5th Annual Meeting of ASEAN Network on Nuclear Power Safety Research

Singapore, 26-28 October 2022 2022

Current Research on Nuclear Reactors in Vietnam after withdrawing from the NPP Construction Plan

Vo Thi Huong, Nuclear Energy Center,

Institute for Nuclear Science and Technology (INST),

Vietnam Atomic Energy Institute (VINATOM)

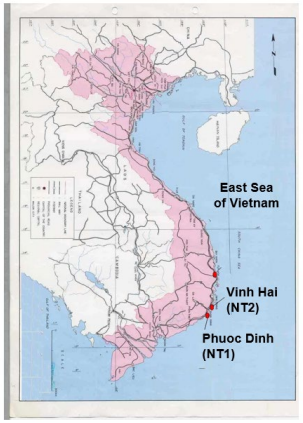
E-mail: vohuong1705@gmail.com

Presentation outline

1. Nuclear power program in Vietnam
2. The new research reactor project
3. Current research on nuclear reactors at VINATOM
4. Concluding remarks

1. Nuclear power program in Vietnam

- **Atomic energy in Vietnam started since 1976:** Establishment of the Dalat Nuclear Research Institute (NRI), based on the Research Reactor (RR) which was built and started operation in 1963 (TRIGA Mark II reactor)
- 1979: Establishment of National Atomic Energy Institute (VINATOM now)
- **1984: Operation of Dalat Nuclear Research Reactor (DNRR)**
- **1996-2002: Study on first NPP introduction in Vietnam**
- 2002-2009: Pre-FS on construction of first NPPs
- 2003: Establishing Vietnam Agency for Radiation and Nuclear Safety (VARANS)
- **2008: Atomic Law was approved (to be changed)**
- **2010: Contracts for Ninh Thuan 1 (NT1) and Ninh Thuan 2 (NT2) NPPs Feasibility Studies (FS)**
- December 2013: Completion of FS (NT1 and NT2)
- **November 2016: National Assembly decided to withdraw from the Ninh Thuan NPP projects.**

