Estimating comparable costs of a nuclear regulated asset base versus a contract for difference financing model

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1. Introduction

New nuclear power plants will not be built by the private sector without some form of government support. The form of government support provided has implications on the balance of risk between the private sector, electricity consumers and the taxpayer. Ultimately this balance impacts the potential value for money of a project and therefore its financial viability.

The most recent form of support, for the Hinkley Point C nuclear power plant, has been evaluated by the National Audit Office.[1] It found that the deal provided did not maximise the chances that it will achieve value for money given its high cost and the level of risk in a changing market. The government is therefore considering alternative options to fund and support the building of new nuclear power plants. In July it published an initial consultation on applying a regulated asset base (RAB) model, that would include government protection from specified risks, as an option for future funding.[2]

In this paper the Commission builds on the approach outlined in the National Infrastructure Assessment by providing a method for evaluating the type and scale of costs associated with applying a RAB model. This includes costs related to the transfer of risk between the private sector, electricity consumers and the taxpayer which are at risk of being ignored as they are not accounted for in the headline price paid by consumers under a RAB model. The evaluation method takes in to account the characteristics of building and operating a nuclear power plant, which are different to projects where the RAB model has been applied in the past.

This evaluation method builds on the Commission's recent work to evaluate the performance of different routes to procuring infrastructure.[3] In this previous paper other factors, such as the supply chain are considered. These are not estimated in this paper. The RAB model has been discussed in previous papers and assessed in a recent paper by David Newbery, Michael Pollitt, David Reiner and Simon Taylor.[4][5] This paper uses available data to estimate the risks which are transferred, whereas the Newbery et al paper uses an assumption.

This paper does not attempt to evaluate the merits of different technologies that can meet future electricity needs, or the optimal mix of these technologies. The appropriate mix of technology for generating electricity is a wider question which must reflect considerations beyond the approach to funding and government support discussed in this paper. The National Infrastructure Assessment explains the Commission's position on priorities for establishing a low cost, low carbon generation mix.

The Commission's aim of this paper is for it to provide guidance on how a like-for-like comparison can be made between a nuclear RAB model and the more familiar, and previously applied, contracts for difference (CfD) model. The analysis assumes that the same carbon constraints are met, regardless of the financing model, and is therefore only suitable for comparing the RAB model for delivering new nuclear power with other low carbon options.

The alternatives compared are the CfD model as applied to the last new nuclear power plant, Hinkley Point C, and as applied to a hypothetical offshore wind site. The evaluation method worked example provided in this paper calculates what price (£/MWh of electricity generated) a RAB model would have to achieve in order to provide better value for money for electricity consumers than alternatives. It focuses on calculating the costs that may otherwise be ignored in a comparison of alternative models. It does not calculate what price a RAB model would deliver as this would require additional information, or assumptions, to be made such as the ongoing operational costs and decommissioning costs.

The evaluation method can, and should be, applied on a project specific basis when the features of a RAB model, including the extent to which government will protect developers from risk, are more certain. This will provide a value for money assessment of the RAB model, or options for a RAB model, against the prevailing alternatives at the time. A project specific evaluation should capture both the alternative routes for funding new nuclear plants and the options for generating low carbon electricity from other sources. The evaluation method could also be adapted to apply as part of an ex-post review of future government funding decisions to build a database to inform ongoing decision-making.

Key considerations for any project specific assessment include:

- Capturing all 'hidden' costs from different financing models, risk allocation and whole energy system interactions
- Basing estimates of risk transfer on data (reference classes) rather than assumptions
- Estimating the personal discount rate where consumers are paying in advance of receiving energy. In general, the case for consumers paying in advance will be weaker if the personal discount rate is higher than the project's weighted average cost of capital
- The correct discount rate to use for the cost of risks transferred to taxpayers. Access to taxpayer financing (even on a contingent basis) is a form of implicit subsidy. For a commercial project, the appropriate discount rate is therefore likely to depend on any future 'state aids' regime.

2. Options for government support for new nuclear

New nuclear power plants will not be built by the private sector without some form of government support. In June 2018 the government announced a review on the viability of applying a RAB model to support development of new nuclear plants. In July the government kicked off this process by publishing a consultation on the high-level framework for how a RAB model could best be adapted to apply to new nuclear power plants.[6]

The focus of this paper is on a like-for-like comparison between a regulated asset base (RAB) model and the familiar, and previously applied, contracts for difference (CfD) approach. It compares:

- A RAB model with government protection: The developer recovers its expenditure and a rate of return. Consumers begin paying the developer, through electricity bills, from the start of construction and take on a share of the risk of cost and time overruns. The taxpayer also takes on a share of the risk of high impact events
- The CfD model: Consumers pay a price per MWh of electricity which is agreed in advance of construction and compensates the developer for its expected expenditure and financing costs, and is fixed for a period of time. Risks in construction, from cost overruns or time delays, remain with the developer and its investors.

The RAB model in more detail

The RAB model is applied widely to fund the building, maintenance and replacement of infrastructure used in the supply of gas, electricity and water. A holder of a licence to operate this infrastructure is allowed to charge consumers a price which covers the capital expenditure it expects to incur in providing the service, plus adjustments based on outturn expenditure, and a rate of return to cover the costs of financing that expenditure.

The RAB model was recently adapted to fund the delivery of the Thames Tideway Tunnel (TTT), a new £4.2bn wastewater network in the Thames valley. The adapted RAB model for the TTT includes government protection that moves risk from the developer to consumers and the taxpayer.

