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Advanced Small and Medium Sized Reactors (SMRs) - Part 2

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International Atomic Energy Agency

Advanced Small and Medium Sized Reactors (SMRs) - Part 2

Prepared by Vladimir KUZNETSOV

(IAEA)

CONTENT

1. IAEA project "Common Technologies and Issues for SMRs"

2. Definition

3. SMR Story: Past, present, and future

4. Incentives for SMRs

5. Reactor types/ distinct groups/ nuclear data for calculations

6. Implementation potential

7. Examples

8. Economics and investments

9. Safety

10. Proliferation resistance

11. Security (physical protection)

12. Energy supply security

13. Load follow operation issues

14. Infrastructure issues

15. Near-term deployment opportunities

16. Summary: What could be done to support SMR deployment?

PROLIFERATION RESISTANCE

"Fundamentals of Proliferation Resistance for Innovative Nuclear Energy Systems" IAEA-STR-322

- ***Proliferation resistance is that characteristic of a nuclear energy system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, by States in order to acquire nuclear weapons or other nuclear explosive devices.***

- ***The degree of proliferation resistance results from a combination of, inter alia, technical design features, operational modalities, institutional arrangements and safeguards measures.***

PROLIFERATION RESISTANCE

- ***Intrinsic proliferation resistance features*** ***are those features that result from the technical design of nuclear energy systems, including those that facilitate the implementation of extrinsic measures.***

- ***Extrinsic proliferation resistance measures*** ***are those measures that result from States' decisions and undertakings related to nuclear energy systems – IAEA Safeguards Agreement Additional Protocol***

METHODOLOGIES FOR THE ASSESSMENT OF PROLIFERATION RESISTANCE ARE BEING DEVELOPED BY INPRO AND GIF

OBJECTIVES

- ***Proliferation resistance explicitly addressed in the plant design***

- ***An overall reactor and fuel cycle activity that is proliferation resistant, e.g., with limited overall amount of fissile material, high degree of contamination providing noticeable radiation barriers, fuel forms that are difficult to reprocess and/ or types of fuel that make it difficult to extract weapons-grade fissile material***

- ***Difficult unauthorized access to fuel during the whole period of its presence at the site and during transportation, and design provisions to facilitate the implementation of safeguards***

PROLIFERATION RESISTANCE – Design Approaches to Facilitate Safeguards (Example CNEA Argentina)

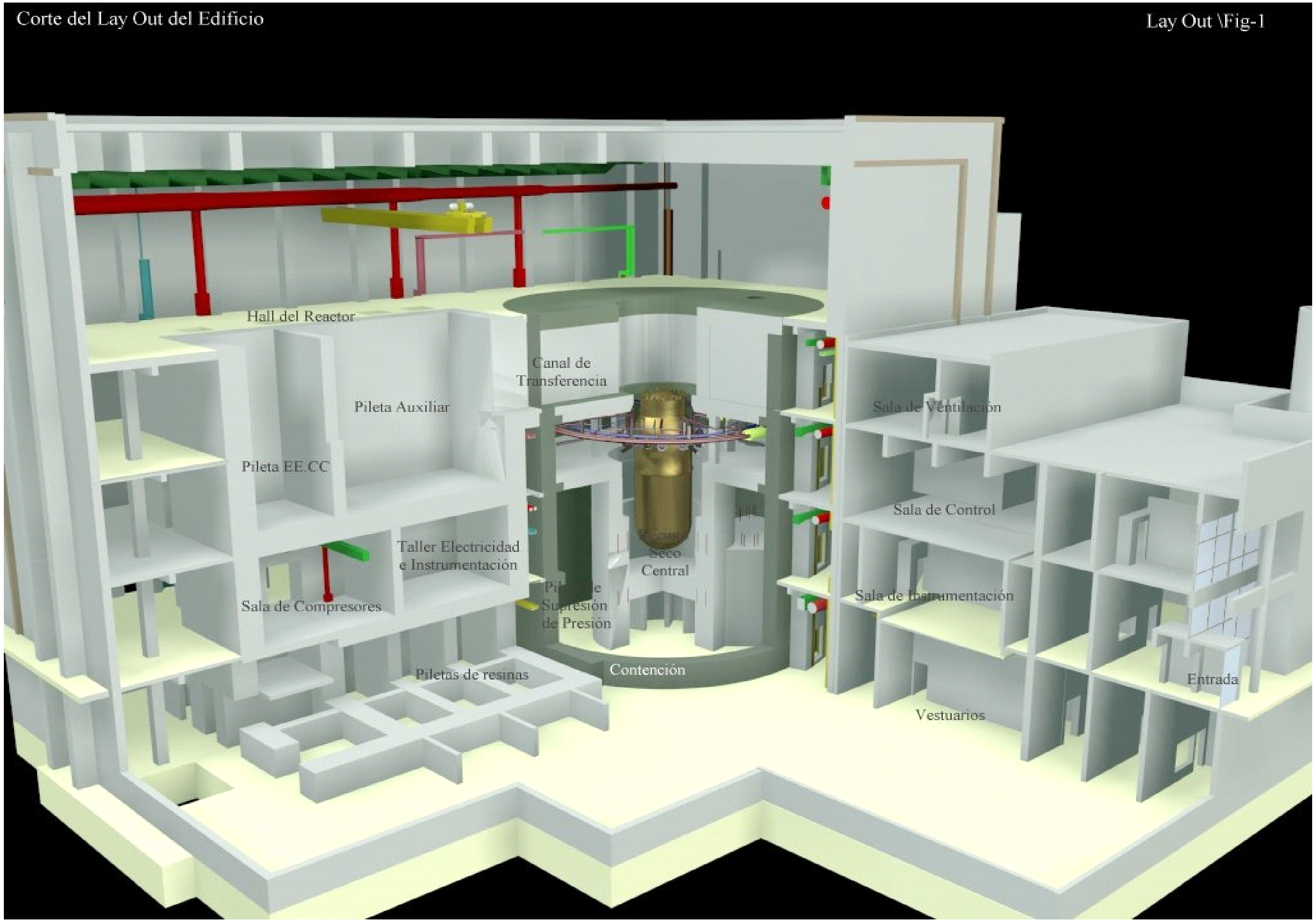


FIG. V-1. Plant layout of the CAREM (Courtesy of CNEA)

PROLIFERATION RESISTANCE

- ***Item accountancy on whole cores - an attractive intrinsic proliferation resistance feature potentially offered by factory fabricated and fuelled reactor with a long refuelling interval, capable of operation with a weld sealed reactor vessel (Small Reactors without On-site Refuelling)***

In addition:

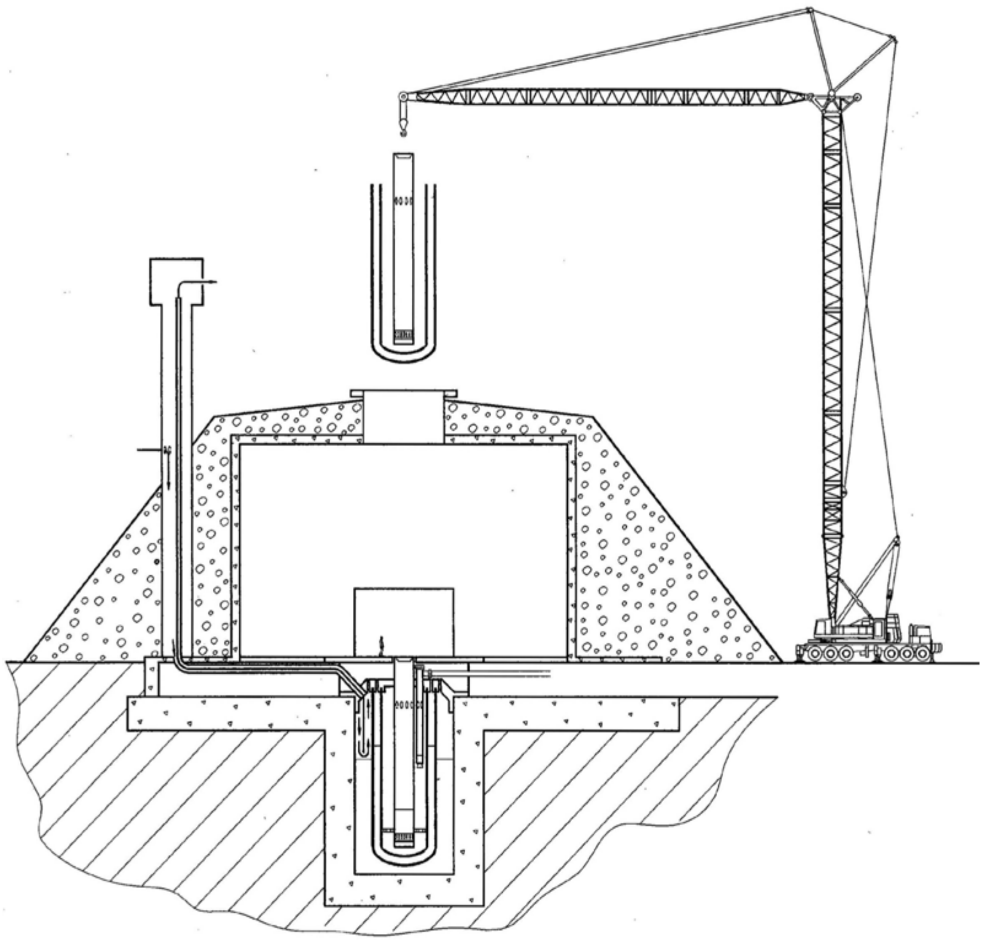
- SRWORs reduce obligations of the user for spent fuel and waste management

- SRWOR are an attractive options for remote regions, including those with severe climatic conditions

- SRWORs provide an attractive domain for reactor unit leasing

PROLIFERATION RESISTANCE

SRWOR – Example Argonne National Laboratory, USA



Rapid site assembly of STAR-H2 reactor (ANL, USA)

SECURITY (Physical Protection)

OBJECTIVE:

➢ ***To increase State awareness and ability to control and protect nuclear and other radioactive materials, nuclear installations and transports, from terrorist and other illegal actions, and to detect and respond to such events and provide engineering safety measures, as necessary.***

➢ **Deals with potential actions from non-State (sub-State as well as trans-national and international) groups**

1. Nuclear explosive device
   - Theft of nuclear weapon
   - Theft of material to make a nuclear explosive device
2. Radiological dispersal device
   - Theft of radioactive material/source
3. Sabotage
   - of a facility or transport to cause dispersal of radioactivity

SECURITY (Physical Protection)

OBJECTIVE:

➢**To increase State awareness and ability to control and protect nuclear and other radioactive materials, nuclear installations and transports, from terrorist and other illegal actions, and to detect and respond to such events and provide engineering safety measures, as necessary.**

FEATURES CONTRIBUTING TO MEETING THIS OBJECTIVE ***(INTRINSIC SECURITY FEATURES ?):***

•***Intrinsic proliferation resistance features***

•***Passive safety design features of nuclear installations***
(Maximized inherent and passive safety features coupled with reasonable combinations of reliable active and passive safety systems)

SECURITY (Physical Protection)

Design Measures that Strengthen the Plant Robustness in General – IAEA-TECDOC-1487 "Advanced Nuclear Plant Design Options to Cope with External Events" (2006)

- **A desirable goal for the safety characteristics of an innovative reactor is that its primary defence against serious accidents is achieved through its *design features preventing the occurrence of* such *accidents.***

- **An important criterion for setting up a goal for safety, either implicitly or explicitly, has been the probability of large release of radioactivity outside the plant or site boundary as a consequence of any credible accident scenario.**

- **Many of the innovative reactor designs aim to minimize this probability by introducing additional robustness (often as a consequence of larger design margins) and by introduction of passive safety features, which *do not require dependence on external sources of power or operator actions* to perform their stipulated functions.**

SECURITY (Physical Protection)

Design Measures that Strengthen the Plant Robustness in General, including both Internal and External Events and Combinations Thereof

Examples (IAEA-TECDOC-1487):

- **Capability to limit reactor power through inherent neutronic characteristics in the event of any failure of normal shutdown systems, and/ or**

- **Provision of a passive shutdown system not requiring any trip signal, power source, or operator action to effect a shutdown of the reactor if the safety critical plant parameters tend to exceed the design limits;**

- **Availability of a sufficiently large heat sink within the containment to indefinitely (or for a long grace period) remove core heat corresponding to abovementioned event;**

- **Availability of very reliable passive heat transfer mechanisms for the transfer of core heat to this heat sink;**

- **Measures to ensure deterministically the immunity of abovementioned functions from external events and malevolent human actions.**

Passive and Inherent Safety Features in Some SMR Designs

Compact containment layout and (partial) embedding of the reactor underground would facilitate protection against aircraft crash; however, the implications on protection against floods and on emergency access to certain equipment items need to be carefully examined

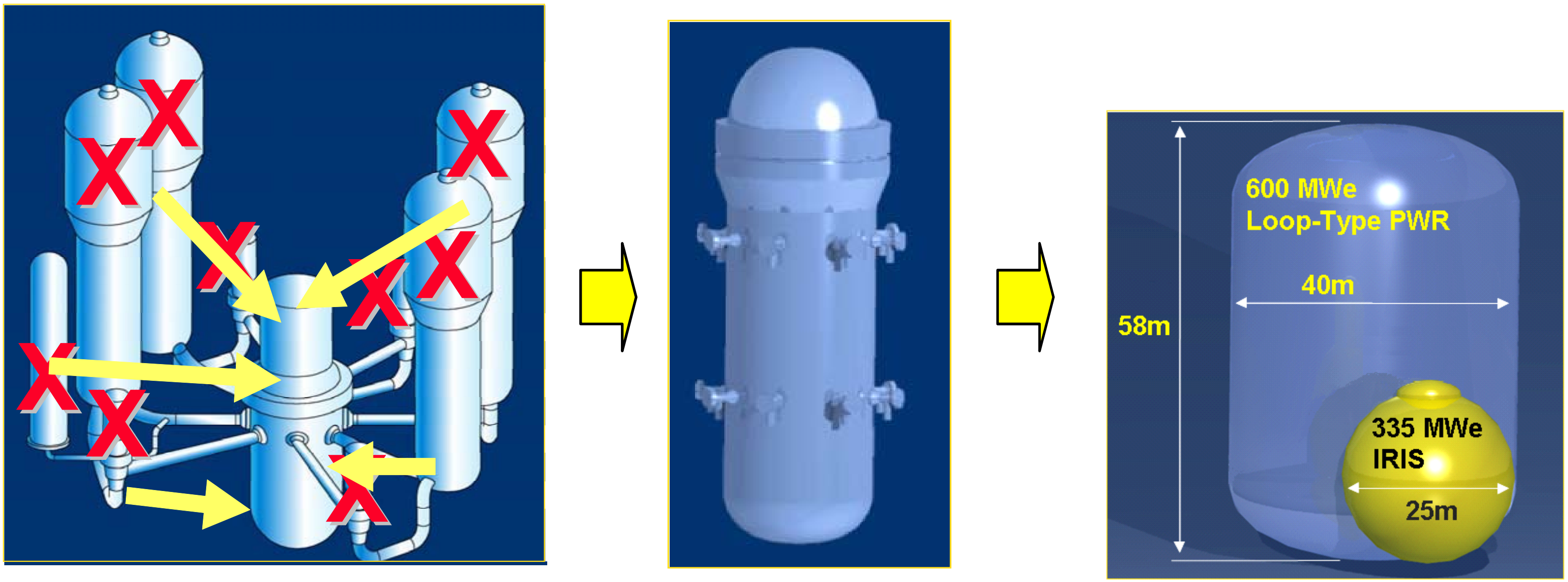


FIG. II-2. Compact integral layout of IRIS (Westinghouse, USA).

