



Nuclear Sector Deal:

Nuclear New Build Cost Reduction

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Foreword by Humphrey Cadoux-Hudson CBE (Working Group Chair)



The nuclear sector makes a major contribution today to the security of supply and the production of low carbon power in the UK, and is also a major UK industrial strength. In recent years the recognition that climate change is one of the most significant challenges we face has risen throughout society. The UK was the first major economy to legislate for net zero. Decarbonisation of the power sector is critical for decarbonisation of the wider economy - transport, heat, and industrial uses.

As the UK begins to emerge from the crisis brought about by Covid-19,

the nuclear industry can play a major role, alongside renewables and other complementary technologies, in helping deliver the joint goals of a strong economic recovery, and the decarbonisation of the energy sector. We have the opportunity to move towards an electricity system with significantly lower carbon intensity and increased grid flexibility. Integrating nuclear's low carbon heat production with storage, hydrogen production, and local energy use can also help with using and managing the electricity grid and enable energy centre decarbonisation of heat, transport and industrial processes.

The nuclear industry is already a major employer in our regions - including the North West and South West, and the industry supports many supply chain partners in those regions and elsewhere across the UK. Nuclear powered energy centres offer the opportunity to co-locate with different technologies to exploit synergies,

where the by-products from one process can be used to increase the efficiency of another, to deliver the most value to the energy system as a whole but also to the local area.

The industry is committed to working with Government to develop a thriving nuclear industry in the UK. Good progress is being made with construction of Hinkley Point C, but this is just the start of what's needed. This report shows what can be achieved by developers working together, sharing learning, developing common UK supply chains, and sharing a skilled workforce. We look forward to supporting the Government in achieving its Net Zero goal.

I am very pleased to say that the nuclear new build cost reduction workstream has made great progress, and this report clearly shows it's possible to deliver a cost-effective programme of new nuclear power stations in the UK. But promises of cost

reduction are not enough - in making this case, the developers of new nuclear plants are showing that we recognise the delivery risks we face. Management of delivery risk is a vital step in building confidence with stakeholders in Government and in the investment community; hence we have given particular weight to empirical evidence to illustrate the steps to deal with the risks whether in gigawatt scale or Small Modular Reactors.

It is also important that learning from big projects can be deployed more widely, supporting investment in infrastructure across the UK, and supporting Government's objective of rebalancing UK economy. The Infrastructure Projects Authority's recent publication 'Principles for Project Success'[1] identifies Learning from Experience as being central to successful project delivery. The work of our group is well aligned with the principles the IPA has set out.

Executive Summary

The Nuclear Sector Deal, published in June 2018, committed the nuclear industry and Government to working together to reduce the cost to the consumer of future new nuclear projects by 30% by 2030, taking the Hinkley Point C (HPC) strike price of £92.50/ MWh as a starting point. Under the Nuclear Sector Deal, the New Build Cost Reduction Working Group (the Working Group) was established to identify the actions needed to deliver this commitment, irrespective of which reactor technologies are deployed. This report focuses on actions common to all technology choices that can reduce cost and risk. The Working Group notes that choice of technology will play a role in cost, and this is discussed in the report. The designs proposed by developers in the UK use a number of additional cost reduction strategies to greater or lesser extents; the Group will undertake further work in future to assess these cost reduction opportunities.

The latest designs that are in construction and operation demonstrate that First Of A Kind (FOAK) projects carry significant risk,

particularly in nuclear newcomer countries, or countries restarting nuclear construction after a significant period of inactivity. This can be seen in the EPR projects in Finland and France, AP1000 projects in USA and China, and advanced modular reactors such as the HTR-PM. The evidence available points to risks arising from project execution, in particular for First Of A Kind designs, as the first order issue.

For the EPR reactors at Hinkley Point C, which has significant design adaptations for the UK context, two thirds (£62/MWh) of the cost to the consumer arose from the costs of financing the build, of which more than half (£36/MWh) can be estimated as the cost required to cover the risks associated with construction, while £11/MWh related to capital costs. The overall cost of construction (capital cost + cost of construction risk) is thus £47/MWh. Reducing the cost of the risk of construction, as well as the capital cost, is therefore key to reducing the end cost to the consumer.

The Working Group commissioned a paper by Ed Merrow[2], from Independent Project Analysis, on

what causes success and failure in the delivery of “industrial megaprojects” (complex projects with multiple interfaces delivered in complex regulatory environments). Through analysis of an extensive international database of 530 projects, Merrow concludes that a small number of identifiable factors often determine project success or failure. If projects are well set up from the outset, and invest sufficiently in early planning and preparation, they can avoid many of the causes of failure. In particular, projects need to do sufficient early planning, driven by an experienced team, to ensure they have the robust basic data that they need to be well scoped and shaped with key stakeholders to avoid subsequent scope change. Design must also be sufficiently mature prior to construction starting. When these things are done, all outcomes are improved – cost, schedule, operability and safety.

The Working Group also commissioned work from Lucid Catalyst[3], which draws on international experience of the construction of nuclear power stations to show that it is possible

to deliver a low cost programme of new nuclear power stations. Taking a programmatic approach is key, because developers can deliver considerable cost savings by building a number of units of the same design, ie replication.

The Working Group reviewed evidence from the construction industry in the UK, commissioning a report[4] that highlights lessons learnt from the experience of constructing nuclear power stations and other large infrastructure projects.

It notes that a series of major projects and programmes has been executed successfully, and there is a deep pool of UK expertise in the delivery of complex major infrastructure projects on which the nuclear sector can draw. The report identifies a number of characteristics of successful construction projects, notably the readiness of design for construction, the effectiveness of project leadership and governance, effective execution and procurement strategies, integrated delivery teams, and use of digital data.

The report also highlights initiatives underway in the construction sector to enhance best practice, which new nuclear developers can utilise.

The Group also drew on the work of Bent Flyvbjerg from the Saïd Business School, Oxford, who additionally emphasised the benefits of finding tasks that can be replicated on large construction projects in order to drive productivity improvements.

The report recognises that choice of technology will affect costs, and each developer has the opportunity to further reduce the cost of their chosen design through the management of construction cost and risk. In addition, the industry recognises that HPC has not only carried First Of A Kind in the UK costs for the EPR design, it has also borne the first of a generation costs for new nuclear in the UK – re-establishing the supply chain, skilling workers, and building capabilities. There is now renewed understanding of the quality standards, processes, and capabilities required to participate in nuclear construction projects. Furthermore, contracting models and construction methodologies have been tested and learnings absorbed by companies and individuals. This will bring great benefit to all future nuclear projects in the UK.

This report sets out why it is much less risky and cheaper in the long run to address project risks through investment in establishing a stable base (of project purpose, stakeholder alignment, governance, design planning and R&D) before construction and manufacturing start. A First Of A Kind project requires significant investment to achieve a strong starting point for construction. Significant cost and risk reductions can be achieved through subsequent copies.

Future projects, whatever the design, will be able to capitalise on all of these points, ensuring that nuclear plants in the UK are cost competitive.

Drawing on this evidence and analysis, the Working Group identified the following actions required to achieve, as a minimum, the 30% cost reduction commitment:

1. Actions for developers to reduce construction cost and risk

Each developer has the opportunity to reduce the cost of their chosen design through the management of construction cost and risk. Hence the main conclusion from the work above was that there is a need for a project to deliver in 14 areas to an adequate,

and preferably high, standard prior to the start of construction. By detailing the precise measures that allow a project to be successful, all stakeholders have objective criteria on which to assess and quantify risk in proceeding.

It is implicit in the difficulty in finalising the design of a First Of A Kind nuclear power plant (or indeed any complex machine such as a car or aeroplane) before the start of construction that risk and hence cost to the consumer will be higher than for a well set up follow-on project that is a replica. This methodology, however, will allow greater clarity on the risk taken for any project. This will be true for large and small nuclear reactors.

The fourteen categories are:

- Financing
- Regulation
- Governance
- Site data
- Technology data
- Design
- Estimates
- Contractual interfaces
- Project management
- Data system
- Construction preparation
- Supply chain
- Skills
- Operations preparation

For each category, the Working Group is developing a scorecard, which will define what low risk and hence construction readiness in each area would look like for a new nuclear power station. This will enable a robust assessment, prior to a Final Investment Decision being taken, of the extent to which a developer has taken the necessary actions to reduce risk and cost.

2. Actions taken by technology providers to reduce construction costs of their designs

The report also recognises that the technology choice for a nuclear power plant project or programme can have an impact on overall cost. Opportunities for cost reduction can be achieved from inherent plant design and construction methodology.

