NEA
NUCLEAR ENERGY AGENCY

Enabling Innovative Technologies for Regulatory Application – Nuclear Safety Research

John A. Nakoski,
Deputy Head for Regulation
Division of Nuclear Safety,
Technology and Regulation

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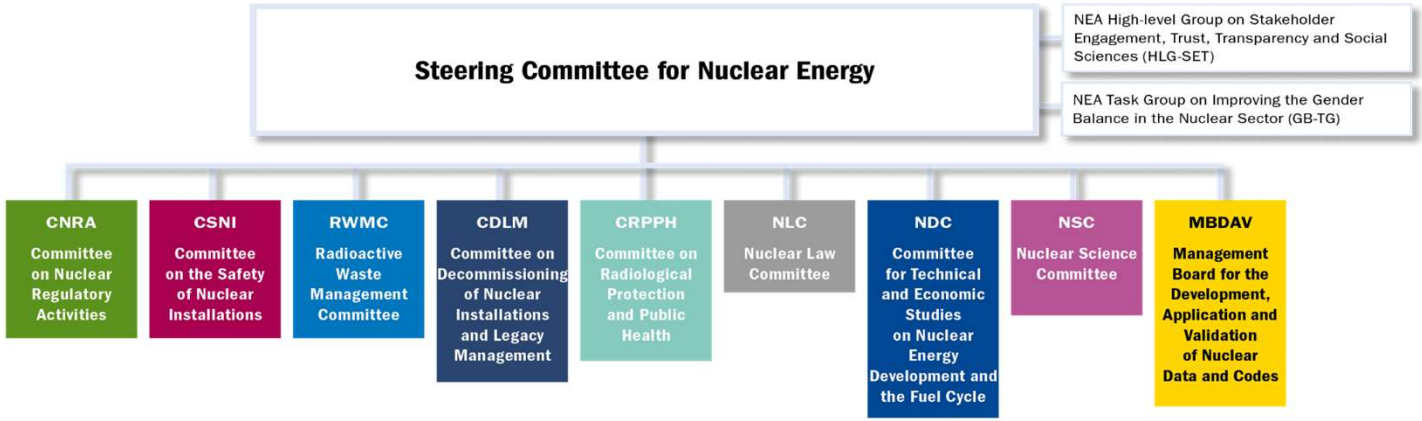
The Nuclear Energy Agency (NEA)

