Strategic Management of Nuclear Industry Development in Newcomer Countries: The Dilemma of Customer and Implementer Competencies on the Example of the Republic of Serbia

Content

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Introduction: Global Nuclear Renaissance and Fundamental Challenges for Newcomer Countries

In the context of the accelerating global energy transition, tightening climate agenda, and states' aspirations to ensure long-term energy security, nuclear energy is experiencing a period of unprecedented renaissance. States that previously abandoned nuclear generation or never possessed it are now forced to revise their energy doctrines.

For countries creating or reviving a nuclear industry for the first time after a long hiatus (so-called newcomer countries), the process of implementing a national nuclear energy program presents a highly complex systemic, technological, and institutional challenge. Developing sustainable nuclear infrastructure requires not only colossal financial investments measured in billions of dollars but also the creation of a multi-level system of competencies capable of ensuring nuclear and radiation safety for over a century, covering stages from design to decommissioning.[1]

During the initiation of a nuclear program, government structures, national energy companies, and academic institutions inevitably face a fundamental dilemma in prioritizing human resource and institutional development. The essence of this dilemma boils down to answering three interrelated strategic questions.

First, what poses a greater threat to the successful and safe implementation of the program: the country's lag in the ability to formulate, specify, and strictly control requirements for international technological vendors, or the lag of the national industry and scientific-technical base in the ability to independently comply with these high requirements?

Second, who should become the true locomotive and driver of industry development: the "creators" — program architects, system engineers, regulators, and competent customers formulating the requirements, or the "implementers" — builders, operators, local supply chain, and production personnel trying to meet these requirements?

Third, based on the logic of the nuclear project lifecycle, whom must the state prepare first?

The answers to these questions form the very essence of the national strategy for technological sovereignty in the nuclear sphere. Historical experience and the analysis of normative directives of the International Atomic Energy Agency (IAEA) demonstrate that the intuitive desire of governments in many developing countries to immediately localize production and prepare NPP "builders" is a strategic mistake.

Using the example of the Republic of Serbia, which in 2024 lifted a 35-year moratorium on the construction of nuclear power plants and proceeded to intensively form a national program [4], the critical importance of the advanced development of the customer's institutional competencies is clearly traced.

The Serbian model, characterized by a strong academic heritage but a prolonged stagnation in applied nuclear energy, perfectly illustrates the fundamental principle of the industry: **technological independence and safety begin not with the ability to pour nuclear concrete or weld primary circuit pipes, but with the state's institutional ability to be an independent, highly educated, and demanding arbiter of proposed global technologies.**[6]

This report presents an in-depth analysis of this issue, exploring the concept of the "Intelligent Customer," the evolution of contract models, the impact of new technologies such as small modular reactors (SMRs), and the strategy of human resource planning, drawing on the current experience and roadmap of the Republic of Serbia.

Conceptual Foundation: The "Intelligent Customer" Doctrine in High-Risk Industries

To answer the question of which lag (in formulating requirements or in the ability to meet them) poses a greater threat, it is necessary to turn to the fundamental principles of safety management in complex socio-technical systems. **In the nuclear industry, this foundation is based on the concept of the "Intelligent Customer" (also known as Informed Customer, Knowledgeable Customer, or Smart Buyer).**[7]

Origin and Essence of the Concept

Initially, the Intelligent Customer concept in the context of high-risk management was crystallized by the UK Office for Nuclear Regulation (ONR) in response to globalization, outsourcing, and supply chain fragmentation trends in the energy sector.[7] Subsequently, this approach gained unconditional international recognition and was integrated into fundamental IAEA safety standards.[7]

Like any complex business, operating organizations in the nuclear industry constantly make strategic "Make or Buy" decisions.[8] Core processes are performed internally (the "make" element), while non-core or highly specialized functions (e.g., construction of the nuclear island, production of heavy equipment, development of software for control systems) are outsourced to third parties (the "buy" element).[8] As the complexity of nuclear technologies grows, organizations increasingly use foreign contractors.[8]

The IAEA defines an "Intelligent Customer" as follows: in the context of nuclear safety, the management of a facility or the customer organization must know exactly what is required, fully understand the need for a contractor's services, be able to specify requirements in bidding and design documentation, conduct continuous technical supervision of the work, and critically evaluate (review) the results before, during, and after their implementation.[8] A crucial nuance of this doctrine is that the "Intelligent Customer" status refers to the attributes of the entire organization, its integrated management system, and corporate culture, rather than merely having a few qualified specialists on staff.[8]

Inalienability of Primary Responsibility for Safety

The key to understanding the dilemma lies in the First Fundamental Safety Principle of the IAEA. This principle states that the **prime responsibility for safety must rest exclusively with the person or organization responsible for facilities and activities that give rise to radiation risks** (i.e., the national licensee/operator).[14] This responsibility is absolutely inalienable; it cannot be delegated, contracted out to a foreign vendor, shifted to a subcontractor, or insured.[7]

According to regulatory documents such as Licence Condition 36 (LC 36 – Organisational Capability), applied in advanced jurisdictions, a **licensee is obliged to maintain adequate financial and human resources to ensure safe operation and strictly control any changes in its organizational structure that could affect safety**.[7] The licensee must maintain a core of in-house staff with sufficient qualifications to manage nuclear safety.[7]

From this principle stems the concept of the "Design Authority," which is closely related to the customer function.