3. Action needed to attract investment

The National Audit Office identified that, for future new nuclear projects, alternative approaches to financing could have reduced the total project cost^[5] which would deliver better value for money for consumers, given that 2/3 of the cost of Hinkley Point C to consumers arises from financing costs.

Government is currently consulting on a Regulated Asset Base (RAB) approach to financing nuclear power plants, under which the project's returns would be overseen by a regulator. It would involve some cost/risk sharing with customers and/ or

taxpayers. This would be appropriate provided that developers are taking sufficient risk reduction measures, as identified above, to make the allocation reasonable. By significantly reducing construction risk, and by sharing some risk with customers and/ or taxpayers, the cost to consumers can be substantially reduced.

The benefit of such an approach would be to provide a mechanism to draw investors to the table, recognising that developers have limited balance sheets.

Widening and deepening the pool of capital available will further reduce the cost of capital and hence costs to

the consumer. The Working Group has concluded that it is possible to achieve at least a 30% cost reduction in new nuclear build through a combination of the measures identified above:

- reduction of the cost of projects through the management of construction cost and risk
- deployment of additional cost reduction strategies
- facilitation of access to wider pool of lower-cost finance

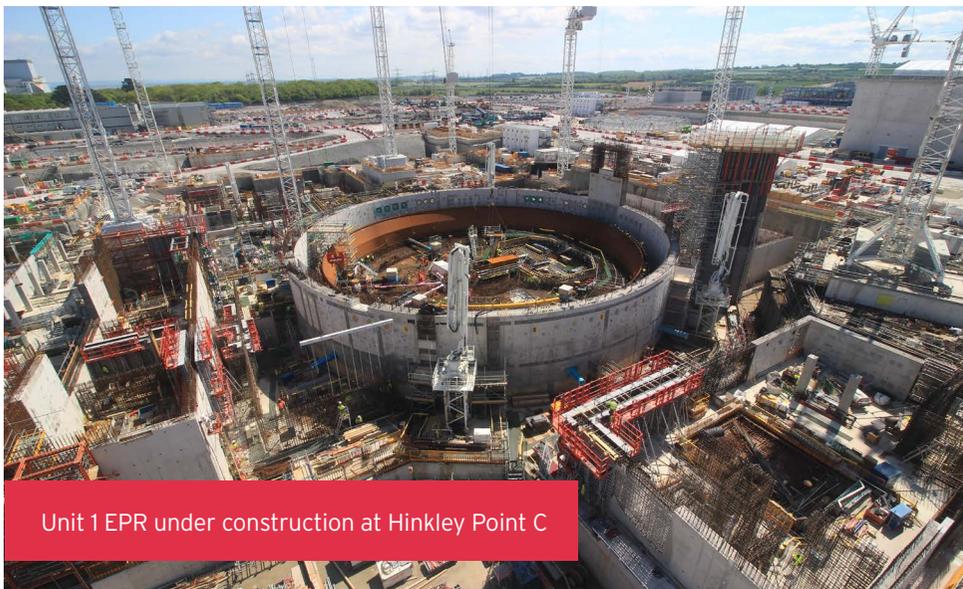
It would not be cost effective for the UK to do as it has in the past and have a large number of different one-off reactor designs¹, each bearing significant First Of A Kind (FOAK) costs. The UK can benefit from the deployment of multiple reactor designs, but only if each of these designs is part of a wider fleet and replicated in a series build to enable cost and risk reductions to be delivered between projects.

Subsequent nuclear power stations should follow on quickly enough from FOAK projects to enable effective lesson learning, and continuity in the supply chain in order to maximise the potential cost savings.

It will be clear that the target of cost reduction to the consumer has been achieved at the point where a final investment decision is taken and a baseline price is agreed.

The risk assessment tool will enable developers, investors and Government to have a robust and shared view of the residual risks in a project at the point where the Final Investment Decision is taken, and then to track the ongoing management of those actions and risks through delivery of the project.

There is a wider set of enablers to support the development of the nuclear industry in the UK, which will benefit a nuclear new build programme, for example around skills and supply chain development and innovation. Actions in these areas are being identified and tracked through separate workstreams as part of the Nuclear Sector Deal programme. The Nuclear Industry Council and the Nuclear Sector Deal Programme Management Office are making sure these actions are coordinated and aligned.



Unit 1 EPR under construction at Hinkley Point C

¹The UK has one PWR reactor (Sizewell B), and a fleet of AGR reactors of differing designs.

Introduction

The Nuclear Sector Deal, published in June 2018, set out a joint commitment by the nuclear industry and Government to maximise the industrial benefits of the nuclear sector in the UK, while delivering secure, affordable, low carbon power to customers.

Nuclear power currently provides around 20% of the UK's electricity, and the UK has a thriving nuclear sector, providing tens of thousands of highly skilled jobs, including around clusters in the North West and South West.

The Sector Deal included a commitment by industry and Government to reduce the cost to the consumer of future nuclear new build projects by 30% by 2030, taking the Hinkley Point C strike price of £92.50/MWh as the starting point. Achieving cost reduction for future new nuclear projects will ensure that nuclear power continues to be competitive with other forms of low carbon generation, which have also experienced cost reductions over the course of their deployment.

In June 2019, following the advice of the Committee on Climate Change, the UK Government legislated to achieve net zero greenhouse gas emissions by

2050. Nuclear power has an important role to play in meeting this target, and it makes the deployment of new nuclear power stations all the more urgent.

The Nuclear New Build Cost Reduction Working Group was established to identify how the 30% new build cost reduction target could be met, and the actions needed to enable it. It includes people with expertise from across the nuclear industry, and has drawn on expert external input from UK construction, nuclear cost specialists, global experts in the delivery of "industrial megaprojects", and from the wider infrastructure community.

This report sets out the findings of the Cost Reduction Working Group, and the actions identified to achieve at least a 30% cost reduction in new nuclear projects.

The findings are relevant both to the current deployment of large-scale new nuclear power stations and to the potential deployment of a future programme of small modular reactors, and indeed to investment in, and the delivery of, major infrastructure projects across the UK.

CASE STUDY: THE BENEFITS OF SERIES BUILD

Horizon Nuclear Power is proposing building the Advanced Boiling Water Reactor (ABWR) at two sites in Wales and England which has been built on time and budget four times in Japan between 1992 and 2006, providing the UK with over two decades of learnings and refinements.

The UK ABWR design passed through the regulators' Generic Design Assessment in 2017. It is modular - large units can be assembled at off-site locations and moved to the Wylfa Newydd site on Anglesey for simpler assembly - and uses 'open top' construction enabling easy installation of components and structures in the reactor before access is restricted by containment structures. Further productivity gains have been achieved through parallel civil and mechanical construction activities. The most recent ABWR, Shika 2, was commissioned in 2006 just 37 months after the pouring of first nuclear concrete. Simplicity and short schedules reduce construction cost and risk. The developer's expectation is that the Wylfa Newydd twin reactor project would be at least as competitive as other same-scale projects built in the UK after Hinkley Point C, with further cost reductions for future units.

Successful deployment of proven designs in the UK for the first time is best facilitated by a clear shared understanding of scope and interface management between developer, engineering, procurement and construction activities. Horizon began substantive supply chain engagement in 2015 to combine the best in class overseas experience of Hitachi GE (Reactor and Steam Supply) and Bechtel (Project Management) with the UK-based companies gearing up to capitalise on up to 60% of the project's value.



Horizon's planned Wylfa Newydd site

Contents of This Report

This report sets out:

- The contribution of nuclear power today and the need for new nuclear
- The make-up of the Hinkley Point C strike price, used as the baseline for the cost reduction target, and the areas to target for cost reduction
- Learning from the delivery of “industrial megaprojects”
- International evidence showing it is possible to deliver new nuclear programmes at a competitive cost
- Learning from the construction sector
- The fourteen key enablers of risk reduction for future new nuclear projects
- An assessment tool to establish the risk profile of future nuclear projects
- The proposals for the financing of future new nuclear projects

1. Where Are We Today?

Today nuclear power provides around 20% of the country's electricity. The existing fleet of nuclear power stations, comprising seven AGR power stations and one PWR, save around 20Mt of carbon dioxide emissions per year². The first AGRs were commissioned in 1976, and are coming to the end of their operating lives - they are all scheduled to close by 2030. Sizewell B, the UK's only PWR, is scheduled to operate until at least 2035 and is likely to continue operating well beyond that date.

