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Real Options: An application to gas network interruptible contract auctions

Supplementary Annex

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Overview:

Gas distribution networks (GDNs) can meet incremental capacity requirements through investing in their own networks, booking capacity on the National Transmission System (NTS), or through an interruptible contract, ie a demand-side measure. An interruptible contract allows the GDNs to defer the investment decision in incremental capacity (a deferral option), and provides flexibility in the context of uncertain future demand. In this paper, we calculate the potential value of the deferral option and set out proposed changes to evaluating interruptible contract offers to incorporate the deferral option value.

Associated documents

Real Options and Investment Decision Making 32/12 - link to document

Real options: An application to gas network interruptible contract auctions (supplementary excel model) 32b/12 – link to document

Contents

1. Summary

1.1. In our RIIO-GD1 March decision document, we stated that we would require gas distribution network (GDN) companies to consider the real option value associated with interruptible contracts for RIIO-GD1.[1] The real option value arises because an interruptible contract provides an option to defer a capital investment decision until a later date, at which point there will be greater certainty with regard to the future level of demand and the requirement for new capacity. The incorporation of real option values in assessing interruptible contract offers would ensure that the GDNs take into account the uncertainty with regard to future network use in optimising between network investment and demand-side solutions to meet capacity requirements.

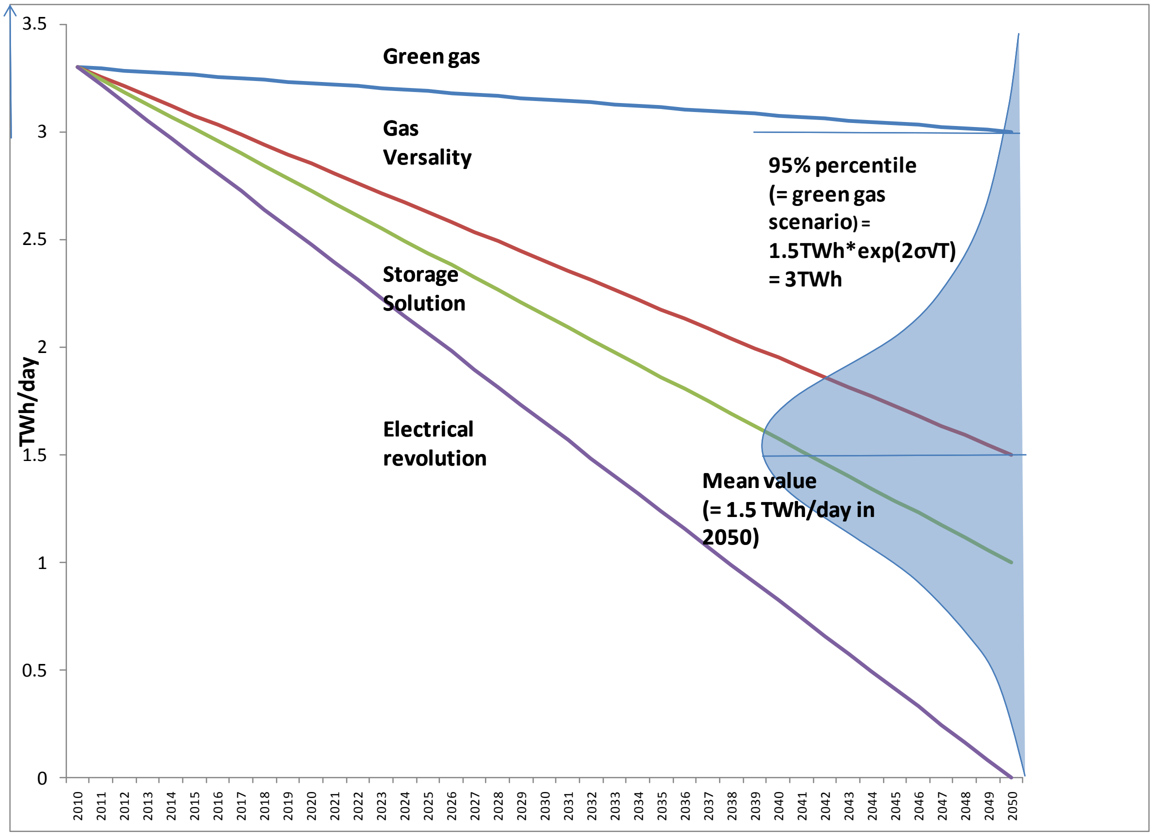
1.2. We follow a standard approach to estimating real option values.[2] This involves constructing binomial event trees which set out the expected future values associated with the investment, and valuing the investment opportunity with and without the right to defer the investment decision. We adopt the utilisation of the asset over the asset life as our measure of the value of investment, that is, a more highly utilised asset has a greater value than a lower utilised asset. Thus, in our framework, the key determinant of the future value of the investment and the value of the option is the expected distribution in (peak-day) gas flows.

1.3. As a first step we need to develop a plausible statistical distribution of peak day gas demand. We base our demand assumptions on scenarios set out in a report commissioned by the industry from Redpoint. We assume a central demand projection equal to the mid-point of Redpoint's high (green gas) and low (electrical revolution) peak-day gas demand scenarios. We derive the expected standard deviation of demand, our measure of demand volatility, by assuming the green gas scenario constitutes the upper 95th percentile of a log-normal distribution. This implies a standard deviation of 5% per unit of time. Figure 1 shows our assumptions for the distribution of peak-day gas demand for 2050, and the Redpoint demand scenarios.

[1] See Ofgem (March 2011) Decision on strategy for the next gas distribution price control - RIIO-GD1, para. 4.35. http://www.ofgem.gov.uk/Networks/GasDistr/RIIO-GD1/ConRes/Documents1/GD1decision.pdf

[2] Copeland, Tom and Vladimir Antikarov (2003) Real Options, A Practitioner's Guide

Figure 1: The expected distribution of peak day gas flows (GDNs) in 2050 and Redpoint demand scenarios



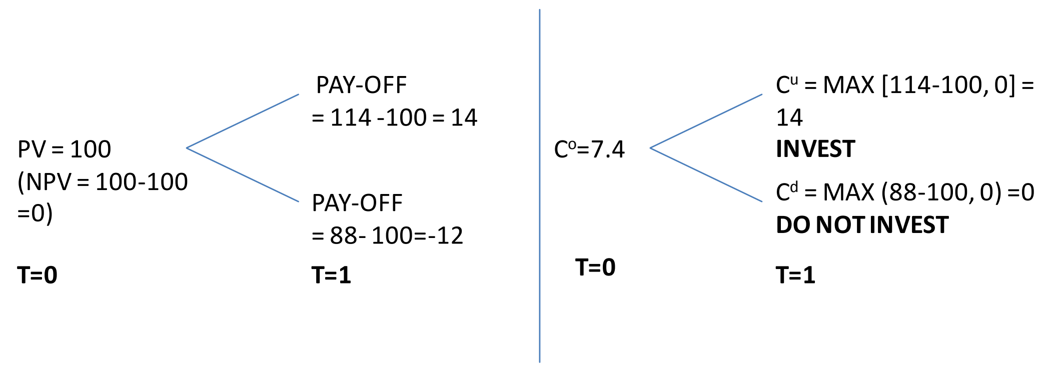
1.4. Drawing on our statistical distribution of demand, the next step is to estimate the volatility of the present value (PV) of future demand. This is our measure of the utilisation of the asset over the asset life, and the future value of the investment. Drawing on our assumptions about demand volatility (as set out in Figure 1), we generated 1000 simulations of future demand over the period to 2050 using Monte Carlo analysis, and we calculated the present value associated with each simulation, and the volatility in the present value (equal to 13%).

