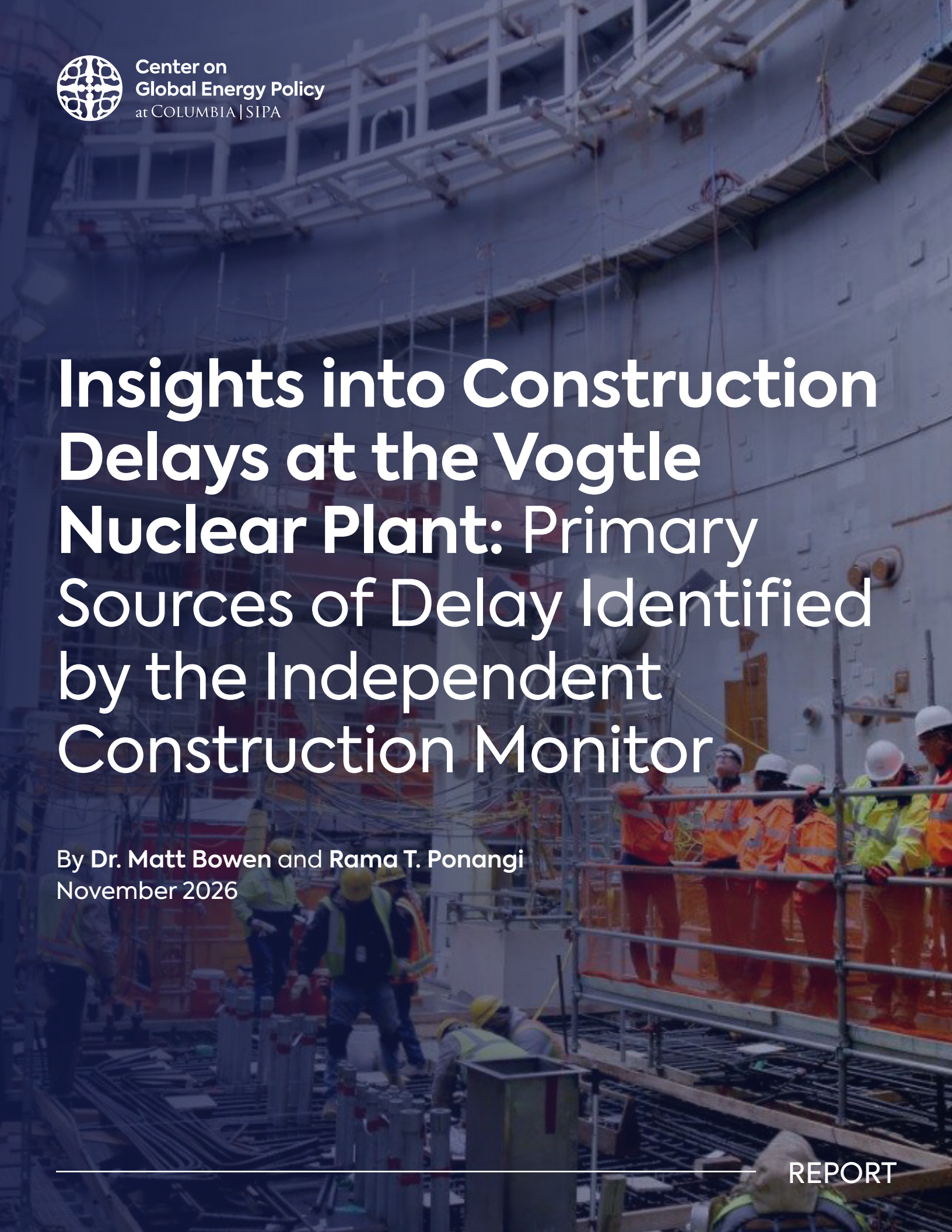


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Insights into Construction Delays at the Vogtle Nuclear Plant: Primary Sources of Delay Identified by the Independent Construction Monitor

By **Dr. Matt Bowen** and **Rama T. Ponangi**

November 2026

REPORT

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Executive Summary

Global concerns about meeting rising electricity demand while maintaining climate commitments have driven some policies to accelerate the deployment of energy technologies with lower greenhouse gas emissions, including nuclear power. Diversifying energy sources is also a national-security and economic-security interest for many countries, and in that vein the United States recently set a goal of achieving 400 gigawatts of domestic nuclear power by 2050, nearly four times its current level.

But the first new reactors built in the United States in decades—two Westinghouse AP1000s, Units 3 and 4, at the Vogtle plant in Georgia that started commercial operations in 2023 and 2024—took more than twice the estimated time to construct and at more than double the cost. This experience raises questions about nuclear power's economic viability and therefore its role in the energy transition and energy diversification.

To better understand what went wrong so utilities and reactor consortia can reduce the chances of such consequential delays in future US reactor builds, the authors examined testimonies by Vogtle's independent construction monitor (ICM). The ICM, Dr. William R. Jacobs Jr., reviewed the project's progress and any issues impacting schedule or cost. Jacobs had a unique vantage point into the unfolding debacle throughout the process, and assessed that the project's three primary sources of delay were the following:

- Vogtle Units 3 and 4 lacked a realistic, achievable schedule. The integrated project schedule (IPS) used to manage the project and estimate commercial operation dates was both incomplete and based on incorrect or unrealistic assumptions.
- Private entities involved in the project failed to adhere to the stringent quality assurance requirements of the US Nuclear Regulatory Commission (NRC). In particular, the use of a new facility in Lake Charles, Louisiana, with no previous nuclear-grade manufacturing experience created lasting problems.
- Westinghouse lacked sufficient design completion at the start of the project and the design changed during construction. Both factors adversely impacted procurement and construction and the changes led to licensing conflicts between what the NRC had certified and what the consortium built.

For future reactor projects, utilities and reactor consortia can take the following corresponding actions to mitigate those sources of delay:

- Require a complete Level 3 IPS with realistic, achievable inputs. If utilities are to bear schedule risks in the future, they should stipulate for an IPS of this kind at the earliest stages of the project and consider having a third party review it.
- Require strong quality control measures at the outset of the project and use suppliers that have experience with nuclear-grade manufacturing. Utilities could perform due diligence to ensure all vendors have a record demonstrating the necessary capabilities.
- Require a more complete design at the start of construction, and consider using the NRC's two-part licensing pathway for first-of-a-kind deployment (which allows for less design specificity at the start, because the construction permit is sought well before details must be solidified for the operating license).

Introduction

Many countries that are eager to meet rising electricity demand without compromising climate commitments are taking another look at nuclear as a means of limiting greenhouse gas emissions. Others are seeking to diversify their energy mix, especially as national-security and economic-security interests have come to the fore with recent conflicts challenging fuel supply chains.

In the US, the Trump administration recently set a goal of achieving 400 gigawatts of domestic nuclear power by 2050,[1] nearly four times its current level. Several reactor projects are under development in the United States, with more potentially underway in 2027. However, the only truly new US reactors ordered and brought online in recent decades—Units 3 and 4 at the Vogtle power plant in Georgia—took more than twice their scheduled time at more than double their expected cost.

For nuclear power to play a growing role in the energy mix of the US and elsewhere, future reactor construction experiences will have to cost less and proceed faster. For that reason, drawing lessons from the primary sources of delay to the Vogtle project is important to reactor developers and utilities, as well as those concerned about addressing climate change with viable alternatives to fossil fuels.

As part of certification of the Vogtle 3 and 4 project, the Georgia Public Service Commission (PSC) stipulated that a co-owner of the plant, Georgia Power Company (GPC), submit semiannual status reports to track construction progress and assess the economic viability of the project. The certification also required that an independent construction monitor (ICM) be hired to assist PSC staff in monitoring the building of the project. Dr. William R. Jacobs Jr. was selected and served as the ICM through the construction of Vogtle Units 3 and 4,[2] producing written testimony on each semiannual report that included the current status of the project and issues that had the potential to impact the schedule or cost of the project. The ICM testimonies provide valuable insights from an experienced veteran of power plant construction who was intimately familiar with the project during its entire construction duration.

The authors reviewed the 27 ICM testimonies (approximately 1,200 pages, covering December 2009 to October 2023 [a few months after Vogtle Unit 3 started commercial operations]) as well as the associated Vogtle Construction Monitoring reports (VCMs)—29 in all, as two were published after ICM testimony was halted. While the ICM could not be expected to know everything about such a large project, was testifying in real time as the project unfolded, and early on said he was not given adequate access to project documents—as well as the fact that substantial portions

of the ICM testimonies have been redacted—Jacobs's collective testimonies help illuminate the challenges that the Vogtle 3 and 4 reactors encountered on their way to commercial operation. The authors perceive particular value in the ICM-identified "primary sources of delay" to the Vogtle 3 and 4 project, which constitute broad areas from which to derive lessons for future US reactor construction efforts to avoid similar outcomes.

The first section of this report provides background on the Vogtle Units 3 and 4 project overall, introducing the private entities involved and their changing contractual relationships, major regulatory developments, important construction milestones, and the final cost and schedule overruns. Section 2 describes the three primary sources of delay to the project, as well as other sources of delay, as identified in ICM testimony. In Section 3, the authors derive lessons from these delays, followed by concluding thoughts in Section 4 on the Vogtle 3 and 4 project as well as future US reactor builds. The authors find that some key obstacles that led to the Vogtle project's profound delay and cost overrun can be avoided by creating a complete and achievable integrated project schedule (IPS), being prepared to adhere to the Nuclear Regulatory Commission's (NRC) stringent quality assurance requirements, and having sufficient design completion before construction commences.