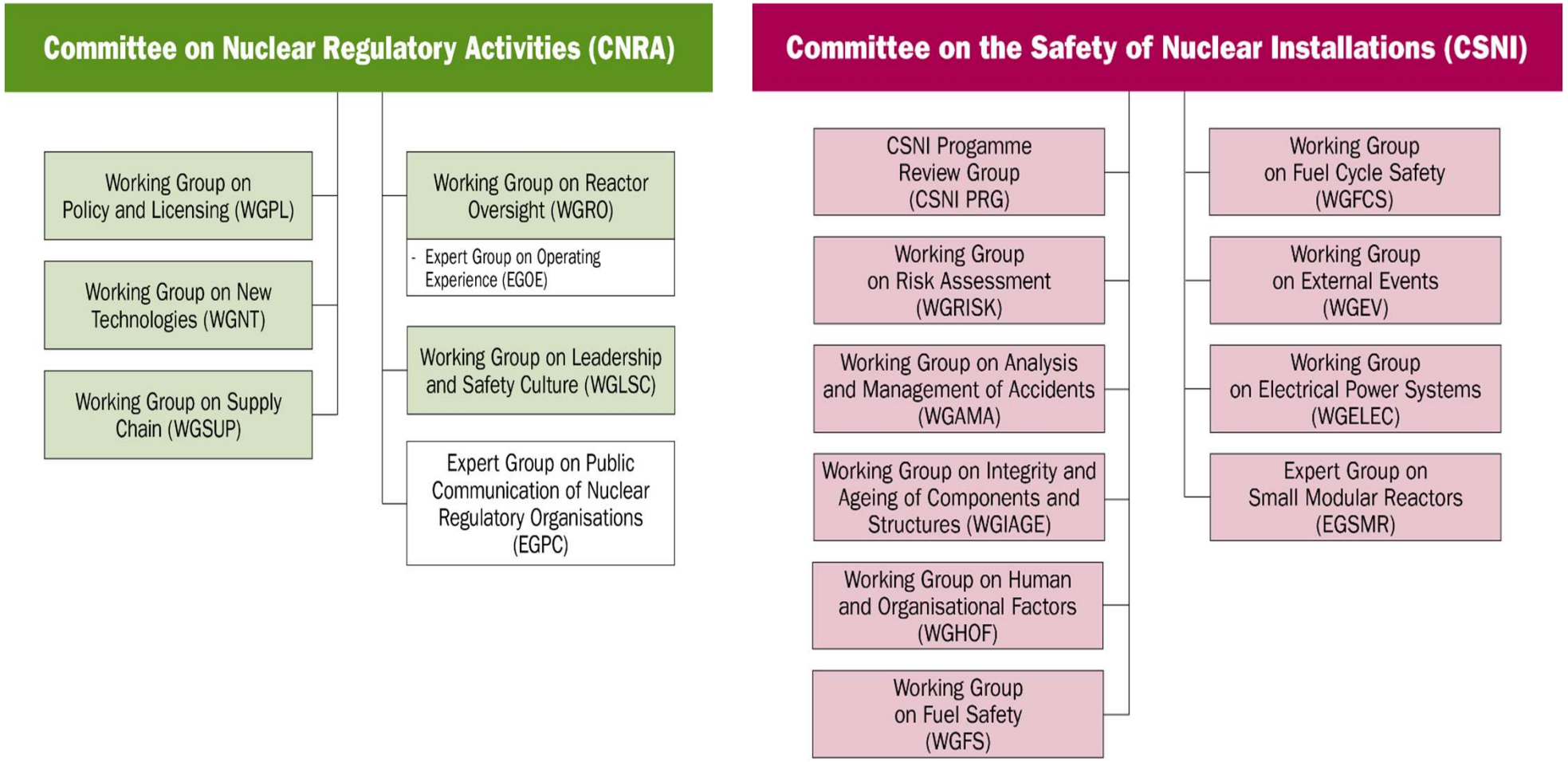
- Founded in 1958
- 34 member countries
- 8 standing technical committees and 1 management board
- ≈ 74 working parties and expert groups
- ≈ 20 ongoing international joint projects

NEA's Mission – Provides a forum for co-operation on nuclear safety and development for the most advanced countries in the world:

- To assist its member countries in maintaining and further developing, through **international co-operation, the scientific, technological and legal bases** required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes.
- To provide authoritative assessments and to forge **common understandings** on key issues as **input to government decisions on nuclear energy policy** and to broader OECD policy analyses in areas such as energy and the sustainable development of low-carbon economies.



NEA Committees focused on Reactor Safety



Major NEA separately funded activities

≈ 20 Major Joint Projects (NEA and non-NEA countries)

- **Nuclear safety research and experimental data** (thermal-hydraulics, fuel behaviour, severe accidents).
- **Nuclear safety databases** (fire, common-cause failures).
- **Nuclear science** (thermodynamics of advanced fuels).
- **Radioactive waste management** (thermochemical database).
- **Radiological protection** (occupational exposure).
- **Regulatory approaches and processes** (security; licensing processes; disruptive, innovative, and emerging technologies)

International Initiatives (Supported by NEA)

- **Generation IV International Forum (GIF)** – with the goal to improve sustainability (including effective fuel utilisation and minimisation of waste), economics, safety and reliability, proliferation resistance and physical protection.
- **Multinational Design Evaluation Programme (MDEP)** – initiative by national safety authorities to leverage their resources and knowledge for new reactor design reviews.
- **International Framework for Nuclear Energy Cooperation (IFNEC)** – forum for international discussion on wide array of nuclear topics involving both developed and emerging economies.