The customer must possess sufficient knowledge to understand the limits of applicability and consequences of any design decisions, to question and challenge the contractor's work, and to demonstrate to the regulator that it exercises an appropriate level of control in practice.[13]

The customer is not obliged to have the depth of knowledge required to independently conduct the most complex thermal physics or neutron kinetics calculations (vendor-implementers are engaged for this), but it **must have the competencies to competently accept these calculations, identify methodological errors, and lead the defense of the safety analysis report before the national regulator**.[13]

Analysis of the Competence Dilemma: Formulating Requirements vs. Their Implementation

Relying on the "Intelligent Customer" doctrine, we can dissect the first question in detail: what is more important for a newcomer country — avoiding a lag in the ability to formulate/control requirements (Customer competence) or avoiding a lag in the ability to meet them (Implementer competence).

Analysis of international practices, regulatory frameworks, and experiences in implementing nuclear energy projects shows that a lag in the ability to formulate and control requirements carries disproportionately greater, existential risks for the entire program.

Risks and Consequences of Lagging in the Ability to Formulate Requirements

If the national customer (operator) or the national regulator lacks a sufficient level of technical expertise to formulate strict specifications and control their execution, the "uninformed licensee" effect arises.[15] This state generates a cascade of critical vulnerabilities that cannot be compensated by any financial injections:

1. **Total vendor dependence (Vendor Lock-in) and loss of sovereignty:** A customer unable to independently define the project boundaries is forced to rely entirely on specifications proposed by the vendor. In recent years, many subcontractors with little or no experience have entered the nuclear market. They exploit poorly defined procurement documents, weak qualification processes, and a lack of information sharing among operators.[16] An incompetent customer becomes a technological hostage to the vendor, losing sovereignty over its own energy facility.[15]
2. **Blind acceptance of critical elements and safety degradation:** In the nuclear industry, even seemingly minor changes in components or materials proposed by a contractor to optimize costs can have catastrophic consequences for safety.[17] The customer must have the competence to carefully examine any modifications proposed by the vendor.[17] Furthermore, without the ability to conduct deep oversight and physical control, counterfeit, fraudulent, and suspect items (CFSI) infiltrate the supply chain, directly undermining nuclear safety.[16]
3. **Regulatory deadlock:** The ability to formulate requirements concerns not only the customer but also the national oversight body. The regulatory body must also be an "Intelligent Customer" concerning its external experts and technical support organizations (TSOs).[18] If the regulator lags in developing its competencies, it will not be able to adequately assess the Safety Analysis Report (SAR), leading either to the illegal issuance of a license for a potentially dangerous facility or to an endless paralysis of the licensing process and project delays.[15]
4. **Hidden economic risks:** When a customer is unable to strictly define specifications, all inefficiency risks are shifted to its budget. Hidden cost overruns, the need to constantly hire foreign consultants to solve trivial operational tasks, and the inability to build an effective spare parts management policy make the project economically unviable in the long term.[21] It is also noted that outsourcing critical engineering functions acts like a "drug" causing addiction and leading to long-term degradation of the organizational structure.[23]

5.

Vulnerability Characteristic	Lag in Formulating/Controlling Requirements (Customer Deficit)	Lag in Ability to Meet Requirements (Implementer Deficit)
Impact on nuclear safety	Critical threat. Fundamental gap in the chain of responsibility. Risk of missing conceptual design errors and defects.[13]	Manageable commercial risk. Local contractors are easily replaced by qualified international vendors under customer control.
Regulatory legitimacy	Project cannot be licensed according to IAEA standards, as a qualified Licensee is absent.[14]	Does not affect the licensing process if the foreign contractor is certified.
Financial control	Impossibility of auditing estimates. Risk of geometric cost growth during construction due to lack of technical arbitration.[21]	Part of the added value goes to foreign companies, but the budget is fixed by contract.
Strategic resilience	Total loss of technological sovereignty over the 60-100 years of the facility's lifecycle.[15]	Temporary dependence during the construction phase with the possibility of gradual localization during the maintenance phase.