1. Background

Early ICM testimonies look prescient. In his first testimony (December 2009), Jacobs noted that both construction and licensing for Vogtle Units 3 and 4 were "aggressively scheduled" and that delays at an early stage of the project could be symptomatic of the "untried nature of the project and maybe a preview of future delays as the project progresses." ICM testimony assessed that GPC's economic analysis in the first VCM filing was incomplete and did not consider the possibility of higher costs for the project, lower natural gas prices, and reduced electricity demand as a result of the economic recession at the time. Overall, the ICM assessed that there was a smaller probability of the Vogtle Units 3 and 4 project providing benefit than GPC had concluded, and that GPC's share of the project would have to end up relatively close to the $6.1 billion estimate at the time to provide benefit or at least break even against the next best alternative: natural gas-fired combined cycle units. GPC's share of the project instead came in at about $15 billion and took about seven years longer than scheduled. (The list of VCM reports and ICM testimonies [ICM1–ICM29] can be found in Appendix A.[3])

This section is laid out chronologically by major project periods identified by the ICM. It starts with the "EPC Period," which began with the signing of the engineering, procurement, and construction (EPC) agreement in 2008, and is followed by a period that includes the Westinghouse bankruptcy in March 2017 and the go/no-go decision as to whether the Georgia PSC would continue the project. It concludes with the "SNC management period," as Southern Nuclear Operating Company (SNC) assumed overall project management in 2017, with Bechtel as its prime construction contractor and Westinghouse as the design authority and engineer.[4]

A. EPC Period

The EPC agreement[5] was signed in April 2008 between "the consortium"—Stone & Webster and Westinghouse—and the co-owners of Plant Vogtle Units 3 and 4: GPC (45.7% ownership), Oglethorpe Power (30%), Municipal Electric Authority of Georgia (22.7%), and Dalton Utilities (1.6%).[6] GPC filed an application for certification of Vogtle Units 3 and 4 on August 1, 2008, in Docket No. 27800, with the Georgia PSC.[7] The Georgia PSC made a formal regulatory determination that the project was needed and in the public interest on March 17, 2009.[8] The eventual construction of Vogtle Units 3 and 4 would mark the first truly new US reactor order since the 1970s.

On February 10, 2012, the NRC issued a combined operating license (COL) for the project[9]—the first such license issued under the 10 CFR 52 licensing process—that authorized both construction

and operation. In March 2013, a major construction milestone was achieved when the first safety-related concrete was poured for the Unit 3 nuclear island basemat[10] (see Appendix B for details on AP1000 structures).

But by late 2013, delays had led to lawsuits among the EPC parties over who was liable. What was called "the definitive settlement agreement" (DSA)[11] ultimately resolved litigation between Westinghouse, the Chicago Bridge & Iron Company (CB&I) (which had acquired the Shaw Group,[12] owner of Stone & Webster), and the Vogtle project owners in December 2015. As a result of the agreement, Westinghouse became the prime contractor for the project, with Fluor Corporation taking over as construction subcontractor. As part of the DSA, Westinghouse agreed to purchase CB&I's subsidiary Stone & Webster. CB&I had reportedly spent over $1 billion on the project, and as part of the deal, sold Stone & Webster to Westinghouse for $0 while also transferring its remaining liabilities.[13] This meant that there would no longer be a consortium counterparty to the EPC Agreement—Westinghouse would be the single prime contractor. Westinghouse would still have the design and engineering functions, but going forward it would have additional procurement scope as well as construction management responsibilities.[14]

B. The Westinghouse Bankruptcy and Go/No-Go Decision

Westinghouse filed for Chapter 11 bankruptcy in the Southern District of New York in March 2017, identifying the construction of nuclear power plants in Georgia and South Carolina as the area of business that was losing money. According to the ICM, before the bankruptcy, Westinghouse and Fluor had developed a new estimate for completion of the Vogtle 3 and 4 project that showed additional delay and increased cost due to a more accurate accounting of the quantities of commodities needed to complete the project as well as more realistic unit rates (how fast work is completed) and productivity factors to determine human capital costs. The recognition of the time and cost that remained ahead in the project led to the bankruptcy filing.

As part of the bankruptcy, Westinghouse rejected the original EPC contract, which left the Vogtle 3 and 4 project in a type of limbo that presented a variety of risks.[15] At this point, the Georgia PSC had to make a go/no-go decision on whether to continue the project. The ICM and Public Interest Advocacy (PIA) staff[16] assessed that there were additional risks facing the project if the PSC elected to continue it.[17] The PIA staff recommended (outside of ICM testimony) that the Vogtle 3 and 4 project either be canceled or continued under specific conditions, including additional protections for ratepayers.[18] The Georgia PSC voted on December 21, 2017, to continue the project and deemed reasonable a revised $7.3 billion estimate for GPC's ownership share. It also considered reasonable

the then-forecasted in-service dates of November 2021 for Unit 3 and November 2022 for Unit 4. (The other two Westinghouse AP1000s under construction in the United States at this time, at the Virgil C. Summer Nuclear Generating Station [V.C. Summer site] in South Carolina, were abandoned after $9 billion in expenditures.)

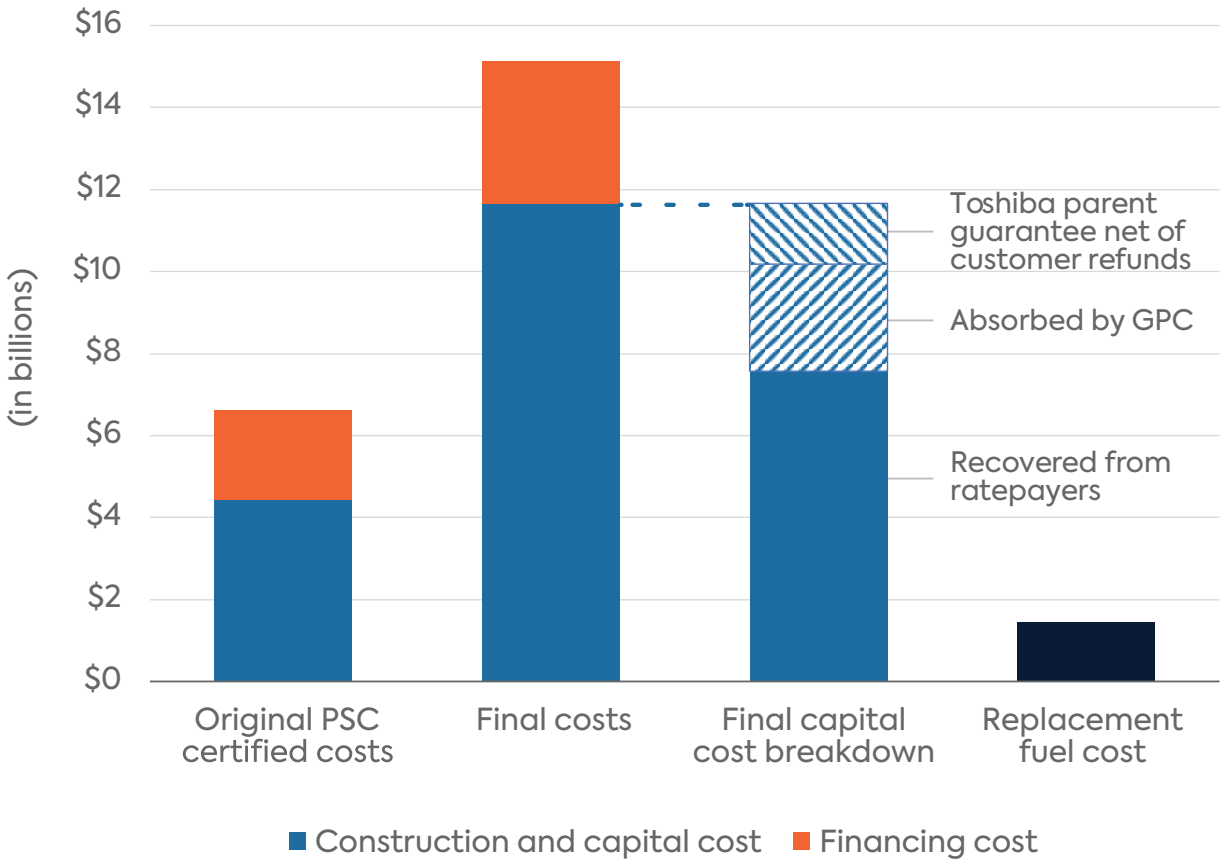
C. SNC Management Period

As noted, SNC assumed overall project management in 2017, with Bechtel as its prime construction contractor and Westinghouse as the design authority and engineer. Contrary to the forecast at the time of the go/no-go decision, Unit 3 would not begin operations until July 31, 2023. Shortly thereafter, PIA staff, GPC, the Georgia Association of Manufacturers, Georgia Watch, Georgia Interfaith Power & Light, and the Partnership for Southern Equity signed what was called "the stipulated agreement"[19] detailing how costs for the project would be allocated. Each party to the agreement accepted its terms as a reasonable and fair resolution of all remaining regulatory issues of the project for PSC consideration. Part of the agreement included a hard cap on capital construction costs ($7.562 billion) that could be recovered from GPC ratepayers, which was slightly more than what the PSC had deemed reasonable at the time of the go/no-go decision.

Unit 4 began commercial operations on April 29, 2024.

In the end, the Vogtle 3 and 4 project cost GPC ratepayers billions more than was originally promised (see Figure 1). GPC's share of total construction and capital cost for the project was originally $4.42 billion but ended up at $11.58 billion. While not all of these costs were passed on to ratepayers (the Toshiba parent guarantee [$1.5 billion][20] and the amount absorbed by GPC shareholders [$2.6 billion] mitigated some of the cost), what remained was still well above what was certified in 2008 and what was promised to the public. And given how much time elapsed between when the units were supposed to start operation and when they actually did (e.g., April 2016 to July 2023 for Unit 3), paying for replacement power was not insignificant—over $1.4 billion. The final financing cost of $3.5 billion was also much greater than the original $1.7 billion, and more than what was expected around the time of the go/no-go decision ($3.1 billion).[21]

Figure 1: GPC costs, original and final



Note: The capital costs in the hashed boxes were not collected from GPC ratepayers and thus mitigated how much of the final costs were borne by them. The fuel costs needed to replace the power that was not produced by Vogtle 3 and 4 were not collected as part of the Vogtle proceedings but were nonetheless borne by ratepayers.

Source: Appendix A: VCM2, VCM29, and VCM31.

2. Primary Sources of Delay

After the Westinghouse bankruptcy, but ahead of the go/no-go decision, the ICM identified in testimony what he perceived to be the primary sources of delay to the Vogtle 3 and 4 project during the EPC period:

1. The parties[22] never had a realistic and therefore achievable integrated project schedule (IPS) with the qualities detailed by the Institute of Nuclear Power Operations (INPO)
2. The parties at inception of the project were not prepared to adhere to the NRC's stringent quality assurance requirements
3. Westinghouse lacked sufficient design completion of the project when it began and through much of its progression[23]

Similarly, in his last testimony after Unit 3 began commercial operations in July 2023, the ICM reflected back on the management decisions, practices, and/or approaches during the SNC management period that he considered imprudent or poor management and contributed to cost and schedule overruns. He noted that "many" of the same issues from the EPC period were repeated by SNC management and impacted the project cost and schedule in this later period.

The three primary sources of delay identified by the ICM for the EPC period are discussed in this chapter, along with other decisions and practices that contributed to cost and schedule overruns in the SNC management period.

