

NUCLEAR ENGINEERING INTERFACE ARCHITECTURE (NEIA)

Standardizing SMR Integration

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Technical Sections

1. Why Standardization Matters

Nuclear energy can serve a wide range of industrial and energy applications, but application demands and reactor capabilities vary significantly.

Without standardization, every reactor–application combination becomes a separate integration exercise.

This limits repeatability and makes comparison across technologies and applications difficult.

Standardization converts this open-ended integration space into a finite set of defined classes and configurations.

The framework establishes:

- **Demand Envelope Classes (DEC)** to standardize application requirements.
- **Reactor Capability Classes (RCC)** to standardize reactor-side capabilities.
- **Energy Integration Architectures (EIA)** to standardize the interface between them.
- A **Deterministic Matrix** to define allowed, conditional, and prohibited combinations.
- **Converged System Classes (CSC)** to provide a common description of the resulting system configuration.

The objective is not to select a reactor or determine a project design.

The objective is to ensure that reactor–application integration is described using a **common, repeatable standard architecture**.

2. The Three-Point Structure

The framework can be represented through three principal elements:

END 1	INTERMEDIATE	END 2
Demand Envelope Class (DEC)	Energy Integration Architecture (EIA)	Reactor Capability Class (RCC)
Application requirement	Standardized integration architecture	Reactor capability

in simple terms:

DEC ↔ EIA ↔ RCC

The two ends are independently classified.

The intermediate architecture provides the standardized connection between them.

The resulting system arrangement can then be represented through a **Converged System Class (CSC)**.

3. END 1 — Demand Envelope Class (DEC)

The Demand Envelope Class standardizes **what the application requires**, independent of any reactor technology.

The classification considers:

- Required temperature,
- Required pressure,
- Required energy form, and
- Load profile or multi-output requirement.

The standardized demand classes are:

Class	Standardized Demand
DEC-01	Low-temperature thermal $\leq 150^{\circ}\text{C}$
DEC -02	Medium-temperature thermal $150\text{--}400^{\circ}\text{C}$
DEC -03	High-temperature thermal $400\text{--}700^{\circ}\text{C}$
DEC -04	Ultra-high-temperature $>700^{\circ}\text{C}$
DEC -05	Power generation / steam cycle
DEC -06	Hybrid / multi-output

The DEC classification therefore creates a common application-side language without reference to a specific reactor.

4. END 2 — Reactor Capability Class (RCC)

The Reactor Capability Class standardizes **what the reactor can provide**, independent of the application.

The classification considers:

- Reactor outlet temperature,
- Pressure capability,
- Coolant type,
- Isolation requirements, and
- Operational flexibility.

The standardized reactor capability classes are:

Class	Standardized Reactor Capability
RCC-A	Low-temperature water-cooled $\leq 350^{\circ}\text{C}$
RCC-B	Medium-temperature water-cooled $350\text{--}450^{\circ}\text{C}$
RCC-C	Medium-temperature non-water $\geq 400^{\circ}\text{C}$
RCC-D	High-temperature advanced $\geq 500^{\circ}\text{C}$
RCC-E	Ultra-high-temperature $\geq 700^{\circ}\text{C}$

The RCC classification creates a common reactor-side language that can be used across technologies and vendors.

5. INTERMEDIATE — Energy Integration Architecture (EIA)

The Energy Integration Architecture standardizes **how the application and reactor sides are connected**.

Five architecture classes are defined:

Class	Architecture	Standard Description
EIA-1	Direct Coupling	Reactor output is used directly
EIA-2	Supplemental Matching	Additional energy is used to bridge the required thermal condition
EIA-3	Intermediate Loop	Reactor and application are separated through an isolation loop
EIA-4	Indirect Conversion	Reactor output is converted through another energy or thermodynamic system
EIA-5	Hybrid Multi-Output	Multiple energy outputs are integrated within the system

These architecture classes provide a finite vocabulary for configurations that would otherwise be described differently from project to project.