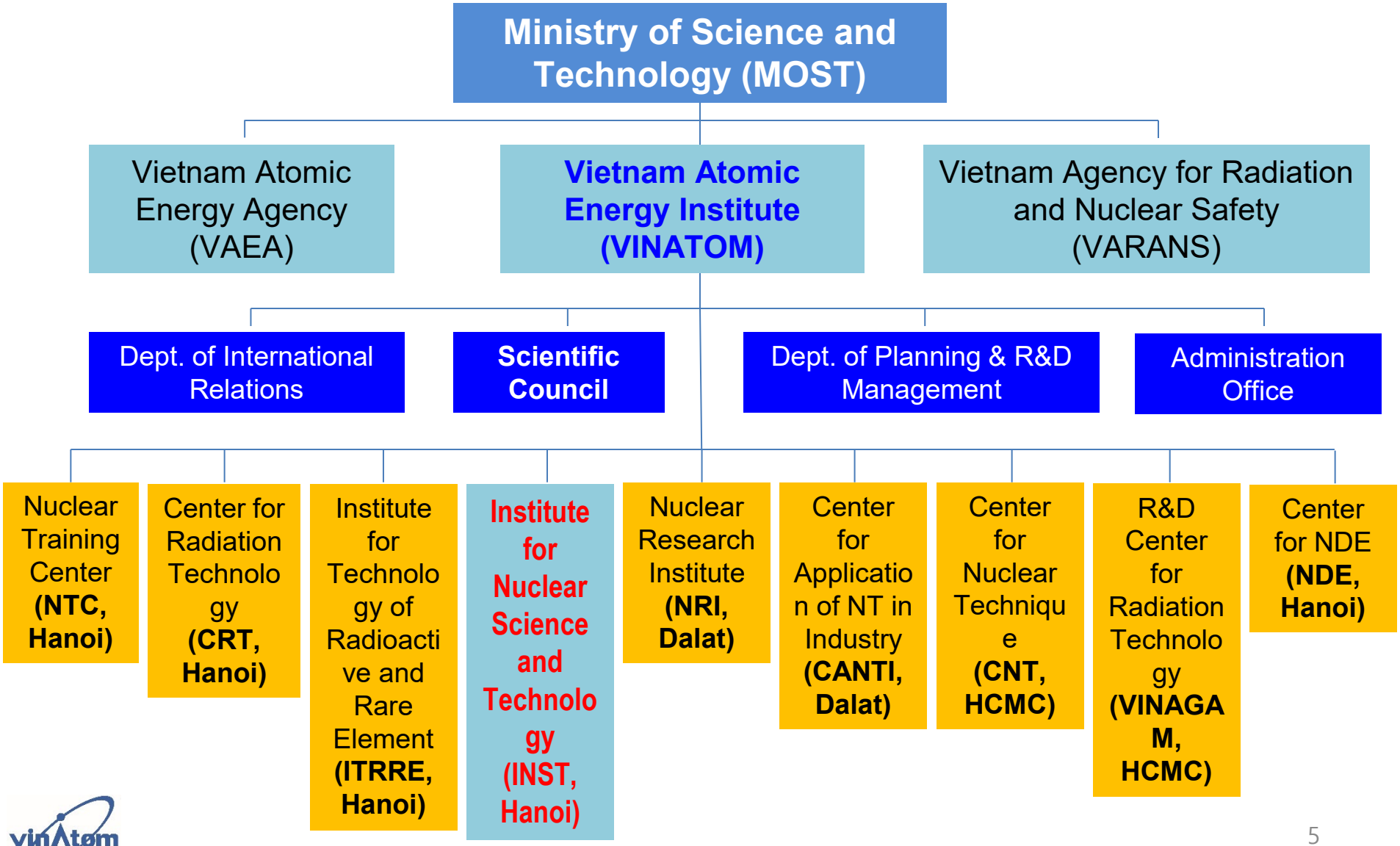


Current Status after NPP Projects

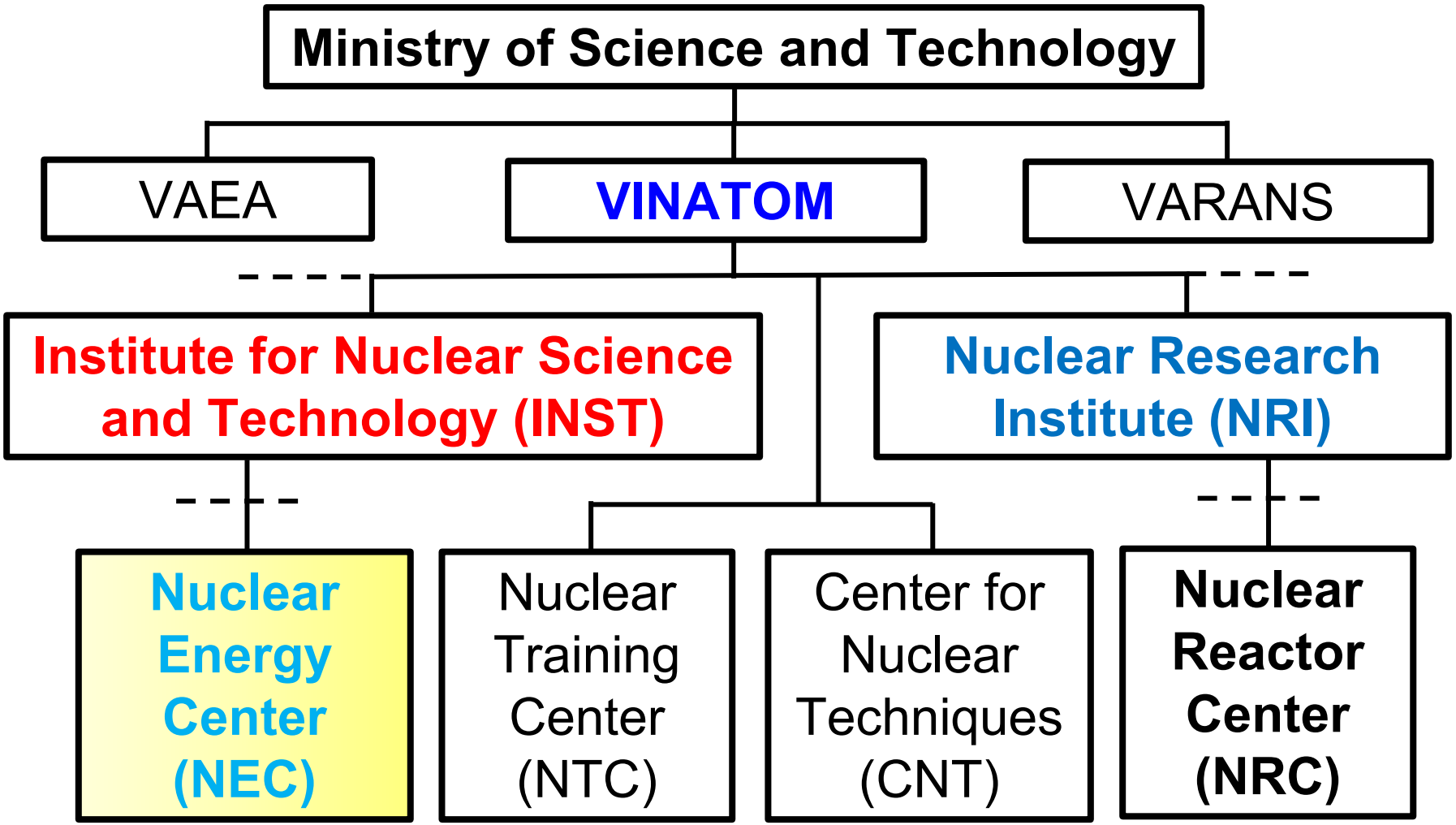
- **NPP programs of China and ASEAN member states.**
  - ✓ Safety concerns about Chinese NPPs near Vietnam
  - Fangchenggang, Bailong, Changjiang, and Yangjiang NPPs
  - **Various Floating NPPs of China** in the East Sea of Vietnam (planned)
  - Building national RMEP network/capacity (RMEP = radiation monitoring and emergency preparedness).
- **Deploying the Research Center for Nuclear Energy Science and Technology, RCNEST (MOST and VINATOM) during 2018-2026**
  - New research reactor with power of 10-15 MW to be imported from Russia.
  - **FS stage:** planned from 2023.
- **Climate change and low-carbon energy sources, e.g., renewable energy and nuclear power.**
  - **COP26:** Vietnam targets **net-zero carbon emissions** by 2050.

