A Cost Stabilization Facility for Kickstarting the Commercialization of Small Modular Reactors

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Forward

This working paper is produced within the Energy Futures Finance Forum (EF^3), a program within the EFI Foundation focused on increasing the investment quality of decarbonization assets. It is one of several products that will help form the basis for a final, comprehensive report on enhancing the bankability of SMRs.

Executive Summary

It is in the national interest for the United States to enable the next generation of civilian nuclear plants, namely small modular nuclear reactors (SMRs). These advanced reactors can contribute to enhancing the nation's energy security, resiliency, reliability and meaningfully contribute to decarbonization of the power and industrial sectors. Nuclear reactors produce large quantities of power with a relatively compact footprint, capable of >95% capacity factor operation and built to withstand various kinds of natural and anthropogenic disasters. Moreover, SMRs will likely experience robust demand internationally, as current nuclear countries as well as those with ambitions to join them see new nuclear as important to solving multiple energy-related issues. With this projected increase of new nuclear plants globally, there is a clear national security and nuclear nonproliferation imperative. Taken together, the United States has the chance to meaningfully shape the trajectory of SMR deployment and the development of its supply chain globally. Where that starts is through enabling SMRs at home.

The dual barriers of cost magnitude and cost uncertainty are the most salient impediments to first-of-a-kind (FOAK) SMR deployment. The two concepts are interrelated; despite their smaller size, modularity, simpler, standardized design, FOAK costs for SMRs remain capital intensive for both Gen III+ and Gen IV reactor designs. Currently, SMRs are at the advanced concept/prototype stages of development and are expected to be deployed commercially in the very near future. The current lack of "real-world" validation of cost estimates has made lenders and equity investors wary of the economic viability of SMRs. Yet, SMRs offer the promise of substantial cost reductions beyond FOAK deployment due to learning effects and cost efficiencies inherent in factory built, simplified components coupled with repeatable construction processes that could lead to cost competitive Nth-of-a-kind (NOAK) installations. These cost reductions would only be realized through iterative deployment; therefore, the imperative is to enable sufficient demand. One approach is to form an "orderbook", defined as multiple, identical installations of a particular design.

This paper presents a **policy framework** to “kickstart” the SMR industry through: (i) harnessing learning effects by focusing on building multiple installations of a given SMR design; (ii) sharing cost risks and development gains across multiple parties; and (iii) capping the capital costs faced by FOAK nuclear developers through a proposed publicly funded financial backstop mechanism. Given the national interest in building out a robust, next-generation nuclear industry, the framework is predicated on the dual notions that, first movers should not be disadvantaged for shouldering pioneering risk and enabling an SMR industry would be significantly supported through a robust knowledge sharing strategy.

The paper focuses on the **key missing ingredient** that is holding up the development of a robust SMR orderbook; namely, addressing the specter of large unanticipated or unforeseen cost overruns for the first sets of deployments of a given design. It proposes a **cost stabilization facility (CSF)** that centers on a special credit mechanism provided by the Federal government through the Department of Energy (DOE) Loan Program Office (LPO). Employing existing authorities within LPO, the CSF would be an augmented loan product with features specifically designed to significantly reduce the tail risk faced by pioneering SMR project proponents during the development and construction phases. The major components of the framework are:

- **Orderbook.** The CSF would only be available to FOAK orderbooks for multiple builds of a given SMR design. Project sponsors would take the lead in choosing the design they wish to build. The minimum number of builds that would be sufficient to constitute an orderbook could vary by SMR design and would be a key parameter negotiated upfront with the LPO. Nothing would preclude multiple orderbooks from being formed by additional project proponents, each focused on a specific Gen III+ or Gen IV design and supported in parallel.
- **Collective Undivided Ownership through an SPV.** The orderbook of SMRs would be placed within a special purpose vehicle (SPV), a holding company that is a separate legal entity from the project sponsor(s). Project sponsors would own pro rata shares in the SPV and, by extension via pass through, each sponsor would own an undivided percentage of each of the plants constructed under this arrangement. Crucially, this structure would allow for individual project sponsors (e.g., utilities) to own undivided shares in the orderbook, enabling them to record the value of such investment on their balance sheets. Provided project sponsors have a noncontrolling investment in the SPV (i.e., less than 50%), any debt carried by the SPV would not get represented on the project sponsors’ books. Management, structure, and operations of the SPV would be determined by the project proponents and codified within the SPV governance bylaws.

- **SPV Capitalization.** Each sponsoring party would be responsible for arranging its own financing to support the SPV orderbook. Project sponsor capital injection would be in a form of its choosing (i.e., mix of equity and debt, however sourced). Funds injection to the SPV by the project sponsors would be on a callable basis as determined by milestones agreed to by the parties to sufficiently pay for activities. Participation in the SPV would be designed to be open ended, with additional project sponsors or investors joining the SPV and providing capital after its formation if agreed across the parties. Effects on ownership shares in the SPV would be determined by the governance bylaws.
- **Cost Containment**. The construction of the individual project plants within the orderbook would be governed by an integrated project delivery (IPD) agreement. An IPD agreement would establish a shared incentive structure among key project stakeholders (e.g., major suppliers, engineering procurement, and construction, owner, operator, etc.) and would outline terms in which implementation risks and costs (and cost savings) are shared. The IPD model would create an incentivized framework among the project proponents to share information and contain costs. It would also be ideal – but not required – that these multiple builds be geographically concentrated to maximize the learning benefits from on-site construction and simplify licensing. Further, a relatively small number of engineering, procurement, and construction firms (EPCs) should be employed to build the orderbook, balancing between capacity constraints if too few and diluted learning effects if too many.
- **Tiered Cost Sharing.** Cost risks would be allocated in tiers. In the first tier, project sponsors would be responsible for all project costs established in the baseline orderbook budget, excluding contingencies. The second tier would be comprised of funds to address reasonably estimated contingencies. These contingencies would be pooled funds assembled by all project participants (designer, EPC, and vendors) through the IPD agreement. In the third tier, DOE LPO would provide backstop financing to complete the orderbook through the proposed CSF.
- **CSF Design and Implementation.** The CSF would be automatically enabled in the event the orderbook is not complete but the total budget (first and second tiers) for all builds has been exceeded. The trigger threshold for the CSF would be known in advance and agreed to at the beginning of the project. *The CSF is a credit facility provided by DOE LPO to the SPV.* Importantly, the CSF loan would be granted to the SPV, not the individual project sponsors. Put another way, it the SPV would become the debtor to the LPO.
- **Project Offtake.** The orderbook agreement would include terms that would provide project sponsors entitlement to pro rata shares of project offtake. In turn, sponsors

could either take power and use for their own purposes, or sell their share of output (e.g., via wholesale markets, long-term PPAs, etc.).

- **Project Operations.** There would be multiple options for completed projects. One option is the SPV could contract for the operation of the completed plants, most likely to experienced nuclear utilities where SMRs are built within their service territories. The SPV may also form its own operating company. Completed plants could also be sold out of the SPV and operated according to separate terms.
- **CSF Repayment.** The CSF agreement between DOE's LPO and the SPV would contain flexible repayment terms and conditions that could differ significantly from conventional loan and loan guarantee agreements. For example, repayment terms might allow for deferral or limited repayment in the near term, graduated repayment terms over the longer term that are linked to long-term value of the projects, and a possible bullet repayment obligation at maturity. Establishment of the repayment terms could need to consider the possibility SPV default if the SPV fails to complete construction of the orderbook or completed projects do not achieve their projected economic value over their operating life. In short, the CSF would be as flexible as feasible within current DOE LPO authorities; conversion of the CSF loan facility to a grant would require new legislation that is beyond the scope of this discussion.
- **Exit Provisions.** The orderbook agreement to establish the SPV would include provisions that allow for orderly exit by sponsors. For example, if the orderbook were successfully implemented without triggering the CSF, the agreement could allow individual sponsors to spin out completed projects to individual utility ownership and operation. If unanticipated costs emerged that might otherwise trigger the CSF, the agreement could allow, in the alternative, for transfer of uncompleted projects to the federal government under mutually agreed-on terms and. Offramps would need to be constructed in the case that, for example: (i) learning and/or cost advantages are not demonstrated in the first few builds and the orderbook needs to be abandoned; and (ii) the CSF is triggered and exhausted before the orderbook is completed.

In sum, by enabling an orderbook of SMRs of a given design, taking advantage of a familiar project finance structures in the SPV, and employing existing LPO authorities to provide a cost cap to FOAK development risk, the CSF mechanism would be designed to kickstart the SMR industry in the U.S.

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Introduction

It is in the national interest for the United States to enable the next generation of civilian nuclear plants, namely small modular nuclear reactors (SMRs). These reactors can contribute to enhancing the nation's energy security, resiliency, reliability and meaningfully contribute to decarbonization of the power and industrial sectors. Nuclear reactors produce large quantities of power in a relatively compact footprint, capable of >95% capacity factor operation, built to withstand various kinds of natural and man-made disasters. Moreover, it is likely that SMRs will experience robust demand internationally, as current nuclear countries as well as those with ambitions to join them see new nuclear as important to solving multiple energy-related issues. With this projected increase of new nuclear plants globally, there is a clear national security imperative. Taken together, the United States has the chance to meaningfully shape the trajectory of SMR deployment and the development of its supply chain globally. Where that starts is through enabling SMRs at home.

The dual barriers of cost magnitude and cost uncertainty are the most salient impediments to first-of-a-kind (FOAK) SMR deployment.[a] The two concepts are interrelated; despite their smaller size, modularity of certain standardized components, and simpler design, FOAK SMRs are still capital intensive across Gen III+ and Gen IV designs.[1,2,3,4] At this stage SMRs are advanced concepts and prototypes on the cusp of commercialization. Given that there is little "real-world" validation of cost estimates, lenders and equity investors are wary of the economic viability of SMRs.

Any lender, whether private or the federal government through Department of Energy (DOE) Loan Program Office (LPO), is likely to require that project funding plans include some form of financing reserves (either via cash, letters of credit, or funding availability) of large amounts to be readily available to cover cost escalations contingencies.

Even with such project cost buffers, there remains a material probability that FOAK costs will surpass engineering, construction, and procurement cost estimates, like what has been experienced at Vogtle Units 3 and 4 and other nuclear power development projects (e.g., Hinkley Point C in the UK, Flamanville in France, and Olkiluoto in Finland). Even though the

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[a] SMR designs generally have a power capacity of up to 300 MWe per unit (the "S" in SMR), use standardized parts thereby increasing manufacturing efficiency, and the finished reactors can be modularly configured into sets of installations to "right-size" a facility (the "M").

stick-built approach in these examples may ultimately be less competitive than manufacturing-based approach envisioned for SMRs, there is a good chance that costs will exceed project budgets in the first few installations because of its relative commercial immaturity. Indeed, developers, utilities, regulators, and shareholders have legitimate worry that first mover costs will exhibit a large uncertainty, strongly dissuading SMR development *en masse*. Taken together, there is the specter of large unforeseen FOAK project costs that could force abandonment if risks cannot be mitigated.

However, SMRs offer the promise of substantial cost reductions due to learning effects and cost efficiencies inherent in factory built, simplified components coupled with repeatable construction processes that could lead to cost competitive Nth-of-a-kind (NOAK) installations. These cost reductions would only be realized through iterative deployment. Therefore, one approach is to form an “orderbook”, defined as firm commitments for multiple, identical installations of a particular design. With the proper risk sharing mechanisms, creditworthy customers such as utilities could be motivated to invest the collective billions needed to “kickstart” SMRs down the cost curve. Put another way, an orderbook with sufficient financial guardrails would ameliorate the first mover disadvantage typical of technologies on the cusp of commercialization.