The RAB model could therefore also be adapted to provide a funding model for the building of a new nuclear plant. This paper assumes that the following characteristics would apply:

- A developer would secure finance from investors to design, construct, operate, maintain and ultimately decommission the nuclear plant

- The developer would receive payment from consumers from the start of construction which would compensate them for expenditure and financing costs related to the construction of the nuclear plant
- Consumers would effectively co-finance the construction project at zero interest over the construction period by paying ahead of receiving the benefit of the electricity generated
- Consumers would also share in the costs or benefits of expenditure being above or below the expected amount at the start of construction
- Government support would be included to limit the exposure of the developer (and their investors) and consumers to high impact events, with the threshold for such support fixed in advance
- Once the plant starts generating electricity, consumers pay for the electricity they receive, but at a price which covers the construction and ongoing financing costs incurred by the developer, and the expected operational costs, including the cost of decommissioning at the end of the plant's operational life.

The model has never been applied in the UK to funding of a nuclear power plant which has some particular characteristics which need to be considered when assessing the viability of such a model. These are:

- The capital required to construct a new nuclear plant is significantly larger than the amount needed to construct the TTT which could lead to different outcomes in terms of the availability of project financing
- Nuclear plants come with complex construction requirements which creates material uncertainty in cost forecasts that cannot be resolved until construction is started and therefore historically have faced challenges that result in greater cost overruns and more delayed completion than other infrastructure construction projects
- Limitations in the expertise available to assess the efficiency of forecast and outturn expenditure due to a lack of comparable data and the unique characteristics of each new nuclear plant built.

How a RAB model compares to the CfD model

A RAB model with government protection changes risk allocation (and therefore changes project financing options) and provides a stable long-term revenue stream for investors, which in turn provides potential for a lower cost of capital. But, the change to the risk profile involves trade-offs which need to be evaluated to ensure a like-for-like comparison against alternative options.[7]

The return that investors require to finance an infrastructure development project is heavily affected by how much risk they are required to bear. Transferring risk from a project will, if all other factors are held constant, lower the cost of capital investors will accept to fund the delivery of that project. The overall cost of the project will depend both on the level of risk and how that risk is allocated between parties. The allocation of risk is not the same in a RAB model as it is in the CfD model:

- Under the CfD model, construction risk (the risk of cost and time overruns in construction) is entirely held by the developer. Once the project is completed, wholesale market price risk is held by consumers (over the duration of the contract) and, it is assumed, that demand risk, i.e. whether there is sufficient demand in the market for the electricity generated, is also held by consumers. The developer also retains operating cost risk and decommissioning cost risk.
- Under the RAB model, construction risk is shared between the developer, consumers and the taxpayer. Once the project is completed, wholesale market price risk and demand risk are assumed to be held by consumers. The developer therefore retains a share of construction risk (up to a cap), operating cost risk and decommissioning cost risk.
- Learning from previous experience, in particular the adaptation of the RAB model as applied to the TTT project, suggests that a RAB model for nuclear could deliver:
- Lower investor financing costs as investors are protected from some risks and therefore would be willing to accept a lower rate of return than might otherwise be the case.
- As described above, the characteristics of nuclear plant project are different to the TTT. In particular, the scale of financing required. It cannot be guaranteed that lower financing costs would be achieved under a RAB model when compared to a CfD model as the change in risk is only one factor that finance providers would take into account. This will be dependent on the market at the time finance is raised.

However, new costs arise from a RAB model:

- Consumers pay from the start of construction which is years before they receive the benefits of the power generated from the plant. There is therefore a cost to consumers as they do not receive any interest on these payments over the construction period, i.e. there is an opportunity cost to consumers from applying a RAB model.
- If there are delays to the project this opportunity cost increases as it increases the length of time between consumers paying and receiving any benefit.
- If construction costs increase beyond original cost projections then consumers, and potentially taxpayers, are required to pay additional costs as the RAB model places some of the risk of these cost overruns on both consumers and taxpayers.

An assessment of the value for money of a RAB model needs to recognise both the benefit and costs described above including the cost of moving risk from the developer to consumers and the taxpayer. If only the benefit of lower financing costs is accounted for then the decisions made on future government support for new nuclear plants will be based on incomplete evidence.

The remainder of this paper explores in more detail the relative costs associated with different options for supporting new nuclear plants. The exact arrangements for a RAB model for funding new nuclear are unknown and therefore a series of assumptions have been made in order to present a credible worked example of the evaluation method.

Each decision related to provision of a new nuclear plant will require an updated evaluation that reflects the prevailing circumstances at the time. For example:

- the nature of the plant itself and experience of its construction which may affect its riskiness
- the whole life cost of different technologies available for generating electricity at the time new nuclear projects are under consideration
- market circumstances and their impact on the risk appetite of different investors and what this means for the level of competition to fund projects
- what has been learned from previous projects in relation to delivery cost and timescales
- consumers' private discount rate which will change over time and is required to estimate the opportunity cost
- the discount rate used for risks transferred to taxpayers, which may be affected by any future 'state aids' regime.

3. Evaluating the value for money of different funding models

This chapter provides a description of a method for evaluating the value for money of a RAB model with government protection. The evaluation captures both the benefit and costs when compared to alternative models and therefore allows a fairer comparison to be made. The alternatives used are the contracts for difference (CfD) model as applied to the last new nuclear power plant, Hinkley Point C, and as applied to a hypothetical offshore wind site. The following chapter provides a worked example of how the categories of costs and benefits explained below should be calculated and how a break-even analysis can be conducted.

In evaluating the value for money of a RAB model the following categories of costs and benefits are captured:

- Financing construction
  - risk transfer of cost overruns to consumers and taxpayers
  - risk transfer of time overruns to consumers
- System impacts.

There are additional design features of a RAB model, such as the use of incentives to encourage certain behaviour from the developer and the market arrangements needed to deliver the model, that may impact on the overall value for money of the project. There may also be other factors such as the supply chain benefits that could arise from ensuring that nuclear remains a technology continuing to be built to generate electricity. The duration of contracts for difference, or a RAB, may vary which would have some option value. In this analysis it has not been feasible to explore these in detail as there is not yet enough detail from government to assess what options may be taken forward in the design of a RAB model.

