SMALL MODULAR REACTORS:

Delayed Privatisation Financing Structure

THE NEW NUCLEAR WATCH INSTITUTE

EXECUTIVE SUMMARY BY TIM YEO, CHAIRMAN, THE NEW NUCLEAR WATCH INSTITUTE

Small modular reactors offer significant potential advantages compared with traditional large nuclear power plants. These include the likelihood of shorter build times, simpler designs requiring fewer structures and components, greater flexibility of location, enhanced compatibility with smaller local load profiles, easier refuelling and maintenance schedules at multi-unit configurations, lower decommissioning and site restoration costs, and savings from repeat in-factory construction.

A further important benefit is the much smaller initial capital investment required for an SMR. This brings SMRs within the reach of a wider range of investors, including many who could not contemplate the huge upfront capital cost of larger plants, and should help to improve the terms on which finance is available.

However, SMRs are still at an early stage of development and have some of the characteristics of first of a kind (FOAK) plants. For example, during the initial phase, even if the fundamental reactor technology is not itself innovative, there remains a need to build and operate a prototype plant to shows that its design can capture the benefits of series production and operational efficiency, satisfy both regulators and licensing agencies, as well as being integrated into a developing supply chain.

Furthermore, even though the danger of serious construction delays should be less than for large scale plants, until a successful FOAK SMR plant has been successfully completed the risk of such delays is not entirely eliminated. If privately financed, this is translated into a cost of capital that may prohibit many projects from going ahead.

Experience shows that conventional project finance, which usually relies on cash flow generated by the project itself, has not worked well for new nuclear plants because of uncertainty about when revenue will start to be received and the track record of recent projects regarding cost overruns and delays. Attempting to mitigate this risk has been part of the reason for the high CfD strike price at Hinkley Point C.

As for the Regulated Asset Base model used to great effect in other industries by the UK government while this could work in theory its structure is complex and it has never yet been used to finance FOAK energy infrastructure.

This makes the “Delayed Privatisation” model, proposed in this report, in which government is directly involved in providing equity funding during the construction period, attractive. Under this model once the plant has been completed the government exits its holding and the project becomes wholly privately financed.

This report illustrates how Delayed Privatisation could work in practice for SMRs. Direct participation by government in the first phase of a project can be justified by the fact that SMRs are an emerging technology that if successfully developed will be an important tool in meeting climate and emission targets. In addition, there is an opportunity for the UK to establish a valuable supply chain in a sector of the nuclear energy industry where a substantial potential export market exists.

The New Nuclear Watch Institute believes that adopting a creative approach to financing SMRs could enable the UK to perform the kind of leading role which it enjoyed in the last century in relation to nuclear energy more generally. We recommend that consideration is therefore given to Delayed Privatisation alongside other alternative financing structures.

ABOUT TIM YEO

Tim Yeo was a Member of the UK Parliament for over 30-years, from 1983- 2015. During his time as an MP, Tim was Chair of the influential Energy & Climate Change Select Committee (2010-2015), and of the Environmental Audit Committee (200510). Prior to this he served in several Government departments (1988-1994) including Minister for the Environment and Countryside (1993-1994) in the John Major Government.

Since leaving the House of Commons in 2015, Tim has been working in various energy and climate change related roles in the business and academic worlds. These include Chair of New Nuclear Watch Europe (NNWE), an industry supported body which campaigns for new nuclear development across Europe, Board membership (and former chair) of AFC Energy plc, an AIM listed UK based hydrogen fuel cell developer, and Chair of the University of Sheffield Energy 2050 Industrial Advisory Board. Tim remains a director of Getlink SE (formerly Groupe Eurotunnel), one of the largest listed companies in France, where he chair's the Board Strategy and Sustainable Development Committee.

In 2016 KOTRA, the South Korean trade office, appointed Tim as the Honorary Ambassador of foreign investment. He is also a frequent visitor to China where he works with the UK-China (Guangdong) CCUS Centre on carbon capture projects, with academic collaborators on the design of China's emissions trading system and with business colleagues on inward investment from China to the UK.

ABOUT THE NEW NUCLEAR WATCH INSTITUTE (NNWI):

Founded by Tim Yeo at the end of 2014 New Nuclear Watch Europe (NNWE) is an interest group which has been established to help ensure nuclear power is recognised as an important and desirable way for European governments to meet the long-term security needs of their countries. Membership is open to all companies, individuals and organisations active in the nuclear industry including those involved in the supply chain.

The New Nuclear Watch Institute (NNWI) is the first think-tank focused purely on the international development of nuclear energy. It believes that nuclear energy is vital for the world to achieve their binding Paris Climate Agreement objectives. Its research will aim to promote, support, and galvanise the worldwide community to fight the greatest challenge of our time: climate change.

