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Drivers of Cost and Risk in Nuclear New Build Reflecting International Experience

For the Nuclear Industry Council's New Build 30% Cost Reduction Working Group

July 2020

Acknowledgements

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Introduction

Nuclear energy has provided about 20% of the UK's electricity with low carbon, secure and reliable baseload power for the last six decades. Significant new nuclear capacity, for both power and ultimately energy, will be needed to meet the UK's carbon reduction commitments at the least cost, whilst also providing the best value.

The UK Industrial Strategy and Clean Growth Strategy identified nuclear energy as having the potential to play a significant role in the UK's transition to a low-carbon economy—provided it is cost competitive and meets a market need. Support for new nuclear was reiterated in the UK Nuclear Sector Deal, which the Government developed in close partnership with the nuclear industry. The Deal confirmed this potential for new nuclear, so long as it represents value for money for consumers and taxpayers. The Deal features ambitious proposals to drive down costs, including the reduction of nuclear new build construction costs by 30%.

The Nuclear Industry Council (NIC) Nuclear Sector Deal (NSD) 30% Cost Reduction Working Group has produced an overarching report demonstrating practical ways in which the industry will deliver upon the cost reduction targets outlined in the UK Nuclear Sector Deal.

In 2018 LucidCatalyst led the Energy Technologies Institute (ETI) Nuclear Cost Drivers Study (NCD).[1] It gathered substantial evidence suggesting that UK nuclear new build has very significant cost and risk reduction potential. The NCD has been widely referenced as demonstrating potential pathways for cost and risk reduction in UK nuclear construction.[2]

The 30% Cost Reduction Working Group therefore commissioned LucidCatalyst to apply the insights gained in the ETI NCD Study to produce this short report as an input to the NIC's overarching report.

This report is organised into the following sections:

- **Context** for why this cost reduction must be achieved for nuclear energy to contribute meaningfully towards the UK net zero ambition
- **Evidence** for achievable cost reduction, including data, and opportunity, for the UK
- **Commitments** by industry to deliver cost reduction
- **Further Action**: Strategies for increasing scale and rate of deployment

1 The summary report can be viewed at: LucidCatalyst (2018), The ETI Nuclear Cost Drivers Project: Summary Report.

2 Cited in the UK Nuclear Sector Deal (2018) and Expert Finance Working Group report: Market Framework for Financing Small Nuclear (2018).

2 Context: Achieving UK Energy Security and Decarbonization Goals

Achieving the UK's net-zero emissions target will be a significant national undertaking. It will require both leadership and strong collaboration among national, regional and local government; innovation and commitment by industries and businesses; and commitment and behaviour change by consumers.

2.1 Legally Binding Commitment to Net-Zero CO_2 Energy Emissions by 2050

Decarbonising the whole economy will require a system-wide perspective that prioritises design of the whole system to deliver the highest possible performance across four metrics/criteria: 1. carbon reduction, 2. reliability, 3. affordability, and 4. flexibility. Most modelling indicates that these system-level performance criteria will most likely be achieved through a diverse portfolio of technologies including renewables, nuclear and carbon capture and storage.

2.2 Decarbonising the Power Sector

In 2019, the Committee on Climate Change identified a need for approximately 150 GW of new clean generating capacity by 2050: the lion's share of which is anticipated to be delivered by offshore wind.

Within this overall target of 150 GW of clean generating capacity, the CCC identified a need for between 30 – 60 GW of firm power by 2050. Nuclear has the potential to make a significant contribution to this requirement for firm low-carbon power.

To do so, nuclear technologies must be cost-competitive with other low-carbon technologies, and also meet the climate change / net zero timeframes. There is strong evidence that a fleet build approach combined with good project management and construction execution, as well as technology innovation, can deliver new nuclear in the UK at significantly lower costs than recently experienced in Europe and the United States.

2.3 A Successful Restart

Through Hinkley Point C (HPC), the industry has made an investment to restart the UK's nuclear industry. HPC is the first nuclear plant to be built in the UK in more than two decades. First-of-a-kind (FOAK) and first-in-a-generation costs and risks are significant: requiring substantial investment to approve the design for UK deployment and to rebuild skills and supply chain capability. However, this does create the potential to significantly reduce the risk and cost of future projects, including through replication of design and series builds.

Global experience consistently demonstrates that investment in first-of-a-kind plants creates a springboard for cost-effective programmes. This investment can also make a significant contribution to a decarbonised power sector, and ultimately to achieving net zero emissions across the whole economy through the decarbonisation of heat, transport and industry. The nuclear industry already sustains almost 60,000 UK jobs and is one of the fastest growing and highest paid employment sectors in the country.

Evidence from nuclear new build programmes around the world also indicates that first-of-a-kind, first-in-a-generation plants represent a major investment in skills and capability. Significant productivity improvements and cost effectiveness can be gained in subsequent projects across the project leadership team, workforce, supply chain, regulators and other stakeholders. The UK now has a window of opportunity to build on its recent investment in HPC to both realise major cost reductions in the delivery of subsequent plants, as well as to sustain and continue to gain socio-economic benefits.

Substantial, measurable progress made through ongoing construction of two units at HPC, and numerous proven examples of successful low-cost programmes in Europe, the United States and the rest of the world, indicate that cost-competitive deployment is highly achievable in the UK today.

Furthermore, the industry has signaled it is ready, willing and able to deliver this ambition.

In Section 3, this report outlines the potential cost reduction that could be achieved as the industry commits to adopting best practices outlined in the ETI NCD Study in order to deliver cost-effective, affordable, reliable and clean power at scale.