Acceptability of Lagging in the Ability to Meet Requirements

Unlike the deficit of customer competencies, a lag in the ability to meet requirements (i.e., **the weakness of the national supply chain, the lack of local qualified builders, nuclear-grade welders, equipment manufacturers) is a natural and acceptable state for any newcomer country at the initial stage.**

IAEA guidelines explicitly state that attempting extensive development of national capabilities during the construction of the first NPP can create unacceptable risks in terms of time and cost.[1] Moreover, diverting massive national resources to NPP construction can jeopardize other infrastructure projects of the country.[1]

If a country plans to build only one or two plants, it is not economically feasible to develop all competencies in design, turbine manufacturing, and construction. The state has the right to

contract out most of the functions required in the early stages of program implementation to a foreign EPC contractor.[1]

However, even in this scenario of maximum delegation of authority to implementers, the IAEA emphasizes: **"The Member State must develop the competence to fulfil the role of the 'intelligent customer', that is, it must be able to assess its requirements, prepare an appropriate bid, and oversee the process."**[1]

Thus, lagging in the ability to formulate requirements is a fatal obstacle to a nuclear program, while lagging in the ability to meet them is a solvable organizational task mitigated by entering the global services market.

True Drivers of Industry Development: Creators vs. Implementers

To answer the second question about who is the true locomotive of industry development, it is necessary to conceptually divide specialists into two macro-categories: "Creators" and "Implementers."

1. **"Creators" (Formulators):** This is the intellectual and strategic core of the nuclear program. These include specialists shaping the system's architecture. They are policymakers making strategic decisions; nuclear scientists; system engineers; analysts of the National Nuclear Energy Programme Implementing Organization (NEPIO); developers of the legal framework; national regulator experts; financial architects, and key personnel of the future licensee body (Design Authority and Intelligent Customer). Their task is to create meaning, define the rules of the game, develop safety strategies, evaluate technologies, and manage macro-risks.[1]
2. **"Implementers" (Compliers):** This is the production, construction, and operational base. These include line operators of the reactor hall, maintenance personnel, employees of construction and installation trusts, local equipment manufacturers, lower-level control system programmers, and technicians. Their key virtue is strict discipline, and rigorous adherence to specifications, regulations, and procedures set by the Creators.[8]

An analysis of international practice and the IAEA's "Milestones" approach irrefutably proves that **the true driver of industry development at the formation stage is exclusively the "Creators."**

The IAEA "Milestones" Approach and Role Distribution

The IAEA approach, documented in the NG-G-3.1 series, divides the process of deploying nuclear infrastructure into three phases covering 19 key infrastructure issues.[1] The dynamics of these phases clearly reflect the priority of the Creators:

- **Phase 1 (Consideration before a decision to launch a nuclear power programme is taken):** At this stage, the country explores the nuclear option within the context of overall energy policy.[2] The preparation of a NEPIO report is required, proving the state's readiness for long-term commitments.[26] At this stage, Implementers are not needed at all. All work is done by Creators: economists, lawyers, diplomats, and physicists who formulate the very possibility of project implementation.
- **Phase 2 (Preparatory work for the contracting and construction of a nuclear power plant after a policy decision has been taken):** This is the phase of crystallizing requirements. The country develops bidding documentation, evaluates financial models, forms a national regulator, and creates the "Intelligent Customer" structure.[2] The role of the Creators reaches its absolute peak here. They negotiate with foreign vendors, evaluate technologies (e.g., EPR, VVER, AP1000), and lay the foundation for safety for decades to come. It is here that mistakes cost the most.
- **Phase 3 (Activities to implement a first nuclear power plant):** Only at this stage do Implementers become massively involved.[3] Builders pour the first concrete, and future operational personnel begin training on simulators and internships at the vendor's reference plants.[2]

Trying to initiate a program using Implementers (for example, giving preferences to local factories to produce equipment without a ready regulatory framework) means putting the system at risk of chaos. The activities of Implementers must be strictly structured, limited by procedures, and subordinated to a safety culture. Without a strong institutional core of Creators capable of developing these procedures and exercising oversight, the actions of Implementers, no matter how qualified they are, will lead to technological dead ends or accidents.[1] **The engine of the industry is the intellect of the Customer, while the Implementers provide the kinetic energy to realize its designs.**

Priorities in Human Resource Planning: Whom to Prepare First?

The conceptual analysis presented above provides a clear answer to the third question: whom needs to be prepared first? The unconditional **priority in the early stages (Phase 1 and Phase 2) is the preparation of "Creators" — the executive, regulatory, and architectural-engineering tier.**

The lack of human resources and competent personnel is one of the most acute problems for newcomer countries.[28] Human resources in a nuclear program span several generations, making workforce planning a continuous process.[1] Developing an HR plan begins with comparing the needs of the national program with existing national resources (Gap Analysis).[1]

For the creation of nuclear infrastructure, it is critically important that the **first to undergo training are the specialists who will join the regulatory body (regulators) and the management core of the licensee body** (future project managers, system architects, chief engineers, contract experts).[13] The IAEA conducts special missions (e.g., INIR) and workshops focusing specifically on helping developing countries establish themselves as "Intelligent Customers."[33]

Preparing "Implementers" (line operators of the main control room, reactor equipment maintenance specialists) during Phase 1 or early Phase 2 is not just premature, but counterproductive. Without knowing the specific technology that will be chosen (which will happen only at the end of Phase 2), it is impossible to conduct specialized operator training.[3] Practice shows that after signing a commercial contract (in Phase 3), the selected vendor (technology supplier) assumes obligations for the technology-specific training of the customer's personnel.[2] That is, the vendor will help train the implementers, but the country must independently (or with the help of neutral brokers like the IAEA) train the customer to formulate requirements for this very vendor.[33]

