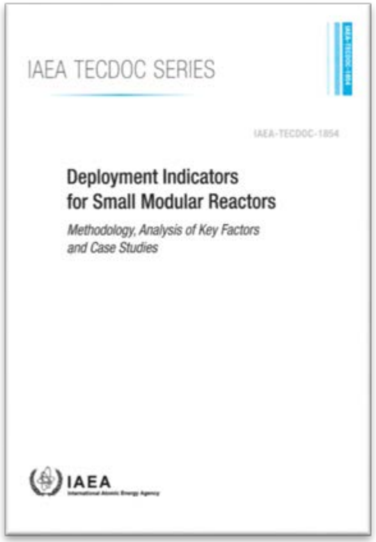
- To advice and support IAEA programmatic planning and implementation in areas related to technology development, design, deployment and economics of SMRs
- 14 Member States and two International Organizations: European Commission and OECD-NEA as invited observers:

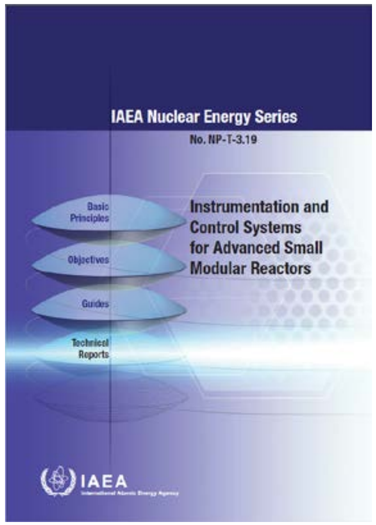
- More countries potentially to join: *Canada, Japan, Saudi Arabia, South Africa, Tunisia and Ukraine*
- Three technical subgroups established:
  - **SG-1:** Development of Generic Users Requirements and Criteria (GURC)
  - **SG-2:** Research, Technology Development and Innovation; Codes and Standards
  - **SG-3:** Industrialization, design engineering, testing, manufacturing, supply chain, and construction technology
- TWG will also address specifically SMR for Non-Electric Applications and coupling with renewables
- 1st TWG Meeting for SMR held on 23 - 26 April 2018 in Vienna
- 2nd Meeting scheduled for 8 – 11 July 2019 in Vienna

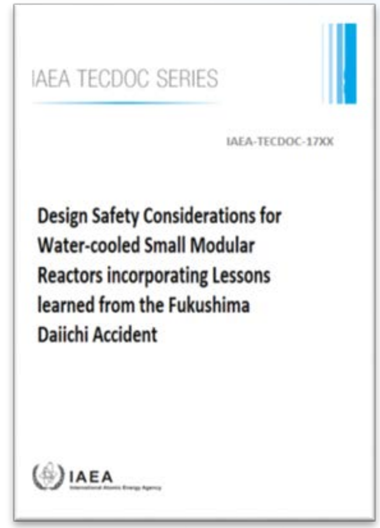
Coordinated Research Ppojects relevant to SMRs

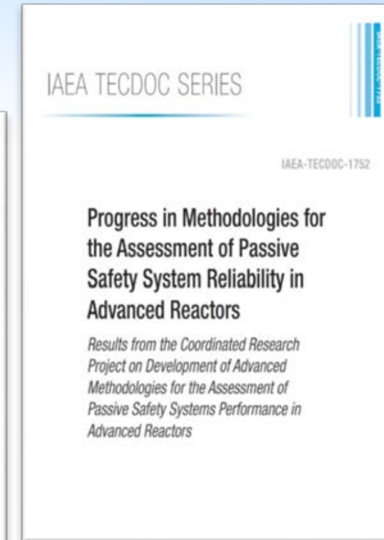
1. High Temperature Gas Cooled Reactor Physics, Thermal-Hydraulics and Depletion Uncertainty Analysis
2. High Temperature Gas Cooled Reactors Safety Design
3. Development of Approaches, Methods and Criteria for Determining Technical Basis for EPZ for SMR Deployment
4. Design and Performance Assessment of Passive Engineered Safety Features in Advanced SMRs.

Recent Publications and Forthcoming Ones









- NES **Technology Roadmap** for Small Modul Reactor Deployment
- TECDOC: Status of Approaches for Environmental Impact Assessment for **SMR** Deployment
- TECDOC: Options to Enhance Energy Supply Security using **Hybrid Energy Systems**

Regional TC EU Project –

Facilitating Capacity Building for Small Modular Reactors: Technology Developments, Safety Assessment, Licensing and Utilization.

IAEA

- Member states in Europe / Eurasia area that plan to initiate or to expand their nuclear energy programme have identified the need to increase their capacity
  - to make knowledgeable decisions…
  - particularly to become capable to identify and perform technical assessments for SMRs commercially available for near term deployment.

- Overall objective to contribute to a new way to meet the European demand for clean and emission-free flexible sources of electricity.