3 Evidence: The Potential for Nuclear Cost Competitiveness

The Energy Technologies Institute (ETI) Nuclear Cost Drivers (NCD) Study has been widely referenced as demonstrating potential pathways for cost and risk reduction in UK nuclear construction. One of the notable findings from the study was that low-cost nuclear new build programs have several common characteristics.

Low-cost nuclear new build programs have these common characteristics:

- Design standardisation and reuse
- Deployment of more units per site
- Complete (or near complete) detailed plant design and comprehensive project plan prior to construction
- Highly productive and skilled labour
- Seamless transition of workers and equipment during unit-to-unit construction
- Strong support from government that is clearly committed to the industry's success

Achieving cost reduction requires reducing risk by increasing certainty in schedule and budget. Lower risk and higher overall confidence benefit all stakeholders, including the public and the project developer. Reducing risk also lowers financing costs related to construction, both in terms of increased schedule/budget certainty but also in a reduced risk premium.

Engaging in the right kind of collective action and demonstrating risk reduction by all project stakeholders are critical. These actions can yield lower electricity costs for the consumer, allow the vendor to realise their desired risk-adjusted rate of return, and expand market potential.

Evidence gathered and analysed during the ETI NCD Study suggests that UK nuclear new build has very significant cost reduction potential. The Study concludes that a carefully designed programme that engages all of the key stakeholders with a shared vision and focus on the key characteristics of low-cost, high quality construction can start the UK down the path to affordable nuclear power. And by so doing, it can also significantly increase the UK's chances of meeting its 2050 net zero carbon targets.

3.1 First-of-a-Kind Plants are Expensive

Recent nuclear projects in North America and Europe have been vulnerable to schedule delays and cost increases. By contrast, the majority of recent and current nuclear build projects throughout the rest of the world are highly cost competitive with both fossil fuels and renewables.[1]

1 The majority of recent and current new build projects included in the ETI Nuclear Cost Drivers Study database are successful, low-cost projects.

Figure 1. **Total Capital Costs for Recent and New-Build Nuclear Projects**

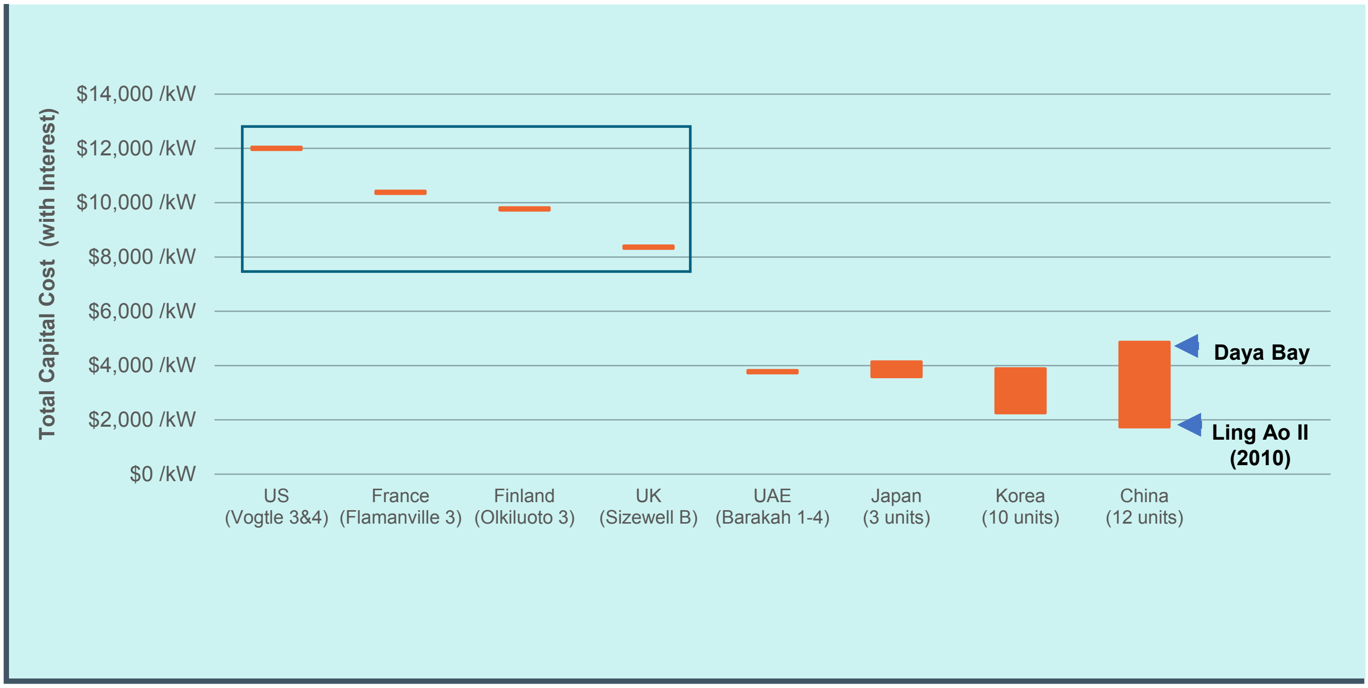
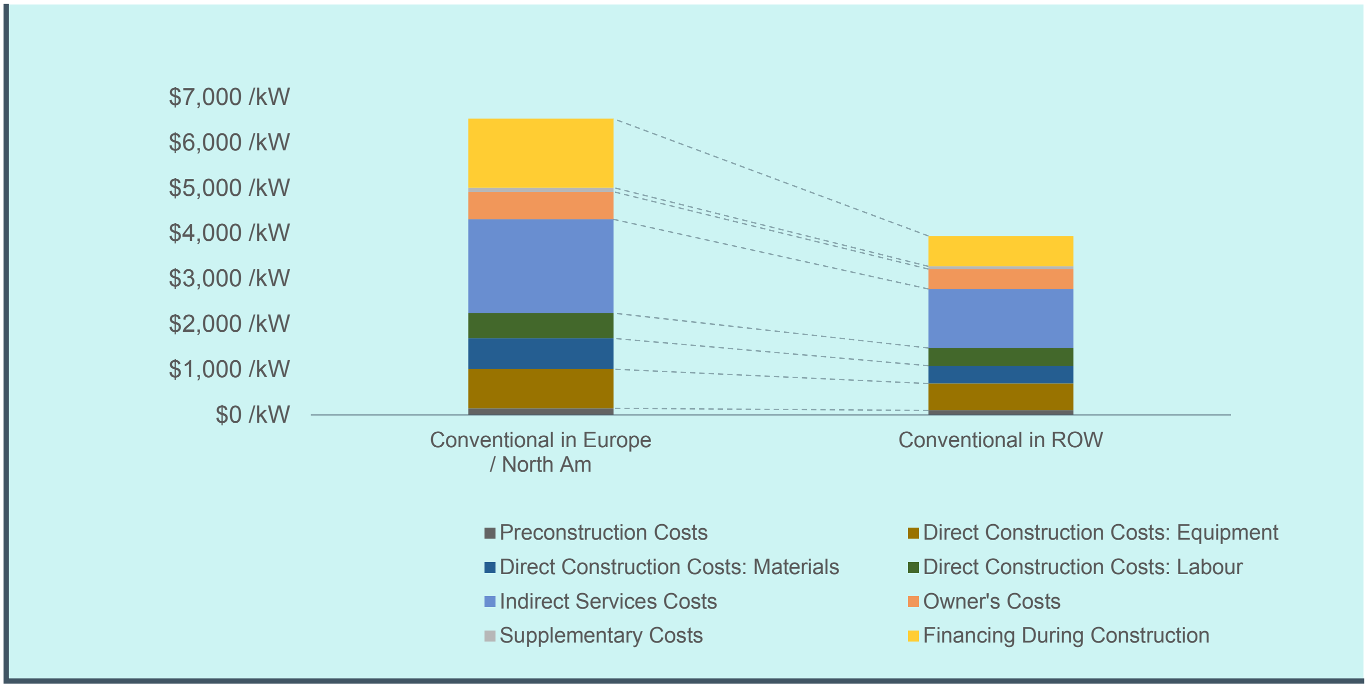


