What will it take for Deployment and Regulation of Advanced Nuclear Systems Internationally?

ANS Risk-informed, Performance-based Principles and Policy Committee (RP3C) Community of Practice

30 June 2023

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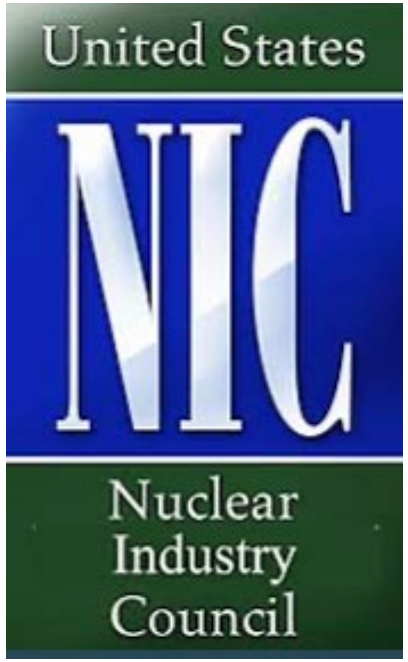

Topics

➢ International Nuclear Deployment

- Existing Nuclear
- New Nuclear technologies
- Driving Forces & Financing
- Advanced Nuclear Reports
- Markets

➢ International Regulatory Collaboration

- Goals & desired outcomes from regulatory collaboration (USNIC)
- Nuclear Harmonization and Standardization Initiative (IAEA)
- European SMR Pre-Partnership
- ELSMOR/TANDEM
- Cooperation in Reactor Design Evaluation & Licensing (CORDEL)
- Multi-lateral initiatives
- Issues

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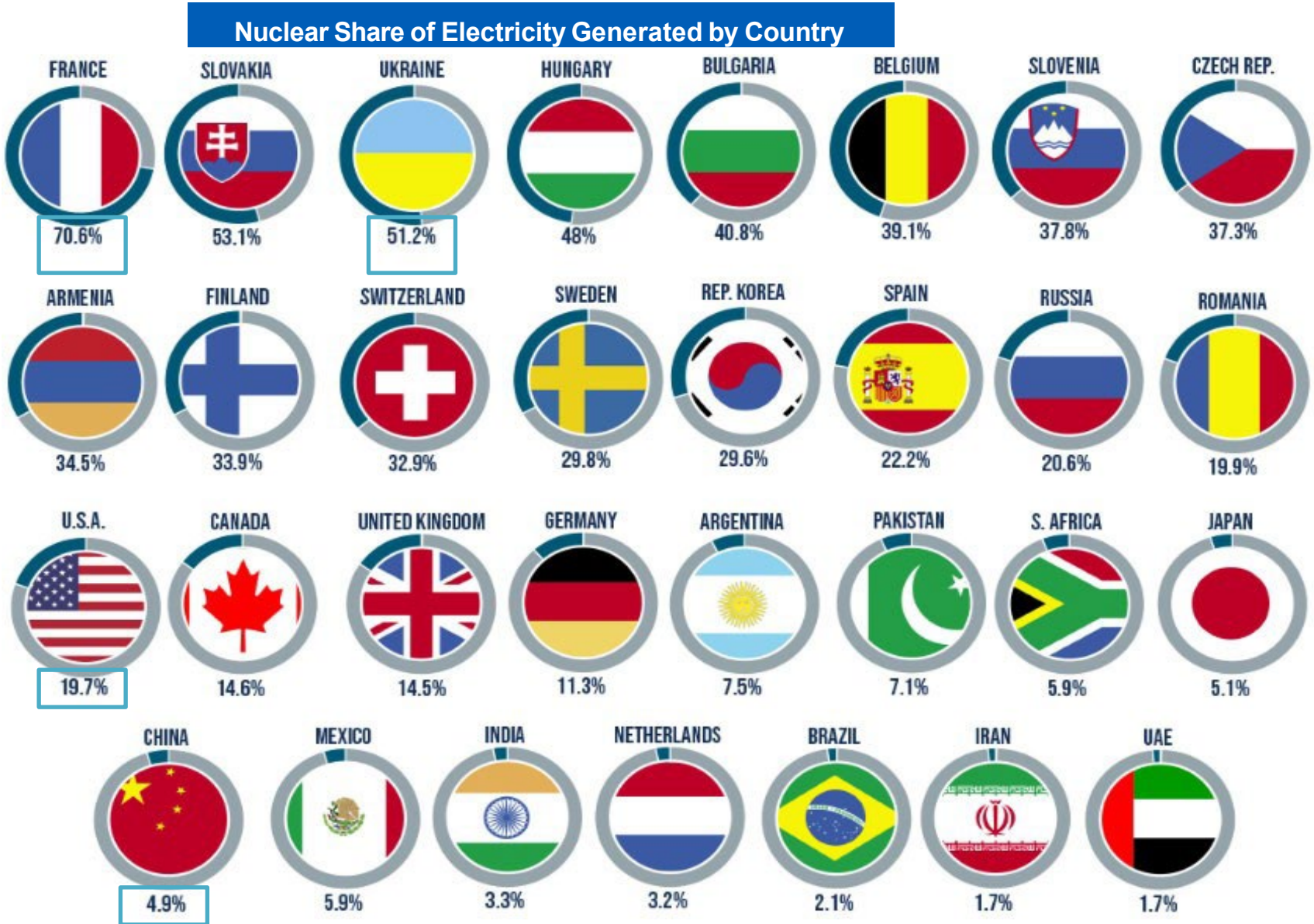
International Nuclear Deployment: Markets, Technologies, Financing