Passive and Inherent Safety Features in Some SMR Designs

Compact module size, embedding the reactor in an underground concrete silo, low pressure in the primary circuit, use of guard vessel, and passive shutdown capability of a reactor contribute to plant security with respect to both internal and external events including aircraft crash and missiles and malevolent insider actions

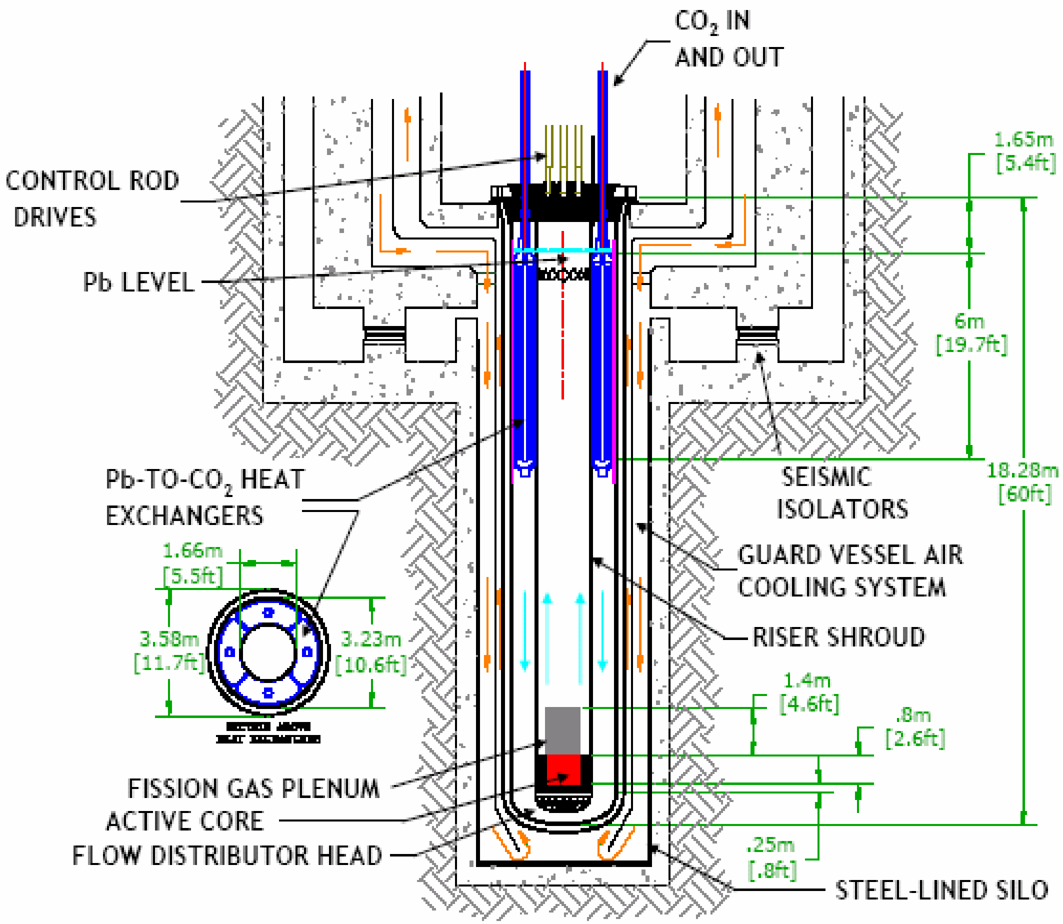


FIG. XXII-1. SSTAR reactor module (ANL, USA).

Non-consensus definition used in member states:

'Passive shutdown' = bringing the reactor to a safe low-power state with balanced heat production and passive heat removal, with no failure to the barriers preventing radioactivity release to the environment; all relying on the inherent and passive safety features only, with no operator intervention, no active safety systems being involved, and no external power and water supplies being necessary, and with the grace period infinite for practical purpose.

SECURITY (Physical Protection)

Security staffing requirements for an NPP are currently independent of a plant size (in some member states)

DILEMMA: How to make an isolated SMR competitive taking into account these requirements?

POTENTIAL SOLUTIONS (NO DEFINITE ANSWER AT THE MOMENT):

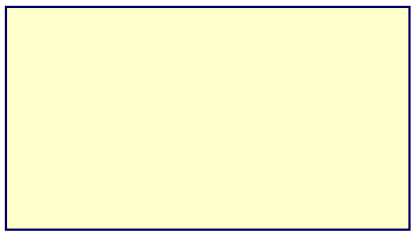
- ***Shared security if an NPP supports energy-intensive industrial site in a off-grid location?***
- ***Revise the requirements taking into account certain benefits offered by the plant itself?***

ENERGY SUPPLY SECURITY

Countries with small electricity grids/ Non-electric applications of a NPP requiring proximity to the user – Example from LEI (Lithuania)

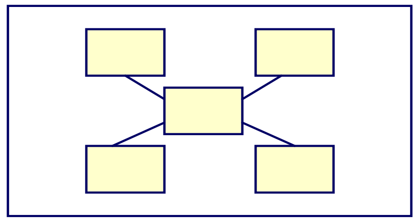
Consequences of a shutdown of one reactor:

LR ~ 1650 MW



Difficulties to compensate for lost energy supply supply

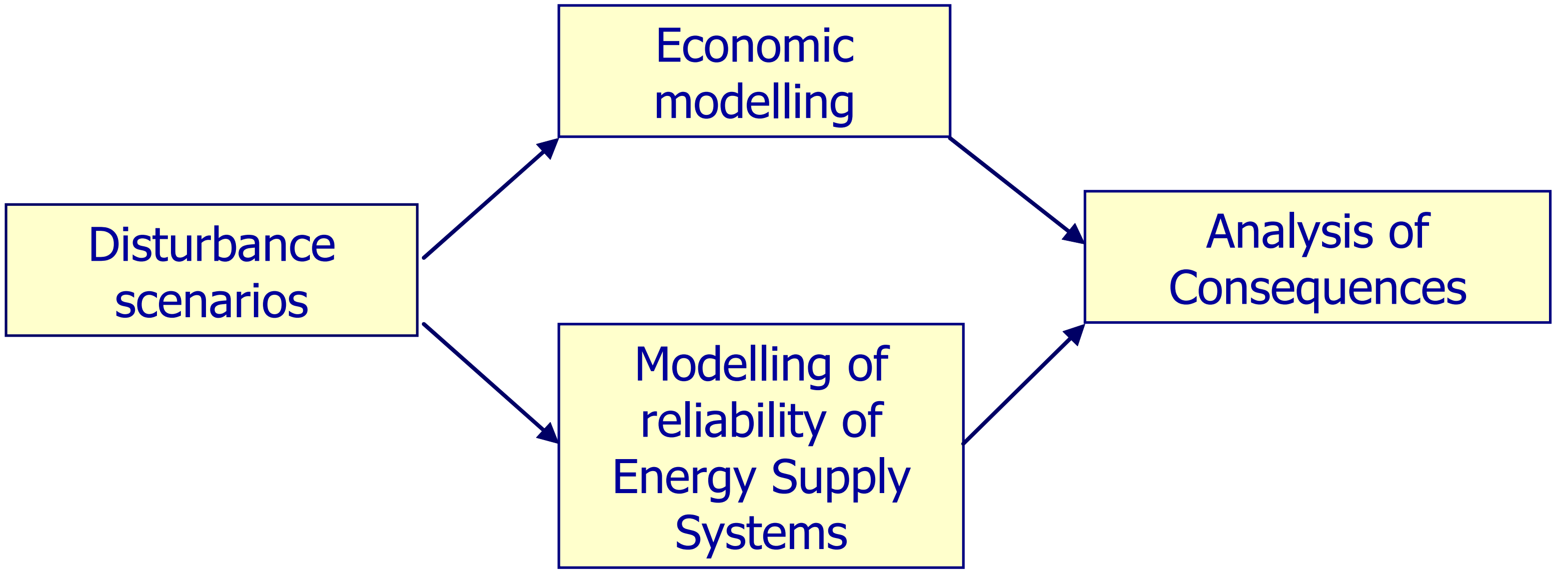
5 SMRs of 330 MW



More 'mild' variant with reserve energy available (4/5)

ENERGY SUPPLY SECURITY

Integrated energy security of supply (ESS) methodology – An example from LEI (Lithuania)



INNOVATIVE OPTIONS FOR LOAD FOLLOW OPERATION – *Example (C. Forsberg, ORNL – MIT, USA)*

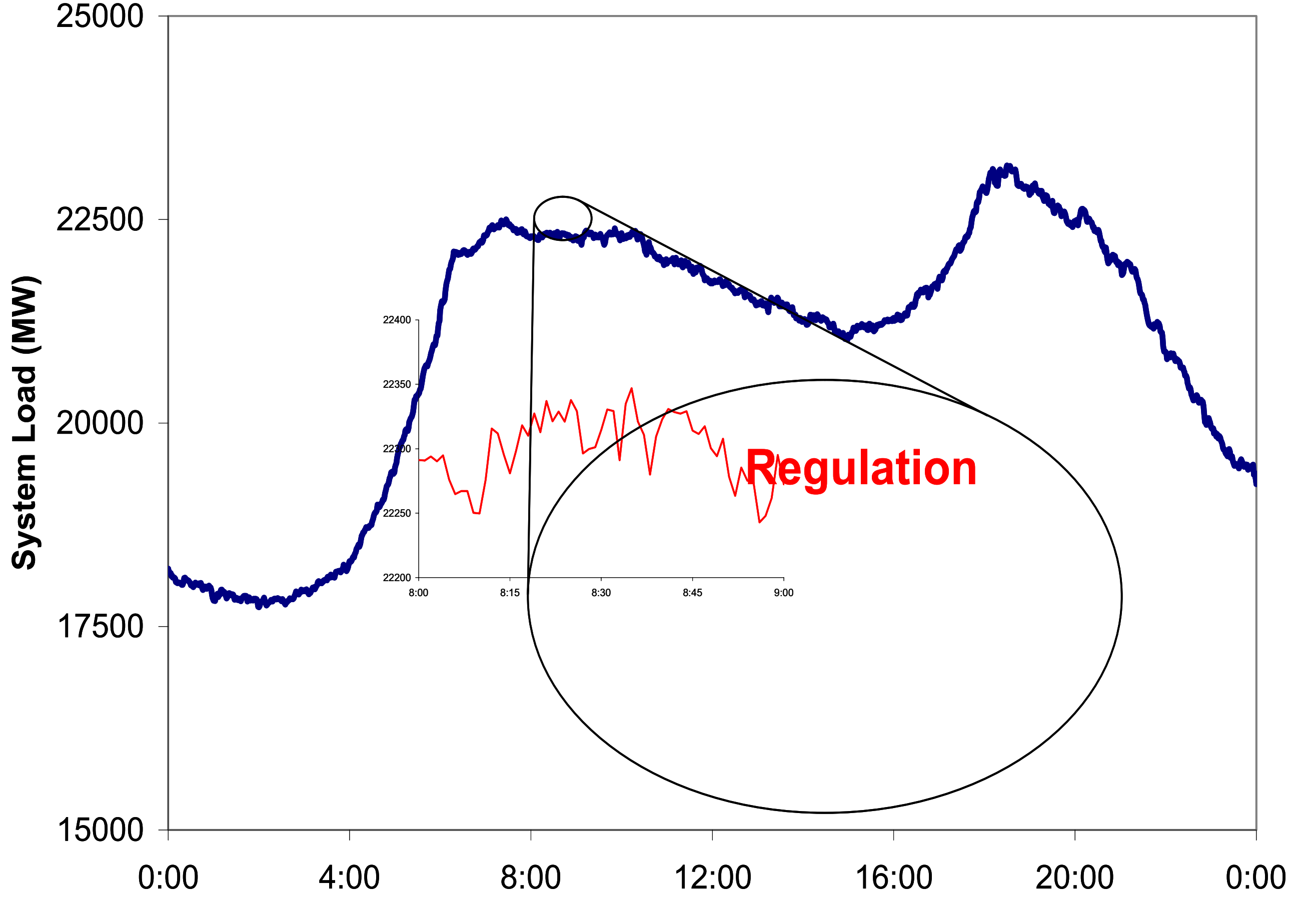


Fig. 5. A typical electric-power demand load on the ERCOT (Electric Reliability Council of Texas) electric grid over a 24-h period on a winter day.[16]

INNOVATIVE OPTIONS FOR LOAD FOLLOW OPERATION – *Example (C. Forsberg, ORNL – MIT, USA)*