Human capital development efforts must be directed towards developing corporate training committees, implementing the Systematic Approach to Training (SAT) for critical personnel, and fostering a deep safety culture among top management.[28]

Lifecycle Phase (by IAEA)	Preparation Priority	Focus of Training and Competencies
Phase 1 (Considering the option)	Exclusively Creators	Strategic planning, macroeconomics, nuclear law, environmental assessment, NEPIO formation.[2]
Phase 2 (Project preparation)	Absolute priority of Creators	System engineering, technology assessment, bidding procedures, site licensing, "Intelligent Customer" skills.[1]
Phase 3 (Construction)	**Mass preparation of Implementers** (while maintaining a core of Creators for oversight)	Operational management, simulator training, maintenance, construction and installation competencies, on-site radiation control.[2]

Architecture and Dynamics: Distinguishing Between Workforce Design and Workforce Planning

The use of the generalized term "workforce planning strategy" often conceals two fundamentally different but inextricably linked processes. For the successful implementation of a nuclear program, it is necessary to conceptually separate the concepts of Workforce Design and Workforce Planning. **The essence of this distinction lies in the difference between creating an architecture of roles and managing the quantitative flows of personnel over time.**

1. Workforce Design (Organizational Architecture)

Workforce design is the process of creating a detailed "blueprint" of the future organization. It is intended to answer qualitative questions: "What roles do we need?", "How do they interact?", and "What competencies must a person in this position possess?". At this stage, the reporting structure, boundaries of responsibility, and job profiles (the so-called Job Architecture) are developed, integrating job families and qualification levels into a single, transparent system. In the context of a nuclear power plant, design identifies specific functional areas (for example, 43 areas), for each of which qualification standards are strictly prescribed.

The main focus of workforce design is on quality and structure, which helps to avoid the duplication of functions and builds a clear career progression system. This process creates a stable foundation for the enterprise that can remain unchanged for years (e.g., a standardized staffing table for a standard power unit). Ultimately, design allows the national customer to determine what the "ideal" operating organization should look like.

2. Workforce Planning (Dynamics and Resources)

In turn, workforce planning is the strategic calculation of the required number of personnel to achieve set goals within specific timeframes. It answers quantitative questions: "How many people do we need by 2030?", "When exactly do we need to start enrollment in technical universities to cover the staff shortage in 7 years?", and "How do we compensate for natural personnel attrition?".

Planning operates on the concept of "stocks and flows". Using specialized tools (such as the NPHR model), it simulates the movement of people over time: from the moment of university enrollment to retirement or career change (attrition). Unlike design, planning is a dynamic process that is continuously adjusted depending on construction schedules, labor market changes, and demographic situations. Its main goal is to identify and close the gaps (GAP analysis) between the current state of human resources and the future needs of the program.

Synchronization of Processes

Both of these processes must develop in parallel. Workforce design sets the structural parameters and profiles, while workforce planning ensures this structure is filled with real people within set budgets and timeframes.

A brief comparison of these processes is presented in the table below:

Characteristic	Workforce Design	Workforce Planning
Key question	What structure do we need?	How many people and when?
Focus	Roles, responsibilities, competencies	Headcount, timeframes, turnover
Result	Competency model, org structure, profiles	Recruitment plan, training schedule, payroll budget
Interrelation	Sets parameters for calculation	Ensures the structure is filled

Historical and Institutional Context of the Nuclear Program of the Republic of Serbia

For a comprehensive understanding of the practical application of the "Intelligent Customer" concept and the priority of preparing "creators," it is necessary to examine the case of the Republic of Serbia in detail. This country represents a unique hybrid: while formally a "newcomer" to commercial nuclear energy, it possesses a rich historical background and a profound, albeit long-stagnant, scientific school.

Yugoslavia's Legacy: From Prime to Moratorium

Yugoslavia's nuclear program originated at the very beginning of the Cold War, shortly after World War II. In January 1948, the Vinča Institute of Nuclear Sciences (originally the Institute of Physics) was founded 12 kilometers from Belgrade.[35] Soon after, the Jožef Stefan Institute in Ljubljana (Slovenia) and the Ruđer Bošković Institute in Zagreb (Croatia) were established.[36]

The Vinča Institute quickly became the intellectual center of the program. The USSR supplied two research reactors (the 6.5 MW heavy-water RA reactor, which operated on 80% enriched uranium, and the RB zero-power reactor), allowing Yugoslav scientists to accumulate colossal experience in reactor physics, radiochemistry, and nuclear materials handling.[35] This powerful foundation of "Creators" enabled Yugoslavia to successfully commission its first commercial nuclear power plant, "Krško," a 664 MW facility in Slovenia, built in a consortium with American Westinghouse in 1982.[39] The country planned a massive expansion: the construction of a series of 4-11 NPPs, starting with the "Prevlaka" project in Croatia.[39] Yugoslav engineers and energy companies acted as demanding and knowledgeable customers, requiring technology transfer and attractive financial packages from international bidders.[39]

