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Real Options and Investment Decision Making

Consultation

Reference:	32/12	**Contact:**	James Grayburn
Publication date:	19 March 2012	**Team:**	RIIO-GD1
Response deadline:	1 June 2012	**Tel:**	020 7901 7483
		Email:	james.grayburn@ofgem.gov.uk

Overview:

Real options analysis seeks to value flexibility in investment opportunities – both the flexibility offered to management once the investment is undertaken, and the flexibility of delaying the investment through time. The real options approach contrasts with the standard approach to investment decision making, the net present value (NPV) approach, which assumes the investment opportunity is a now-or-never decision, and once the investment is undertaken, there is no scope for managers to react to new information and to change course.

By ignoring the value of flexibility, the NPV framework has a bias towards projects which do not provide flexibility (e.g. large scale capital investments) relative to more flexible options (e.g. interruptible contracts or demand-side options in the context of energy networks). In this paper, we identify the factors which lead to high real option values, and the circumstances under which we should apply a real options framework. As we set out, a real options approach should help decision making where the investment environment is characterised by uncertainty and management flexibility in responding to investment needs.

Context

As part of our work in regulating energy markets, we undertake formal appraisals of potential policy options using cost benefit analysis. We set out the way we undertake cost benefit analysis in our Impact Assessment Guidance.[1] In the context of price-regulated companies, we also undertake appraisals of companies' proposed investment decisions, and issue guidance to regulated companies on how to undertake investment appraisals where they are seeking funding from customers.

This document describes a real options approach to undertaking policy or investment appraisals, and how this contrasts with the standard net present value (NPV) approach. Following responses to this consultation, we will consider how we incorporate real options analysis within our policy and investment appraisal work.

Associated documents

Associated documents

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

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

[1] See: http://www.ofgem.gov.uk/About%20us/BetterReg/IA/Pages/ImpactAssessments.aspx

Contents

1. Introduction **4**

2. NPV and real options analysis **5**
Why is a real options framework important? 5
What is a real option and what determines its value? 6
When does a real option approach to investment potentially provide a materially different answer to a NPV approach? 8
Why is real option analysis likely to be useful in the energy sector? 9
Conclusion 12

3. Real options in energy networks **13**
Introduction 13
Network investment: an expansion option 13
Network investment: a deferral option 15

4. Conclusions **20**

Appendices **21**

Appendix 1 - Consultation Response and Questions **22**

Appendix 2 – Regulatory Precedent **24**
Introduction 24
New Zealand 24
Australia 25

Appendix 4 - Feedback Questionnaire **26**

1. Introduction

1.1. Discounted cash flow (DCF) or net present value (NPV) analysis is the standard approach to investment decision making. However, the approach makes some limiting assumptions. Once the investment decision is taken, the NPV approach assumes that there is no scope for managers to react to new information, although in practice many investments confer future options and management flexibility. For example, over the life of an investment, decisions can be made to expand, contract, or shut-down projects, and such flexibility may contribute significantly to the value of the project. In addition, the NPV approach ignores flexibility with regard to timing of an investment decision, i.e. the option to defer a project or "wait-and-see".

1.2. The static nature of the NPV approach means that it systematically undervalues investment opportunities which provide future options. Under certain circumstances, eg where there is significant uncertainty and flexibility, the NPV approach can lead to poor policy and investment decisions. As we set out in this paper, uncertainty and option flexibility characterise many investment decisions in the energy sector.

1.3. By contrast, real options analysis seeks to value flexibility - both the flexibility embedded within the investment option, and the flexibility of delaying the investment through time. In this paper, we explain the difference between a NPV and real options approach to investment decision making. We also set out the factors which lead to high real option values, and identify the circumstances where we should consider applying this framework.

1.4. Finally, we also provide examples of the application of the real options analysis in the energy sector, including a detailed application in relation to interruptible contract auctions in the gas distribution sector drawing on analysis undertaken in the context of the current gas distribution price control review (RIIO-GD1). As we set out in the supplementary annex to this paper, the proposed changes require GDNs to consider the option value of associated with an interruptible contract (a deferral option) and should lead to an increase in the use of interruptible contracts to meet incremental capacity requirements.

Structure of this paper

1.5. This report is structured as follows:

- Section 2 provides an overview of real options analysis, and contrasts this with an NPV approach.
- Section 3 provides two potential applications of the real options approach in the energy sector.
- Section 4 draws conclusions and sets out next steps.

2. NPV and real options analysis

Chapter Summary

In this section we describe the real options approach to investment appraisal, and contrast this with the standard discounted cash flow (DCF) or net present value (NPV) approach.

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

Why is a real options framework important?