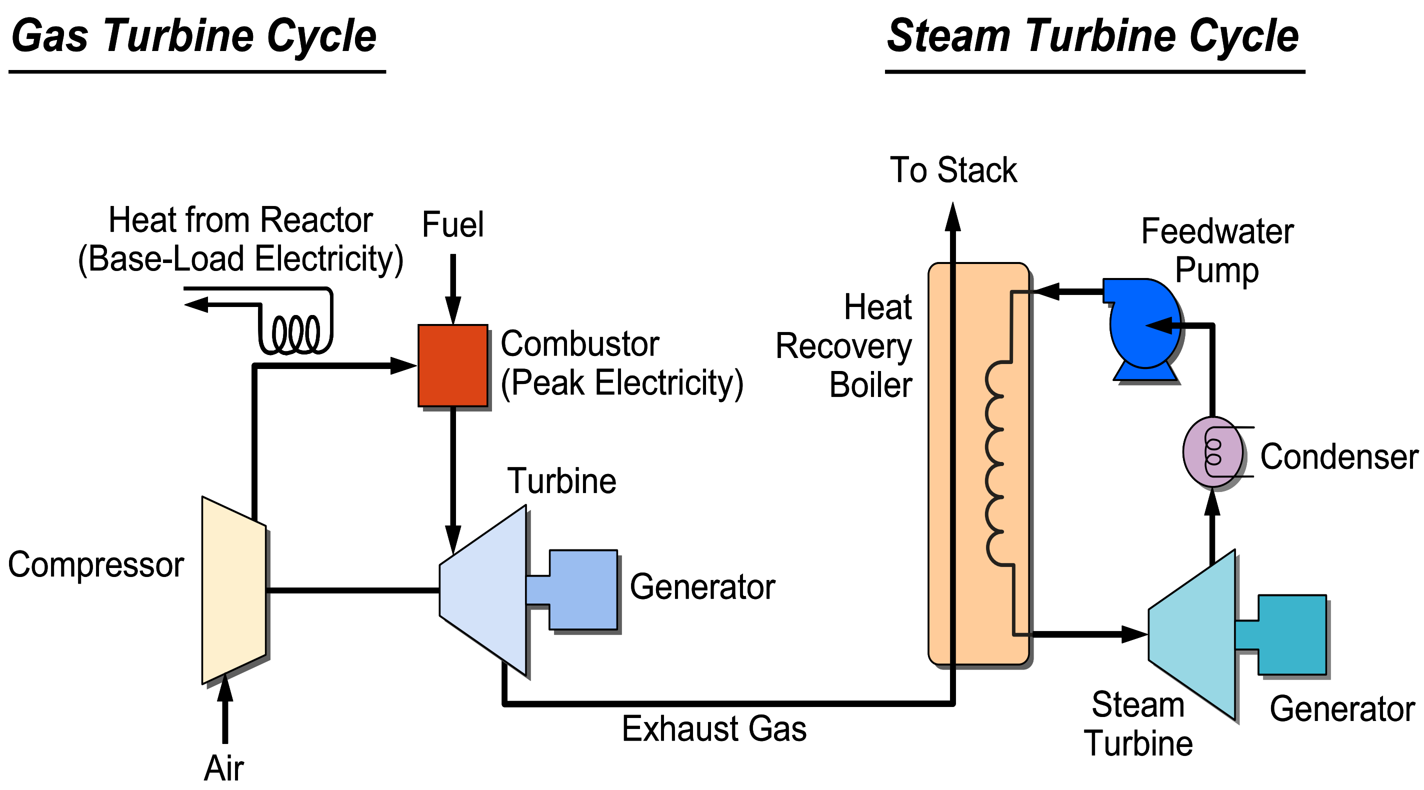
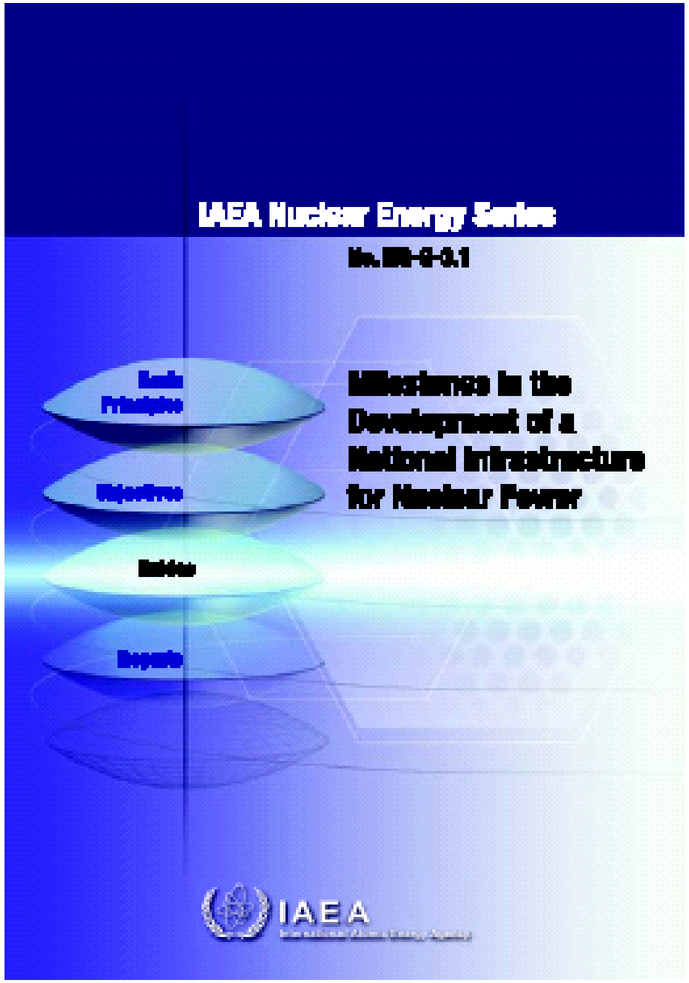
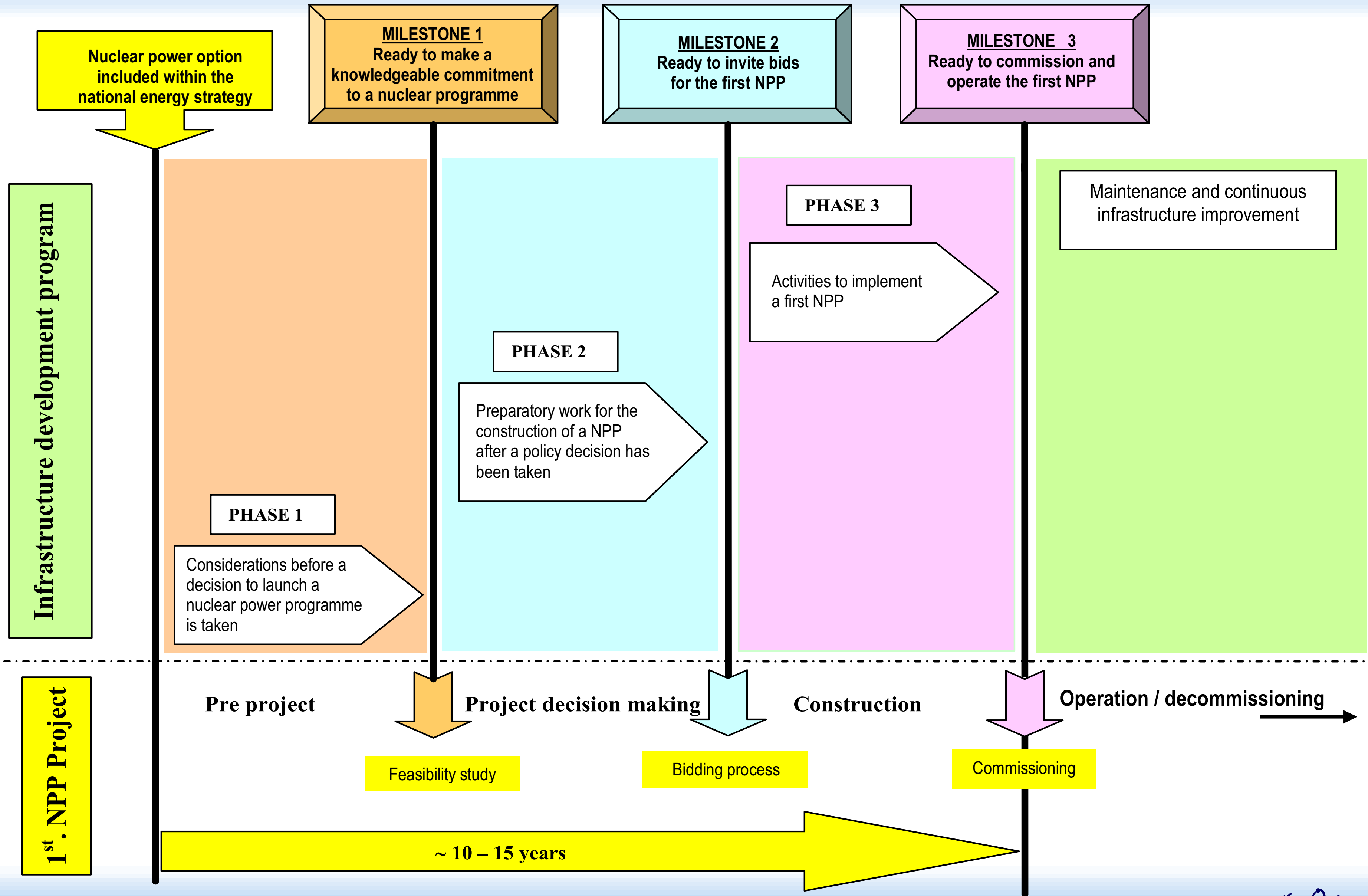


Fig. 1. Nuclear-combustion combined-cycle electric plant.

BASIC INFRASTRUTURE DEVELOPMENT – IAEA Nuclear Energy Series Guide NE-G-3.1 “Milestones in the Development of a National Infrastructure for Nuclear Power” (2007)



BASIC INFRASTRUTURE DEVELOPMENT – NE-G-3.1



BASIC INFRASTRUTURE DEVELOPMENT – NE-G-3.1

Table 2. Infrastructure issues and milestones (NG-G-3.1)

ISSUES	MILESTONE 1	MILESTONE 2	MILESTONE 3
National position			
Nuclear safety			
Management			
Funding and financing	CONDITIONS	CONDITIONS	CONDITIONS
Legislative framework			
Safeguards			
Regulatory framework			
Radiation protection			
Electrical grid			
Human resources development			
Stakeholder involvement			
Site and supporting facilities			
Environmental protection			
Emergency planning			
Security and physical protection			
Nuclear fuel cycle			
Radioactive waste			
Industrial involvement			
Procurement			

IAEA/INPRO Activity "INFRASTRUCTURE ISSUES FOR TRANSPORTABLE NPPs"

Table 1. Options for transportable, relocateable, and mobile reactors

Category	Construction	Fuelling procedure	Facility	Transportation	Mode of operation
Conventional NPP (reference point)	On-site	At operational site	Reactor, steam, and turbine units combined	Separate parts; or separate modules of factory assembled structures, systems, and components	Fixed permanently; not transportable, not relocateable, not mobile
Transportable	Country of origin	At operational site	Reactor, steam, and turbine units combined	Assembled reactor or reactor compartment – No fuel	Fixed permanently at operating site
		At site of manufacturing	Reactor, steam, and turbine units combined	Assembled reactor or reactor compartment – with fuel	Fixed permanently at operating site
		At site of manufacturing	Reactor only	Assembled reactor or reactor compartment – with fuel Steam and turbine systems locally provided	Fixed permanently
Relocateable	Country of origin	At operational site	Reactor, steam, and turbine units combined	NPP as a whole	Fixed but NPP as a whole can be moved
		Defueled before relocation	Reactor, steam, and turbine units combined	NPP as a whole	Fixed but NPP as a whole can be moved
Mobile	Country of origin	At site of manufacturing	Reactor, steam, and turbine units combined	Potentially able to move with reactor operational	Potentially mobile, e.g. Buoy moored

IAEA/INPRO Activity “INFRASTRUCTURE ISSUES FOR TRANSPORTABLE NPPs”

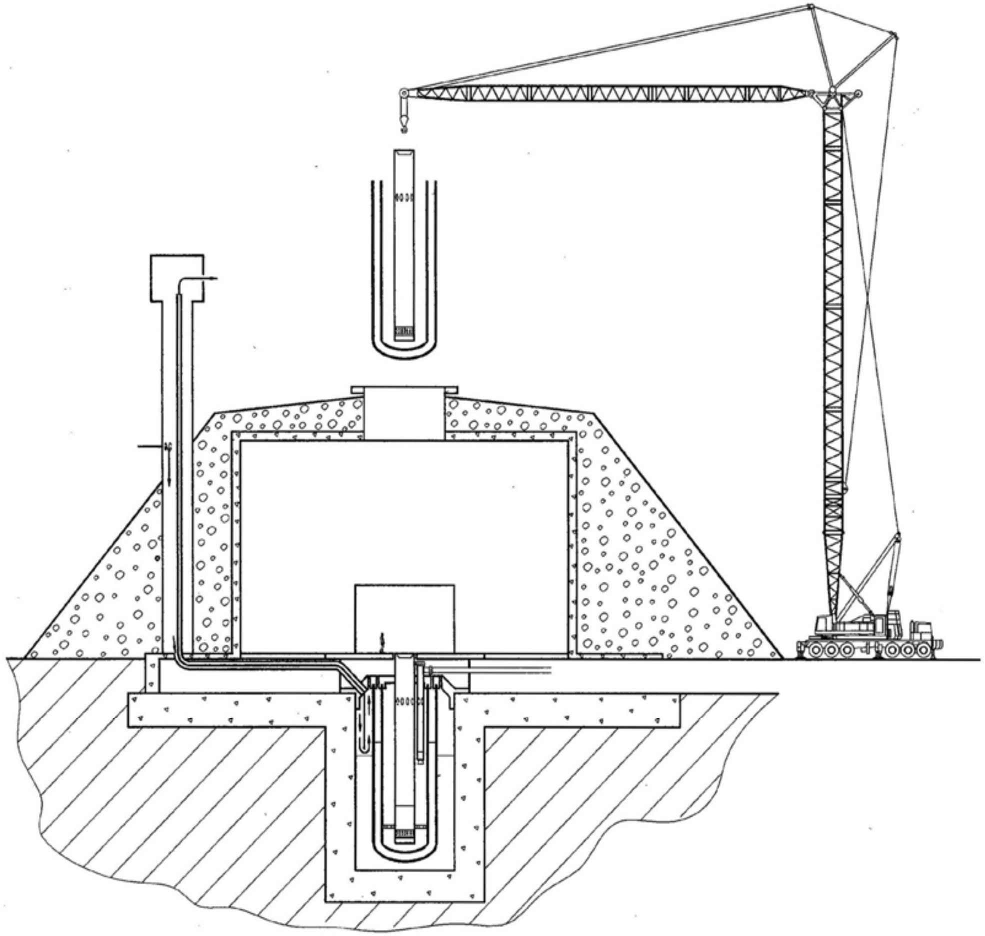
The objectives of this activity:

- **Study challenges for deployment of transportable SMRs with a focus on legal and institutional aspects but considering their economics and technical aspects and various deployment options related to ownership and contract**

- **Propose solutions and associated action plans to address the identified challenges**

- **Study implications to the infrastructure of the recipient countries**

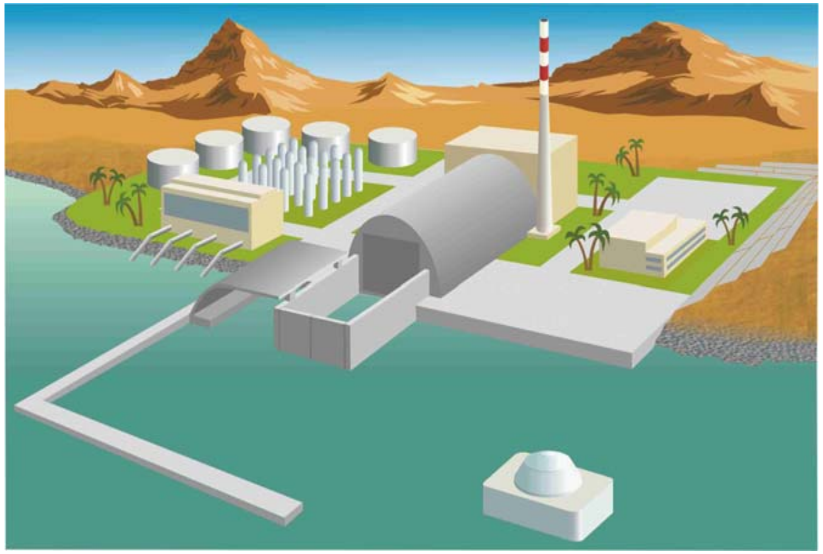
Innovative Infrastructure Options – *Small Reactors without On-site Refuelling*

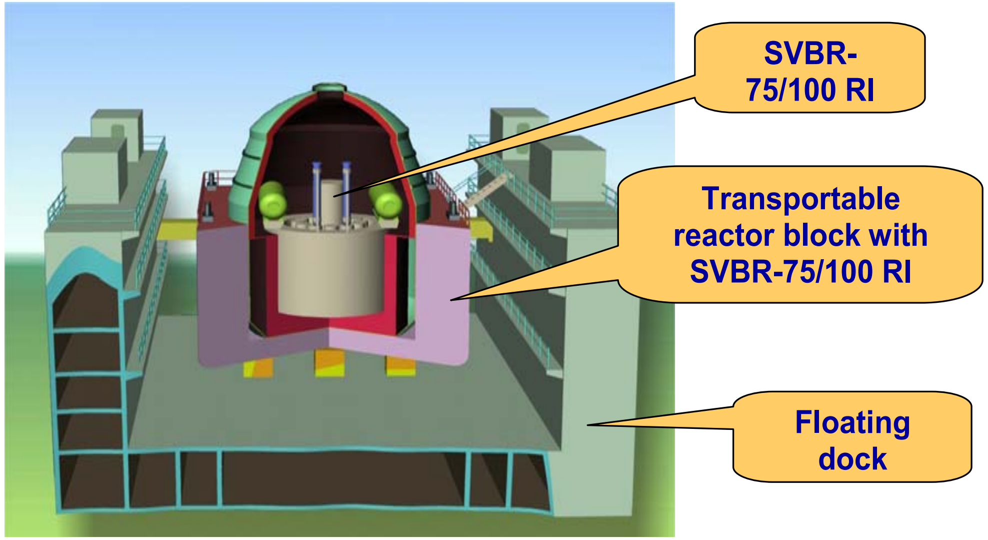


Rapid site assembly of STAR-H2 reactor (ANL, USA)

Innovative Infrastructure Options – *Barge-Mounted NPPs*

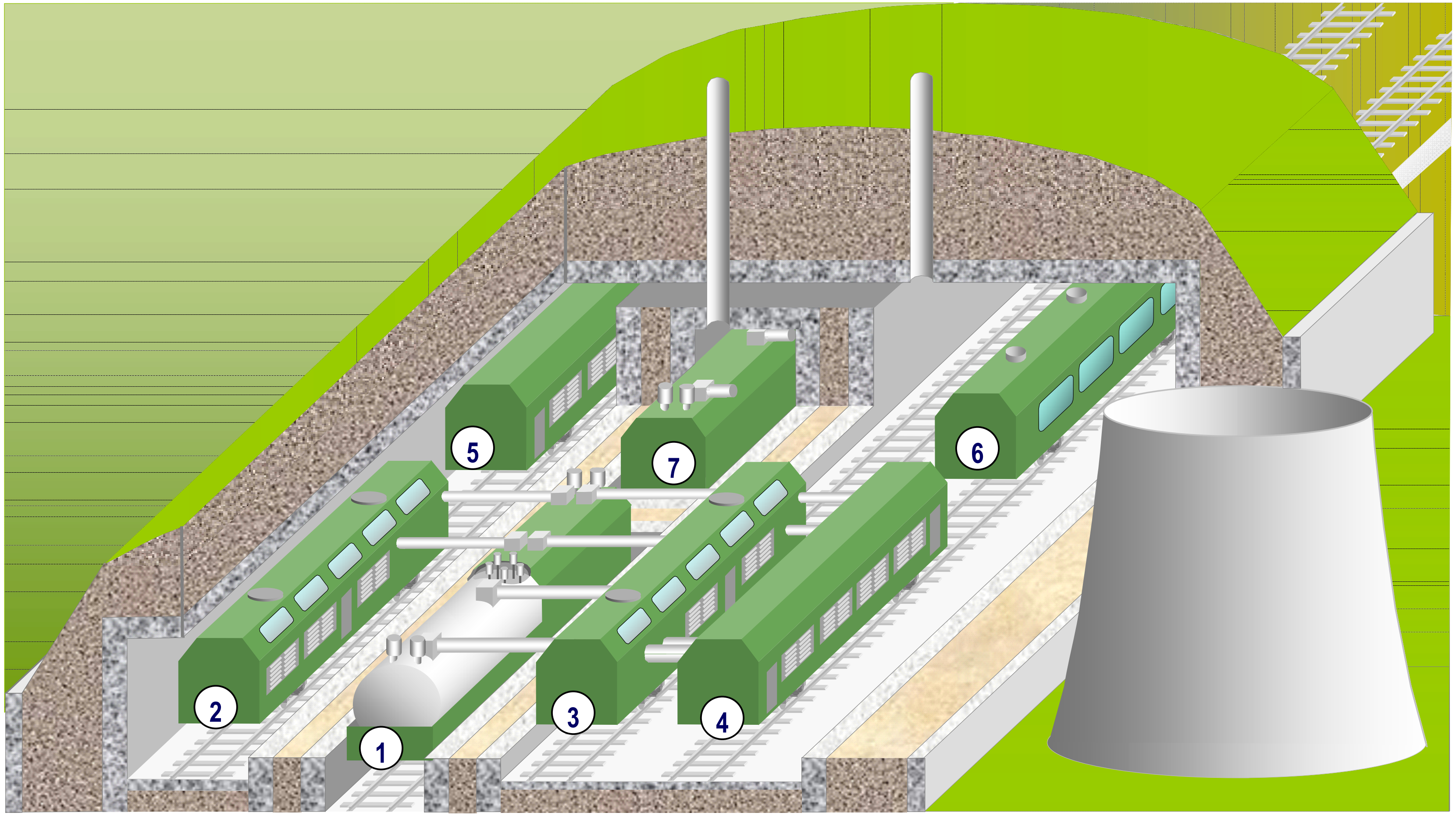
Innovative Infrastructure Options – *Leasing of reactor modules*





Floating NPP for Pb-Bi cooled reactor SVBR-75/100
IPPE – Gidropress (Russia)

Innovative Infrastructure Option - *Relocateable SMRs*



1 –Rail transportable reactor module; 2 – Generator module; 3 –Compressor module; 4 – Heat exchanger module;
5 –Auxiliary equipment module; 6 –Control room and reserve equipment module; 7- – Reserve reactor module**.**

FIG. XVIII-1. BN GT 300 single-unit nuclear power plant (NPP); section of the shelter building.

Innovative Infrastructure Options for NPPs

Not confined to SMRs

- ***BOO (Build-Own-Operate)***
- ***Leasing agreement***
  - ***Leasing of fuel***
  - ***Leasing of reactor modules***
  - ***Leasing of NPPs***

IAEA/INPRO activity "Innovative Infrastructure Options for Transportable SMRs" is open for participation !

SMRs - Options for Immediate Deployment

Only two options are available:

- ***CANDU-6 AECL (Canada)***

The plant can responds to fluctuations in grid demand while running at full power, which enhances grid stability is possible due to the frequency control at all power levels. This design feature allows CANDU 6 plants to vary reactor power from 100% to 60% in a daily or weekly cycle.

- ***PHWR-220; PHWR-540 (NPCIL, India) – export pending subject the resolution of issues with NSG/IAEA***

All immediate options are heavy water reactors

SMRs - Options for Near-Term Deployment

Reactors with Conventional Refuelling Schemes

PWRs with integrated design of primary circuit

- IRIS - Westinghouse (USA) + Intl. Team
- SMART – KAERI, the Republic of Korea
- CAREM – CNEA, Argentina

PWRs – marine reactor derivatives

- KLT-40S – Rosenergoatom, Russia
- VBER-300 – OKBM + Government of Kazakhstan, Russia

Advanced Light Water Cooled Boiling Water Moderated Reactors, Pressure Tube Vertical Type

- AHWR – BARC, India

High Temperature Gas Cooled Reactors

- HTR-PM – INET, China
- PBMR – PBMR Pty, Ltd., South Africa

Small Reactors without On-site Refuelling

- ABV – OKBM, Russia

PWRs with Integrated Primary Circuit – IRIS (Westinghouse, USA)

- ***International Reactor Innovative and Secure (IRIS)***
- ***335 MW(e), electricity only or cogeneration***
- ***Targets: Licensing -2012; FOAK deployment 2015***

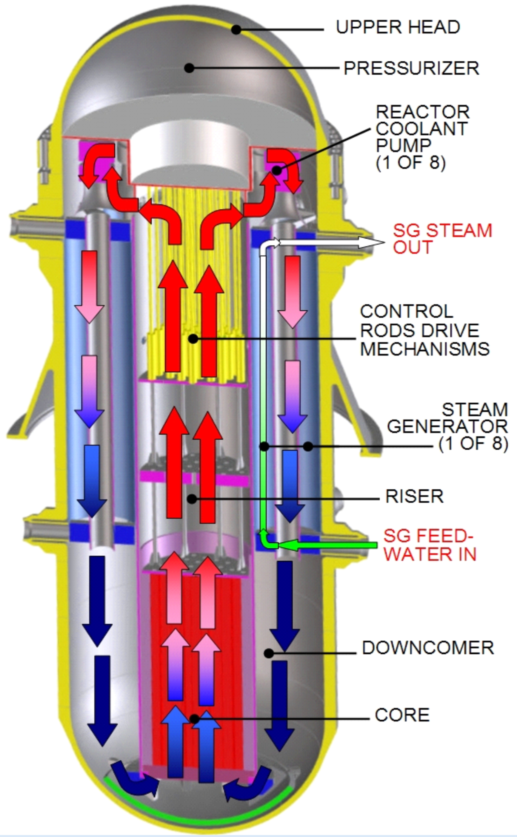


FIG. II-1: Integral primary system of IRIS.

PWRs with Integrated Primary Circuit – IRIS (Westinghouse, USA)

PARAMETERS	FEATURES
Core thermal power	1000 MW
Mode of operation	Base load operation standard. Enhanced load follow mode with control rods ("mechanical shim" or M-SHIM strategy)
Plant design life	Over 60 years
Fuel	Sintered ceramic UO_2/MOX fuel
Enrichment	Up to 4.95 % U fuel readily available, enabling extended cycle up to 4 years. Option for infrequent refuelling (8-10 years) requires 7~10% fissile content.
Coolant and moderator	Light water, sub-cooled.
Number of coolant pumps	Integral primary system; forced circulation with 8 in-vessel fully immersed pumps
Containment	Pressure suppression, spherical steel
Reactivity feedback	Moderator temperature coefficient (MTC) negative over the whole cycle and power operating range.
Power flattening approach	Burnable absorbers
Reactivity control	Soluble boron, burnable absorber, control rods.
Shut down system	Control rods, emergency boron system.
Fuel cycle options	Near-term deployment – fuel licensable today; Mid-term deployment with extended refuelling interval – requires fuel irradiation testing.
Average discharge burn-up	Up to 60 GW·day/t U (immediately available); Increased discharge burn up option (expected available by ~2020)

PWRs with Integrated Primary Circuit – IRIS (Westinghouse, USA)

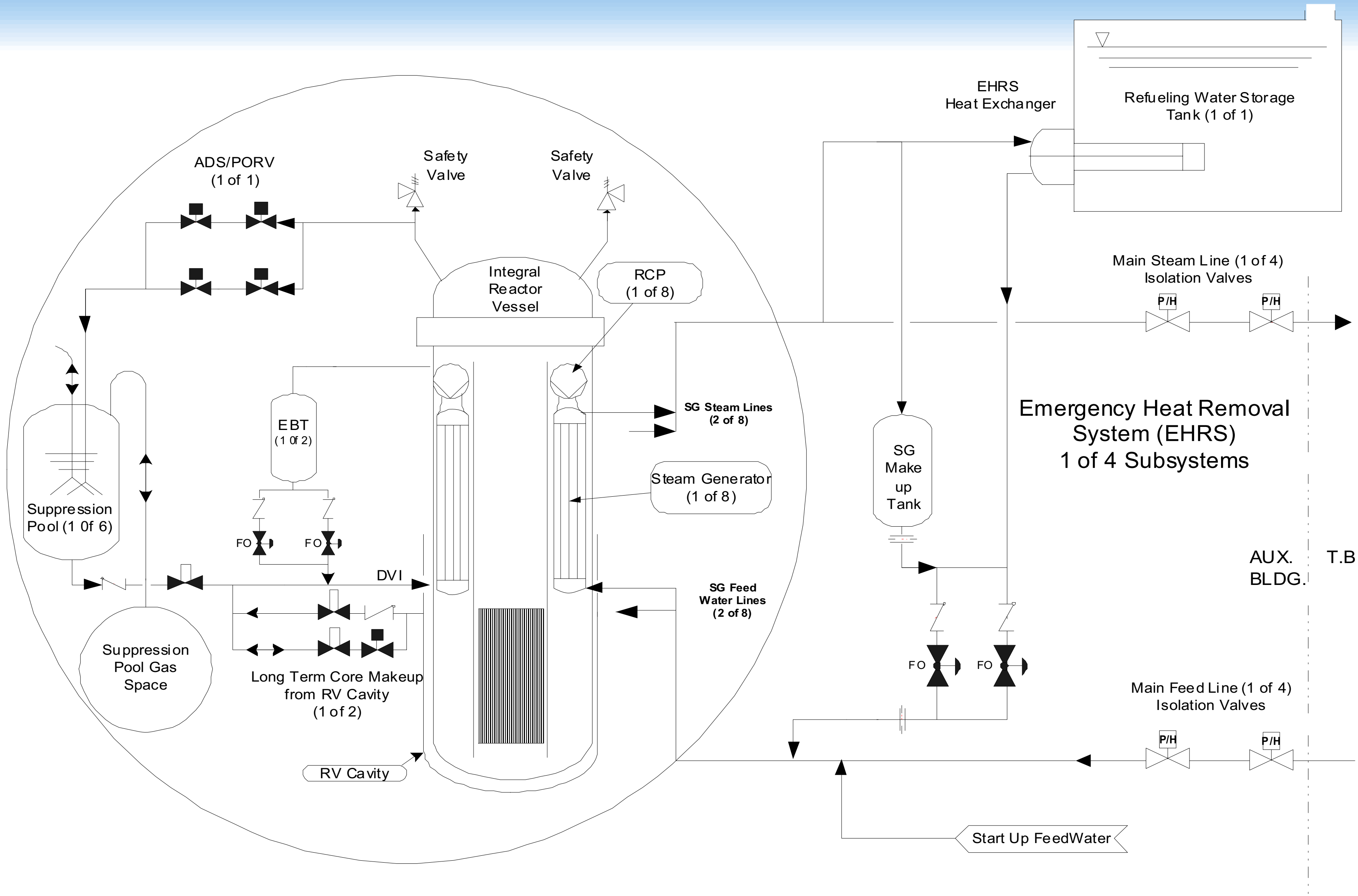


FIG. II-3. Schematic view of the IRIS passive safety systems.