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A. SMRS: ECONOMIC AND TECHNICAL CONSIDERATIONS:

The primary characteristics of SMRs, defined by the IAEA as advanced reactors that produce up to 300 MWe per unit, are their low power output (in comparison to traditional large NPPs) and modularity. A comprehensive economic assessment of a functional plant has not been possible (no facility- and commercial-scale units are yet operational) to date but designers claim that the per kWe overnight cost of an SMR facility could be lower than that of a large NPP. At present, more than fifty SMR designs are under development across the world and construction has begun on three: the CAREM (Argentina), the KLT-40S (Russia), the HTR-PM (China)[1]. Additionally, SMRs such as the RITM-200 (Russia) have already been installed on icebreaker vessels and are being adapted to a power plant configuration. The OECD have estimated a potential SMR market (in 2035) of 21 GW[2], while the UK National Nuclear Laboratory (NNL) have forecast up to 65-85 GW on the proviso that SMRs are cost-competitive with large NPPs[3].

The claimed (low) cost profile of SMRs is a result of the following features:

- the factory assembly manufacturing of individual modules that should lead to shorter construction times as repeated processes – or 'learning-by-doing' – allow for efficiency gains along serial production (the 'economies of serial production') as observed in the aviation and automobile industries;

- multi-unit configuration (an SMR plant would be composed of a number of identical SMRs) allows for a reduction in per MWh O&M costs as certain activities (refuelling and maintenance work for example) can be performed on a unit-by-unit basis, not requiring the outage of the entire facility;

- the initial investment required to construct an SMR is small compared to that required for a large NPP and so financing terms should be easier, as a capital-intensive generation asset (in contrast to coal- and gas-fired plants) the cost of capital of the project is a highly significant determinant of its viability;

- the module structure and small-size of individual units should reduce costs associated with decommission and site restoration;

- the scale of power output of SMRs could reduce transmission infrastructure requirements as well as increase the number of locations in which a nuclear facility is compatible with the local load profile;

[1] *IAEA, Advances in Small Modular Reactor Technology Developments, pp. 2-3, (2018)*
[2] *OECD-NEA, Small Modular Reactors: Nuclear Energy Market Potential for Near-Term Deployment, (2016)*
[3] *UK National Nuclear Laboratory, SMR Feasibility Study, (2014)*

- and, almost all SMR designs contain fewer structures and components than traditional NPPs;

Moreover, the design of several SMRs contain passive safety features – those that do not require the active intervention of an operator or electronic feedback system in order to return the reactor to a safe state – that are possible due to the smaller core size. While it will take time for regulators to assess these novel safety features – indeed the time taken to license SMR designs will an important determinant of the eventual schedule of their construction and deployment– it is thought that they will reduce the regulatory burden on plant operators. Equally, the existence of passive safety features will reduce the occurrence of redundancy, with a commensurate financial benefit.

AI. SMRS AND LARGE NUCLEAR POWER PLANTS: KEY DIFFERENCES WITH RESPECT TO FUNDING AND FINANCING

The recent experience of large NPP projects in Europe is beset by cost overruns and construction delays. Indeed, as noted by Locatelli, 'the larger the [NPP] project, the greater is the likelihood to be over budget and experience a delay[4]'. Similarly, Portugal-Pereira et al. find that 75% of the most recent generation of reactors constructed since 2010 now face substantial construction delays[5]. It should also be made clear that the two difficulties are intrinsically linked as the vast amount of upfront capital investment required is (predominantly) financed with debt, the burden of which increases as the construction period is extended by delays.

The reasons proffered in explanation of this trend are numerous – including optimism bias, the impact of competitive pressures, unrealistic cost and/or construction estimates, and so on – but consensus has converged on three overarching features of contemporary NPP deployment: the large scale, the high degree of project complexity, and the absence of a standardised, repeated design. As such, the particular delivery model of SMRs – outlined on the previous page – can be seen to directly mitigate these core issues by virtue of their smaller size, modular design, and repeat construction.

With particular regards to project size, the lower upfront capital investment necessitated by an SMR plant allows for access to a wider range of market investors

[4] *Locatelli, Why are Megaprojects, including Nuclear Power Plants, Delivered Overbudget and Late? Reasons and Remedies, (2018)*

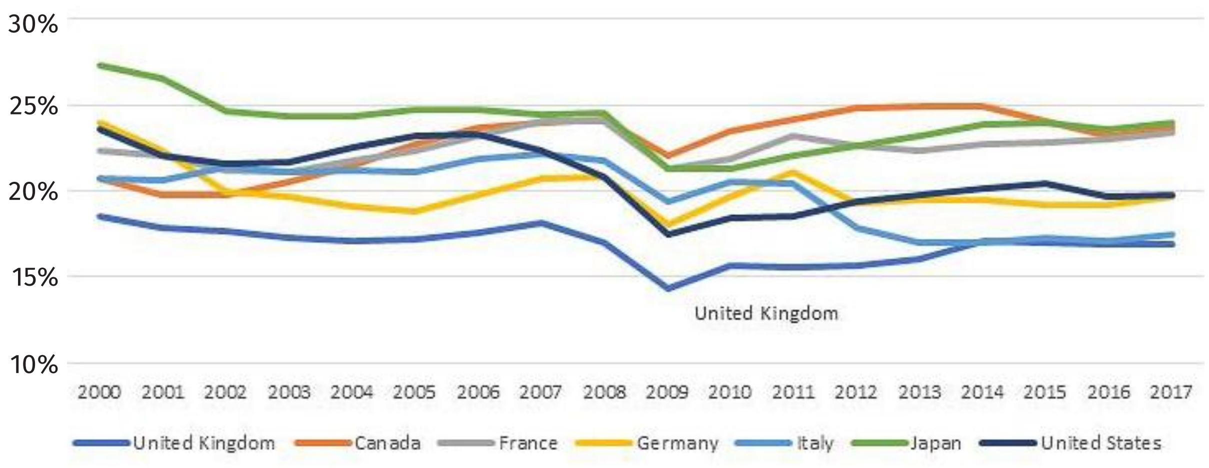
[5] *Portugal-Pereira et al., Better Late than Never, but Never Late is Better: Risk Assessment of Nuclear Power Construction Projects, Energy Policy (2018)*