NEA Joint Projects for Nuclear Safety Research

https://www.oecd-nea.org/jcms/pl_72332/

Cooperation through projects

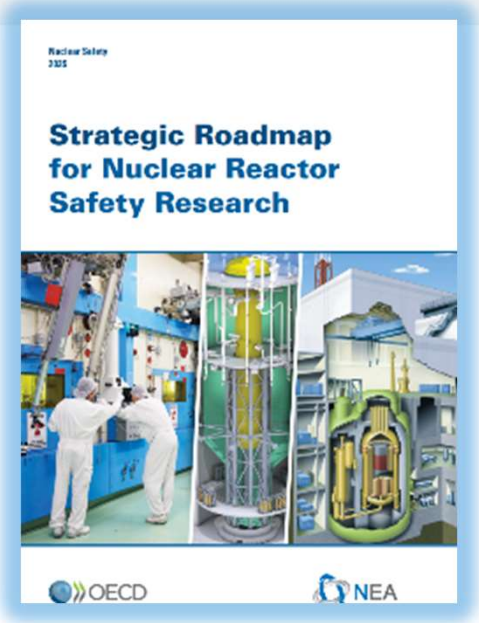
- **Share world-wide expertise** on safety topics and experimentation in a flexible research framework
- **Share resources**, leveraging investments and facilities
- Maintain key research **facilities and competencies**, support operating agents, contribute to education
- Facilitate **cooperation** between countries and various stakeholders

Applications and perspectives

- Understand **phenomena** that affect safety (e.g. data for assessing accident management)
- Quantify and reduce **uncertainties**
- Obtain **high quality data** for safety code validation, benchmark safety codes
- Be ready for the future
  - License renewal of **existing reactors**
  - **New reactor applications** (WCR, non-WCR, SMRs)

Advancing Nuclear Safety - NEA joint projects accelerate consensus on key safety challenges through shared expertise and cost-effective research

Strategic Roadmap for Nuclear Reactor Safety Research



https://www.oecd-nea.org/jcms/pl_111029/strategic-roadmap-for-nuclear-reactor-safety-research

- Aims to guide international nuclear safety research by identifying priorities and strategic directions
- Focuses specifically on reactor safety
- Presents a comprehensive assessment of current technological capabilities, research infrastructure needs, stakeholder engagement, and funding challenges
- Highlights the most urgent technical areas
- provides actionable recommendations to support prioritised safety
- Can be used to align research initiatives with the safe acceleration of nuclear deployment

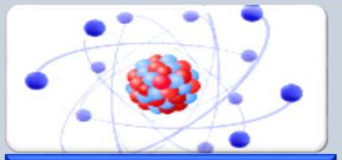
Safety Research Roadmap Topics

Thermal-Hydraulic & Containment
Ensuring safe natural circulation and passive heat removal; validating safety codes for new designs.

Projects:
ATLAS 4,
SYSTHER,
POLCA,
RBHT 2,
THEMIS 2,
PANDA-2

Severe Accident
Understanding corium behavior and improving accident models; enhancing containment safety, especially for submerged SMRs.

Projects:
COPS,
ROSAU 2,
FORESEEN



Fuel Performance and Safety
Testing advanced fuels and claddings; addressing accident scenarios and fuel cycle management.

Projects:
FIDES II,
SCIP 5

Material Integrity
Developing reliable structural materials for long-term advanced reactor and SMR operation.

Projects:
FIDES II, INCREASE 1&2,
HITEC

Multi-Unit Operation
Studying how multiple units (SMRs) operate together using simulators.

Project:
HALDEN HTO

Nuclear Security
Creating frameworks to address new security challenges for advanced reactors and SMRs.

Project:
FUNSEC

Safety Research Roadmap - Strategic Pathways for Globally Aligned Research

Involving

Ongoing discussions and development of new networks and platforms

TH network and platform ATHENA

Harvesting components

Severe Accident

NEA/ATHENA

- **Global platform for nuclear thermal-hydraulic (TH) safety research**.
- **Focus**: water-cooled reactors, SMRs, advanced designs.
- **Goals**: sustain facilities, validate codes, share data.
- **Add-ons**: training, data preservation, new applications.
- **Impact**: safe, efficient, innovative nuclear expansion.