It will be important that the final evaluation by government is applied on a project specific basis so it can present evidence based on the prevailing characteristics of the electricity system as foreseen at the time and the alternatives available.

The sections below set out the assumptions and methodology used.

Financing construction

Financing costs are represented by the weighted average cost of capital (WACC), which reflects both equity and debt costs. A range for the WACC is used in the calculations in the following chapter based on the WACC applied in recent regulatory settlements. The actual WACC achieved if a RAB model was applied to a future new nuclear plant construction may be very different. The WACC to apply in a RAB model could be set by the government or could form part of the competitive selection process for building a new nuclear power plant.

During construction consumers pay the RAB value x WACC, where the RAB value represents the capital costs of constructing the nuclear power plant incurred up to that time and approved by a regulator.

The opportunity cost of consumer financing arises as consumers pay from the start of construction and therefore before they receive the benefits of the electricity generated. Paying for something before it provides any benefit to the payee amounts to a cost. Consumers may have to borrow in order to make the payments or, alternatively, consumers could have paid in to alternative investments and received benefits, in terms of interest on their investment. Each consumer will have a different discount rate, dependent on that individual's personal financial circumstances. There is extensive literature on the estimation of personal discount rates and the estimates vary widely.[8] Evidence suggests that it would not be unreasonable to explore a personal discount rate considerably above the prevailing market rate. For the purposes of the calculations in the following chapter, a range is used, from the social time preference rate (3.5% real) used to discount government costs and benefits to a higher value (10% real) more in line with the academic literature reviewed, though still below many estimates.[9]

The Stern Review argues that when considering the optimal extent of climate change mitigation, a lower discount rate should be applied.[10] The analysis presented in this paper looks across a series of low carbon solutions to generating the same amount of electricity and meet the same carbon target. The argument in the Stern Review does not therefore apply to this case.

Risk transfer of cost overruns

A RAB model means that the difference between anticipated costs and outturn costs are shared with consumers. If the project costs less than anticipated consumers receive a share of these savings. But, equally, if costs turn out higher, then consumers share the additional costs with the developer. To attract investors, it is also likely that the government will provide backstop protection from high impact construction risks of a magnitude that would lead to investors being unable to continue with the project. Under this approach it is assumed that the taxpayer would step in and take on these risks and therefore face a cost. The evaluation method assumes a fixed percentage of cost overruns are shared with consumers.

The sharing of risk of cost overruns is a feature of the RAB model which is not a feature in the alternative models considered in this paper. It could reduce the incentive on the developer to efficiently manage its costs as overruns are shared with consumers. This moral hazard exists as one party, in this case the developer, can assume additional risk that leads to higher costs or not efficiently manage its costs, which negatively affects other parties, in this case consumers and the taxpayer. The use of a reference class (see below), based on past data, to estimate the probability of cost overruns may mitigate issues around moral hazard. Many of the nuclear power plants included in a reference class will have been built with some degree of risk sharing, and hence the effects of any moral hazard may be internalised within the data.

The potential for moral hazard exists in all situations where some of the risk of cost overruns is moved away from the party with the greatest ability to manage costs. But the issue may be amplified when applied to new nuclear builds because of the magnitude of costs and the probability of cost overruns. The construction of infrastructure to generate electricity is prone to cost overruns. There is evidence that nuclear reactors overrun most frequently and by a greater amount.[11,12]

The appropriateness of applying a RAB model to the funding of new nuclear plants needs to thoroughly assess the risk of construction cost overruns as it impacts the materiality of the risk that is passed to consumers and taxpayers through both the sharing of cost overruns and the backstop protection.

Cost overruns are driven by several factors some within the control of the developer, such as estimation of the cost and quantity of materials required, to external factors such as changes in safety standards during construction. A RAB model shares the risk of costs turning out to be different from the initial estimate with consumers. It is therefore important that the basis of an evaluation of this risk is based on experience of the past through use of an available, reliable and comprehensive data set. Optimism bias can lead developers into considering that lessons from the past have been learnt and that future projects will not suffer from the problems of cost underestimation seen in past projects. But the data tells a different story. There is also a body of evidence to support the use of data and improved estimation methods to reduce the need for judgements to be made that may be at risk of optimism bias.[13] An approach to estimating risk which attempts to dismiss the data and instead rely on an expectation alone is not robust.

This evaluation method relies on available data on the distribution of cost overruns on completed nuclear projects based on the work of Budzier et al.[14] This dataset covers a sample of over 200 completed nuclear power plant projects and provides a reference class forecast for construction time and cost overruns. This was found to be the source of data with the largest sample size and, unlike most of the existing literature on nuclear cost overruns, provided a ready to use quantitative schedule. The data does not provide information on the reasons for the cost overruns, which are likely to have been driven by a number of factors, some within and some outside the control of the developer. The Commission worked with Oxford Global Projects to develop bespoke reference classes, using this dataset. Details are published as an Annex to this paper.[15]

The distribution of cost overruns is calculated by comparing the cost estimate at the time of the decision to build and the final cost at completion of the project. This available data has some limitations, principally that it is not possible to dissect whether, and if so what value, of contingency was included in the cost estimate. This impacts on the distribution of cost overruns as a project with no contingency included may be more likely to cost more than the estimated cost. When the evaluation method is applied on a project specific basis consideration can be given to what is included in the cost estimate and therefore what is the most appropriate dataset to use.

When looking at applying the framework on a project specific basis account should be taken of the project characteristics, like the type of nuclear reactor and whether it is first-of-kind or next-of-a-kind, and a dataset sourced that most accurately reflects these characteristics while still providing a robust sample size.