1.5. We then used the estimated volatility in the project's value to construct the event tree. For example, Figure 2(a) shows the event tree for a one-year period. We assume that in time period zero the notional investment has a cost of 100, a present value of 100, and therefore a net present value (NPV) equal to zero. That is, we assume that the expected level of utilisation of the notional investment scheme justifies the expenditure. The company invests in time period 0. Drawing on our forecast volatility of the returns to the project of 13%, the present values of the investment in time period 1 are 114 and 88, with an associated pay-off to the project of 14 in the high-state and -12 in the low-state.

1.6. Figure 2(b) shows the event tree where the company defers the decision to invest to time-period 1, ie where it signs a one-year interruptible contract. In time-period 1, if demand outturn is high the project has a PV of 114, and the company exercises its option to invest at a cost of 100, with a net pay-off of 14. On the other hand, if demand outturn is low, the project has a PV of 88 and the network company chooses not to exercise the option to invest, with an associated net pay-off of zero. Discounting the future pay-offs (Cu = 14, and Cd = 0), we calculate an option value of the project with management flexibility (Co) of 7.4.

1.7. The value of the real option is equal to the difference in the value of the project with flexibility (Figure 2b) and without flexibility (Figure 2a) or 7.4 – 0 = 7.4 or around 7% of the project investment cost.

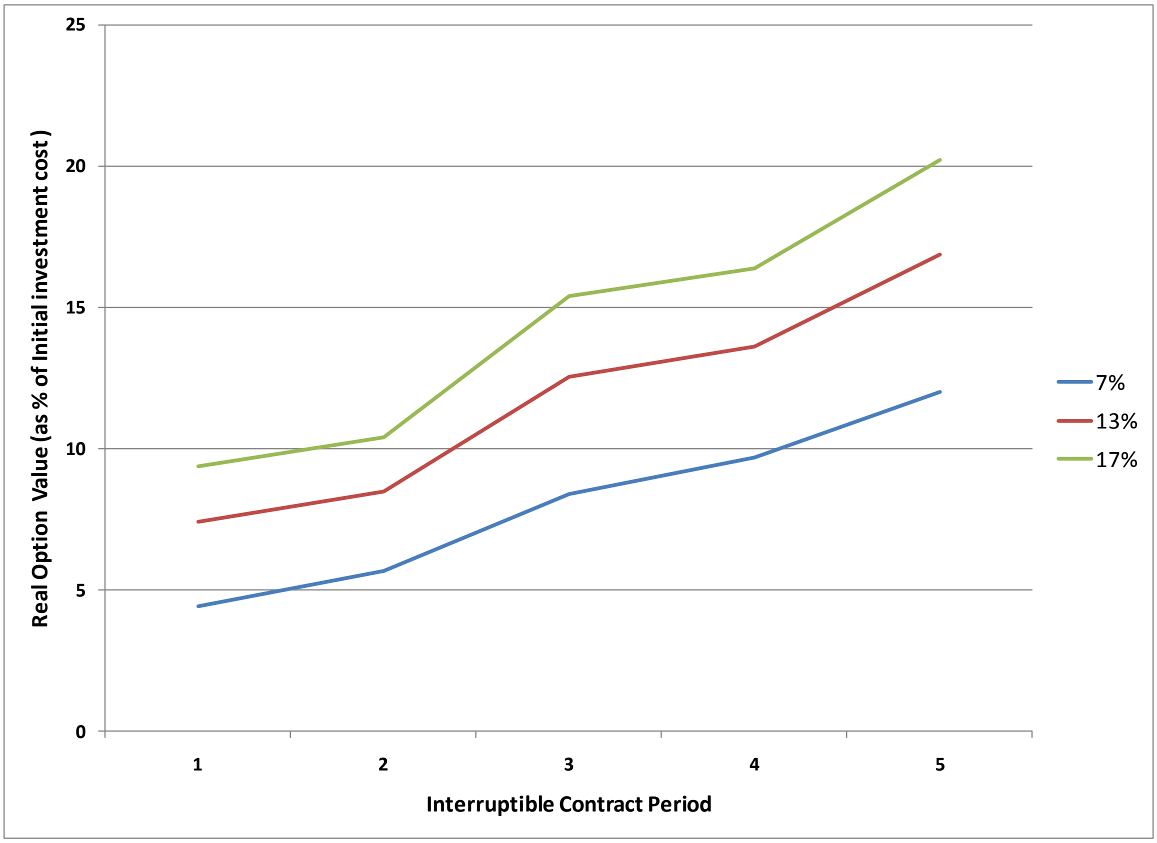
Figure 2(a): Project value with no flexibility and 2(b) Project value with flexibility



1.8. The value of the option to defer varies according to the length of the deferral option (ie the length of the interruptible contract), as well as our assumption about the volatility of the future returns to the project. Figure 3 sets out the real option values for interruptible contract lengths between 1 and 5 years, and for different project volatility assumptions. This shows that the real option value increases with an increase in the contract length, and increases with volatility.

1.9. The Figure shows that under our central volatility assumption of 13%, we estimate a real option value of between 7% and 17% of the initial investment cost for a 1 and 5 year interruptible contract respectively. For a project volatility estimate of 7%, the equivalent real option value is 5% to 12%. For a higher volatility estimate of 17%, the option value lies between 10% and 20% of the initial investment cost.

Figure 3: Real option values as a % of initial project investment cost



1.10. We will require GDNs to consider the real option value associated with the interruptible contract in evaluating contract offers. In evaluating offers GDNs currently compare the expected cost of executing the interruption with the annuitised cost of the capital solution plus operating costs. This process should be adapted to incorporate the value of the deferral option, ie the GDN should accept all bids (assuming the bid satisfies non-price criteria) where:

Expected value of executing interruptible contract < annuitised capital cost + operating cost + real option value

1.11. We can express the real option value as a % mark-up to the annuitised capital cost. (See Table 1.) As set out the % mark-up varies according to the length of the interruptible contract, as well as our assumption with regard to future volatility of the returns to the notional project. For example, we estimate the option value associated with a 3 year contract and demand volatility of 13% equal to 64% of the capital annuity.