This paper presents a framework to (i) harness learning effects by focusing on building multiple installations of a given SMR design, (ii) share cost risks and development gains across multiple parties, and (iii) cap the capital costs faced by FOAK nuclear developers through the availability of a publicly funded financial backstop mechanism. The framework is predicated on the dual notions that first movers should not be disadvantaged for shouldering pioneering risk and that “kickstarting” an SMR industry would be significantly supported through a robust knowledge sharing strategy. The motivation ultimately rests on the national interest in developing the SMR industry and its supply chain.

The First Mover Disadvantage

Experts and experience indicate that large cost reductions for a particular SMR design could occur both at construction sites and in the factory for 2-OAK, 3-OAK and subsequent projects (collectively defined as “next-of-a-kind” or NXOAK), but if and only if the first mover disadvantage is addressed. If nobody can be induced to accept the first mover disadvantage, then there are no NXOAK units.

At the construction site for conventional large PWRs, experienced contractors and managers have cited substantive cost reductions even between first and second twinned units (as with Vogtle 4, which is said to be ~30% less costly than the twin Vogtle 3; the same has been experienced at Hinkley Point C between units 1 and 2). Another example: schedule and cost are interrelated, and the critical Hot Functional Testing period was shortened by 60% in going from Vogtle 3 to 4. Much of this cost reduction between a first and second instance at a given site is attributed to more complete construction drawings, more efficient movement, and placement of labor on site, improved material handling, and more efficient inspection processes. This is significant, as civil works constitute 40-60% of the overall capital cost of nuclear projects of current design (i.e., traditional light water reactors).[5] This includes the material and labor associated with installing reinforcing nuclear grade structural steel and concrete and the associated indirect costs. For Al Barakah (4 units/KEPCO), while the average unit cost would be $3,700/kW, the fourth unit is expected to be $2,300/kW.[6]

Importantly, these cost and schedule savings do not include possible additional manufacturing efficiency driven cost-reductions since the units described were essentially stick built. This is true for the Vogtle reactors, which though claimed to be “modular”, only used the so-called modular construction for a modest portion of the total project scope. Moreover, inadequate manufacturing quality and factory site inspection resulted in modules that had to be reworked at the plant site at considerable cost.

In contrast to conventional PWRs, manufacturing cost savings should be realistically achievable for the next wave of Gen III+ and Gen IV SMRs. Many of the largest cost drivers of componentry of SMRs such as turbine generator, steam generator, primary coolant pump, reactor pressure vessel, containment pressure vessel are largely destined to be factory fabricated, depending on the specific SMR design.[7] Provided that labor productivity is significantly higher in a manufacturing setting (i.e., 200% of onsite labor), coupled with design simplicity that shifts more of the SMR componentry into the factory, progressive process optimization offers cost reductions through iterative builds. Critically, to the extent that licensing regimes for SMR designs accept inherent design or passive safety features as a substitute for traditional steel and concrete containment domes, conventional on-site construction work would represent a much smaller fraction of the overall project budget, with the manufacturing component correspondingly becoming more significant.

However, no project sponsor will want to contract and assume the risks of the first one or two units, even though the site-level and factory floor cost savings available to future customers are significant; there is a first mover disadvantage. The first mover disadvantage is illustrated in Figure 1.[b] For a given design and an orderbook of four installations, three notional cost reduction trajectories due to presumed learning effects with different starting costs for FOAK are presented. The baseline approach (shown in red in Figure 1) assumes a FOAK cost of $6,667/kW that reduces to $5,500/kW at the fourth installation. These cost values presume the factory manufactured nuclear island components and are subject to a 16% learning rate, while remaining civil and onsite work experiences a 6% learning rate. [8,9] The capex split between manufactured vs. onsite cost items is 33% vs. 67%.[c,d] The *average* cost per installation is ~$6,000/kW (10% less than FOAK), with full overnight cost equal to $7.1 billion for the portfolio. The average cost would fall to ~$5 billion with the application of a 30% 48E ITC, and ~$4.3 billion with a 40% 48E ITC (base value credit plus 10% bonus for domestic content requirements); see Figure 2a-c for per unit effects of the 48E ITC on overnight costs.

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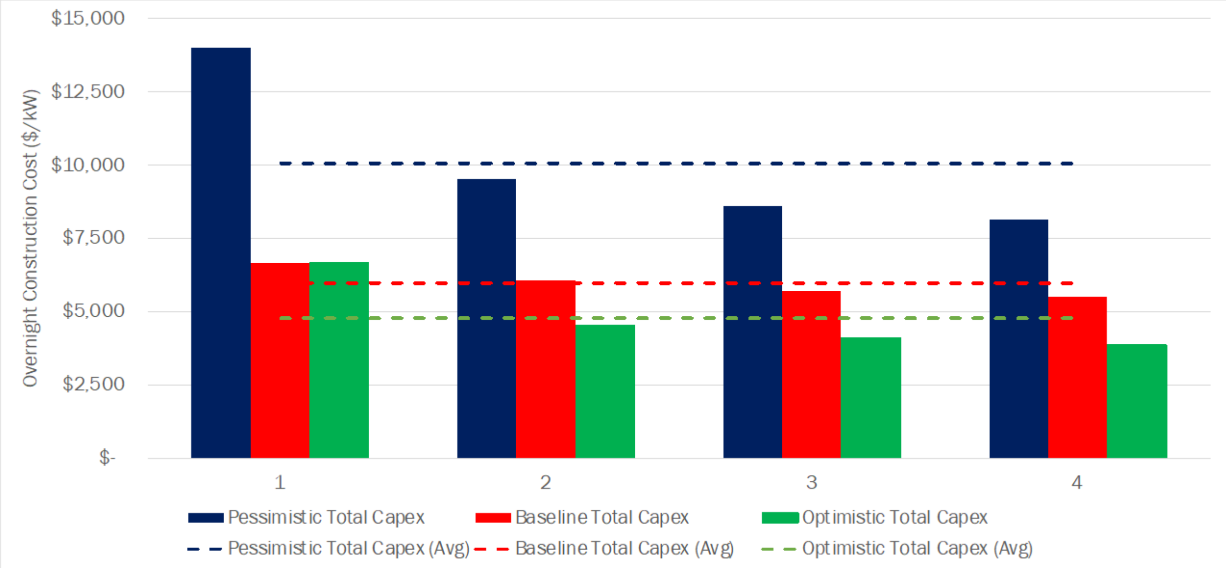
[b] Refer to Appendix A for cost calculation assumptions.

[c] Onsite costs include direct and indirect costs associated with materials and site labor. Materials includes structural steel, concrete, electrical and conduits. Offsite, or manufactured, costs include turbine generator plant equipment, reactor equipment, the main heat transport system, reactor instrumentation and control. The split in cost was estimated from TIMCAT. TIMCAT hosts Nuclear Cost Estimation Tool (NCET). https://github.com/mit-crpg/TIMCAT

[d] Alternative designs may have a higher capex fraction attributed to factory production. In a capex split between manufactured vs. onsite cost items of 67% vs. 33% (opposite of what is shown in Figure 1), the projected 4-OAK cost would fall from $5,500/kW to ~$5,100/kW (a reduction of 7.2%) due to a greater portion of costs subjected to 16% vs. 6% learning rates.

Figure 1: Illustrative SMR capex cost trajectories



While FOAK costs are relatively high, subsequent installations could have meaningful cost reductions due to supply chain maturity, manufacturing efficiency, workforce development and serial deployment, investor comfort leading to lower costs of capital, amongst other factors. However, given the presumed cost advantages obtained for 2-OAK onward, there is a natural tendency for would-be developers to wait for another entity to shoulder the first-mover risk. This is known as the first-mover disadvantage.

The pessimistic approach assumes a FOAK cost of approximately $14,000/kW, which is equivalent to the as-built unit cost for the Vogtle Units 3 and 4 AP-1000 large scale power plants.[e] The second installation experiences a 30% cost reduction as experienced between Vogtle Unit 3 and 4 construction, and the two units at Hinkley Point C (UK). After the second installation, the learning rates match those in the baseline approach, with cost for the fourth plant being ~$8,100/kW. The average cost per installation is ~$10,000/kW (28% less than FOAK), with full cost equal to $12 billion for the portfolio. Again, this overnight cost would fall to ~$8.5 billion and ~$7.2 billion with the application of a 30% and 40% 48E ITC, respectively. Finally, the optimistic approach assumes the same cost reduction trajectory as described in the pessimistic approach, except for the FOAK (beginning) cost equal to the baseline estimate (i.e., $6,667/kW). Here, the fourth build is projected to be ~$3,800/kW, with the portfolio (average) cost ~$4,800/kW. The full portfolio cost would be $5.8 billion and would fall to ~$4 billion and ~$3.5 billion with the application of a 30% and 40% 48E ITC, respectively.

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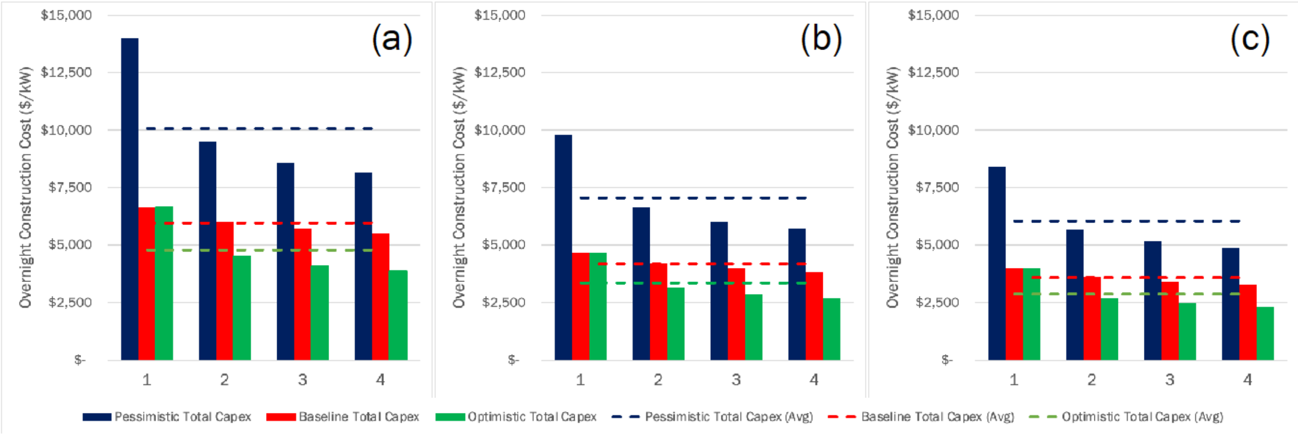
[e] Based on $34 billion cost and nameplate capacity of 2,430 MW, the unit cost is $14,000/kW. Note that this high cost was due to extraordinary events not likely to be repeated, such as the COVID-19 pandemic effect on labor and the bankruptcy of a major supplier (in this case, Westinghouse).