- Technically aspects supported by NE and NS Departments

- A two-year project (2018/19)

- 3 Workshops in 2018: SMR technology (x2) and on Infrastructure, economic and financing aspects

- In 2019 activities on Non-electric applications, IAEA technology assessment, Regulatory framework and licensing issues; Siting and Design Specific Issues

RER 2/014 Participants / beneficiaries

Albania	FYR Macedonia
Armenia	Poland
Azerbaijan	Romania
Croatia	Russia
Czechia	Slovakia
Greece	Tajikistan
Hungary	Turkey
Lithuania	Ukraine

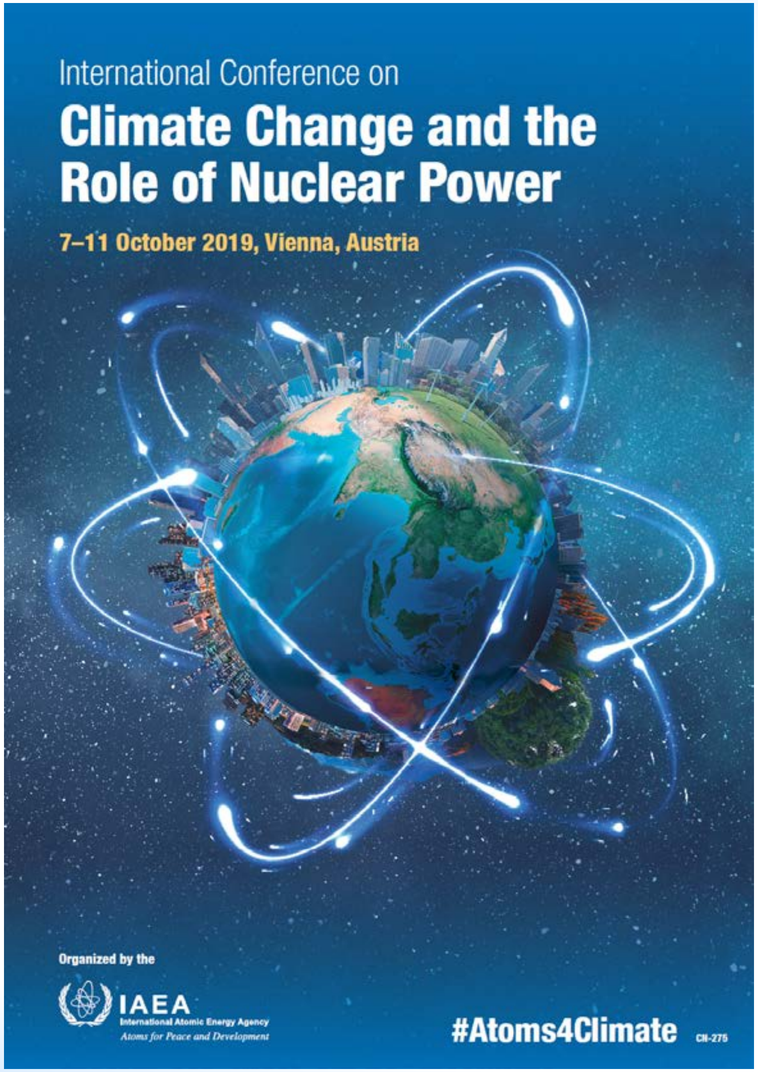
- The IAEA is acting as the secretariat for the SMR Regulators' Forum
- Established working groups:
  - Graded approach; Defence in Depth; Emergency planning zone
  - Report available at: https://www.iaea.org/topics/small-modular-reactors/smr-regulators-forum
  - Current topics: Licensing issues; Design and Safety; Manufacturing, Commissioning and Operations

- Other NS activities to address MS needs and requests is being discussed in a newly formed joint working group on SMRs:
  - Technology-neutral safety approach for new reactor designs
  - Activities to consider transportable SMRs
  - Security-related issues
  - Coordination and one-house approach

Summary

- ❖Many SMRs under development …
- ❖Wide variety of technologies under consideration
- ❖Only 3 SMRs under construction; only few more with specific deployment plans
- ❖Technology readiness differ substantially
- ❖Many IAEA member States interested

- ❖IAEA is engaged to support Member States interested in SMR Technology Development and Deployment



iaea.org/Atoms4Climate

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#Atoms4Climate

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Thank you!

For inquiries on SMR, please contact:

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Design Features and Deployment Status of Water Cooled SMRs (Land Based)