Figure 1 plots a small sample of representative plants from the ETI NCD study cost database, illustrating the wide range of costs in current and recent new build experience around the world. The small sample of the highest cost plants shown here are first-of-a-kind, first-in-a-generation projects being built in Europe and the United States after decades of inactivity in construction. In contrast, the majority at the low-cost end of the scale are nth-of-a-kind units—illustrating the effect that experienced leadership, design standardisation and mature capability can have on reducing cost, as well as reducing risk to budget and schedule.

3.2 Differences Between High-Cost and Low-Cost Projects

Figure 2 contrasts the EU/US light water reactor genre (conventional in Europe and North America) and the Rest of World (ROW) genre. Evidence suggests that a relatively small number of understandable factors drives the cost and risk of nuclear plants and that relatively significant cost reduction is possible, beyond reducing the cost of capital during construction. The cost reductions in Rest of World LWRs demonstrate how a highly focused, deliberate and intentional programme will drive down costs and improve performance over time through consistent, rational implementation of best practices.

Figure 2. **Differences Between High- and Low-Cost Projects**



3.3 Common Characteristics of High-Cost and Low-Cost Projects

The ETI NCD Study demonstrated that a relatively small number of understandable factors drive the vast range of cost outcomes in nuclear construction around the world. The findings suggest a strong correlation between high costs and high scores against the identified cost drivers. In addition, there was a notable consensus amongst experts interviewed for the Study about the key characteristics within projects that drive costs.

Documented experience with successful multi-unit builds and intentional new build programmes in other countries indicate the range of cost savings that could be achievable in the UK context. Key characteristics of low-cost and high-cost new build programmes are strongly supported by evidence from multiple sources and documented experience. Evidence gathered and analysed during the ETI NCD Study suggests that UK nuclear new build has very significant cost reduction potential and that these best practices are highly transferable to the UK context.

Key characteristics of both low- and high-cost projects that were consistently highlighted by multiple sources are summarised in Figure 3 on the following page.

Figure 3. **Common Characteristics of Low- and High-Cost Plants**

Low-Cost Plants	High-Cost Plants
Design at or near complete prior to construction	Lack of completed design before construction started
High degree of design reuse	Major regulatory interventions during construction
NOAK design	FOAK design
Experienced construction management	Litigation between project participants
Low-cost and highly productive labour	Significant delays and rework required due to supply chain
Experienced EPC consortium	Long construction schedule
Experienced supply chain	Relatively higher labour rates and low productivity
Detailed construction planning prior to starting construction	Insufficient oversight by owner
Intentional new build programme focused on cost reduction and performance improvement	
Multiple units at a single site	

3.4 US Historical Track Record Includes a Large Number of Cost-Effective Nuclear Plants

The ETI NCD Study analysed a range of current and recent projects against a ‘benchmark plant’ representing the median experience from the United States fleet build recorded in the US Department of Energy’s Energy Economics Database (EEDB).