PWRs with Integrated Primary Circuit – IRIS (Westinghouse, USA)

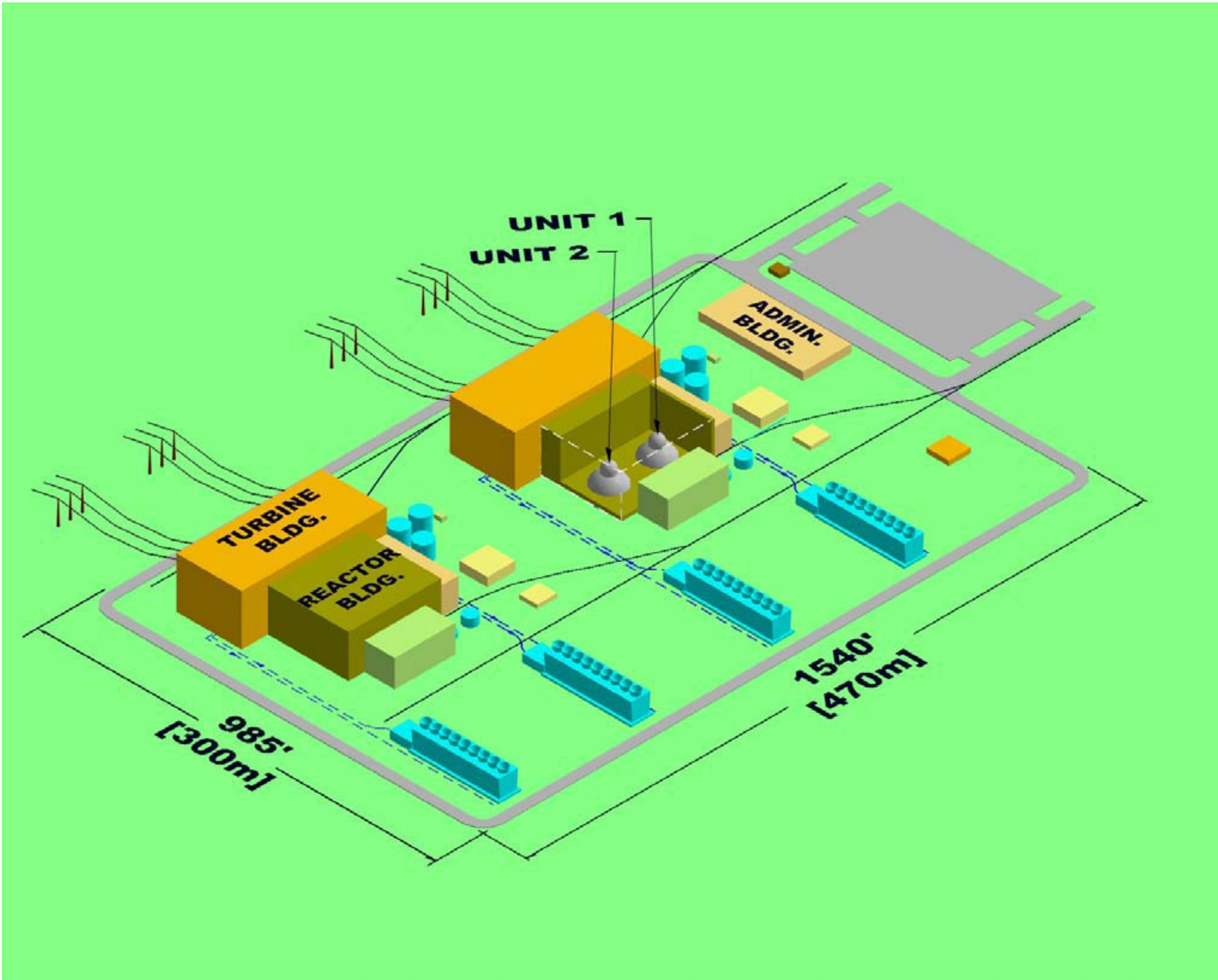


FIG. II-10. Perspective view of IRIS multiple twin-unit site layout.

PWRs with Integrated Primary Circuit System – SMART (KAERI, RoK)

- System-integrated Modular Advanced Reactor
- 330 MW(th) with a cogeneration option (unit power is under review);
- Since 1997, KAERI has been developing the system-integrated modular advanced reactor
- Targets: Licensing start-up – soon; FOAK – 2014

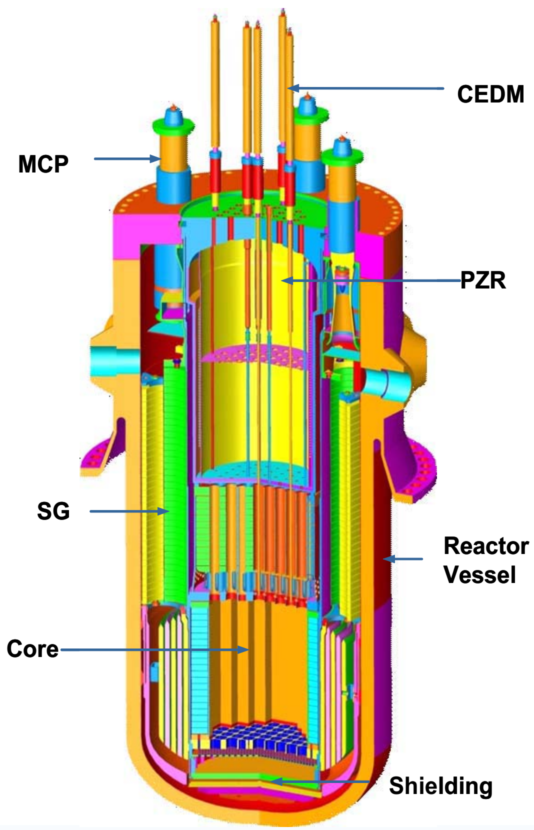


FIG. I-1. SMART reactor.

PWRs with Integrated Primary Circuit System – SMART (KAERI, RoK)

Installed capacity:

Power plant output: Electricity 90 MW(e) and 40,000 tons of fresh water /day

Reactor thermal output: 330 MW(th)

Mode of operation: **basic and/or load follow operation**

Availability factor: **more than 90%**

Summary of major design characteristics:

Fuel material	Sintered UO_2
Enrichment	4.95 weight % ^{235}U
Rod array	Square, 17×17
Type of coolant	Light water
Type of moderator	Light water
Core type	57 square fuel assemblies
Core characteristics	Soluble boron free Low power density
Core dimension:	
Active core height	2.0 m
Equivalent core diameter	1.832 m
Type of reactor vessel:	
Cylindrical shell inner diameter	4072 mm
Wall thickness of cylindrical shell	264 mm
Cycle type	Indirect (Rankine cycle)
Number of circuits	3 (Primary, secondary, and condenser cooling system)
Soluble boron reactivity control	No

PWRs with Integrated Primary Circuit System – SMART (KAERI, RoK)

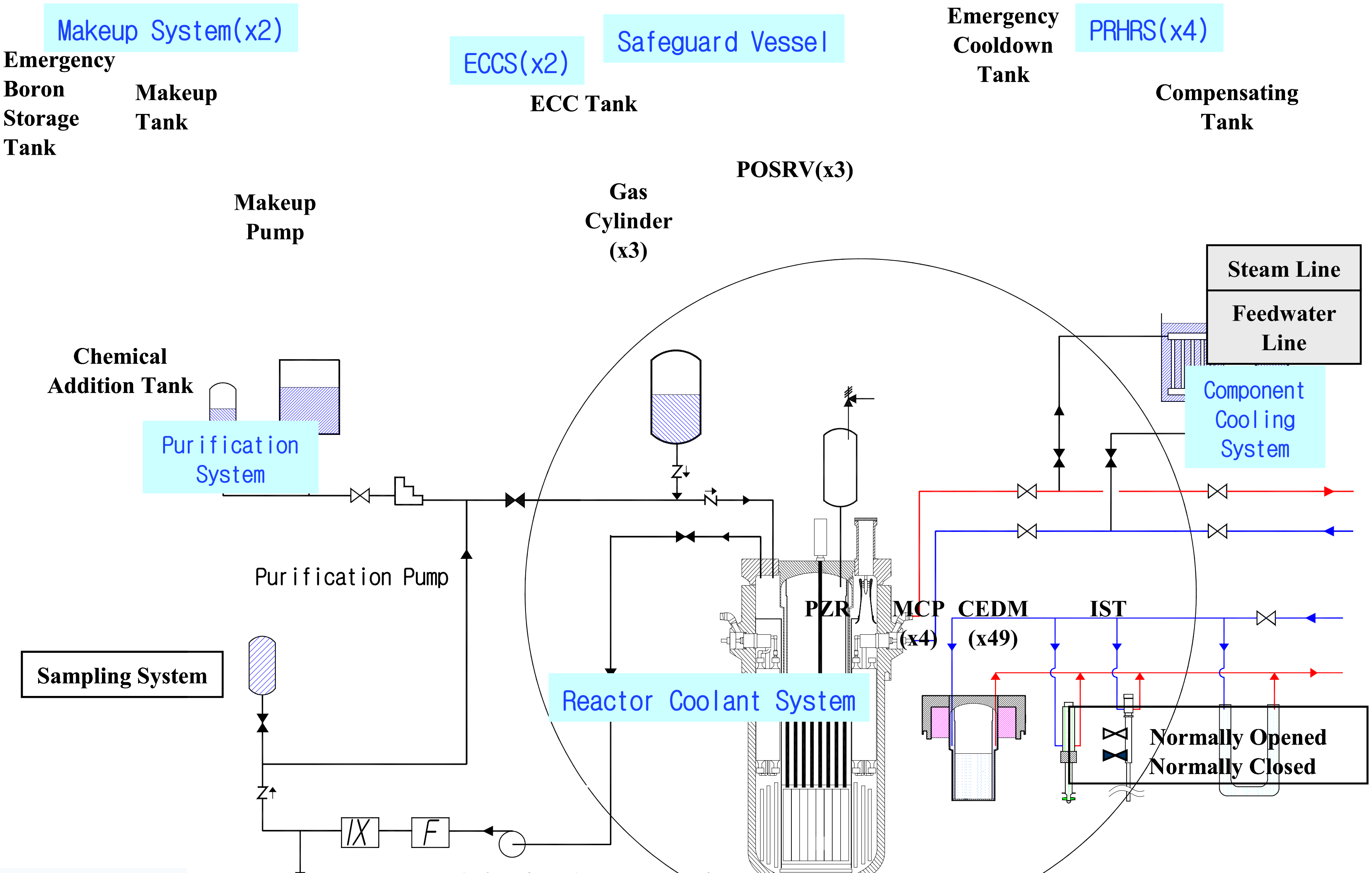
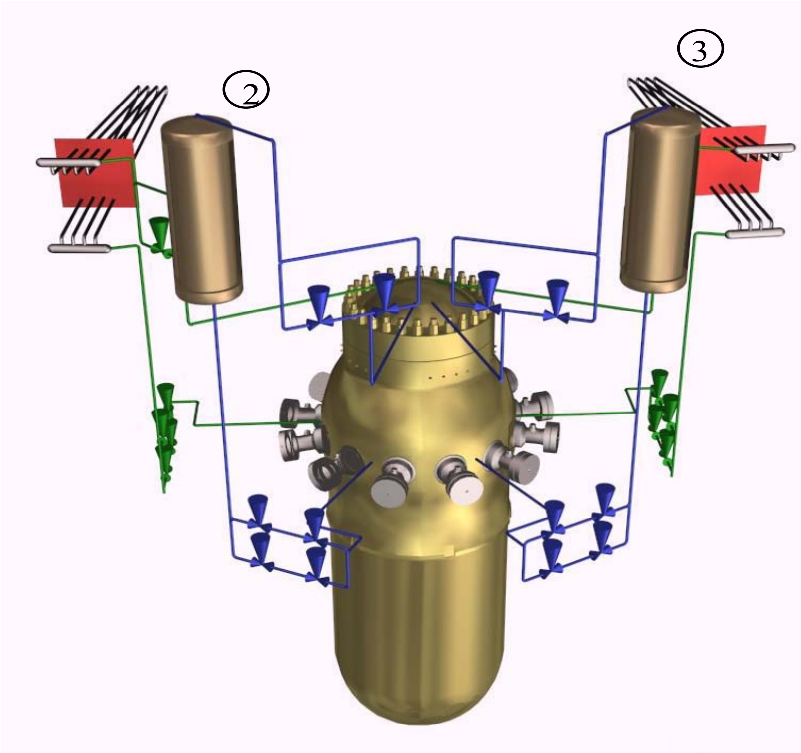


FIG. I-2. Simplified schematic diagram of the SMART NSSS.