➢ **TRENDS: new RR; SMRs and FNPPs; advanced power reactors** and Gen-IV reactors; **Chinese NPPs and FNPPs near Vietnam; nuclear safety R&D; HRD in nuclear power.**

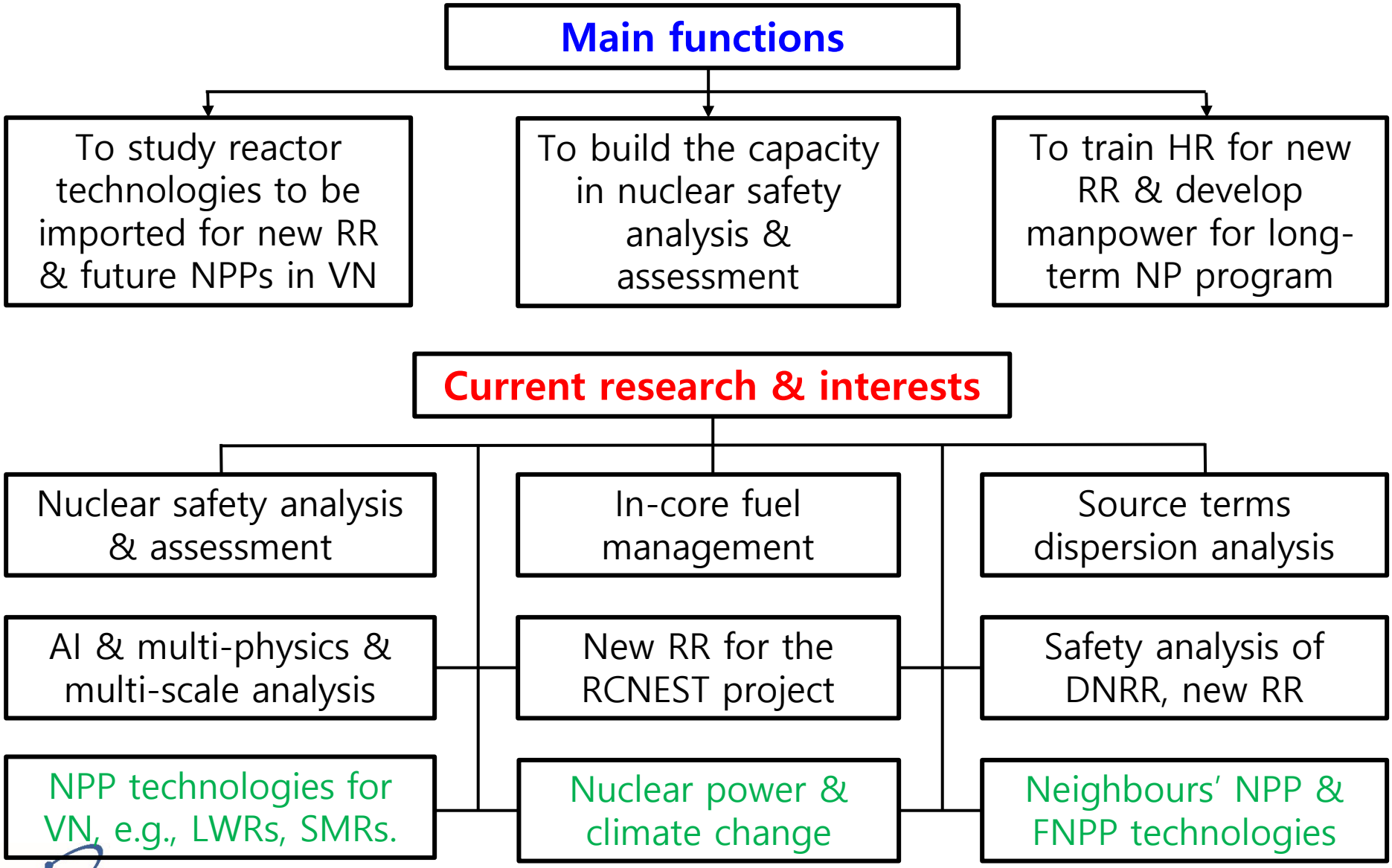
Vietnam Atomic Energy Institute (VINATOM)



Reactor Research Groups in VINATOM



Nuclear Energy Center at INST/VINATOM

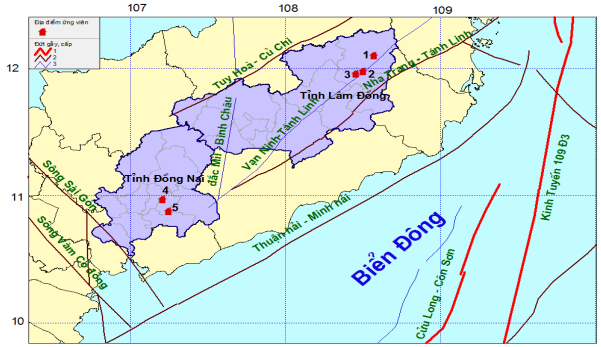


Nuclear Safety Capacity Building in VINATOM

- **Main objectives up to 2030**
  - Capacity building in support for safety assessment of the new RR
  - Capacity building in conceptual design and safety analysis of SMRs & FNPPs
  - Maintain and develop human resources on nuclear reactor engineering
- **Main research directions**
  - Nuclear safety R&D in support for safety assessment of the new RR
  - Study on conceptual design and safety analysis of FNPP using SMR
  - Study on preliminary safety assessment of FNPPs of neighbouring countries
  - Study on nuclear safety with focus on passive safety systems, two-phase flow heat transfer, multi-physics and multi-scale calculations, and analysis of source terms under nuclear accident scenarios.