Figure 4 on the following page plots this benchmark plant against both current Europe and US experience, and the Rest of World. It is sometimes assumed that low-cost outcomes achieved in China, Japan and Korea, for example, are not transferable to US or EU contexts due to cultural differences and country-specific working practices. However, this assumption is largely not supported by the evidence gathered in the ETI NCD Study. In fact, additional analysis further reveals that previous US best experience (brought up to 2017 dollars, and with a standard interest rate during construction of 7% applied across all units) aligns closely with current Rest of World experience.

This data supports the conclusion that low-cost outcomes in Rest of World plants are indeed transferable to the UK context, particularly if the following characteristics were consistently applied and demonstrated:

- Policy environments strongly affect the cost of building plants (See Figure 5)
- Continuity is critical to maintain skills and supply chain, project leadership and application of learning
- Standardisation of design enables regulatory efficiency, construction planning and supply chain readiness
- Efficient interaction with the regulator drives cost-efficient outcomes
- Investment in and depth of supply chain delivers competitive and high-quality outcomes
- Cost of capital can be reduced when risk is reduced through increased budget and schedule certainty
- Experienced project delivery organizations reduce risk by increasing budget and schedule certainty

Figure 4. **Nuclear Costs: Current Global and Historical Compared with First-of-a-Kind**

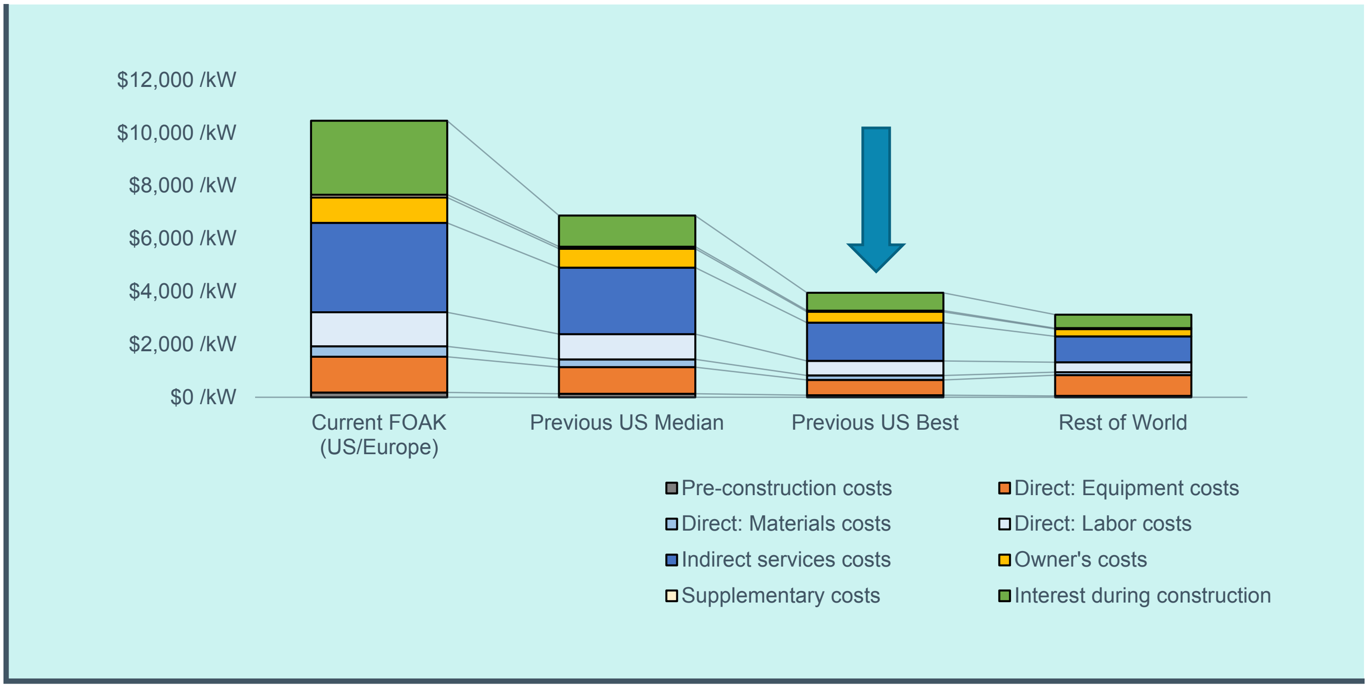


Figure 5. **How Commitment Drives Competitiveness**

Government commits to a consistent nuclear “programme” that includes a coordinated set of activities and policies to promote low-cost nuclear deployment, including low-cost financing.

Government requires that its assistance comes with a set of specific, non-negotiable requirements that ensures developers follow best practices and cost/risk reduction measures (as listed in the ETI NCD Study).

Government and Industry makes major investments in educational, regulatory, and industrial infrastructure related to nuclear and supports highly efficient licensing.

Universities invest in departments to train the next generation of designers, engineers, and managers. Vocational schools begin to train top-notch welders, pipefitters, electricians, technicians, etc.

Government, Industry, Academia and Government-affiliated organisations (Innovate UK, NAMRC, etc.) work with developers to prioritise areas that could benefit from further innovation and application of manufacturing environment (including modularisation and pre-fabrication). This is extended to automating the nuclear Quality Assurance process, to dramatically reduce the cost premium for nuclear quality.

Developers invest in upfront detailed design readiness and constructability review, as far as possible for FOAK, and particularly for SOAK, plants. Plant designs are specifically designed to maximise reuse.

Developers apply for (and are prepared to make the appropriate investments) at least two units at a given site.

Regulator has the necessary resources to perform its duties as efficiently as possible. ONR allows for efficient licensing of reactor designs that are mature and operating safely in other countries.