Oxford Global Projects therefore produced for the Commission a number of specialised reference class forecasts, for nuclear power plants. This includes classes based on reactor type, country, decade and whether the plant was first- or next-of-a-kind. The data has been used to calculate a risk of cost and schedule overruns for use in the worked example presented in this paper.

Converting expected cost overruns into ongoing payments per MWh requires a discount rate. For this example, it is assumed that cost overruns which will ultimately be funded by consumers are financed at the project WACC. Cost overruns which fall to taxpayers are assumed to be funded as they fall and are then discounted at the social time preference rate, effectively the government's discount rate. However, since this would constitute taxpayer support to a commercial project, an alternative discount rate might be required under any future 'state aids' regime to avoid implicit subsidy.

Risk transfer of time overruns

If a project takes longer than planned then these time overruns increase the opportunity cost of consumer financing. Consumers, in effect, make payments and receive no benefit for a longer period under the RAB model.

As with cost overruns, the appropriateness of applying a RAB model to the funding of new nuclear plants needs to thoroughly assess the risk of construction time overruns as it impacts the materiality of the risk that is passed to consumers as it increases the opportunity cost to them.

There is a correlation between cost and time overruns. For the purposes of this evaluation method they are treated as independent to simplify the analysis. The reference class dataset has been used to evaluate the potential for time overruns in the same way it has been used for cost overruns. Again, it is important that the basis of an evaluation of risk is based on experience of the past through use of a reliable and comprehensive data set. A range of time overruns has been accounted for in the calculations in the next chapter. To avoid double counting, time overruns only impact on the opportunity cost of consumer financing in the worked example. The direct cost of project delays, and the associated risk transferred to consumers and taxpayers, are assumed to be included within cost overruns.

In addition, time overruns may affect the cost of alternative technologies. If the cost of alternatives is falling, then later commissioning of the nuclear plant under a RAB model should be compared against the lower cost of alternatives at that later date. There may also be costs arising from the need for interim solutions over the delay period. For simplicity this additional impact has not been quantified in the worked example.

System impacts

Different types of electricity generation, e.g. nuclear, wind and solar, result in different costs on the system. These costs cover the transmission and distribution of the electricity and the cost of balancing supply and demand on the system.

For a fairer comparison against the alternatives to a RAB model for new nuclear these costs are included in the evaluation method. The marginal impact is calculated for use in the evaluation method.

System impacts will vary depending on the proportion of different technologies on the system and therefore it is important that an evaluation at the time a project is being considered takes into account the characteristics of the current system and the latest forecast of those characteristics over the lifetime of the plant. The costs used in this paper have been adapted from previous work undertaken for the Commission on the costs of a highly renewable system.[16]

4. Applying the evalutaion method: worked example

This chapter provides the calculation of values for the categories of costs and benefits described in the previous chapter. A set of assumptions have been used and are described, including, where relevant, the range of values that have been tested given the uncertainty in the value of parameters that would apply on a project specific basis. A project specific assessment would be able to narrow down these ranges to assess whether the RAB model proposed provided better value than the alternatives available at the time for generating the same amount of electricity.

A break-even analysis is used to show what price (£/MWh of electricity generated) a RAB model would have to achieve in order to provide better value for money than the alternatives. A break-even analysis is used in order to avoid the calculation of what price a RAB model would achieve as this would require additional information, or assumptions, to be made such as the ongoing operational costs and decommissioning costs. Robustly estimating the likely materiality of decommissioning costs will be a particular challenge given the limited experience to draw upon. This analysis sets out the break-even RAB price compared to alternatives, i.e. the price below which the RAB model would offer better value for money than the alternatives, using the categories of costs and benefits described in this paper.

Assumptions applied

A series of assumptions about the characteristics of electricity generators has been used. These are outlined in Table 1. For simplicity, all parameters are assumed to be set in real terms (and hence RAB prices are assumed to be indexed).

Parameter	Assumed value	Source (if applicable)
Nuclear plant construction length	8 years	Government data[17]
Nuclear generation capacity	3,300 MW	
Nuclear plant lifetime	60 years	
Nuclear plant load factor	90%	
New nuclear plant starts construction in	2022	Scenario assumption

Parameter	Assumed value	Source (if applicable)
Offshore wind construction length	3 years	Government data[16]
Offshore wind lifetime	20 years	Scenario assumption
Length of time the RAB is depreciated over	60 years	Scenario assumption – same as plant lifetime

Table 1: Assumptions applied in the evaluation method worked example

There is uncertainty around future financial parameters and design features of a future RAB model. Table 2 outlines the lower and upper bounds of the ranges applied to key parameters.

Parameter	Lower bound	Upper bound
Nuclear plant construction cost estimate (2019 prices)	£10bn	£20bn
Weighted average cost of capital (WACC) (real, gross)	2.5%	4%
Personal discount rate (PDR) (real)	3.5%	10%
Threshold for government support (% cost overruns)	30%	60%

Table 2: Parameter ranges applied in the evaluation method worked example

Financing construction

In this worked example the planned construction period is set at eight years. Consumers begin paying for the project from the start of construction and continue to pay upfront until construction is complete. During construction, the amount consumers pay will increase incrementally as the construction proceeds and costs arise. A flat profile for construction costs are assumed to be added to the RAB each year. This is before taking account of any cost overruns during construction. Consumers pay the return to investors, represented by a weighted average cost of capital (WACC), over the construction period. This element of financing costs is calculated as:

WACC x cumulative estimated construction cost

Consumers do not receive a rate of return on their investment over this period. The opportunity cost that arises is calculated by applying the personal discount rate (PDR):

PDR x (WACC x cumulative estimated construction cost)

Once the plant starts generating electricity, consumers pay for the electricity they receive, at a price set as part of the RAB model decision. These payments cover the capital that the developer has invested in constructing the plant and the developer's rate of return (represented by WACC) on that capital. It is assumed that the capital is depreciated – and hence repaid by the consumer – over the asset life of 60 years. These payments will also cover expected operating costs and significant decommissioning costs, which have not been estimated in this example.