than is the case for a typical NPP, which should improve not only access to finance but also the terms of finance. As already noted, the capital-intensive nature of nuclear facilities means that the economic viability of any project is strongly determined by the (weighted average) cost of capital and so an improvement in the available terms of finance is of significant importance.

B. FINANCING CHALLENGES: MAJOR RISKS IN THE CONTEXT OF EMERGING TECHNOLOGIES:

The UK, as noted by the OECD[6] and illustrated in the graph below, has spent less on infrastructure than other OECD countries and G7 peers since the early 1990s. Within the energy sector, investment in new generation capacity has increased since 2010 in the face of anticipated supply constraints brought about by the gradual phase-out of aging coal- and gas-fired plants. In contrast to the transport, waste, and social sectors, projects in the energy and utilities sector have been almost entirely privately funded[7] (close to 95% of projects currently planned between 2017/18 and 2020/21).

G7 Investment as % of GDP



BI. SMR TECHNOLOGY: MAJOR RISKS

In this section, the key risks to the development of an SMR project are presented; a full analysis of all potential risks as well as a detailed allocation matrix can be found in *Market Framework for Financing Small Nuclear* (a report for HMG). From

[6] *OECD, OECD Economic Surveys: United Kingdom 2015, (2015)*
[7] *Rhodes, Infrastructure Policies and Investment, House of Commons Briefing Paper, (2018)*

a techno-risk perspective, the two most pertinent features of a hypothetical SMR project are that it is an infant technology and so would be (at least for the initial module) a first-of-a-kind (FOAK) construction.

#1

Phase One - Technology Development:

First-stage risk is determined by the maturity of the technology to be deployed. While SMRs are certainly novel in their output range, physical size, and so on, the fundamental reactor technology is in many cases – such as the NuScale Power Module – based on the (Integral) Pressurised Water Reactor (PWR) and so is not 'innovative' as such[8]. Therefore, the key risk at this stage (for SMRs based on IPWR technology, as opposed to other reactor models such as the HTGR or the LCFR) is not the uncertain outcome of exclusively reactor-focused R&D but instead the design and specification of a saleable – as well as regulatory approved and licensed – product.

An important stage in the initial phase is the build and operation of a functional prototype and/or demonstrator plant, which in turn exhibits the quality and capacity (or otherwise) of the related supply chain; a significant factor at this juncture will be the integration of the SMR design process with the development of the supply chain as this will determine both the scalability and the efficiency of production in the subsequent (construction) phase.

#2

Phase Two - Construction:

The construction – and timely completion – of a nuclear plant is a critical economic period for two reasons: a) the daily cost – in terms of manpower, equipment, and so on – is largely fixed, and b) a delay of any significant period entails both an equal delay in the receipt of inbound cashflow and an increase in debt service costs. Moreover, due to the complexity of a nuclear plant, a single delay – even brief in relation to the planned construction timeframe – is likely to be

[8] *Atkins, SMR Techno-Economic Assessment – Project 1: Comprehensive Analysis and Assessment, Department of Energy and Climate Change, (2016)*

exacerbated as the mass interconnection – and consequent need for exact coordination – between the various plant components means that it will be 'echoed', repeated, and amplified elsewhere. As noted by Llyvbjerg[9], this increases the likelihood of a project falling into the 'debt trap', 'where a combination of escalating construction costs, delays, and increasing interest payments make it impossible for income [...] to cover costs, rendering the project non-viable'.

However, the construction risk faced by an SMR – at least after the successful completion of a FOAK unit – should be smaller than that of a large NPP due to the reduced design complexity – eased further by the modular fabrication of the components – and the potential to advance along the 'technology learning curve' at a faster and more consistent rate than has been the case for NPPs in Europe due to the nature of serial production. It should be noted that a 'successful' FOAK construction does not necessarily (and indeed is unlikely to) constitute a per kW cost aligned with that expected for subsequent (NOAK) builds but one that verifies the underlying fabrication, construction, and organisation methods and presents real and attainable efficiency gains as well as the opportunity to leverage economies of series production.

