# NUCLEAR BUSINESS: TRANSITION FROM

# SUPPLY CHAIN TO ECOSYSTEM CONFIGURATION

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**Abstract**

The potential market for small modular reactors (SMR) is up to 375 GW of installed capacity by 2050. However, the current linear supply chain configuration, often characterized by short-term contracts and limited suppliers, is a major constraint for this vision. Linear supply chains have bottlenecks i.e. high transaction costs for the stakeholders involved e.g. vendors, suppliers, and utilities. Crucially the linear “supply-buy” relations in the nuclear industry do not allow the flexibility and scalability required for large scale SMR deployment. Achieving such a large-scale deployment requires a shift from the traditional “supply chain” to a more flexible “ecosystem” mindset and business model. This isn’t easy to immediate, for instance, the nuclear sector needs to reach a balance between the nature of the business (e.g. the strict quality and regulation in components provision) and the openness of ecosystem business model. Embracing an ecosystem perspective needs e.g. shifting from “one-off projects” procured in a supply chain approach to a “program” (ideally across countries and design) leveraging an ecosystem business model built around standard platforms. Establishing this ecosystem approach, particularly in the value-added segments of the business, has already proved to be successful in other sector, such as the aircraft industry. Therefore, the question is not if the nuclear industry should follow a similar path, but how to create nuclear ecosystems?

## INTRODUCTION

It is time for nuclear sector to change its business and therefore delivery model. While EU policies state nuclear power to become an essential contributor to decarbonisation targets (e.g. RePowerEU) with installed capacity of 375 GW by 2050 [1], traditional nuclear delivery model as “megaprojects” hinders this vision. The complexity, uniqueness, and fragility of nuclear construction projects (i.e. design, supply chain etc.) have resulted in often being overbudget and late [2]. This is one the main reasons why there are just a few ongoing nuclear construction projects in Europe or USA. However, the recent limited examples of nuclear capacity deployment within a program (e.g. South Korea’s fleet [3]) demonstrate the potential of standardization across the design and modularization of major equipment, as well as keeping a long-term perspective by embracing active international collaboration on further technology development and know-hows. Thus, one of the pillars that nuclear business should incorporate in its business model is a “programme” perspective, instead of projects” perspective. Nuclear experts have been recommending this for the last two decades, yet, the key elements missing is “how”? Historically nuclear programmes have been championed by governments with a long-term commitment and perspective on nuclear (see e.g France in the 80-90s or Korean in the 00). Yet, for several reasons, governments are decreasing their participations in the utility business. So, the key questions is: *How to foster a “programme like” approach when governments are less and less involved in electricity provision?* The answer put forward by this paper is: shifting from supply chains and projects to ecosystems and platforms.

There are several examples highlighting how, by embracing standardization and modularization concepts at both organisational and technological levels, complex product systems (later – CoPS) manufacturers (e.g. satellite [4], aircraft [5], and industrial machinery [6]) are able to craft their innovation ecosystems to deliver platform-based complex solutions. This paper aims at analysing best practices and lessons learned of other CoPS industries, as well as explaining the benefits of platforms and ecosystems in facilitating “program-like” nuclear approach.

The rest of the paper is structured as follows. Section 2 summaries the key references about platforms and ecosystems in other CoPS industries and the way these configurations differ from the traditional supply chains. Section 3 details the methodology used to collect and analyze data; Section 4 shows and discusses the results of interviews conducted with the nuclear field experts. Section 5 concludes with the future research agenda.

## literature background

Despite the relatively large amount of literature published on SMRs, there is a gap in knowledge on the merit of SMR delivery model. However, several studies provide relevant insights on platforms and ecosystems in other CoPS industries. This section is divided into two subsections: (1) the literature background on platforms and ecosystems, and the empirical evidence of platforms and ecosystems from other CoPS, as well as (2) its possible implications to nuclear industry.

### Supply chains v. Ecosystems

CoPS manufacturers are heading towards formation of wider connected, flexible, and scalable networks with a larger set of interdependencies due to the changing competitive landscape (e.g. lower-price competitors solutions), and customer preferences (e.g. interconnected modules, digitally-enhanced solutions) [7]. For instance, the largest European aircraft manufacturer found its centralised supply chain to be ineffective to keep with the changing dynamic market environment, and had to initiate its business transition to a more flexible network (by aligning small and medium digital mature partners) [5]. Another study on biogas equipment manufacturers [8] highlights how traditional linear supply chain configuration, focused solely on fuel production, failed to capture the full potential of bio-resource utilization, and shows the value of embracing modularity and standardisation of the focal product across the industrial suppliers.