A. Lack of a Realistic, Achievable Schedule

A primary source of delay identified by the ICM was the lack of a credible IPS. In the construction of megaprojects (i.e., projects costing typically over a billion dollars), an IPS is a critical management tool, as it integrates the potentially hundreds of thousands of activities that have to be accomplished by thousands of workers over thousands of days into a logically tied, sequence-dependent manner. It is a necessary management tool in part because of the inherent activity dependencies—a given activity cannot be started until another one is completed. For example, an order for a component cannot be placed with a supplier to manufacture it until the engineering and design are finalized; similarly, installation at the construction site cannot happen until procurement of the component is completed.

Specific to Vogtle 3 and 4 construction, the installation of structures and components at the plant site (see Appendix B) had various dependencies, including simple ones such as:

- the "basemat"—essentially a large slab of concrete reinforced with steel—of the nuclear island had to be built before structures and components could be installed on top of it
- the steel containment vessel that surrounded the nuclear steam supply system could not be completed until all of the large components that needed to be lifted in and installed were inside
- construction of the project had to be nearly complete in order to conduct hot functional testing, where temperatures and pressures in the nuclear steam supply system would reach normal operating conditions
- hot functional testing had to be completed before nuclear fuel was loaded, which in turn had to occur before commercial operations could begin

In modern megaproject construction, the logical sequencing of activities—including engineering, procurement, and construction activities—is typically done using modern software programs such as Oracle Primavera.[24] The type of IPS used to manage construction at a project like Vogtle 3 and 4 is referred to as a "Level 3" IPS. By contrast, a "Level 1" IPS is a summary of major milestones, perhaps for senior leadership, that might only be a few pages long and therefore not usable for managing site construction.

A Level 3 IPS can be described as "complete" and "resource loaded" if all of the activities needed to accomplish the project are included in the schedule and each activity is assigned the resources (e.g., amounts of materials, hours of craft work) needed to accomplish it. Such an IPS then enables the determination of which activities are on the "critical path" ("the series of sequential activities that yields the longest path to the end of the project and subsequently commercial operation" [ICM12, page 21]) as well as activities that are near the critical path. If the time taken for any activity on the critical path lengthens, then the forecasted time needed to complete the project lengthens. Which activities are on the critical path may change during construction if activities progress differently than what was originally forecast. Thus, a different sequence of activities can end up forming a longer duration to project completion than was envisioned at the start of construction.

As the ICM pointed out, the nuclear industry's own self-funded organization—the INPO—considered schedules to be of such significance to best industry practices for building new reactors that it articulated the need for such a schedule in fundamental nuclear construction principles (ICM11, page 25). Specifically, the ICM pointed to INPO Principle No. 4:

> Schedules are realistic and understood. Effective project controls and detailed planning are key factors in the success of any large construction project. Unrealistic, uncoordinated, or obsolete schedules or insufficient resources can have a negative effect on construction quality and personnel safety, especially when appropriate

actions are taken to accelerate construction or to reduce cost.

The ICM listed nine other INPO-defined schedule attributes (see Appendix C). As the ICM explained, if an IPS is reasonable and achievable, it allows management to drive accountability and allocate resources to the areas of the project that are on or near the critical path. A reasonable IPS in turn provides contractors the opportunity to be successful in meeting schedule milestones.

However, for most of the Vogtle 3 and 4 project, ICM testimony identified shortcomings with the consortium's IPS and explained how it did not conform to INPO principles and was thus not usable for managing the project. The ICM noted in several testimonies that it was not possible to know if the commercial operation dates for Vogtle 3 and 4 were credible, given that a reasonable, detailed IPS did not exist.

Problems with the Vogtle 3 and 4 IPS

The lack of a credible IPS was first noted in June 2012 testimony (ICM6), and in 2017 the ICM stated that the IPS used by the consortium prior to the Westinghouse bankruptcy had been unusable to manage the project. PIA staff further testified that it was their belief that there had never been a project IPS that met the criteria of INPO 4 (i.e., "Schedules Are Realistic And Understood") and thus there had never been an achievable IPS for the project (ICM17, page 42). The ICM's belief was that given the scope and complexity of the Vogtle 3 and 4 project, not having a quality IPS made it nearly impossible to proactively identify, mitigate, and move beyond inevitable challenges the project would encounter (ICM16, page 27).

PIA staff analysis of Vogtle 3 and 4 project schedules found that they were not of high quality and fidelity for reasons such as:

- thousands of activities were missing
- thousands of activities were not resource loaded (in some instances, there were no estimates of craft hours needed to complete them)
- unit quantities (for example, the amount of material required) were inaccurate
- entire areas, such as procurement activities, were absent or not logically tied to construction activities
- the dates for activities to end were held constant though the date for the activities to start had been delayed (i.e., the use of "hard constraints"[25])
- the dates for activities to start *had already passed by*, but the dates for the activities to end had

> remained constant in the schedule, thereby compressing the days available to complete that activity [emphasis added] (i.e., construction activities had "negative float")

As an example of the second bullet: PIA staff analyzed an IPS dated April 2017 and found that it contained only 7% of engineering activities loaded, 46% of procurement activities loaded, and 57% of construction activities loaded.

Schedule Issues Persisted in the SNC Management Period

The ICM identified in his final testimony three shortcomings related to the project schedule during the SNC management period (ICM29, pages 31–33):

1. Failure to develop a complete, fully loaded IPS
2. Failure to utilize an achievable schedule to manage the project
3. Failure to use achievable unit rates based on experience in development of project schedules

As the ICM saw it, the site working plan during the SNC period was seldom, if ever, achieved and usually became obsolete shortly after issuance. For that reason, the ICM felt compelled to again emphasize that realistic schedules should account for resource loading, major milestones, logic ties, critical paths, long lead procurements, and risk-ranked activities. Rather than using achievable unit rates based on past experience at the project, the ICM found that SNC's project schedules were based on unit rates that had never been achieved in the field. This resulted in projected schedule durations that were unachievable as well as overstaffing.

Not long after the go/no-go decision, in mid-June 2018, the ICM assessed that the project schedule through April of that year was still not complete. Specifically, monthly schedules were not adequately resource loaded, were missing or had incorrect activity sequence logic, and contained significant negative float, among other issues (ICM18, page 21). ICM testimony judged that SNC often found itself fighting fires because long-range planning was not effectively identifying upcoming problems with sufficient time and resources to take proper corrective actions.

In late 2019, the ICM again assessed that the project schedule was not realistic or achievable and thus was not a viable management tool (ICM20/21, page 14). This meant once more that it was difficult for stakeholders to determine the true completion status of the project and the work that remained. The ICM judged that the primary reason construction progress was far behind the April 2019 baseline was that the schedule assumptions were too aggressive—from the outset, unit rates were not based on actual, observable historical unit rates. He also noted the use of hard constraints (i.e., keeping the completion date of an activity even though the planned start date of the activity

had been delayed), which was a practice also observed during the EPC period. Specifically, the ICM pointed to the presence of 141 hard constraints in the Unit 3 IPS in June 2020 testimony (ICM22, page 22).

Harsh ICM judgments of the Vogtle project schedule continued even farther into the SNC period.[26] In June 2022, Jacobs noted a surprising revelation that "the Unit 3 schedule continues to be extended at a rate of nearly one month of schedule slippage per calendar month of work on the Unit" (ICM26, page 7). In other words, the project was not getting closer to the start of commercial operations at Unit 3.

Thus, the forecasted dates for Units 3 and 4 to enter commercial operation could not be considered reliable and indeed were often delayed. In his final testimony (ICM29, pages 32–33), the ICM noted the following negative impacts of the unrealistic and unachievable schedule:

- Difficult to determine the project cost and schedule
- Inability of senior management to hold personnel accountable to the schedule
- Promoted a culture of production over quality
- Promoted a culture of poor inspecting or non-inspecting of work
- Inability to efficiently staff activities
- High personnel turnover and absenteeism
- Large backlogs of work scopes
- Large backlogs of work package closures (i.e., completions)
- High first-time component testing failure rates
- Extensive rework and retesting

B. Not Adhering to the NRC's Stringent Quality Assurance Requirements

The ICM assessed that no party to the EPC agreement was initially prepared for the rigor required to develop, implement, and execute a 10 CFR 50 Appendix B quality assurance program and that the lack of preparedness impacted the project for years (ICM17, page 49). For example, ICM testimony in 2017 highlighted seven violations that came out of NRC inspections (ICM17, pages 56–61) and noted that some of the failures were *repeat violations of the same Part 50 Appendix*

B criteria, which indicated a deficient quality assurance program. The ICM also noted that the inability of the contractors to meet the quality assurance requirements resulted in GPC having to step in at its own considerable cost to oversee the quality assurance work (ICM17, page 50).

While the ICM mentioned multiple companies that struggled to execute adequate quality assurance programs for Vogtle (e.g., Specialty Maintenance and Construction, Inc., Cives, Aecon, Westinghouse), testimony focused heavily on problems with the Shaw Modular Solutions (SMS) facility in Lake Charles, Louisiana.[27] SMS was primarily responsible for fabricating structural submodules, which were to be shipped to the site and assembled into full modules (e.g., the CA01 and CA20 modules discussed in Appendix B). Each was made of steel and required an enormous amount of welding to fabricate.

An NRC inspection in November 2011 identified nine Part 50 Appendix B criteria where SMS was deficient. Specifically, the NRC inspection team determined that SMS was not fully implementing its quality assurance program in the areas of training, design control, procurement document control, control of special processes, control of measuring and test equipment, control of nonconforming items, and corrective actions consistent with regulatory and contractual requirements and applicable implementing procedures.

An unannounced NRC inspection in September 2012 again found problems with the quality assurance program. Subsequent NRC inspections in February 2014 and December 2014 also found deficiencies. NRC investigations would even find that multiple instances of willful misconduct had occurred (ICM17, pages 49–73) (examples of willful misconduct would include knowingly falsifying quality control documentation or knowingly violating a procedure). Problems with SMS quality assurance translated to construction delays, one of which is described below.

CA20 Module Fabrication Challenges

ICM testimony detailed quality assurance problems in building one of the large structural modules in the AP1000 nuclear island, the CA20 (see Appendix B for details about the nuclear island and its structures). The CA20 module made up a portion of the auxiliary building and was composed of 72 submodules that were to be manufactured at the Lake Charles facility, trucked to the Vogtle site, welded together in the modular assembly building, and lifted into place by the heavy-lift derrick. The ICM, however, assessed that many of the problems with the procurement and fabrication of CA20 could be traced to the contractor's decision "to fabricate the submodules at a new facility with no nuclear experience" (ICM17, page 71).

