International Atomic Energy Agency

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The Importance of an Enhanced Nuclear Engineering Curriculum in Newcomer Countries to support SMR Development and Deployment

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Numerous SMR Designs at Various stages

LWRs
- ABV
- CAREM
- CPR-300
- IRIS

LWRs
- KLT-40S
- mPower
- MRX
- NHR-200

LWRs
- NP-300
- NuScale
- RITM-200
- SMART

LWRs
- VBER-150
- VBER-300
- VK-100/300
- SMR-200

FRs
- 4S
- BREST-300
- HPM
- SVBR-75/100

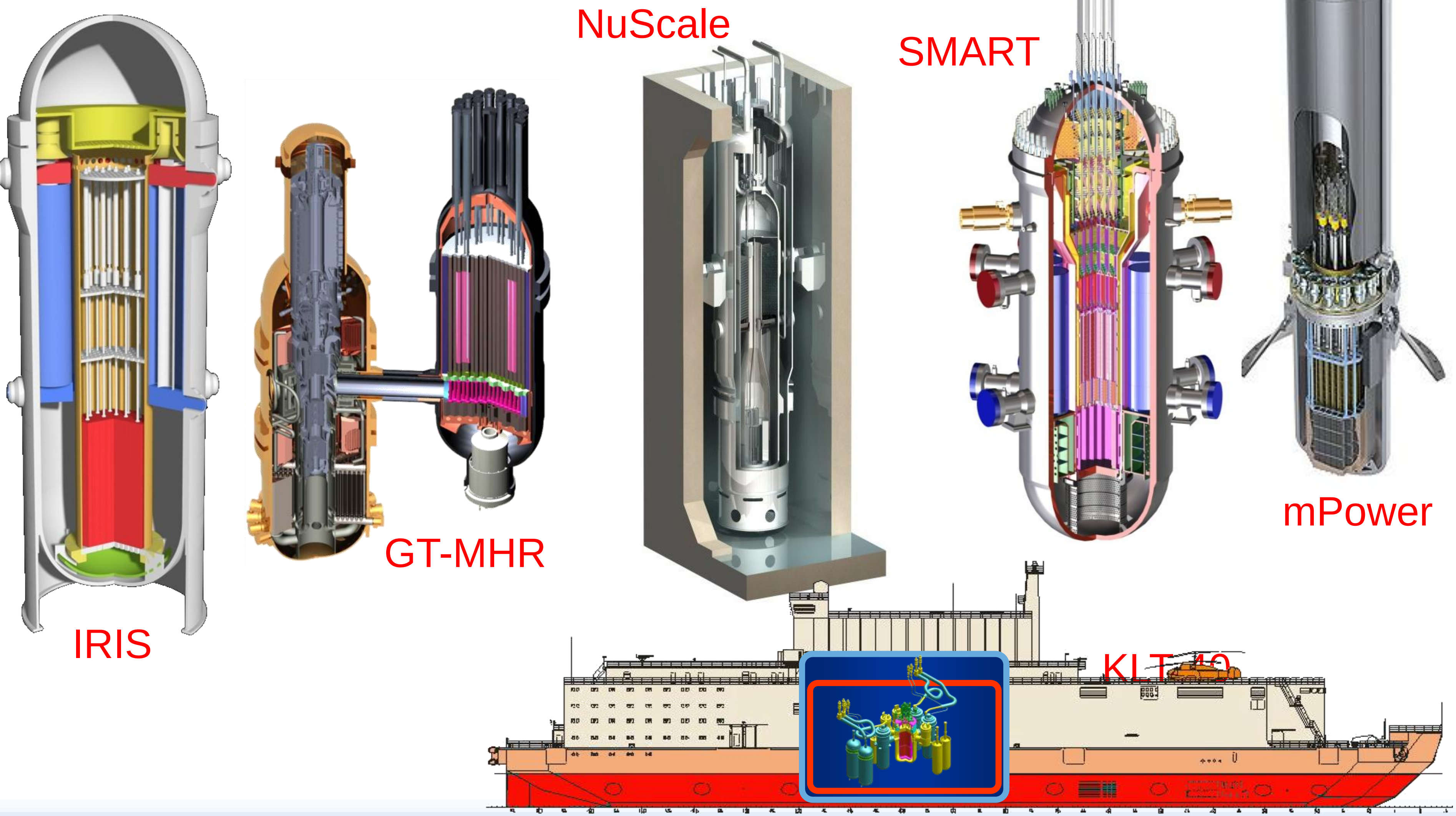
FRs
- LSPR
- PFBR-500
- PRISM
- ENHS

iPWRs
- VKT-12
- FBNR
- IMR
- Flexblue

PHWRs
- AHWR
- CANDU-6
- PHWR-220
- PHWR-540

GCRs
- HTR-PM
- EM^2
- GT-MHR
- PBMR

Contemporary SMR designs represent evolution from designs of the 70s, 80s, 90s…



Perceived Advantages and Challenges

	Advantages	Challenges
Technological Issues	• Shorter construction period (modularization) • Potential for enhanced reliability and/or safety • Reduced complexity in design and human factor • Suitability for non-electricity application (i.e. process heat and desalination) • Tolerance to grid instabilities	• Licensability (delays due to design innovation) • Non-LWR technologies • Impact of innovative design and fuel cycle to proliferation resistance • Operability • Spent fuel management and waste handling policies
Non-Technological Issues	• Fitness for smaller electricity grids • Options to match demand growth by incremental capacity increase • Site Flexibility • Lower upfront investment capital cost per installed unit • Easier financing scheme	• Economic competitiveness (impact of economy of scale) • Reduced emergency planning zone • Regulation for fuel or NPP leasing • Limited market opportunities • First of a kind cost estimate • Availability of design for newcomers • Infrastructure requirements

Lessons Learned from the Fukushima Event

- Issues to be addressed for innovative SMRs deployment:
    - Multiple external initiating events and common cause failures