#3

Phase Three - Operation:

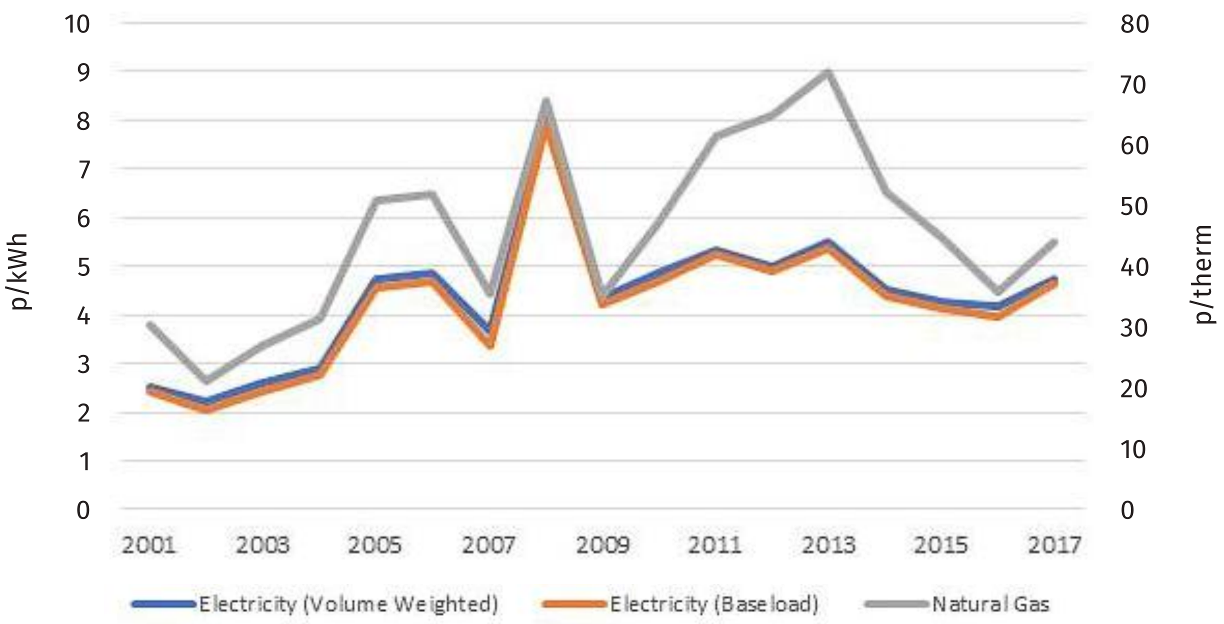
Upon completion of the SMR facility, the risk focus transfers to the operation of the plant itself (internal) as well as the wider market (external) conditions in which it operates. The internal aspect relates to the management and performance of the SMR plant operators, typically captured by plant capacity factor (net of own power use). The multi-unit or fleet-based nature of an SMR facility should allow for the more efficient optimisation of expected unit outages – scheduled maintenance, periodic refuelling, etc. – as processes that take individual units offline can be scheduled sequentially, thus the plant-level capacity factor can be held at higher levels than would otherwise be the case. Unexpected outages –

[9] *Flyvbjerg, What you should Know about Megaprojects, and Why: An Overview, Project Management Journal, (2014)*

borne out in negative deviations from the nameplate availability factor of the unit – can have multifarious causes but should decline in impact as serial production proceeds and unforeseen weaknesses or blockages in FOAK models are rectified.

The economic performance of an SMR plant will be determined in the wider power market in which it operates and so price risk – in terms of uncertainty as well as in relation to the levelised or breakeven cost of electricity produced by the plant – represents a significant operational risk. To a certain degree, an SMR facility is akin to any power generation asset in that it sells output into a competitive market place where the clearing price fluctuates. However, there are two specific trends that deserve particular attention. The first concerns the high level of correlation between the price of electricity and the price of natural gas in the UK, a result of reliance – especially with regards to baseload generation – on the fuel. As such, power market risk is acutely affected by fluctuations in the price of natural gas, although not a wholly global market it is at least reflective of wider pan-European gas conditions.

Electricity and Natural Gas Price Correlation



The second relevant trend is the increasing – and indeed accelerating – expansion of the share of the generation mix accounted for by variable renewable energy (VRE) sources. The intermittent nature of power generation from solar and wind resources prohibits the removal of 'traditional' or conventional generation assets – referred to as the low 'capacity credit' of VRE sources – as backup capacity is required for periods of low or zero VRE production. However, the requisite backup capacity will operate at a depressed capacity factor over any extended period; the low cost – supported in some regions by FiTs and/or renewable purchase obligations – of VRE generation 'crowds out' other sources of power (via the merit-order effect) and so reduces the conventional output that can be matched to load. As noted by Ueckerdt et al., the 'integration costs' of intermittent generation increase with its share in electricity generation and are further exacerbated in the short-term, when grid flexibility is constrained[10].

C. POTENTIAL SMR FINANCING STRUCTURES:

The allocation of the individual risks described in the previous section is to a large extent dependent on the particular financing structure underlying the SMR project; as such the discussion below will make clear by what mechanism and to whom the alternative strategies apportion risk. It should be noted that the discussion is tailored to the UK context.