Thus, future CoPS manufacturers strategies are likely to be focused on crafting configurations different from vertical supply chains (the most common for CoPS industries). One of the possible solutions is to shift towards an “ecosystem” configuration defined by the *“alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize”* [9, p. 2]. Table 1 provides an insight on the difference between supply chain and ecosystem configurations, as well as the insights on such transition from the scientific literature.

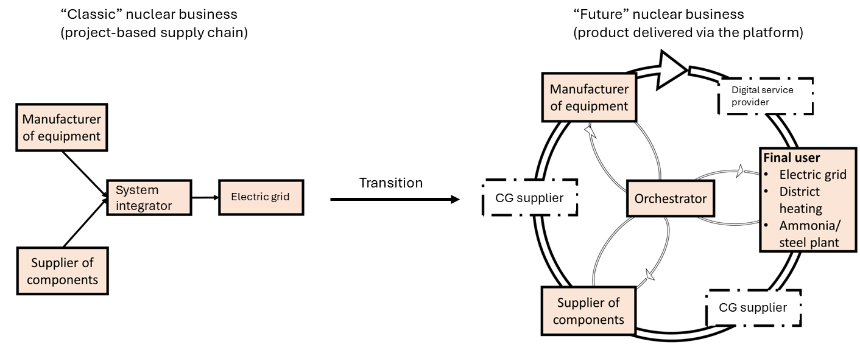
TABLE 1. Difference between a supply chain and an ecosystem configuration (grounded on [10]).

|  |  |  |  |
| --- | --- | --- | --- |
| Element | Supply chain | Ecosystem | Empirical evidence |
| Business environment | Stable | Dynamic | Aircraft industry [5], Complex industrial machinery [6], [11], [12], automotive industry [13], [14]. |
| Resources | Proprietary resources, design, and technology | Modular and standard technical systems | Aircraft industry [14], Complex industrial machinery [6], wind turbines industry [15], biogas plants [8] |
| Governance | Contracts govern the price, quality, and risk | Contracts govern a broader set of the access conditions | Aircraft industry [5], Complex industrial machinery [6], [16], wind turbines [15], satellite [4]. |
| Suppliers | Limited pool of key suppliers | Attraction of numerous suppliers | Aircraft industry [5], [14], automotive industry [13], biogas plants [8], complex industrial machinery [6], [11], [17]. |

Ecosystems, especially in the CoPS settings, are often enabled by the technological platforms defined as *“products, services, or technologies that are similar in some ways, but provide the foundation upon which outside firms (in the ecosystem) can develop their own complementary products, technologies, or services”* [18, p. 418]. Thus, platform ecosystems are essentially bounded with standardized interfaces, which ensure interconnectivity and complementarity within the modular and standardized architecture of the focal offer (i.e. product or service). Such architectures are usually structured around the core (i.e. standard components that are not subject to change) and peripheral (i.e. variable components subject to modularization and complementarity) logic [18]. For instance, industrial machinery manufacturers find it necessary to shift from traditional stand-alone complex products to collaborative platform strategies [16]. Such transition towards platforms often starts with strategic re-orientation of integrated complex products and systems provided by the limited sample of incumbent partners (e.g. system integrators) [6]. The standard protocols and interfaces are first established and aligned between this preliminarily set of partners and frame the core of the technological platform. These standards are then gradually extended across the potential ecosystem partners (i.e. the suppliers, manufacturers etc able to follow the standard) [17], thus creating industry platform.

### Implications for nuclear business

Platform approach and ecosystem mindset can essentially contribute to a large-scale SMR deployment in series. For instance, ecosystem logic facilitates on how both nuclear and non-nuclear manufacturers can work aligned across countries, allowing for the cross-reconciliation of codes and standards, thus enabling standardization of the manufacturing processes and capabilities. The standard platform implication is as follows: development of a licensable platform core (i.e. standard module) harmonized across selected counties requirements. Such approach can be especially relevant when a set of counties is interested in deploying same design, thus, matching their manufacturing capabilities along with localization strategies, and enabling vendor(s) to adjust its design(s) and reconcile the codes & standards (e.g. Nuward Joint Early Review [19]). Reaching the common vision on the necessary requirements, the part of the licensing process potentially could be done “in the factory” [20], [21], while the rest of it – by each specific ecosystem partner in accordance with the its specific requirements. Regarding the countries with nascent nuclear industries, such platform ecosystems can play the role of “accelerators”, thus, help and guide in development of the relevant capabilities, and adaption of already aligned codes and standards. However, such standardization of licensing process requires strong support and incentives from the governments [19]. For instance, the wind industry experience highlights the importance of national and sub-national policies to accelerate the development of internationally competitive wind turbine manufacturing companies [15]. Though this study does not explicitly highlight the value of industrial platforms and ecosystems, it explains how by promoting collaboration between industry, government, and research institutions, the wind turbine industry moved towards a more interconnected industrial network, however, securing high degrees of localisation. Fig.1. incorporating the insights from the literature review and nuclear business specifics, and provides a conceptual framework used further in the paper.