International Existing Nuclear



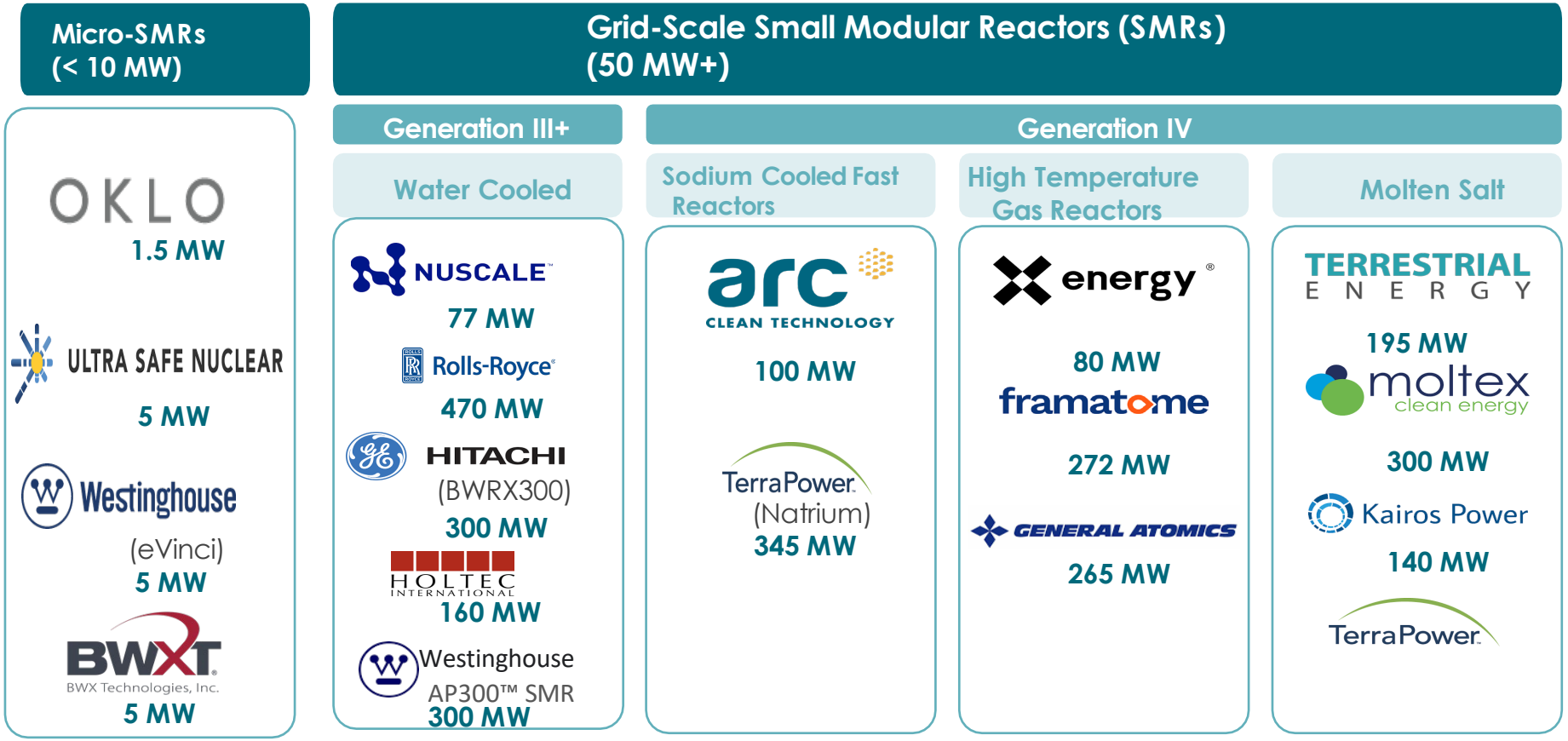
Note: each country's short-form name is used.
Source: IAEA, Power Reactor Information System database, as of June 2021 for 2020