While the plant is producing electricity, consumers are effectively repaid their upfront co-financing, to the extent that the cost of electricity is lower than it would otherwise have been. Until consumers' upfront co-financing is entirely repaid, the remaining amounts continue to incur an opportunity cost for consumers. This analysis assumes that the break-even RAB price requires that consumers are repaid at a constant rate per MWh of electricity generated over the 60 year asset life.

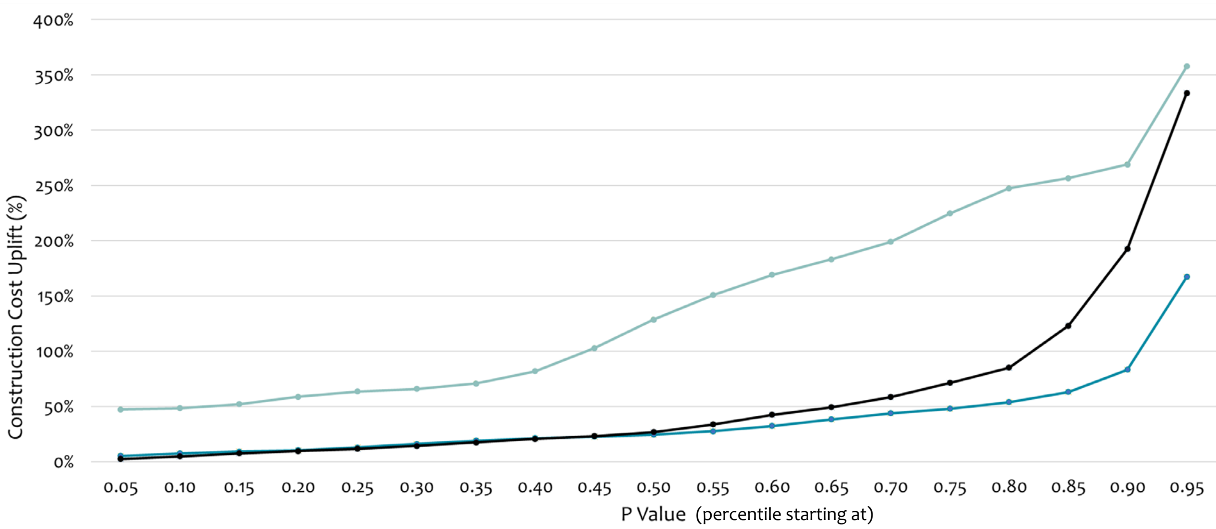
Applying the ranges for WACC and PDR outlined in Table 2 results in an opportunity cost to consumers of financing the project of between £1.20 per £8.0 MWh.[18] The price per MWh has been calculated by dividing the total cost by the electricity expected to be generated over the asset lifetime, accounting for the load factor of a nuclear power plant. This assumes a constant load factor over the lifetime of the plant.

Risk transfer of cost and time overruns

The first step in calculating the cost of the transfer of risk from cost and time overruns is to estimate the probability of overruns. Any assessment of risk transfer costs must be based on historical, observed data. This worked example uses reference class forecasts developed by Oxford Global Projects as discussed in the previous chapter and available as an Annex to this paper.

As the next new nuclear power plant will likely be next-of-a kind (NOAK), the following reference class forecasts have been tested:

- NOAK plants – excluding US plants for cost and Japanese plants for schedule[19] (n=110)
- NOAK plants from Europe (n=61)
- All plants built post 1990 (n=20).



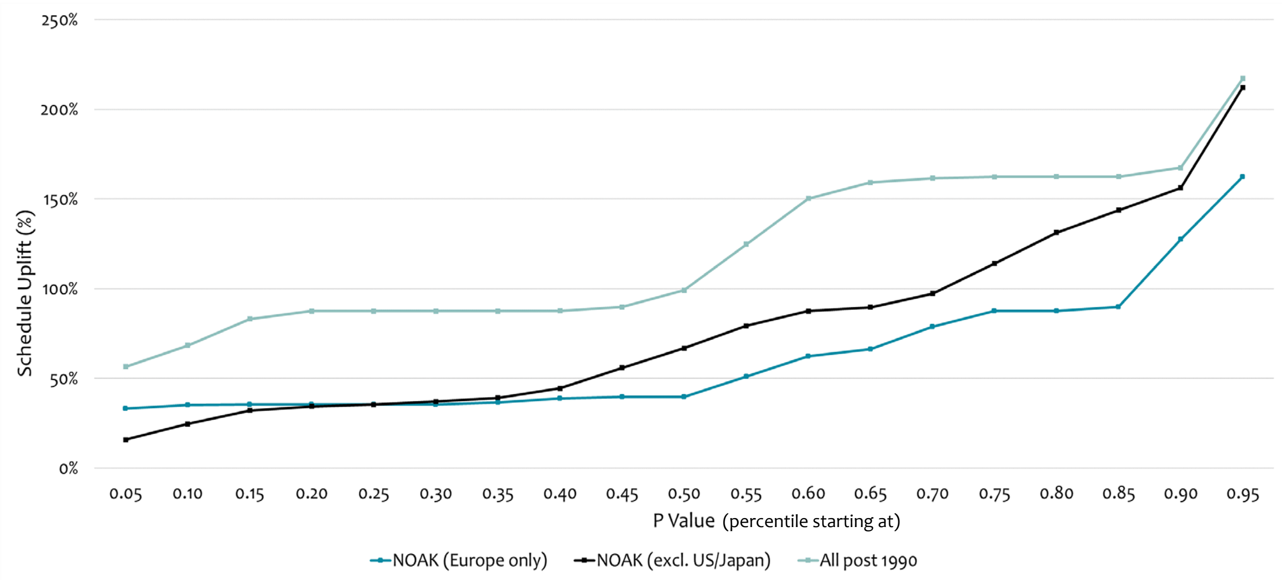


Figure 1. Reference class forecasts – schedule and construction cost overruns for NOAK (excl. US/Japan), European NOAK and plants built after 1990.