The first new nuclear power station in the UK in a generation is currently being built by EDF and its partner CGN at Hinkley Point C (HPC) in Somerset. The two EPR reactors being built on the site will have a combined capacity of 3.2GW and will provide 7% of the country's electricity when they come on line. The first reactor is due to be commissioned in 2025.

²Nuclear fleet output was 59 TWh in 2018. Assumed counterfactual is a fleet of efficient CCGTs with an average carbon intensity of 349gCO₂/kWh. 59TWh x 349gCO₂/kWh = 20.6 MTCO₂ savings.

³The Office for Nuclear Regulation (ONR) and the Environment Agency (EA)

CASE STUDY: A THRIVING NUCLEAR INDUSTRY IN THE UK REGIONS

The new nuclear programme offers opportunities for businesses across the UK to win work and develop expertise, and to bring economic benefits to UK regions.

For example, working collaboratively with local partners, Hinkley Point C is acting as a catalyst for long-term socio-economic development across the South West Region. Almost 1,000 South West businesses are already engaged within the supply chain and benefitting from over £1.3 billion of direct spend to date.

The Project is also benefitting companies from across the UK - whether it's supplying thousands of tonnes of Welsh steel or the hi-tech nuclear components being built on Teesside. For many companies, the contracts are helping them gain new skills and expertise which is boosting their competitiveness and the nation's industrial capacity.

The supply chain that is serving Hinkley Point will also be in a strong position to bid for and win work with other developers in the UK, and help them deliver lower costs to the consumer through the application of their learning.

The Government's National Policy Statement for Nuclear identified eight sites that are suitable for the deployment of large-scale nuclear power stations in England and Wales: Hinkley Point, Sizewell, Wylfa, Moorside, Bradwell, Oldbury, Hartlepool and Heysham.

There are currently three nuclear power plant technologies that have progressed through the regulators³ Generic Design Assessment (GDA) process and received design acceptance.

The UK EPR received its design acceptance in December 2012, the AP1000 in March 2017 and UK ABWR in December 2017. The UK HPR1000 is currently in Step 4 of GDA.

GDA is an important milestone in gaining regulatory confidence in the safety of a design; however all the GDAs completed to date have included a significant number of assessment findings that need to be subsequently resolved. Resolution of these issues and completion of design, including any resulting modifications, is undertaken under a project's Nuclear Site Licence, the grant of which is subject to the satisfaction of the regulator that the Licence holder is capable of ensuring the safety through design construction operation and decommissioning. The GDA assessment findings for the UK EPR led to changes in the design for HPC after completion of the GDA (with associated impact on cost and risk).

EDF and CGN are developing a project to build two more EPR reactors of the same design as Hinkley Point C at Sizewell in Suffolk. CGN and EDF are developing a project to build two UK HPR1000 reactors on the Bradwell site in Essex. Horizon's plans to build 2 ABWR reactors at Wylfa in North Wales and 2 at Oldbury on Severn

were suspended in 2019, but the company has maintained the option to remobilise. A recently formed consortium has also put forward outline proposals for a clean energy hub at the Moorside site in Cumbria.

Government is also considering the potential for the development of small modular reactors in the UK, and a number of developers have expressed an interest in this. Rolls Royce has invested over the past 6 years, and formed an industry wide Consortium which is participating in progressing an SMR design into GDA.

Looking further into the future, Government is providing funding for a feasibility and development programme for advanced reactor technologies.

Without further nuclear new build, from 2030 only Sizewell B and Hinkley Point C are due to be operating, reducing nuclear capacity to 4.4GW or 11% of electricity generation⁴.

CASE STUDY: FIRST OF A KIND IN COUNTRY

When the EPR design was brought into the UK, significant changes to the baseline Flamanville 3 design were required to comply with UK requirements. This means that the HPC design is effectively a First Of A Kind (FOAK) in country design. For example, in total there are around 30% more cables and pipes in the HPC design compared to Flamanville 3. Only the Nuclear Steam Supply System was virtually unchanged. One major example of a change to the design was the requirement for a backup system to two digital reactor control systems that can safely shut down the plant without any computer aided operations.

The impact of changes to the design can be far reaching on cost and schedule. The requirement to add pipes, for example, requires seismic and safety studies to be re-done, and those studies re-assessed by the internal and external regulators.

⁴Electricity generation in 2030 estimated at 330TWh (Source: FES 2019). Sizewell B (1.2GW) and Hinkley Point C (3.2GW) would produce c35TWh (4.4GW * 8760 hours * 91% load factor = 35.1TWh), c10.6% of total generation

2. Need for New Nuclear

Nuclear power provides firm, reliable, low carbon generation. It also makes an important contribution to the stability and security of the electricity network.

The UK is now legally committed to achieve net zero carbon emissions by 2050. The Committee on Climate Change advises that electricity consumption could double^[6] due to electrification of transport and heat by that date, requiring a quadrupling of low carbon generation. Renewables (principally onshore and offshore wind and solar) can make a significant contribution to that. The Committee on Climate Change is clear that the UK also needs firm low carbon generation, capable of providing power and system stability 24/7, irrespective of weather conditions. Energy Systems Catapult, in their latest report^[7], has recommended the UK commit now to around 10 GWe of additional new nuclear Gen III+ reactor capacity beyond Hinkley Point C's 3.2 GWe.

Nuclear is a proven technology for providing firm, reliable, low carbon power, and can make a major contribution to meeting the UK's net zero target, alongside renewable

generation. A number of studies have shown that having a diverse generation mix, including both nuclear and renewables, is the most cost-effective way of decarbonising the power sector while maintaining security of supply^[8&9]. The value of nuclear power in the system increases as we reach higher levels of decarbonisation^[10].

The scale of the deployment of nuclear power will depend in part on its future cost reduction trajectory - nuclear power must be demonstrably competitive with other sources of low carbon generation, on a whole system basis. The costs of other low carbon technologies have fallen over time - the first offshore wind contracts signed in 2014 had a strike price of £140/MWh and £150/MWh, whereas the clearing price in the latest offshore wind auction⁵ was c£40/MWh⁶. The success of the offshore wind sector in reducing costs has been driven in part by an intentional commitment from Government to deploy offshore wind at scale. This has enabled developers to apply continuous learning in construction execution, in the workforce, in the supply chain and to

CASE STUDY: CLEAN ENERGY HUB

A "Clean Energy Hub" has been proposed by a consortium of 15 companies for the Moorside site on the Cumbrian coast. The site would host a package of nuclear projects, including a new 3.2 GW UK EPR power station, small modular reactors (SMRs) and advanced modular reactors (AMRs). The principal objective of The Moorside Clean Energy Hub will be to use the electricity and heat generated from nuclear power at Moorside to create lasting economic impact and social benefit. Ideas under consideration include:

- Using low-carbon power and heat from nuclear generation for industrial processes
- Making hydrogen, synthetic fuels and, if it becomes the future of clean shipping, ammonia
- Linking the energy hub with maritime opportunities, including exploring the provision of electricity and heat to freeports
- Provision of heat, chilled water and power

There are several development sites along the Cumbria coast and beyond that could benefit from the Clean Energy Hub. Heat and electricity from the hub could be used to meet needs at the adjoining Sellafield site and other sites in the region.

standardise equipment and materials. This has in turn enabled reductions in both the cost of construction and risk of construction, which has driven a reduction in the cost of finance. Nuclear projects are larger in scale and far fewer in number, but the principle that costs and risks can be reduced over time, including by transferring learning and experience

from one project to the next, is equally applicable to nuclear projects.

The nuclear sector deal recognised the potential and necessity for cost reduction in nuclear new build, and set the goal that the expected costs to the consumer of new nuclear projects should reduce by 30% from the Hinkley Point C strike price by 2030.

⁵Data taken from Low Carbon Contracts Company CfD Register. All strike prices in £2012. https://www.lowcarboncontracts.uk/cfds?title=&technology_type%5B%5D=77&agreement_type=All&field_cfd_current_%20strikeprice=All&allocation_round%5B%5D=Allocation+Round+3&sort_by=name_1

⁶Note that this does not consider the additional system costs attributable to intermittent renewable generation.

3. The Baseline for Cost Reduction (The Cost of Hinkley Point C)

The Sector Deal takes the cost of Hinkley Point C (HPC) as the baseline for its 30% cost reduction commitment. By examining a breakdown of the cost of HPC it is possible to target some key areas for cost reduction irrespective of the technology deployed, while noting that technology can play a role in cost reduction. Hinkley Point C has a Contract for Difference (CfD), under which the developers will receive the “strike price” of £92.50/MWh for the power produced. Under the CfD, the project developers, EDF and CGN, fund the full costs and bear the full risks of development and construction, and only receive revenue once the power station is operational.