NEA/ATHENA – Priorities and Technical Focus

- **Operation with advanced fuels** (e.g., ATFs, HALEU) and **operational flexibility** (HBU, extended cycles, variable power conditions, load-following management)
- **Passive safety systems performance**
- **SMR compact designs** and related phenomena

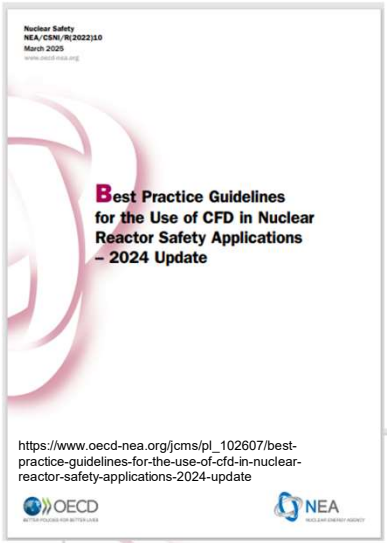
- **Core TH phenomena** (RIA, LOCA, etc.)
- **RCS behavior and performance**
- Coupled **RCS–containment interactions**
- **Innovative components & compact systems**
- **Cross-cutting issues** relevant to both WCRs and non-WCRs.

- **Multi-physics coupling** (TH, neutronics, mechanics)
- **Fluid-Structure Interaction (FSI), Flow-Induced Vibration (FIV)**
- **Active/passive systems interactions, low-pressure & gravity-driven flows**
- **Hydrogen combustion**, **thermal stratification**, **phase change**
- **Spent fuel pool TH**

- Coordination with **WGAMA activities (e.g., CCVM, ISPs)**, **FIDES-II**, **severe accidents research** frameworks
- Promote International Standard Problems (**ISPs**), benchmarks, and **data preservation**
- Support development of **AI/ML-ready datasets**

- **Non-electric applications** (e.g., cogeneration, storage)
- **Use of innovative modelling tools and methods** (e.g. AI/ML)

NEA/ATHENA – addressing Advanced Reactors and SMRs

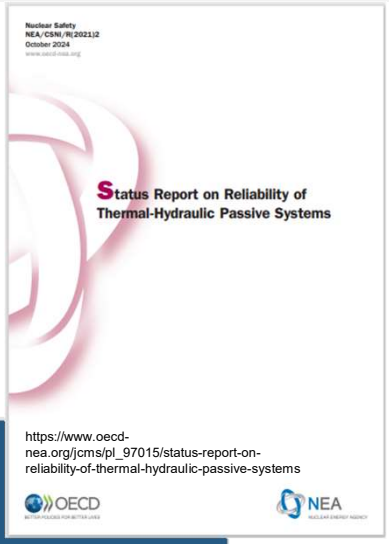


https://www.oecd-nea.org/jcms/pl_102607/best-practice-guidelines-for-the-use-of-cfd-in-nuclear-reactor-safety-applications-2024-update

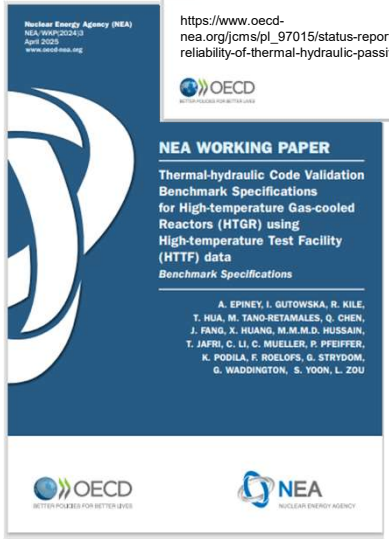
https://www.oecd-nea.org/jcms/pl_106729/rod-bundle-heat-transfer-rbht-project-phase-i-summary-report

To address advanced technologies applicable for advanced reactors, including SMRs, in the fields of **T/Hs, CFD** and **Severe Accidents (SA)** the NEA conducted a review that confirmed most of the achievements to confirm and/or improve the safety of operating NPPs are applicable to the advanced reactor designs.