Prepared 2023 by GE Hitachi Nuclear Energy Americas, LLC

Regulations for New Nuclear

- Industry needs to understand different regulations and approaches for each country (prescriptive vs goal setting)
- Industry/associations work with licensing harmonization groups to develop regulatory approaches to new nuclear

New Nuclear – different technologies and sizes



Source: Company information, Generation IV Safety Report; compiled by ARC Clean Technology)

- For more worldwide technologies, see Nuclear Energy Agency Small Modular Reactor Dashboard (78 pages, March 2023, details on 21 SMRs worldwide)
  https://www.oecd-nea.org/jcms/pl_78743/the-nea-small-modular-reactor-dashboard

Driving Forces & Financing Support for Deployment

Driving forces

- Zero Carbon Goals for electricity and industry
- Geostrategic—vs. Russia & China
- Job creation

U.S. programs to support U.S. exports of Advanced Nuclear projects

- U.S. Export-Import (EXIM) bank
- U.S. International Finance Corporation (DFC)
- U.S. State Department Foundational Infrastructure for Responsible Use of Small Modular Reactor Technology (FIRST) program
- U.S. Commerce
- U.S. Trade & Development Administration
- U.S. DOE Loan Program Office

Plus Inflation Reduction Act and other financial incentives

Advanced Nuclear 2023 Reports

Small Modular Reactor Technologies

- Nuclear Energy Agency Small Modular Reactor Dashboard (78 pages, March 2023, details on 21 SMRs worldwide)
  https://www.oecd-nea.org/jcms/pl_78743/the-nea-small-modular-reactor-dashboard

Commercialization and Financing

- DOE/Office of Clean Energy Demonstrations report on "Pathways to Commercial Liftoff: Advanced Nuclear", Pathways to Commercial Liftoff - Advanced Nuclear (62 pages, March 2023). [Industrial Decarbonization later in 2023)

Assessment

- National Academies, "Laying the Foundation for New and Advanced Nuclear Reactors in the United States" (Richard Meserve, Chair), (278 pages, 27 Apr 2023)
  https://r.smartbrief.com/resp/qJyeCnfOltDwdKaACigacTCicNmbZS
- EPRI/NEI North American Roadmap (66 pages; May 2023)
  https://www.epri.com/research/programs/065093/results/000000003002027504

Advanced Nuclear Markets

- Electricity (TVA, Ontario Power, Nuclearelectrica- Romania)
- Industrial: Process Heat and 24/7 electricity (Dow, Nucor)
- Remote/small facilities

Issues include supply chain

Example: Canadian Roadmap Found Significant Market Potential for SMRs

- ✓ **Steam for "steam-assisted gravity drainage" and electricity for upgrading facilities**
- ✓ **29 coal-fired units in Canada at 17 facilities that can be replaced by SMRs**
- ✓ **heavy industry locations (chemicals, refining, etc.)**
- ✓ SMRs could facilitate and enable new mining developments
- ✓ remote communities in Canada with energy needs >1 Mwe
- ✓ Likely serviced by micro-SMRs that can replace costly diesel & heating oil

International regulatory collaboration– Goals and desired outcomes

Harmonization hopes

Aspiration

Phase 3

- Alignment of requirements / approaches
- Mutual validation and acceptance of regulatory assessments

