Topic 4: Track 15

**Facilitating SMR deployment through sustainable project financing:**

***A developer’s perspective***

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**Abstract**

Financing nuclear projects is one of the major impediments to Small Modular Reactor (SMR) fleet deployment. There is an ongoing debate about the role of governments in supporting SMR projects, particularly the early-stage financing of the first-of-a-kind (FOAK) reactors. Many governments in North America and Europe have launched grants, tax credits, and other financing initiatives to facilitate demonstration projects of FOAK technologies. While many SMR developers consider government support for FOAK projects as essential, the subsequent commercial fleet deployment of SMRs will still require an innovative financing approach. In this paper we explore the challenges faced by both SMR developers and aspiring customers of the heat and power that they deliver, when attempting to initiate and sustain a nuclear project that is geared towards large-scale industrial decarbonisation. Our proposed project finance model utilizes the best approaches common to the commodity sector, such as energy and mining.

We assert that the bankability of the SMR sector and the widespread deployment of SMRs, hinges upon securing long-term offtake agreements (OAs) with industrial end-users boasting strong balance sheets and having ready access to private funds and debt financing. The commodity sector has become highly scalable thanks to the provision of debt financing. In order to achieve the same in the SMR sector, Multilateral Banks must lend to nuclear projects that offer the only scalable supply of clean, reliable energy for the achievement of the net zero by industry. Lenders may require guarantees from project sponsors until commercial production begins. Project sponsors must adhere to industry best practices to mitigate this risk for timely and cost-effective project delivery. Until many more SMRs are operational, support from financial investors and governments will facilitate the provision of guarantees needed to maintain deployment momentum.

1. INTRODUCTION

The COP28 recognised nuclear power as having a major role to play in the required global reductions in greenhouse gas emissions (GHGs). Consequently, many attendant nations made pledges to increase nuclear power output in the coming 10-20 years. SMRs were singled-out for particular mention with many delegate nation’s believing them to be quicker and easier to deploy than large giga-scale nuclear power stations. Certainly, by virtue of their smaller size and modularized construction, they are expected to achieve shorter construction times, which is a key factor in the cost of nuclear power. Also, if regulators deliver on promises to streamline licensing and permitting systems for these reactors, then planning and approval processes should be faster and cheaper. But the lower economies of scale, when compared to gigawatt-scale reactors, suggests that SMRs will have high unit power costs or levelized costs of energy (LCOE). To achieve competitive unit energy production costs, SMR manufacture and installation processes need to be production-lined, ideally underpinned by robust order books, to efficiently deliver multiple deployments at single sites, or to multiple sites around the World. The former is clearly preferable from the perspective of minimised development costs and speed of delivery, while a global fleet of SMRs offering standardized design applications for the decarbonization of specific industries is critical to achieving GHG emission reductions.

While, a strong order book for SMRs would, in part, be a consequence of successful FOAK deployments together with the demonstration of novel applications at an affordable price, firm orders are only possible if a viable and sustainable financing mechanism exists that supports the deployment process from feasibility investigations through to commissioning. Currently, SMR developers and industry believe that generous government funding is still key to successful deployment, or at least for in-country FOAKs. This perception can pose a challenge to global SMR deployment. The nuclear power sector must be transformed from a specialist energy technology that is the prerogative of advanced nations to an every-day commodity with wide geographic application.

This paper presents a low-risk financial approach to support the sustainable, scalable and rapid deployment of small high temperature gas reactors for industrial decarbonization. It does this by treating the energy produced as an affordable, long-term user-pays utility cost that is integrated into the financial model of the business. The SMR is neither a major capital cost that threatens to dwarf the financial value of the business, nor is it a large debt item that has to be serviced for decades against uncertain interest rates. The energy products produced by SMRs will be sold to industrialists via long-term Offtake Agreements (OAs) with secure short and long-term alternative energy product selling opportunities, in the event that a customer encounters production problems or changing fortunes. The objective is to provide secure, clean energy to industries with a long-term product demand that can weather various existential challenges. Such contracts will render an SMR project bankable to lenders and investors by virtue of demonstrating a secure revenue stream that is underpinned by the projected productivity of reputable industries and coupled with proven nuclear technology. Whilst the historical balance sheet performance and credit rating of a customer is important for financial risk calculations, project cashflows will also be measured against the future market demand for low-carbon products, the likely price of those products and the ability to fend-off competition from other low-cost producers using lower-cost high carbon-emitting energy sources. This innovative approach to SMR financing is key to achieving affordable decarbonisation in high energy-demanding industries.