IAEA

Design	Output MW(e)	Type	Designers	Country	Status
WATER COOLED SMALL MODULAR REACTORS (LAND BASED)					
CAREM	30	PWR	CNEA	Argentina	Under construction
ACP100	100	PWR	CNNC	China	Basic Design
CAP200	150/200	PWR	CGNPC	China	Conceptual Design
DHR400	(District Heating)	LWR(pool type)	CNNC	China	Basic Design
IRIS	335	PWR	IRIS Consortium	Multiple Countries	Conceptual Design
DMS	300	BWR	Hitachi GE	Japan	Basic Design
IMR	350	PWR	MHI	Japan	Conceptual Design
French-SMR	170	PWR	French Consortium	France	Conceptual Design
SMART	100	PWR	KAERI	Republic of Korea	Certified Design
ELENA	68 kW(e)	PWR	National Research Centre "Kurchatov Institute"	Russian Federation	Conceptual Design
KARAT-45/100	45/100	BWR	NIKIET	Russian Federation	Conceptual Design
RITM-200	50 × 2	PWR	OKBM Afrikantov	Russian Federation	Under Development
RUTA-70	70 MW(t)	PWR	NIKIET	Russian Federation	Conceptual Design
UNITHERM	6.6	PWR	NIKIET	Russian Federation	Conceptual Design
VK-300	250	BWR	NIKIET	Russian Federation	Detailed Design
UK-SMR	443	PWR	Rolls-Royce and Partners	United Kingdom	Mature Concept
mPower	195 × 2	PWR	BWX Technologies	United States of America	Under Development
NuScale	50 × 12	PWR	NuScale Power	United States of America	Under Development
SMR-160	160	PWR	Holtec International	United States of America	Preliminary Design
W-SMR	225	PWR	Westinghouse	United States of America	Conceptual Design

Design Features and Deployment Status of Water Cooled SMRs (Marine Based)

IAEA

Design	Output MW(e)	Type	Designers	Country	Status
WATER COOLED SMALL MODULAR REACTORS (MARINE BASED)					
ACPR50S	60	PWR	CGNPC	China	Preliminary Design
ABV-6E	6-9	Floating PWR	OKBM Afrikantov	Russian Federation	Final design
KLT-40S	70	Floating PWR	OKBM Afrikantov	Russian Federation	Under construction
RITM-200M	50 × 2	Floating PWR	OKBM Afrikantov	Russian Federation	Under Development
SHELF	6.4	Immersed NPP	NIKIET	Russian Federation	Detailed Design
VBER-300	325	Floating NPP	OKBM Afrikantov	Russian Federation	Licensing Stage

Design Features and Deployment Status of Gas Cooled SMRs

HIGH TEMPERATURE GAS COOLED SMALL MODULAR REACTORS					
Design	Output MW(e)	Type	Designers	Country	Status
HTR-PM	210	HTGR	INET, Tsinghua University	China	Under Construction
GTHTR300	300	HTGR	JAEA	Japan	Basic Design
GT-MHR	285	HTGR	OKBM Afrikantov	Russian Federation	Preliminary Design
MHR-T	205.5x4	HTGR	OKBM Afrikantov	Russian Federation	Conceptual Design
MHR-100	25 – 87	HTGR	OKBM Afrikantov	Russian Federation	Conceptual Design
A-HTR-100	50	HTGR	Eskom Holdings SOC Ltd.	South Africa	Conceptual Design
HTMR-100	35	HTGR	Steenkampskraal Thorium Limited	South Africa	Conceptual Design
PBMR-400	165	HTGR	PBMR SOC Ltd	South Africa	Preliminary Design
SC-HTGR	272	HTGR	AREVA	United States of America	Conceptual Design
Xe-100	35	HTGR	X-energy LLC	United States of America	Conceptual Design

Design Features and Deployment Status of Fast Neutron Spectrum SMRs

FAST NEUTRON SPECTRUM SMALL MODULAR REACTORS					
Design	Output MW(e)	Type	Designers	Country	Status
4S	10	LMFR	Toshiba Corporation	Japan	Detailed Design
LFR-AS-200	200	LMFR	Hydromine Nuclear Energy	Luxembourg	Preliminary Design
LFR-TL-X	5~20	LMFR	Hydromine Nuclear Energy	Luxembourg	Conceptual Design
BREST-OD-300	300	LMFR	NIKIET	Russian Federation	Detailed Design
SVBR-100	100	LMFR	JSC AKME Engineering	Russian Federation	Detailed Design
SEALER	3	Small Lead Cooled	LeadCold	Sweden	Conceptual Design
EM^2	265	GMFR	General Atomics	United States of America	Conceptual Design
SUPERSTAR	120	LMFR	Argonne National Laboratory	United States of America	Conceptual Design
WLFR	450	LFR	Westinghouse	United States of America	Conceptual Design

Design Features and Deployment Status of Molten Salt SMRs

MOLTEN SALT SMALL MODULAR REACTORS					
Design	**Output MW(e)**	**Type**	**Designers**	**Country**	**Status**
IMSR	190	MSR	Terrestrial Energy	Canada	Basic Design
CMSR	100-115	MSR	Seaborg Technologies	Denmark	Conceptual Design
CA Waste Burner	20	MSR	Copenhagen Atomics	Denmark	Conceptual Design
ThorCon	250	MSR	Martingale	International Consortium	Basic Design
FUJI	200	MSR	International Thorium Molten-Salt Forum: ITMSF	Japan	Experimental Phase
Stable Salt Reactor	37.5×8	MSR	Moltex Energy	United Kingdom	Conceptual Design
Stable Salt Reactor	300~900	MSR	Moltex Energy	United Kingdom	Pre-Conceptual Design
LFTR	250	MSR	Flibe Energy	United States of America	Conceptual Design
Mk1 PB-FHR	100	MSR	University of California, Berkeley	United States of America	Pre-Conceptual Design
MCSFR	50	MSR	Elysium Industries	USA and Canada	Conceptual Design