Mid-term goals

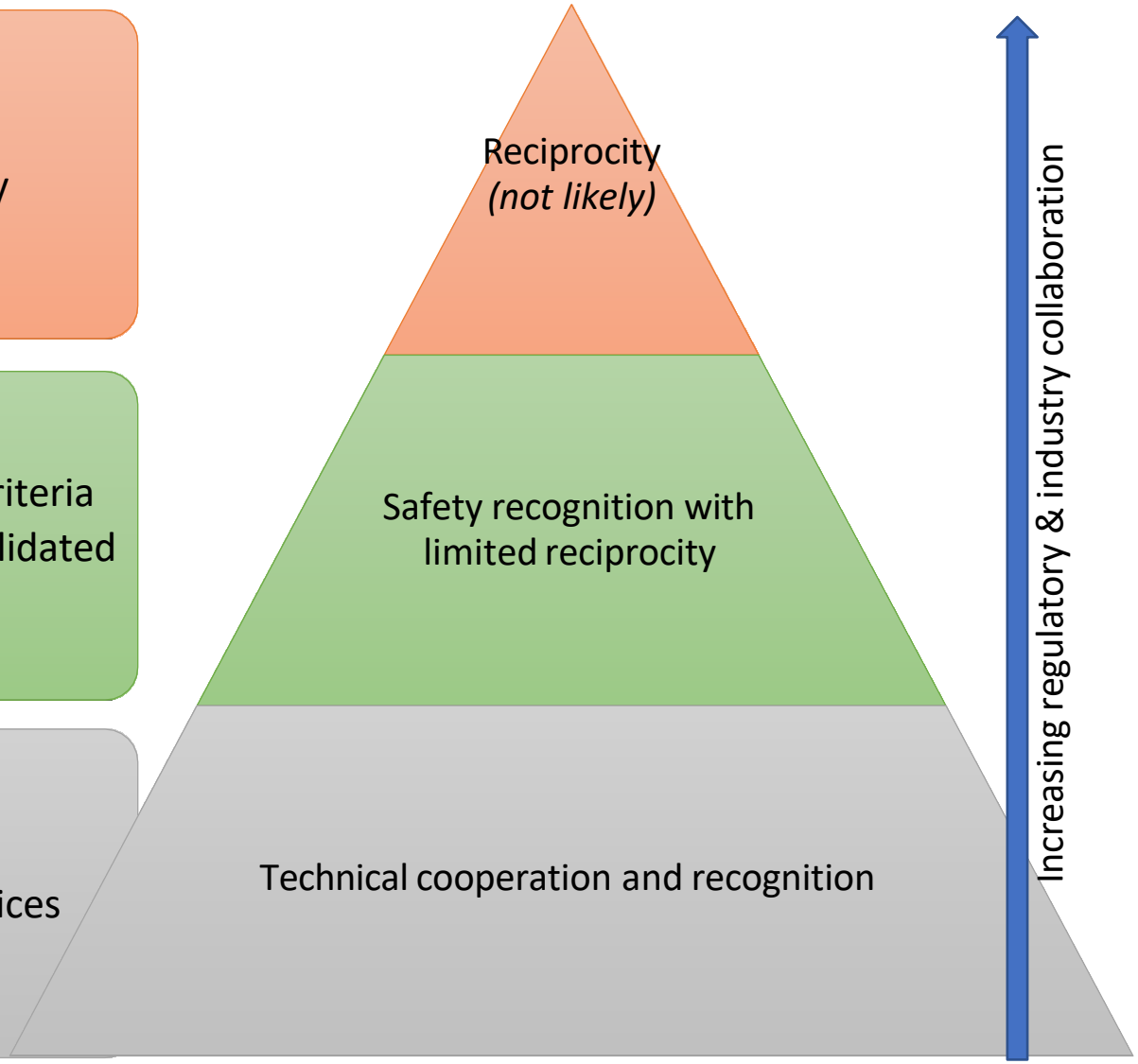
Phase 2

- Define approach to acceptance on key safety criteria
- Define scope of areas that can be accepted /validated from one regulator to another

Near-term objectives

Phase 1

- Align existing activities
- Understanding of intra-regulator working practices
- Share information and agree common terms



Goals for International Nuclear Regulatory Collaboration

A. **Efficient, in time and resources**, for developers and operators to obtain approval of their **initial** safe advanced nuclear reactor system designs

B. More efficient, in time and resources, for developers and operators to obtain approval of 2nd, 3rd, 4th and **subsequent license applications for identical or similar advanced nuclear designs** already approved by one regulator in the same country or different countries

C. Coordination and synchronization of regulatory approaches from countries that will use **co-approval and co-certification** (perhaps with joint safety assessments or joint recognition assessments, and regulators having access to previously approved designs)—some countries want own in-detail assessments