#1

Project Finance:

Project finance – typically employed in the financing of long-term assets, such as infrastructure – is a financial structure that relies on the asset-generated cashflows of the project for capital and loan repayment and the asset itself as collateral. It has proven an attractive strategy within the private sector as funding takes place off-balance sheet. In many subsectors, financing is agreed on a limited recourse basis – in which the creditor has limited claims on the assets of the parent company – but this method – at least as a standalone structure – has not yet been achieved in the financing of

[10] *Ueckerdt et al., System LCOE: What are the Costs of Variable Renewable?, Energy, (2013)*

large NPPs, due to the often-underwhelming performance of projects in the pre-operational phase, the scale of financing required, and the elevated risk of financing projects based on new or nascent (FOAK) technology.

As such, a number of financial addendums or modifications have been proposed to the pure project finance structure in order to make new nuclear build projects viable and able to attract the required investment. One often-proposed – and indeed practiced – structure is to offer the operator(s) of the plant either a Power Purchase Agreement (PPA) or a Contract for Difference (CfD) – as in the case of Hinkley Point C. This structure alleviates the price or revenue risk taken on by the operator (and transfers it to the seller of the PPA or CfD) that is associated with the operational phase of the project, with the PPA eliminating it entirely (by setting a fixed reference price without a link to ongoing market conditions and so determining the revenue stream in advance of operation) and the CfD doing so only partially (payments are made relative to a reference market price).

However, the addition of a PPA or CfD (in part dependent on the level at which they are set) may still prove insufficient to attract sufficient investment at viable cost to a new SMR project, due to the elevated pre-operational risks associated with the FOAK construction of an emerging technology without a track record of reliable and consistent performance. As such, two forms of UK Government involvement have been proposed: a) via direct investment (whether equity or debt), or b) acting as a guarantor of private debt. Indeed, the Government, as reported in the BBC[11], has signalled that it is at least taking a direct equity stake – alongside Hitachi and Japanese state agencies – in the Wylfa Newydd plant in Anglesey (Wales) although no final decision has yet been reached.

These structures – based on a direct or indirect role for public support – allow for the project terms of finance to reflect (at least partially) the low cost of capital of the Government and to either improve the debt rating – potentially allowing institutional and more risk averse debt investors to partici-

[11] *BBC, UK Government to 'Finance' Wylfa Newydd Nuclear Plant, Published: 17-05-2018*

pate – or the attraction to private equity of it (both enabled by the perceived de-risking that Government support allows). It should be noted that both direct and indirect will have an impact on the balance sheet of the Government (with the former representing a higher involvement) and may be subject to challenge under State Aid considerations.

#2

Non-Project Finance: Regulated Asset Base (RAB) Model:

As described by Helm[12], the 'RAB is a statement of the investors' sunk funds in a utility, to which the duty to finance functions applies'. The duty in effect gives a guarantee that invested capital will be recovered over time – with an additional regulated rate of return – from consumers. This is achieved via the setting of a tariff by an appointed economic regulator – that also determines the types and scale of capital expenditure that can be classified under the RAB – and is a structure that has been used in the UK as part of the privatisation process of industries such as water and power transmission. However, the applicability of this model to a FOAK construction is not straightforward as the infancy of the technology and design means that the risk of stranded assets in the case of project non-performance remains.

Another noted drawback of the RAB structure is its complexity and it is by no means certain that consumers or taxpayers would have to pay for the costs of its administration as well as the implementation of new regulatory framework (as the RAB has not yet been applied to power generation asset). However, EDF has proposed the RAB model as a means to finance a new large NPP at the Sizewell facility in Suffolk arguing that the structure – combined with assumed construction efficiencies taken from its experience with the Hinkley reactor – could reduce the project weighted average cost of capital from 9.2% to 5.5-6%, in turn allowing for the delivery of power at close to £60/MWh[13].

[12] *Helm, The Nuclear RAB Model, (2018)*
[13] *The Financial Times, EDF Seeks to Charge Customers Upfront for UK Nuclear Plants, Published: 22-11-2018*

Case Study: The Thames Tideway Tunnel – Weighted Average Cost of Capital of 2.497% (Vanilla)

In August 2015, Ofwat – the economic regulator of the water industry in England and Wales – accepted a cost of capital for the construction phase of the Thames Tideway Tunnel (TTT) – a so-called 'super sewer' beneath London — of 2.497%[14], an extraordinary low figure in its own right and substantially below the 3.29% estimated by Ofwat in its draft guidance on regulating the TTT[15].

The low cost of capital has been attributed to three principal factors:

- the declining cost of debt that has resulted from monetary measures (low base rates) implemented in response to the financial crisis that has fuelled significant levels of corporate debt – as well as increasing the price of other financial securities – at historically low rating-adjusted rates;
- a Government support package designed to mitigate the negative impact of 'high-cost/low-likelihood' risks that is able to provide insurance cover of last resort, a short-term liquidity feature, and an equity contribution should a significant construction cost overrun take place;
- the regulatory regime of Ofwat and in particular its liquidity allowance – permitting the earning of a return on the expected spend of the following charging year to compensate for capital expenditure – and a debt adjustment feature that allows for the WACC to fluctuate with a specified debt index.