Figure 2a-c: Illustrative SMR capex cost trajectories with 30% and 40% 48E ITC applied



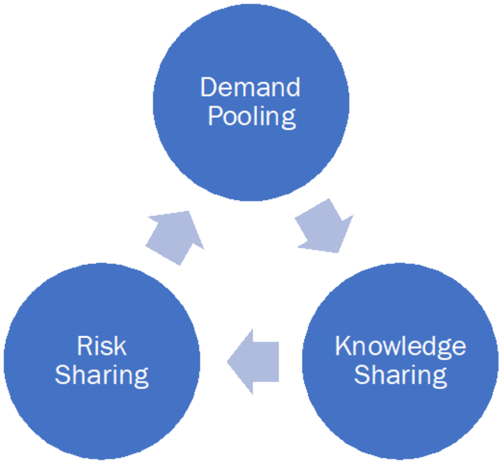
Application of a 30% ITC (b) and 40% ITC (c) compared to no use of the tax credit (a). Use of these tax incentives reduces overnight capital costs substantively, referring to the baseline average, it drops from $6,000/kW to $4,200/kW and $3,600/kW when comparing 0% ITC to 30% and 40%, respectively. The capital expenditure reduction is crucial to SMR commercialization; however, the first mover disadvantage remains.

In all cases, the highest unit cost – and the greatest development and execution risk – reside within the FOAK installation. If the FOAK is completed successfully, learning effects across manufacturing, procurement and construction could begin to accumulate to subsequent builds. Presuming that that knowledge can flow from one developer to the next, developers of later units are in some sense “free riders”, benefitting from, but not paying for, the first movers. The logical conclusion for would-be developers is to not be the first mover, as it is advantageous to wait for another entity to do so. Thus, leading to a hold-up, where no development takes place as all prospective developers hope to be “fast followers.”

Addressing the First-Mover Disadvantage: Pooling Demand, Gaining Knowledge, and Sharing Risk

To eliminate the first-mover disadvantage and effectively enable cost reduction trajectories like those shown in Figures 1 and 2a-c, three interlocking elements are required: pooling of demand, gaining and disseminating knowledge, and sharing risk, as illustrated in Figure 3.

Figure 3: Eliminating first-mover disadvantage by addressing three interlocking elements



To eliminate the first mover disadvantage, three dimensions need to be enabled or addressed. Addressing any one of these dimensions will further the economic case for SMRs, however, all require adequate attention. Arguably, it is risk sharing that requires the greatest policy innovation to "kickstart" cost reduction trajectories.

Demand Pooling

First, there needs to be a sufficient demand signal for a given SMR design. There are various macro and micro-level estimates indicating that there is a need for the emissions free baseload energy that Gen III+ (electricity) and Gen IV (electricity and higher-quality heat that such SMRs can provide). At a macro-level, some studies suggest dozens to hundreds of gigawatts of new nuclear capacity need to come online globally between now and midcentury to help meet security, resilience, and decarbonization goals.[10, 11, 12] At a micro-level, SMRs are being considered as part of the integrated resource plans (IRP) of utilities. One example is Dominion Energy, which proposes SMR development in four of its five potential pathways for Virginia, with procurement beginning in the mid-2030s.[13] A similar demand signal is expressed in the PacifiCorp 2023 IRP, which call for 500 MW of advanced nuclear by 2030 and an additional 1000 MW by 2032.[14] Finally, Tennessee Valley Authority (TVA), through its partnership with Ontario Power Generation (OPG), is actively examining the deployment of SMRs at its Clinch River site.[15] However, provided the market nascency, these indications of demand have not coalesced around specific designs of sufficient volumes.

As shown in Figures 1 and 2a-c, costs can come down for subsequent builds but will only do so if there are preceding builds, starting with FOAK. Moreover, the cost reductions illustrated are predicated on an orderbook of a single design that is repeatedly deployed, therefore, the demand signal must be targeted. Sufficient demand could come from a single entity willing to purchase enough plants. It is likely, however, that a coalition of utilities, large industrial users or other project sponsors would be the source of aggregate demand underpinning an orderbook.[f] Given a coalition approach of potential buyer(s), such project sponsors would self-assemble and announce their desire – if the cost magnitude is generally certain and acceptable– to purchase a “bulk” order of plants, i.e., an orderbook.

This orderbook concept is employed in the aviation industry, where multiple airlines create a trajectory of future purchases of aircraft of a specific design. For example, from November 2022 – March 2023, Boeing received orders from two Saudi airlines, Air India and United Airlines, amounting to approximately 200 787 Dreamliners to be delivered in the coming decade.[16] Such demand certainty motivates aircraft manufacturers to not only invest in the necessary, costly facilities to produce the airplanes, but also enables the spread of capital recovery over a relatively large number of units, thereby reducing unit prices to airlines.

Therefore, demand to form an orderbook if the “price were right” is a fundamental building block to kickstarting the commercialization of SMRs. The current book of business for SMRs appears relatively limited. There has been some progress in forming single-firm orders: one GEH BWRX-300 ordered by Ontario Power Generation, one NuScale VOYGR being intended for UAMPS, one TerraPower Natrium intended by PacifiCorp, a technical collaboration agreement between GEH, TVA, OPG and Synthos Green Energy focused on the BWRX-300, and a joint development agreement between X-Energy and each of Energy Northwest and Dow Chemical. However, single unit purchase orders per design is insufficient to harness learning effects, drive down costs and spur a credible SMR industry. Therefore, an orderbook

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[f] For perspective, the average market capitalization of the top ten utilities in the U.S. is $58 billion. Taking the optimistic and pessimistic examples outlined above, a group of four facilities would represent 12% - 21% of market cap, which is substantial given the concentration in one project. It is likely that in the event such a project would proceed under the aegis of one firm, it would be placed within a special purpose vehicle (SPV) to separate the liability of it from the rest of the company. Even so, most of the capital infusion of the SPV would originate from the sponsoring developer.

of sufficient size of a particular design, predicated on latent demand from a coalition of multiple buyers (i.e., a buyer's club), is a desirable element to remove the first mover disadvantage.

In this sense, the orderbook - and not an individual project - is the appropriate unit of analysis; while the FOAK and 2-OAK builds may be relatively costly, the anticipated learning effects should reduce the average cost of the portfolio. By aggregating several customers who will agree to pay an acceptable *average* price, the first/early disadvantage is erased. All parties share a portion of the downside of inevitable challenges for FOAK and 2-OAK, and all parties share in the cost savings hoped through follow-on 3-OAK unit and onward. Instead of an inherent advantage in delaying being one of the last purchasers, in the orderbook concept, all the participants experience the same average cost based upon the total cost of all the units in the orderbook.

Knowledge Sharing

Provided there is sufficient latent demand should projects become economic, said costs will primarily decrease and estimates become more certain through (i) applying existing nuclear construction knowledge and experience gained through stick built to SMR development and (ii) rigorously capturing and sharing knowledge gained through successive builds of SMRs within an orderbook. While the former is principally focused on reducing cost and cost uncertainty for the FOAK (and perhaps 2-OAK), the latter has to do with cost optimization for subsequent builds.

Multiple studies indicate that significant cost reductions can be obtained for FOAK builds through rigorous and extensive use of construction planning best practices.[17, 18, 19, 20] This is critical since a significant portion of the costs of SMRs resides within the direct and indirect costs of construction, not the manufactured nuclear componentry.[21, 22] These lessons learned are fully applicable to the SMR setting and include: (i) completed design before starting construction; (ii) detailed constructability review of design in addition to design to construct and design to operate analyses; (iii) project go/no-go once there is resource loaded, achievable, and detailed integrated project schedule; (iv) strict adherence to quality assurance/quality control and documentation standards; and (v) implementation of rigorous risk assessment across the lifecycle of the project. These are the hallmarks of integrated project delivery (IPD) best practices. IPD is concerned with integrating people, systems, business structures and practices to "optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction."[23] Some estimates indicate that FOAK costs can be reduced by as much as 30-40% through the implementation of IPD.[24] IPD is a collaborative project delivery approach that involves a more deliberate form of integration among project participants, emphasizing collaboration, information sharing, multiparty agreements and pooled risk and reward structures. Examples of large infrastructure projects that have employed IPD elements include: Hinkley Point C Nuclear Power Station (UK), Suez Canal Expansion (Egypt), Istanbul New Airport (Turkey), Gerald R. Ford-class Aircraft Carrier Construction (USA).

The actual construction of a FOAK SMR and subsequent builds will develop knowledge across multiple stakeholders including the engineering, procurement, and construction (EPCs) firms, the project sponsors, the financial community, third party design and engineering entities, trade and training facilities, academia, and regulatory and policymaking entities. This knowledge creation and dissemination would be maximized if multiple SMR plants were co-located at the same site and utilizing the same workforce (both craft work and project management). With each build – either through multi-build co-location (heavily preferred for the first sets of builds) or geographically dispersed – the value chain surrounding becomes more mature. The quality and dissemination of knowledge will have a direct impact on the emergent learning rates and actual cost reductions across the portfolio. In this regard, there is a natural incentive for buyers forming the demand for an orderbook to share knowledge to reduce the costs for the entire portfolio.

Risk Sharing

The third, and arguably the most crucial, element is risk sharing. Risk sharing mechanisms are legal and commercial arrangements that allocate the risks associated with FOAK/NXOAK installations among various entities that are best positioned to address such risks. The key entities within a FOAK/NXOAK SMR project are the reactor designer/manufacturer, the project sponsor(s), the EPC, and the federal government. Importantly, risk sharing mechanisms are designed to motivate all the entities involved to reach an amenable solution as cost and time efficiently as possible, given quality requirements. There are two tiers of risk sharing, (i) within the project group and (ii) outside of the project group.

Within the project group. The IPD model is a known approach for risk sharing. The primary goal of risk sharing in IPD is to foster collaboration and incentivize all parties to work together to mitigate risks and achieve project success.[25] It ought to be a baseline requirement for any SMR development and construction project, as it has been proven well in similar industries.[26] Key elements of risk sharing within an IPD model include early involvement of key project participants, allowing better collaboration and risk identification at early stages, collective identification and assessment of potential risks and uncertainties, evaluation of risks allocated to parties within the project team through mutual agreement, shared risk pool or contingency funds, and shared incentive mechanisms. The IPD model is already being implemented in the SMR industry, as witnessed in the OPG (project owner and license holder), Aecon (construction including project management), SNC-Lavalin (architect and engineer), and GE-Hitachi (technology developer) project to place a GE-Hitachi BWRX-300 plant at the Darlington, Ontario site before the end of the 2020s.[27] While the specific details of the arrangement have not been made public, it is presumed the six-year agreement outlines the shared value-at risk (contingencies) and information sharing, communication protocols, and assessment tools to be deployed to minimize such risk.

Outside the project group. The next risk sharing tier expands economic participation to address residual risks that cannot be sufficiently mitigated within the project group. Even provided that the cost magnitude and some of the various risks could be reduced through the IPD application, there remains a significant uncertainty related to project execution because – simply stated – FOAK builds are new. While best practices from adjacent experiences largely apply, commercial SMR project execution has not yet been demonstrated. This lack of specific experience leads to worries concerning project budget "tail risk." Tail risk in this case is defined as the potential cost overruns above project budgets and contingencies for FOAK builds. Cost overruns can disrupt project schedules, delay completion, and strain relationships among stakeholders. The specter of cost overruns also increases the cost of capital to the project as projected returns can be low and even negative if not addressed.