1. **passive systems**
2. **modelling innovations in CFD**
3. **Severe Accident Management countermeasures**
4. **advanced measurement methods and instrumentation**
5. **modelling robustness of T/H and SA safety analysis codes**



https://www.oecd-nea.org/jcms/pl_97015/status-report-on-reliability-of-thermal-hydraulic-passive-systems



https://www.oecd-nea.org/jcms/pl_103833/thermal-hydraulic-code-validation-benchmark-specifications-for-high-temperature-gas-cooled-reactors-htgr-using-high-temperature-test-facility-httf-data

Advances in the CSNI Code Validation Matrix (CCVM)

Update and expand **CCVMs** for new reactor types (advanced LWRs, PHWRs, SMRs).

CCVMs: Provide experimental data sets for validating safety codes.

Process: Identify priority technologies and reactor designs.

- *List relevant accident scenarios and safety phenomena.*
- *Match phenomena to suitable test facilities and data.*
- *Analyze and update CCVMs for accuracy.*

Focus: Reactor coolant system and containment thermal-hydraulics.

References: Multiple NEA/CSNI reports document previous matrices.

Update Needs: Address new technologies, ensure data quality and completeness.

Collaboration: Work with international experts including IAEA.

Matrix I
CROSS REFERENCE MATRIX FOR LARGE BREAKS IN PWRs

- **Phenomena versus test type**
  + occurring
  o partially occurring
  - not occurring
- **test facility versus phenomenon**
  + suitable for code assessment
  o limited suitability
  - not suitable
- **test type versus test facility**
  + performed
  o performed but of limited use
  - not performed or planned

		Test Type			Test Facility and Volumetric						
		Blowdown	Refill	Reflood	CCTF 1:25	LOFT 1:50	BETHSY 1:100	PKL 1:145	LOBI 1:712	SEMISCALE 1:1600	UPTF 1:1 (a)
Phenomena	Break flow	+	+	+	o	o	o	o	o	o	o
	Phase separation (condition or transition)	o	+	+	+	+	+	+	+	+	+
	Mixing and condensation during injection	o	+	+	o	o	o	o	o	o	+
	Core wide void + flow distribution	o	+	+	o	o	o	o	o	-	o
	ECC bypass and penetration	o	+	o	+	+	-	o	o	-	+
	CCFL (UCSP)	o	+	+	o	o	o	o	o	-	+
	Steam binding (liquid carry over, act.)	-	o	+	o	o	-	o	o	o	o
	Pool formation in UP	-	+	+	o	o	o	o	o	o	+
	Core heat transfer incl. DNB, dryout, RNB	+	+	+	o	+	+	+	o	o	-
	Quench front propagation	o	o	+	+	+	+	+	-	+	-
	Entrainment (Core, UP)	o	o	+	o	o	+	o	o	o	+
	Deentrainment (Core, UP)	o	o	+	o	o	o	o	o	o	+
	1 - and 2-phase pump behaviour	+	o	o	-	o	-	o	+	+	-
	Noncondensable gas effects	-	o	o	-	-	o	-	-	-	o
Test Facility	CCTF	-	o	+	important test parameter - break location/break size - pumps off/pumps on - cold leg injection/combined injection (a) UPTF integral tests						
	LOFT	+	+	+							
	BETHSY	-	-	+							
	PKL	o	+	+							
	LOBI	+	+	-							
	SEMISCALE	+	+	+							
	UPTF	o	+	+							

Consensus

Developed matrices constitute a commonly recognised set of data for code validation

Conclusion

Nuclear safety research requires wide support from across the nuclear sector to enable the deployment of new, advanced, and small modular reactors

Promising new technologies requires maintaining existing facilities and accelerating the development of research programs and expertise

NEA has created the frameworks to encourage wider international collaboration to efficiently meet stakeholders' safety research needs

Thank you for your attention

john.nakoski@oecd-nea.org