PWRs with Integrated Primary Circuit System – CAREM (CNEA, Argentina)

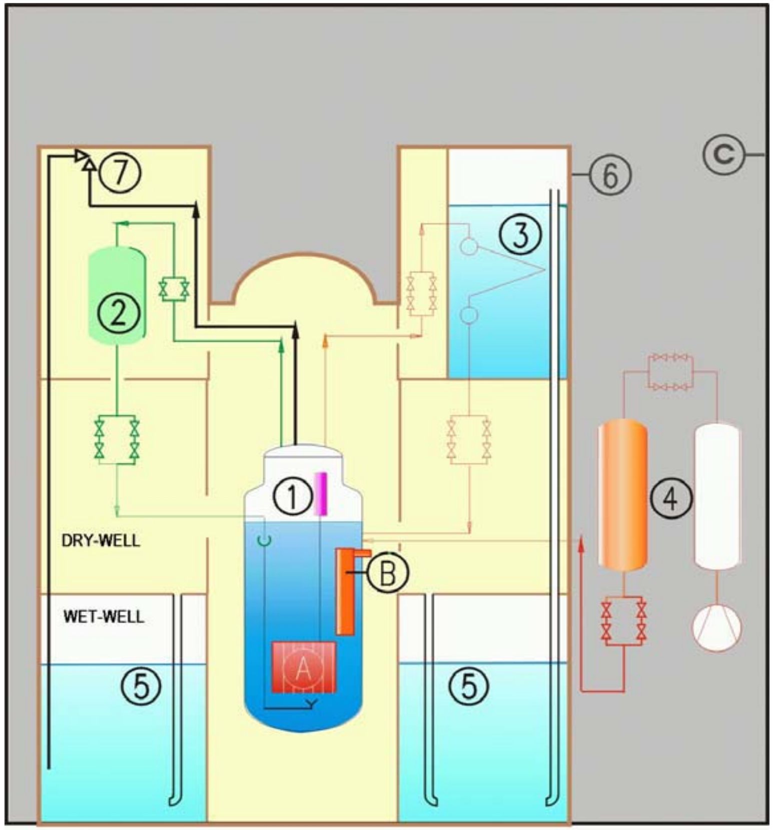
- **Central Argentina de Elementos Modulares (CAREM)**
- **Construction of a prototype of about 27 MW(e) (CAREM-25) goes first.**
- **Targets: Licensing – started; CAREM-25 – 2011; Commercialization (150, 300 MW(e)) to follow.**



PWRs with Integrated Primary Circuit System – CAREM (CNEA, Argentina)

CHARACTERISTICS	DESIGN PARTICULARS
Installed capacity	900 MW(th)/ 300 MW(e) for CAREM-300 100 MW(th)/ 27 MW(e) for CAREM-25 (prototype)
Type of fuel	PWR type fuel assembly with low enriched UO_2
Fuel enrichment	About 3.5%
Moderator	Light water
Coolant	Light water
Primary circuit design	Integral, with internal steam generators, pumps, pressurizer, and control rod drives
Primary circulation	Natural convection for designs < 150 MW(e); Forced convection for designs > 150 MW(e)
Reactivity control	Control rods, no soluble boron

PWRs with Integrated Primary Circuit System – CAREM (CNEA, Argentina)



1: First shutdown system
2: Second shutdown system
3: Residual heat removal system
4: Emergency injection system
5: Pressure suppression pool
6: Containment
7: Safety valves

A: Core
B: Steam generators
C: Reactor building

FIG. III-2. Containment and safety systems of CAREM.

PWRs – Marine Reactor Derivatives – KLT-40S (Russia)

- **The KLT-40S is a modular reactor unit developed for a pilot floating nuclear cogeneration plant (PATES, in Russian), currently under construction in Severodvinsk, the Russian Federation.**
- **Thermal power – 150 MW(th)**
- **PATES – two units, 300 MW(th), 70 MW(e)**
- **Targets: Construction started; pilot plant deployment -2010**

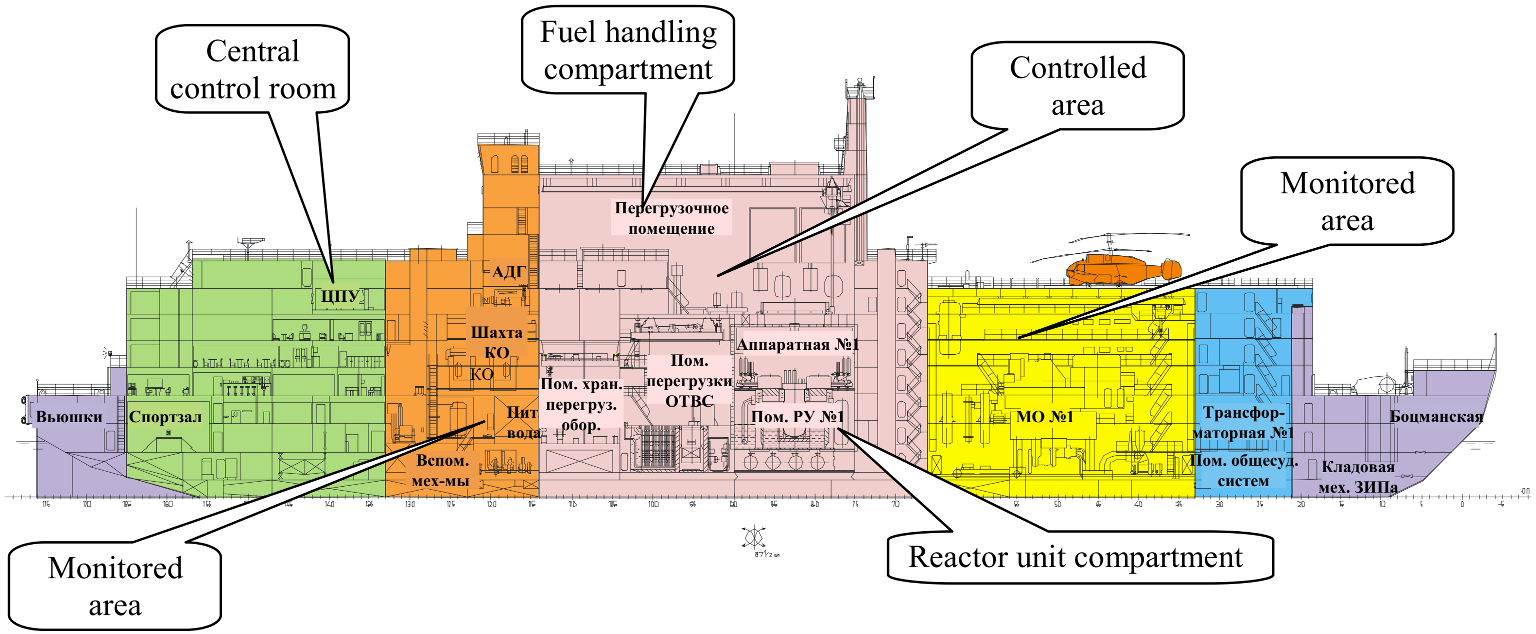
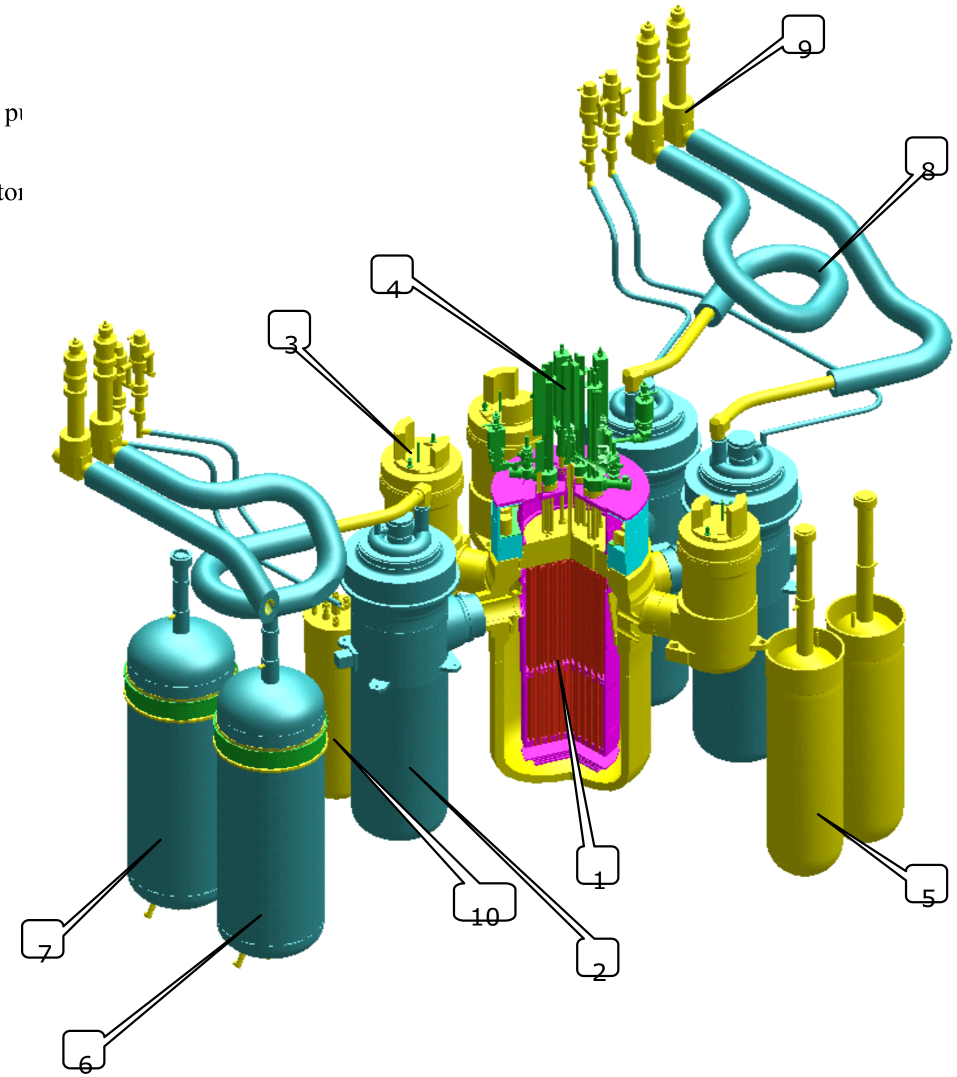


FIG. I-2. Floating power unit with two KLT-40S nuclear installations.

PWRs – Marine Reactor Derivatives – KLT-40S (Russia)

1 Reactor
2 Steam generator
3 Main circulating pı
4 CPS drives
5 ECCS accumulatoı



Modular layout of the KLT-40S reactor plant (OKBM, Russian Federation).

PWRs – Marine Reactor Derivatives – KLT-40S (Russia)

- Modular design of reactor unit: the reactor, the steam generators (SGs) and the main coolant pumps (MCPs) are connected with short nozzles, without using long pipelines;

- Four-loop reactor cooling system with forced and natural convection of the coolant in the primary circuit;

- Leak-tight primary circuit with canned motor pumps and leak-tight bellows-type valves;

- Once-through coil type SGs;

- Gas based pressurizer system in the primary circuit;

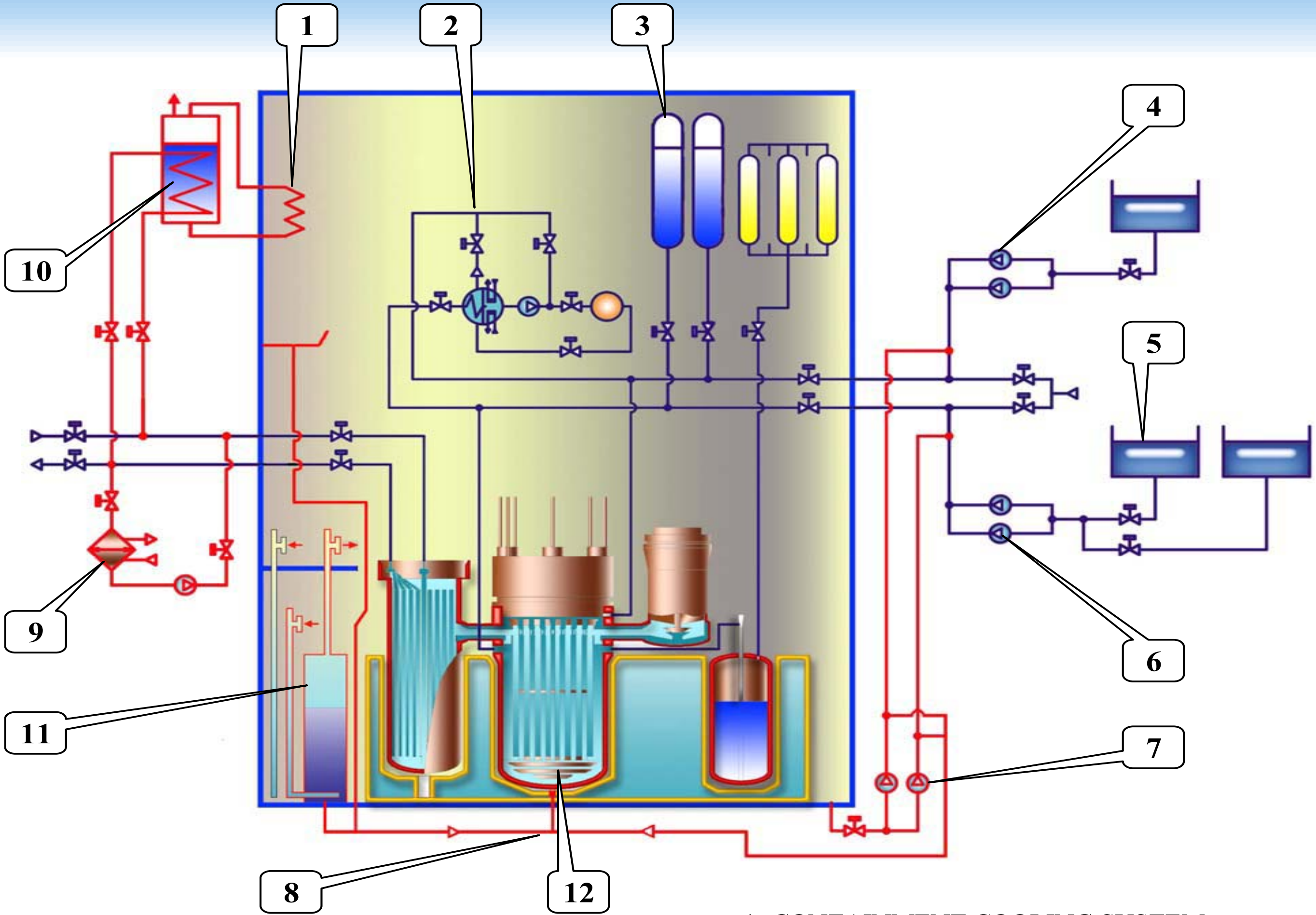
- Use of passive safety systems;

- Use of proven techniques for equipment assembly, repair and replacement; incorporation of proven diagnostics equipment and proven monitoring systems.