According to ICM testimony, as production lagged and schedule pressures grew at the Lake Charles

facility, management there failed to ensure an environment in which workers could bring up safety issues without fear of reprisal (i.e., it was not a "safety conscious work environment"). The NRC issued a violation specifically related to this issue (ICM17, page 72).

Furthermore, ICM testimony assessed that the submodules delivered to the Vogtle site from the Lake Charles facility were of very poor quality and that essentially every one required substantial rework at the Vogtle site to bring it into compliance with the design. Eventually, due to a lack of confidence in the Lake Charles facility, unfinished submodules were brought to the Vogtle site for completion. This added significant time to assemble the full CA20 module. Some fabrication scope for Unit 4's CA20 was shifted to a different supplier, Oregon Iron Works.

Quality Assurance Issues Persisted in the SNC Management Period

Quality assurance continued to be problematic in the SNC management period (ICM29, page 35). As the ICM recounted, SNC had originally chosen to delegate the primary responsibility of the quality assurance programs to the contractors under the EPC agreement. After taking control of the project following the Westinghouse bankruptcy, however, SNC's role was to varying degrees one of oversight of its contractors' quality assurance programs. At the inception of construction, Stone & Webster and Westinghouse had each operated their own quality assurance programs, but by 2012–2013 it was apparent that neither was capable of executing its program.

In the eighth VCM in 2013, GPC requested additional funding from the Georgia PSC for the project, in large part to stand up a quality assurance organization that had the capacity and expertise to develop an integrated corrective action program (ICAP). The intent of the ICAP was to envelop all the contractors' quality assurance programs under one umbrella for SNC to maintain reasonable confidence that quality work was being performed (ICM24, pages 64–65). However, the ICM assessed that management was unable to implement an effective corrective action program.

The quality of the first attempt at something (known as "first time quality"), such as installing a piece of equipment, was so bad at Vogtle 3 that at one point 75% of initial attempts to operate plant equipment failed, and a large percentage of safety-related cabling was installed in violation of requirements (IEEE 384). During the SNC period, a backlog of over 25,000 incomplete construction inspection records was allowed to accumulate, which resulted in a lengthy delay of fuel loading for Unit 3. The ICM judged that these failures were a clear result of an ineffective ICAP that did not identify significant quality issues in a timely manner and did not implement corrective actions to improve quality and prevent recurrence of the issues (ICM29, page 35).

Well into the SNC management period, the ICM noted (in June 2020) that 80% of the components tested did not initially function properly and required some corrective actions to function as

designed, which was far above what would normally be expected. A failure rate of 80% indicated that construction, quality control, and the initial test program had not been doing an adequate job to verify that the components were ready for testing (ICM22, pages 30–31).

In 2021 testimony, the ICM discussed a specific incident where the fuel transfer canal and spent fuel pool had been found to be leaking. Subsequent investigations showed indications of either deficient welding or weld damage (ICM24, page 20). The ICM assessed in the same testimony that the multitude of quality issues and associated rework with the project had delayed the start of hot functional testing, which further delayed the fuel load date (ICM24, page 30).

In March 2021, SNC had to order a sitewide stand down, as it had lost confidence in Bechtel and Bechtel's managed subcontractors' ability to meet required quality standards. Subsequently, SNC initiated greater oversight of the quality assurance program, including having the program report directly to the senior management of SNC (ICM24, pages 66–67).

C. Westinghouse Lacked Sufficient Design Completion and the Design Changed During Construction

The ICM found that many aspects of the AP1000 design were incomplete when construction began at the Vogtle site. The backlog of design detail impacted procurement and construction, and the thousands of design changes in some cases varied from the NRC-certified design and impacted fabricators trying to make components of the design. The ICM said this was one of the major lessons from the early round of nuclear plant construction: the design of the project should be well advanced prior to initiation of construction activities.

The ICM observed that the contractor struggled to keep the plant design ahead of construction. When the combined license for both construction and operation was issued by the NRC in February 2012, only about 40% of the AP1000 standard plant engineering documents had been issued.[28] Almost two and a half years later, the Westinghouse scope of engineering documents was only 75% complete, and the design of the balance of the plant was only 80% complete. Even by mid-2017, the design of the Vogtle 3 and 4 project was not complete—the ICM quoted a monthly project report stating the nuclear island design was 99.6% complete, the balance of plant was 99.6% complete, and the site-specific design work was 92.2% complete (ICM17, page 74–75).

Jacobs judged that late design completion had left insufficient time for the design to be reviewed for constructability, interferences, and other issues prior to clearance for construction, and that this was responsible in part for the many thousands of design changes initiated on the Vogtle project

and contributed to the construction delays.

To try to quantify the issue of design changes, PIA staff requested in September 2016 a list of all engineering design and coordination reports since the inception of the project that impacted the fit, form, and/or function of the design. In response, PIA staff received a list of 12,296 design changes, some of which were made to implement lessons learned from the AP1000 projects in China. However, many changes were made because the original design was found to be not constructible or was otherwise deficient. Jacobs said the "impact on the project of the implementation of more than 12,000 design changes cannot be over emphasized" (ICM17, page 79).

Discrepancies with the Licensing Basis

An incomplete and changing design led to challenges with licensing, too. SNC was using a licensing pathway—10 CFR 52—that had never been used to build US nuclear power plants. All previous US plants had used the original licensing pathway of 10 CFR 50, which was a two-step process: a construction permit application was submitted to the NRC, followed later by an operating license application. That two-step process allowed for the design to be less complete at the construction permit stage since there would be a later review of the completed design at the operating license application stage.

By contrast, 10 CFR 52 is a one-step process where both a construction permit and an operating licensing are issued at the same time (this is known as a combined license [COL]) *and before safety-related construction begins*. Logically, for the regulator to have sufficient information to issue an operating licensing years before the reactor starts operations, a higher level of design detail (specifically, more than to obtain merely a construction permit under Part 50) would be required from the applicant to reach the necessary safety determinations. Moreover, in Part 52, designs are codified in an NRC *rulemaking*, substantially raising the bar for future design changes.[29] Since the Vogtle project used the certified AP1000 design, the licensee was generally not permitted under NRC regulations to deviate from that certified design, though the means and methods for doing so are included in Appendix D of 10 CFR 52.

The assumed date for issuance of the Vogtle COL to support the original commercial operation date of April 2016 for Unit 3 had been October 2011. But certification of the revised AP1000 design was delayed until December 2011, when NRC staff concerns with the design—including the shield building—were resolved.[30] Once the design was certified, the COL could be issued, which happened in February 2012 and authorized the licensee to construct and operate the project in accordance with the AP1000 Design Control Document (DCD).[31] However, as Jacobs explained, the DCD design was conceptual in many areas and did not provide the detail required to construct the plant (ICM17,

page 74). As changes to the AP1000 design accumulated in real time, there was a risk that the as-built reactor would no longer conform to the NRC-certified design details.

First Nuclear Concrete Issues

In one instance, changes to design contributed to a substantial delay in the pouring of concrete for Unit 3's basemat, the foundation of the nuclear island, which was an activity on the project's critical path. The pouring of this massive slab of reinforced concrete is often referred to as "first nuclear concrete" and typically signifies the start of reactor construction (though years of construction activities and billions of dollars can precede this milestone, as they did at Vogtle 3 and 4).

According to ICM testimony, NRC resident inspectors discovered there was a discrepancy between the installed rebar in the basemat area and the design basis (i.e., the DCD).[32] As a result, significant amounts of installed rebar had to be removed, re-procured, and reinstalled. In addition, ICM testimony recounted how SNC had to submit three license amendment requests to the NRC to change the detailed rebar design in order to meet applicable American Concrete Institute codes (ICM17, pages 77–78). In total, the ICM assessed that the pouring of first nuclear concrete was delayed by 10 months (from May 2012 to March 2013) due to such issues.

D. Other Sources of Delay

In addition to schedule, quality assurance, and design change issues, Jacobs reflected in his last testimony in October 2023 on several other shortcomings during the SNC management period, including the following (ICM29, pages 31–36):

Failure to meet required productivity, and failure of efforts to improve productivity. Management issued numerous productivity improvement plans throughout the project, including a plan discussed in VCM15 that identified 108 separate actions to improve productivity, which the ICM considered ineffective. While Jacobs said these plans occasionally resulted in short-term improvements in productivity, overall they failed to achieve what was necessary to meet project schedules.

Failure to stay in the bulk construction mode before starting commissioning activities. The ICM thought that staying in bulk construction mode until a high percentage of construction was completed was in general the most efficient approach for megaproject construction. For example, in a bulk construction mode, all or the majority of the cables that go through a particular area would be installed at the same time. However, when the Vogtle 3 and 4 project focused on system completion and testing, individual cables were installed to specific equipment that then required early testing. Jacobs considered this approach much less efficient than installing all of the cables in bulk first.

Extensive use of the Partial Release for Test (PRT) process. As part of an attempt to begin testing equipment prior to turning it over from the construction team to meet major milestones, a "partial release for test" process was developed. This process allowed for jurisdictional control of plant equipment to be temporarily transferred to an initial test program (ITP) group and then transferred back to construction when the testing was finished. Jacobs said this approach created significant administrative issues due to the massive amounts of paperwork it generated.

The PRT process was also disruptive for construction at the site, as the ITP group's priorities were different than those of the construction team. In addition, the PRT process forced construction out of bulk construction mode to allow for testing of individual pieces of equipment. The ICM assessed that the PRT process had been developed to try to meet unrealistic major schedule milestones.

Failure to prioritize completion of planned work in the most efficient sequence and prioritizing completion of major milestones with the bare minimum of required equipment operational. In the ICM's view, the decision to reach major milestones in a minimal configuration (i.e., not truly complete) resulted in lengthy durations between milestones as remaining required construction was completed. Jacobs cited several durations between milestones on Unit 3 (including between cold hydro testing to the start of hot functional testing [191 days], completion of hot functional testing to the 103(g) letter [371 days], and the 103(g) letter to fuel load [71 days]), saying they were much longer than planned and two or three times the durations experienced on Unit 4. Unit 4's progress was quicker because its project management had employed lessons from the first experience to stay in bulk construction as long as possible, keep use of the PRT process to a bare minimum, install cables in accordance with requirements, and sign off inspection records as work was completed.