The total lifecycle cash costs (capital and operating costs) of the plant make up only 1/3 of the strike price, with the other 2/3 (£62/MWh) of the costs arising from the costs of financing the build.

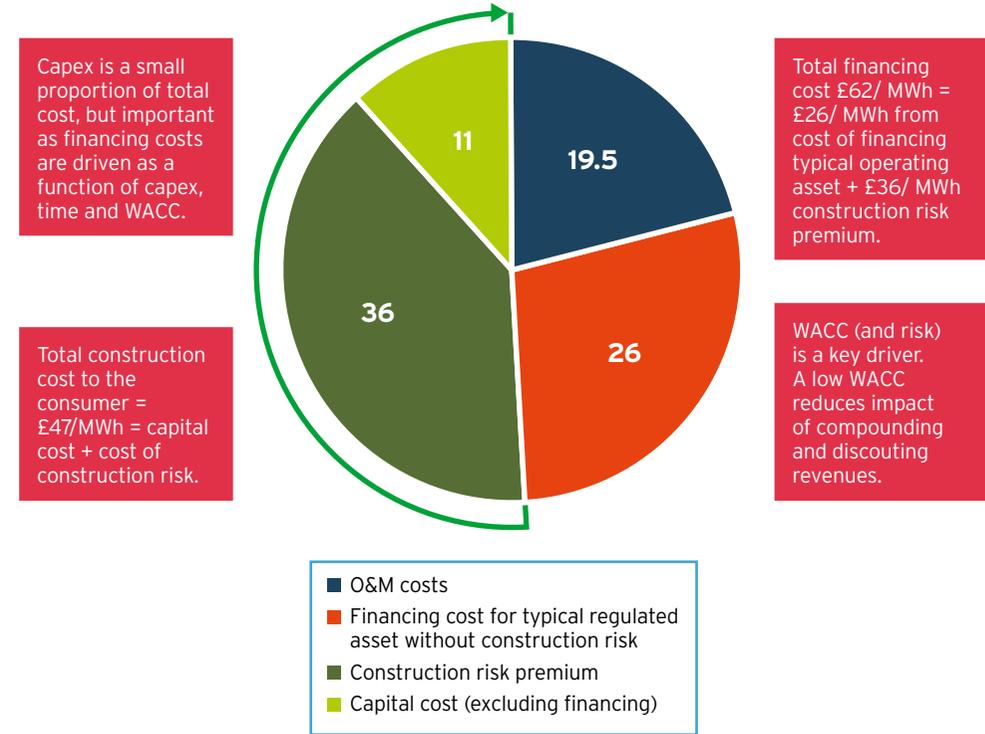
If the project were a standard regulated infrastructure company then the cost of financing would have been c£26/MWh. The additional cost to cover the additional construction risks of the project adds a further £36/MWh to the price⁷.

Construction cost and the financing costs of construction risk together account for nearly half the strike price, and should be the primary target for cost reduction actions. In summary:

- Directly addressing construction risk is a clear route to reducing the construction risk premium and hence the cost to the consumer of new nuclear.
- Reduction in the cost of a project, the capital cost, is an important factor as this also reduces the cost of capital due to the lower financing needs.
- Hence the 30% target could be met in different ways by different technologies.

Breakdown of the Hinkley Point C Strike Price

Total HPC Strike Price = £92.50/MWh



WACC (weighted average cost of capital) is the financing cost which for HPC was 9.2% on a post-tax nominal basis at time of final investment decision in 2016.

⁷Risks associated with a cost and schedule overrun such as additional capital costs, additional financing costs or impact of delayed revenue.

4. Learning From the Delivery of “Industrial Megaprojects”

The Working Group commissioned a study from Ed Merrow of Independent Project Analysis, an expert on the delivery of “industrial megaprojects” and what causes them to succeed or fail.

Megaprojects are defined as commercial infrastructure projects with a high degree of complexity. Typically, they have a high capital

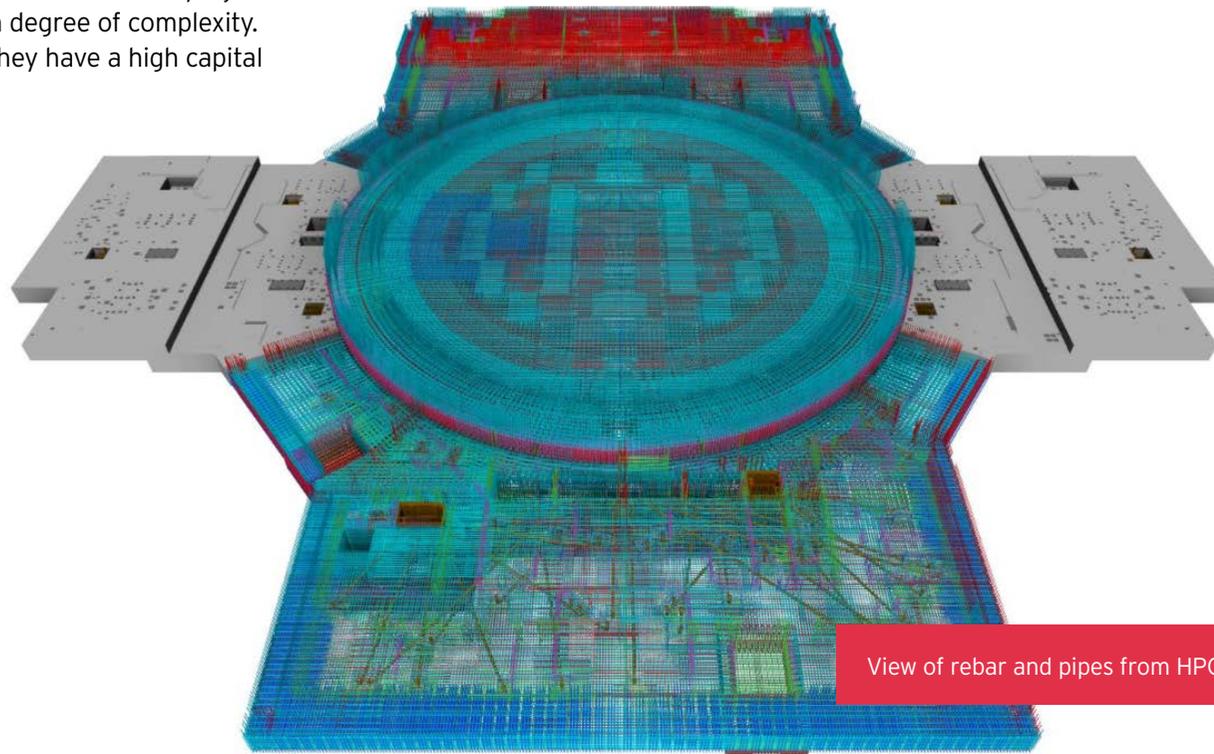
cost running to multiple billions of pounds, with multiple delivery partners and stakeholders and a large number of interfaces to manage, often in a challenging regulatory context. All these factors are true of new nuclear power stations irrespective of the technology deployed.

Through examining their extensive database of international projects, they conclude that a small number of identifiable factors determine project success or failure. While many projects suffer disappointing outcomes in terms of cost and/ or schedule over-run, if projects are well set up from the

outset, and invest sufficiently in early planning and preparation, they have a high chance of success, and can avoid many of the failures that are largely predictable.

Key lessons that Merrow draws for the successful delivery of industrial megaprojects, including new nuclear power stations are:

- Developers need to invest sufficient time and money in early preparation – this yields considerable time and cost savings in the overall delivery of the project
- Developers must have robust basic data, and have resolved R&D elements, at a sufficiently early stage of project planning
- Projects must be well scoped and avoid significant scope change once construction has started - this is a major cause of cost and schedule overruns
- Ensuring all key stakeholders are aligned on project scope, output characteristics and risk allocation is key to ensuring subsequent scope change



View of rebar and pipes from HPC 4D Model

- Site-specific factors must be well understood
- Design must be sufficiently mature prior to construction starting
- There must be a detailed project execution plan, including a high quality schedule, prior to authorisation being given for the project to proceed

Merrow notes that when these things are done, all outcomes are improved - cost, schedule, operability and safety. He concludes that there is every reason to believe that new nuclear power stations can be successful in their delivery, and achieve low cost / risks status, provided there is sufficient early planning and the projects are set up for success from the outset.

One challenge that nuclear power projects face in undertaking sufficient early planning work is that developers are currently required to cover all pre-development costs at risk up to the point of a Final Investment Decision (FID) and contract signing with Government. This is clearly demonstrated by the amounts written off on nuclear projects that have not managed to achieve FID. The key milestone for project readiness is the point at which construction starts. Significant risk reduction could be



achieved from an early conditional FID, and have a later separate hold point for the start of construction.