2.1. The standard approach for evaluating investment opportunities is to use discounted cash-flow (DCF) analysis or net present value (NPV) techniques.[2] The simplest statement of the NPV decision rule is that you should discard all projects with negative NPVs and undertake all projects with positive NPVs. Such a decision rule ensures that companies maximise value for shareholders (or in the case of public investment decisions, economic welfare).

2.2. The NPV framework is the standard model for investment decision making; however, it is also subject to extensive criticism. Academics and practitioners criticise the NPV framework for failing to value management flexibility associated with investment decisions.[3] The NPV approach presupposes a static approach to investment decision-making – which ignores the possibility for management to react to future events. The critics claim that over the life of an investment, decisions can be made to expand, contract, or even shut-down the project investment, and the flexibility offered by such investments may contribute significantly to the value of the project. However, the NPV framework systematically undervalues such flexibility, which can lead to managers making the wrong investment decision (i.e. one that does not maximise economic welfare).

2.3. The NPV framework also ignores flexibility with regard to the timing of the investment. Every project competes with itself delayed in time. For example, it might be valuable to delay an investment decision to a future date when key determinants of the project's value are known. By contrast, the NPV approach

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[2] See for example, Copeland, T., and Antikarov, V., (2002) Real Option, A practitioner's guide, p.56.

[3] This criticism has a long history. See for example: Trigeorgis, L. and Mason, Scott P (1987) *Valuing Managerial Flexibility*, Midland Corporate Finance Journal, 1987, 5 (1), pp.14-21. For a more recent critique, see Copeland, T and Antikarov, V, (2002) op. cit., Chapter 4.

assumes that the investment decision is a take-it-or-leave-it decision at that moment in time.

2.4. Real options analysis seeks to value such flexibility - both the flexibility embedded within the investment opportunity (eg expand, contract etc.), and the flexibility of delaying the investment through time.

2.5. A common analogy used to describe the different approaches to investment appraisal is the decision over a mode of transport to complete a journey.[4] Consider the decision over whether to undertake a journey between London and Edinburgh either by car or by aeroplane. We might consider travelling by plane offers relatively little flexibility, in terms of responding to unexpected events such as adverse weather conditions and associated delays. Once the decision is made to travel by air, it is relatively difficult to change destination. By contrast, travelling by car offers the flexibility to respond to traffic and weather conditions, e.g. by altering our route or stopping-off on the way etc. NPV analysis weighs up the merits of the two options by assuming that we will always follow the standard route, regardless of any unexpected events. That is, NPV analysis considers only the expected (or central) cost and journey times associated with the air and car options. By contrast, real options analysis uses the values associated with NPV (i.e. the expected cost and journey time) but augments this with analysis of the value associated with the flexibility offered by travelling by car (e.g. the ability to change destination, abandon the journey etc.)

2.6. In summary, conventional static NPV analysis may undervalue projects by suppressing the value of flexibility embedded within many options. As a consequence, the NPV framework has a bias towards projects which do not provide flexibility (e.g. large scale capital investments) relative to more flexible options (e.g. demand-side options in the context of energy markets). There is evidence to suggest that firms incorporate the value of real options within investment decision-making in a heuristic way, eg by applying a discount rate higher than the cost of capital.[5] However, the real options framework provides a more objective approach to valuing flexibility and the optimal timing of investments.

What is a real option and what determines its value?

2.7. Formally, a real option is an option which arises in relation to a real investment decision, in which there is flexibility to take decisions in the light of

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[4] See for example, Copeland t., and Antikarov, V., (2002) op. cit., p.4; Boyle, et al (February 2006) op. cit. p.4

[5] For example, Dixit and Pindyck discuss the prevalent use by firms of hurdle rates in excess of their cost of capital in investment decision-making, as well as decisions to stay in markets for lengthy periods where the firm is incurring operating losses. Such behaviour appears irrational, but can be explained by real option values and irreversibility of investments. See Dixit, A, and Pindyck, R. (1994) Investment Under Uncertainty, pp 6 & 7.

subsequent information. Real option theory is concerned with valuing this flexibility, and determining the optimal timing of such investment decisions.[6]

2.8. Like a financial option, a real option is the right but not the obligation to take a pre-defined action, at a pre-determined cost called the exercise price, for a predetermined period of time – the life of the option. The actions concern deferral, expansion, contraction, abandonment etc. of a real investment decision. The analogous actions for financial options relate to the right to buy (a call option) or sell (a put option).

2.9. Like financial options, the value of a real option depends on five characteristics. Table 2.1 shows the characteristics of a real option that determine its value alongside the equivalent parameters for a financial (call) option.

2.10. The first determinant of a real option value is the present value of a project's cash-flows (S). For financial options, this is known at the value of the "underlying asset or stock", on which the option is written. The second determinant of value is the amount of money that needs to be invested if you are constructing an asset (with a call option) or the amount of money to be received if you are selling an asset (with a put option). For financial options, this is known as the exercise price of the option (X).