PWRs – Marine Reactor Derivatives – KLT-40S (Russia)

CHARACTERISTIC	VALUE
Thermal power, MW	150
Primary circuit pressure, MPa	12.7
Coolant temperature, °C: - at core outlet - at core inlet	 317 279
Parameters of superheated steam downstream of the SG: - pressure, MPa - temperature, °C.	3.73 290
Feedwater temperature, °C	170

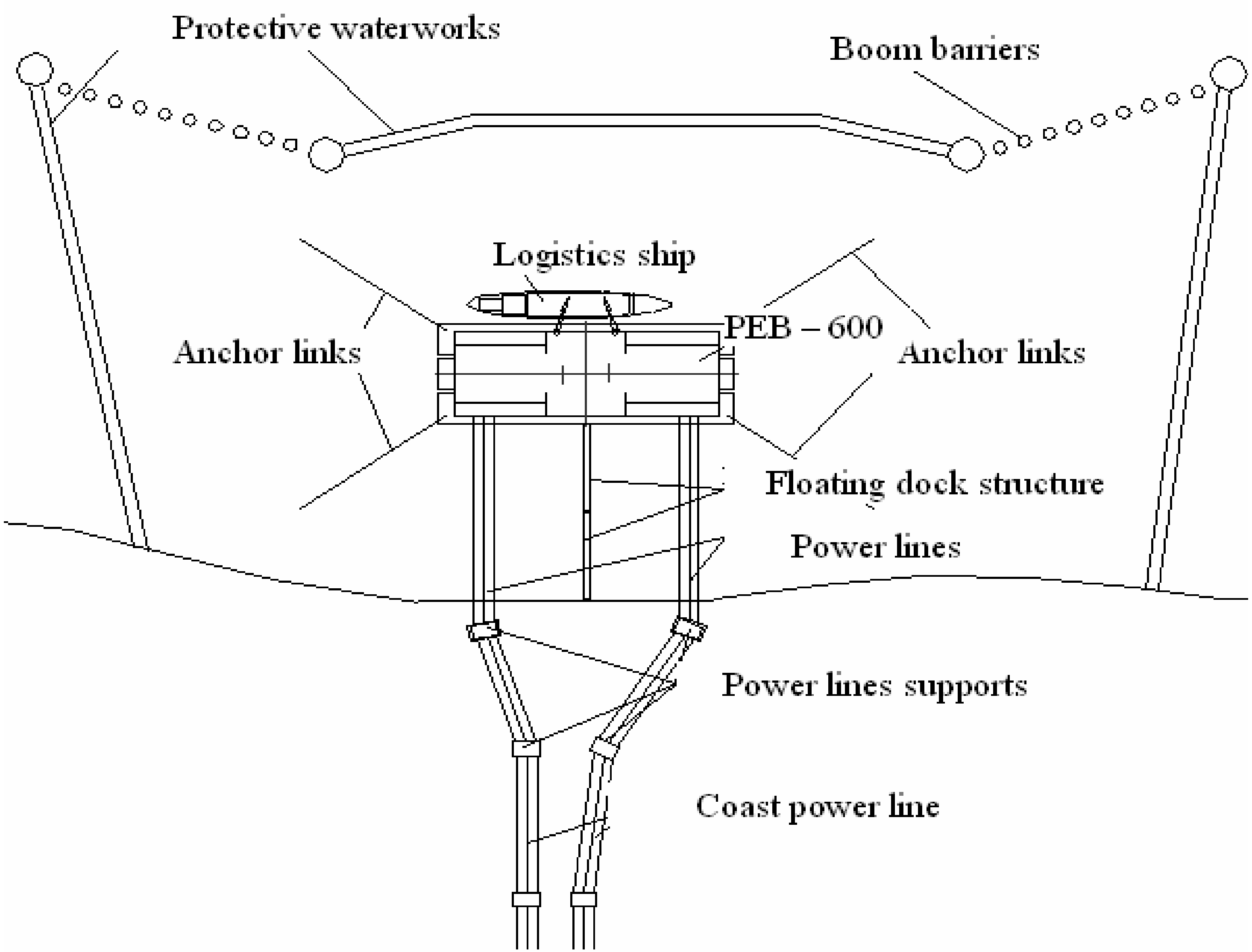
PWRs – Marine Reactor Derivatives – KLT-40S (Russia)



1- CONTAINMENT COOLING SYSTEM;
2-PURIFICATION AND COOLDOWN SYSTEM
3-ECCS ACCUMULATORS;
4, 6-ACTIVE ECCS;
5-ACTIVE ECCS TANK;
7-RECIRCULATION SYSTEM PUMPS;
8-RVCS;
9-ACTIVE EHRS;
10-PASSIVE EHRS;
11-CONTAINMENT BUBBLING SYSTEM;
12-REACTOR

ECCS – emergency core cooling system RVCS – reactor vessel cooling system
EHRS – emergency heat removal system

PWRs – Marine Reactor Derivatives – Coastal Infrastructure for a Floating NPP

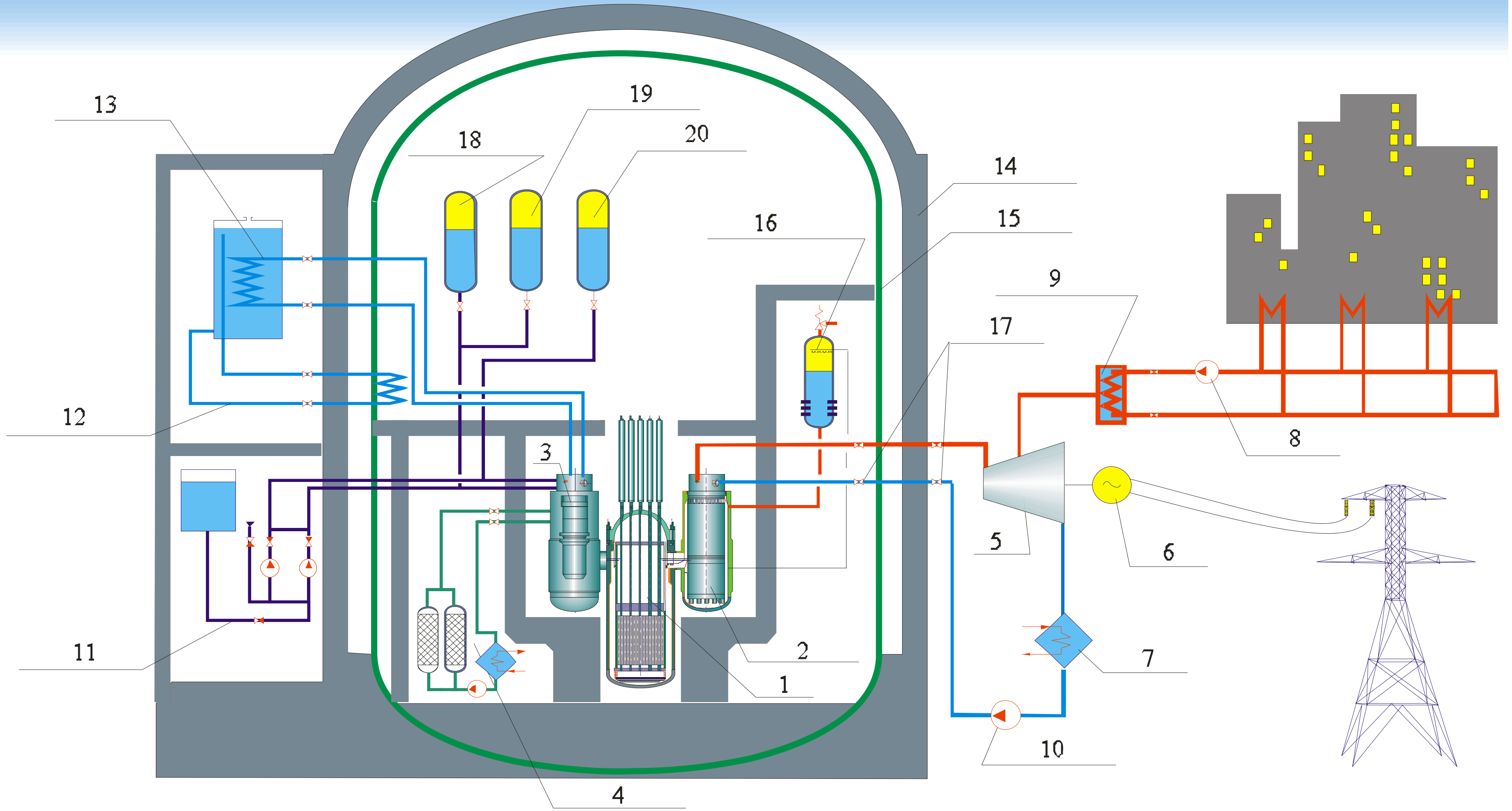


PWRs – Marine Reactor Derivatives – VBER-300 (Russia, Kazakhstan)

- **The VBER-300 reactor is a small-to-medium power source for land-based NPPs and cogeneration plants as well as for floating NPPs and desalination plants.**
- **Power 200-400 MW(e), depending on the number of loops.**
- **Targets: FOAK deployment – 2015.**

PARAMETER	VALUE
Design characteristics	
Reactor power, MW - Thermal; - Electric	 850 295
Operation mode	Base load operation; load follow modes, e.g., to track daily load changes, or a dispatcher mode with maintaining the frequency are possible
Capacity factor	0.85-0.9
Fuel	
Fuel type	Pellets of sintered uranium dioxide
Fuel element	Rod-type fuel element similar to standard fuel elements of the VVER-1000 reactor
Fuel enrichment	Not more than 5%
Reactor type	PWR

PWRs – Marine Reactor Derivatives – VBER-300 (Russia, Kazakhstan)



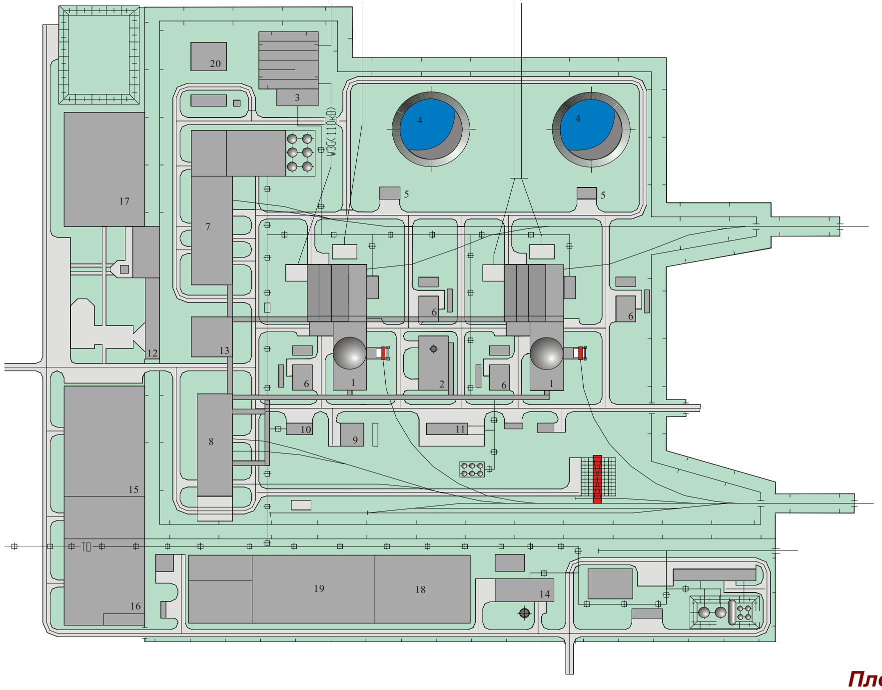
1-Reactor
2-Steam generator
3-Main circulating pump
4-Primary
5-Turbine
6-Generator
7-Condenser

8-Circuit pump
9-Circuit heat exchanger
10-Feedwater pump
11-Water and boron solution makeup system
12-Protective enclosure pressure drop system
13-Emergency heat removal system
14-Containment

15-Steel protective enclosure
16-Steam pressurizer
17-Stop valves
18-Hydraulic accumulator
19-Secondary stage ECCS tank
20 Boron solution passive supply system

PWRs – Marine Reactor Derivatives – VBER-300 (Russia, Kazakhstan)

600 MW(e) NPP with 2 VBER-300 units



1 Главный корпус
2 Специальный корпус
3 Блок сооружений с ЦЩУ
4 Градирня
5 Насосная станция турбинного отделения
6 Здание охлаждения воды ответственных потребителей с РДЭС
7 Объединенный вспомогательный корпус
8 Специальный объединенный вспомогательный корпус
9 Блочная РДЭС
10 Объединенный газовый корпус
11 Азотно-кислородная станция
12 Административный корпус
13 Санитарно-бытовой корпус
14 Пускорезервная котельная
15 Здание пожарной службы
16 Гараж
17 Учебно-тренировочный пункт
18 Здание и сооружения водопровода
19 Здание и сооружения канализации
20 Пункт управления противоаварийными действиями

Площадь территории АТЭЦ в ограде – 30 га

Advanced Light Water Cooled Boiling Water Moderated Reactors, Pressure Tube Vertical Type – AHWR (BARC, India)

- **The Advanced Heavy Water Reactor (AHWR)**
- **300 MW(e), cogeneration option.**
- **Targets: 2012 start of construction;**
- **Licensing ongoing**