D. Standard or generic approach that enables regulatory authorities to accept **levels of review, and methodologies** by other regulatory authorities to inform their efforts to effectively permit, design certify, and/or license the nuclear reactor technology(s) in their country

E. Collaboration that results in a **single, cost-effective design that can be deployed** in more than a couple countries with no design changes other than those driven by site-specific characteristics

F. Site-specific approvals that can be done expeditiously and effectively when sufficient site characterization and reactor safety design data are available

G. Improved speed of cost-competitive nuclear reactor deployment by **rapid sharing of regulatory and operational lessons learned**

Approach for International Nuclear Regulatory Collaboration

1. Phased approach
2. **Multi-lateral cooperation** to deploy a specific design (e.g., France, Sweden, Czech for EDF NUWARD; NRC and CNSC for GE-Hitachi BWRX-300 with UK and Poland Multi-lateral information exchanges)
3. International regulatory collaboration for **newcomer** countries
4. International **codes and standards** collaborations (e.g., with American Nuclear Society, ASME, CSA, NRC, CNSC, Nuclear Safety Standards Commission (KTA), IAEA, World Nuclear Association's CORDEL, International Organization for Standardization).
5. International cooperation in training and technical **information dissemination** on assessment technologies
6. **Lessons learned** on regulatory experience, and construction and operation
7. Regulatory reviews addressing **aspects** of the design review / certification process that are **independent of siting** can be used in future applications of the same design in different countries
8. Regulatory design review and certification process collaboration that leads to individual regulator's approvals of specific "**building blocks**" of an application / design review that can be directly referenced and used by other international regulators

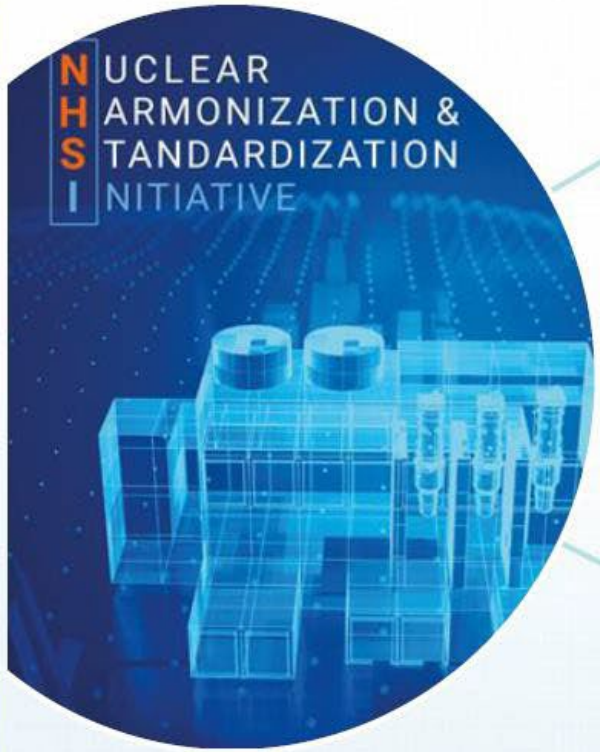
International regulatory collaboration– Activities Underway

(Challenge: Harmonizing the Harmonizers)

Note: some slides from Allan Carson, World Nuclear Association

IAEA Nuclear Harmonization & Standardization Initiative (NHSI)

Effective Global Deployment of **Safe and Secure** Advanced Nuclear Reactors



Harmonization of Regulatory Approaches Track

- **WG1:** Framework for information exchange
- **WG2**: International pre-licensing regulatory reviews
- **WG3:** Leveraging other regulatory reviews

IAEA as facilitator
within and between the tracks

Harmonization and Standardization of Industrial Approaches Track

- **Topic 1:** Harmonization of high-level user requirements
- **Topic 2**: Information sharing on Codes and Standards
- **Topic 3:** Experimental Testing and Validation for Design and Safety Analysis Computer Codes
- **Topic 4:** Acceleration of nuclear infrastructure implementation for SMR

Regulators

Governments

Technology Holders

Operators and other end-users

International Organisations and Associations

27 June 2023 Plenary Meeting (Grossi: 9 benefits)

European Union SMR Pre-partnership

- Identify enabling conditions and constraints, including financial ones, towards safe design, construction and operation of SMRs in Europe
  - 5 WorkStreams
    - WS1: Market analysis (nucleareurope)
    - WS2: Licensing (ENSREG)
    - WS3: Financing (nucleareurope)
    - WS4: Supply chain adaptation (nucleareurope)
    - WS5: Innovation, research & development (SNETP)