Alongside the Merrow Analysis, the Working Group also drew on the work of Bent Flyvbjerg from the Said Business School, Oxford. A key insight from Flyvberg is the concept of

“flywheels” - finding individual tasks which can be replicated in order to drive productivity improvements.

There is considerable scope for this in tasks that must be repeated in the construction of a nuclear power station, such as the placement of reinforcement bar, or the installation

of cable racks. There is also scope for productivity improvements from one reactor to the next on a multi-reactor site, and when a design is replicated on a second, or subsequent sites. Importantly this is also a central benefit of the factory-build approach of some designs.

5. It Is Possible to Deliver New Nuclear Power Stations at a Competitive Cost

There is strong international evidence that demonstrates it is possible to deliver new nuclear power stations at a competitive cost, benefiting from a programme to build multiple units of the same design, irrespective of the reactor technology deployed. There are also opportunities for cost reduction from inherent plant design and construction methodology.

That evidence was reviewed and presented in the Nuclear Cost Drivers Study, prepared for the Energy Technologies Institute (ETI) by Lucid Catalyst[11]. The authors have a large database of nuclear new build projects from around the world, including their costs and key features of the development of the projects. The ETI report set out the learnings from international programmes in terms of the key drivers of cost.

The authors of that report were commissioned to update their analysis by the Working Group, and their report is published alongside this report [3].

Key findings from the report are:

i) First of a Kind (FOAK) projects are more expensive

There are significant costs associated with building the first reactor of a given design. This includes the costs of designing the plant and/ or adapting it to a particular country's regulatory framework.

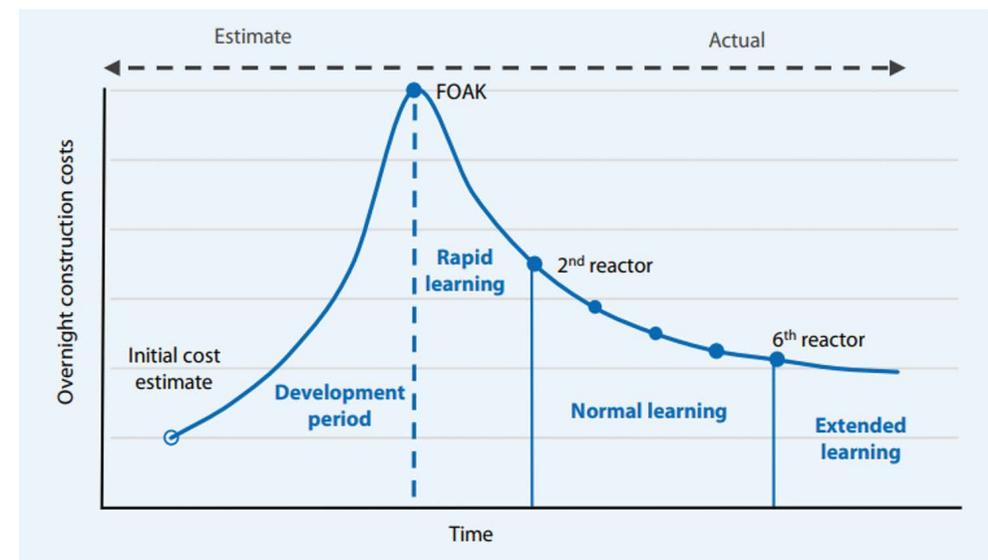
The higher cost plants in the database of new build projects are FOAK/ first in a generation projects being built in Europe and the US, with decades having elapsed since the last new nuclear power stations were built in those countries. In contrast the lower cost projects, which were the majority of the projects in the database, were nth of a kind, demonstrating the effect that design standardisation, experienced leadership, and mature capability can have in reducing cost as well as risk to budget and schedule.

Once a design is approved for deployment and the supply chain is

established, considerable cost savings can be achieved by replicating that design for subsequent projects and using many of the same supply chain partners. Any subsequent design modifications should be evaluated carefully, to establish if they really deliver benefits, compared with the cost and risk implications of design change.

A key implication of this finding is that it would not be cost effective for the UK to have a large number of

different one-off reactor designs, since these would each have significant FOAK costs. The UK can readily benefit from the deployment of multiple reactor designs, but only if each of these designs has multiple reference projects and is replicated in a series build to enable cost and risk reductions to be delivered between projects. The new-build learning curve is illustrated in the OECD NEA's recent report[12] and reproduced below (adapted from Yemm et al[13]).



ii) There are key common characteristics of high and low cost projects

The ETI study demonstrated that there is a relatively small number of understandable factors that drive the vast range of outcomes in nuclear construction around the world.

LOW COST PLANTS

Design at or near complete prior to construction

High degree of design reuse

Experienced construction management

Low cost and highly productive labour

Experienced EPC consortium

Experienced supply chain

Detailed construction planning prior to starting construction

Intentional new build programme focused on cost reduction and performance improvement

Multiple units at a single site

NOAK design

HIGH COST PLANTS

Lack of completed design before construction started

Major regulatory interventions during construction

FOAK design

Litigation between project participants

Significant delays and rework required due to supply chain

Long construction schedule

Relatively higher labour rates and low productivity

Insufficient oversight by owner

iii) Commitment to a programme enables cost and risk reduction

Commitment to a programme, or programmes, of nuclear power stations can enable significant cost and risk reduction by:

- Design standardisation, enabling replication of design - avoiding each project being FOAK.
- Allowing for establishment of best practice and knowledge transfer between projects.
- Enabling investment by Government, industry and the supply chain in education / training and industrial infrastructure.

CASE STUDY: DESIGN STANDARDISATION BETWEEN SITES

A positive example of the benefits of design standardisation is the nuclear island basemat, which is a complex, seismically qualified structure. By initially designing the basemat to cover a broad range of site geologies (soft rock, hard rock) and analysing a broad seismic spectrum, a single standardised design can be used across different project sites. This reduces risk and allows the incorporation of lessons learned across multiple global projects.

Reviewing and incorporating lessons learned is a hallmark of the nuclear industry and inherent to nuclear safety culture. From the completion of detailed design, optimisation of the design for construction, refinement of construction processes and streamlining commissioning, great benefit can be taken from each successive global construction project.

- Enabling developers to invest in detailed design readiness and planning for construction.
- Facilitating construction of more than one unit per site.

The advantage of programmatic nuclear power plant construction has recently been endorsed by the OECD NEA[12] who have stated that *“the most effective way to reduce construction costs in the near term (early 2020s) is to develop a nuclear programme that takes advantage of serial construction with multi-unit projects on the same site and/or the same reactor design on several sites”*.

iv) Increased confidence around budget and schedule reduces cost and risk

Reducing delivery risk in nuclear projects lowers the construction financing costs, both by reducing the risk of schedule over-runs, and also lowering the risk premium for projects. Given construction cost and risk are key drivers of the cost to the consumer of new nuclear, this is an important factor in terms of reducing the cost of future nuclear power stations. Identifying actions that can reduce project risks, and thereby give greater confidence around project schedule and budget, is key to reducing cost.

This links with the finding that replication of reactor design is a key way to reduce cost and risk - design replication provides much greater certainty of the project schedule and costs, which can be based on known quantities and real experience of supply chain costs and delivery.

v) Further key cost-reduction strategies can be implemented

The ETI study concludes that fleet deployment by itself does not necessarily guarantee cost reduction. To realise cost reduction within a fleet or sequenced, multi-unit build, project, delivery consortia must implement a programme that incorporates multiple cost reduction opportunities by all principal actors. To deliver new nuclear in the UK at the rate and scale of deployment needed to achieve Net Zero, the following additional strategies need to be considered:

- a. Reducing schedule and risk through advanced construction methodologies
 - Design standardization/replication to enable a series effect
 - Optimise material usage (eg: Substitute concrete with structural steel)

- Increased use of modular, factory-style construction and preassembly of mechanical and electrical systems

b. Design for Low-Cost Delivery

Design for low-cost deliver is another cost-reduction strategy which would include:

- Passive safety and the elimination of failure modes by design (resulting in plant simplification and the reduction in quantity of nuclear-grade components)
- Design using previously licensed technology
- Factory-based preassembly of mechanical and electrical systems

c. Design for Innovation, Manufacturing and Deployment

There is potential for reduction in the cost of advanced reactor technologies and Small Modular Reactors. While these technologies are not yet licensed, or ready to construct, there is evidence in support of early testing of design claims by regulators, and the examination of cost reduction strategies by potential investors.