Table 1: Real option values as a % of annuity (notional investment = 100)

Option Contract Period	1	2	3	4	5
Total annuity payment over contract period (notional investment = 100; WACC = 6.1%[1;] period = 45 yrs)	6.6	13.1	19.7	26.2	32. 8
Option value % of annuity (7% project volatility)	68%	43%	43%	37%	37%
Option as % of annuity (13%)	113%	65%	64%	52%	51%
Option value % of annuity (17%)	143%	79%	78%	62%	62%

*Source: Ofgem analysis. (1) Equal to GDPCR1 WACC. Calculated as: =3.55%*62.5%+7.25%/(1-30%)*(1-62.5%)*

Recommendation

1.12. We are seeking views on how the proposed approach could be applied in practice. Our preliminary view is that we would require GDNs to use a default real option value in evaluating interruptible contract offers, and only undertake a detailed analysis of the option value where the interruptible contract decision is marginal (based on the default value). Such an approach would avoid the cost of undertaking detailed analysis where it is unlikely to change the investment decision.

1.13. We also recommend adopting a default value at the lower-end of the estimated option values. We consider that there are a number of reasons for interpreting the results set out above with caution.

1.14. First, we are concerned that there are potential real world complications with our approach as set out. For example, there is the possibility that in some instances GDNs forfeit options from signing an interruptible contract, eg the option to expand to meet demand growth. The notional investment upon which our estimates are based also has a NPV of zero by assumption, which creates a high option value. (If for example, the project had a strongly positive NPV, there is a much lower value in a wait-and-see strategy, and a much lower option value.). We have also excluded any dividend payments arising from the investment in capacity as an opportunity cost to striking a contract; the inclusion of dividend payments would reduce the estimated option value.[3] For all these reasons, we recommend the use of a default value at the very low-end of our range of around 30% of the annuity value. We would propose that companies re-visit the default assumption (ie consider the

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[3] See for example, Copeland and Antikarov (2003) op. cit Chapter 5, p.121 for a discussion of the inclusion of dividend payments in option value analysis. The reason why we have excluded dividend payments is that we do not consider foregone dividends represent an opportunity cost in this context. The capital not invested in capacity can be returned to shareholders or re-invested in alternative projects, and could earn and equivalent (risk-adjusted) return. However, we would welcome respondents' views on this point.

specifics of the proposed capital investment) if the decision between an interruptible contract and the capital solution was marginal.

1.15. However, before making a decision on the practical application of the real option approach in interruptible auctions, we would welcome respondents' views on our proposed methodology and our proposed interpretation of the results.

Structure of report

1.16. The remainder of this report is structured as follows:

- Section 2 briefly describes the current arrangements for assessing interruptible contract bids.
- Section 3 sets out our relevant RIIO-GD1 policy decision.
- Section 4 provides a simple example of a deferral option.
- Section 5 sets out our approach to deriving the real option value.
- Section 6 draws conclusions.

2. Current Arrangements and RIIO Decision

Introduction

2.1. This section briefly discusses the arrangements for securing interruptible contracts before 2011, and the reforms we introduced at the first gas distribution price control review (GDPCR1).

Current Arrangements

2.2. At GDPCR 1 we reformed arrangements for the allocation of interruptible capacity. The previous arrangements allowed shippers to nominate any customer supply point as being interruptible for up to 45 days per year. In return for interruptible status shippers received a discount from the capacity element of distribution network (DN) transportation charges in respect of the nominated supply points. Interruptible status and the associated discounts were available to customers irrespective of local network constraints or the likelihood that a customer would be interrupted. Under such arrangements, a large number of customers were receiving discounts even though there were no network constraints and there was a low probability of being interrupted.

2.3. At GDPCR1, we introduced new arrangements whereby from 1 October 2011 all supply points would be reclassified as firm supply points and the DNs would be able to purchase the rights to interrupt customers for capacity management purposes.[4] The change in arrangements was intended to ensure that DNs only offered interruptible contracts where there was a network capacity constraint, and therefore an associated benefit to wider customers from the avoided investment cost. In addition, the new arrangements allocate interruptible contracts to the customers who require the lowest level of compensation to be interrupted through a competitive auction process.[5]

2.4. The DNs hold an auction for interruptible contracts that commence one to eight years from the date of the auction (ie the next auction will be held in July 2011 for interruptible contracts starting between 2012 and 2019).[6] The DNs can request

[4] These new arrangements were given effect by modification UNC 090 which can be found at the link: http://www.ofgem.gov.uk/Licensing/GasCodes/UNC/Mods/Documents1/UNC090D.pdf

[5] Interruptible rights are allocated via a centralised annual interruption auction tender process or by ad hoc tenders run by the GDN. The auction process is set out in part 6 of Section G of the UNC transportation document.

[6] Source: UNC Section G: The DNs must run an annual tender process for interruptible contracts in gas years Y+4 to Y+8 and may tender for contracts in year Y+1 to Y+3.

interruption periods for between 1 and 5 years; specify minimum interruptible volumes; and, the number of days for which interruption is required.

2.5. Customers (via shippers) submit interruptible bids in response to the DN specification. The customer specifies the interruptible volume and number of days, an option and an exercise price (in p/kWh/day)[7] and, the number of years for which they are willing to sign an interruptible contract.

2.6. The UNC requires the DNs to bring forward an interruptible capacity methodology, to be approved by the Authority, which sets out the terms for accepting interruptible bids and how they are ranked.[8] In summary, in evaluating the interruptible contract bids the DNs must consider the total expected cost of the IC over the contract period against the capital or operating cost solution to meeting the network constraint,[9] along with other non-price factors, such as the total interruptible amount bid and the location of the bidder.[10]

2.7. Although not set specified in the methodology, from our discussions with the GDNs, we understand that in evaluating the interruptible contract bids they compare the expected cost of exercising the interruptible contract with the annuitised capital and operating expenditure if they do not secure the interruption, where the annuity is calculated over a 45 year period. In accepting or rejecting the bids, the GDN will also take into account other aspects of the bid, eg the amount of capacity bid relative to the requirement etc.

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[7] The option price is paid in respect of interruptible capacity for each day of the contract irrespective of the whether the customer is interrupted. The excise price is paid in the event of interruption for each kWh/day of interruption.