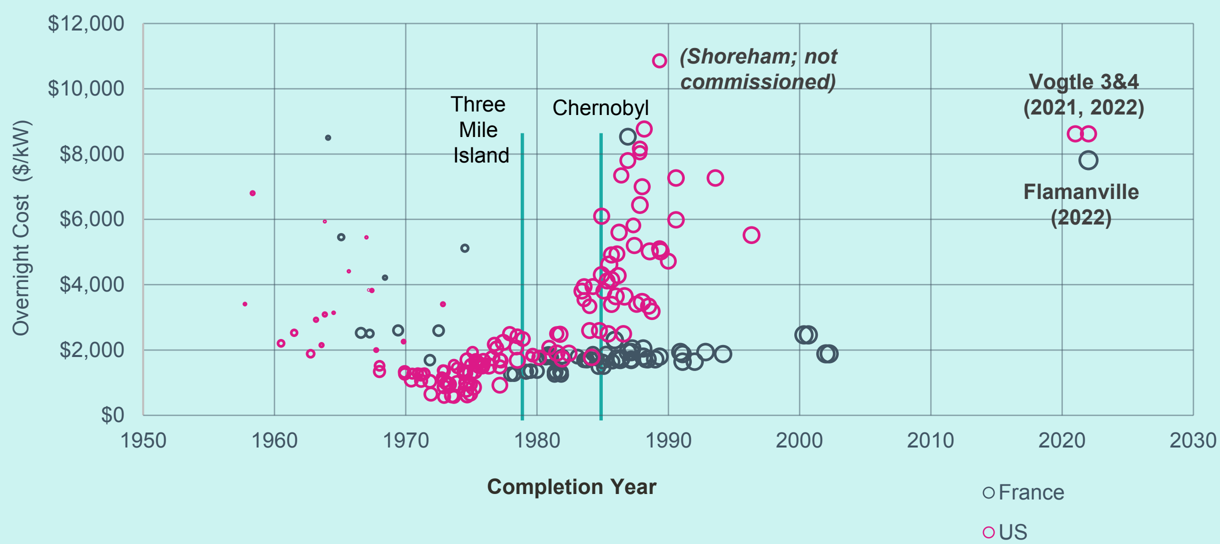
Investment in the supply chain over multiple units strengthens capability and increases competition within the supply chain.

3.5 What Factors Raised the Cost of Nuclear in the Past?

Examining the French and US historical programmes in more detail, it is possible to identify the key drivers that led to dramatic spikes in otherwise relatively low-cost construction cost. Following the accidents at Three Mile Island and Chernobyl, plants that were in construction at that time were paused for extensive regulatory review, leading to escalating costs. The conclusion is that regulatory interventions during construction drive schedule delays and higher costs. Figure 6 shows a gap of decades before new build is attempted again, requiring substantial investment to enable inexperienced regulators, supply chain, work force and project leadership to deliver the first complex, highly regulated major infrastructure project of this kind in a generation. Key factors driving cost in these projects include:

- Regulations and standards changed during construction
- Every plant built with different vendors, design, EPCs, etc.
- Construction started with incomplete design
- Waited 25 years before building the next plant
- No cost-benefit analysis performed for safety requirements

Figure 6. **Overnight Capital Cost of US and French Nuclear Power Plants**



Source: Jessica Lovering, Arthur Yip, Ted Nordhaus, Energy Policy Volume 91, April 2016, Pages 371-382.

3.6 Increased Budget and Schedule Certainty Reduces Risk

Cost reduction inherently requires increasing schedule and budget certainty. In so doing, there is less project risk and higher confidence in successful project delivery, which benefits all stakeholders, including the public and the project developer. Reducing risk lowers overall construction financing costs, both in terms of leading to a shorter construction period, but also a lowering in the risk premium. Engaging in the right kind of collective action and demonstrating risk reduction by all project stakeholders, including through regulatory and policy certainty, can therefore yield lower electricity costs for the consumer, allow for the vendor to realise their desired risk-adjusted rate of return, and expand market potential.

4 Commitments: Achieving 30% Cost Reduction and Beyond

Documented experience with multi-unit and intentional new build programmes demonstrates a range of potential cost savings. Achieving these reductions, as identified in the Nuclear Sector Deal, requires, "the right kind of collective action and demonstrating risk reduction by all project stakeholders..."

The goal for industry and government is to begin to identify, in concrete terms, specific evidence-based actions for each stakeholder type that can lead to meaningful cost and risk reduction for UK new build projects.

4.1 Industry Actions and Commitments to Cost Reduction

The NIC Working Group has compiled a table of industry actions that represent wide ranging commitments being undertaken to reduce cost and risk in nuclear new build construction. These actions are anchored in best practices identified in the ETI NCD Study. They are linked to actions identified in the main report and to a much wider range of activities that are either planned or already underway in existing projects, and in other linked sectors such as construction and manufacturing. The majority of these actions are largely consistent with the replication strategy: using the same completed design from a previous project. The Table of Industry Actions below will form the basis for wide industry engagement and iteration upon agreement with the NIC.