In addition to the factors highlighted in this chapter from the 2017 and 2023 testimonies, Jacobs discussed separate contributors to project challenges, including contractual dynamics (e.g., contract structure, litigation, and impacts from the Westinghouse bankruptcy),[33] the shuffling between four different construction entities (Shaw, CB&I, Fluor, and Bechtel) over the course of the project, fallout from the COVID-19 pandemic, and difficulties with attracting and retaining workers.[34] However, given that issues related to project schedule and quality assurance persisted in the SNC management period, and that earlier design changes to the AP1000 post-construction caused significant bottlenecks, these three primary sources of delay deserve particular attention when considering future US reactor builds.

3. Lessons Learned for Future US Reactor Builds

While multiple lessons can be gleaned from the Vogtle 3 and 4 experience for reactor developers and utilities considering new builds, this chapter discusses lessons that correspond to the three primary sources of delay identified by the ICM (highlighted in Chapter 2).

A. Require a Complete Level 3 IPS with Realistic, Achievable Inputs

The ICM said that managing a complex, large-scale construction project like Vogtle Units 3 and 4 without an effective IPS was not prudent project management, nuclear or otherwise. The lack of such an IPS was also in violation of requirements in the EPC agreement as well as the nuclear industry's own self-funded INPO principles for nuclear project construction.

If utilities are to bear schedule risks in the future, they should require a transparent, complete, fully loaded Level 3 IPS with realistic inputs at the earliest stages of the project. To ensure it is realistic, they might also consider having the IPS reviewed by a third party to assess whether the activity resources (materials, worker hours, etc.) and durations are sound. Doing so at an earlier point would make it easier for a utility to walk away from a project if the schedule is found to be unrealistic or if a revised schedule shows unacceptably longer timelines and greater costs.

To use the Vogtle 3 and 4 example, the ICM testified that if an IPS with the qualities detailed by INPO had been produced in the early years of the project, it likely would have shown that greater time would be needed to reach commercial operations. That longer schedule probably would not have met GPC's stated timeline for needed power, and a more realistic estimate of the cost to complete the project probably would not have been competitive with a natural gas combined cycle plant.

Using an EPC experienced in nuclear construction from the outset should mitigate this particular issue somewhat. It is unlikely that a skilled construction management organization would begin a nuclear power plant project without an integral management tool such as a Level 3 IPS. For example, Bechtel recommended in its 2016 report on the V.C. Summer Units 2 and 3 project in South Carolina that a new, more achievable project schedule be created as a top priority.[35]

B. Require Strong Quality Control Measures Early and Use Suppliers That Have Experience with Nuclear-Grade Manufacturing

Given the widespread and lasting problems with quality control on the Vogtle 3 and 4 project, utilities considering reactor builds could lean into the issue earlier and more strongly than SNC did. As the ICM testified in 2017, it was known or knowable that quality assurance would be a significant challenge to the Vogtle project for several reasons, including a 30-year nuclear construction hiatus in the United States and a corresponding need to re-establish the commercial nuclear supply chain (ICM 2017, page 52–53).

Utilities should understand that the NRC does not allow the abrogation of responsibility for the quality assurance program simply because a contractual agreement between the licensee (i.e., the utility) and its contractors may say so. As Jacobs explained, even though the EPC contract for Vogtle 3 and 4 designated the contractor as solely responsible for meeting the requirements of 10 CFR 50 Appendix B, it was still incumbent upon the licensee, SNC, to ensure that the contractors were sufficiently prepared to deploy and administer a quality assurance program that met NRC requirements.

Years after the EPC contract was signed, SNC did ultimately ramp up its oversight and compliance group to fill the gap between the level of adherence the contractor could perform and Appendix B requirements. Along the way, the NRC had even suggested that the company develop an integrated corrective action program that would provide the company with visibility of quality issues facing the entire project, including from vendors. Utilities in the future could start such efforts at an earlier point and perform intrusive inspections and audits of all safety-related work on a given project.

In addition, some suppliers to the Vogtle 3 and 4 project struggled with quality assurance more than others. As Jacobs observed in 2014, valuable lessons could be learned from contracting with the new Lake Charles facility that had no previous nuclear experience and was clearly not prepared for the rigor of nuclear construction. On the other hand, Newport News Industrial (from a family of companies with substantial experience working on nuclear-related projects for the US Navy) fabricated the shield building panels for Vogtle 3 and 4 that the ICM assessed to be quality compliant. Performing due diligence to ensure that vendors have demonstrated nuclear-grade manufacturing experience would reduce the risk of another Lake Charles debacle.

C. Require Higher Design Completion at the Start of Construction and Consider Using the Two-Part Licensing Pathway for First-of-a-Kind (FOAK) Deployment

Starting the construction of any megaproject with an immature design has long been identified as a contributor to construction delays.[36] Inversely, having a mature design at the outset of construction has been cited as an important component of successful FOAK nuclear power plant deployments.[37]

The use of 10 CFR 52—a licensing pathway for both construction and operation that had never before been used for nuclear power plants in the United States—added challenges for a construction project using a reactor design with low design completion. As the ICM noted, building a nuclear plant to specifications under 10 CFR 52 requires more diligence than building under a Part 50 construction permit because the contractor and licensee have to ensure that the plant is constructed in accordance with the certified design. For Vogtle, evolving design changes led to a situation where the consortium had built something that no longer conformed with the design that had been certified by the NRC.

This was the first use of Part 52 to build a US reactor, and therefore the learning curve was likely steep for both the applicant and the NRC. The experience showed that this pathway is not optimal for designs that remain in flux. For an applicant to get an operating license from the NRC years in advance of operation, a higher degree of design information is required by the regulator, and the applicant cannot change safety-related portions of it during construction without applying for a license amendment from the NRC. Part 52 may, however, be suitable for future AP1000 builds if the design remains the same, as well as for others for which designs have been certified by the NRC and whose construction conforms to what has been approved.

Otherwise, the two-step Part 50 licensing pathway benefits from a first step—issuing the construction permit—that does not require as much design specificity as is needed when securing both construction and operating licenses at the start. The second step in Part 50—an operating licensing application—requires a higher degree of design specificity but occurs at a later point, which allows time for the design to reach greater completion. Most of the applications submitted to the NRC in recent years for FOAK reactor deployment (from, for example, Kairos Power, Abilene Christian University, TerraPower, and X-energy) have been for construction permits under Part 50.[38] Thus, this lesson appears to have already been learned by industry.

4. Conclusions

Few emerged unscathed from the Vogtle 3 and 4 project: ratepayers in Georgia were charged billions of dollars more than they were initially promised; GPC stockholders absorbed billions of dollars in costs; Westinghouse went bankrupt and its parent company, Toshiba, lost billions of dollars; and CB&I took a loss of over a billion dollars to escape the project.

While past publications have listed many factors contributing to Vogtle's delays,[39] this report focuses on the three primary sources identified by the ICM, which deserve emphasis as part of future reactor builds given Jacobs's extensive industry background and unique vantage point throughout the project's evolution.

ICM testimonies on the Vogtle 3 and 4 project schedule raise many questions: Did the consortium internally possess what it considered to be a credible Level 3 IPS that gave it confidence that Units 3 and 4 could be built in four years? If so, how did the timeline diverge so greatly when it came to actual implementation? If the consortium did not possess such an IPS, how was consortium leadership assessing the risks of proceeding with the project under a firm/fixed contract? Since new AP1000 builds in the United States are now estimated to take on the order of 6.5–8 years, it is impossible to view Vogtle's four-year schedule for a FOAK build as credible. Unfortunately, given the lawsuits, the criminal proceedings in South Carolina over the canceled AP1000s there, reputational damage to companies and individuals, as well as the billions of dollars either lost by companies or charged to ratepayers, it may be very difficult to get the answers to these questions from the key decisionmakers involved in the project.

One way of looking at the history of the Vogtle Units 3 and 4 project is that it was continually beset by delays compared to its projected schedule. But another perspective is that the schedule was not reasonable in the first place, and some of the "delays" were instead reality catching up to a schedule that was not carefully built to the nuclear industry's own standards.

Issues with project schedules could certainly emerge with future AP1000 projects, but if an EPC experienced in nuclear construction is managing the project from start to finish, the project IPS will likely be much more reliable than what Vogtle 3 and 4 depended on. Using suppliers with demonstrated nuclear-grade manufacturing experience could also help future AP1000 builds avoid the delays Vogtle 3 and 4 faced in tapping the novice Lake Charles facility to fabricate submodules.

Finally, the now-completed AP1000 design will help future builds avoid the impacts on procurement and construction from an immature design that underwent over 12,000 changes during Vogtle 3 and 4 construction. In addition, there should not be nearly as many licensing issues in a future build,

such as the 10-month delay in pouring first nuclear concrete due to a discrepancy between the certified design and what the consortium was building. Nowhere near the 200 license amendment requests should occur in a future AP1000 build.

Each of the three primary sources of delay could pose challenges to non-AP1000 reactor builds in the future, though utilities and reactor vendors involved in those projects have the opportunity to learn from the Vogtle 3 and 4 project and mitigate those challenges. A new report from the Nuclear Energy Institute (NEI) on lessons learned and best practices for new nuclear power plant construction is both consonant with the observations of the ICM and delves into many other construction management topics as well.[40]

The calamitous experience of the Vogtle 3 and 4 project will need to be avoided in the future if new reactors are to become a growing part of the US energy mix. Getting a nuclear plant built cost-effectively and on time will be especially consequential as reactors compete with alternative energy sources in varying policy and public acceptance environments in the United States.[41]

Appendix A: VCM Reports and ICM Testimonies

Vogtle Costruction Monitoring reports (VCMs) order	Date	Independent construction monitor (ICM) testimony order	People testifying	Date
VCM1	08/31/2009	ICM1	William R. Jacobs Jr., PhD Tom J. Newsome, PE, CFA Philip M. Hayet	12/02/2009
VCM2	03/01/2010	ICM2	William R. Jacobs Jr., PhD	06/18/2010
VCM3	08/31/2010	ICM3	William R. Jacobs Jr., PhD	12/10/2010
VCM4	02/28/2011	ICM4	William R. Jacobs Jr., PhD	06/09/2011
VCM5	08/31/2011	ICM5	William R. Jacobs Jr., PhD	12/02/2011
VCM6	02/28/2012	ICM6	William R. Jacobs Jr., PhD	06/30/2012
VCM7	8/31/2012	ICM7	William R. Jacobs Jr., PhD	12/07/2012
VCM8	02/28/2013	ICM8	Steven D. Roetger William R. Jacobs Jr., Phd	08/08/2013
VCM9&10	02/28/2014	ICM9&10	Steven D. Roetger William R. Jacobs Jr., Phd	06/20/2014
VCM11	8/28/2014	ICM11	Steven D. Roetger William R. Jacobs Jr., Phd	11/21/2014
VCM12	02/27/2015	ICM12	Steven D. Roetger William R. Jacobs Jr., Phd	06/10/2015
VCM13	08/28/2015	ICM13	Steven D. Roetger William R. Jacobs Jr., Phd	11/20/2015
VCM14	02/26/2016	ICM14	Steven D. Roetger William R. Jacobs Jr., Phd	06/17/2016
VCM15	08/31/2016	ICM15	Steven D. Roetger William R. Jacobs Jr., Phd	11/17/2016
VCM16	02/28/2017	ICM16	Steven D. Roetger William R. Jacobs Jr., Phd	06/08/2017
VCM17	08/31/2017	ICM17	Steven D. Roetger Ralph C. Smith William R. Jacobs Jr., PhD	12/01/2017
VCM18	02/28/2018	ICM18	Steven D. Roetger William R. Jacobs Jr., Phd	06/06/2018