However, the Chernobyl disaster in April 1986 became a turning point. Public pressure and political shifts led to the adoption of a federal law in the SFRY in 1989 banning the construction of new nuclear power plants.[5] The subsequent breakup of Yugoslavia left the Krško NPP in Slovenia, and the moratorium remained in the legislation of independent Serbia for a long 35 years.[3]

The years of the moratorium dealt a severe blow to Serbia's human resource potential. A colossal gap occurred in generational renewal; practitioners with real experience in NPP projects left the industry. The RA reactor was shut down in 1984, and the issue of spent nuclear fuel, stored in sub-optimal conditions at the Vinča Institute, turned into a complex international challenge. This issue was successfully resolved only in the 2010s through an unprecedented operation to repatriate highly enriched uranium with the support of the IAEA, Russia, and the USA.[37]

Nevertheless, Serbia managed to preserve its basic scientific potential and regulatory framework. The Vinča Institute continued to operate as a multidisciplinary scientific center employing over 300 PhDs.[44] The Serbian Radiation and Nuclear Safety and Security Directorate (SRBATOM) was formed and operated successfully, regulating issues of radiation protection, medicine, radioactive waste management, and environmental monitoring.[20]

Lifting the Moratorium: New Challenges and Strategic Connectivity

The modern energy landscape forced Serbia to reconsider its position. The country faced a sharp increase in electricity consumption, falling production at aging state-owned EPS coal power plants, pressure from EU environmental standards, the introduction of a carbon footprint tax (CBAM), and the needs of new high-tech industries (such as planned artificial intelligence data centers).[48]

As a result, in November 2024, the National Assembly of Serbia adopted historic amendments to the Energy Law, officially lifting the 35-year moratorium.[3] The country's new energy strategy until 2040, with projections to 2050, integrated the potential use of nuclear energy, setting an ambitious goal to establish 1200 MW of nuclear capacity (primarily through small modular reactors - SMRs).[4]

For Serbia, nuclear energy has become not just a question of kilowatt-hours, but a tool of geopolitical positioning — a mechanism of "strategic connectivity."[5] By integrating into

European energy systems and building partnerships with technological leaders, Serbia seeks to enhance its role as a reliable actor in Southeast Europe.[5] However, this status cannot be bought; it requires the highest level of internal expertise. Serbia understands that to become an equal partner, rather than an appendage to someone else's technological chain, it must become a strong "Intelligent Customer."

Analysis of Serbia's Modern Strategy: Mobilization of "Creators"

The actions of the Serbian government after lifting the moratorium present a textbook example of correct priority setting, fully consistent with the IAEA approach. Realizing that the country has no time for an evolutionary path, the government began a forced mobilization of national intellect — forming the core of the "Creators."

Architecture of the Memorandum of Understanding

In July 2024, a large-scale Memorandum of Understanding (MoU) on nuclear energy development was signed. The architecture of this document is a model for newcomer countries. It brought together five ministries, over 20 academic faculties and scientific institutes (including the Vinča Institute, the Institute of Physics, faculties of electrical and mechanical engineering of the University of Belgrade), the SRBATOM regulatory body, and key energy enterprises — EPS and grid operator EMS.[6]

This consortium is de facto an incubator for the creation of a Specialized Coordination Body — an analogue of the NEPIO (National Nuclear Energy Programme Implementing Organization), whose approval by the government was expected in the shortest possible time.[6] Analysis shows that investments in this scientific pool are viewed as a strategic imperative.[6] Minister of Energy Dubravka Đedović Handanović explicitly stated that the Vinča Institute, with its personnel, technical, and research capabilities, is the foundation for planning, educating, and implementing the program.[51] The Institute announced its intention to become a regional educational center providing scientific support for the national project.[52]

Thus, Serbia did not start by looking for builders or buying cement; it started by bringing together physicists, engineers, and lawyers, i.e., it proceeded with the emergency preparation of "Creators" capable of formulating requirements for vendors in the future.

EDF Roadmap and the Phased Approach

In parallel with internal consolidation, Serbia actively attracts international expertise for Phase 1. A crucial step was cooperation with the French energy giant EDF. Supported by the French Development Agency (AFD), EDF and the engineering company Egis Industries prepared a "Preliminary Technical Study on the Peaceful Use of Nuclear Energy in Serbia."[3]

The roadmap proposed by EDF includes 19 key steps, strictly structured according to the three IAEA phases:

- **Phase 1 (until 2027):** Completion of all studies (development of legal and institutional framework, identifying potential sites, analysis of available technologies) necessary for the government to make an informed decision.[3] The main focus during this period is on identifying, developing, and training local experts (Creators) using proven EDF engineer training programs applied in Italy and China.[3]
- **Phase 2 (by 2032):** The country must be fully prepared to select a technology type and enter the formal construction contracting process.[3] It is by this date that the Serbian "Intelligent Customer" and the strengthened SRBATOM regulator must reach operational maturity.
- **Phase 3 (after 2040):** Physical construction and commissioning of the NPP.[3]