Companies that are looking to invest in clean production technology and secure low-carbon energy products, are especially attractive as the respective lifespans of the new production and energy generation facilities can be synchronised to yield maximum returns. Investing in clean production systems that still rely on electricity produced from fossil fuels, is a high-risk strategy that is similar to providing low-carbon electricity to an older industrial plant that was designed at a time when emissions and environmental considerations were not prioritized.

Initial energy products supplied by SMRs under this proposed approach will be electricity, heat, hydrogen and hydrogen-derived products. However, as indicated earlier, the preparedness to install multiple SMRs in order to increase output and meet more of a client’s clean energy needs, or those of their neighbours, is the primary aim once reservations over the use of nuclear power have been resolved. It is expected that in many instances the demand for low-carbon hydrogen may feature strongly in the energy demand mix, and the capacity to deploy the most appropriate and lowest-cost hydrogen production technology, in tandem with small high temperature reactors, will be paramount. Again, demonstrating the deployment and novel application of SMRs to industrialists at an early stage will be key to ensuring full order books and lower energy costs.

1. TARGET INDUSTRIES

Perhaps one of the early miscalculations of SMR developers, aside from being too optimistic over the time and cost of bringing a new nuclear reactor to market, was to focus on grid electricity supplies. In doing so, they challenged many large thermal power plants, including nuclear, to a contest that was going to be difficult to win. Until SMR technology achieves economies of scale, it will be important to focus on early adopters that are willing to pay a premium price for clean, reliable energy. Advanced Modular Reactors (AMRs) have a distinct advantage in this regard due to operating temperatures of more than 550°C, compared to light water SMRs with reactor output temperatures of between 265°C to 300°C. The opportunity to use the thermal energy output from the reactor as industrial process heat offers industrialists a very real alternative to fossil fuels. AMR developers are now beginning to carve-out a heat energy niche that is difficult for conventional electricity generators to challenge. Moreover, the by using clean heat, manufacturers are able to produce premium-priced, low-carbon products that are resilient to border carbon adjustment levies and which can access more discerning, higher value markets.

The broad categories of industrial customers that will benefit from SMRs and high temperature SMRs include:

* Petro-chemical plants
* Mining and minerals processing
* Iron and Steel plants
* Industries using dedicated electricity generation from fossil fuels in remote areas
* Data centres
* Synthetic fuel plants
* Road and rail transport hydrogen stations
* Cement manufacturing

1. CONTRACTUAL MODEL

The proposed contract model for the deployment of SMRs is based on the developer and industrial customer entering into a long-term OAs for a period of 20 years or more. However, such an agreement can seldom be entered into without the involvement of government. Thus, a contractual agreement for industrial decarbonization involving industry, government and the developer, as shown in Figure 1, is needed.



*FIG. 1. Industrial decarbonization contract*

Figure 1 demonstrates how the proposed financial model for SMR deployment builds on, and integrates with, the efforts of both governments and industrialists to decarbonize in order to meet internationally agreed targets and market requirements for ‘greener’ products. It shows that no single party can achieve this in isolation.

Industries may be able to give governments a commitment to invest in cleaner production technology, but without a reliable and affordable supply of low-carbon energy, they are not always able to deliver on that commitment nor can they offer their investors the dividends that stem from selling premium-priced ‘green’ products into a global market. Similarly, governments can (and often do) set ambitious targets for reduced carbon emissions and then require industries to meet those targets with minimum consideration for how this might be achieved, how much it will cost or who must pay.

To date, industries have sought to purchase low-carbon electricity such as the renewable energy produced by solar and wind farms, in order to lessen the carbon intensity of their operations. While this can prove affordable, the quantities of power required and the desired reliability of supply are seldom available. The recent drop in battery storage costs has eased the supply reliability issue in some cases, but the cost has been high, particularly for industries that operate 24/7. Moreover, renewable electricity is an unsuitable and costly replacement for those industries that burn coal and gas to produce process heat. In essence, governments may not have considered how decarbonization targets will be cost-effectively met by their high-heat-demanding industries. The emergence of SMRs in recent years and the prospect of high temperature SMRs supplying both heat and electricity, has presented a glimmer of hope, but the high capital cost of such solutions and uncertain delivery time has pushed the adoption of this technology well into the next decade and beyond.

The proposed participant model is intended to resolve the responsibility problems besetting industrial decarbonization by clearly defining what each of the three parties must contribute. More specifically, it requires the following inputs and obligations.