*FIG.1. Conceptual framework of nuclear business supply chain to ecosystem transition (CG – commercial grade)*

## research methodology

This section is concerned with the methodology used for the study explained above. The research is designed as an inductive, exploratory study. The data collection is structured as follows: primary data collected via interviews with nuclear industry experts and offering an insider's perspective on the ongoing and future development of the nuclear supply chain, and secondary data (i.e. available scientific literature, industrial reports, white papers etc.) serving to triangulate the primary findings.

### Data collection

Data for this study were collected through online interviews, with a total of five in-depth interviews with nuclear experts. Discussions focused on the participants roles and company background, experience in nuclear supply chain and procurement, and the view on large-scale SMR deployment, further discussing related issues and examples. The interviewees selection criteria were based on the relevant experience, affiliation (i.e. international organisations, consultancy companies, etc.), as well as major in nuclear, business & management, or other relevant engineering fields. In all interviews, English was used to communicate. Table 2 presents an overview with details of the five interviews, taking into consideration the anonymity of the interviewees.

TABLE 2. Profile of the interviews

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | Job title | Activity | Experience | Duration |
| 1 | Technical Officer | Consultancy company | 10 years | 65 minutes |
| 2 | Full Professor | Nuclear business, nuclear engineering | 30 years | 30 minutes |
| 3 | Senior Engineer | Supplier | 18 years | 90 minutes |
| 4 | Systems Engineer | Operator | 12 years | 25 minutes |
| 5 | Project officer | International organisation | 7 years | 35 minutes |

Secondly, this study is enriched with the secondary data to strengthen the triangulation of the primary data. The secondary data encompassed a range of sources, e.g., industry reports, conference presentations, website news and industrial podcasts etc. Moreover, if interviewees referred to some specific documents during the interview, we incorporated them as supplementary secondary sources, where applicable.

### Data analysis

From the data collection stage, the interview transcripts were documented and were thoroughly read and understood. Then, by reading the interview transcripts and summarizing each section of data, the different categories or themes were identified. To facilitate the “how” question, this paper focuses on the main barriers (Table 3) of the project to program transition and the role of platforms ad ecosystem to tackle these barriers (Chapter 4 of this paper).

TABLE 3. Main elements hindering the adaptation of nuclear delivery model to a “standard project” within a program

|  |  |
| --- | --- |
| Barriers | Main sources |
| Heritage of the EPC delivery model | In-depth discussion, [2] |
| Investment risk for suppliers | In-depth discussion, [20] |
| Lack of long-term commitment and agreements | In-depth discussion, [22] |

## findings and discussion

This section summarises the findings and discusses the results of interviews in relation to the literature.

### Heritage of the EPC delivery model

Traditionally, EPC supply chains (especially for the megaprojects) are complex at both organizational (i.e. unique suppliers with unique capabilities) and technological (i.e. complex designs and manufacturing processes) levels. Such complexity is one of the main reasons nuclear construction projects are often delivered overbudget and late [22]. Thus, complex EPC vision plays as a bottleneck for adaptation of a new “program-like” deployment of SMRs. One of the experts described it as follows: *“…I think this is like a major challenge, which vendors are facing right now because they don't know how to deliver it (i.e. SMR) as a product. The only way they know is to do it through an EPC, and EPC is like good at doing big construction project”.* Thus, there is a need of shifting the paradigm from “on-off” the projects to “standard” projects delivered within a program. This shift requires standardisation across the designs, manufacturing, and licensing processes. Expert highlighted the following: *“I think, one of the key issues currently with the nuclear, which is not helping it to become more product-based-like approach is definitely the lack of standardization, it is missing right now and for right reasons because there is no standard product which is being produced in the market”*. The standard platform adopted across selected set of partners (across countries) can essentially enable delivery of a standard SMR with a standard module. The expert highlighted the need of such a platform as follows: *“So, I feel that this mismatch, or no interaction, or non-availability of any kind of such platform which can actually guide them”.*