CASE STUDY: KNOWLEDGE TRANSFER BETWEEN REPLICA REACTORS

There is already strong evidence of learning through doing at Hinkley Point C. The lessons learned and innovations applied during the ongoing construction of HPC's first reactor unit are already benefitting the second.

On average it has taken 25 hours to install a tonne of rebar on Unit One. At Unit Two, the average is now 16 hours - an improvement factor of 1.6. Learning from reactor one enabled the pre-stressing gallery on unit two to be completed seven weeks ahead of the initial schedule.

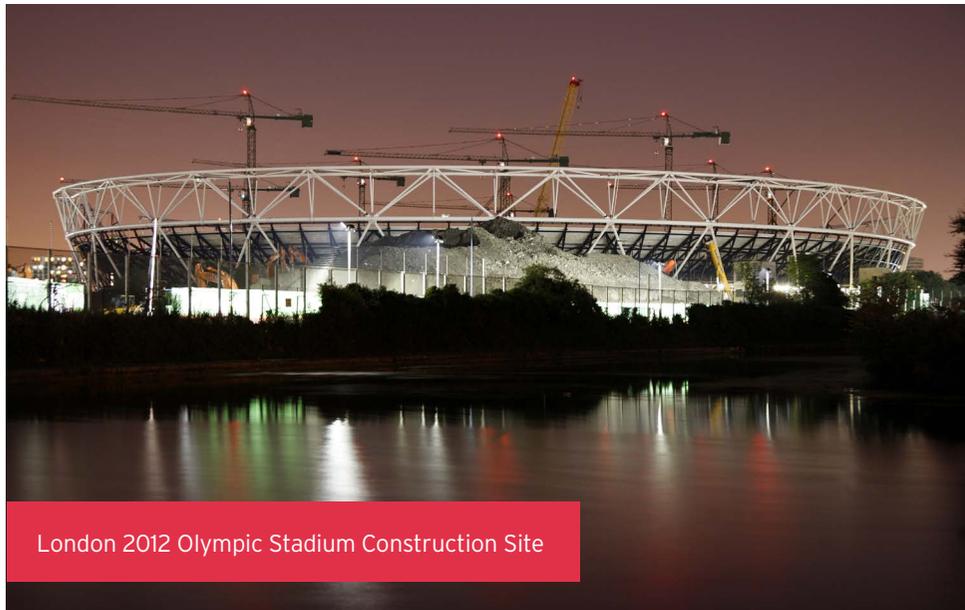
The designs proposed by developers in the UK use a number of these strategies to greater or lesser extents. These strategies are reviewed further in Section 8.

6. Learning From the Construction Sector

Many of the factors driving cost and risk in nuclear projects are in fact common to the delivery of large and complex construction projects in other sectors, rather than being specific to nuclear power stations.

The Nuclear Sector Deal Working Group commissioned a report reviewing recent experience in the construction sector, and drawing

out lessons for construction best practice that are relevant to the nuclear sector[4]. The report draws on previous studies of nuclear construction carried out by the World Nuclear Association and the Royal Academy of Engineering, and broadens this to consider the experience of large-scale construction projects in the UK over the last 20 years, considering where lessons have



London 2012 Olympic Stadium Construction Site

CASE STUDY: USE OF 4D MODELLING

The delivery of Hinkley Point C, like any major infrastructure project, is a huge logistical challenge. During construction, there will need to be precise co-ordination of cabling and pipework in 2,500 rooms throughout each unit of the power station, and a total of 235,000 tonnes of steel reinforcement bars have to be set in concrete. At Flamanville 3, design clashes meant some of the steel had to be moved to make way for other components, causing delays and difficulties.

At Hinkley Point C, a 4D modelling system is in use at the site - this takes extensive 3D modelling data and adds data from the schedule of works as another dimension. Rooms can be viewed at any point on the construction timeline to show how they will look. The 4D model is being used to plan ahead to avoid bottlenecks and therefore to minimise risk to the schedule during construction. The model can also be used by workers on site on their tablets to show them the full and fixed design. This has been used before for pinch points in major UK projects but it has never before been used on this scale.

been learnt and initiatives developed, that can and should be applied in the nuclear sector.

There has been a series of initiatives intended to improve construction practice in the last decade, a number of them with Government involvement. A series of major projects and programmes, including the flagship London 2012 Olympics, has been executed successfully. Together this has created a deep pool of UK expertise in the delivery of complex major infrastructure projects on which the nuclear sector can draw. The

Construction Leadership Council has signed its own sector deal with the UK Government with a similar scale of ambition to reduce costs. It will be important for these two delivery programmes to collaborate closely given the high level of common ground identified in this report.

7. Characteristics of Successful Construction Projects

The accompanying report, on how the nuclear sector can benefit from initiatives in the construction sector[4], identifies a number of characteristics of successful construction projects, which share similar themes to the ones identified in the Lucid Catalyst review of the nuclear sector. As with the Lucid Catalyst study, these characteristics highlight the importance of the client organisation and their key supply chain partners committing resource at the front end of projects to establish sound fundamentals:

- Readiness of design for construction
- Clarity of purpose
- Effective project leadership and governance including:
 - Strong interface management arrangements
 - Strong design change and communication arrangements
- Identification and alignment of optimal:
 - Target Operating Model
 - Delivery Organisation (including capabilities required to be an Intelligent Client)

- Overall Execution Strategy
- Procurement Strategy and Commercial Model
- A collaborative and integrated delivery team
- Creation and exploitation of through life asset data (a Digital Twin)
- Identifying opportunities to leverage Modern Methods of Construction including offsite fabrication, onsite pre-fabrication and industrial production systems

There are initiatives already underway in the construction sector to help codify and embed best practice in the delivery of major construction projects, for example the Project Initiation Routemap, which was developed out of HM Treasury's Infrastructure Cost Review.

Additionally, the Infrastructure Projects Authority has just released its own 'Principles for Project Success'[1]. The work of the New Build Cost Reduction Group is well aligned with these principles, in particular the IPA's focus on:

- managing complexity and risk,
- learning from experience, and
- controlling scope



EPR under construction at Hinkley Point C

8. Further Key Cost-Reduction Strategies

As we have seen, there are generic actions that can be taken by repeating deployment and laying the groundwork for success using the 14 enablers that drive the cost trajectory for each technology downward. There is also the potential for specific cost-saving for different technologies and different designs of reactor as a result of how they impact upfront cost, setup, build-time, etc. This technology-specific cost saving potential is a function of each technology's ability to access some of the following cost reduction strategies.

The Lucid Catalyst report highlights that beyond the previously outlined programmatic opportunities, and cost and risk reduction, further strategies are needed to deliver new nuclear in the UK at the rate and scale of deployment needed to achieve Net Zero. The report identifies that these opportunities need to be pursued in parallel to ensure the UK can meet its Net Zero commitment.

a) Reducing schedule and risk through advanced construction methodologies

By incorporating advanced construction methodologies at the initial design stage of a new nuclear technology, significant reductions to construction cost, schedule and risk can be achieved.

These benefits can be more pronounced in high-cost labour markets such as the UK, but require a higher degree of design completion prior to the start of construction. There may be FOAK challenges when utilising these advanced construction methods, but significant benefits can be realised for subsequent reactor deployments when detailed designs have been completed and optimised.

Evidence from reviews such as the MIT's Future of Nuclear in a Carbon-Constrained World[10] indicates significant cost and risk reduction potential for GW-scale conventional

CASE STUDY: ADVANCED CONSTRUCTION METHODS

Advanced construction methods have been used extensively in other industrial sectors to reduce costs and schedule, and improve productivity, safety and quality and there is scope to incorporate these methodologies into nuclear power plant designs to different extents.

The AP1000 nuclear plant was designed from the ground up to embrace a modular construction philosophy to the fullest and utilises over 300 structural, piping, mechanical and electrical equipment modules. Depending on site location and logistics channels, the largest structural modules can arrive at site by road or rail in sub-modules, for assembly adjacent to the construction area or by barge as complete, fully-outfitted modules weighing up to 1000 tonnes.

This facilitates the safety, quality and efficiency advantages of factory fabrication, reduces construction risk and schedule by increasing the opportunity for parallel path activities and reduces congestion in the construction area.