    - Station Black-Out
    - Reliability of emergency power supply
    - Enhanced containment seismic/hydrodynamics strength
    - Hybrid passive and active engineered safety features
    - Safety viability of multi-modules – first of a kind engineering
    - Direct containment heating
    - Wider scenario of Beyond Design Basis Accident (DBA)
    - Accident management/Emergency response capability and costs
    - Spent fuel pool seismic and cooling provision
    - Hydrogen generation from steam-zirconium reaction; recombiner system
    - Environmental impact assessment and expectation
    - Waste handling and policy
    - Public Acceptance

Need for a Curriculum covering all concerns related to SMRs

- Are the current conventional NE curriculum sufficient to address new global challenges? *(i.e. safety, technology + social engineering)*
- Are SMR **safe** enough? →Lessons-learned from the three major nuclear accidents (Fukushima, Chernobyl, and Three-Mile Island)
- **Environmental impact**? → Capability to perform Multidisciplinary Environmental Impact Assessment
- Post accident **radioactive waste** treatment? → Options of spent fuel storage and enhanced waste management
- **Proliferation risks?** → Proliferation Resistance Fuel Cycle consideration early from the conceptual design stage
- **Security** and **Physical Protection**
- **Emergency preparedness and guidelines**
- **Capability on Technology Assessment**

✓ **Nuclear workforce required → Personnel Training**

Combination of engineering and technology and effective public policies → Interdisciplinary Approach

Social Engineering?

Environmental Impact Assessment (EIA): Why?

- ✓ For assessing potential environmental effects and make sure they are taken into account
- ✓ For providing information (public participation)
- ✓ For optimizing project design and planning (aspects of location, technical solutions, construction, operation)
- ✓ For evaluating the alternatives
- ✓ For determining the viability of the economic activity.

