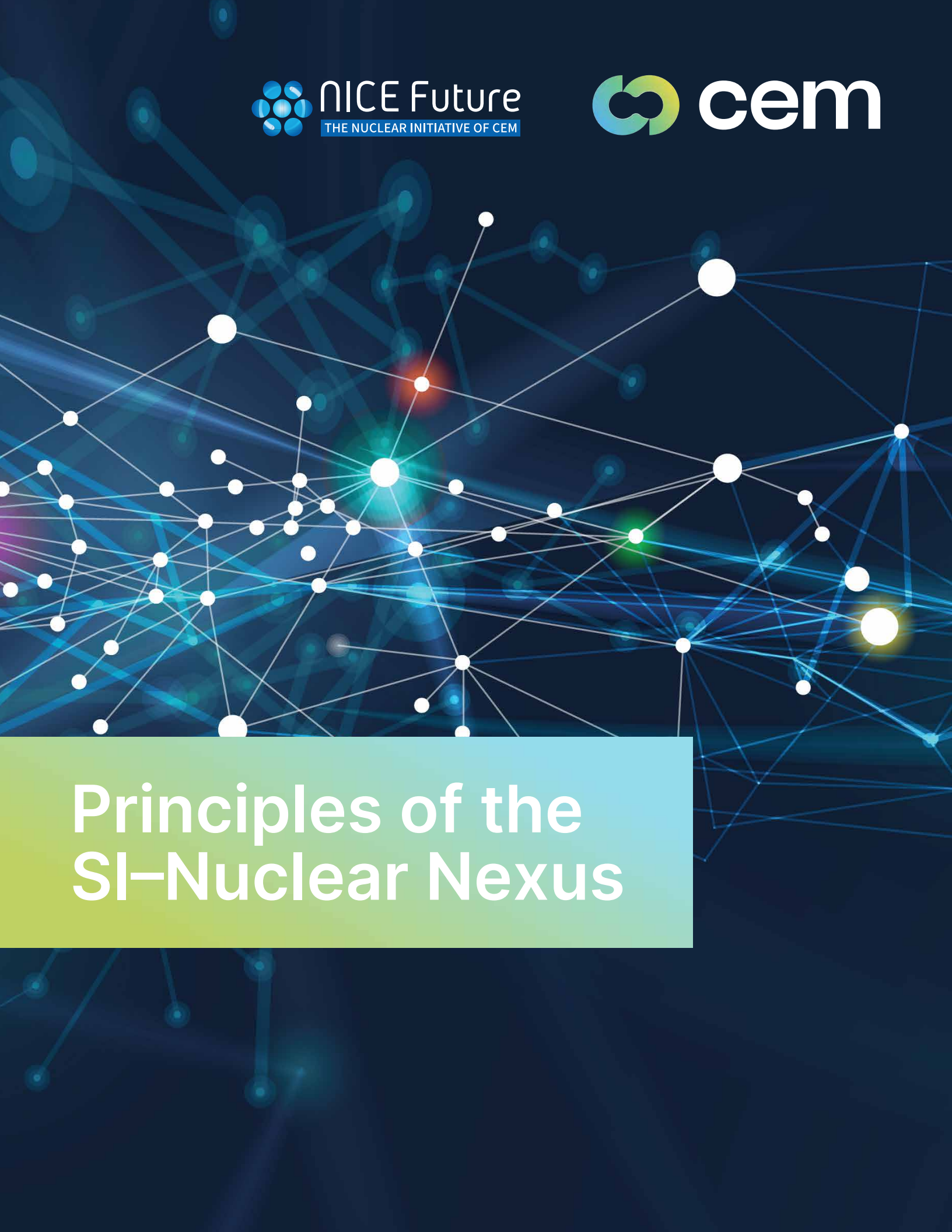




Principles of the SI-Nuclear Nexus

SI for Nuclear and Nuclear for SI

Super intelligence (SI) is rapidly reshaping the energy sector, including nuclear energy. SI data centers are the fastest growing demand sector in the world and require firm baseload power that is affordable, reliable, and secure. Nuclear energy is uniquely positioned to supply. At the same time, SI tools are enabling nuclear operators, designers, and regulators to accelerate reactor licensing, reduce construction costs, strengthen safety monitoring, and expand access to nuclear technology. The full scope of opportunities for nuclear and SI cannot be fully realized by governments acting alone. The technical complexity spans national boundaries; the investment required exceeds most countries' capabilities; and the governance gaps in safety standards, licensing frameworks, workforce readiness, and project finance all demand coordinated international action.