Beyond the factors outlined above, the process employed a bidding process to bring competitive forces to the setting of the cost of capital, further incentivising a low cost project and improving its economic profile.

[14] *UK Regulators Network, Cost of Capital – Annual Update Report, (2017)*
[15] *Oxera, Agenda: The Thames Tideway Tunnel: Returns Underwater?, Published: 09-2015*

PART II. PROPOSED ALTERNATIVE SMR PROJECT FINANCIAL STRUCTURE

A. CONTEXT: DELAYED PRIVATISATION

The structure proposed below is based upon a recognition of the two-stage – pre- and post-operational – risk profile of an SMR project. The first stage – construction – is characterised by a high degree of risk that thus far has proved prohibitive to private investment at viable terms. This being the case – and with the added risk of FOAK construction in mind – Government participation and its beneficial impact on the cost of capital is considered to be the sine qua non of project viability. However, upon completion of the construction phase and subsequent commencement of normal operation the SMR facility presents an almost diametrically opposite risk profile, characterised as it is by stable output, consistent cashflows, and low (relative to capital expenditure) O&M and fuel expenses.

As such, this transition presents a clear opportunity for the project to be refinanced and for the Government to release its investment and exit its position in the project. In this sense, the project can be thought of as a delayed or sequential privatisation. The model presented herein is structured as above and the subsequent analysis is driven towards identifying the parameter conditions under which it presents as a financially viable proposition (for all parties involved).

B. METHODOLOGY

The two-step structure is modelled as follows:

- Stage One (Construction): finance is raised to fund the construction of a series of SMR units (to form an SMR plant) and is wholly composed of equity finance, with the Government taking a majority stake in the project and the remaining capital being a vendor-arranged private equity investment.

- Transition: upon completion of the final unit (by which point the first units will already be generating power and so receiving a cashflow), the project is refinanced, the Government exits its holding, and the resultant project is now financed entirely with private capital at a 70:30 debt-to-equity ratio; the necessary condition under which refinancing takes place is that the value of the construction cost is at least equal to the net present value of the operational stage of the project .

- Stage Two (Operation): the SMR facility is now operated as an independent private entity until the eventual decommission of the units, which is wholly funded

[7] *House of Commons: Committee of Public Accounts, Hinkley Point C: Third Report of Session 2017-19, (2017)*

by the asset-generated cashflow; the output of the facility is sold under a Purchase Price Agreement (with a fixed price over the course of the project lifetime).

BI. BASELINE TECHNICAL AND FINANCIAL PARAMETERS

The initial demonstration of the model is based upon a set of baseline parameters – now presented – that are not intended to be taken as predictive of market conditions or realised technical conditions (in part due to the FOAK nature of the SMR facility itself). However, the parameters constitute a reasonable framework with which to assess under what conditions the proposed structure may be viable and to which individual parameters viability is most dependent. Following the analysis of the baseline model output, a sensitivity analysis is performed to identify the viable scope of deviation from the baseline parameters.

Financial Parameters:

	Stage One	Stage Two
Debt-to-Equity	*0:100*	*70:30*
Government Stake in Equity	*70%*	*0%*
Risk-Free Rate	*1.40%*	*1.40%*
Market Risk Premium	*6.00%*	*6.00%*
Project Beta	*0.50*	*0.50*
Project Risk Premium	*5.00%*	*0.00%*
Tax Rate	*19%*	*19%*
Cost of Government Finance	*4.00%*	*/*
Cost of Private Equity Capital	*9.40%*	*4.40%*
Cost of Private Debt Capital (Pre-Tax)	*/*	*5.50%*
Cost of Capital (WACC)	*5.62%*	*4.44%*
PPA Tariff	*£50/MWh*	*£50/MWh*

Technical Parameters:

The SMR unit is based upon the NuScale SMR, a light-water-cooled PWR, whose power output was upgraded from 50 to 60 MW in June 2018[16] leading a reduction in its marketed capital cost per unit. It should be made clear that the model itself is techno-neutral and the choice of the NuScale SMR is merely intended to be indicative of an SMR technology.

Unit Capacity	*60 MW*	
Net Capacity	*95%*	
Capacity Factor	*80%*	
Units per Fleet	*12*	
Construction per Unit (Years)	*4*	
Unit Parameters	***Capital Cost per Unit (£/kW)***	***Construction Start-Finish (Year)***
1	*4200*	*1-4*
2	*3600*	*2-5*
3	*3300*	*3-6*
4	*3150*	*4-7*
5	*3075*	*5-8*
6	*3038*	*5-8*
7	*3019*	*6-9*
8	*3009*	*6-9*
9	*3005*	*7-10*
10	*3002*	*7-10*
11	*3001*	*7-10*
12	*3000*	*7-10*

[16] *World Nuclear News, NuScale says its SMR Promises Cost Savings, Published: 06-06-2018*

C. RESULTS AND DISCUSSION

The viability condition – described in the opening to this section – is validated if the net present value (NPV) of the second stage of the project is at least equal to the future value (FV) of the finance invested at the start of the project, with both valuations taken at the end of the final year of construction (here, ten years after project inception). In essence, the condition seeks to determine whether or not the refinancing – and thus the broader concept of delayed privatisation – of the project is economically viable.