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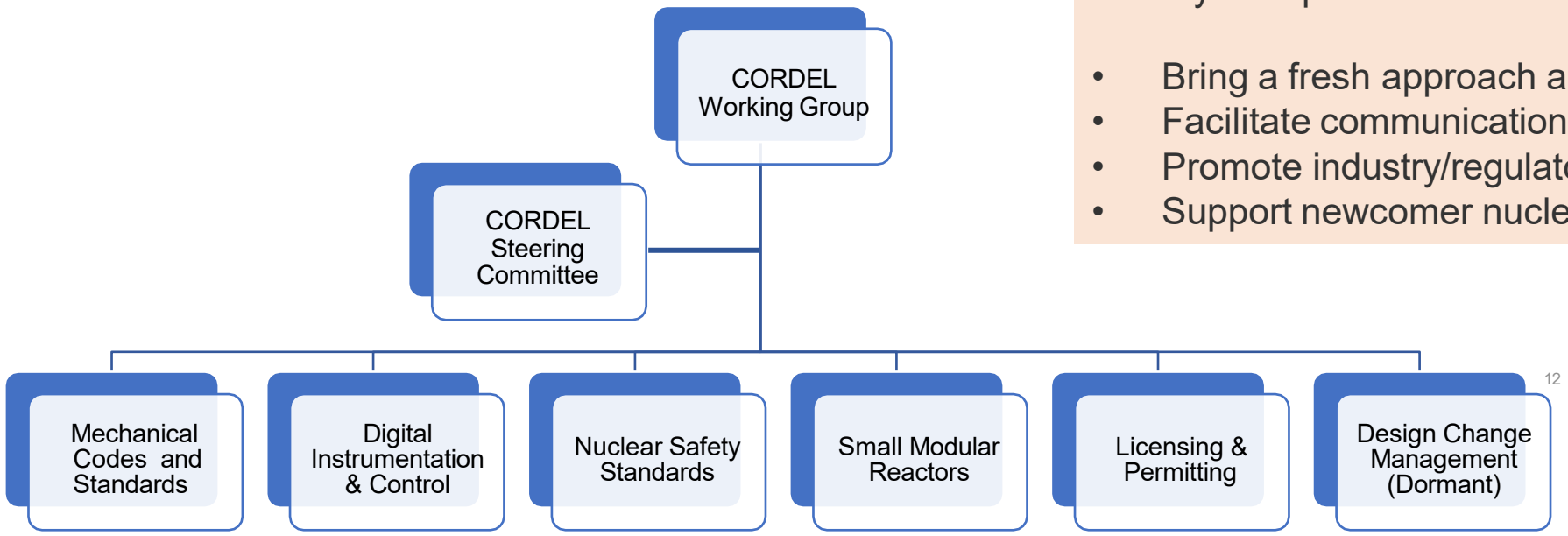
Workstream reports may be released 30 June 2023; stakeholder event in 3 October 2023- Brussels

World Nuclear Association's Cooperation in Reactor Design Evaluation & Licensing (CORDEL)

➢ Mission Statement:

- To promote the standardization of nuclear reactor designs and harmonized approaches to licensing.

➢ Structure:



Identify best practices in licensing for nuclear new build to:

- Bring a fresh approach and new solutions
- Facilitate communication within the global industry;
- Promote industry/regulator
- Support newcomer nuclear countries.

World Nuclear Association Working Group meetings 4-6 Sept 2023 – London

ELSMOR (European Licensing of Small MOdular Reactors)

- Project aims at investigating selected safety features of LW-SMRs
- Focus on safety justification methodology for potentially challenging safety features of LW-SMRs
- Project website: www.elsmor.eu 32
- Funded from the Euratom research and training programme 2014-2018 under Grant Agreement No. 847553

TANDEM

Coordinated by: cea

- Commenced in Sept 2022 – 36-month duration
- Objectives
  - Assess safety compliance of SMR integrated into energy systems
  - Provide guidance for deployment of SMRs and their integration in hybrid energy systems (electricity, heat, hydrogen)
  - Create an enabling environment to create hybrid energy systems based on SMRs