Achieving the full benefits of a modular construction philosophy requires its incorporation into the fundamental plant design, a high degree of design completion prior to construction and a specialist supply chain. There were FOAK challenges in this respect for the first wave of AP1000 reactors, but the detailed design has now been completed and optimised across the build of 6 units, an experienced supply chain developed, and lessons learned incorporated supporting the conclusions of this report. This will greatly benefit future global AP1000 plant projects.

light water reactors is possible. Opportunities include:

- Seismic isolation to reduce need for site specific design changes
- Design standardisation and incorporation of lessons learned
- Design replication to enable a series effect
- Modular construction
 - Greater efficiency realised by factory build
 - Incorporation of construction philosophy at the design stage

- Parallel paths to reduce schedule challenges
- Advanced construction materials
 - Steel plate composites
 - Self-consolidating and ultra-high performance concretes
- Advanced construction management-planning
- Automation

b) Design for Low-Cost Delivery

The Lucid Catalyst report also highlights that further cost reduction can be achieved by having clear cost targets from the outset, 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:

- Passive safety and the elimination of 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 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 Nuclear Cost Drivers Study indicates 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.

c) Design for Innovation, Manufacturing and Deployment

The ETI Nuclear Cost Drivers Study identified that there is potential for reductions in the cost of advanced reactor technologies and Small Modular Reactors.

CASE STUDY - PASSIVE SAFETY PHILOSOPHY

The AP1000 nuclear plant is the first fully passive Generation III+ nuclear power plant to be designed, licensed and constructed and with 4 units entering commercial operation between 2018 and 2019, with a further 2 units expected to load fuel between 2020 and 2021.

The passive safety philosophy means that all safety systems use only the forces of nature and stored energy. The plant simplification achieved by this approach results in:

- More than 50% reduction in plant footprint
- More than 50% reduction in building volume (particularly seismic building volume)
- More than 50% reduction in equipment (particularly safety-class)
- Reduction in construction/installation cost and schedule
- Commissioning/operation/maintenance/decommissioning efficiencies

This has led to a dramatic reduction in the need for nuclear safety grade equipment, which reduces cost, lead-time and diversifies the supply chain opening more opportunities for local supply. By example, there are several thousand valves in the AP1000 plant, but only several hundred of these need to be safety rated.

In a further example of how passive safety can reduce equipment costs and diversify supply chain, the AP1000 plant utilises only two reliable, high-quality industrial-grade back-up diesel generators to support day to day operations in the event of a loss of off-site power. The plant does not need multiple nuclear safety-rated generators, because none of the AP1000 plant safety systems require AC power to actuate them.

While these technologies are not yet licensed, or ready to construct, 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 securing regulatory design approval and completing a detailed design can a company build a commercial demonstration or first-of-a-kind plant. There are positive messages about the cost trajectory for these plants, but 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.

The range of designs proposed by developers in the UK use a number of the above strategies to greater or lesser extents.

CASE STUDY: SMALL MODULAR REACTORS

Small modular reactors aim to capitalise on a number of the strategies highlighted in this report:

- Lower capital cost per unit potentially making raising funding easier
- Short build time per unit, again influencing access to funding
- Repeat, factory production can lead to a rapid learner curve for nth of a kind units, thereby reducing risk. However, a first of a kind SMR project will face similar challenges from design approval and completion and qualification of equipment common to complex engineering projects. The Rolls Royce SMR seeks to mitigate this through a UK design team and a UK design
- Volume production is key to reducing cost through learner curve benefits, emphasising the importance of a programme build
- Modularisation can achieve significant capital cost reductions with the approach designed around realising the benefits of repeatable factory fabrication. However, this means that design completion for reactor and factory have an elevated significance.
- Sizing of modules to be road transportable reduces the capital cost of facilities, transportation and installation.
- Commoditisation -the use of standard parts and commercially available parts where appropriate, and qualified to nuclear safety requirements, can remove one-off specialist components and enable the benefits of a broader industrial demand to be realised.
- An increase in factory fabrication allows for modules to be manufactured and tested in a controlled environment and reduces site activity.
- Smaller footprint/ scale reduces the amount of site activity, disruption and associated risks (eg: by construction under a canopy)
- The smaller power output of SMRs allows them flexibility in regard to location. With a greater number of sites being able to accommodate a smaller plant there comes the opportunity to deliver at pace and volume once the design and construction has been proved through the prototype, and without using sites earmarked for large-scale nuclear

9. Risk Assessment Tool for New Nuclear Projects

Drawing on the reports cited above, and a broader literature review of major infrastructure project delivery, the Working Group identified the key root causes of failure in the delivery of major infrastructure projects including new nuclear power stations, and the specific actions that should be taken to reduce risk and cost and avoid failure.

The sources on which this work has drawn are:

- The ETI report of cost drivers of international nuclear projects[11], and the follow-up Lucid Catalyst study[3]
- The Folz Report[14], looking at lessons learnt from the construction of the EPR new nuclear power station at Flamanville

	Theme	ETI costs drivers	INPO Report	IPA Initiation RouteMap	NAO report on Cross Rail	NAO report on HS2	NAO report on MOD nuclear regulated sites	Morrow	Folz Report on FA3	Key risk reduction enablers
1	Financing			X	X	X	X	X		Is the financing model secure, are stakeholders aligned and HMG committed and aligned?
2	Regulation	X		X		X		X	X	Are Regulation and permitting requirements understood?
3	Governance	X		X	X	X	X	X	X	Is the governance defined and fit-for purpose: roles of Owner and delivery team defined and distinct, with a strong multidisciplinary owner's team?
4	Site Data				X			X		Are the site-specific data understood and taken into account?
5	Technology Data							X		Are the data on processes and components accurate enough, and innovations under control?
6	Design	X		X	X	X	X	X	X	Is the design mature?
7	Estimates		X		X	X	X	X	X	Are Costs and schedule estimates realistic, integrating robust risk assessment?
8	Contractual Interfaces	X		X	X	X	X	X	X	Are interfaces identified, understood and managed at each level of the project?
9	Project Management	X	X	X	X			X	X	Is the management of the project strong enough: Robust organisation and processes, effective and experienced project team?
10	Data System			X		X				Is the data structure access and related systems strategy consistent with the Project context?
11	Construction Preparation	X	X	X	X	X		X	X	Is the construction execution plan fit for purpose? Are Nuclear Safety and Construction special requirements taken into account, including management of quality and defects?
12	Supply Chain	X		X	X	X	X	X	X	Are the Procurement and contracting Strategies defined and fit-for-purpose; Are suppliers incentivised to deliver the best for the project?
13	Skills	X	X	X			X	X	X	Are the critical skills identified and managed - With particular attention to safety and quality culture?
14	Operations Preparation	X	X	X						Is the transition to operations planned , with operation staff embedded in the project early?

- Report by the Institute of Nuclear Operations “Principles for Excellence in Nuclear Project Construction”, May 2010 [15]
- NAO reports on Crossrail [16] and HS2 [17]
- Project Initiation Route Map handbook, by the Infrastructure Projects Authority and Infrastructure Client Group[18]
- Industrial Mega Projects, by Edward W. Morrow[19]

- The Oxford Handbook of Megaproject Management, Ed. Bent Flyvbjerg[20]

This has been supplemented by discussions with a wide range of experts in infrastructure delivery.

The Working Group identified fourteen key “risk reduction enablers” for new nuclear projects, as shown in the table above.

For each risk reduction enabler, work is ongoing to establish the specific tests that would enable a robust risk scoring of the project. For each enabler, a target state will be identified with associated deliverables, which represents the best possible state in which the project could be in order to minimise risk.

For example, for the enabler “Regulation and permitting requirements understood”, this would include:

- Generic Design Assessment and a Nuclear Site Licence granted by the ONR
- Planning consent granted and all key conditions being cleared
- All environmental permits being granted
- Process and people in place to enable compliance with the requirements

Once the full list of deliverables is developed, it will enable a comprehensive, robust, and objective scoring of the risk profile of a new nuclear project, based on specific and measurable milestones. An example of a scoring tool is shown below.

Attaining a top score in every category may not be possible for a particular project, but the risks that arise from a project being less ready for construction than is optimum need to be understood by all stakeholders at the time the commitment to construct is taken and action plans put in place to address the risks.

The assessment will be of benefit to project developers, investors, Government and others, who wish to

Short summary stating the criticality of the enabler.

Overall rationale for fail / pass / max score.

List of topics.

Specific conditions for failure; regardless of scores on other enabler, project cannot move to next gate.

Specific conditions for top / pass score.

establish the risk profile of a new nuclear project and its readiness for construction.