[8] The approved methodology can be found here: http://www.gasgovernance.co.uk/sites/default/files/InterruptibleCapacityMethodologyStatement_0.pdf

[9] The relevant factors as set out in the approved methodology are: *"(f) the total potential cost to the DN Operator of executing Interruption over the duration of the contract";"(h) any alternative reinforcement capital expenditure to provide the optimal solution to meet the DN Operator's Licence obligations and requirements; (i) any alternative operating costs to provide the optimal solution to meet the DN Operators requirements; (j) any Licence or incentive arrangements."* Source: See http://www.gasgovernance.co.uk/sites/default/files/InterruptibleCapacityMethodologyStatement_0.pdf

[10] The other issues that the DN must consider are: *(a) the Interruptible amount offered by each Supply Point;(b) the locational impact of each Interruptible amount on the network; (c) the Interruption Allowance offered by each Supply Point; (d) the number of Interruptible Periods in the Interruption Offer; (e) duration of the Interruption Offer relative to Interruptible Period(s); […](g) the Interruptible Option Price and Interruption Exercise Price.* Source: See footnote http://www.gasgovernance.co.uk/sites/default/files/InterruptibleCapacityMethodologyStatement_0.pdf

RIIO Decision

2.8. In our December RIIO-GD1 consultation document, we consulted on a proposal to require network companies to consider the option value associated with an interruptible contract in evaluating bids. The real option value arises because an interruptible contract provides an option to defer a capital investment decision until a later date, at which point the future requirement for new capacity will be clearer. The incorporation of real option values in the auction process would ensure that the GDNs take into account the uncertainty with regard to future network use in optimising between network investment and demand-side solutions to meet new capacity requirements.

2.9. In our December document, we set out two potential methods for establishing the real option price. First, we stated that we could derive real option values based on binomial event trees, eg based on future expectations of gas network utilisation. Second, we noted that instead we could require network companies to use a shorter economic asset life in calculating the annuitized cost of the capacity investment for comparison with the interruptible contract bids. [11] Respondents to our consultation supported our proposal to introduce a real option price within the interruptible contract auction process but no views were expressed with regard to the preferred approach. We confirmed our intention to provide companies with a methodology for incorporating real option values in our March decision document.

2.10. In this report, we derive an option value by constructing binomial event trees reflecting the expected future utilisation of the network, ie the first approach set out in our December document.

[11] Ofgem (December 2010) Consultation on strategy for the next gas distribution price control - RIIO-GD1 Overview paper, para. 8.29.

3. A Simple Example

3.1. In this section, we set out a simple deferral option in order to demonstrate the basic concepts that we will use in valuing the interruptible contract real option in Chapter 4.

3.2. In our simple example, we consider a decision that a network company must make either to invest in new capacity at a cost of £200 today or to defer the investment decision for a year. Once made, the investment is irreversible (ie the salvage value of the network investment is zero). We assume the investment has a perpetual life, and the future cash-flows accruing to the project will be either £10 or £30 p.a with a 50-50 probability. The expected cash-flow is therefore £20 p.a. We assume the cost of capital is 10%.

3.3. Applying standard net present value (NPV) analysis to this project, ie discounting net cash-flows using the cost of capital, we calculate that the project has an NPV of 20 and the network company (on the basis of NPV analysis) would undertake the investment. (See Equation 1.)

Equation 1:

3.4. Now we assume the GDN can defer the decision on the project until the following year when the future annual revenues accruing to the project will be known with certainty. What would be the value of the project with the option to defer? For the purposes of the simple explanation, we assume the project has the same risk, and we discount the cash-flows at the discount rate of 10%. Equation 2 sets out the value of the project where we have the flexibility to delay for one year.

Equation 2:

3.5. Equation 2 states that if the annual revenue is £10 then the PV of future revenues (110) is less than the investment cost (200), and the network company would decide not to invest at the end of period 1. On the other hand, if annual revenue is £30 then the PV of revenues (330) is greater than the investment cost (200). In this case, the network company would choose to invest 200 at the end of period 1, or in other words would exercise the deferral option. In other words, the deferral option mitigates the investment loss that would otherwise incur in downside states-of-the-world.

3.6. The value of the option is the difference between the value of the project without flexibility (ie 20) and the value of the project with the deferral option (59). That is the value of the deferral option is 39. We would pay up to this amount for an option to defer.

3.7. We can draw on this simple example to show the factors that affect the value of the option. For example, consider the example where there is a 50-50 probability that the future cash-flows will be £40 p.a. or £0 p.a. Under such an example, the NPV remains unchanged because the expected value is still £20 p.a. However, the value of the deferral option will increase as there is more to be gained from waiting to see what future revenues will be. With this example, the value of the project with flexibility is 109, and therefore the value of the option is 109-20 or 89. The option value increases with increased volatility.[12]

3.8. We draw on the same framework to value the real option associated with interruptible contracts, as we set out in the following section.

[12] Where the future cash-flows for the project cash-flows are £40 or £0 in perpetuity and with certainty from the end of year 1, the value of the project today with the option is:

$=1\propto 01.1\ ,\ 0+0.5 \quad -2001.1+ =1\infty 401.1\ ,\ 0;= 0.5 \quad -200+01.1,0+0.5 \quad -200+4401.1,0;\ =$

4. Our Approach

Question 1: Do you have any views on our approach to estimating the option value associated with interruptible contracts?

Introduction

4.1. We calculate the real option value using a standard practitioner's guide, "Real Options" by Copeland and Antikarov.[13] As set out in this guide, the valuation of real options involves four key steps:[14]

- Step 1: Calculate the present value of the investment under the central case scenario using discounted cash-flow (DCF) analysis.
- Step 2: Model the uncertainty around the base case using binomial event trees.
- Step 3: Identify and incorporate management flexibility within the event trees
- Step 4: Price the real option using a simple algebraic methodology.

We briefly describe our approach step-by-step.

4.2. Our approach to valuing the option for GDNs differs in a key respect to real option pricing for companies operating in competitive markets. Under the current regulated framework, there is limited (or no) demand risk for the GDN associated with an investment in new capacity. Once the investment is approved, the GDN can expect to earn the allowed rate of return on the capital investment irrespective of the level of future demand. That is, the expected variation in future financial returns to the GDN is zero (or practically zero), and the deferral option value from the perspective of the GDN is minimal. However, there is an option value to customers from deferring the decision to invest, and it is this (societal) value that GDNs need to take into account in optimising between capital investment and demand-side management.

4.3. Thus, in deriving the deferral option value we need to abstract from the financial returns to the network company (which are constant irrespective of demand, and would lead to a near-zero option value). Instead, as we discuss below, we estimate the variation in demand and the utilisation of the asset over the asset life as our proxy for the variation in returns to the project.

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13 Copeland, Tom, and Vladimir Antikarov (2003) Real Options , A Practitioner's Guide
14 Copeland, Tom, and Vladimir Antikarov (2003) op. cit. p. 220

Step 1: Calculate the present value of the project

4.4. The first step in calculating the option value is to calculate the expected present value (PV) of the project.

4.5. We calculate an option value for a generic investment in network capacity rather than a specific project. We assume that the network company has to undertake a notional investment of 100 to meet a network capacity constraint. We also assume that the investment has an expected future pay-off of 100, and therefore the project (without flexibility) has a NPV of zero at time zero. That is, we assume that the project being considered by the GDN is required to meet its obligation to meet network loads, and is justified in cost-benefit terms.

Step 2: Modelling uncertainty

4.6. We need to establish the expected volatility in the return to the notional investment of 100. We make the assumption that the only source of uncertainty with regard to the project return is demand risk.[15] As a first step, we need to consider the expected volatility in future demand. Based on the expected volatility in demand, we then need to derive the expected volatility in the PV of demand, as our measure of the economic value.