Figure 7. **Table of Industry Actions**

Cost Driver	Action Owner	Cost Driver Description	Actions for Cost Reduction
Plant Design	Developer	Includes all pre-construction efforts related to plant design, including design decisions, design completion and ability to leverage past project designs. This covers specific plant details such as plant capacity, thermal efficiency and seismic design, but also includes broader topics related to constructability and project planning processes.	Complete design prior to starting construction Design for constructability Increasing modularity in the design should be prioritised by its potential to shorten and de-risk the critical path Plant design team should be multidisciplinary and include current construction expertise Design for plant design reuse Replicate design to minimize redesign Consider specific design improvements against full costs and potential benefits of implementation

Cost Driver	Action Owner	Cost Driver Description	Actions for Cost Reduction
Equipment and Materials	Developer	Encompasses quantities of equipment, concrete and steel (both nuclear and non-nuclear grade) used in the plant but also covers strategies used to address materials cost.	Reduce quantity of nuclear-grade components as much as possible Substitute concrete with structural steel where possible Follow best practices to reduce material use Develop opportunities to use emerging technologies being used in other sectors Reduce over-ordering / waste of materials via (digital) production management
Construction Execution	Developer	Covers all the decisions and practices carried out and support tools used by the EPC during project delivery. This starts with site planning and preparation and design rework costs and spans all onsite decisions (e.g., project execution strategies, schedule maintenance, interactivity with subcontractors and suppliers, etc.) until the Commercial Operation Date. This includes independent inspection processes, QA, QC and other major cost and risk centres during project construction. This driver is a measure of efficiency and productivity across the entire delivery consortium. For multi-unit construction on the same site, this should get better with each subsequent unit.	Projects will be guided by effective and experienced leaders Projects will be guided by an integrated, multidisciplinary project delivery team operating as long-term enterprise with aligned incentives Leverage offsite fabrication and on-site pre-fabrication Ensure systems / processes are in place for the transfer of people and expertise between projects Digitally enabled production management system (workflow & co-ordination) will linked to digital twin and managed by an Integrator (see Project 13)[1]
Workforce	Developer	Involves all direct and indirect construction labour performed on the project site. This also includes any labour related to offsite manufacturing or assembly. It covers productivity, wages, training and prep costs, percentage of skilled workers with direct applicable experience, etc. This driver measures efficiency and productivity at the individual level.	Innovate new methods for developing alignment with labour around nuclear projects Improve labour productivity Invest in the labour force

1 Project 13 is an industry-led response to infrastructure delivery models that fail not just clients and their suppliers, but also the operators and users of our infrastructure systems and networks. It seeks to develop a new business model—based on an enterprise, not on traditional transactional arrangements—to boost certainty and productivity in delivery, improve whole life outcomes in operation and support a more sustainable, innovative, highly skilled industry. http://www.p13.org.uk/

Cost Driver	Action Owner	Cost Driver Description	Actions for Cost Reduction
Project Governance and Project Development	Developer	This driver includes all factors related to developing, contracting, financing, and operating the project by the project owner. This covers topics from the interdisciplinary expertise of the owner's team to number of units ordered (at the same site), discretionary design changes, WACC and contracting structures with the EPC	The owner's organisation will have an experienced, multi-disciplinary team Project owner will develop multiple units at a single site Programmatic approach to planning multiple projects, including systems / processes to transfer people / expertise between them Follow contracting best practices (as per ETI study) Procure for a cyber-physical asset (Plant and its Digital Twin) Establish cooperative partnership between owner and vendor Sequence multiple projects to maintain labour mobilisation and consistency in delivery teams and construction supply chain
Political and Regulatory Context	Government	Includes the country-specific factors related to regulatory interactions and political support (both legislatively and financially). This driver includes regulatory experience, pace of interactions and details on the site licensing process. It also includes topics related to the government's role in financing and how well it plays certain roles otherwise reserved for the project customer	Government support should be contingent on systematic application of best practices and cost reduction measures Government can play a role in putting in place framework to enable projects to be financed Design a UK program to maximise and incentivise learning, including clarity on potential future pipeline Work closely with the regulator to deliver on cost-effective safety Industry will engage the Regulator early and agree on a process for resolving licensing issues
Supply chain	Supplier/ Vendors	Involves factors that characterise supply chain, experience, readiness and cost of nuclear qualification as well as nuclear-grade and non-nuclear-grade equipment and materials	Embrace a highly proactive approach to supply chain management and qualification, as well as nuclear-grade and non-nuclear grade equipment and materials qualification Deliver a high level of local content Develop incentive programme for suppliers against a schedule of milestones
Operation	Owner	Covers all costs related to nuclear power plant operations (e.g., fuel price, staff head count, wages, capacity factor, unplanned outages, etc.)	Involve commissioning staff and operators in project planning and related construction activities Develop excellence in plant operations and maintenance through training and benchmarking such as the World Associated of Nuclear Operators peer review programme

4.2 Delivery to Date

The following case studies provide strong evidence of the programmatic learning, productivity improvements and risk reduction already being achieved through the construction of two units at Hinkley Point C.

Case Study 1

Series effect in Unit 2

Experience from nuclear power station construction around the world shows the efficiency benefits of building a series of reactors. At Hinkley Point C work on Unit 2 is already providing evidence of this ‘series effect’.

Excavation of Unit 2 has been 15% faster than Unit 1 with ‘right first-time’ figures rising to an industry-leading 95%. Spray concrete work has been 30% faster. Drilling techniques and sequencing of work were perfected during the first dig and were applied from the beginning of the second. Some work from Unit 1 was considered to be unnecessary and was eliminated for Unit 2. A new tool was designed to install and handle the 7,500 ground nails used on each unit—resulting in a 5% increase in productivity. Geologists with two years’ work on the excavations for Hinkley Point C were moved directly to Sizewell C at the end of 2018 to apply their experience and supervise work.

It is clear that the same drivers are at play with regard to both cost and risk reduction. Hence the learning from Unit 1 to Unit 2 has also reduced the level of risk as the project progresses. The same effect is expected at Sizewell C, essentially a replica of Hinkley Point C, assuming that there is an effective hand-off between the projects, including the transfer of core workers. The advantage that this risk reduction gives Government from enabling a programme of new build is in increased freedom in how it can enable access to lower cost financing.