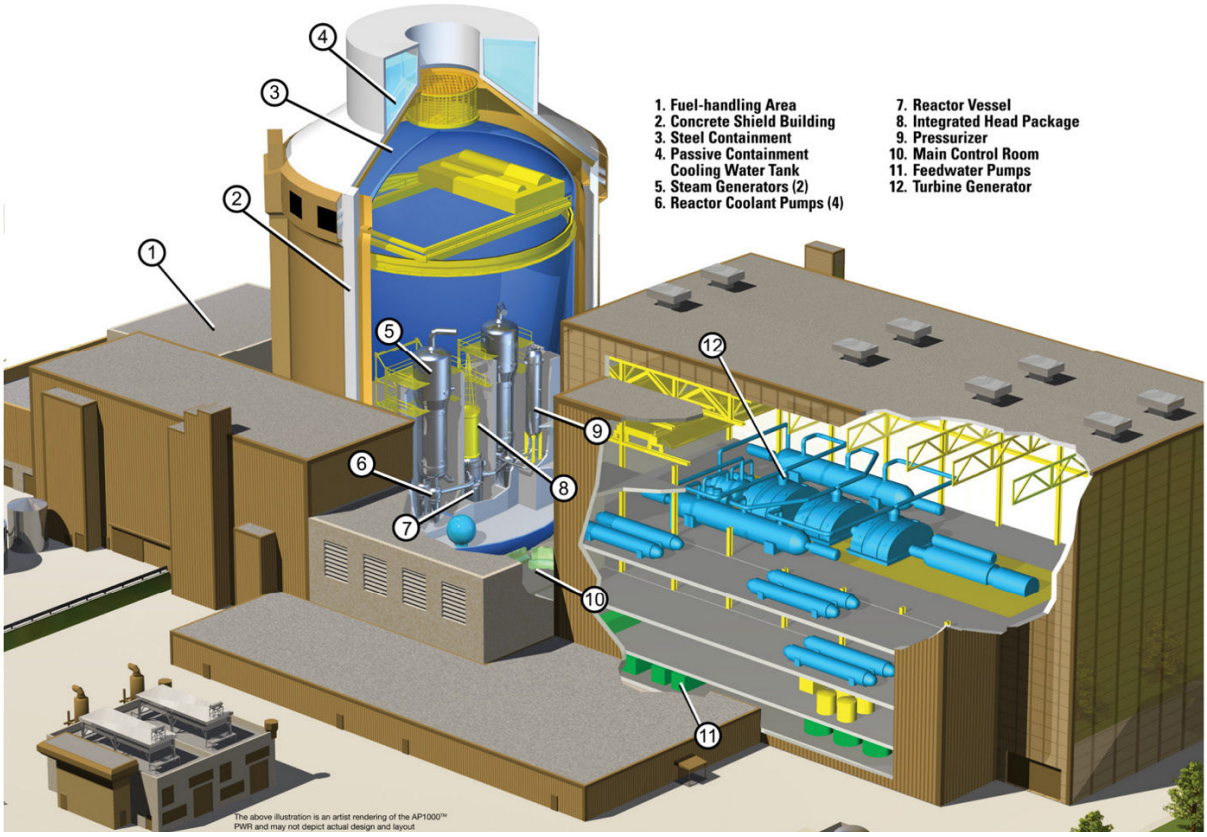
Vogtle Costruction Monitoring reports (VCMs) order	Date	Independent construction monitor (ICM) testimony order	People testifying	Date
VCM19	08/31/2018	ICM19	Steven D. Roetger William R. Jacobs Jr., Phd	11/30/2018
VCM20&21	08/30/2019	ICM20&21	Steven D. Roetger William R. Jacobs Jr., Phd	11/22/2019
VCM22	02/19/2020	ICM22	Steven D. Roetger William R. Jacobs Jr., Phd	06/05/2020
VCM23	08/31/2020	ICM23	Steven D. Roetger William R. Jacobs Jr., Phd	11/24/2020
VCM24	02/18/2021	ICM24	Steven D. Roetger William R. Jacobs Jr., Phd	06/07/2021
VCM25	08/31/2021	ICM25	Steven D. Roetger William R. Jacobs Jr., Phd	12/01/2021
VCM26	02/17/2022	ICM26	Steven D. Roetger William R. Jacobs Jr., Phd	06/17/2021
VCM27	08/31/2022	ICM27	Steven D. Roetger William R. Jacobs Jr., Phd	01/03/2023
VCM28	02/16/2023	ICM28	Steven D. Roetger William R. Jacobs Jr., Phd	06/22/2023
VCM29	08/30/2023	ICM29	Steven D. Roetger William R. Jacobs Jr., Phd	10/27/2023
VCM30	02/15/2024			
VCM31	08/30/2024			

Note: The ICM's service ended after VCM29, so there are no testimonies on VCM30 and VCM31. All ICM testimonies can be found on the Georgia Public Service Commission website (https://psc.ga.gov/) under docket number 29849.

Appendix B: AP1000 Nuclear Island and Select Modules

The AP1000 power block complex (see Figure 2) consists of five principal building structures: the nuclear island, the turbine building, the annex building, the diesel generator building, and the radwaste building. Each of these building structures is constructed on individual basemats.[42] The focus of this report is on the nuclear island because this is where the critical path for the Vogtle 3 and 4 project ran during construction. Therefore, this appendix will describe the nuclear island in greater detail and in particular will discuss modular construction, especially as applied to some of the structures in the nuclear island, as these structures are discussed in the body of the report.

Figure 2: AP1000 plant layout



Source: Westinghouse.

A. The Nuclear Island

The nuclear island is structurally designed to meet seismic requirements defined by the NRC. It consists of a freestanding steel containment building, a concrete shield building, and an auxiliary building. The foundation for the nuclear island is an integral basemat which supports these buildings. The nuclear island structures are designed to withstand the effects of natural phenomena such as hurricanes, floods, tornados, tsunamis, and earthquakes without loss of capability to perform safety functions. The nuclear island is also designed to withstand the effects of postulated internal events such as fires and flooding without loss of capability to perform safety functions.

Containment Building

The containment building is the containment vessel and the structures within the containment vessel. It is designed to house the reactor coolant system and other related systems and provides a high degree of leak tightness. Its functions are containing the release of airborne radioactivity following design basis accidents (postulated accidents based on the design) and providing shielding for the reactor core and the reactor coolant system during normal operations. The containment vessel is also an integral part of the passive containment cooling system. The containment vessel and the passive containment cooling system are designed to remove sufficient energy from the containment to prevent the containment from exceeding its design pressure following specified accidents.

Shield Building

The shield building is the structure that surrounds the containment vessel. During normal operations, a primary function of the shield building is to provide shielding for the containment vessel and the radioactive systems and components located in the containment building. Another function of the shield building is to protect the containment building from external events. The shield building protects the containment vessel and the reactor coolant system from the effects of tornadoes; during accident conditions, the shield building provides the required shielding for radioactive airborne materials that may be dispersed in the containment, as well as radioactive particles in the water distributed throughout the containment. The shield building is also an integral part of the passive containment cooling system.

Auxiliary Building

The primary function of the auxiliary building is to provide protection and separation for certain mechanical and electrical equipment located outside the containment building. The auxiliary

building provides protection for safety-related equipment against the consequences of either a postulated internal or external event. The auxiliary building also provides shielding for the radioactive equipment and piping that is housed within the building. The most significant equipment, systems, and functions contained within the auxiliary building are the following:

- Main control room
- Class 1E instrumentation and control systems
- Class 1E electrical system
- Fuel handling area
- Mechanical equipment areas
- Containment penetration areas
- Main steam and feedwater isolation valve compartment

B. Modular Construction

Modular construction was a key component of the AP1000 build strategy. As described by Westinghouse, it was key to supporting delivery certainty for the construction of the plant and allowed tasks traditionally performed in sequence to be completed in parallel.[43] Factory-built modules would be installed at the site in a planned schedule, which was supposed to lead to increased safety, schedule predictability, and improved quality.

Several types of modules were used in the AP1000 plant construction: structural, piping, mechanical equipment, and electrical equipment. Within the first category, there were several types of structural modules, including those that comprised walls and steel stairways. The wall structures, such as CA01 and CA20, were steel formwork modules that were to be filled with concrete after they were installed.