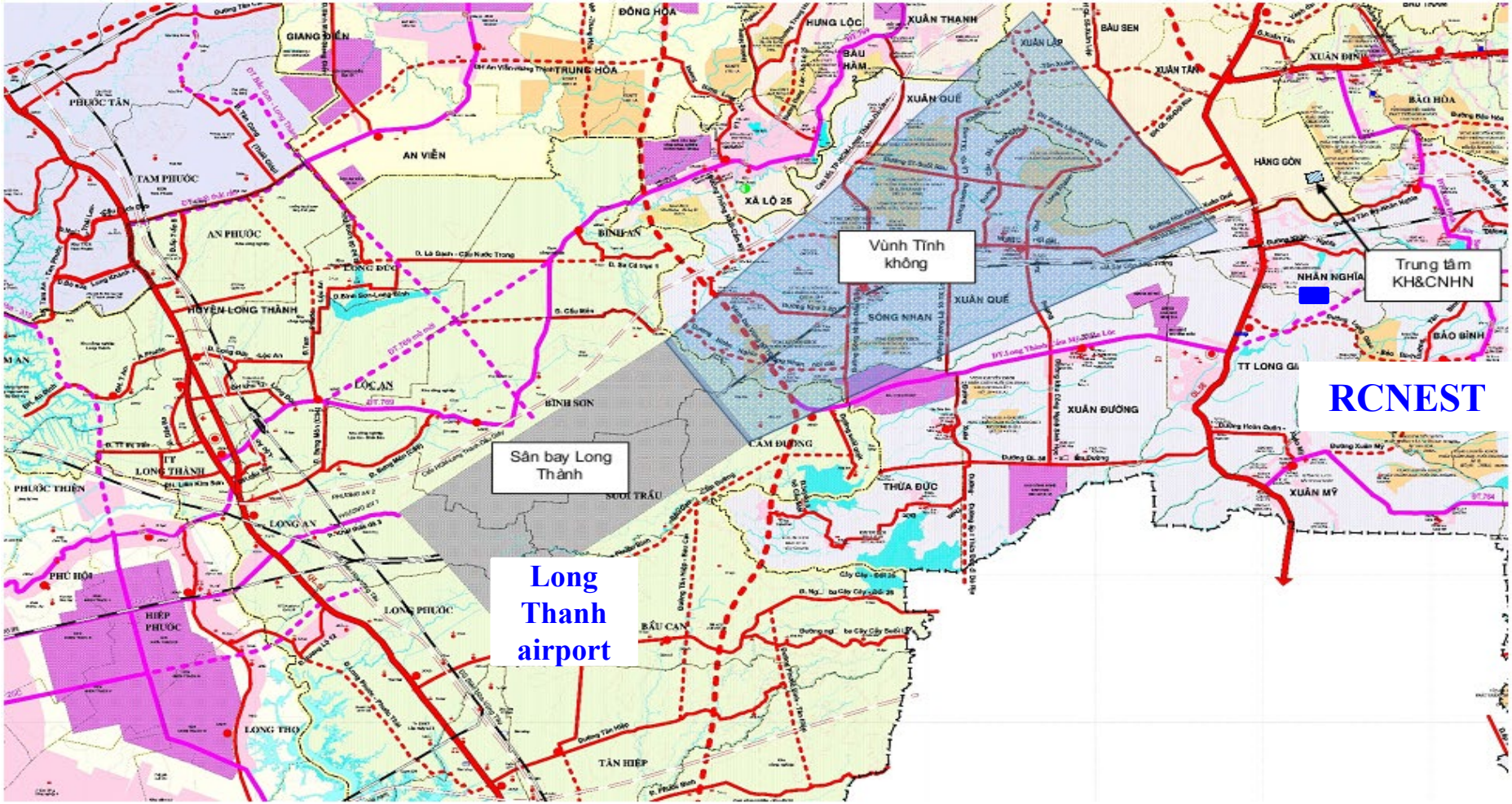
2. The New Research Reactor Project

- Project of **Research Center for Nuclear Science and Technology (RCNEST)**, with a focus on the new nuclear research reactor with a power of 10-15MW.



- 2010: Discussion during the visit of the PM of Vietnam to Russia
- **21 November 2011: Signing the Intergovernmental Agreement between Vietnam and Russia**
- 2012-2014: Considering Dalat site – Approval of the Government, and then cancelled. **Considering other sites in Dong Nai province.**
- 2015: The Pre-FS has been completed.
- 2016: Updating the Pre-FS due to NPP cancelling
- 2017: The Pre-FS has been reviewed by inter-ministerial Committee.
- **2018: Approval of the Pre-FS (19/11/2018)**
- **FS stage: planned from 2023**

Location of the New Research Reactor



- About 50km from Long Thanh Airport
- About 80km form HCM city

Preparation for Safety Assessment

- **Preparing regulatory framework for the new research reactor based on the regulatory documents of Russia and IAEA:**
  - **Circular 05/2020/TT-BKHCN** on Safety Requirements for research reactors.
  - Particular Decision of Minister of MOST on **Requirements for the Format and Contents of Safety Analysis Report (SAR)** for research reactors supporting the application of FS approval (submitted for approval).
  - **Other regulatory documents** in support for application of FS approval.
- **Capacity building for safety assessment of the new research reactor:**
  - VARANS (Regulatory Body)
  - **VINATOM (TSO)**
    - **Institutional project:** Study on acceptance criteria for evaluation of SAR report for the new research reactor (2020-2021; Joint-study: VINATOM & VARANS**).**

3. Current Research on Nuclear Reactors at VINATOM

1) **Study on 3D kinetics and reactivity initiated accidents of the Dalat nuclear research reactor (DNRR) with LEU fuel using PARCS (2018-2020)**
   - Joint-research: Nuclear Energy Center (NEC)/INST, Nuclear Reactor Center/NRI, VARANS (Vietnam Agency for Radiation and Nuclear Safety); funded by MOST (Ministry of Science and Technology of Vietnam).
2) **Study on in-vessel melt retention (IVR) principle and applicability for VVER-1000 (2018-2020)**
   - Joint-research: Nuclear Training Center (NTC)/VINATOM, NEC/INST; funded by MOST.
3) **Development of a simulator for the Dalat Nuclear Research Reactor (2018-2020)**
   - Center for Nuclear Techniques (CNT); funded by MOST.
4) **Study on fluid-structure interaction (FSI) phenomenon leading to breakage of a thermometer well in a prototype fast breeder reactor (2019)**
   - NEC/INST; funded by VINATOM.