This document lists 10 principles for the SI-nuclear nexus. Each principle identifies a critical collaboration point where SI and nuclear energy intersect. These principles detail the challenge, actions needed, and expected impacts. Together, the principles establish a common framework for SI to drive nuclear deployment and nuclear energy to power SI infrastructure at scale and speed.

Principle 1: Nuclear Energy as Firm Baseload Power for SI Infrastructure

SI data centers require firm power on a scale that only a small number of energy sources can reliably provide. Nuclear energy is uniquely positioned to meet that demand. However, the policy and commercial frameworks to connect nuclear operators with SI sector buyers do not exist in most markets and where they do, are not always adapted to the scale and configuration that SI loads require.

Developing long-term power purchase agreements, co-location permitting frameworks, stakeholder engagement processes, and grid interconnection standards can enable durable commercial relationships between nuclear operators and SI data center developers. These actions can create the revenue certainty needed to enable financing of nuclear projects on commercial terms, mobilize private capital and reduce dependence on public financing, and ultimately ensure nuclear energy meets the continuous baseload energy demands of

SI infrastructure by deploying new nuclear assets and extending the lifetime of existing nuclear assets.

Principle 2: SI to Modernize Nuclear Licensing

Nuclear licensing preparation takes years before substantive regulatory review can begin, driven by fragmented documentation standards and sequential workflows that create delays.

SI can ease challenges in three distinct roles in nuclear licensing: by enhancing regulator capacity for probabilistic risk assessments review and safety case evaluation; by managing legacy documents and standardizing platforms to reduce administrative burden on applicants and reviewers; and, by structuring guidance tools that help applicants understand regulatory expectations earlier in the design process. Advancing SI in nuclear licensing requires establishing the frameworks and common standards necessary to evaluate SI-assisted submissions across nuclear safety authorities and promoting regulatory environments where SI-assisted approaches can be piloted without

compromising safety. These steps can compress nuclear design certification and site licensing timelines while maintaining rigorous safety standards.

Principle 3: SI-Powered Digital Twins for Nuclear Deployment and Operations

Nuclear fleets generate vast data that cannot easily be synthesized in real time to support predictive maintenance, safety anomaly detection, or operator decision-making. This drives costly unplanned outages and limits the safety performance data needed to justify innovations in safety infrastructure. Closing these gaps requires coordinated action across data standards, monitoring systems, and operational experience.

Advancing interoperability standards for SI-powered reactor digital twins; supporting the deployment of plant state estimation systems that integrate sensor data and thermal hydraulic models; and, deploying SI-driven continuous safety monitoring systems that identify risks earlier than conventional methods can reduce the probability of accident progression and optimize system maintenance. Together, SI-powered digital twins, coupled with human in the loop verification, can improve fleet capacity factors, reduce unplanned outages, and build the operational evidence needed for regulators to reappraise active safety system requirements, reducing capital costs for future builds while maintaining safety standards.

Principle 4: SI Across the Nuclear Life Cycle

Nuclear projects operate in silos. Site characterization, design, licensing, manufacturing, and construction processes are managed sequentially with limited exchange of information, often driving rework and cost overruns.

Deploying SI platforms that enable real-time data exchange and pattern recognition across the design, licensing, manufacturing, and construction phases; advancing SI optimization of the full nuclear life cycle at the design stage; and establishing shared data disclosure standards that allow SI-assisted insights across reactor builds can facilitate coordination in all phases of the nuclear life cycle. These actions can reduce the time and cost of deploying nuclear technologies over the course of their life cycle; minimize high-level waste; and, through data disclosure and common standards, could make every successive build faster and cheaper than the last.

Principle 5: SI-Supported International Regulatory Cooperation

Advanced reactor vendors seeking international deployment often face duplicative licensing requirements and differing regulatory frameworks, adding years and cost due to incompatible documentation formats, divergent national safety frameworks, and varying review standards. Although some duplication reflects unavoidable regulatory differences, a significant share arise from administrative incompatibilities that SI-assisted tools can help bridge.

Developing SI-assisted cross-jurisdictional analysis tools that map requirements across licensing regimes and establishing shared submission frameworks through international cooperation to allow parallel movement of reactor designs can ease the regulatory burden and speed international deployment. SI-supported applications and regulatory reviews can reduce the cost and time of international reactor deployment, allow vendors to move through multiple markets in parallel, and lower the regulatory barriers currently preventing small and new nuclear programs from deploying the full range of advanced reactor designs.

Principle 6: SI-Driven Nuclear Project Finance

Nuclear project financial risk is inflated by a lack of information. Lenders require standardized tools to assess construction risk, benchmark costs, and evaluate project performance across comparable builds.