Unanticipated or unforeseen cost overruns have been experienced in many complex projects and endeavors of various types. Examples span IT to homebuilding, from aircraft new design to new kinds of submarines, from FOAK wind turbine installation to new EV development.[28] Vogtle Unit 3 and 4 were essentially a FOAK build in the U.S. given that these projects marked the first new construction of a nuclear generation station in 30 years.[29] For a variety of reasons that have been well documented, including the FOAK nature of the project and the unforeseen circumstances of COVID-19, the original construction cost of $20 billion ($2023), ballooned to $34 billion ($2023) yielding a cost overrun of $14 billion, or 70%. There is good reason to believe that the lessons learned at Vogtle are applicable to the SMR context, since most of the Vogtle overrun issues were civil works caused by inefficient mobilization and increased rework, stemming from incomplete construction and manufacturing design specification.[30] If teams constructing the SMR orderbook units can apply the lessons learned, then the extent of the orderbook SMR cost overruns can be reduced.[31] Nonetheless, overrun risks are not likely to be fully mitigated within the project team through the normal mechanisms (IPD, infrastructure insurance policies, etc.); and in some instances, some risks are challenging to quantify and eliminate without experience of building the first.

Therefore, for an orderbook that contains FOAK builds, the overrun risk should be borne partially by an entity outside the project team that has sufficient capacity to take on the cost, the bounds of which will be relatively poorly understood at project onset. A government entity has sufficient capacity to fulfill this role, especially if it serves the national interest. More importantly, the federal government has a strong interest in the success of the orderbook in advancing policy objectives for energy security, national security, and clean energy transition. The clean baseload electricity and clean heat provided by SMRs, supported by a domestic supply chain, makes a significant contribution to policy objectives.

Employing the "balance sheet" of the government to substantially offset the overrun cost associated with FOAK/NXOAK SMR builds would be an appropriate role analogous to the role played by the government in similar capital-intensive projects that cannot be (initially) handled by the private sector alone. One recent example of this in the clean energy sector is the Coastal Virginia Offshore Wind Project (see Box 1). Within the nuclear industry specifically, there is the OPG/GEH/SNC-Lavalin/Aecon example given that OPG is fully owned by the government of the province of Ontario, therefore there is an implied support mechanism offered.

Box 1: Coastal Virginia Offshore Wind

Scheduled to begin offshore construction in 2024, Coastal Virginia Offshore Wind (CVOW) project is a 2.6 GW offshore wind energy project that will consist of 176 wind turbines located 27 miles off the coast of Virginia Beach. The Virginia State Corporation Commission (SCC) approved in PUR-2021-00142 that, should the construction cost exceed the initial $9.8 billion estimate, then cost sharing would occur between the developing company (Dominion) and its customers according to a schedule (see below).[32] As cost overruns increase, away from the initial estimate, the more of the overrun cost burden is shouldered by the development company. Beyond a stipulated cost threshold, the disposition of the project would be the subject of a future proceeding. In the current ruling, it is argued that the project is "legislatively favored" for both economic and non-economic reasons, and the General Assembly of Virginia is "uniquely positioned to align general fund appropriations or other funding for this Project." [33] This suggests the State Legislature ought to make a commitment to consider offsetting extraordinary costs (e.g., above $13.7 billion) should they occur because the project serves the purposes of the State's clean energy mandates (i.e., 100% carbon free electricity generation by 2045).[34] In other words, there is an argument to be made for the public sector to shoulder the cost overrun on this project.

Construction Cost	**Cost Sharing Percentages**	
	Customers	**Company**
$9.8 billion - $10.3 billion	100%	0%
$10.3 billion - $11.3 billion	50%	50%
$11.3 billion - $13.7 billion	0%	100%
Above $13.7 billion	Disposition to be determined by SCC	

Putting it all Together: Developing a Cost Stabilization Facility for an SMR Orderbook

There exists sufficient latent demand for SMRs whereby an industry could emerge through the buildout of an orderbook backed by, preferably, a consortium of prospective owners. Of the three interlocking elements (demand pooling, knowledge sharing, risk sharing) illustrated in Figure 3, the missing ingredient is a mechanism to address the potential cost overrun. This risk is residual to those addressed through the implementation of cost containment approaches, such as IPD within a project and rigorous knowledge sharing across projects.

To address the missing ingredient that holds up development of a robust orderbook, this paper proposes a cost stabilization facility (CSF) consisting of a special backstop loan facility provided by the federal government. The loan facility is specifically targeted to address potential unforeseen orderbook cost overruns that could exceed typical project contingencies. In the event of an orderbook cost overrun, subject to eligibility conditions, a low-interest loan would be made available to cover the additional costs required to complete the orderbook. Further, terms of the loan allow for repayment terms that are flexible in the short-term, with long-term repayment linked to long-term value of the projects.

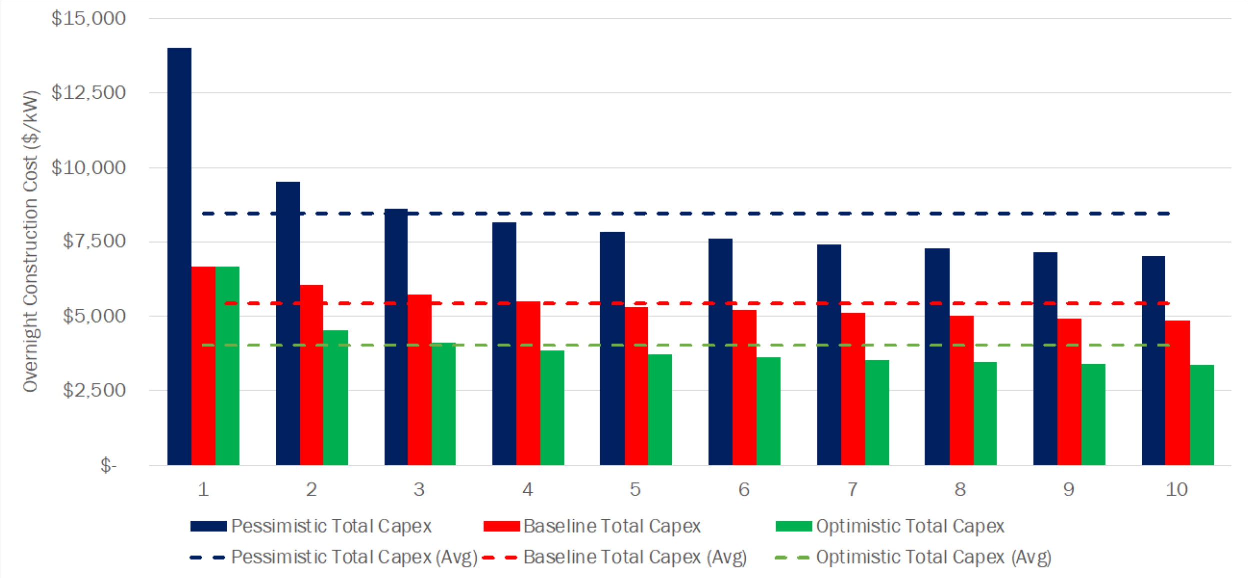
This support mechanism is in addition to existing incentives provided through the ARDP, which in 2021 through the IIJA was appropriated $2.477 billion annually through FY2025 and the 45Y/48E clean energy production and investment tax credits (with direct pay provisions for some) through the IRA in mid-2022.[35] While these two existing incentives are helpful in demonstrating and maturing the technology, they need to be augmented to fit the purpose of addressing the cost overrun tail risk associated with commercializing new nuclear.[36] Further, decarbonization targets alone generally help to retain existing nuclear capacity but are typically not enough to bring new nuclear capacity online in the absence of significant cost declines.[37]

The goal of the CSF is minimizing cost uncertainty to SMR customers, regulators, SMR developers, technology providers, and EPCs for a package of FOAK/NXOAK deployment projects, provided IPD and knowledge sharing practices are followed. With a sufficient risk sharing mechanism in place acting as a backstop for a specified number of SMR installations of a given reactor design — both among project sponsors as to "normal levels" of cost risk and government entities as to tail risk — it is anticipated that a significant demand signal will materialize (i.e., move from “latent demand” to “actual demand”) to kickstart the SMR industry in the United States.

Orderbook Size

The orderbook size is a key parameter, as the installation average cost decreases as the number of builds increase. These cost decreases are largely attributable to value chain maturity through learning effects and implementation of efficiencies. The effects of orderbook size are illustrated by comparing Figure 1 (orderbook of four) to Figure 4 (orderbook of ten).

Figure 4: Illustrative SMR capex cost trajectories for an orderbook of ten



Cost trajectories of an orderbook of ten installations, absent application of federally available tax credits. While FOAK costs are relatively high, subsequent installations could have meaningful cost reductions due to supply chain maturity, manufacturing efficiency, workforce development and serial deployment, investor comfort leading to lower costs of capital, amongst other factors. An orderbook that has a larger number of installations will likely have a lower average cost per build given that all in said orderbook are completed.

Clearly, the average cost per build (i.e., per reactor) in the orderbook of ten is less than that of four: $4,000/kW vs. $4,800, $5,440/kW vs. $6,000/kW and $8,400/kW vs. $10,000/kW for optimistic, baseline and pessimistic scenarios, respectively.[g] What this shows is that learning effects accumulate within a portfolio given more builds; cost reductions occur with successive iterations of deployment a given design. These costs, however, are predicated on the idea that all the projects in the orderbook get built. If the CSF also includes provisions that the

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[g] These figures do not include any tax incentives or other subsidies.

entirety of the orderbook is backstopped and fulfilled, then the value chain can scale-up with greater confidence. Therefore, a larger orderbook size would tend to better align with this policy objective. Thus, for the remainder of this paper, an orderbook size will be assumed to be ten projects/builds for illustrative purposes.[h] However, the minimum number of builds that would be sufficient to constitute an orderbook could change by SMR design and would be a key parameter negotiated upfront with the federal government, including any changes to this value as the project progresses.

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[h] It is readily understood that some configurations of SMR designs are conceptualized as “four-packs” or “six-packs”, that is, four or six reactors being co-located at the same site. In these cases, the ideal orderbook size would require some consideration, but should be sufficient to demonstrate both manufacturing and site-specific learning effects. For a four-pack example, it is conceivable that four or five installations (meaning 16-20 reactors at 4-5 sites) would be sufficient to accomplish both.

Cost Stabilization Facility Basic Structure

The CSF principles and basic structure are explained, using illustrative scenarios to aid in comprehension. While principles and basic structure should hold across instances of CSF implementation, the actual parameters for any given CSF would need be set by participants who have settled on a specific SMR design in consultation with the government to enable the public-private partnership.

Summary of CSF Mechanism

There are six principles of the CSF: (i) orderbook of sufficient minimal size; (ii) project sponsor owners with undivided interest in the orderbook through a special purpose vehicle (SPV); (iii) formulaic trigger; (iv) funds injection to the orderbook in the form of a backstop loan to the orderbook through the SPV; (v) flexible repayment terms of said loan including possible default in a future year depending upon the long-term economics of the projects implemented in the orderbook; and (vi) exit provisions for project sponsors and plants.

The CSF would only be available to orderbooks of SMRs of a given design, meaning that a project must contain multiple builds of the same design. It is ideal – but not required – that these multiple builds be geographically concentrated to better harness learning effects and simplify licensing. The specific design would be chosen by the project proponents.

The orderbook of SMRs would be placed within an SPV, which is a separate legal entity from the project sponsor(s). Project sponsors own pro rata shares in the SPV and by extension, each sponsor owns an undivided percentage of each the builds constructed under this arrangement. Each participant would be responsible for arranging its own financing to support its investment in the SPV orderbook; the financing could consist of a mix of equity and debt.[i] Funds injection to the SPV by the project sponsors would be on a callable basis as determined by milestones agreed to by the parties and LPO to sufficiently pay for activities. In terms of project sponsors, the SPV could be open-ended, with additional investors providing capital after its formation. Crucially, this structure allows for ownership in an undivided interest in the orderbook, enabling traditional business models (e.g., regulated utilities would be able to rate base the unlevered portion of their pro rata share in each project).