Current Research on Nuclear Reactors at VINATOM (cont'd)

5) **Study on rod ejection accidents in PWR UO2 and MOX/UO2 fuelled cores (2019-2021)**
   - Joint-research: NEC/INST, HUS; funded by NAFOSTED.
6) **Study on technology and safety of Floating Nuclear Power Plants using Small Modular Reactors (2019-2020)**
   - Joint-research: NEC/INST, VARANS, DTU (Duy Tan University); funded by MOST.
7) **Conceptual design of a PWR SMR fuel assembly with high burnup (2020)**
   - NEC/INST; funded by VINATOM.
8) **Study on Flooding Experiments with Blocked Arrays (FEBA) using RELAP5/MOD 3.3 (2020)**
   - Joint-research: NTC/VINATOM, NEC/INST; funded by VINATOM.

.

Current Research on Nuclear Reactors at VINATOM (cont'd)

9) **Study on design of SMR using fuel assembly of AP1000 reactor (2020-2021)**
   - NEC/INST; funded by NAFOSTED (National Foundation for Science and Technology Development).

10) **Preliminary study on thermal-hydraulic system for SMR based on ACPR50S technology (2021)**
   - NEC/INST; funded by VINATOM.

11) **Development of a simulator for the reactor core of a research reactor based on foundation of reactor physics and fluid dynamics (06/2021-06/2023)**
   - Center for Nuclear Techniques (CNT); funded by MOST.

12) **Study on neutronic and thermal-hydraulic design and safety analysis of SMR for FNPP (06/2022-06/2024)**
   - Joint-research: NEC/INST, NTC/VINATOM.

Recent Researches on SMRs

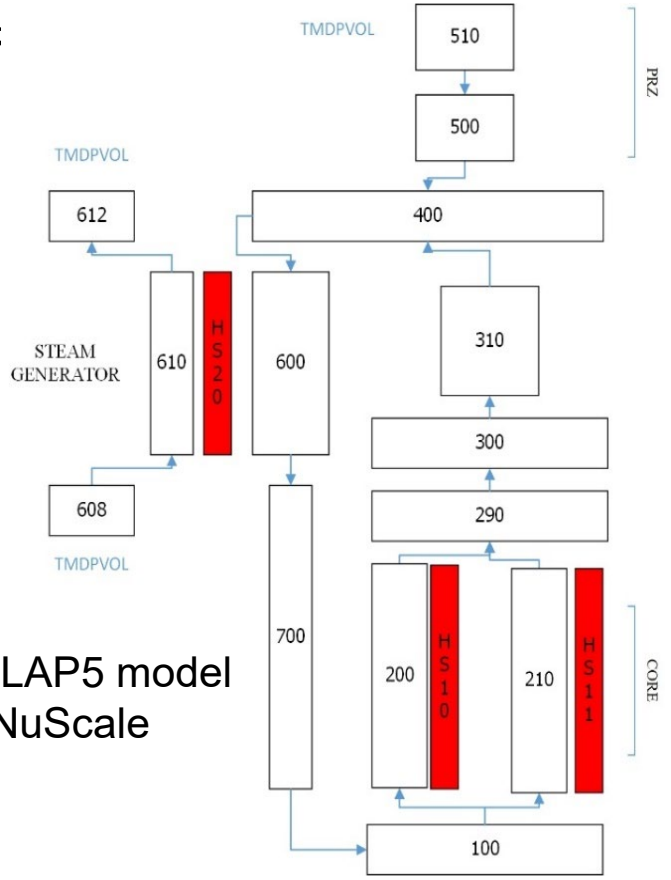
i) Study on technology and safety of Floating Nuclear Power Plants using Small Modular Reactors (2019-2020, funded by MOST)

- Overview of SMRs and FNPPs: **Akademik Lomonosov**, NuScale, OFNP-300, **ACPR50S**, Flexblue, etc.
- Technology and safety systems of FNPPs with SMF
- Safety and security criteria of FNPPs with SMRs
- Research on neutronic characteristics and T-H safety of SMRs used in FNPPs

		F235 0.490	F340 0.692	F445 0.681		
	F340 0.762	F445 1.167	F445 1.328	F445 1.198	F340 0.762	
F445 0.682	F445 1.199	F340 1.376	F235 1.236	F340 1.376	F445 1.168	F235 0.490
F340 0.692	F445 1.329	F235 1.237	F235 1.254	F235 1.237	F445 1.329	F340 0.692
F235 0.491	F445 1.168	**F340** **1.377**	F235 1.237	**F340** **1.377**	F445 1.199	F445 0.682
	F340 0.763	F445 1.200	F445 1.330	F445 1.169	F340 0.763	
		F445 0.683	F340 0.693	F235 0.491		