6. The Deterministic Matrix

The central element of the standardization framework is the **Deterministic Matrix**.

It maps:

$$\text{DEC} \times \text{RCC} \rightarrow \text{EIA}$$

Each matrix cell describes the standardized relationship between a demand class and a reactor capability class.

Importantly, the matrix does not treat every combination equally.

Three relationship states are used:

Symbol	Standardized Meaning
☑	Allowed configuration
⚠	Conditional configuration
✗	Prohibited configuration

The conditional designation is important. It preserves combinations that are recognized within the framework but require additional integration provisions represented by the applicable EIA.

The exact matrix is:

DEC ↓ / RCC →	RCC-A Low-T LWR	RCC-B Med- T LWR	RCC-C Med-T Non-water	RCC-D High- T Advanced	RCC-E Ultra High-T
DEC-1 Low-T Heat	☑EIA-1; ☑EIA-3	☑EIA-1	⚠ EIA-3	⚠ EIA-3	⚠ EIA-4
DEC-2 Med-T Heat	⚠ EIA-2	☑EIA-1; ☑EIA-2	☑EIA-3	⚠EIA-3; ⚠ EIA-4	⚠ EIA-4
DEC-3 High-T Heat	✗	⚠ EIA-2	☑EIA-3	☑EIA-3; ☑EIA-4	☑EIA-4
DEC-4 Ultra High-T	✗	✗	⚠ EIA-3	⚠ EIA-4	☑EIA-4
DEC-5 Power (Steam)	☑EIA-1	☑ EIA-1; ⚠EIA-2	☑EIA-3	☑EIA-3; ⚠ EIA-4	⚠ EIA-4
DEC-6 Hybrid	⚠ EIA-5	⚠ EIA-5	⚠ EIA-5	☑EIA-5	☑ EIA-5

This matrix is the core standardization mechanism.

It establishes **who can connect with whom, through which standardized architecture, and under what status.**

A combination can therefore be:

Allowed, where the architecture falls within a defined standard configuration

Conditional, where the combination remains within the framework but requires additional integration provisions.

Prohibited, where the combination is outside the permitted configuration space

This prevents the same fundamental integration question from being reconsidered independently for every project.

7. Converged System Class (CSC)

Once the integration architecture is established, the overall configuration can be represented through a corresponding Converged System Class.

EIA	CSC	Standardized System Configuration
EIA-1	CSC-1	Direct coupling system
EIA-2	CSC-2	Supplemental thermal system
EIA-3	CSC-3	Isolated intermediate-loop system
EIA-4	CSC-4	Indirect conversion system
EIA-5	CSC-5	Hybrid multi-output system

CSC therefore provides a standardized name for the resulting system architecture.

The complete standardized structure becomes:

DEC + RCC → EIA → CSC

8. What the Framework Achieves

The framework creates a common language across reactor developers, application owners, EPC organizations, equipment suppliers and other stakeholders.

It standardizes four fundamental questions:

What does the application require? → DEC

What can the reactor provide? → RCC

How can the two be integrated? → EIA

What is the resulting system configuration? → CSC

The deterministic matrix then establishes which combinations are **allowed, conditional, or prohibited**.

The framework does not make reactor-selection or project-design decisions.

It standardizes the **configuration space within which those projects can be described and developed**.

9. Conclusion

NEIA standardization converts reactor–application integration from an open-ended engineering description into a finite set of defined classes and configurations.

The three-point structure is:

Demand Envelope Class → Energy Integration Architecture → Reactor Capability Class

The deterministic matrix connects these elements and preserves the distinction between:

☑ **Allowed configurations**

⚠ **Conditional configurations**

✗ **Prohibited configurations**

The Converged System Class then provides a common description of the resulting architecture.

The objective is not to make every reactor or application identical.

The objective is to ensure that **fundamentally similar integration arrangements are classified, bounded and communicated in the same way across projects.**

Standardization transforms nuclear energy–application integration from a collection of bespoke interfaces into a repeatable set of defined configurations.

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