In the event the orderbook is not complete but the total budget for all builds has been exceeded, the CSF is automatically triggered. The trigger threshold for the CSF will be known

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[i] Project sponsors could use debt from an LPO loan as part of its capital contribution to the SPV, however this would be entirely separate from any arrangement between the SPV and the LPO, with separate terms and conditions.

in advance and agreed to at the beginning of the project. Once triggered, LPO would then extend a loan to the SPV. Importantly, the CSF loan is made to the SPV, not the individual project sponsors.

The CSF agreement between DOE LPO and the SPV would contain flexible repayment terms and conditions that could differ significantly from conventional loan and loan guarantee agreements. For example, repayment terms might allow for deferral or limited repayment in the near term, graduated repayment terms over the longer term that are linked to long-term value of the projects, and a possible bullet repayment obligation at maturity. Establishment of the repayment terms also would need to consider the possibility of a default by the SPV if the SPV fails to complete construction of the orderbook, or that the completed projects do not achieve their projected economic value over their operating life.

Finally, orderly exits for project sponsors and plants are imperative. Provisions for project sponsor buyout from the SPV would be detailed in the SPV governance bylaws, so too the sale of completed plants out of the SPV to willing buyers (including project sponsors). In addition, for uncompleted projects for which the CSF has been already triggered and exhausted, the federal government could take over the project under terms and conditions that would be mutually agreed upon. Moreover, offramps would need to be constructed in the case that, for example (i) learning and/or cost advantages are not demonstrated in the first few builds and the orderbook needs to be abandoned and (ii) the CSF is triggered and exhausted before the orderbook is completed.

Features of CSF and Illustrative Example

Suppose an orderbook comprising of a set of ten SMR installations of a given reactor design, generally located in pre-determined sets of service territories, with a possible first multi-unit installation of reactors.[j] The features of the CSF risk sharing structure and notional values for illustrative purposes are summarized in Table 1. It must be reemphasized that the CSF mechanism is designed to accommodate any selected reactor design, orderbook size (subject to a negotiated minimum), and project sponsor makeup.

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[j] The installations do not need to be co-located but would benefit from enhanced learning effects if they were.

Table 1: Features of the CSF risk sharing structure and illustrative notional values

Parameter	Assumptions
Orderbook (notional size)	Ten SMRs of a given design
Average cost across 10 units (notional cost)	$6,667/kW or $20 billion total including contingencies[k] Total cost is eligible for federal tax credits (e.g., 45Y production tax credit, 48E investment tax credit and associated bonus credits)
Participants (notional number)	Five regional utilities which commit to build two builds each (i.e., each utility builds two SMRs). Utilities could be IOUs, MOUs, joint powers agencies or Coops, or a mix thereof
Entity formation (see Figure 5)	Model would resemble typical mixed ownership-type model common in the large electric generating unit industry: • A holding company special purpose vehicle (SPV) is created • Each owner places capital into the SPV, creating a pool of funds • Each owner has flexibility as to how to finance its capital contribution to the SPV, consisting of a possible mix of debt and/or equity contribution (depending on whether corporate or governmentally owned). Debt incurred by individual owners could be backed by DOE loan guarantees. • As is common practice, some similar entities could form an ownership sub-group (i.e., the coops, IOUs, and municipals might each band together in some higher level holding company or joint action agency, that jointly commits to the SPV)
Ownership rights and obligations	Each owner (or ownership group) owns an undivided interest share in all ten units, pro rata to capital contributed. Each owner, therefore, is entitled to a pro rata share of capacity and output (subject to true ups in case of different dispatch decisions and excess energy sales during a budget period). Each owner is obligated to pay its pro rate share of annual operating budget.
Location/siting (notional)	• Five sites in five service territories, with each site developing two SMR installations[l] • Site(s) would be optimized to assure ease of transportation of the largest possible

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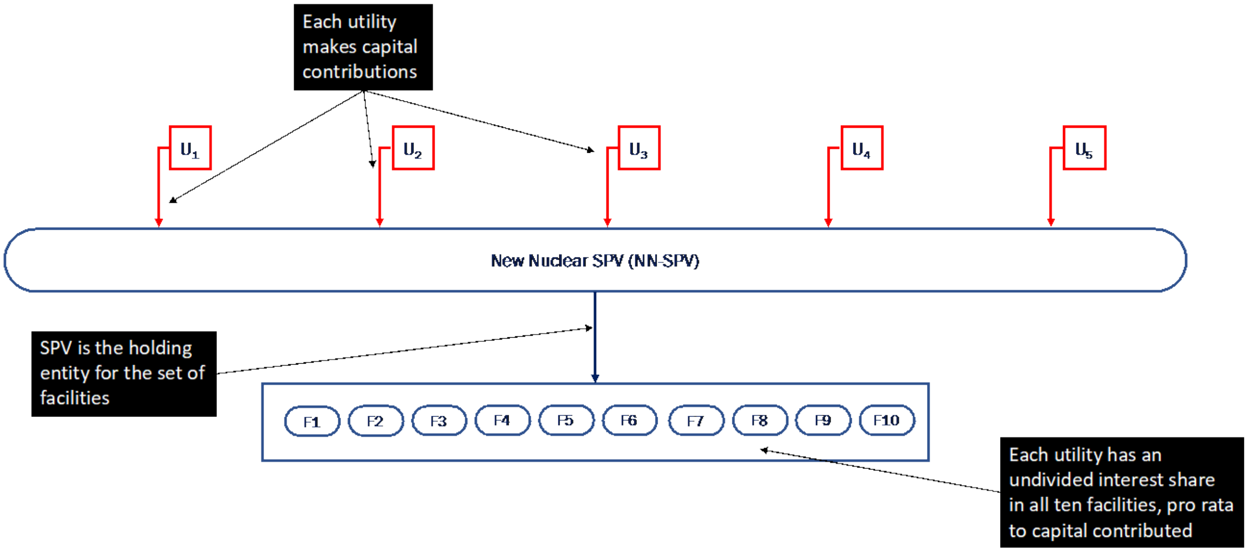
[k] Capacity is notional and for illustrative purposes; CSF is open to any orderbook of a given design and sufficient size.

[l] For illustrative purposes, it is conceivable that siting could encompass a joint powers authority covering one large service territory with multiple sites within it.

	manufactured modules/components, as well accounting for workforce considerations. • Transmission to be arranged so that each participant has a verifiable delivery path from site(s) to its load control area
Government role	• Federal government provides cost overrun mitigation mechanism to eligible consortia • Eligible consortia must agree to specific conditions, such as implementing IPD best practices to incentivize collaboration and knowledge sharing through pooled risk and reward structures • The CSF severely limits the exposure of the developers to the overrun cost while not fully eliminating it, to keep shared responsibility between the consortium and the government • In the case of a cumulative cost overrun, an automatically triggered loan of pre-agreed size is provided to the consortium from the federal government • CSF allows for flexible repayment of loan used to cover cost overruns. The loan facility can be structured to allow for significantly deferred repayments that could be linked to the long-term value of the projects
Requirement to build	• Commitment by all entities – including the government – to build the entire orderbook even if the cost overrun mechanism is triggered • If the CSF is triggered and exhausted before the completion of the orderbook, the project proponents will have the option to abandon the remaining, unbuilt projects subject to an exit penalty, negotiated with the LPO and the federal government may take over the incomplete project(s)

Figure 5: Illustration of SPV Concept



Each utility makes capital contributions to the SPV, which then acts as a pooling entity from which funds will be drawn to pay for development and construction of the orderbook of ten SMR builds. Each utility holds an undivided interest share in all ten builds, in proportion to the capital contributed.

The SPV Explained Using Illustrative Example

A group of project proponents (in this example, a set of five utilities) forms a buyers' club, choosing a specific reactor design, committing to an orderbook of ten builds at five locations and, *a priori*, estimating the average per unit (kW) cost per build (accounting for expected learning effects). In this illustrative example, ten plants constitute the orderbook and the expected cost per unit is shown in the table within Figure 6. The utilities subsequently form an SPV (titled here as the New Nuclear SPV, or NN-SPV), which receives pool funds and holds the individual projects. The SPV acts as a holding company for the reactors placed within it, and is a legal entity organized as a limited liability corporation (LLC).[m] The SPV is an independent entity separate from each of the owners, a familiar concept in project finance that shields the economics of the project from the sponsoring utilities.

The utilities own pro rata shares in the SPV and by extension, each utility will own an undivided percentage of each the SMRs constructed under this arrangement. There is flexibility in this arrangement such that individual project sponsors can have differentiated equity interests in the SPV. In this way, regulated utilities could claim ownership of their respective undivided interests on their balance sheet to enable asset rate basing. The SPV structure allows for individual project sponsors (e.g., utilities) to own undivided shares in the orderbook, enabling

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[m] An LLC is comprised of members who have ownership interests in the entity and are responsible for its management. Typically, an operating agreement is used between the members to organize and control the LLC's management structure.

them to record the value of such investment on their balance sheets. Further, with respect to accounting for the SPV by the project sponsors, so long as they own a noncontrolling investment in the SPV (i.e., less than 50%), any debt carried by the SPV does not get represented on the utilities' books.[38] Joint ownership of nuclear reactors is not a new concept in the industry; it has been practiced in the past and continues to present day; see Box 2 for examples. Finally, there would be the ability for foreign entities to participate in such a structure, subject to restrictions on foreign investment in U.S. commercial nuclear power plants.[n] In the illustration provided in Figure 6, given equal contribution by the five utilities, each utility owns 20% of each build, but in practice ownership shares could vary among the participants.[o]

Box 2: Examples of Nuclear Plant Joint Ownership

There are several examples of joint nuclear plant ownership in the United States. Of note, of the 95 nuclear reactors in operation currently, 33 (35%) are jointly owned by two or more entities.

Palo Verde Generating Station. The Palo Verde Nuclear Generating Station located in Arizona is a three-unit PWR capable of 4.2 GW total of capacity. While each reactor is operated by Arizona Public Service Company (APS), its largest shareholder (29.1%), is it co-owned by six other utilities, located within and outside Arizona and organized under different business models (investor-owned utility, municipal owned utility, and a joint powers authority). The six other utilities, their location and ownership share are: Salt River Project (AZ, 20.2%), Southern California Edison (CA, 15.8%), El Paso Electric (TX, 15.8%), Public Service of New Mexico (NM, 7.5%), Southern California Public Power Authority (CA, 5.9%), Los Angeles Department of Water and Power (CA, 5.7%).[39] As per the operating license for the plants, all parties are licensed to possess the reactors, while APS is licensed to use and operate the reactors.[40]

Nuclear Management Company (NMC). Formed in late 1999, NMC was established as a Wisconsin limited liability corporation owned equally by Alliant Energy Nuclear, LLC, NSP Nuclear Corporation, WEC Nuclear Corporation, and WPS Nuclear Corporation to provide services in connection with the operation and eventual decommissioning of licensed nuclear facilities on behalf of and for the benefit of the owner utilities.[41] In each case, the owners of the NMC member plants retained ownership of their respective facilities and retained the necessary authority under the licenses to possess the plants.[42]

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[n] Atomic Energy Act of 1954 prohibit the issuance of a reactor license to a person or entity that is subject to foreign ownership, control, or domination (FOCD), as per 42 U.S.C. §§ 2133(d), 2134(d). However, the Nuclear Regulatory Commission's (NRC) Foreign Ownership Standard Review Plan (SRP) permits 100% indirect foreign ownership of a domestic "operator licensee" only if the foreign parent's stock is principally owned by U.S. shareholders and FOCD conditions acceptable to the NRC are implemented (i.e., U.S. operational control authority, etc.). Additionally, the SRP does not preclude 100% indirect ownership of a minority "owner licensee" that lacks operating authority. In practice, the NRC has permitted up to a 50% indirect ownership in an operator licensee and 100% indirect ownership of a minority owner licensee. For a deeper discussion on the matter, please refer to Morgan Lewis & Bockius, LLP article titled "Foreign Investment in U.S. Nuclear Reactors: Mitigation Measures to Overcome Statutory Roadblock" dated August 15, 2009.