Fuel type
Relative power

Proposed core of SMR 200 MWt

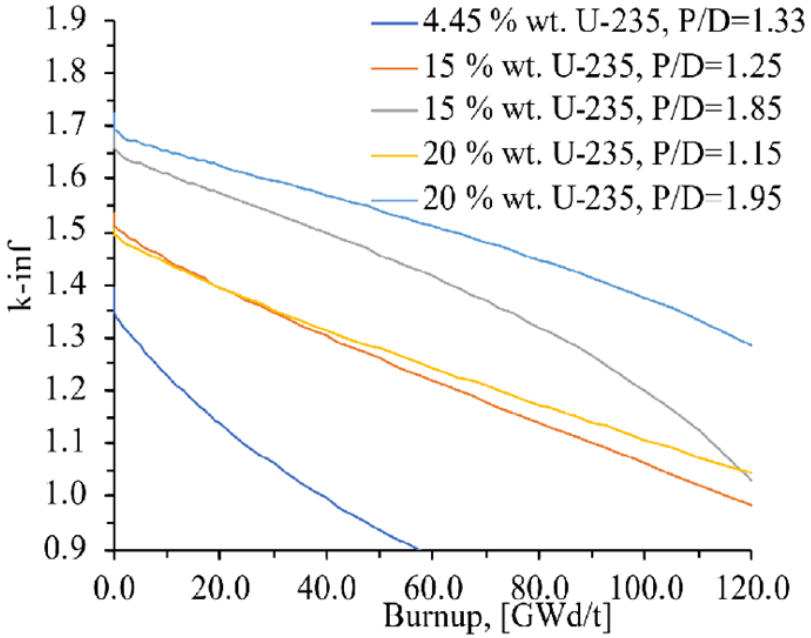


RELAP5 model of NuScale

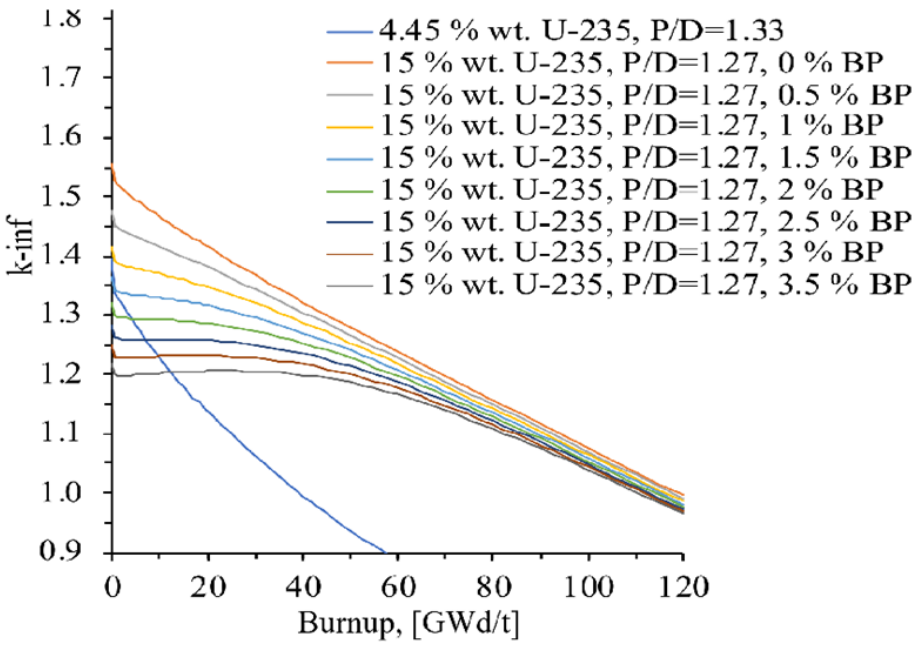
V. P. Tran et al., Application of Evolutionary Simulated Annealing Method to Design a Small 200 MWt Reactor Core, Nucl. Sci. and Tech., Vol.10, No. 4 (2020), pp. 16-23; ISSN: 1810-5408.

Recent Researches on SMRs (cont'd)

ii) Conceptual design of a PWR SMR fuel assembly with high burnup



Effect of enrichment and pitch-to-diameter ratio (P/D)



Effect of BP on reactivity of fuel cell

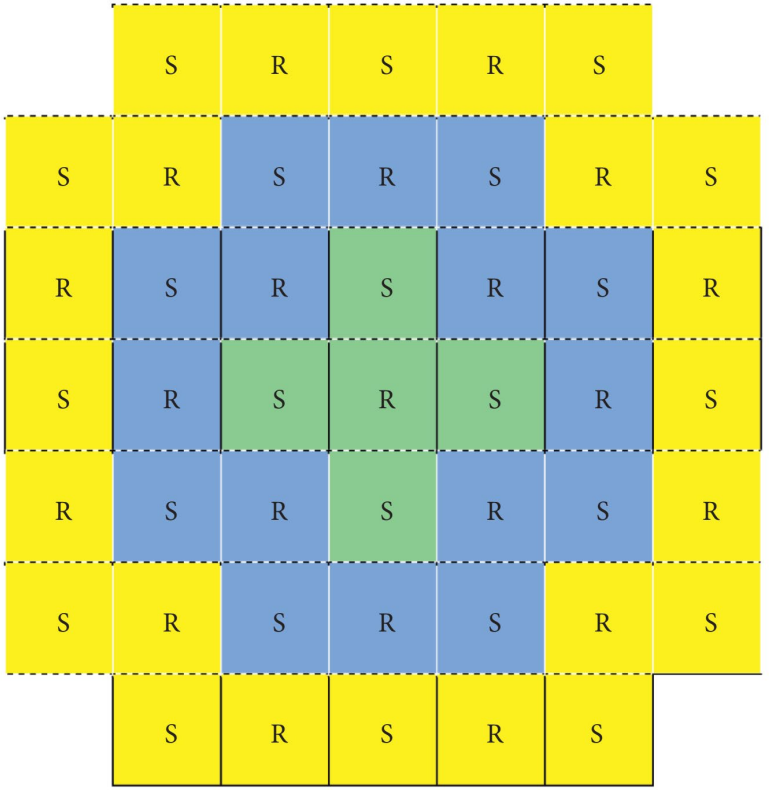
- Fuel of 15 % wt. U-235 enrichment and 1.0 to 3.5 % of Erbium as BP can achieves high burnup, up to 100 GWd/tHM;
- Using SiC as cladding material would enhance strength and ductility of ATF cladding to mitigate against severe accidents.