4.7. In modelling demand uncertainty, we assume that the demand follows a geometric Brownian motion (GBM). This is a simple functional form and is commonly employed in modelling stochastic processes.[16] The functional form is as follows:

4.8. This equation states that demand in time t is equal to demand in time t-1 multiplied by a continuous growth factor r, a constant standard deviation per unit of time of σ, and a random shock factor, ε, drawn from a standard normal distribution. The functional form is often referred to as a random walk as the resulting series has no memory, ie to make a prediction of the level of demand in the next time period we only need to know the value now, and not anything about the path it took to get to the present value. The GBM functional form also has the advantage that the forecast variable is bounded below by zero (which is useful as demand cannot be negative), and is log-normally distributed (ie the natural logarithm of demand is normally distributed).

4.9. To model demand volatility using the GBM we need to determine the growth rate (r) and volatility term (σ). In order to do this, we draw on the demand

[15] In practice, there might be other sources of uncertainty such as cost uncertainty but we do not consider other sources of uncertainty within our option analysis.

[16] See Copeland, Tom, and Vladimir Antikarov (2003) op. cit. p. 260

scenarios set out in a report by Redpoint, who were commissioned by the network companies to set out future gas flow scenarios over the period 2010-2050.[17]

4.10. The Redpoint report identifies four future natural gas scenarios referred to as green gas; storage solution; gas versatility and electrical revolution. The four scenarios are differentiated according to the commercialisation of carbon capture and storage (CCS), and the commercialisation of electrical heat and storage technologies. For example, the green gas scenario is characterised by the rapid development of CCS but slow development of electricity and heat storage technologies. Thus, future expected gas flows are highest under this scenario. By contrast, the electrical revolution scenario is characterised by slow CCS development but high heat storage technologies, and under this scenario peak gas flows on the distribution network fall to zero by 2050. (See Figure 4.1.).

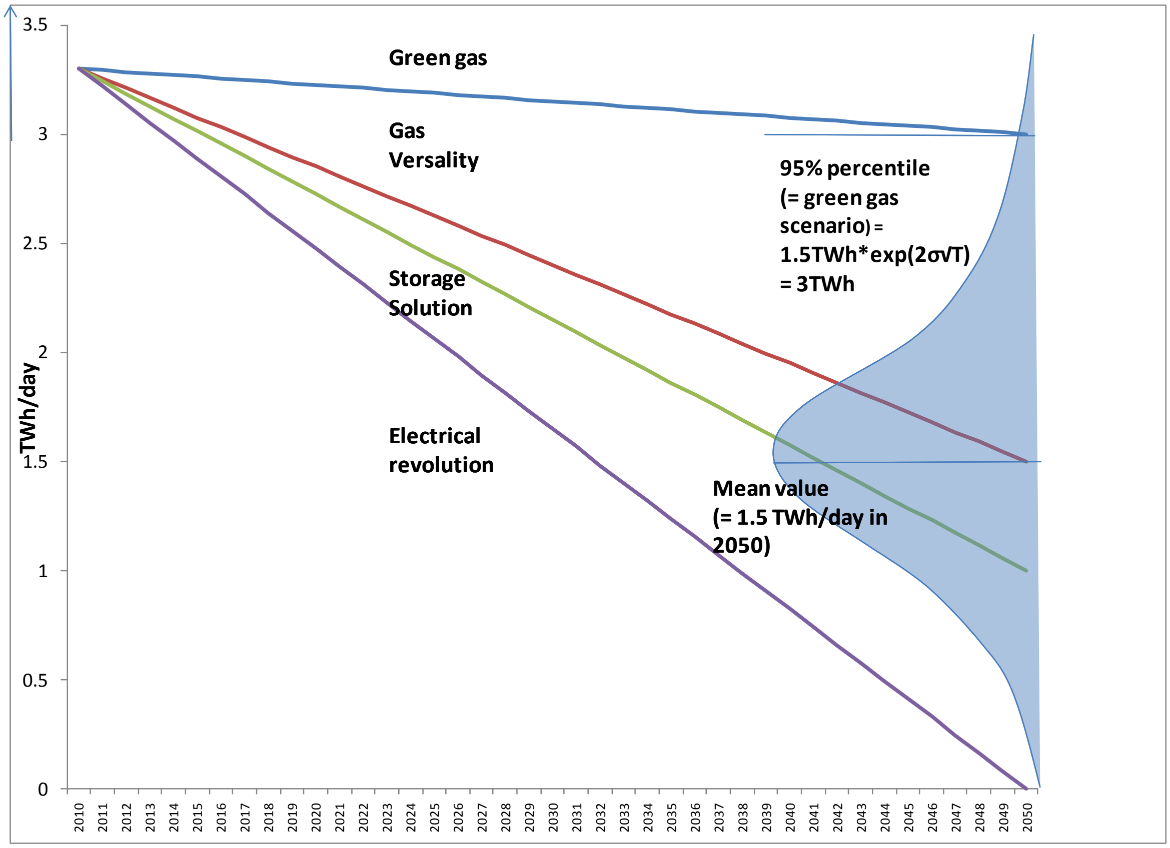
4.11. We note that the Redpoint study sets out plausible scenarios rather than demand forecasts, ie Redpoint do not attach any probabilities to their scenarios. We therefore need to assign probabilities. First, we assume a central demand forecast equal to the mid-point of the green gas and electrical revolution scenarios (ie the high and low scenario values). In particular, we assume demand is equal to the mid-point level of peak day demand of 1.5TWh in 2050, implying a constant growth rate in peak day demand (r) of -2% over the period 2010 to 2050.

4.12. In order to estimate the volatility term, we assume the green gas scenario constitutes the 95% percentile or confidence interval of the log-normal distribution in 2050. Based on this assumption, we derive the expected constant standard deviation term (σ) equal to 5%.

4.13. Figure 4.1 sets out a graphic representation of the expected distribution of peak day gas flows on the GDN network in 2050 based on our assumptions. As shown, our assumptions correspond to a log-normal distribution of demand where the mean is equal to 1.5TWh/day and the 95% confidence interval is equal to 3TWh/day in 2050. The Figure also shows the Redpoint demand scenarios which we use as the basis for our mean growth rate and volatility assumptions.