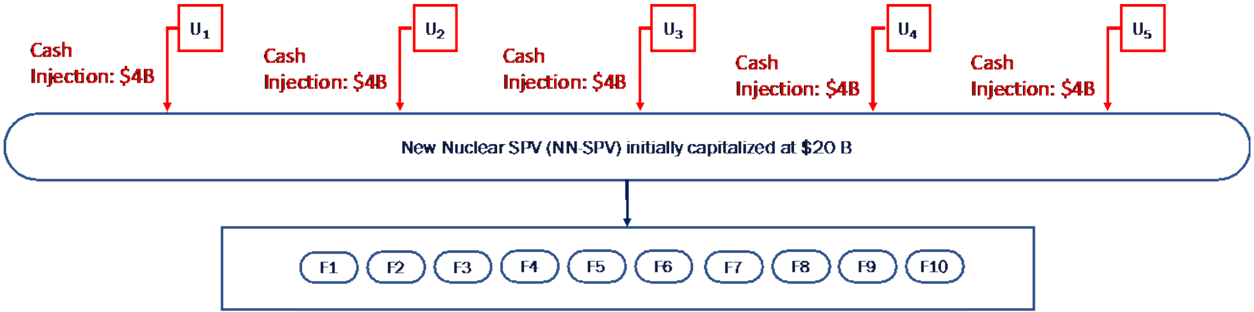
[o] It is presumed that one of the participating could be TVA, which is able to enter into such an arrangement, provided it has a "small" minority share of the SPV. The appropriate participation share for TVA in such a structure will require guidance from Government Corporation Control Act. Further consideration will be required because, under the current Consent Order, all output of a TVA owned (partial, controlling or otherwise) must serve TVA customers only. Moreover, there is some uncertainty regarding the extent LPO loans provided to a (partially) owned TVA entity – such as the NN-SPV - violates Congressionally imposed limitations regarding LPO extending loans/loan guarantees to federal agencies.

Yankee Atomic Electric Company (YAEC). YAEC was formed in 1953, as a joint venture of ten utility companies in New England (Boston Edison, Central Maine Power, Central Vermont Public Service, Connecticut Light and Power, Eastern Utilities Associates, Hartford Electric Light, New England Electric System, New England Gas and Electric, Public Service Co. of New Hampshire, and Western Massachusetts Electric).[43] In 1956, YAEC signed the first contract in the Atomic Energy Commission's (AEC's) Power Reactor Demonstration Program. This program sought to build and operate a variety of nuclear power reactors, with partial government financing, to advance the country's nuclear power technology development.[44] From the late 1950s to the mid-1970s, YAEC constructed six operational power plants consisting of 8 reactor cores. Notably, while the basic technology was PWR and BWR, each design was significantly different from one build to the next, owing to the philosophy of technology exploration rather than cost-competitive commercialization.

In the event that completed plants remain within the NN-SPV and are subsequently operated, there are two options available: (i) the NN-SPV owns all the equity of each of the operating companies (OpCo, not shown in Figure 6, but assumed to be one per build) which themselves act as both the owners and management companies for each SMR installation, or (ii) the SPV forms its own operating company (not shown here), and operates some or all of the completed plants. For illustrative purposes in this example, one OpCo is the management entity for one SMR installation (i.e., there is a 1-to-1 relationship between the operating company and the SMR). The NN-SPV chooses the OpCo to operate each SMR installation. There are multiple ways to accomplish this, however, it is likely that if an SMR is located within the service territory of an experienced nuclear utility, that experienced utility would enter into contract with the NN-SPV and operate the reactor. Ultimately, the operation of the installations is awarded on a competitive basis, accounting for overall effectiveness and efficiency.

The orderbook agreement includes terms that would provide project sponsors entitlement to pro rata shares of project offtake. In turn, sponsors could either take power and use for their own purposes, or sell their shares (e.g., via wholesale markets, long-term PPAs, pledge to other project sponsors, pledge to the SPV, etc.). The key point is that it is the project sponsors, which own pro rata share of the output per plant (not the SPV), act as the counterparty to any contractual agreement to market the offtake.

Figure 6: Numerical Example of the SPV Structure



	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	
Expected Cost $B	2.45	2.22	2.10	2.02	1.96	1.91	1.88	1.84	1.82	1.79	**Avg. = $2B**
Exp. Cum. Cost $B	2.45	4.67	6.78	8.80	10.8	12.7	14.6	16.4	18.2	20.0	
Expected Cost $/W	8.1	7.4	7.0	6.7	6.5	6.4	6.3	6.1	6.0	5.9	**Avg. = $6.7/W**

Orderbook expected cost for ten units @ $2B each = $20B

The basic setup of the NN-SPV is such that a consortium of participating entities, such as utilities (in this illustration there are five denoted U_1 – U_5) pool funds within the SPV to build the orderbook (e.g., ten units denoted as F_1 – F_{10}). The NN-SPV is a holding company for the units; each utility owns an undivided share of each plant on a pro rata basis to the contributed capital to the NN-SPV. In this case, given that each utility has placed an equal amount of capital into the holding company, then each utility owns 20% of each SMR build as part of the orderbook. Notably, as shown in the embedded table, while the average cost of each SMR installation is notionally $2 billion, the FOAK has the highest cost while the 10-OAK is lowest. The first-mover disadvantage is thus eliminated, enabling each participating utility to share in the anticipated cost reductions through learning effects and other efficiency gains. Note that costs indicated in this figure do not include the application of federal tax credits; such application would reduce costs ~30% - 40%.

A numerical example of NN-SPV arrangement is provided in Figure 6. The consortium forming the orderbook (i.e., the participating utilities U_1 to U_5) predetermines the expected average cost of the per reactor for the portfolio. This value is vetted by LPO through its diligence process. Key considerations in forming this estimate are FOAK costs, projected learning rates given the entire orderbook is built, supply chain constraints, lead-times, licensing requirements, etc. Essentially, the consortium will be performing an exercise whose result will be like a given cost trajectory shown in Figure 4. In the numerical example shown in Figure 6, the average reactor cost is notionally $2 billion ($6.7/W), for a total orderbook cost of $20 billion to build ten (F_1 to F_{10}) including contingencies. Note that the average is calculated based on the expected cost per SMR, shown in the first row in the table in Figure 6, where FOAK has an expected cost of $2.45 billion and 10-OAK at $1.79 billion. Crucially, there is nothing the precludes the use of existing tax credits to reduce the orderbook and total capex, see Box 3 for more information. In this example, if the 30% 48E ITC were applied, it would reduce the NN-SPV capital requirement by $6 billion.

Box 3: A Note on Tax Credits

While not shown here for simplicity, the SMRs built within the NN-SPV arrangement are fully amenable to make use of the tax credits provided through the IRA. The most applicable tax credits are the 45Y clean energy production tax credit and the 48E clean energy investment tax credit. In either case, the IRS proposed rules are such that if an applicable entity is a co-owner of an applicable credit property through an ownership arrangement treated as a tenancy-in-common or pursuant to a joint operating arrangement that has properly elected out of subchapter K of chapter 1 of the Code (subchapter K) under §761, then each owner is considered to own an undivided interest in or share of the underlying applicable credit property and thus, any applicable credits are determined separately with respect to each owner.[45] The NN-SPV in this case acts as the tenancy-in-common ownership arrangement, therefore each owner (i.e., each utility) would be entitled to applicable credits for each SMR they own according to the pro rata share in said facility.

Further, IRA proposed rules address mixed ownership arrangements, where in this case, a mixed ownership refers to a joint ownership arrangement involving tax-exempt entities eligible to claim "direct pay" tax credits (i.e., elective payment) and tax paying entities eligible only for traditional tax credits. Specifically, an applicable entity may make an elective payment election under §6417(a) with respect to its share of the applicable credits determined with respect to its undivided ownership interest in or share of the underlying applicable credit property.[46]

The required $20 billion (pre-tax credit) is provided by the participating project sponsors in whatever proportion of debt and equity they believe is appropriate. A key benefit of the holding company approach is that each participating entity funds as it chooses, according to what is economically advantageous for its business model. For example, an investor-owned utility (IOU) may choose from a variety of capital forms to fund the "equity" portion of the contribution to the NN-SPV, such as a revolving loan or a direct cash injection (see Box 4 for more detail). A municipally owned utility (MOU) could issue tax-exempt bonds and use the proceeds, same as a cooperative utility or a joint action agency. If debt is provided through loans offered through the DOE LPO, such loans are made to the participating utilities (individually, not to the NN-SPV), with the maximum debt-to-equity ratio set at 80/20, given 80% maximum capital contribution allowed under Title 17 Clean Energy Financing Program.[47] LPO authority appears to be available under both the original Innovative Clean Energy loan program, known as §1703, and under the new Energy Infrastructure Reinvestment (EIR) loan program, known as §1706; both can lend to nuclear power plant projects.[48] From the point of view of a borrower (i.e., one of the project sponsors indicated in Figure 5), it is not apparent that there is any material difference in borrowing under one or the other. The amendments to the relevant CFR sections governing loans pursuant to recent LPO "interim final regulations" seem to now govern both programs.[49]

Box 4: Treatment of SPV Assets within a Regulated Utility Environment

Crucially for regulated utilities, the NN-SPV structure allows for ownership in the underlying SMRs, thereby enabling said utilities to obtain regulatory approval for initial participation in the orderbook and for subsequent inclusion of the dollar amount the regulated utility invested into the regulatory rate base. Such inclusion allows the utility to recover costs (interest, depreciation, share of operating costs of the orderbook units) and to earn a regulated equity rate of return on the imputed equity portion of the amount invested into the SPV.[p] In detail, the typical regulatory regime would be to treat the entire investment by the regulated entity into the NN-SPV as a new regulatory asset, i.e., a part of the regulatory "rate base." Even though each regulated entity would raise funds from a combination of equity and debt (including LPO debt), the combined funds when injected into the NN-SPV would effectively represent equity investment in ownership of the NN-SPV that also conveys a percentage undivided interest share in the physical assets (i.e., the nuclear generating units and accompanying infrastructure). Referring to Figure 6 above, the total investment included in the rate base of one of the five utilities would be $3.2 billion, and an equity return would be earned on the equity-sourced investment of $0.8 billion. Cash flow for repayment of LPO debt would be generated by inclusion of regulatory depreciation of the entire $3.2 billion. The incurrence of debt (including regulated entity debt) would typically require regulatory approval, obtained concurrently with approval of the investment by the regulated entity. Unless the regulated entity's existing bond indenture is reasonably flexible, some amendments might have to be made to permit LPO loans to be *pari passu* with existing senior, unsubordinated indebtedness of the regulated entity. For an IOU, interest expense on the debt, return on imputed equity investment, and an allowance for depreciation would then become part of the revenue requirements that support the IOU's rate case.