V. K. Hoang et al., Neutronic analysis of fuel pin design for the long-life core in a pressurized water reactor, Nucl. Sci. and Tech., Vol. 11, No. 1 (2021), pp. 09-15.

Recent Researches on SMRs (cont'd)

iii) Study on design of SMR using fuel assembly of AP1000 reactor

Parameters	Core model 3
Max cycle length (years)	2.22
Max k-eff over cycle (-)	1.2826
Max 3D PPF (Fxyz) (-)	1.85
Max 2D PPF (Fxy) (-)	1.34
Max 2D PPF (Fxz) (-)	1.38
Max power density (W/cm^3)	141.1
MDNBR at nominal conditions (-)	3.12
Max fuel temperature (K)	1001.9
Max clad temperature (K)	642.4
Max coolant temperature (K)	610.2
Outlet coolant temperature (K)	610.2
Max critical boron (ppm)	2555



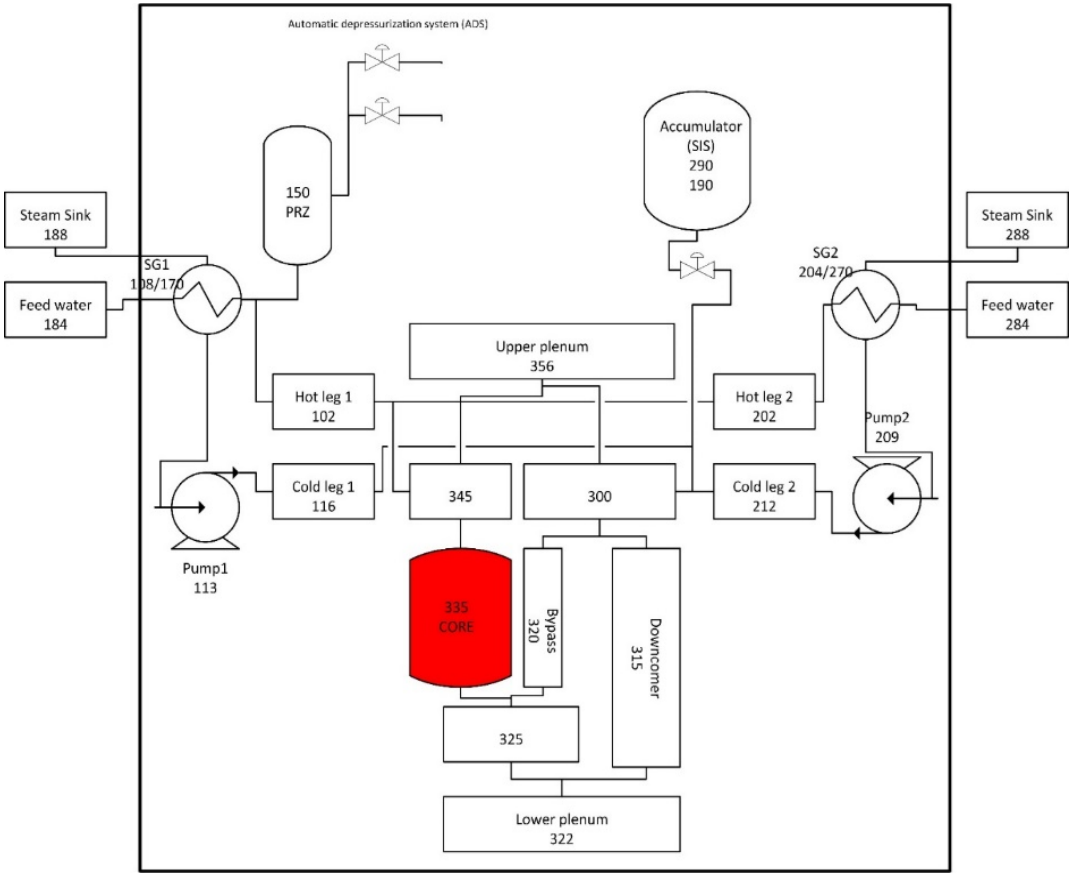
- Design a 300 MWt SMR based on the assemblies of the AP1000 with 45 assemblies, 190 cm high active core and cycle length of 2.22 years.