EIA as a way of dealing with public acceptance issues

Waste Management

- Residual materials from the “front end”+ wastes from the “back end” of the fuel cycle

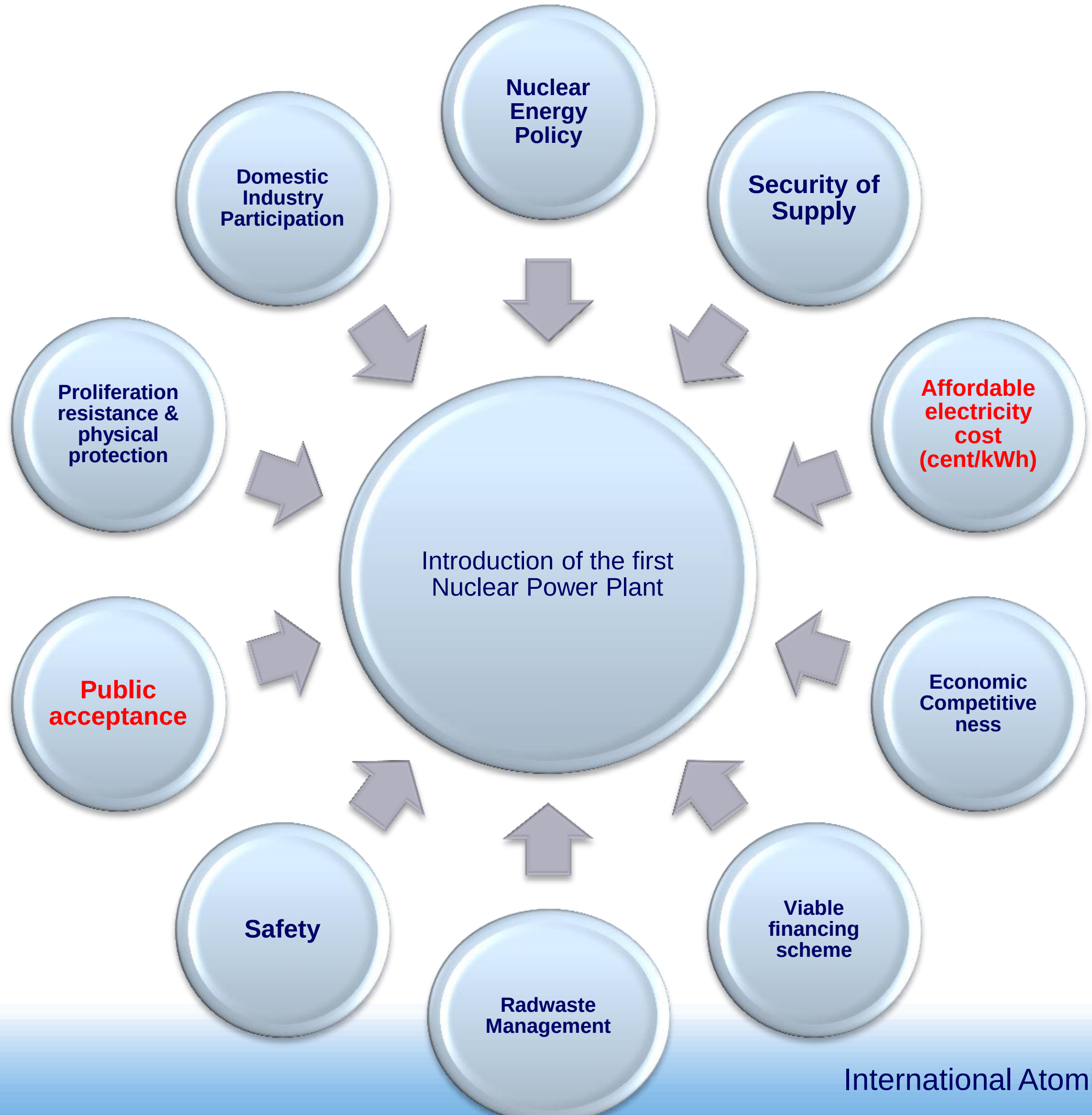
Need for **Safety** and **Sustainability**

- Dealing with questions:
  - Do SMRs produce innovative type of waste?
  - Is there any type of characterization of the SMRs’ waste?
  - Reprocessing challenges?
  - For high-level waste: enhanced vitrification technology?