The NN-SPV acts as the funding vehicle for the entire orderbook, injecting cash to projects as needed. In parallel, actual funding of the NN-SPV by the project sponsors is accomplished through a series of callable injections as determined by the governance bylaws. The cumulative cost of the orderbook is shown in the second row in the table in Figure 6. The proper interpretation of this cumulative cost is that, if cost projections are as expected, the budget allocated within the NN-SPV to plant construction will be zero once the final plant (10-OAK) is completed.

The CSF Explained Using Illustrative Example

For the arrangement as described in the NN-SPV model, physical construction of the plants in the orderbook proceeds as planned. However, it is possible that the total cost of the project – i.e., the total cost to build the orderbook – exceeds what is estimated. In that case, the CSF is triggered. What happens next is illustrated in Figure 7, continuing from the numerical example provided in Figure 6.

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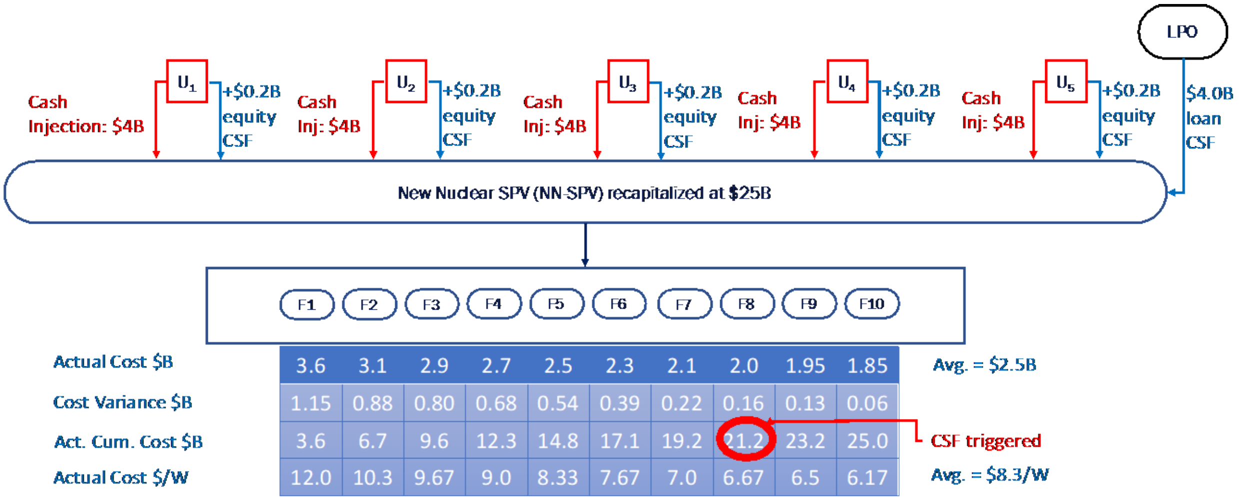
[p] Typically, this would be the PUC that is responsible for the territory (state) for which the SMR is located.

Figure 7: Numerical Example of the CSF in the event of Cost Overrun



	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Actual Cost $B	3.6	3.1	2.9	2.7	2.5	2.3	2.1	2.0	1.95	1.85
Cost Variance $B	1.15	0.88	0.80	0.68	0.54	0.39	0.22	0.16	0.13	0.06
Act. Cum. Cost $B	3.6	6.7	9.6	12.3	14.8	17.1	19.2	21.2	23.2	25.0
Actual Cost $/W	12.0	10.3	9.67	9.0	8.33	7.67	7.0	6.67	6.5	6.17

In the event of a cost overrun for the orderbook, the CSF is triggered, where a special loan is made available to the NN-SPV. As shown, the cost overrun in this example occurs during the build of F8. A loan of 80% of the cost to complete the orderbook is made available to cover the cost overrun, where the remaining 20% of the cost is covered by the participating entities. Provided that an additional $5 billion is needed to complete the orderbook, $4 billion is provided by the LPO, and $1 billion is provided by the utilities ($0.2 billion each). The CSF loan is subject to special provisions, where under certain conditions some if not all the total loaned amount (i.e., $4 billion in this example) can be paid back according to amenable schedules or be waived.

Recall that the purpose of the CSF is to mitigate the cost risk to the consortium during its construction period should the actual costs of the orderbook (and by extension, the average cost per SMR) exceed what is planned. The numerical example provided in Figure 7 shows that the actual cumulative cost of the orderbook exceeds what was estimated during the construction of the eighth plant (see table, third row, column F8). To be clear, the total estimated cost of the orderbook was pegged at $20 billion, however during the construction of F8, that total was exceeded. What this means is that additional funds will be needed to complete the orderbook of ten plants. It is notable that in this example (and what would be expected in reality), the largest cost variance on a per plant basis occurred during the FOAK construction, where the cost above the anticipated budget for that plant is ~47%. For each successive build, the cumulative orderbook cost trajectory would be updated, based on actual cost, and observed learning rates. It will be known well in advance when the cost overrun will occur, and all participating entities (including LPO) will be prepared.

The CSF construct requires LPO to make available a loan to the NN-SPV, not the sponsoring entities. In this way, the added debt obligation of the CSF does not reside with the individual consortium utilities, rather it is separated from their balance sheets. This provides a financial cushion to the project sponsors while limiting their exposure to additional debt. The CSF is negotiated during the diligence phase between the project sponsors and LPO, well before construction of the first plant. For illustrative purposes as shown in Figure 7, the size of the CSF available is $5 billion, therefore allowing 25% above the original estimate of $20 billion (and increasing the average installation cost to $2.5 billion each from $2.0 billion).

Provided that 100% of the existing budget (orderbook baseline costs and contingencies) has been exhausted, LPO releases additional capital through a loan to the NN-SPV. However, accessing the CSF is not entirely costless to the sponsors; it does require a relatively small equity contribution by each consortium utility, as shown by the blue arrows from each utility to the NN-SPV in Figure 7. In keeping with the debt-to-equity limits, LPO would fund the CSF to 80% of the required value; the remainder would come from contributions made by the participating utilities. In the case of the example shown in Figure 7, each utility injects $0.2 billion to access the total of $4.0 billion made available by the LPO, or 4% each of the total $5.0 billion required to complete the orderbook. It should be noted that this equity infusion from the participating project sponsors would not include the credit subsidy cost levied by LPO. However, this cost might be covered by the appropriated $3.6 billion by the IRA to LPO for this express purpose.

The monies needed to unlock the LPO-CSF funds by the participating utilities could be from pooled reserved set aside as part of an IPD arrangement. In this sense, the CSF is like a tiered risk sharing model, where different entities shoulder the cost burden as it relates to the initial orderbook total cost estimate. Tier 1, up to the project baseline cost, the project sponsors through the NN-SPV are responsible for 100% of the costs. Tier 2, beyond the baseline cost and including all contingencies and/or pooled capital-at-risk, the NN-SPV is responsible for 100% of the costs as well. Once all private capital is exhausted (notionally here, $20 billion), the participating utilities are responsible for 20% of the overrun cushion (in this case 20% of $5 billion), whereas the Federal government, through the LPO, is directly responsible for 80% of said value (in this case, 80% of $5 billion).

Discussion & Further Considerations Regarding the CSF

If triggered, the CSF allows the NN-SPV to draw upon an LPO loan to complete the orderbook. There are two key differences between a typical LPO project loan and a loan provided as part of the CSF. As stated before, one difference relates to the entity that receives the loan; in the case of the CSF, it is the NN-SPV, not the project sponsors. As such, consideration would have to be given to the collateral pledged to secure the loan. In the case of the NN-SPV, it could be a mix of completed and to-be completed plants, contractual rights to projected output from some of the reactors, a notional cash held within the SPV, a combination of these or other considerations. Importantly, the details surrounding the collateral pledge will have to be agreed to at project outset; likely this will be scenario-based to enable formulaic triggering of the CSF. It should be noted that extending a loan to an SPV has been done before by LPO, where the underlying review is used to secure the debt.[50]

The second distinction is that the CSF is subject to flexible repayment terms, including provisions that could allow limited repayment in the short term and longer-term repayment terms linked to the long-term value of the projects. Loans with flexible repayment terms are sometimes offered by government agencies as a form of financial assistance or incentive to promote specific activities or outcomes.

A loan with flexible repayment terms to the NN-SPV provides multiple beneficial features from the perspective of the SMR developers. Such a mechanism allows for a planned injection of funds needed to complete the orderbook, while minimizing the capital outlay by the project entities. It is critically important to the project sponsors that such a mechanism is known to be available to them when contemplating an orderbook and the trigger be formulaic; reliable access to the CSF supports orderbook bankability.

In the illustrative example, the trigger for the CSF is the full exhaustion of the original project budget, however, other tiered approached could be considered. Existing and recently amended Title 17 rules allow for the extension of a loan to a project that has gone over budget. This kind of additional loan availability to enable continued construction of a project given cost escalations above initial projections has precedent at the LPO, namely for Vogtle units 3 and 4. LPO offered $8.33 billion in loan guarantees in February 2010 for the construction of Vogtle 3 and 4. In March 2019, $3.7 billion of additional guarantees were made available to finance continued construction.[51]

However, the extra $3.7 billion for Vogtle could not have been legally included in the initial Vogtle LPO loan because at the time so doing was not authorized. For instance, in the LPO loans to Municipal Electric Authority of Georgia (MEAG) in Vogtle 3 and 4, MEAG seems to have applied in 2008 and gotten conditional loan approval shortly thereafter (2010); but bond validation court cases were not resolved until 2015, when the first tranche of notes were taken down and proceeds received.[q] The second tranche of Vogtle loans was a separate, discretionary decision by LPO several years after the first tranche was documented. Of critical note, recent regulatory changes make it possible to provide for locked-in funding for a cost overrun at the beginning of the project, unlike what occurred with Vogtle (which had no assurance of an additional loan for cost overruns at the outset of the project). Specifically, recent updates by DOE through an interim final rule published on May 30, 2023 make explicit that project costs include "escalation and contingencies" and are "necessary, reasonable, customary, and directly related to the design, engineering, financing, construction, startup, commissioning, and shakedown of an Eligible Project."[52] Taken together, there seems to be both precedent and regulatory authorization for pre-establishing the mechanism and funding source for the CSF through an LPO loan.

Eligibility for the CSF by Project Sponsors

A framework for eligibility for project sponsors to apply for the CSF should include the following dimensions.

Orderbook Size of a Pre-Selected SMR Design. Given that the CSF is intended to help commercialize SMRs, there should be a minimum threshold for the orderbook size to access the facility. The minimum could be set based on the perceived maturity of the FOAK design and the prospects for cost reductions and value chain scale-up, amongst other criteria. It could be, for example, that a Gen III+ design might have a minimum orderbook size of five, whereas a Gen IV design might have a different quantity, based on the relative novelty of the underlying technology. In all cases, however, there should be a strong bias toward minimum values that are above three.[53] Finally, and importantly, it is up to the discretion of the project sponsor(s) to determine which SMR design would form the orderbook. LPO would examine loan applications based on the economic and technical dimensions of the orderbook (project portfolio as a whole) and may promulgate broad performance attributes that it would deem preferred but would not directly pick a specific vendor or technology. Moreover, the CSF would be made available to concurrent orderbooks, each of different SMR designs, so long as the project (given the availability of the CSF) could pass LPO due diligence.