The multi-vector nature of Serbian diplomacy proves that the country is setting its own agenda rather than simply following a single supplier. Despite deep cooperation with France in the preparatory stage, the Minister of Energy stressed that the decision on technology selection has not yet been made.[56] Serbia is holding active negotiations with the CEO of the Russian state corporation Rosatom on comprehensive cooperation and training of Serbian students in Russian nuclear universities.[41] The President of Serbia noted that proposals from China, Japan, South Korea (an MoU on experience sharing was signed with KHNP), and the USA (Westinghouse) are also on the table.[48]

The ability to objectively compare these proposals, evaluate the advantages of French EPRs, Russian VVERs, or Korean APR-1400s, and select the optimal variant for the Serbian energy system depends entirely on the success of implementing Phase 1 — preparing competent internal specialists capable of formulating requirements. If Serbia fails to prepare the "Creators," the choice of technology will be determined not by engineering and economic logic, but by external pressure.

The Trap of Turnkey Contracts and the Illusion of Delegation

One of the main challenges for governments of newcomer countries under the pressure of energy crises (similar to the risk of energy deficit in Serbia declared by the president [48]) is the temptation to accelerate the process by signing a full-cycle contract, transferring maximum responsibility to a foreign vendor. **Analyzing contractual models provides a deeper understanding of why lagging in the ability to formulate requirements is deadly dangerous even under the most comfortable commercial conditions.**

Historically, three main models of nuclear project implementation have emerged:

1. **Split/Multiple Package:** The customer signs separate contracts for the nuclear island, balance of plant, and turbine, acting as the project integrator itself (sometimes hiring an Architect-Engineer).[14] This model, used, for example, by the Japanese TEPCO in building the Kashiwazaki-Kariwa units [14], requires a colossal level of competencies and is practically impossible for newcomers.
2. **Engineering, Procurement, and Construction (EPC - Turnkey):** The vendor provides a ready-made plant "turnkey."[58]
3. **Build-Own-Operate (BOO):** The vendor not only builds but also owns and operates the plant throughout its entire lifecycle (as in the case of the Akkuyu project in Turkey).[57]

It would seem that EPC or BOO contracts are perfectly suited for countries lagging in the ability to meet requirements (lacking their own builders and installers). The contractor brings the technology, builds the facility, and possibly even operates it, solving the problem of preparing implementers.[25]

However, herein lies the main conceptual trap, bringing us back to the principle of the inalienability of responsibility. In the nuclear industry, there is no such thing as a "turnkey" contract in the everyday sense. IAEA conventions and national laws prohibit the existence of an "uninformed licensee."[15]

Even under the BOO model, the national regulator of the host country (in Serbia, this is SRBATOM) is obliged to license the site, conduct a safety expertise of the project, issue permits for construction and operation, and monitor radiation safety.[20] A state entity representing the country's interests must act as an "Intelligent Customer" to monitor the activities of the foreign owner/operator.[14]

The illusion that a turnkey contract eliminates the need to create a strong intellectual core (creators) leads to catastrophic consequences:

- **Blind spots in quality control:** If the customer lacks intelligent customer capability to inspect concealed work, it cannot guarantee safety.[13] Experts warn that turnkey contracts can induce lax management and lower risk perception, which is unacceptable.[25]
- **Financial vulnerability:** Without a competent customer capable of critically assessing vendor requests for project modifications or material cost increases, the state loses control over the project budget.[22]
- **Security infrastructure vulnerabilities:** Transferring physical and cyber security risks to an external contractor without proper oversight creates national security threats.[10]

Legislative frameworks require the licensee to demonstrate deep knowledge of the plant's Safety Case for all operations and lead the presentation of safety arguments before the regulator, even if the analysis was performed by a foreign contractor.[13] Thus, even **with maximum delegation of tasks to contractor-implementers, the intellectual function of formulating and controlling requirements (Creators) must be localized within the country.**[8]

Challenges of New Technologies: Small Modular Reactors (SMRs) and Increased Requirements for "Creators"

An additional factor exacerbating the competence dilemma is the technological evolution of the industry. Serbia's energy development strategy until 2050 is focused on creating 1200 MW of capacity specifically through Small Modular Reactor (SMR) technologies.[4] Serbian leadership, including the Minister of Energy, believes that by 2032 SMR technologies will reach a sufficient level of commercial maturity to become a preferred option over traditional large NPPs.[48]

SMR technologies (typically under 300 MW capacity) indeed have several theoretical advantages for newcomer countries. Their smaller size is ideal for small power grids, and modular construction with factory assembly of components is intended to reduce construction time and financial risks.[14] The IAEA is actively updating its methodologies, including the Milestones Approach, to account for the specifics of SMR deployment and is supporting countries (such as Estonia, Jordan, Poland) in evaluating these technologies.[63]