ATTRIBUTES	DESIGN PARTICULARS
Major design specifications	
Core configuration	Vertical, pressure tube type
Fuel	Pu-ThO_2 MOX, and $^{233}UO_2$-ThO_2 MOX
Moderator	Heavy water
Coolant	Boiling light water
Number of coolant channels	452
Pressure tube inner diameter	120 mm
Pressure tube material	20% Cold worked Zr-2.5% Nb alloy
Lattice pitch	245 mm
Active fuel length	3.5 m
Calandria diameter	7.4 m
Calandria material	Stainless steel grade 304L
Steam pressure	7 MPa
Mode of core heat removal	Natural circulation
MHT loop height	39 m
Shut-down system-1 (SDS-1)	40 mechanical shut-off rods
Shut-down system-2 (SDS-2)	Liquid poison injection in moderator

Advanced Light Water Cooled Boiling Water Moderated Reactors, Pressure Tube Vertical Type – AHWR (BARC, India)

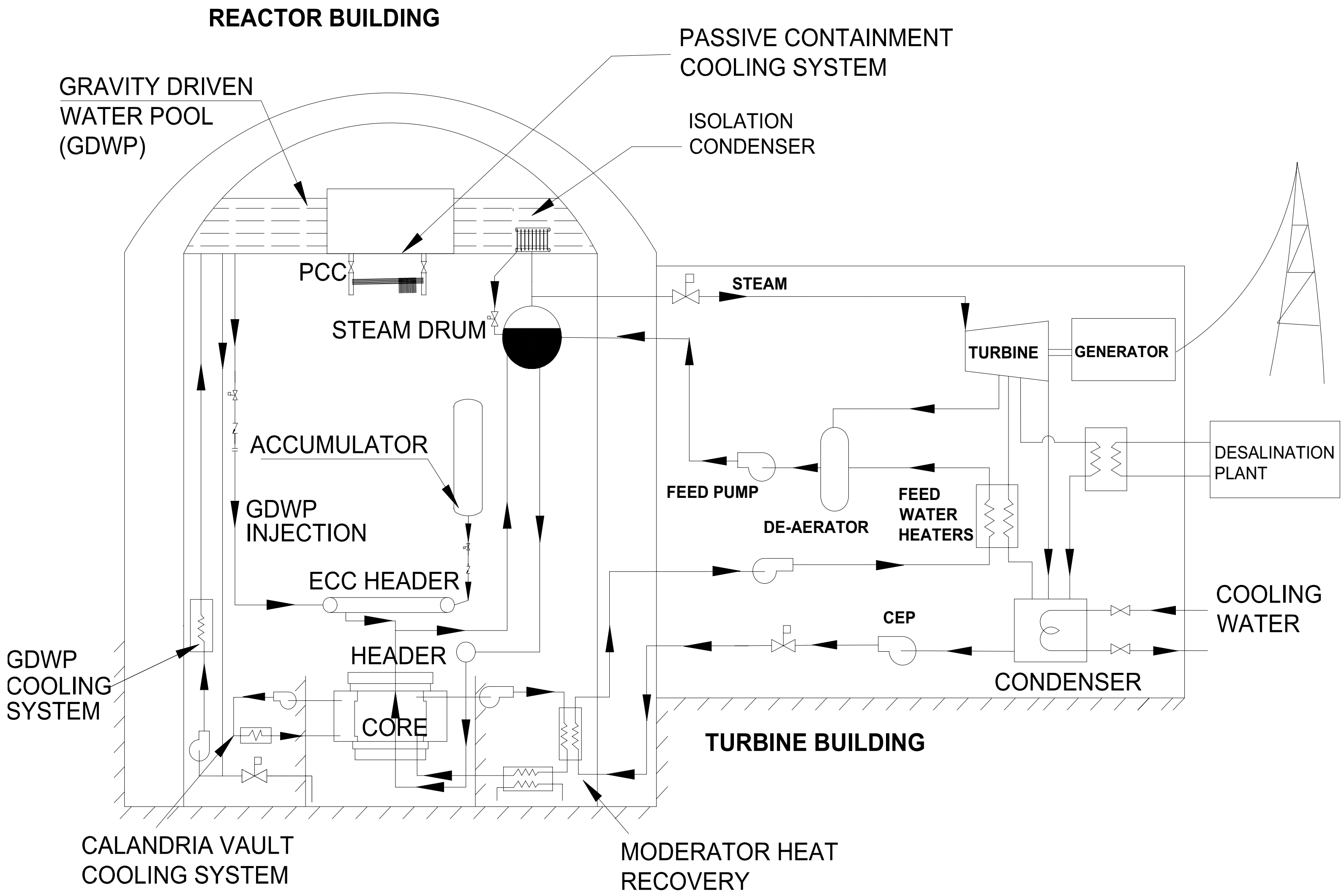
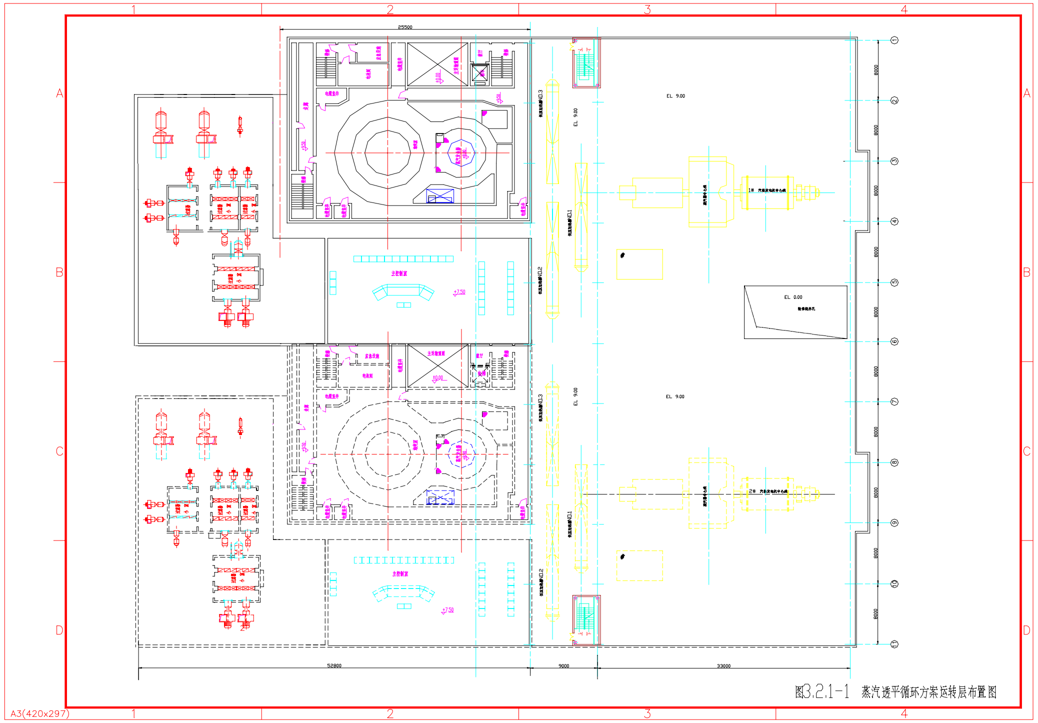


FIG. VI-1. General arrangement of AHWR [VI-1].

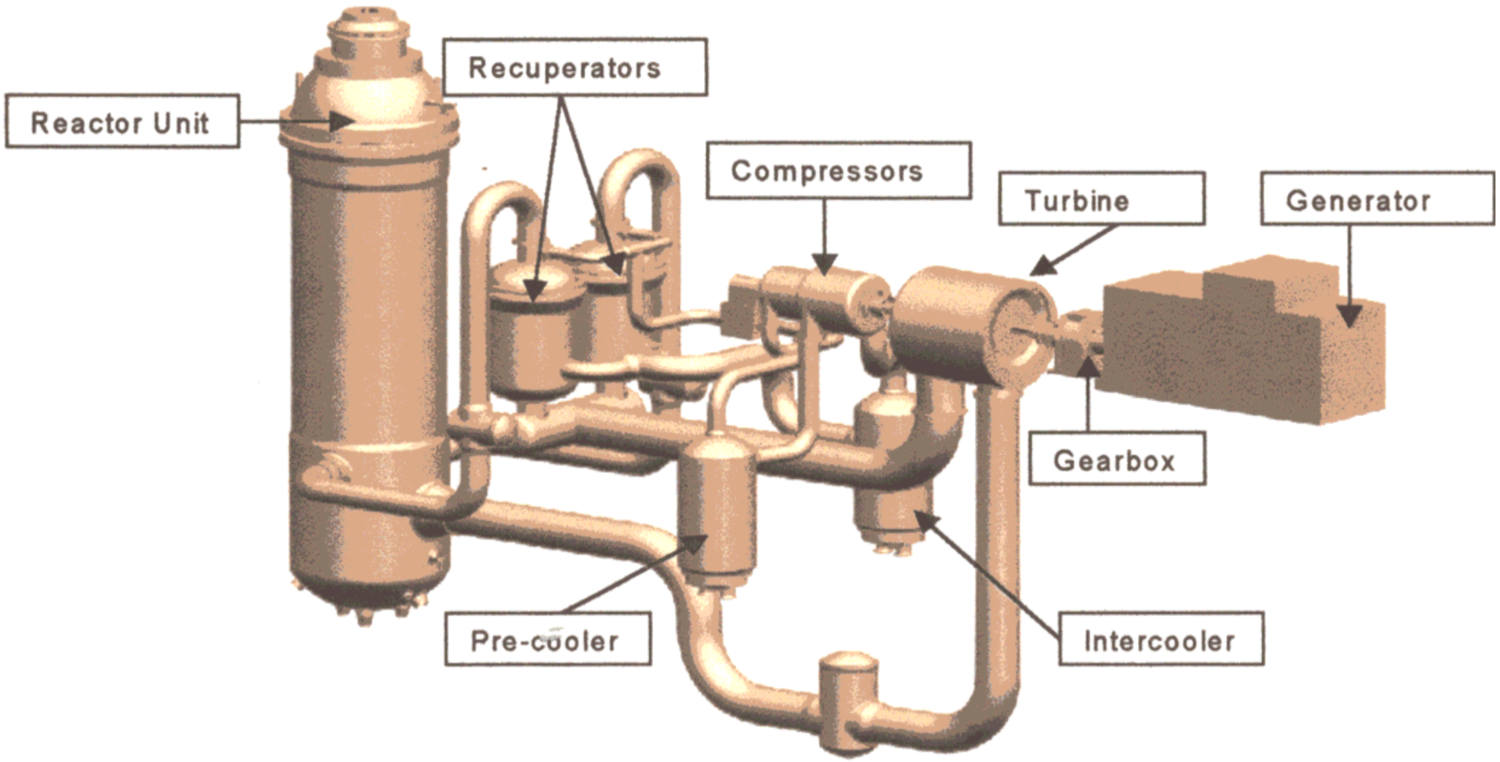
High Temperature Gas Cooled Reactors – HTR-PM (INET, China)

- High Temperature Gas Cooled Reactor – Pebble Bed Module (HTR–PM)
- Indirect cycle modular HTGR plant, which is designed by the Institute of Nuclear and New Energy Technology (INET), Tsinghua University of China.
- 250 MW electrical output per module.
- Targets: Start-up of construction in 2010



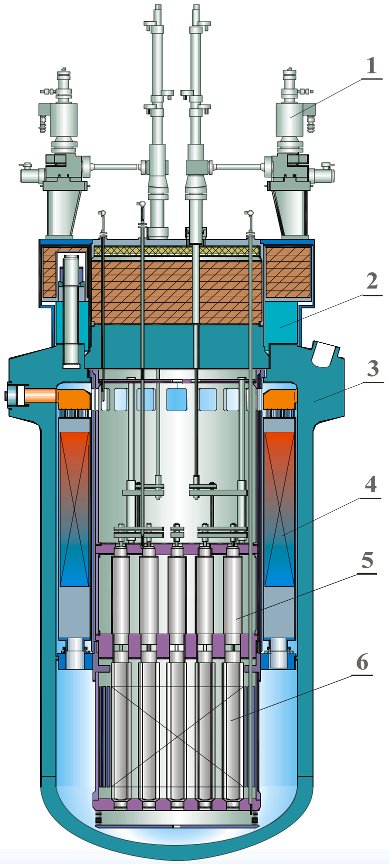
High Temperature Gas Cooled Reactors – PBMR (PBMR Ltd., South Africa)

- Pebble Bed Modular Reactor (PBMR)
- Direct Brayton cycle modular HTGR,
- 400 MW(th)/ 165 MW(e) per module
- Demonstration at a full size by 2012



Small Marine-Derivative PWR without On-site Refuelling – ABV (Russia)

- Designed by OKBM (Russia)
- 11 MW(e) per module
- Operating experience – available
- Design – partly licensed
- Targets: Floating NPPs around 2012-2014



1 – CPS drive
2 – Reactor cover
3 – Reactor vessel
4 – Steam generator
5 – Block of protective tubes
6 – Core

Small Marine-Derivative PWR without On-site Refuelling – ABV (Russia)

The ABV reactor installation is a nuclear steam-generating plant with an integral pressurized light water reactor and natural circulation of the primary circuit coolant.

CHARACTERISTIC	VALUE
Major design characteristics	
Rated power, MW - Thermal; - Electric	 45 (reactor thermal power may be within the range of 18 to 60 MW) 11
Operation mode	Base load operation; it is possible to realize load follow mode to track daily power changes or a dispatch mode maintaining the frequency
Capacity factor	0.85-0.9
Reactor type	Integral pressurized water reactor on thermal neutrons
Number of circuits	2
Cycle type	Steam-turbine cycle with slightly superheated steam
Fuel enrichment by ^{235}U	16.5 weight %
Refuelling interval	10 - 12 years

What could be done to support innovative SMR deployment?

- *Adjust regulatory rules toward technology neutral and risk-informed approach*

- *Quantify reliability(?) of passive safety systems*

- *Justify reduced or eliminated EPZ (proximity to the users)*

- *Justify reliable operation with long refuelling interval (Licence-by-test + periodic safety checks)*

✓ *Demonstrate SMR competitiveness for different applications (many users require technology proven by operation)*

What would happen if this is not done?

➢ *All innovative SMRs are licensable against current safety requirements and regulations*

➢ *There are established methods for validation of passive safety systems*

➢ *Reduced EPZ can be partly justified using current regulations in some countries*

➢ *Long refuelling interval has experience with submarines*

✓ *Would SMRs be competitive if new regulatory approaches are not applied?*

IAEA General Conference Resolution GC(51)/RES/14

Requests the Director General to continue taking appropriate measures to assist Member States, particularly developing countries in the development of safe, secure, economically viable and proliferation-resistant SMRs, including with respect to nuclear desalination and hydrogen production

THANK YOU!

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