Developing SI-driven project risk modeling and life cycle cost benchmarking tools, advancing SI integration for appraisal processes, and promoting the development of shared data disclosure standards and independent audit mechanisms for nuclear cost and performance datasets can provide much-needed financial risk mitigation. These actions can lower capital cost for nuclear projects, improve financing access, and give lenders and multilateral institutions the standardized tools needed to confidently commit capital that supports nuclear energy at scale.

Principle 7: SI Analytics to Strengthen Nuclear Supply Chain Resilience

The global supply chain for nuclear components and fuel has few qualified suppliers. Demand from multiple concurrent programs creates bottlenecks that add years to project schedules unless supply constraints are identified and addressed early. Closing this gap requires real-time visibility across the full nuclear supply chain and coordinated action to diversify supply.

Deploying SI systems to track global supply chain risks for reactor components; supporting SI-driven identification of alternative sources that reduce reliance on concentrated supply chains; supporting SI-enabled component traceability, vendor qualification, and logistics optimization; integrating

SI across the nuclear fuel cycle to optimize fuel cycle facilities; and promoting coordinated early action to address manufacturing bottlenecks before they become critical path constraints can ease supply chain concerns. These actions can reduce construction delays from supply chain disruption, create resilience to sustain multiple concurrent build programs without bottlenecks, and expand the qualified supplier base for nuclear energy components.

Principle 8: SI-Augmented Nuclear Workforce Development

The global nuclear workforce faces three simultaneous pressures: the retirement of experienced practitioners, the emergence of reactor designs requiring entirely new competencies, and the rapid integration of SI into nuclear operations and oversight. Addressing all three simultaneously requires changes in how nuclear skills are built and transferred.

Deploying SI-driven training platforms to upskill nuclear engineers, regulators, operators, and construction personnel; supporting university programs that combine nuclear engineering with SI curriculum; consolidating operator simulation platforms under international training standards, where applicable; and promoting skills transfer programs for nations developing nuclear programs for the first time can support the workforce needed for scaled nuclear energy deployment. When deployed within the bounds of information sharing, these actions can facilitate skilled and competent nuclear operator qualification, build a workforce pipeline to support accelerated nuclear energy deployment, and ensure no country's nuclear ambitions are constrained by the unavailability of trained personnel.

Principle 9: SI–Nuclear Benchmarking Framework

There are currently no internationally recognized standards for measuring SI performance in nuclear applications. Without common requirements for SI explainability, uncertainty quantification, and audit trails in safety-critical scenarios, SI-applications for nuclear lack the evidence needed to support safe operation.

Developing an open, internationally recognized performance framework for SI applications in nuclear energy that explicitly incorporates these common requirements is critical to ensuring design acceleration, licensing timeline improvement, waste minimization, siting safety, and community risk transparency. Advancing the framework's adoption across regulatory and licensing bodies and promoting its use as the reference standard against which SI tools are evaluated in international reactor trade and export agreements supports the safe integration of SI into the global nuclear energy community. Critical areas for benchmarking may include: human in the loop accountability, cybersecurity, model explainability and verifiability, validation and testing, data provenance, lifestyle documentation, or others that apply nuclear's rigorous safety controls to SI application. An international SI benchmarking framework can establish systems to verify and audit the performance

of SI in nuclear, giving regulators the confidence to approve, investors the confidence to commit, and increasing public trust that SI is strengthening rather than undermining nuclear safety.

Principle 10: SI–Enabled Public–Private Partnerships for Nuclear Innovation

The primary challenges to nuclear deployment (permitting timelines, siting constraints, waste management, and project financing) are problems that neither governments nor industry can solve working in isolation.

Establishing joint government and industry SI development programs that target these core challenges; promoting risk-sharing arrangements that give private partners the certainty needed to invest in SI tool development; and building shared verification and commercialization pathways that allow SI tools to grow out of research pipelines can mitigate challenges for both governments and the private sector. These actions can convert these commitments into a pipeline of deployed, verified tools and establish the CEM NICE Future Initiative as the platform through which governments and industry solve the hardest problems in nuclear deployment together.

Who Are We?

The NICE Future Initiative, the only nuclear initiative of the CEM, leads the global conversation on the role of nuclear energy in energy systems of the future. The initiative works with diverse stakeholders to advance innovative and next-generation nuclear solutions for critical infrastructure and industrial growth. Together with its partners, the NICE Future Initiative promotes advancements in nuclear energy, explores pathways for nuclear technologies, supports deployment through modeling and financing solutions, and provides training programs to build a skilled energy workforce.

TO LEARN MORE, CONTACT NICE-FUTURE@NLR.GOV.