However, a dangerous misconception frequently circulates in political and journalistic circles that SMRs, being "reactors out of the box," allegedly lower the entry barrier into the nuclear industry and require fewer competencies from the host country. A systemic analysis of regulatory challenges demonstrates exactly the opposite: **the introduction of innovative SMRs requires the customer country to have an even higher level of intellect, competencies, and regulatory sophistication than purchasing a reference large pressurized water reactor.**[21]

The introduction of SMRs multiplies the requirements for "Creators" in several directions:

1. **Highly complex procurement and manufacturing oversight processes:** Unlike a traditional NPP, where main works are conducted on-site, SMRs are assembled at vendor factories. Regulatory requirements indicate that the module procurement process must consider its incredible complexity compared to individual components.[67] The Serbian "Intelligent Customer" and SRBATOM inspectors will need to possess the competencies to conduct highly complex quality and management system audits right at the factories in the supplier country (in France, Russia, the USA, or South Korea).[67]
2. **Non-standard licensing and regulatory adaptability:** SMRs have unique characteristics: integral layouts, passive safety systems, innovative fuel types (e.g., TRISO), multi-module configurations on a single site (when one module operates while another is

refueled), and reduced emergency planning zones.[21] National rules written for traditional reactors are often inapplicable to them. The Serbian regulator and customer body must possess a profound understanding of neutron physics and thermal hydraulics to jointly develop or adapt a new regulatory framework with the vendor.[21] Dogmatic or incompetent application of old norms will lead to delayed and costlier regulatory approvals.[68]

3. **Evaluation of innovations:** Many SMR concepts belong to Generation IV reactors. The technologies require deep research and development (R&D) to confirm their safety in real conditions.[30] If Serbia plans to be an early adopter of such technologies, its "Creators" must possess top-level research potential capable of engaging in dialogue with the vendor's designers as equals.[30]

As noted in guidelines, the unique aspects of SMRs require the future licensee to establish Intelligent Customer attributes in advance and demonstrate these capabilities to the regulator as early as the licensing stage.[21] Thus, **Serbia's orientation towards small modular reactors makes the task of proactively preparing scientists, analysts, and regulators even more urgent and alternative-free.**

The Role of the NuclearSerbia Platform as a basis for Technical Support Organization (TSO)

In the context of establishing a sovereign "Intelligent Customer" function, a critically important element of the architecture of Serbia's nuclear program is the presence of strong and independent Technical Support Organizations (TSOs). The national regulator (SRBATOM) and the operating organization need external expert support that is loyal to national interests for the objective assessment of technologies proposed by foreign vendors, risk management, and the safe integration of local industry into global supply chains.

The complex hybrid role of the foundation for such an organization can be undertaken by the expert-analytical platform NuclearSerbia and the companies acting as its curators — Consilio B and NUCON.

Information and Analytical Foundation: The NuclearSerbia Platform

At the public level, NuclearSerbia functions as an open incubator of ideas for Serbian "Creators" (state strategists, regulators, analysts) and as a tool for overcoming public skepticism. In its first six months of operation, the resource published over 100 original articles and 1,200 news reports, garnering over 50,000 views, and formed a deep knowledge base on organizational and technical issues, regulatory aspects, and human resources policy.

The most important principle of the platform, which directly corresponds to the "Intelligent

Customer" concept, is strict vendor independence: it does not engage in lobbying for specific suppliers (whether projects from France, the Russian Federation, the USA, or Asia) but provides the objective analytics necessary for an informed technology choice at the state level.

However, the potential of the NuclearSerbia ecosystem goes far beyond educational activities. Relying on the resources of its supervising companies, it forms a full-fledged, two-tier contour of an independent TSO: strategic and engineering-technical.

Strategic TSO Contour: Consilio B Consulting Bureau

The consulting bureau Consilio B assumes the role of a strategic TSO partner and coordinator of localization processes. For newcomer countries, integrating local industry (construction trusts, equipment manufacturers) into a nuclear program presents a colossal risk, as the general Customer will not compensate for the lack of specific competencies among local contractors. As an organization for technical and management support, Consilio B implements the following tasks:

- **Risk management and a "single window":** Creating a joint project office to coordinate the interaction of dozens of Serbian suppliers with a future global vendor (for example, with EDF or Rosatom), ensuring the transparency of procurement and bidding documentation.
- **Adaptation to nuclear standards:** Preparing local companies to undergo highly complex qualifications and implement quality management systems for the nuclear industry, such as ISO 19443, ISO 3834 (welding requirements), and ISO 9712 (non-destructive testing).
- **Workforce design and workforce planning:** Creating an architecture of roles and managing quantitative personnel flows over time.
- **Strategic consulting (Soft Power):** Navigating a complex regulatory environment and acting as an intellectual "translator" between international standards and the realities of the Serbian industry.