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[q] MEAG Official Statement for Vogtle 3&4 Project Bonds Series 2023A and 2023B, dated Jan 12, 2023, pp. 56-58. https://emma.msrb.org/IssueView/Details/P2420332

FOAK Maturity. The CSF mechanism is meant to be a bridge to commercialization, and as such, should only be used to help offset the development risk of a given SMR design from FOAK to NOAK maturity. Of course, the specific number of deployments needed to achieve NOAK for a given SMR design is contingent upon multiple factors beyond the underlying technology. Therefore, a performance-based assessment should be used to determine if the intended orderbook of a given SMR design is indeed of FOAK maturity. One promising approach is the Commercial Adoption Readiness Assessment Tool (CARAT), co-developed by the Office of Technology Transitions and Office of Clean Energy Demonstrations within DOE. CARAT uses an Adoption Readiness Level (ARL), akin to the familiar Technology Readiness Level (TRL). ARL represents important factors for private sector uptake beyond technology readiness, and can be determined by performing a qualitative, but fact-based, risk assessment across 17 dimensions of adoption risk spanning four core risk areas: (i) value proposition, (ii) market acceptance, (iii) resource maturity, and (iv) license to operate.[54]

IPD Best Practices. As outlined previously, IPD best practices when applied to nuclear construction projects could have a significant impact on containing costs and laying a solid foundation for subsequent builds of a given design. Therefore, project sponsor(s) ought to be required to submit a comprehensive IPD plan and execute it for the life of the project. Even if there is not an explicit requirement from the LPO, it is in the best interest of the project sponsors to use such approaches that contain costs, protect margins, and increase the capital efficiency of the orderbook construction.

Knowledge Sharing. As mentioned previously and reported elsewhere, the U.S. has no institutionalized project-management knowledge for nuclear plant construction to inform future nuclear construction projects.[55] It is important to implement a knowledge management strategy not only for the purposes of internal sharing (part of IPD best practices), but for public dissemination as well. Of course, project sponsors and their partners ought to be able to protect and retain their private patents, intellectual property, and critical know-how. There needs to be a balance struck, however, between rewarding the project sponsor who has put resources at risk and supporting would-be follow-on developers who benefit by learning from first movers.[56] That is in effect a price of benefiting from the governmental backstop. The industry in general would greatly benefit from wider access to actual costs and operational data tied to federally supported projects. Therefore, project sponsor(s) ought to be required to submit a comprehensive knowledge sharing plan and execute it for the life of the project in collaboration with DOE.

A Flexible Repayment Approach to Loans Extended through the CSF

Under current LPO authority, the CSF loan borrower would be the project entity, i.e., the NN-SPV for the entire amount of the CSF.[r] In such a case, payments on the CSF loan would represent ongoing project expenses included each year in the project budget. So doing would clearly allow for a different initial drawdown date and a longer final maturity date. In concept, this allows for a flexible CSF repayment approach, which further reduces the near-term financial burden to the project sponsors should cost overruns on the orderbook be encountered. For example, the near-term repayment obligations on the CSF could be limited to a minimum amount to maintain the loan, with longer-term repayment terms linked to the value of the portfolio of project assets. This could result in a sculpted repayment schedule with provisions to allow adjustments in the repayment schedule based on the level of future net operating revenues. In one example, cash needed for repayment could be generated through very long-term PPAs (e.g., +50-years), which align with the average operational lifetime of the orderbook SMRs. There is precedent for flexible repayment terms offered by the U.S. government (see Box 5a and 5b).

LPO would have to decide upon the reasonable prospect of repayment based not only projected revenues, but also other factors such as the aggregate funding available for the CSF program in general, considering *inter alia*, the number of design-specific orderbooks expected and the acceptable percentage over the total project budget the CSF would cover. Recall in the numerical example, the CSF made available was 20% of the $20 billion.

If the projects in the orderbook do not generate sufficient revenues over the longer-term, in the extreme, the SPV could default on the CSF loan. This would trigger a negotiated exit by the undivided owners from the SPV arrangement, including a determination of the disposition of collateral pledged to secure the CSF. Crucially, the negotiated exit will have to account for the completeness of the orderbook at the time of the default, whereby the owners of the SPV may take direct ownership of the completed projects (that have not already been sold from the SPV, but subject to the terms arranged with LPO), and the federal government would be

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[r] As per “Program Guidance for Title 17 Clean Energy Financing Program” (OMB Control Number 1910-5134), page 63, a Project Sponsor is defined as any “Person that assumes substantial responsibility for the development, financing, and structuring of an Eligible Project and owns or controls, by itself and/or through individuals in common or affiliated business entities, a five percent or greater interest in the proposed Eligible Project or the Borrower.” A Person in this case is defined “as any natural person or any legally constituted entity, including a state or local government, tribe, corporation, company, voluntary association, partnership, limited liability company, joint venture, and trust.” Therefore, by construction of the NN-SPV, LPO could provide a loan/loan guarantee to it.

encouraged to complete any partially built SMRs or find an appropriate final disposition of such.

By offering flexible repayment terms, the federal government, acting through the LPO, would be in effect sharing the cost overrun risk by employing its “balance sheet” and its ability to accommodate a lower time value of money vis-à-vis a private corporation. Provided that such acts are deemed to be in the public interest, which ostensibly is true of kickstarting the SMR industry domestically, then there is an argument to be made that this kind of support is similar in purpose and scope as other publicly backed funding mechanisms. Further, because the CSF is offered as a loan and not a grant, it makes use of the large lending capacity of the LPO already approved by the IRA (through §1703 and §1706), without the need to seek Administration and Congressional action to provide new authority and funding for this purpose (especially in the short-term).

Box 5a: LPO loan flexible repayment terms: bullet payment schedule without forgiveness

LPO statutory/regulatory maximum maturity limit is 30 years, with LPO stating that the measurement period runs from initial note drawdown of funds under a loan until final amortization of the last note under the loan. There does seem to be some flexibility in amortization, however, because the MEAG projects in relation to Vogtle 3 and 4 that were backed by 50-year power purchase agreements (PPAs) were allowed to have nominal 40-year amortization of principal with the unamortized portion left as a bullet payment at year 30 (2045).[57] What this means is that a 40-year theoretical loan repayment schedule was calculated on a “level mortgage” basis in which the sum of principal and interest is the same dollar payment in each year. Over time the interest component of each individual payments falls, and the principal component correspondingly rises. The actual total LPO payments for years 1-29 exactly followed that theoretical 40-year schedule. However, the loan ends at year 30. Thus, at year 30, the final payment would be very large because, in addition to the “normal” 30-year payment, this final payment would include all the unamortized principal *that would have been paid* in years 31-40 if the loan were truly for a 40-year term.

Box 5b: USDA loan flexible repayment terms: forgivable loans

Powering Affordable Clean Energy (PACE) Program, administered by USDA’s Rural Utility Services (RUS), provides partially forgivable loans, with varying levels of forgiveness, for renewable energy generation and storage projects that benefit rural areas.[s] [58] To receive eligibility, at least 50% of the service area of a proposed renewable energy project must serve communities with populations of 20,000 or fewer.[59] The Inflation Reduction Act (IRA) authorizes and appropriates $1 billion for the PACE program, but RUS expects to have $2.7 billion available to lend for the program.[60] The percent of loan forgiveness a project receives is dependent upon the community the project serves, or if a project meets certain conditions:[61]

Category I: 20% loan forgiveness for any qualifying loan that meets minimum requirements. Minimum requirements include an eligible applicant and project, as well as an application that demonstrates ratepayer benefit, financial feasibility, technology feasibility, reliability, and resiliency, and securable.

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[s] Eligible projects include wind, solar, hydropower, geothermal, or biomass, as well as for renewable energy storage projects

Category II: 40% loan forgiveness if the 50 percent or more of the population in the proposed service area is designated energy community, or a disadvantaged or distressed community

Category III: 60% loan forgiveness if the project is in U.S. territories or Compacts of Free Association Areas; serves areas with Tribal populations of 60 percent or greater or are in a Substantially Underserved Trust Area (SUTA) or is owned by a Federally Recognized Tribe.

$300 million of appropriated funds are committed to each category. Additionally, projects must be based on bankable power purchase agreements (PPAs) or through a financial guarantee that ensures financial feasibility.[62]

Potential Amortization Schedules for CSF Repayment

As indicated, there is precedent within the LPO to offer alternative amortization schedules to projects, specifically nuclear projects (see Box 5a). Potential amortization schedules for the CSF should be constructed with an eye toward balancing the stream of benefits from the expected operational life of an orderbook of SMR, the financial preferences of the project sponsors and the goals of the federal government. It would seem desirable to minimize the ratepayer burden of the CSF upon the customers of each project sponsoring utility, since there is already an intergenerational equity issue inherent in the mismatch between 30-year LPO loan lives and the much longer expected asset life of the SMRs. Nuclear plants have historically lasted 40-60 years (with 80 years a possibility),[63] with financings often having been extended repeatedly as project lives and licenses were extended. For example, this was the case for the Bonneville-guaranteed tax-exempt debt relating to the Washington Public Power Supply System projects such as Columbia Generating Station.[64]

With the tenor of LPO loans extending only roughly half the life of the new nuclear plant assets, the intergenerational equity issue would be partially ameliorated if the CSF is a separate purchase agreement with a different borrower (the SPV), with a new (later) initial drawdown date, and hence with new (later) final maturity date versus, say, any LPO loans offered to the individual project sponsors. For instance, suppose the first CSF drawings occurred at Year 10, then the final CSF maturity could be in Year 40. Optimally, the CSF would be structured using securities features that minimize the near-term rate impact of cost overruns on LSE ratepayers (see Box 6 as for an example).

Box 6: Example amortization schedule for CSF repayment

One example of an amenable amortization schedule for CSF is for said notes to be structured in a manner like that of U.S. Treasury's Series EE savings bonds. In savings bonds, the investor buys the bond for an original principal amount (say $100) and all interest is accrued and compounded until paid back, together with the original principal amount at maturity (e.g., $100, plus accumulated interest of $143 for 30 years at 3%, for a total of $243 paid at maturity). In the U.S. Treasury bond market, such securities are known as zero-coupon bonds generically and can be created by "stripping" individual interest payments from a cash-paying conventional U.S. Treasury Bond, hence being called "Strips." Such securities are also common in tax-exempt (municipal) bond market financings, often being called "Capital Appreciation Bonds" or CABs. In this structure, 100% of the interest payments accruing on the CSF during the period for e.g., the first 30 years (the repayment period for the original tranche of LPO loans to the project sponsors) would be accrued and compounded (a.k.a. "accreted" in technical terms); and the accreted interest would then be repaid along with the original CSF principal borrowed during Years 31-40.

Conclusion

The United States has a unique opportunity to meaningfully shape the trajectory of SMR deployment globally and the development of its supply chain. Where that starts is through enabling SMRs at home. To overcome the dual barriers of cost magnitude and cost uncertainty, this paper presents a policy framework to “kickstart” the SMR industry domestically by addressing the specter of large unanticipated or unforeseen cost overruns for the first set of deployments of a given design. It proposes a cost stabilization facility (CSF) that includes a special loan facility provided by the federal government. The CSF provides a flexible yet effective cost cap to project sponsors of an orderbook of SMRs by using existing authorities within LPO to lend to an SPV and advantageously shaping repayment terms thereof. By focusing on an orderbook of multiple SMRs of a given design as the unit of analysis, the eligibility criteria for CSF takes advantage of the prospective cost reductions enabled by SMRs through learning effects, helping remove the first mover disadvantage of FOAK builds by reducing the per SMR average cost.

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