### Investment risk for new suppliers

Another implication of the current megaproject’s approach is its temporality i.e. short-term commitment with different partners involved from project to project. The long-term programme vision can be essentially strengthened by the ecosystem mindset i.e. the predefined set of partners is working together form one to another “standard project”. One of the experts commented: *“So, definitely, there is a need to reinforce this supply chain to have also a European approach to take benefit … and to have a long-term vision to maintain capacities and resources. There is also a need to reinforce trust and confidence (across the industry)”.* Moreover, reduced capacity and size of the SMR equipment allow nuclear business to benefit from other technologically advanced suppliers` capabilities (e.g. oil&gas, defence, chemical sectors). However, nuclear business should reduce the risk and uncertainties of entering the nuclear supply chain for new suppliers. One of the experts described it as follows: *“But you cannot have this kind of (flexible) supply chain unless you have volume, which is a problem. The SMRs don't have volume yet, and the negotiations are very, very different. They (i.e. CGD suppliers) are thinking that, should we invest on this kind of products, or should we not invest? Can we trust the market that we will get the orders?”.* One of the possible solutions to reduce the investment risk, especially for small and medium manufacturers, is to create a favourable environment (i.e. clear type of interfaces, manufacturing process aspects, etc). One of the experts commented on it: *“These procedures and the ….. methodology can be a gate for suppliers, or an easier gate, for suppliers to enter nuclear business”.*

### Lack of long-term commitment and agreements

First SMR projects should not be considered binary as a “failure” or “success”, but instead should be seen through “as future” lens, enabling further large-scale deployment, sharing of best practices and lessons-learned across newly framed industrial ecosystem [23]. This philosophy was implemented in the wind farm industry, where first offshore wind projects were first pushed by policymakers, and later found to be a solution to multiple challenges (both social and environmental) [24]. Thus, standard SMR delivered through programs will lock the relationships and trust across vendors and suppliers (to be part of an ecosystem). The expert highlighted the following: *“So, this becomes a big bottleneck for them (i.e. suppliers) because the know-how was lost, the company was lost… So, to avoid that, what role SMR could play is that if they're able to be deployed with a faster deployment timeline, not like 10 years, but maybe in two to three years. Then the equipment suppliers will remain in the picture, and they will be able to provide the components and services very fast”.* At the same time, the long-term planning should be done wisely to satisfy both increasing capacity and create a robust industry to avoid potential bottlenecks in the procurement process [20]. The standardized manufacturing process within the technological platform can prevent such misalignment. The expert highlights it as follows: “*…But the real bottlenecks that they (i.e. suppliers) might face is when the demand increases quite dramatically…So this is an important area that we need to plan ahead for and really share best practice on how we can optimize some of these procurements*”.

## conclusion and future research agenda

The potential market for small modular reactors (SMR) is 375 GW of installed capacity by 2050. However, the current supply chain configuration of nuclear business poses a significant challenge for this vision due to short-term contracts and limited suppliers, leading to bottlenecks and increased transaction costs for industrial stakeholders. Despite many studies focused on the economics and modularisation aspects of SMRs, very few of them provide an insight on how nuclear business can change it delivery model to enable large-scale SMR deployment. This paper addresses this gap in knowledge analysing how SMRs with standard module can be a precondition to create, what in business and management studies is called an “ecosystem”. Paper describes, through a literature review analysis, key insights on the platforms and ecosystems in other CoPS industries. Moreover, the paper summarises and discusses the results of interviews with nuclear industry experts on hindering factors of current supply chain to ecosystem transition. The results of the literature review analysis and the interviews suggest that to establish the program-like approach, it is first needed to tackle the following barriers (1) heritage of the EPC delivery model, (2) investment risk for new suppliers, and (3) lack of long-term commitment and agreements.

The paper provides a general insight on the way platforms and ecosystems can facilitate SMR deployment within the programs. The conceptual framework used for the data collection should be supported (and improved) by the large number of in-depth discussions with the industrial experts (i.e. commercial grade dedication suppliers, large incumbent nuclear suppliers, operators, and regulators etc.). Thus, such questions as standardization of the licensing approach across ecosystem partners, the possible orchestrator of such new governance model, and the inter-governmental alignment in nuclear settings should be studied more in detail in future research.

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