- **Proliferation Resistance:**
  - **SMRs' Intrinsic proliferation resistance characteristics**
  - **Can they operate for long time without refueling?**
  - **Are SMRs without on-site refueling a viable option?**
- **Nuclear Fuel Cycle Challenges:**
  - **Aim: to find an optimum system combination of the NPPs with SMRs and the associated fuel cycles in order to minimize the overall energy product cost**
  - **Nuclear Fuel Cycle options:**
    - **Uranium, plutonium or thorium fuels**
  - **Need of a Nuclear Fuel Cycle tackling proliferation risks:**
    - **Offering a limited amount of material**
    - **High degree of contamination providing radiation barriers**
    - **Fuel forms difficult to reprocess and make it difficult to extract weapons-grade fissile material**

Proliferation Resistance, Nuclear Fuel Cycle, Waste Management of SMRs are some aspects to be addressed in an Enhanced Nuclear Engineering Curriculum

Newcomer Countries Expectations



The IAEA's role contribution to an Enhanced Nuclear Engineering Curriculum to Support SMRs

- **The IAEA has on-going education and training promotion projects on SMR:**
  - **Project 1.1.5.6 (14) Provide education and training on various aspects of SMR technology development and assessment and SMR applications**
  - **Project 1.1.5.6 (1) Provide a forum for discussion of SMR user needs with technology holders**
  - **Project 1.1.5.6 (2) Facilitate networking among SMR users planning near-term deployment in areas of common interest**

IAEA's Project 1.1.5.5 (2010 - 2011)

- Consultancy Meeting on "Status of Innovative SMR Designs with a Potential of Being Deployed by 2020"
  - Date/place: **2 - 4 May** 2011 in IAEA – Vienna (DONE)
- Research Coordination Meeting for the CRP on "Development of Advanced Methodologies for the Assessment of Passive Safety System Performance in Advanced Reactors (I31018)"
  - Date/place: 26 - 28 April 2011 in IAEA – Vienna (DONE)
- TC - Workshop on Advanced Nuclear Reactor Technology for Near Term Deployment
  - Date/place: 4-8 July 2011 in IAEA – Vienna
- **3rd Technical Meeting on "Options to Incorporate Intrinsic Proliferation Resistance Features to NPPs with Innovative SMRs"**
  - **Date/place: 15 - 18 August 2011 in IAEA – Vienna**
- **TM** on "Options to Enhance Energy Supply Security with NPPs based on SMRs"
  - Date/place: 3 -6 October 2011 in IAEA – Vienna
- Workshop on "Technology Assessment of SMR deployable by 2020"
  - Date/place: 5 – 9 December 2011 in IAEA – Vienna
  - **Extra-budgetary from Republic of Korea**

IAEA's Project 1.1.5.5 (2012 - 2013)

- Develop **roadmap** for technology development, assessment and deployment
- Review **newcomer countries requirements**, **regulatory infrastructure** and business issues
- Define operability-performance, maintainability and constructability **indicators**
- Develop **guidance** to **f**acilitate **c**ountries with planning for SMRs technology **i**mplementation
- Coordinate CRP on development of methodologies
- Provide education and training
- Improve economic competitiveness evaluation methodology

Conclusions

- SMR - an attractive nuclear power option for newcomer countries with small electricity grids and less-developed infrastructure
- High potential for deployment in mid-term (2020 – 2025), but much work yet to be accomplished by reactor designers, national nuclear regulators, and electric utilities.
- Innovative SMR concepts have several common technology development challenges: licensability, competitiveness, financing schemes, energy policy
- Urgent need to satisfy Training, Education and International Nuclear Human Resource Development challenges.
- Moving lessons-learned from the Fukushima Accident into the design, safety, economic, financial, licensing, and public acceptance considerations for SMRs

… Thank you for your attention.

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