Engineering and Technical TSO Contour: NUCON

While Consilio B provides managerial expertise, the company NUCON offers a deep, highly specialized engineering base. Relying on half a century of experience working at actual nuclear power facilities, NUCON is capable of functioning as a classic technical TSO, evaluating "hard" engineering.

Its critical functions within the framework of supporting the Serbian customer include:

- **Technical audit and independent expertise:** Consulting on high-tech components, such as systems for the control of radioactive gases, ventilation, and filtration. This allows the state not to take the vendor's design decisions for granted, but to subject them to professional auditing.

- **Quality assurance and control (QA/QC):** Inspecting production equipment, supervising installation, and ensuring strict compliance of components with ASME standards and IAEA directives.
- **Technology transfer:** Providing Serbian contractors with access to advanced testing methods, as well as engineering and technical support directly during the FEEP (Front-End Engineering Planning) and FEED stages.

Conclusion to the chapter

In aggregate, the NuclearSerbia platform and its corporate curators (Consilio B and NUCON) form a distributed Technical Support Organization that perfectly meets the complex needs of a newcomer country. This triad **protects the interests of the Republic of Serbia from the technological dictates of global suppliers, providing the state with independent analytics, and purposefully elevates the national industry to the level of strict international nuclear standards. Such a partnership is a powerful tool guaranteeing that Serbia acts as a true "Intelligent Customer," controlling the safety and economics of its future energy sovereignty.**

Conclusions and Strategic Recommendations

An in-depth analysis of the nuclear industry development dilemma for newcomer countries, conducted through the prism of IAEA international safety standards, institutional risk management theory, and the practical case of the Republic of Serbia, allows us to provide comprehensive answers to the questions posed and formulate strategic imperatives.

1. Priority of Formulating Requirements Over the Ability to Implement Them For countries creating a nuclear industry for the first time, lagging in the ability to formulate, specify, and strictly control requirements for vendors (the absence of the "Intelligent Customer" function) poses a critical, existential threat. The principle of inalienable responsibility for nuclear safety means that the state is obliged to understand, analyze, and bear responsibility for every element of the complex socio-technical system, even if it was physically built by foreign contractors.[7] The lack of this capability leads to technological dependence (vendor lock-in), safety degradation due to blind acceptance of designs, paralysis of the licensing system, and financial overruns.[15] Conversely, a lag in the ability to meet requirements (weakness of the national manufacturing and construction base) is acceptable in the initial stages. A country can successfully compensate for this by hiring qualified international EPC contractors, provided it maintains strict intellectual oversight over their activities.[1] No contract, even the most comfortable "turnkey" one, exempts the customer from the need to be a competent arbiter of technologies.[15]

2. Creators as the True Locomotive of Industry Development The true and only driver of industry development in the stages of its initiation and design are those who shape the requirements — the "Creators." This category includes system architects, analysts of the strategic body (NEPIO), employees of the national regulator, scientists of specialized institutes, and experts of the customer body.[1] According to the IAEA "Milestones" approach, it is they who implement Phases 1 and 2 of nuclear infrastructure development.[2] Without their deep analytical work, regulatory framework development, and contracting procedures, the activities of any "Implementers" (builders and operators), regardless of their qualifications, are impossible and illegal.[1] The engine of the industry is the intellect and will of the Customer, while the Implementers ensure the realization of its detailed design in Phase 3.[3]

3. Chronological Imperative of Personnel Training The chronology of human resource development is strictly determined by the project lifecycle. The state is obliged to prepare the "Creators" first.[2] Their preparation must begin even before the final decision is made (in Phase 1) and be completed by the time the technological vendor is selected (in Phase 2) to ensure an independent and competent evaluation of proposals.[2] Preparing "Implementers" (plant operators, maintenance crews) in the early stages is impractical, as their training is strictly tied to the specifics of the particular technology that will be chosen only in Phase 3 with the direct participation of the vendor.[2]

The Example of the Republic of Serbia demonstrates a deep understanding of this logic. After lifting the 35-year moratorium on NPP construction [4], Serbia did not invest in the immediate training of line operators but focused on reviving its intellectual core. The signing of a Memorandum of Understanding involving 20 academic institutes, including the historical center of expertise — the Vinča Institute, and specialized ministries, is a textbook example of the emergency mobilization of "Creators."[6] The 19-step roadmap being developed jointly with EDF clearly separates the period of creating the regulatory and institutional framework (Phases 1 and 2 until 2032) and the period of physical construction (Phase 3 until 2040).[3] Moreover, Serbia's focus on introducing Small Modular Reactors (SMRs) [4] makes the task of preparing highly qualified "Creators" even more strictly necessary due to the unprecedented complexity of licensing innovative solutions.[21]

In summary, it can be stated that creating a nuclear industry is not merely an infrastructure project, but a fundamental test of national and scientific maturity. True energy independence will not be achieved at the moment of the reactor's physical startup, but rather when an established national school of independent experts, strategists, and regulators is capable of taking full responsibility for every technical decision and guaranteeing the safety of the most complex processes for many generations to come.

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CONSULTING ENGINEERING COMPANY

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