A range has been tested for the probability of time and cost overruns as outlined in Figure 1. Consumers will only pay a share of cost overruns and in this worked example this has been set at 50%. A monetary impact to the consumer for a cost overrun is calculated using the following formula at each probability of an overrun occurring:

Consumer share x (% cost overrun x estimated construction cost)

Under this worked example there is a maximum exposure that consumers face, after which the cost of additional risk is recovered from taxpayers. This maximum exposure, the threshold at which government support is provided, is tested as a sensitivity.

As well as exposing consumers, and potentially the taxpayer, to additional costs of construction when costs overrun, both cost and time overruns also impact the opportunity cost. In the case of cost overruns it increases the amount consumers pay in advance of receiving benefits. In the case of time overruns it increases the length of time in which consumers are paying but receiving no benefit, which in turn, increases the opportunity cost of consumer financing.

The resulting impact from the different reference classes are represented in Table 3. To look at the impact of changing the reference class only, we have kept the other parameters constant. This includes:

- £15bn initial construction cost estimate
- 30% cost overrun threshold for taxpayer intervention
- 3.5% personal discount rate
- 2.5% WACC.

£/MWh, real 2019 prices	Reference class forecast used					
	NOAK plants - excluding US for cost/ Japan for schedule		NOAK plants, Europe only		All plants built after 1990	
	Cost to consumer	Cost to taxpayer	Cost to consumer	Cost to taxpayer	Cost to consumer	Cost to taxpayer
Cost overrun impact	2.0	5.1	2.0	2.1	2.8	15.7
Opportunity cost impact of cost overruns	0.9	-	0.9	-	1.2	-
Opportunity cost impact of time overruns	2.0	-	1.6	-	2.8	-
Opportunity cost of consumer financing	1.8	-	1.8	-	1.8	-
Total cost of risk transfer and consumer financing	**6.7**	**5.1**	**4.6**	**2.1**	**8.6**	**15.7**

Table 3. Risk transfer cost components - £15bn initial estimate, 30% taxpayer threshold

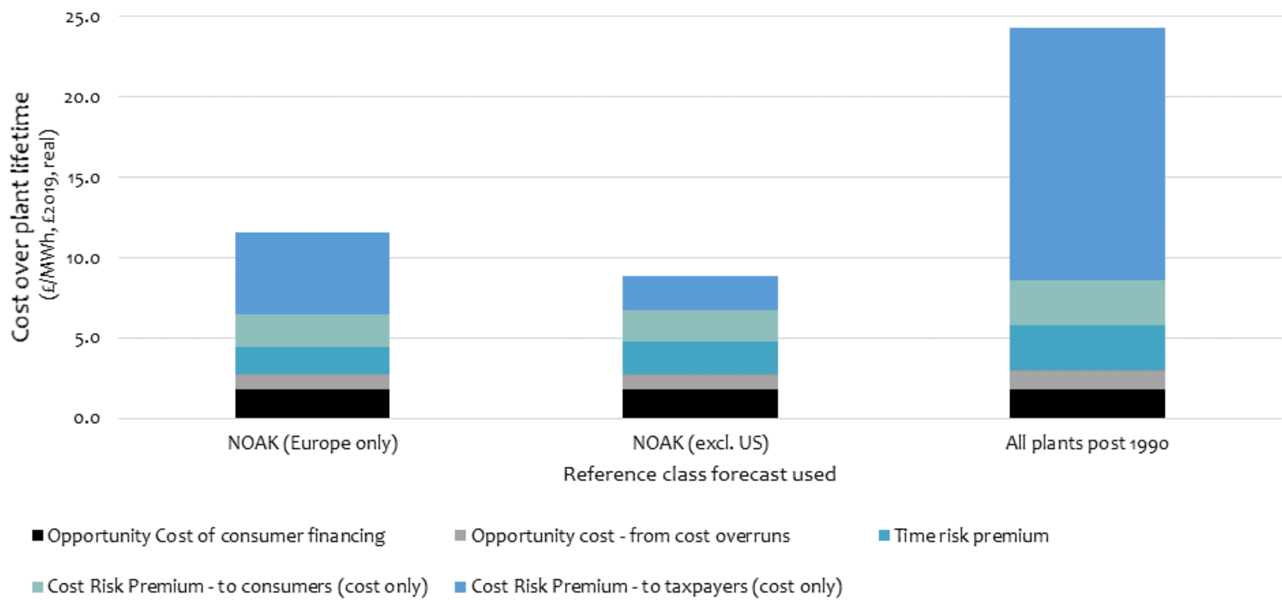


Figure 2. Range of risk transfer costs under different reference class forecasts

The reference class forecast impacts the expected costs and schedule overruns, paid for mostly by consumers and taxpayers. As figure 2 shows, this has no impact on opportunity cost, as this is calculated based on the baseline estimate of construction cost, personal discount rate and WACC. However, the reference class used, due to both the distribution and scale of uplift values at each percentile, can shift the spread of risk transfer costs between consumers and taxpayers, as well as the total risk transfer costs of the RAB.

Flatter, or more normal, distributions (such as the post 1990 reference class) mean that there is greater expected cost to taxpayers at each percentile. In comparison, distributions with 'fat tails' (such as the NOAK (excl. US) reference class) have fewer percentiles where taxpayers need to intervene, meaning the expected cost is more similar to that of consumers, even if the 'worst-case' scenario (expressed as the P0.95 in Figure 2) is similar.