17 Redpoint (October 2010) Gas Future Scenarios Project, page 32

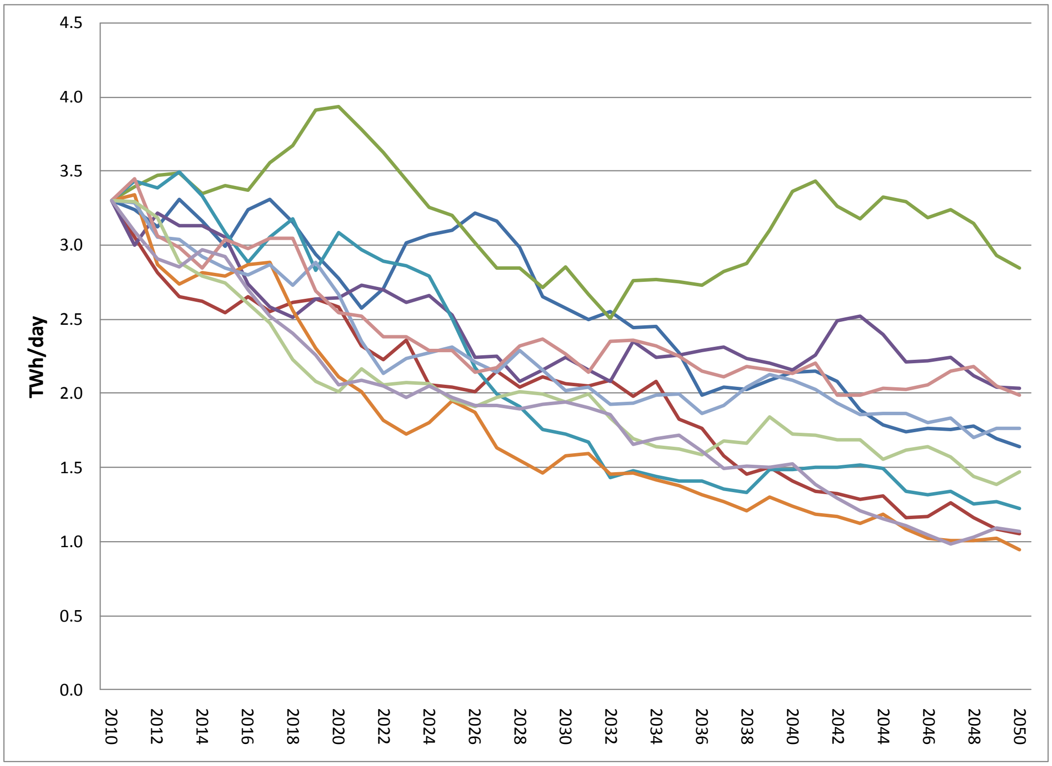
Figure 4.1: The expected distribution of peak day gas flows (GDNs) in 2050 and RedPoint demand scenarios



4.14. In order to value the real option, we need to estimate the volatility in the returns or PV of the project. To derive this volatility estimate, we undertook simulations of future demand over the period 2010 to 2050 based on the above stochastic process. For each simulation, we calculated the PV of future demand as a proxy for the value of investment in new capacity, and we use the standard deviation of the sample as our estimate of the volatility in the returns to the project. Our estimate of the standard deviation in the return or PV to the project is equal to 13%.[18] (See Figures 4.2 and 4.3.)

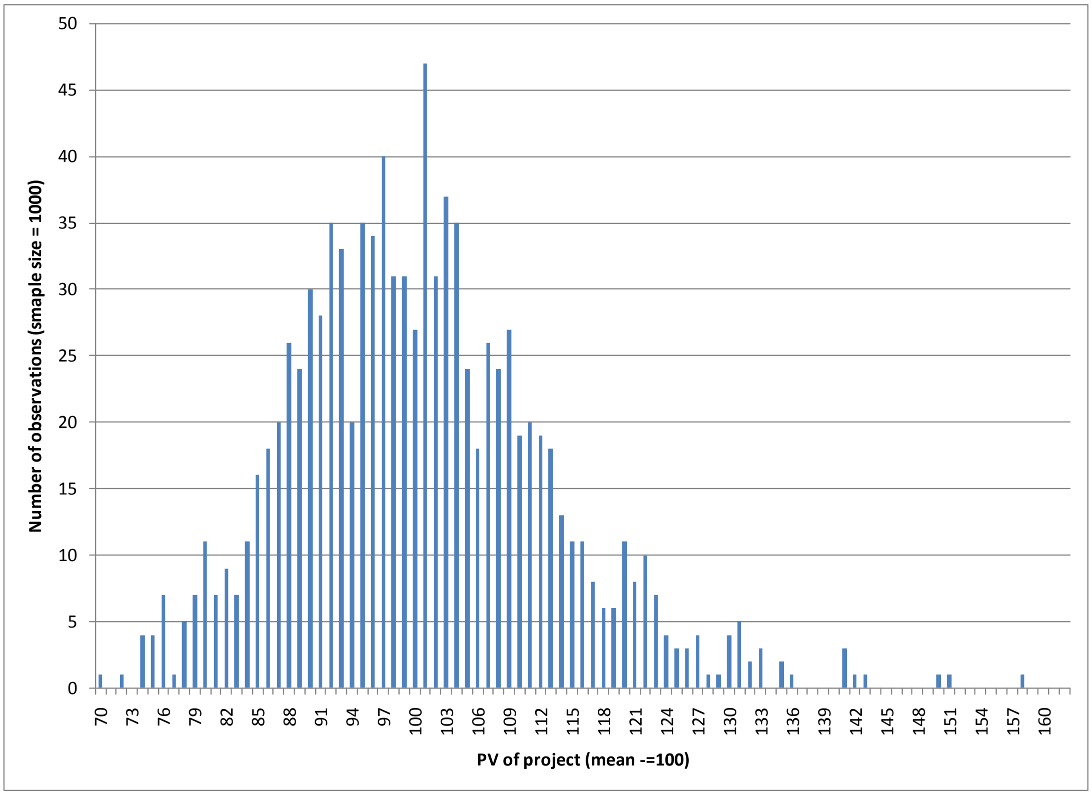
[18] To calculate the PV of future demand, we assume a discount rate equal to a pre-tax WACC at GDPCR1 of 6.1%. This is calculated as: = 3.55%*62.5%+ 7.25%*(1-62.5%)/(1-30%) = 6.1%

Figure 4.2: Simulations of the Peak Day Gas Flows - GDNs (TWh/day)



Source: Ofgem analysis. Note, the Figure shows ten simulations of a total of sample of 1000 simulations.

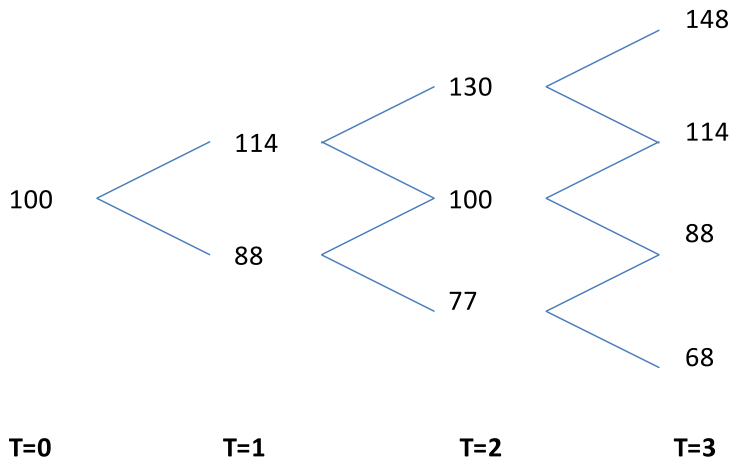
Figure 4.3: Forecast distribution of project PV based on simulations in Figure 4.2 (mean = 100, standard deviation = 13%)



Source: Ofgem analysis.