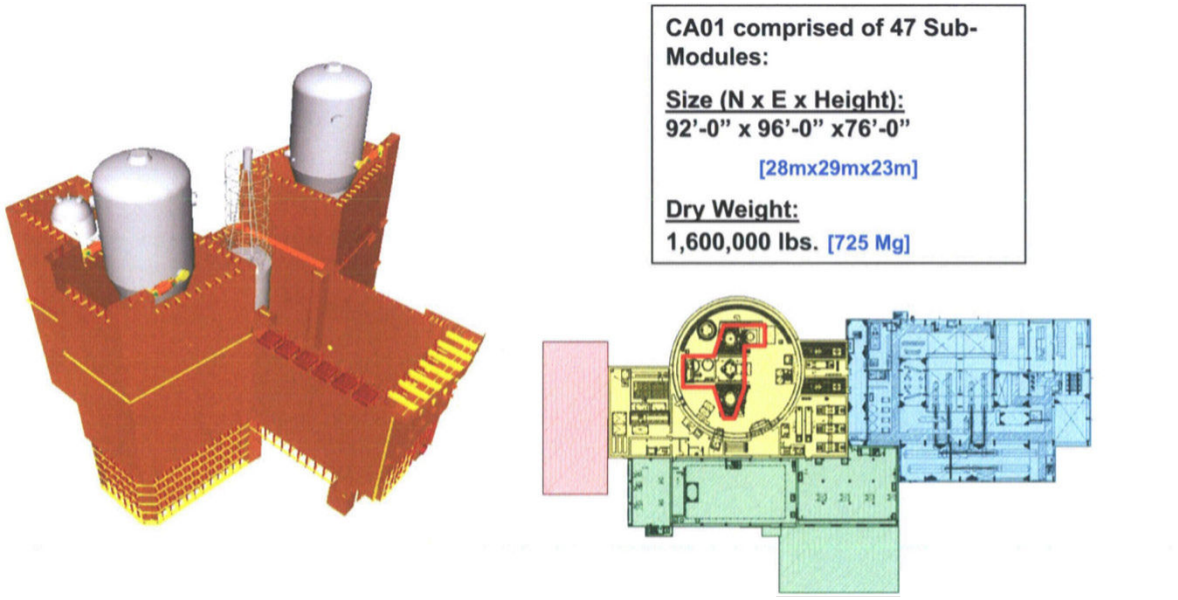
Between the nuclear islands for Units 3 and 4 was a heavy-lift derrick—one of the largest cranes in the world, which was able to rotate 360 degrees in order to serve both Units 3 and 4.[44] The derrick was used to lift heavy components such as the reactor pressure vessel, steam generators, and containment ring sections into place for each unit. Separate from the nuclear islands was the module assembly building (MAB), where large structural modules such as CA01 and CA20 were assembled from the smaller modules that had been fabricated offsite (e.g., at the Lake Charles facility in Louisiana). After assembly, they were moved to the heavy-lift derrick and lifted into place.

The CA01 and CA20 structural modules and the shield building were all large structures that at one point in time were on the critical path for the project. They are discussed in greater detail below.

CA01

CA01 module was a massive, structural module that housed several major components within the containment structure, including the reactor pressure vessel, steam generators, and the pressurizer. It was built in the MAB from 47 submodules that had been shipped to the site. After assembly in the MAB, the CA01 module measured 24 meters long, 29 meters wide, and 24 meters high, with a weight of over 1,000 tons.[45] After assembly in the MAB, it was moved to and lifted into position by the heavy-lift derrick. The CA01 module and its location are shown in Figure 3.

Figure 3: CA01 module and location

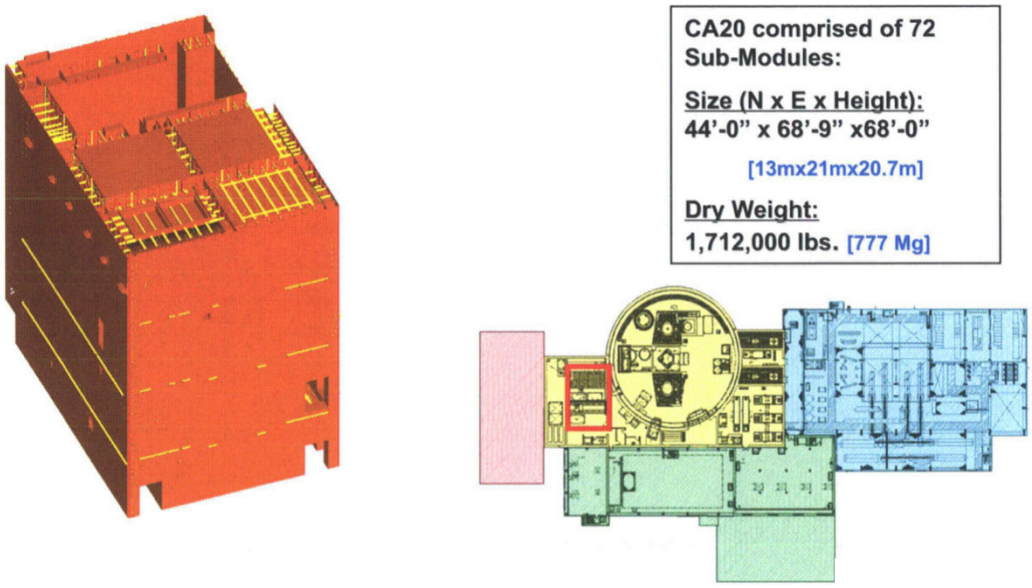


Source: Westinghouse.

CA20

The CA20 structural module was similarly a massive prefabricated steel structural module. It was part of the auxiliary building and housed various plant components, including the spent fuel storage area.[46] The module was assembled in the MAB from 72 submodules and then lifted into place by the heavy-lift derrick. Once installed and filled with concrete, CA20 provided the structural framework needed to support auxiliary mechanical and electrical systems and enabled continued vertical construction adjacent to containment and shield building structures.[47] The CA20 module and its location are shown in Figure 4.

Figure 4: CA20 module and location



Source: Westinghouse.

Shield Building

The shield building consisted of more than 160 individual steel panels weighing from 90 to 150 tons.[48] The roof of the shield building measured 41 meters in diameter and 11 meters in height.[49] The panels were fabricated by a Newport News facility in Virginia and were placed around the containment vessel and subsequently filled with concrete, creating a robust structural barrier.[50]

Appendix C: AP1000 Nuclear Island and Select Modules

The following are INPO-defined IPS attributes:

1. Schedules are developed to reflect realistic (achievable) engineering, procurement, manufacturing, fabrication, construction, and start-up durations. A realistic schedule accounts for resource loading, major milestones, logic ties, critical paths, long lead procurements, and risk-ranked activities.
2. Schedules allow for worker orientation, training, and skill verification.
3. Schedule adherence is emphasized to minimize the risk from out-of-sequence activities.
4. Schedules are integrated and used to ensure effective coordination of activities among all organizations.
5. Schedules are maintained to reflect the best available information. They are reviewed periodically by key stakeholders, and key milestones are identified and communicated throughout all involved organizations.
6. Schedules are used as a forecasting tool to ensure sufficient resources, equipment, and materials are available to meet the schedule. Impacts on resources are identified, analyzed, and addressed; for example, the availability of skilled labor or additional resources needed to compensate for unanticipated delays.
7. Resource plans address mobilization and demobilization. Contingency plans are developed to address the turnover of skilled personnel needed to complete the project appropriately.
8. High-risk activities are identified in the schedule and are planned carefully. Additional oversight and contingency plans are developed, where appropriate.
9. Metrics are developed, and performance is evaluated as a tool to monitor project health (ICM17, page 44).

Notes

1. The White House, "Ordering the Reform of the Nuclear Regulatory Commission," Executive Order 14300, May 23, 2025, https://www.whitehouse.gov/presidential-actions/2025/05/ordering-the-reform-of-the-nuclear-regulatory-commission/.

2. The ICM's formal duties were to assist the Public Interest Advocacy (PIA) staff in providing regulatory oversight over all aspects of the project and to keep the Georgia PSC informed of significant project issues or changes in the projected cost and schedule as they occurred. Among other activities, he reviewed weekly metric and monthly project status reports by GPC, monthly engineering, procurement, and construction (EPC) status reports, GPC's semiannual Vogtle Construction Monitoring (VCM) reports, correspondence between the NRC and GPC, and correspondence between GPC and the consortium. He also participated in Nuclear Regulatory Commission (NRC) public meetings as well as touring and witnessing construction activities at the site. Dr. Jacobs had over 35 years of experience in a wide range of activities in the electric power generation industry, including extensive experience in the construction, start-up, and operation of nuclear power plants; he had worked at the Institute of Nuclear Power Operations (INPO), Westinghouse, and Southern Nuclear Engineering; his areas of expertise included evaluation of reactor technology, EPC contracting, risk management and mitigation, and project cost and schedule; he had evaluated combustion turbine projects (i.e., nonnuclear power projects) and nuclear power construction projects; and he had assisted with the start-up of several reactors in and outside the United States.

3. Other PIA staff at times testified in tandem with Jacobs. Most prominently, Steven Roetger, a PIA staff member, testified 20 times with Jacobs. For simplicity, and given that Jacobs was the technical lead and testified in every case, these testimonies are collectively referred to as ICM testimonies.

4. The description of these periods is found in ICM29, for example.

5. GPC, *Engineering, Procurement and Construction Agreement for Vogtle Electric Generating Plant Units* 3 and 4, April 8, 2008, U.S. Securities and Exchange Commission, https://www.sec.gov/Archives/edgar/data/3153/000009212208000048/x10c1.htm.

6. Preceding the signing of this contract, GPC had filed its 2007 Integrated Resource Plan (IRP) on January 31, 2007, which identified a need for baseload generation in 2016 and 2017. In this filing, GPC evaluated nuclear power as a baseload option. The Georgia PSC issued an order on July 13,

2007, approving GPC's IRP. GPC issued a request for proposals for baseload power in the 2016 and 2017 timeframe. The two Westinghouse AP1000 reactors at the Vogtle site were the only bids submitted.

7. Georgia PSC, *Application of Georgia Power Company for Certification of Vogtle Electric Generating Plant Units 3 and 4 and Updated Integrated Resource Plan*, Docket No. 27800, August 1, 2008, https://psc.ga.gov/facts-advanced-search/document/?documentId=113519.

8. Georgia PSC, "PSC Approves Agreement to Allow Construction of New Units at Vogtle Nuclear Power Generation Plant; Approves Conversion of Plant Mitchell to Biomass," News Release No. 7-09. March 17, 2009. https://www.psc.state.ga.us/newsinfo/releases/2009/20090317-b.pdf.

9. US NRC, *Combined Licenses for Vogtle Electric Generating Plant, Units 3 and 4 (License Nos. NPF-91 and NPF-92)*, February 10, 2012, https://www.nrc.gov/docs/ML1133/ML113360395.pdf.

10. GPC, *Ninth/Tenth Semi-Annual Vogtle Construction Monitoring Report*, Docket No. 29849, February 2014, 10.

11. See GPC, *Application for Review and Approval of the Definitive Settlement Agreement*, Docket No. 29849, January 21, 2016, for background on the DSA.

12. CB&I, *Form 10-K for the Fiscal Year Ended December 31, 2013*, February 27, 2014, U.S. Securities and Exchange Commission, https://www.sec.gov/Archives/edgar/data/1027884/000102788414000003/a2013123110k.htm.

13. Westinghouse would later try (unsuccessfully) to sue CB&I on account of these liabilities. Sonal Patel, "Court Dismisses Westinghouse Claim for $2B Recovery from CB&I," *Power Magazine*, June 29, 2017, https://www.powermag.com/court-dismisses-westinghouse-claim-for-2b-recovery-from-cbi/.