System impacts

System impacts capture the cost of transmission cabling and reinforcement; and the costs of balancing mechanisms. The marginal system costs for offshore wind have been calculated based on modelling work carried out for the National Infrastructure Assessment.

The marginal system cost for offshore wind, relative to nuclear, is calculated based on modelling results for different future renewables penetrations. This has been calculated using the difference in generation and costs between the 70 per cent to 80 per cent renewables penetration scenarios, in 2040-2050. Between these scenarios, nuclear capacity decreases from roughly two nuclear plants to one, reflecting the marginal increase in system costs from having one fewer nuclear plant.

Using the evidence above results in marginal system costs for offshore wind, relative to nuclear, of £27 per MWh (2019 prices). This assumes that a RAB is being considered for one additional nuclear plant beyond Hinkley Point C and the existing Sizewell B plant. Any subsequent plants would lead to different marginal system costs, which would need to be separately assessed.

Evaluation against alternatives

The RAB model is compared to two alternatives:

- The CfD model with a strike price that applies to Hinkley Point C (HPC) which is £106 per MWh (2019 prices)[20]
- The CfD model with strike price for an offshore wind (OSW) site which is £45 per MWh (2019 prices), plus the estimated £27 per MWh system cost.[21]

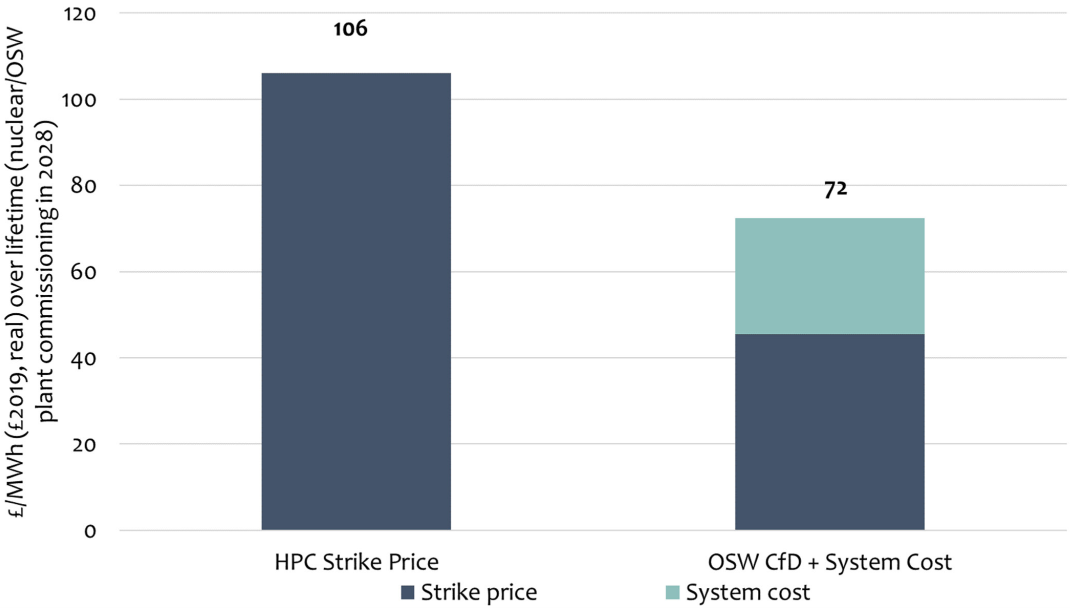


Figure 3. Break-even comparators

Bringing the components above together, using the following formula, allows a break-even analysis to be carried out against these prices above:

Using the NOAK (excl. US/Japan) reference class forecasts and using the upper and lower bounds in Table 2 generates the following range for a break-even point.

£/MWh, 2019 prices	Upper bound parameters	Lower bound parameters
Opportunity cost of financing	£8	£1
Cost of risk transfer to consumers	£8	£3
Cost of risk transfer to taxpayers	£7	£3
CfD price - nuclear	£106	
Break-event point - CfD nuclear	**£83**	**£98**
CfD price - offshore wind	£45	
Marginal system cost - offshore wind	£27	
Break-even point - CfD offshore wind	**£50**	**£65**

Table 4. Break-even range

Table 4 and Figure 4 illustrate that the risk transfer costs of RAB funding model vary significantly depending on the parameters applied. The reference class forecast used, the assumed personal discount rate, WACC and baseline construction cost estimate have the largest impact on the costs of risk transfer.

The personal discount rate has a large impact on the opportunity cost of consumer financing, to the extent that increasing the personal discount rate assumption from 3.5 per cent to 10 per cent decreases the break-even RAB price by nearly £10/MWh. In the modelling, the cost of the risk transferred to taxpayers is discounted at the social time preference rate. However, this could be seen as providing an implicit subsidy since alternative providers in the energy market cannot access taxpayer support in this way. Alternative discount rates for taxpayer support should be considered in the light of any future 'state aids' regime. It is likely that the break-even RAB price would be sensitive to the discount rate chosen.

Changing the assumed WACC has a small impact on the break-even RAB price. This is because the WACC affects only the opportunity cost and a portion of the cost risk premium to consumers. However, a lower WACC would ultimately affect the developer portion of the financing too, which would form part of the expected RAB price in this worked example.