Under the baseline assumptions regarding technical and financial parameters, the results are as follows:

Stage One	
WACC	*5.62%*
PV_1 (Construction Finance)	*£ 1,294,292,351*
FV_{10} (Construction Finance)	*£ 2,236,114,389*
Stage Two	
WACC	*4.44%*
NPV_{10} (Stage Two Free Cash Flow to Firm)	*£ 2,368,060,942*
Viability Condition:	
NPV_{10} (Stage Two FCFF)-to-FV_{10} (Constr. Fin.)	*1.06*

Therefore, delayed privatisation – under the condition of the baseline parameters already described – is a viable financial structure for a FOAK SMR facility. Indeed, given its status as an emerging technology – yet to be commercially proven – the proposed finance model presents an opportunity for the UK to establish a valuable SMR supply chain – sustained by domestic investment in the technology – and seek a leading role in related export markets, as is targeted in the *Nuclear Sector Deal* policy paper (June 2018).

CI. SENSITIVITY ANALYSIS

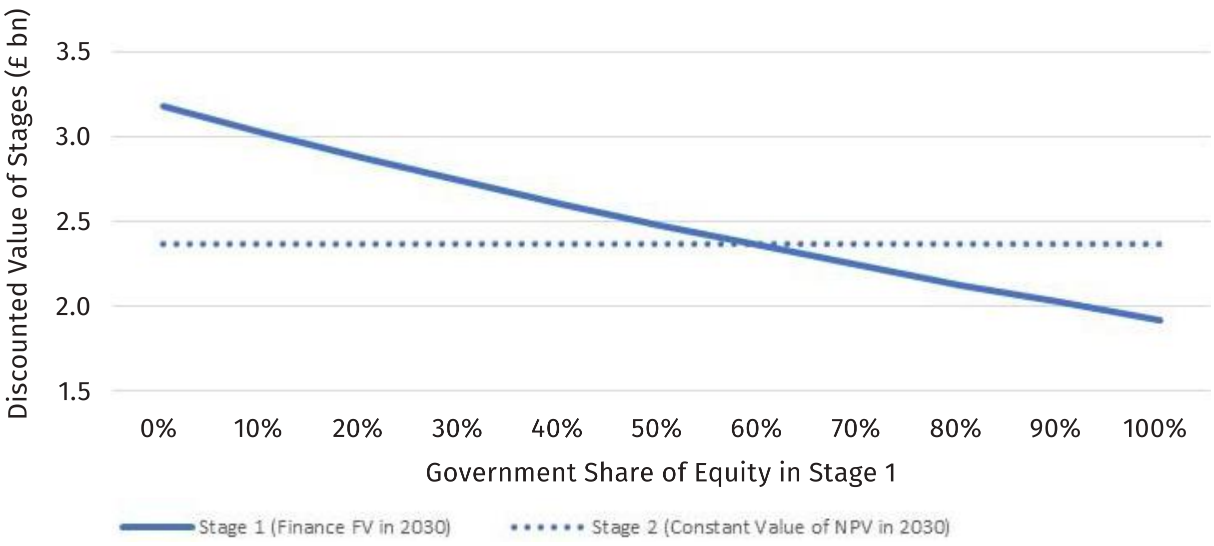
In the subsequent sections, a single parameter is allowed to fluctuate – ceteris paribus – in order to analyse the sensitivity of the viability condition to potential variation of it. This is done so as to identify those variables most significant in determining the suitability of the delayed privatisation model and to acknowledge the inherent uncertainty of many of its underlying parameters. From the perspective of the Government, the sensitivity analyses relating to the technical parameters of the SMR technology many also serve as a guideline on the assessing the relative development and commercial readiness of competing SMR vendors.

#1

Public-Private Equity Split in Stage One

Concerns as to the potential impact on the balance sheet of the Government of an equity stake in the SMR project, the total risk exposure represented by the project, or project governance and/or conflict of interest issues that may arise according to the relative size of the Government stake may lead to a reassessment of the amount of Government equity provided. As such, the model was rerun with a variable Government split to identify the 'cut-off' point at which the structure is no longer viable. As illustrated below, the viability condition is violated at shares below 58%.

Impact of Public-Private Split on Stage 1 Viability



#2

Private Equity Project Risk Premium in Stage One

In the baseline setup the project risk premium required by private investors is 5% - this is added as a premium to the result of a standard CAPM calculation to determine the cost of private equity – but could be higher – given risk preferences, sentiment concerning the viability of SMR technology, broader financial conditions, and so on – and so is varied in order to again identify the level at which the finance structure becomes unfeasible. As the table below demonstrates, a project risk premium in excess of 10% violates the viability condition.