For **Industry**, conditions include the adoption of clean production technology (assuming that it is not already in place) that will ensure the production of low-carbon products for which a robust market is likely to exist for the duration of the OA. A solid historical balance sheet coupled with a strong future product demand that is resilient to border adjustment taxation, are important credentials for this model. Ideally, there should be a preparedness on the part of industries to move to premium product production and to seek out global markets that are willing to pay high product prices.

For the host **Government**, contract conditions need to be equally specific. The siting, licensing, and permitting of an SMR can be a time-consuming, expensive, and uncertain process. Moreover, most nations are yet to amend their nuclear planning regulations to ensure that they are appropriate for smaller and safer SMRs, leaving the developers of a small 10MWe SMR to face the same regulatory requirements and costs as the developer of a 3GW power station. While such inequalities persist, it is important that governments appreciate that unnecessary regulations can lead to significantly increased costs, schedule delays, and project delivery uncertainties. Knowing, with a reasonable degree of certainty, when a reactor will be operational and when it will start to generate cash flows, is critical information for an investor. Uncertainty surrounding these target dates is similar to being asked to sign a blank cheque. The most important contribution that governments can make in supporting SMR-led industrial decarbonisation is providing developers and investors with fit-for-purpose regulations and certainty surrounding the time and cost of licensing and permitting. Such certainty has a significant cash value to a project developer, which may exceed other financial incentives. The simplest way for host governments to provide this certainty is to enter into technology adoption and licensing agreements with the nuclear-exporting nation.

Lastly, the **Developer**’s and/or **Energy Supplier**’s obligations include the investigation, financing, project management, regulatory affairs, equipment supply, construction, commissioning, and operation (or partnership with a local operator) of the SMR according to agreed schedules. The Developer will also be responsible for the establishment of a Special Purpose Company (SPC) or legal entity that will plan, construct, own and operate the SMR, and into which various investors, individuals and organisations can purchase equity. But by far the most important contribution of the Developer is to design an innovative, functional, and viable project finance model that manages risk appropriately and can attract a variety of investors from individuals to institutions with the promise of secure long-term returns.

1. FINANCIAL MODEL

The financing of an SMR deployment project can be considered in three distinct phases, each with its own risk profile. These are:

1. Phase 1: Concept to Final Investment Decision (FID)
2. Phase 2: Post-FID to authorization for the First Nuclear Concrete (FNC)
3. Phase 3: FNC to Commissioning

The characteristics of each phase are summarised in Table 1 and discussed more fully below.

TABLE 1. CHARACTERISTICS OF THE PHASES OF AN SMR PROJECT



**Phase 1** investigations will need to be conducted on the basis of a prefeasibility study culminating in a Memorandum of Understanding or similar agreement to proceed with detailed Feasibility Planning and Pre-FEED investigations. Depending upon the proposed site, this work can take from 1 to 2 years to complete for an in-country FOAK reactor. This expenditure poses a high risk in that there is no guarantee that SMR deployment will proceed after the work has been completed. For this reason, a significant contribution from the public sector towards Phase 1 costs will be required. Public sector funding can be received from either the host government and/or from governments looking to export SMR and associated decarbonization technology. Ideally, a contribution to Phase 1 costs would be required from the industry looking to decarbonise their operations by using clean energy from an SMR. Such a contribution is essential to ensure meaningful inputs to the project and discourage frivolous enquiries. In the case of perceived low-risk, genuine projects, the developer’s financial backers may also be able to make a contribution towards this Phase of the work, particularly in the early years of SMR deployment.

**Phase 2** investigations commence after the FID has been taken by all three contracting parties and a firm OA has been entered into. These two milestones also signal the establishment of the Special Purpose Company (SPC). This detailed planning work and FEED studies can require the mobilisation of up to 100 professional staff for periods ranging from 3 to 4 years. Consequently, the cost can exceed US$200 million depending upon the type of SMR plant, its deployment maturity and the complexity of the site. Developments that envisage the eventual deployment of multiple reactors at a single site to achieve incremental decarbonization and/or the future growth in energy demand, will be more expensive to plan, but the benefits will be realised later when the deployment of additional SMRs can proceed unhindered. In general, the financing of Phase 2 will largely comprise income from the sale of equity in the SPC set-up to develop, deliver, own and operate the SMR(s). It is possible that the host government, indigenous nations (if applicable), or the industrial customer(s) may wish to take an equity stake in the SPC and contribute to costs. Given the strong global call for increased nuclear power at the COP28 it would be encouraging if international development banks were to make grant or bridge loan funding available, either individually or via a collective fund, to the developer to enable them to contribute to both Phases 1 and 2 and even purchase equity in the project. Lenders are only likely to become involved in project financing once all regulatory hurdles have been overcome, supply chains secured and a project Engineering Procurement Contractor (EPC) appointed.