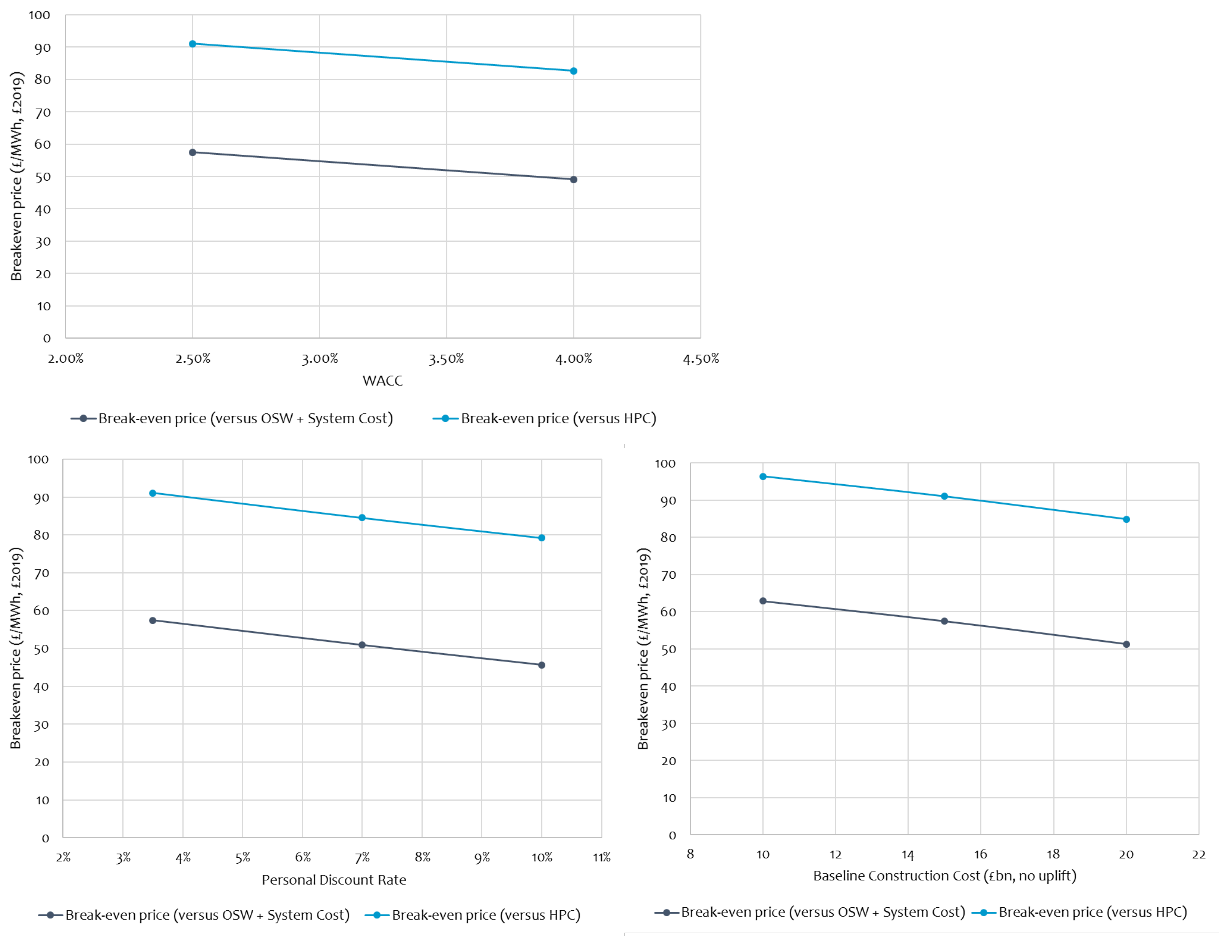


Figure 4. Break-even RAB prices under different personal discount rate, taxpayer threshold, and construction cost estimate assumptionsConclusions

5. Conclusions

Changes in the balance of risk between different parties has an impact on the cost, and therefore the value for money, of different models for funding the provision of new nuclear power plants. Private financing costs that are achieved are an important feature in ensuring value for money but they must be considered alongside the costs to consumers and the taxpayer under a model that means they face risks and costs that they would not face under alternative approaches.

This paper highlights the importance of carrying out a full evaluation of the different costs and not relying on a high-level evaluation of only the financing costs of different options. This paper demonstrates that it would be inappropriate to compare the price achieved under a CfD model, into which the developer has priced the risks of cost and time overruns, with a price achieved under a RAB model made on the basis that the project will be built on time and on budget.

A number of assumptions have been made in order to provide a worked example. Based on the set of parameters chosen the worked example provides a benchmark for the assessment of a RAB model against alternative models for funding low carbon generation. This emphasises the importance of a thorough examination of how assumptions are evaluated and the results transparently provided in future decision-making.

Key considerations for any project specific assessment include:

- capturing all 'hidden' costs from different financing models, risk allocation and whole energy system interactions
- basing estimates of risk transfer on data (reference classes) rather than assumptions
- estimating the personal discount rate where consumers are paying in advance of receiving energy. In general, the case for consumers paying in advance will be weaker if the personal discount rate is higher than the project's weighted average cost of capital
- the correct discount rate to use for the cost of risks transferred to taxpayers. Access to taxpayer financing (even on a contingent basis) is a form of implicit subsidy. The discount rate is therefore likely to depend on any future 'state aids' regime.

Before any new nuclear projects are granted a nuclear RAB licence, the government has committed that a full value for money assessment should be undertaken. This paper provides guidance for conducting this assessment on a like-for-like basis with the CfD model.

Endnotes

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16 Aurora Energy Research (2018), Power sector modelling: System cost impacts of renewables, report for the National Infrastructure Commission
17 Department for Business, Energy & Industrial Strategy (November 2016), Electricity Generation Cost Report
18 Range based on using the NOAK (excl. US/Japan) reference class forecasts, and varying the parameters set out in table 2
19 As proposed by Oxford Global Projects, outlined in the Annex to this paper
20 Hinkley Point C awarded a strike price of £92.50 per MWh (2012 prices) in 2014 inflated to 2019 prices using the Consumer Prices Index (CPI)
21 Resulting strike price for 2024/25 of £41.61 (2012 prices) from the government's third CfD allocation round announcement on 20 September inflated to 2019 prices using CPI

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