Project Premium	*5%*	*6%*	*7%*	*8%*	*9%*	*10%*	*11%*	*12%*
Cost of Private Equity	*9.40%*	*10.40%*	*11.40%*	*12.40%*	*13.40%*	*14.40%*	*15.40%*	*16.40%*
WACC	*5.62%*	*5.92%*	*6.22%*	*6.52%*	*6.82%*	*7.12%*	*7.42%*	*7.72%*
Stage 1-to-Stage 2	*106%*	*105%*	*104%*	*102%*	*101%*	*100%*	*99%*	*98%*

#3

Construction Cost Overrun in Stage One

Perhaps the clearest uncertainty with regards to the SMR project as proposed in the baseline setting is the likelihood of the construction phase being completed on time and to cost. Given that the nuclear industry supply chain in the UK is relatively weak after a long period of stagnant activity and that the modular-style fabrication underpinning all SMR technology relies on a as yet undeveloped manufacturing specialisation, it could be considered unlikely that the installation schedule proposed by vendors is not achieved. As such, a capital cost overrun was modelled by adding a fixed percentage of the baseline per kW unit costs to each construction year. The results – displayed in the table below – indicate that the viability condition is particularly sensitive to the overrun factor, with the viability condition only met up to a 5% overrun.

Capital Cost Overrun	*0%*	*5%*	*10%*	*15%*	*20%*	*25%*
Stage 1-to-Stage 2	*106%*	*101%*	*96%*	*92%*	*88%*	*85%*

This result should not be surprising; large infrastructure projects are capital-intensive undertakings that tend to have minimal O&M costs once operational. This being the case, a significant portion of their total cost – and so a significant weight on their economic viability – is accounted for by the cost of capital.

#4

Private Equity Project Risk Premium in Stage Two

While the transition to the operational stage of the project heralds the completion of construction – and with it the element of construction risk – the project may still be viewed as containing inherent risk due to its dependence on a technology not yet tested on a commercial scale for its full lifetime (forty years). As such, the second stage project risk premium is made variable – in the baseline it is set to 0% - and the impact on the viability condition evaluated. The analysis indicates that a project risk premium above 1.5% renders the project non-viable.

Project Risk Premium	*0.0%*	*0.5%*	*1.0%*	*1.5%*	*2.0%*
Cost of Equity	*4.40%*	*4.90%*	*5.40%*	*5.90%*	*6.40%*
Stage 1-to-Stage 2	*106%*	*104%*	*102%*	*100%*	*98%*

#5

Power Purchase Agreement Tariff in Stage Two

The choice of a £50/MWh PPA tariff was based upon a forecast of the wholesale electricity price made by the Department of Business, Energy, and Industrial Strategy (BEIS) in the Energy and Emissions Projections: 2017; the average estimated (baseload) electricity price between 2020 and 2035 (the forecast horizon) in the published dataset is £51.55/MWh and so £50/MWh was taken as a conservative measure. However, to assess the significance of the PPA tariff on the viability of the project, the model was rerun with a tariff of £60/MWh. As would be expected, the binding constraints identified in the sensitivity analyses performed thus far were relaxed – as demonstrated in the table below – and the economic profile of the project strengthened.

	PPA of £50/MWh	PPA of £60/MWh
	Viability Condition Limit	
Public-Private Equity Split (Stg. 1)	*58%*	*8%*
Project Risk Premium (Stg. 1)	*10%*	*32%*
Construction Cost Overrun (Stg. 1)	*5%*	*35%*
Project Risk Premium (Stg. 2)	*1.5%*	*8.5%*

D. THE ROLE OF PUBLIC EQUITY

To assess the impact of Government participation on the viability of the project, the model was rerun under the assumption that the construction phase is financed entirely through private (equity) investors. Next, the PPA tariff required to sustain the reformulated structure was calculated. As illustrated in the table below, a PPA tariff of close to double that of the baseline structure is required for the project to meet the viability condition. The cost of private equity in the pure private structure is set at 30%, to reflect the 15% rate usually sought by venture capital investors in FOAK technologies[17] and a 50% probability of cancellation resulting from the reduced Government involvement and subsequent heightened political risk (reduced public 'buy-in').

Stage 1	Government Participation	Cost of Private Equity	Breakeven PPA Tariff
Baseline	*70%*	*9.4%*	*£48/MWh*
Pure Private Structure	*0%*	*30%*	*£94/MWh*

[17] *European Commission, Innovative Financial Instruments for First-of-a-Kind, Commercial-Scale Demonstration Projects in the Field of Energy, (2016)*

E. CONCLUDING REMARKS

The analysis has shown that the delayed privatisation finance structure for an inaugural SMR project merits consideration but also makes clear the conditions under which it remains economically viable and so the limitations of its applicability. While it is certainly the case that the SMR risk profile is lower than that of a large NPP – by virtue of the significantly smaller sum of upfront capital required – its status as an emerging and uncertain technology means that a wholly privately financed venture is unlikely. As such, and given the interest in and commitment to the development of an SMR industry capable not only of reducing domestic nuclear power costs but also a leading export role made by the UK Government, it seems more than probable that various means of Government support are currently being considered and so the purpose of this report has been to develop a viable SMR financing structure and identify key determinants of its use.