It will be important for the developer and the investors to be compensated during Phase 2 in the event of regulatory delays or the unexpected termination of the project by government and/or the industrial customer. In such circumstances, compensation should cover both the cost of capital and the capital used. Payments can take the form of periodic grant payments, possibly using regulated asset-based mechanisms, or bridging loans. It is important that Phase 2 financing arrangements incentivise both the host government and the customers to support and expedite development of the project. Moreover, professional project management of the highest quality, together with strong commitment from the host government and the customers, will be required to maintain budgetary discipline during this Phase. Another possibility would be to convince international development banks to support this critical Phase of an SMR project either directly or by the provision of auditable funding to the host government possibly in the form of loans or convertible loans. Similarly, if host governments could offer concessionary bridging loans via state-owned financial institutions, this would help reduce the burden on private financial institutions and reduce their risk profile. Moreover, if SMR exporting governments were to assist vendors with SMR delivery via tax relief or grants, at any stage of the project, this will expedite deployment, strengthen supply chains and further reduce the risk to private financial institutions.

**Phase 3** of the project is the most demanding stage of the development in that a large amount of finance must be secured through both debt and equity to procure the primary components of the SMR and build the facility. In reality, down payments for the primary SMR components will have been made at the time of placing firm orders, around halfway through Phase 2. These transactions should be supported by export loans and guarantees from the technology exporting government. Depending upon the size and type of SMR being built, Phase 3 can cost upwards of US$600 million and take between 2 and 4 years for the first unit to be built and commissioned. Subsequent units should take less than 2 years to build and some SMR developers are looking to reduce the construction times to less than 12 months per reactor on a multiple SMR site. If experienced international construction teams are used for the in-country FOAK, then construction times can be close to 2 years. As with Phase 2, the developer will need to protect the project, and the finance it has borrowed, from external delays caused by legal challenges, political change, supply chain issues and labour disputes. Again, the highest quality construction planning and project management will be essential in keeping the cost of capital to a minimum.

Although Phase 3 will come to an end once the first SMR is commissioned and producing energy products, there is always the likelihood that an SMR project may involve the deployment of multiple reactors, possibly comprising two, three or four units. In such circumstances, costs can be minimized by the concurrent, and possible overlapping construction of reactors, subject to safety protocols concerning construction activities in close proximity to an operational reactor. Alternatively, SMR plant expansion can be implemented over several years to meet anticipated increases in the demand for clean energy and phased industrial decarbonization investments. In such circumstances, securing finance for additional SMRs is not expected to present any challenges given that an SMR has already been built, commissioned and is generating revenues. Indeed, modelling work for multiple SMR developments has highlighted the possibility of financing a significant portion of additional SMR costs from operational cash flows, provided shareholders are prepared to periodically forgo dividends in exchange for a much higher share valuation. Figure 2 depicts the proposed financial model for efficient SMR deployment.

At this stage, attention should be drawn to the role of Government in subsidising clean energy innovation for the decarbonisation of large industries that may be considered economically strategic and which are likely to employ a large workforce. All technological innovations are expensive at first be it personal computers, smartphones, electric vehicles (EVs) or SMRs. Many governments consider sustained EV uptake to be central to their national decarbonisation targets and as such are prepared to subsidise them and introduce punitive regulations that increasingly discourage the purchase of petrol and diesel vehicles. The deployment of SMRs to achieve industrial decarbonisation is no different. Government support, both financial and regulatory, is required until the SMR market matures and the deployment of Nth-Of-A-Kind reactors is both commonplace and low risk.



*FIG. 2. Financial model*

1. CONTINGENCY PLANNING

A critical, aspect of an SMR project design is contingency planning. Contingency planning must cover eventualities from small delays in the project caused by typical implementation issues to the unlikely prospect of an industrial customer closing down. Contingency planning must focus on protecting investor’s money and being able to service outstanding debt regardless of the prevailing political and corporate dynamics. The OA will aim for an effective duration of 20-30 years or even longer, sufficient to pay all debts and provide investors with acceptable returns. However, an SMR can have an operational life of up to 60 years, during which political and corporate change is likely to happen. It is therefore important to make provision for the alternate sale of energy products produced by the SMR for the duration of its operational life, not only to maintain profitability but also to ensure that adequate funds are set aside for the liabilities associated with plant decommissioning, waste management, and incident handling.