4.15. Drawing on the assumptions above, we can construct our event tree based on a notional project PV of 100 in time zero and an expected volatility of 13%. Figure 4.4 shows the event tree and PV for each year of a 3 year deferral option. For example, at time zero, we assume a present value of 100. In time period 1, the PV of future demand (our proxy for the value of the project) is either 114 or 88. In time period 3, the PV of demand lies in the range 148 (=100*exp(13%)ˆ3) to 68 (100*1/exp(13%)ˆ3). In the high-state, the notional project is worth more than today's value because of high demand and high utilisation of the asset (indeed, the GDN might need to provide additional capacity beyond the planned investment). In the low state, the project is worth less than today's PV because demand has fallen, and the asset is underutilised relative to today's planning assumption.

Figure 4.4: Future pay-offs to network investment (binomial event tree for a 3 year period)



Step 3: Introducing management flexibility into the event tree, and Step 4: Valuing the option

4.16. We then need to consider the flexibility associated with an interruptible contract. An interruptible contract provides the network company the option to defer the investment decision to the end of the contract period (ie of between 1 and 5 years). At the end of the contract period, the company effectively has three options: to invest; not to invest; or hold an auction for a further interruptible contract (ie effectively, there is a sequential option).

4.17. With regard to the sequential option, we assume that the payment that the GDN has to make for the sequential interruptible contract is equal to the benefit of deferring the investment decision, and therefore we assume the sequential option has a value of zero.

4.18. In our decision tree, we therefore consider the option to invest or not to invest. Equally, the "not to invest" option could be viewed as the option to undertake the right scale of investment, eg consistent with outturn demand.

4.19. As a first step, we need to start on the right hand side of the event tree, and determine the management decision and the value of the option for each node in year 3 (see Figure 4.5). As shown in Figure 4.5, the company would exercise the option (at an investment cost of 100) where outturn demand is 148 or 114 but would not exercise the option where the project PV is less than the investment cost (or would alternatively downscale the investment). We note that the GDN can only call the deferral option at contract expiry and not during the contract period.[19]

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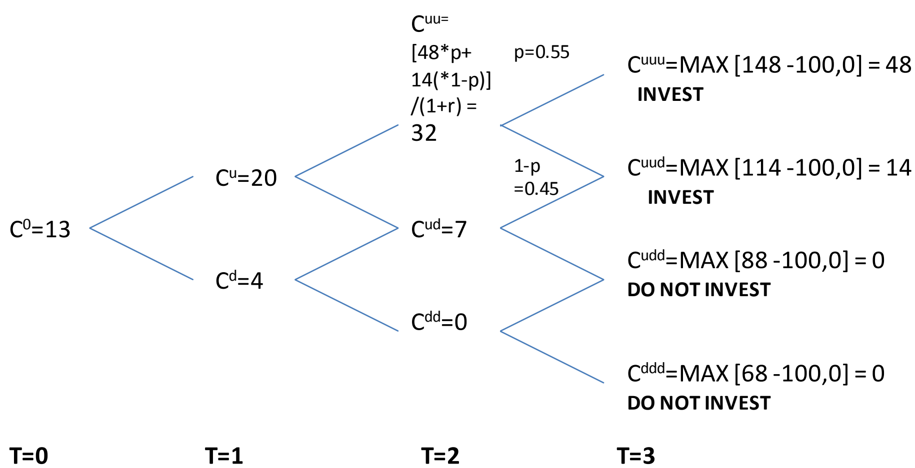
[19] This is known as a European option, ie an option that can only be exercised at

Therefore, we do not need to consider the management decision at the interim nodes in the decision tree.

4.20. Once we have calculated the value of the project with the deferral option at expiration, we then derive the value of the option today by backwards induction. The value of the option in time period 2 is equal to the discounted value of the future option values, discounted at the risk-free rate and using risk-adjusted probabilities. This is a standard approach to valuing options.[20] For example, as shown in the diagram the value of option C^{uu} in time period 2 is equal to the discounted value of options C^{uuu} and C^{uud}, with probabilities p = 0.55 and (1-p) = 0.45, and discounted at the risk-free rate (1+r) which we assume is 2%. Working from right to left, we calculate today's value of the project with flexibility (C^0) equal to 13 as the discounted value of the C^u and C^d.

Figure 4.5: Option value associated with 3-year interruptible contract



4.21. To calculate the option value we then need to subtract the value of the project without flexibility. As set out in Figure 4.4, the PV of the project is 100 and the investment cost is 100, and therefore the project without flexibility has a NPV of zero. Thus, the value of the option is 13. This figure can be interpreted as a % of the project PV or investment cost without flexibility which we assumed was equal to 100. That is, the three-year option value is equivalent to 13% of the initial project PV or investment cost.

4.22. As discussed in Section 2, the GDNs sign interruptible contracts for periods of between 1 and 5 years. Figure 4.6 sets out the option value for a 1 to 5 year period

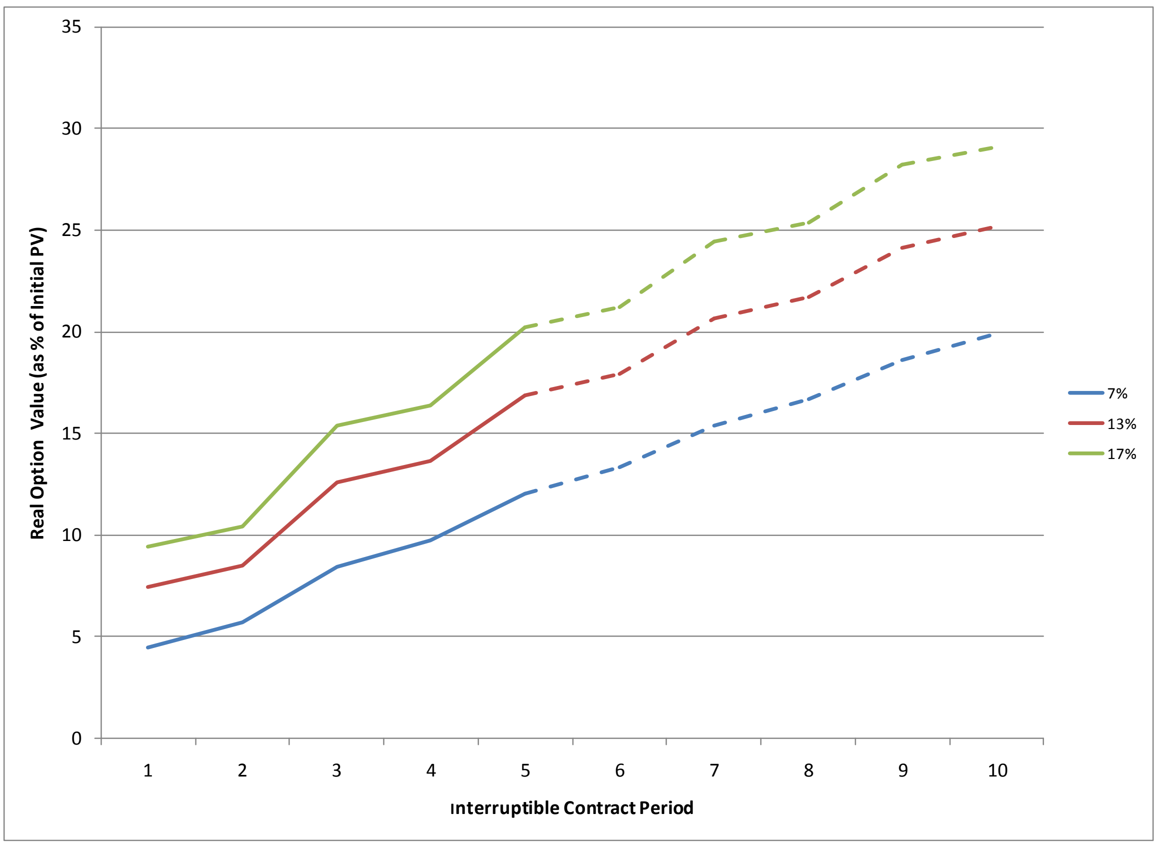
expiration. The alternative is an American option which can be exercised prior to its expiration.