14. Westinghouse's original scope of work had included the procurement of most major components for the nuclear steam supply system and some turbine building components, so in this context, additional procurement represents the balance of procurement.

15. ICM17 listed several risks to the project: many of Westinghouse's subcontractors, including Fluor, had not been paid for a period of time, even prior to the bankruptcy; many of the skilled craft personnel working on the project were from other parts of the country and would soon depart if it appeared that their employment and paychecks were in jeopardy; many suppliers of critical parts and material were likely to stop working on equipment in fabrication and stop shipping needed material to the site; and some suppliers had already asked that the project return material that was already at the Vogtle site.

16. The PIA is a group of professional staff within the PSC that represent and protect the interests of utility customers and the general public in regulatory proceedings before the PSC.

17. In ICM17, the risks were listed as: The risk that Toshiba would be financially unable to meet the payment obligations of the Toshiba parent guaranty; the risk that Westinghouse would not meet its obligations under the new Services Agreement; the risk that the labor force and craft would be unable to maintain their productivity improvements (project execution risk); the risk that the project would be unable to continue to meet first-of-a-kind (FOAK) challenges; the risk that Congress would not extend the production tax credits (which at the time were due to expire at the end of 2020); procurement risk; unidentified scope risk; stranded technology risk; testing/start-up risk; and the impact of the V.C. Summer Owners' decision to cease construction on V.C. Summer Units 2 and 3 (the only other AP1000s under construction in the United States at the time, just across the border in South Carolina).

18. Testimony of Tom Newsome, Philip Hayet, Lane Kollen on behalf of the Georgia Public Service Commission Public Interest Advocacy Staff, Docket No. 29849, December 1, 2017.

19. Steven D. Roetger and William R. Jacobs Jr., *Direct Testimony and Exhibits*, before the Georgia Public Service Commission, *In the Matter of Georgia Power Company's Application to Adjust Rates to Include Reasonable and Prudent Plant Vogtle Units 3 and 4 Costs*, Docket No. 29849, October 27, 2023, 9.

20. In support of the EPC contract for Vogtle 3 and 4, Toshiba had provided a financial backstop agreement that was capped at $3.68 billion. GPC's share was $1.7 billion, though some was refunded to customers, which is reflected in the $1.5 billion.

21. Southern Company, *Quarterly Report* (Form 10-Q) for the Quarterly Period Ended March 31, 2018, U.S. Securities and Exchange Commission, May 2018, https://www.sec.gov/Archives/edgar/data/3153/000009212218000027/so_10qx3312018.htm.

22. As the ICM defined it, "Parties" in this context represented the signees to the EPC Agreement: SNC, Westinghouse Electric Company, and Stone & Webster Inc. Westinghouse and Stone & Webster were sometimes referred to as "the Contractor" in ICM testimony.

23. ICM17, page 42. The exact wording has been mildly edited for, e.g., verb tense, brevity, and clarity.

24. Level III Primavera software is specifically mentioned in ICM17 testimony on page 36.

25. By holding the end date constant, in the ICM's view, management was assuming that the same amount of work could be completed in the shorter duration, which might not have been a valid assumption.

26. Other assessments of aggressive and unachievable schedule included: November 2020: "Since inception of the project in 2009, all IPS iterations have been overly aggressive and unachievable" (ICM23, page 9), and June 2021: "History has shown, every iteration of the planned forecast for commercial operation issued by SNC was unachievable" (ICM24, page 65).

27. SMS was changed to CB&I Lake Charles (CB&I LC) when CB&I purchased the Shaw Group.

28. These engineering packages were primarily for the nuclear island, and a similar number of engineering documents were required to complete the design of the balance of the plant.

29. Specifically, under Part 52, a nuclear steam supply system and safety related systems, structures, and components are approved by the NRC, codified in a rulemaking, and a licensee (SNC, in the case of Vogtle 3 and 4), incorporates by reference the approved licensing basis in a COL application.

30. The COL could not be issued until the AP1000 Design Control Document (DCD) was certified, and several concerns had been identified by NRC staff related to the AP1000 design that needed to be resolved, including several issues related to the design of the shield building. As explained by the ICM in 2009, the NRC had promulgated design enhancement requirements to protect against airplane impacts for all newly constructed shield buildings (ICM1). To meet the new requirements, Westinghouse had changed its design of the AP1000 shield building from a technology which had a supportable design basis to a new and untested design basis. Additionally, though the new design defended against airplane impacts, it also raised questions regarding its suitability to protect against possible natural events such as tornadoes and earthquakes. ICM testimony in June 2011 discussed design issues related to the shield building that still had to be resolved, as well as errors in analyses of containment that had been identified, which necessitated corrections and having to redo the analyses (ICM4). In December 2011 testimony, the ICM noted that the technical issues had been resolved and there were no outstanding contentions in the Vogtle licensing proceeding (ICM5).

31. The DCD was a technical description of the AP1000 plant submitted by Westinghouse which had been reviewed and certified by the NRC in a rulemaking. The COL also contained specified inspections, tests, analyses, and acceptance criteria that would be needed prior to operation of the AP1000s. These tests would be to demonstrate that each unit had been designed and constructed according to the approved design.

32. ICM8, page 8 describes the technical details of the design changes the consortium made and how the licensee did not submit a required license amendment request to the NRC to change the design specified in the DCD.

33. In addition to noting the lawsuits between parties to the EPC contract, the ICM observed in ICM29 three specific drawbacks to the contract. First, while the EPC required the consortium to provide an IPS and initially the consortium provided SNC with digital IPS copies of the schedule, the consortium very quickly interpreted the EPC language to mean that only a "hard copy" of the IPS needed to be provided. The copy provided was printed, not digital, which made it very difficult to assess its credibility. Second, another major drawback of the EPC contract was that it assigned all quality adherence to the consortium. This second drawback proved to be problematic from the onset of the project. The third major drawback was that the EPC contract assigned all the means and methods for fulfilling the terms of the contract to the consortium. Thus, SNC was incapable of intervening at critical times. The agreement only permitted SNC to declare the consortium in "default."

34. ICM testimony also discussed challenges both with attracting workers and retaining them. During the SNC management period, for example, the ICM noted that as experienced electricians were transferred from Unit 3 to Unit 4, about 50% chose to leave the project, which he called "an enormous attrition rate." He observed that the planning for Unit 4 assumed that these experienced electricians would be present, and onboarding craft persons with little to no nuclear experience would require a steeper learning curve for those people, who would in turn need greater supervision and would in all likelihood create more re-work than would have been expected from Unit 3 craftspersons (ICM24, page 69).

35. Bechtel, *V.C. Summer Nuclear Generating Station Units 2 & 3: Project Assessment Report*, February 5, 2016, https://dms.psc.sc.gov/Attachments/Matter/72a1472c-5304-4f8c-aaa8-a5103cea03cc.

36. Edward W. Merrow, *Industrial Megaprojects: Concepts, Strategies, and Practices for Success* (Wiley, 2011).

37. MIT Energy Initiative, *The Future of Nuclear Energy in a Carbon-Constrained World*, January 1, 2018, https://energy.mit.edu/research/publications-reports/future-nuclear-energy-carbon-constrained-world.

38. On the NRC webpage for advanced reactor projects, potential deployment of reactors from TerraPower, X-energy, and General Electric are all utilizing the Part 50 licensing pathway. NRC, "Advanced Reactor Application Projects," last updated as of writing on June 18, 2026, https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/applicant-projects.

39. For example, pages 47–51 of DOE's advanced nuclear liftoff report from 2024 discuss seven root causes associated with Vogtle cost and schedule overruns. However, there is no judgment from

DOE as to the relative weight of these different factors in terms of delaying the project.

40. NEI, *Strategic Project Management Lessons Learned & Best Practices for New Nuclear Power Construction* (November 2025), https://www.nei.org/getContentAsset/c2495a20-2e43-4b38-9fb5-ca4e56c0e87c/8d8ff8d6-b2ae-401b-a63c-f6b108e809d2/NEI-20-08-NEI-Construction-Best-Practices-Rev-1-FINAL.pdf?language=en-US.

41. Matt Bowen, Emeka Ochu, and James Glynn, *The Uncertain Costs of New Nuclear Reactors: What Study Estimates Reveal about the Potential for Nuclear in a Decarbonizing World* (Center on Global Energy Policy, Columbia University, December 2023), https://www.energypolicy.columbia.edu/the-uncertain-costs-of-new-nuclear-reactors-what-study-estimates-reveal-about-the-potential-for-nuclear-in-a-decarbonizing-world/.

42. Much of the basic overview material for this chapter, including the nuclear island and building sections, is taken from Chapter 1 of the AP1000 DCD, including sections that are used verbatim from the DCD.

43. Westinghouse Electric Company, "The Art of Innovation: AP1000 Power Plant Modular by Design," July 29, 2016, https://info.westinghousenuclear.com/blog/the-art-of-innovation-ap1000-power-plant-modular-by-design.

44. GPC, "Building Vogtle," April 9, 2026, https://www.georgiapower.com/about/energy/plants/plant-vogtle/units-3-4/building-vogtle.html.

45. Southern Company, "Vogtle Expansion Project Completes Heaviest Lift to Date," August 10, 2015, https://southerncompany.mediaroom.com/2015-08-10-Vogtle-expansion-project-completes-heaviest-lift-to-date.

46. PR Newswire, "2.2 Million Pound CA20 Module Placed into Vogtle Unit 3 Nuclear Island," March 6, 2014, https://www.prnewswire.com/news-releases/22-million-pound-ca20-module-placed-into-vogtle-unit-3-nuclear-island-249319311.html.

47. World Nuclear News, "Modular Milestone for Vogtle 3 Shield Building," March 8, 2016, https://world-nuclear-news.org/Articles/Modular-milestone-for-Vogtle-3-shield-building.

48. PR Newswire, "150-Ton Shield Building Panels Placed at Vogtle 3 & 4 Nuclear Expansion," November 20, 2018, https://www.prnewswire.com/news-releases/150-ton-shield-building-panels-placed-at-vogtle-3--4-nuclear-expansion-300753705.html.

49. Southern Company, "Vogtle Unit 4 Shield Building Roof Set," December 11, 2020, https://southerncompany.mediaroom.com/2020-12-11-Vogtle-Unit-4-shield-building-roof-set.

50. Southern Company, "150-Ton Shield Building Panels Placed at Vogtle 3 & 4 Nuclear Expansion," November 20, 2018, https://southerncompany.mediaroom.com/2018-11-20-150-ton-shield-building-panels-placed-at-Vogtle-3-4-nuclear-expansion.



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