Case Study 2

MEH Alliance

In the next phase at Hinkley Point C, contractors will need to co-ordinate their work as they install complex cabling and pipework in the power station’s 2,500 rooms. This phase is known as the MEH phase (Mechanical, Electrical and HVAC—heating, ventilation and air conditioning). As part of the MEH work, it is anticipated that Bilfinger will design, prefabricate and install components and auxiliary systems. This, coupled with other work on the Nuclear Steam Supply System (NSSS), means that Bilfinger has plans to manufacture some 70 km of pipework in the UK. This will take place at Immingham in Lincolnshire in a newly modernised facility which will boost UK industrial capacity and double the current workforce at that location.

Experience at Taishan in China has shown the benefits of bringing contractors into a single organisation where collaboration is incentivised and skills and expertise shared. At Hinkley Point C, this organisation is known as the *MEH Alliance* and brings Altrad, Balfour Beatty Bailey, Cavendish Nuclear and Doosan Babcock into a single entity. The alliance also aims to create new industrial capacity and jobs by manufacturing specialist pipework in Britain.

4.3 Industry Actions and Commitments to Cost Reduction

The ETI NCD Study identified the salient characteristics of a range of 31 nuclear projects across the cost drivers used in the analysis. Cost drivers are scored from -2 (low cost) to +2 (high cost). The score for each cost driver is determined through the examination of 10 to 15 more detailed indicators. The following table summarizes key indicators that are associated with each cost driver score.

Figure 8. **Summary of Cost Driver Findings**

	+2	+1	0	-1	-2
Vendor Plant Design	Complex plant, FOAK, >10 million person hours (~$1.5 billion) for design	FOAK in that country	NOAK, low degree of design reuse, 5 million person hours ($850M) for design	Some design reuse, some site-specific design required	Simpler design, NOAK in that country, high degree of design reuse, minimal site-specific design required
Equipment and Materials	Expensive materials environment, high nuclear cost premium, high percentage of 'nuclear grade' materials and equipment	More complex equipment and or higher materials use than the benchmark	US materials costs and benchmark level of materials and equipment use	Low-cost materials environment	Low-cost materials environment *and* highly cost-optimised use of materials
Construction Execution	Long construction schedule (84+ months), significant rework, significant schedule delays (> 12 months)	Longer construction schedule (72+ months), but on time delivery (<12 months delay)	Medium construction schedule (60 months), no delays to final delivery	50-month schedule	No rework, short construction schedule (40 month), experienced construction management, balancing of labour between multiple projects
Labour	Higher labour rates than benchmark *and* more person hours	Higher rates *or* lower productivity (more person hours)	$50/hour, 20 million person hours for direct construction, 10 million person hours for indirect	Low-cost *or* highly productive labour	Low-cost *and* highly productive labour
Project Development and Governance	Inexperienced developer/owner, problematic contract structure, lawsuits between project participants	Some, but not all of the +2 drivers.	No major problems caused by the Project Developer and Project Governance	Some, but not all of the -2 drivers	Experienced developer/owner, well-designed and proven contracting structure, no lawsuits, strong project oversight, efficient decision making, strong leadership
Political and Regulatory Context	Not applicable – no units received this score	Some changes required by regulator after construction starts, political ambivalence towards project	Not applicable – no units received this score	Some, but not all of the -2 drivers	Regulator experienced with design and construction of that plant, no delays due to regulator intervention
Supply Chain	Significant delays and rework required due to supply chain, failure to meet regulatory and quality requirements	Some, but not all of the +2 drivers.	No significant delays caused by supply chain	Some, but not all of the -2 drivers	Efficient supply chain, experienced with the plant design and meeting quality and regulatory requirements
Operations	Not applicable – no units received this score	Some, but not all of the +2 drivers.	Similar headcount, wage, fuel price and capacity factor as Benchmark Plant	Not applicable – no units received this score	Low staff headcount, low staff wage, low fuel price, high capacity factor

5 Actions: Strategies for Scale and Rate of Deployment

This section summarises the opportunities for cost and risk reduction that enable the increased scale and rate of deployment identified as necessary in the context of net zero legislation.

These strategies include, and go further than, previously outlined programmatic opportunities to improve performance of GW-scale conventional nuclear new build today.

For nuclear to deliver a meaningful contribution towards meeting climate and energy security goals by mid-century, all three categories of strategic intervention are needed, and should be pursued in parallel.

5.1 Improve Delivery via Programmatic Approach

Cost Competitive GW-Scale LWRs

As indicated above, a carefully designed programme that engages all of the key stakeholders with a shared vision and focus on the key characteristics of low-cost, high quality construction (with any build planned for a series—not one offs) can put the UK on the path to affordable nuclear power.

In addition, evidence from reports such as the MIT Future of Nuclear Study[1] indicates further cost and risk reduction potential for GW-scale conventional light water reactors. Identified opportunities include, but are not limited to:

- Seismic isolation to reduce need for site specific design changes
- Designed standardisation
- Design replication to enable a series effect
- Modular construction
- Advanced construction materials
- Advanced construction management-planning
- Automation

1 The Future of Nuclear Energy in a Carbon-Constrained World: An Interdisciplinary MIT Study, 2018.

5.2 Design for Innovation, Manufacturing and Deployment

The ETI NCD Study identified the potential for further reductions in the cost of advanced reactor technologies and SMRs. Whilst such technologies are not yet licensed, nor construction ready, the Study provides evidence in support of early testing of design claims by regulators, and the examination of cost reduction strategies by potential investors.