[20] See Copeland, Tom and Vladimir Antikarov (2003) op. cit, p.95

(continuous line in Figure 4.6), as well as for the further period of 5 to 10 years (discontinuous line) to demonstrate how the option value changes with the contract period . This shows that the option value increases with contract length but at a decreasing rate. For our central project volatility assumption, the option value is equal to around 7.4 (1 year), 16.9 (5 year) and 25.2 (10 year).

4.23. Figure 4.6 also shows the option value for an assumed volatility in the PV of the project of 7% (associated with demand volatility of 3%), and for project PV volatility of 17% (demand volatility of 7%) for a 1 to 10 year period.

Figure 4.6: Real option values as a % of initial project PV - 1 to 5 years and project volatility = 7, 13 & 17%



Source: Ofgem analysis

5. Conclusions

Question 1: Do you have any views on how we should apply in practice a real options approach and our estimated values to interruptible contract auctions?

5.1. In this report, we have estimated the real option value associated with an interruptible contract. An interruptible contract provides the GDN with the option to defer a capital investment decision for the duration of the contract, ie for between 1 and 5 years.

5.2. We will require GDNs to consider the real option value associated with the interruptible contract in evaluating bids. As set out above, in evaluating interruptible contract offers GDNs currently compare the expected cost of executing the interruption with the annuitised cost of the capital solution. This process should be adapted to incorporate the value of the deferral option, ie the GDN should accept all bids where:

Expected value of executing interruptible contract < annuitised capital cost + operating cost + real option value

5.3. We can express the real option value as a % mark-up of the annuitised capital cost. (See Table 5.1.) As set out the % mark-up varies according to the length of the interruptible contract, as well as our assumption with regard to future volatility of the returns to the notional project. For example, we estimate the option value associated with a 3 year contract and demand volatility of 13% equal to 64% of the capital annuity.

Table 5.1: Real option values as a % of annuity (notional investment = 100)

Option Contract Period	1	2	3	4	5
Total annuity payment over contract period (notional investment = 100; WACC = 6.1%[1]; period = 45 yrs)	6.6	13.1	19.7	26.2	32. 8
Option value % of annuity (7% project volatility)	68%	43%	43%	37%	37%
Option as % of annuity (13%)	113%	65%	64%	52%	51%
Option value % of annuity (17%)	143%	79%	78%	62%	62%

*Source: Ofgem analysis. (1) Equal to GDPCR1 WACC. Calculated as: = 3.55%*62.5% + 7.25% /(1-30%)*(1-62.5%)*

5.4. We are seeking views on how the proposed approach could be applied in practice. Our preliminary view is that we would require GDNs to use a default real option value in evaluating interruptible contract offers, and only undertake a detailed analysis of the option value where the interruptible contract decision (versus investing capital) is marginal based on the default value. Such an approach would avoid the cost of undertaking detailed analysis where it is unlikely to change the investment decision.

5.5. We also recommend adopting a default value at the lower end of the estimated option values. As set out in paragraph 1.14, we consider that there are a number of reasons for interpreting the results set out above with caution primarily because of real-world complications and the potential forfeited options from signing an interruptible contract, and the assumption that the notional project has a NPV of zero (which creates a high option value). For these reasons, we recommend the use of a default value towards the lower-end of our range of 30% of the annuity value. The GDN would revisit the default value, and its supporting assumptions, where the contract decision was marginal.

5.6. However, before making a decision on the practical application of the real option approach in interruptible auctions, we will take into account respondents' views in relation to our methodology and proposed interpretation of the results.

Appendices

Appendix 1 - Consultation Response and Questions

1.1. Ofgem would like to hear the views of interested parties in relation to any of the issues set out in this document.

1.2. We would especially welcome responses to the specific questions which we have set out at the beginning of each chapter heading and which are replicated below.

1.3. Responses should be received by 1 June 2012 and should be sent to:

- James Grayburn
- RIIO-GD1
- RIIO.GD1@ofgem.gov.uk
- +44 (0) 20 7901 7483

1.4. Unless marked confidential, all responses will be published by placing them in Ofgem's library and on its website www.ofgem.gov.uk. Respondents may request that their response is kept confidential. Ofgem shall respect this request, subject to any obligations to disclose information, for example, under the Freedom of Information Act 2000 or the Environmental Information Regulations 2004.

1.5. Respondents who wish to have their responses remain confidential should clearly mark the document/s to that effect and include the reasons for confidentiality. It would be helpful if responses could be submitted both electronically and in writing. Respondents are asked to put any confidential material in the appendices to their responses.

1.6. Next steps: Having considered the responses to this consultation, we intend to set out our views on the application of real options in our policy and investment appraisal.

CHAPTER: Two (Main Paper)

Question 1: Do you agree or disagree that a real options approach is useful in the context of investment appraisal in the energy sector? Please provide reasons.

CHAPTER: Three (Main Paper)

Question 1: Do you have any views on the practical applications of real option pricing set out in this paper in relation to: (i) scale and timing of network investment, and (ii) valuing interruptible contracts (see also supporting appendix)?

Question 2: In what other policy areas, if any, do you consider the real options approach could help us improve decision making?

We also include questions in the supplementary annex. These are:

CHAPTER: Four (Supplementary annex)

Question 1: Do you have any views on our approach to estimating the option value associated with interruptible contracts?

CHAPTER Five (Supplementary annex)

Question 1: Do you have any views on how we should apply in practice a real options approach and our estimated values to interruptible contract auctions?