This is a much more detailed and comprehensive assessment than has been available for other infrastructure projects, and it is hoped the approach may have applications beyond the nuclear sector. An objective assessment of readiness applied to major projects has the

Enabler #4: Site data understood and taken into account

- **Site data is a fundamental building block for the project; design, safety case, permitting, constructability can be impacted by it.**
- **Because of these dependencies, the top score for this enabler should be reached early to enable a mature design and hence mature costs and schedule.**

- **Difference between fail and pass:** Data should be available before project commitment, with a robust process in place ensuring accuracy and communication management across the project.
- **Difference between pass and top score** driven by time: the earlier the data is available, the better.

Enabler #4 Site data understood and taken into account		Owner: Technical Director	
Topic	Failure means...	Test for pass score	Test for top score
Air and water temperature - normal conditions	Data not available, or not validated by key stakeholders	Data report finalised and approved by all stakeholders	
Ground conditions	Data not available, or not validated by key stakeholders	Data available, validated by key stakeholders Data fed into detailed design	
External hazards	Data not available, or not validated by key stakeholders	External hazards identified, validated with key stakeholders Results integrated in seismic and static load studies	Data available and quality assured by key stakeholders and reflected in design
Environmental issues on site	Data not available, or not validated by key stakeholders	Data available, validated by key stakeholders Data fed into permitting	
Water supply	Data not available, or not validated by key stakeholders	Secured and approved by key stakeholders	
Grid connection	Data not available, or not validated by key stakeholders	Secured and agreed with Grid operator	
Site layout and accesses	Data not available, or not validated by key stakeholders	Defined and validated with stakeholders	
Impact on local communities	Impact assessment incomplete, or diverges from other stakeholders' view	Impact assessed reflecting stakeholder's view	Impact assessment validated by key stakeholders with appropriate mitigation plans

potential to improve learning over time as feedback from completed projects is assessed and better align the interests and understanding of

developers, supply chain partners, Government and others.

10. Financing for Future Nuclear Projects

Given HPC was the first new nuclear project in a generation in the UK, it was appropriate that the project developers should bear the development and construction risk. However The National Audit Office identified that, for future new nuclear projects, alternative approaches to financing could have reduced the total project cost[5].

Taking the specific example of Sizewell C (the proposed follow-on to Hinkley Point C), EDF/ CGN now have experience that the plant can be replicated. As this report shows, this means that capex will be lower by avoiding FOAK costs, and cost of capital will be lower through risk reduction. This lower cost does not however mean that the developers can finance the project themselves: developers have limited balance sheets and a mechanism is required to draw investors to the table, widening and deepening the pool of capital available, and further reducing the cost of capital and hence costs to the consumer.

Government is currently consulting on an alternative Regulated Asset Base (RAB) approach to financing future nuclear projects. Under this approach, investors would receive some revenues during construction, the project's returns would be overseen by a regulator, and there would be cost/ risk sharing mechanisms with customers and/ or tax payers. This approach has the potential to substantially reduce the overall cost of future nuclear power stations to customers, and is appropriate if developers take the steps to reduce construction risk identified above. This approach would facilitate the construction of new nuclear on the scale to match the Government's ambitions with regard to Net Zero, again irrespective of the technology deployed.

Putting in place a new financing structure that can better reflect the risks of a project and allocate the cost to the parties involved to achieve an optimum result for customers is the final piece of the puzzle to deliver the 30% cost reduction target.



11. Conclusion/Next Steps

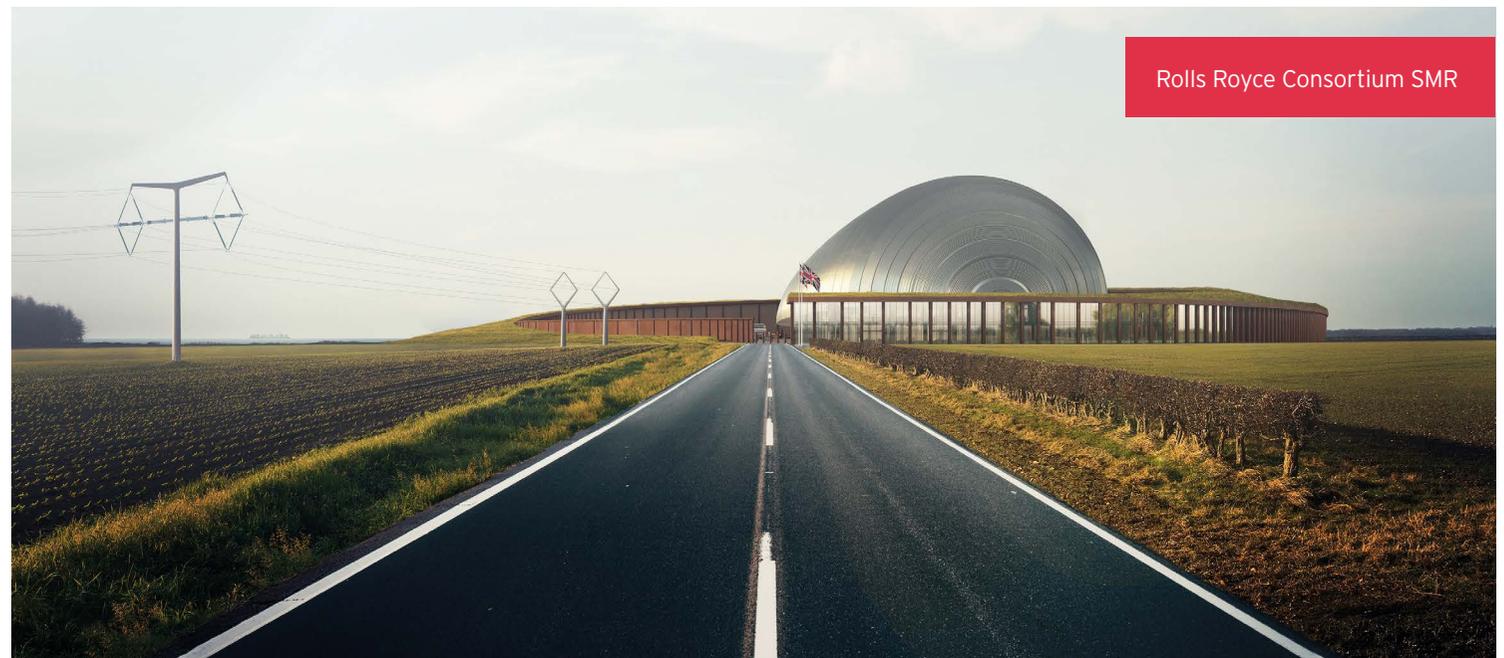
This report has identified the key actions that industry and Government need to deliver in order to achieve at least the 30% reduction in the cost to the consumer of new nuclear power stations by 2030, taking the Hinkley Point C strike price as a starting point.

The bulk of the actions are for project developers to take, to ensure their projects are set up for success which will allow them to deliver the cost reduction potential of their chosen technologies. The risk assessment tool described above will enable developers, investors and Government to have a robust, shared assessment of whether those actions are being taken, and to track them through the delivery of the project.

Each project should be thoroughly assessed using the risk assessment tool prior to a Final Investment Decision being taken. That will be the point, when a baseline price is agreed, when it will be apparent for each project whether the target of a 30% cost reduction to the consumer has been achieved.

The report recognises that there are technology differences, but each developer has the opportunity to reduce the cost of their own design through the management of construction cost and risk. In addition, the industry recognises that HPC has not only carried first of a kind in the UK costs for the EPR design, it has also borne the first of a generation costs for new nuclear in the UK -

setting up the supply chain, skilling workers, and building capabilities. Future projects, whatever the design, will be able to capitalise on this. In short, it is clear that whatever nuclear plants are built in the coming years to support the Government's Net Zero ambitions, the cost to the consumer will be less than for HPC.



12. Summary of Steps to Deliver 30% Cost Reduction Target

- 1. Cost Reduction Working Group** will continue to develop the risk assessment tool
(All projects will feed lessons into the tool as part of a process of continuous learning)
- 2. Cost Reduction Working Group** will undertake further work to assess the impact of additional cost reduction strategies
- 3. Government** plans to lay out, in a White Paper in Autumn;
 - expectations on the sector for new build
 - a framework for financing projects, enabling developers to connect to new sources of low-cost finance
- 4. Project developers and Government** will assess projects using the tool prior to final investment decisions being taken, and put in place governance arrangements to continue to track performance and risk
- 5. Developers** will take the necessary cost / risk reduction actions identified in the 14 categories in the assessment tool



Front cover shows 4D model view of systems in nuclear island and conventional island at Hinkley Point C

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- **Barry Dye,**
Laing O'Rourke
- **David Hurcomb,**
NG Bailey
- **Harry Bowcott,**
McKinsey