At this juncture it is worth noting that many existing nuclear power stations with a typical operational design life of 40 years, are currently having their life-spans safely extended through maintenance and upgrading work in order to meet the recent surge in demand for clean energy. The contribution of these low-cost, low-carbon energy generators in preventing global warming from being far worse than we currently experience, is almost incalculable. Moreover, as these facilities age gracefully into their fifth decade of service, they continue to be extremely relevant and profitable.

Most SMRs will be legally required to be connected to the transmission system of the region or country in which they are located. This allows the SPC to sell clean energy contractually or into a balancing market, should one exist. The contribution of a thermal power plant to producing a stable synchronous supply to transmission systems that may be dominated by asynchronous renewable generation can be highly significant in preventing frequency events and in enabling higher levels of renewable power to be transmitted.

As hydrogen is a key energy product from high-temperature SMRs, it will be prudent to identify markets for both hydrogen and its more manageable derivatives such as green ammonia, e-methanol and sustainable aviation fuel. A good business case can be made for the short-term storage and off-sale of nuclear hydrogen to the transportation sector, either for use in hydrogen fuel cell vehicles or as a feedstock for the production of synthetic fuels.

Lastly, industrial process heat is not an product that can be transported far from its point of production. In some countries, planning is underway to relocate or attract heat-demanding industries to sites adjacent to high-temperature reactors as an alternative to the continued burning of fossil fuels. A diverse array of industries all requiring a variety of energy products, can be the perfect commercial contingency for an expanding SMR facility.

1. OPERATION

While the proposed SPCs will begin life as project developers, they will eventually become owner-operators of SMRs. Moreover, regulators require a specific level of experienced nuclear operators to be present in an SPC before awarding licenses and permits. Consequently, SMR operational skills must form a key part of a deployment project from the outset. These skills may initially be drawn from experienced nuclear utilities in other countries until a largely domestic operational workforce can be trained. Unfortunately, such skills can be scarce in countries that are new to nuclear power. They have to be nurtured and developed from an early stage, a process that can take more than 10 years. As such, the developer and the host government will need to look closely at existing tertiary educational institutions and the training they offer to ensure that the long-term staffing needs of SMRs are adequately met. It is important that nuclear facilities are staffed by highly-trained local people as soon as possible in order to reinforce technology acceptance and ensure sustained benefit streams into the local economy.

It will be important to stress the limited number of employment opportunities offered by an SMR when compared to a conventional large-scale nuclear power plant. Streamlined design, passive cooling, and advances in control and automation have resulted in employment projections for SMRs of around 20 staff plus 2 people per 10MWe installed capacity, as reported by various developers. Thus, a 15MWe SMR may require around 23 personnel whereas a 300MWe SMR will require around 90 personnel.

The SPC must be prepared to provide an Integrated Service Delivery (ISD) depending upon the status of the nuclear sector in the host nation. ISD may be comprehensive in nations that are new to nuclear power and may include security issues, waste management, national skills development, long-term public and industrial engagement, and community and environmental outreach. An early SMR deployment that is able to demonstrate complete ISD package would be highly beneficial to the SMR industry and global industrial decarbonisation.

1. CONCLUSION

The SMR sector requires a comprehensive strategy to transition from dependence on government support to becoming an investable and bankable commodity sector. This shift will enable SMR projects to be funded by debt and equity, thereby providing firm, clean, and affordable energy worldwide.

An innovative and robust model has been developed to facilitate the global deployment of SMRs for industrial decarbonization and thus, bring about a significant reduction in GHGs. This model leverages the balance sheets, credit ratings, and long-term product demand of industries to secure affordable and timely financing for the planning, permitting, construction, and commissioning of SMRs. These reactors will provide low-carbon electricity, process heat, hydrogen, and downstream hydrogen products. These energy streams are supplied through long-term Offtake Agreements (OAs) to produce premium-priced 'green' products that are expected to be in high demand and which will be compliant with increasingly stringent carbon importation standards.

Key inputs are required from governments (both SMR exports and SMR hosts), industrial customers, and global financial institutions. These include regulatory frameworks tailored to SMRs, offering significantly more investor certainty. Government and financial sector recognition of SMRs' critical role, especially high-temperature SMRs, in decarbonizing heavy industries worldwide is essential for the widespread adoption of this model.

While early applications may be challenging and potentially more expensive, maintaining resolve and discipline among contracting parties will lead to quicker, more cost-effective deployments over time. This scalable solution can significantly contribute to meeting 2050 decarbonization targets. SMRs and their decarbonization applications must demonstrate technical viability, sustainability, and profitability to satisfy governments, industries, and the financial sector. This model provides the organizational, financial, and transactional foundation to achieve these essential goals.