Current Multi-lateral Initiatives

- Ontario Power Generation / TVA / GE-Hitachi / CNSC / US NRC joint review activities for GE-H BWRX-300
  - Early in development of work plans (including steel brick construction, safety methodology, fuel design)
  - Building upon Memo of Cooperation activities between CSNC and US NRC over last 3 years

- France / Finland / Czech Republic joint review activities for EDF NUWARD
  - Early in review of 6 topic areas
    - Safety objectives and study rules
    - List of Design basis conditions
    - Use of passive cooling systems
    - Development plan for computer codes – validation and verification
    - Incorporation of two reactors into one installation (multi-module considerations)
    - Probabilistic Safety Assessment

International regulatory collaboration– Issues

Multiple harmonization initiatives – still work to do

Achievements

Regulatory collaboration

Industry efforts

Number of Regulators

Common Standards & Regulatory Guides
SMR Regulators Forum NHSI

Multinational Design Evaluation Partnership (MDEP)

- Common positions on specific technical issues

Implementation of nuclear safety directive

- Supporting member states

EU SMR partnership

Safety Reference Levels

- Expected practices to be used in member countries
- Method of incorporation of outputs into member states frameworks

NUWARD Licensing agreement

- Increasing knowledge of regulatory practices at the European level

Bilateral Memoranda of cooperation

- Assessment of frameworks and areas for greater attention
- Joint early review of BWRX-300

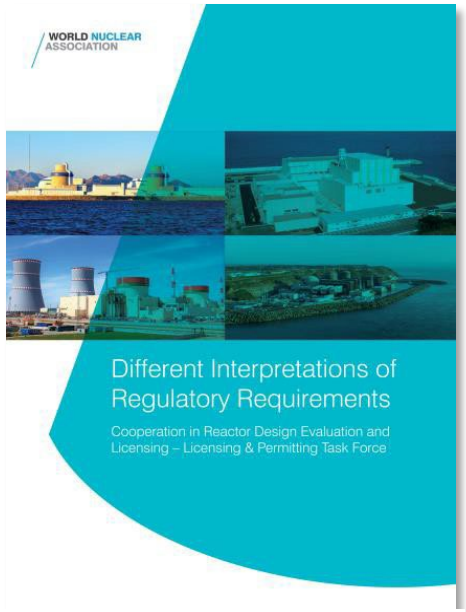
CORDEL Working Group

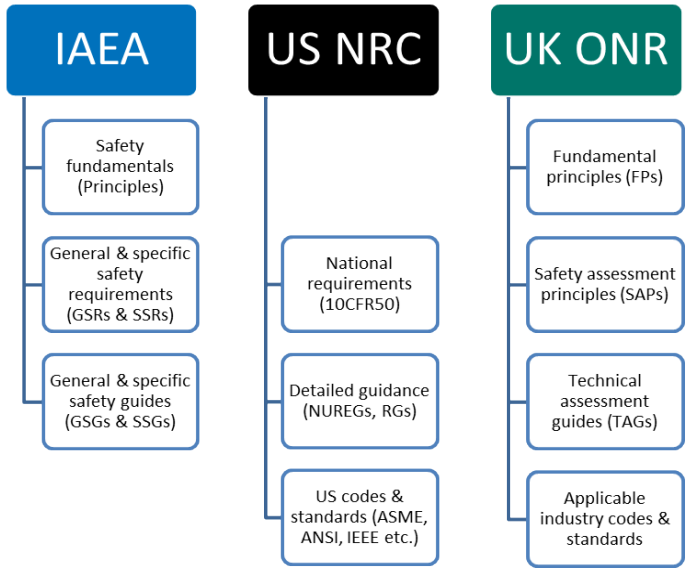
- Mapping of initiatives and achievements
- Development of strategies to streamline international licensing
- Coordination of industry standards alignment

Owner/Operator Requirements

- Common set of requirements for utilities – recent efforts on SMRs
- Increased confidence in regional nuclear markets

Areas of Focus for Reactor Evaluation and Licensing





- General Licensing
- Defense-in-depth
- Postulated initiating events
- Internal & external hazards
- Common cause failure
- Design limits
- Engineering design rules
- Safety classification
- Control systems
- Protection systems

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Plans to move forward together

- **Regulation**: Effective collaboration among international organizations, regulators, and industry to streamline international licensing and regulatory frameworks

- **Deployment**: Achieve Nth-of-a-kind cost-effective reliable deployment models for range of reactor designs and applications through global approaches to markets, regulation, and project financing