Recent Researches on SMRs (cont'd)

iv) Preliminary study on thermal-hydraulic system for SMR based on ACPR50S technology

Parameter	Calculated
Power (MWth)	200
Primary loop pressure (MPa)	15.5
Mass flow rate in the core (Kg/s)	1325.0
Inlet temperature (K)	575.2
Outlet temperature (K)	600.6
Secondary loop pressure (MPa)	4.85
Feed water temperature (K)	490

Main parameters after 5000 sec



RELAP5 model for the SMR based on ACPR50S

Future Research Plan for SMR and FNPP

- **Study on conceptual design and safety analysis of a barge-type FNPP using PWR SMR**
  - To build capacity in conceptual design of a barge-type FNPP based on PWR SMR(s);
  - To build capacity in safety assessment of future FNPP(s) in the region in marine environment.

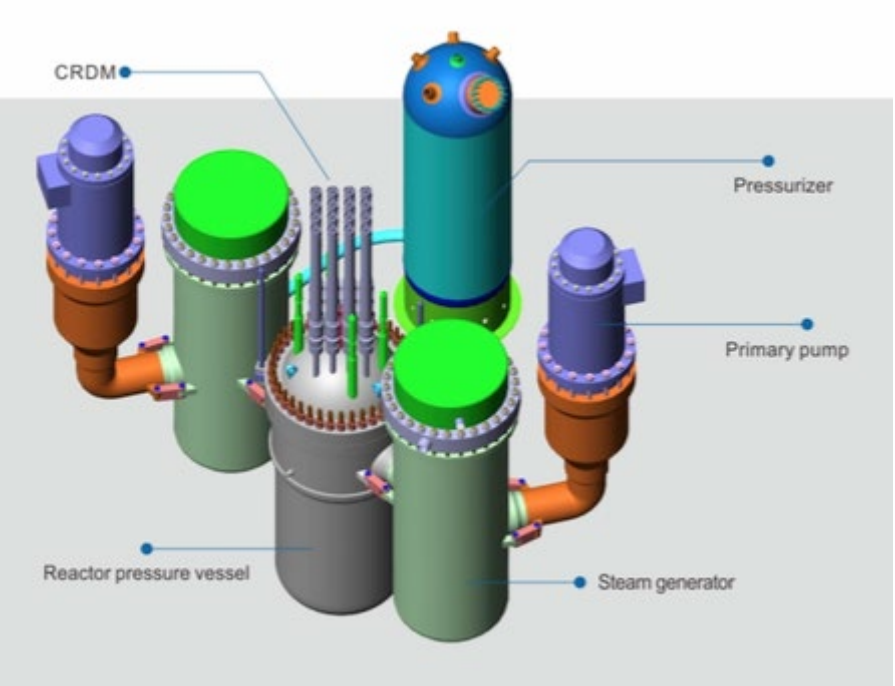
➢ **The following R&D schedule is envisaged**

- 2021-2022: Pre-conceptual design;
- 2022-2024: Conceptual design (barge-type floating platform, PWR SMR, reactor safety);
- 2024-2026: Application of this design to preliminary safety analysis and assessment of future FNPP(s) in the region.

Relevant SMR Research started in 2022

- **Study on neutronic and thermal-hydraulic design and safety analysis of SMR for FNPP (06/2022-06/2024)**

  - Building capacity for design, safety analysis and assessment of PWR SMR;
  - Verification & validation of thermal-hydraulic computation tools for PWR SMR;
  - Preliminary design of reactor core of a PWR SMR (SMR-VN1);
  - Preliminary design of thermal-hydraulic and safety systems of SMR-VN1.



ACPR50S reactor system (Source: CGN)

Research Contents

SMR technology status & preliminary conceptual design proposal for SMR-VN1

- Proposing core design concepts for SMR-VN1
- Proposing thermal hydraulic design concepts for SMR-VN1

Preliminary design of neutronic characteristics for SMR-VN1 reactor

- Calculation of the physical characteristics at the beginning of the cycle
- Calculation of physical characteristics and density of fission products during operation of SMR-VN1

V&V of thermal-hydraulic computation tools for PWR-SMR

- Demonstration of LOCA Scenario based on RELAP 5/mode 3.3 calculation by using FLECHT-SEASET Reflood test
- V&V of the CFD code calculation by using PSBT – NUPEC PWR Sub-channel and Bundle Test benchmark

Preliminary T-H design and application safety analysis for PWR SMR-VN1

- Preliminary thermal hydraulic design for main components such as: Reactor Core, Reactor Vessel, SG, Pressure etc…
- Preliminary thermal hydraulic design for passive and active safety systems
- Application of this design to preliminary safety analysis

Concluding Remarks

- **Capacity building for nuclear power safety R&D in VINATOM**
  - Most of researchers are young (postdocs, PhD/MSc candidates);
  - Maintaining manpower (HRD) after cancellation of the NPP projects;
  - Manpower training through R&D projects & collaborations.
- **Building capabilities to support the new RR project (RCNEST)**
  - Practice with the DNRR and the new RR proposed using SRAC2006, MVP, MCNP6, SCALE, Serpent 2, PARCS, TRACE/PARCS, RELAP5, CFD, etc.;
  - 3D kinetics and coupled neutronic-TH analysis of the DNRR and new RR;
  - Reactor physics experiments and other relevant ones with the DNRR.
- **Understanding NPP/FNPP safety and technologies of neighbouring countries.**
  - Building capacity in nuclear safety analysis & assessment, radiation dispersion analysis, radiation monitoring, and emergency preparedness & response.
- **Studying NPP technologies which can be introduced to Vietnam in future, e.g., LWRs and SMRs**
  - Conceptual design study on SMR for FNPP;
  - Study on effects of marine environment on floating SMR;
  - Study on advanced reactor technologies, e.g., advanced LWRs.

Thank you !