Generation-IV plants are still in the relatively early stages of commercial development. None of the companies have a completed detailed design and all are actively engaged (or preparing to engage) in the first stages of reactor licensing activities. Only after obtaining a reactor license and completing a detailed design can a company build a commercial demonstration or first-of-a-kind plant. While advanced reactor companies are projecting lower costs than conventional plants, these costs will remain inherently uncertain until FOAK (and perhaps several additional plants) are delivered. At present, these reactor technologies are not available for near-term deployment.

5.3 Redesign for Low-Cost Delivery

Further cost reduction can be achieved by starting with clear cost targets and maintaining strict cost target discipline throughout the design process. This is very similar to the process for developing cost-effective, high-performance products in manufacturing environments. This process requires interdisciplinary teams and detailed working knowledge of the costs of manufacturing and construction so that these costs can be factored in during the design-to-cost process. The following strategies would be included in this approach:

- Eliminate failure modes by design
- Design using previously licensed technology
- Design for higher volume commercial components
- Prefabrication of major components and civils
- Factory-based preassembly of mechanical and electrical systems
- Design for shorter construction schedules

The combined effect of these strategies result is designed to reduce construction scope, duration, and labour, particularly at site due to fewer buildings and fewer safety systems needed due to passive safety design.

Achieving the high rates of deployment necessary for net zero will require technical as well as cultural and organisational innovation. Evidence from the ETI NCD Study and “What Will Advanced Reactors Cost”[2] indicate that moving from a project-based approach to high-volume, high productivity manufacturing will enable very low-cost products to be delivered and deployed competitively at scale.

2 What Will Advanced Reactors Cost? A Standardized Cost Analysis of Advanced Nuclear Technologies, written by LucidCatalyst for Energy Options Network and the Energy Reform Project, 2017.

6

Recommendations

Through the Nuclear Cost Drivers Study for the Energy Technologies Institute, LucidCatalyst gathered substantial evidence suggesting that UK nuclear new build has very significant cost and risk reduction potential.

Global data in the ETI NCD cost database and model indicate a range of achievable cost savings based on global experience with multi-unit builds and intentional new build programmes. Achieving these reductions, as cited in the recent Nuclear Sector Deal, requires, "the right kind of collective action and demonstrating risk reduction by all project stakeholders."

The purpose of the Energy Technologies Institute (ETI) Nuclear Cost Drivers (NCD) Study was to identify what drives costs within nuclear projects completed globally in the last twenty-five years. The goal was to then identify and quantify the potential for meaningful reductions in capital cost and levelised cost of energy (LCOE) in the UK.

The key recommendations included the need to maintain an experienced supply chain and the value in sequencing multiple projects to maintain a mobilised labour force and drive consistency in construction delivery.

Because significant cost reduction opportunities require coordinated and sustained action of multiple parties, a key outcome was a framework designed to enable shared understanding and coordination between all stakeholders.

Reducing cost also requires reducing project risk by increasing certainty on schedule and budget. Less risk and higher overall confidence in budget and schedule—and therefore cost of energy—benefit all stakeholders, including the public and the project developer. Reducing project risk—whether related to project development, construction or supply chain—benefits all parties, creating a 'win-win' outcome.

By committing to deliver against a well-defined set of industry actions, anchored in the global evidence presented in the ETI Nuclear Cost Drivers Study, the NIC 30% Cost Reduction Working Group is demonstrating action that will deliver material results for cost and risk reduction of nuclear projects that will meet, and potentially exceed, cost targets in the UK.

Timely decision making is critical to capture programmatic benefits and best value for the UK.

- **Optimise sequencing** to deliver savings and drive the best value outcome for Government and consumers in order to capture the best value case for nuclear new build. Although Governments may attempt to decrease risk by delaying projects, evidence clearly shows that delaying projects massively increases risk.
- **Enable early investment in the pre-construction planning** in order to reduce risk and optimise outcomes. Structure cost recovery to incentivise early investments that help capture and optimise project planning.
- **Planning is critical**. The ETI NCD Study shows that those projects that invested in thorough pre-construction planning processes achieved the lowest scores and most risk reduction. Therefore,

delaying investments in construction planning increases project risk and likelihood of high-cost outcomes.

- **Maintaining a pipeline of projects supports skills and capability** that boosts the sector and delivers benefits to the wider UK economy.

The ETI NCD cost database and model is a strong indicator for cost reduction potential. However it lacks UK-specific data to deliver a cost reduction programme tailored for the UK that can deliver “the right kind of collective action” to drive down cost and risk for new build projects and ensure value for money and fiscal responsibility in UK nuclear new build. To achieve consensus and confidence—throughout government, industry, and among investors—in a detailed, cost reduction programme that accounts for clearly identified UK-specific context and risks, a detailed ‘should cost’ nuclear cost model should be developed that is rooted in verifiable, UK-specific costs and informed by evidence of how learning and best practices have been successfully applied elsewhere—and which could apply to the UK.

To achieve this, further work is recommended as follows:

1. **Analysis**: Sophisticated, detailed, and UK-specific analysis and gathering of evidence to set and deliver optimal strategies for the UK new build programme, including potential cost reductions through learning across multiple units.
2. **Programme Design**: Design the UK nuclear build programme, based on analysis and evidence, to drive down cost and risk for new build projects, ensure value for money and fiscal responsibility.
3. **Active Engagement**: Engaging with industry and other key stakeholders in support of the Government’s cost and risk reduction goals. Substantiate, convey, and deliver on the potential for capturing and applying learning to achieve cost and schedule containment, which will lead to greater confidence in projected costs and timescales.

This further analysis will identify specific actions for specific stakeholders that, rooted in evidence, can lead to very substantial, and near-term, cost and risk reduction for UK new build projects.

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