2.11. Along with a measure of the project's systematic risk, these two parameters constitute the NPV, i.e. equal to the present value of the investment's cash-flows (S) relative to the investment cost (X) or (S-X).

2.12. The two constituent elements of NPV analysis (S and X) are also central to a real options approach to investment appraisal. However, the real options analysis draws on three further factors. The third determination of an option value is the time elapsed until the option is no longer valid or time to expiration (t). The option value increases the longer the time to expiration, as the option provides the ability for the decision-maker to react to new information over a longer-period of time. A fourth factor is the volatility of the returns to the investment or underlying risky asset (σ). The value of an option increases with volatility as the option holder benefits from upside risk, as the option can be exercised at a fixed price (at a profit of S-X) but the holder is protected from downside risk, as we can choose not to exercise (when $S<X$). A fifth variable is the risk-free rate over the life of the option, which is used to discount future cash-flows.[7]

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[6] International Encyclopedia of Business and Management (1996), Real Options, p.4255.

[7] Future cash-flows are valued using the risk-free rate and risk-adjusted probabilities. For a discussion of this approach, see Copeland, and Antikarov (2003) Real Options, A Practitioner's Guide, Chapter 5.

Table 2.1: Determinants of real option values and financial (call) options[8]

Real option parameters	Financial (call) option parameters	Variable
Present value of a project's cash-flows	Stock price	S
Investment expenditure	Exercise price	X
Length of time over which decision may be deferred	Time to expiration	t
Time value of money	Risk-free rate of return	r_f
Riskiness of project's cash-flows	Variance of returns on stock	σ

When does a real option approach to investment potentially provide a materially different answer to a NPV approach?

2.13. First, the investment needs to be partly irreversible (or sunk). If the cost of investment is fully recoverable, then there is no value in waiting to obtain new information and hence no option value.

2.14. Second, there must be a significant element of uncertainty, which is related to both the volatility of the underlying asset and the time before we have to make a decision (e.g. exercise the option). The greater the uncertainty the greater the value of managerial flexibility in responding to new information.

2.15. Third, there must be investment opportunities which provide management with flexibility to respond to the new information. For example, real option analysis is valuable where we have the option to phase the investment (expansion options) or to delay the investment (a deferral option).

2.16. Fourth, the investment decision should be relatively marginal, i.e. the smaller the value of (S-X) the greater the option value. In other words, if the project NPV is high, then the option to invest (say) is always likely to be exercised and the component of the project's value which is represented by the option is relatively minor. Conversely, if the NPV is extremely negative, no amount of optionality can rescue the project. Thus in the extreme cases (ie where S-X is very high or very low), an options framework is unlikely to yield a different investment strategy relative to the static NPV analysis.

[8] See: Leuhrman, Timothy A. (1998) Harvard Business Review, July-August 1998, *Investment Opportunities as Real Options: Getting Started on the Numbers*

Why is real option analysis likely to be useful in the energy sector?

2.17. First, investment in the energy sector is often characterised by long-lived irreversible investments, for example, in relation to generation plant or network investments. The irreversibility of these decisions means that there is significant value in getting such decisions right as the salvage value is low.

2.18. Second, investment decisions in the energy sector frequently involve the consideration of a range of investment opportunities with different embedded options or degrees of management flexibility. For example, in deciding how to meet a network capacity constraint, we might have the option of investing on the network (in long-lived irreversible assets), investing in more flexible generation, or making constraint payments (i.e. a contractual solution). Thus, there are often different levels of managerial flexibility associated with the investment opportunities which NPV analysis fails to value.

2.19. Third, the anticipated decarbonisation of the UK energy sector means that there is significant uncertainty surrounding the way energy will be produced, consumed and transported in the UK. The level of uncertainty means that there is significant value to investment options which provide flexibility. We provide a brief overview of the key areas of uncertainty in the UK energy sector below.

Uncertainty in the energy sector

2.20. The government's carbon emission reduction target is expected to lead to a significant change in the future electricity generation mix.[9] However, the future generation mix will depend on the resolution of a number of uncertainties. There are technological uncertainties, for example, in relation to the development and future role of carbon capture and storage (CCS). There are also significant cost uncertainties, eg in relation to nuclear capital and decommissioning costs and future fossil fuel prices. In addition to uncertainties in relation to the generation mix, there is also additional uncertainty over future capacity requirements. For example, there is uncertainty in relation to future electricity demand from other carbon intensive sectors (which might decarbonise) such as the transport sector, for example, through the adoption of electric vehicles.

2.21. DECC's has set out a number of illustrative pathways for energy use, including electricity generation, to achieve the government's decarbonisation target. DECC's analysis highlights the uncertainty with regard to the future generation capacity and mix. Figure 2.1 sets out the reference case and two of DECC's six scenarios or pathways. [10] For example, under the reference or base case, characterised by little

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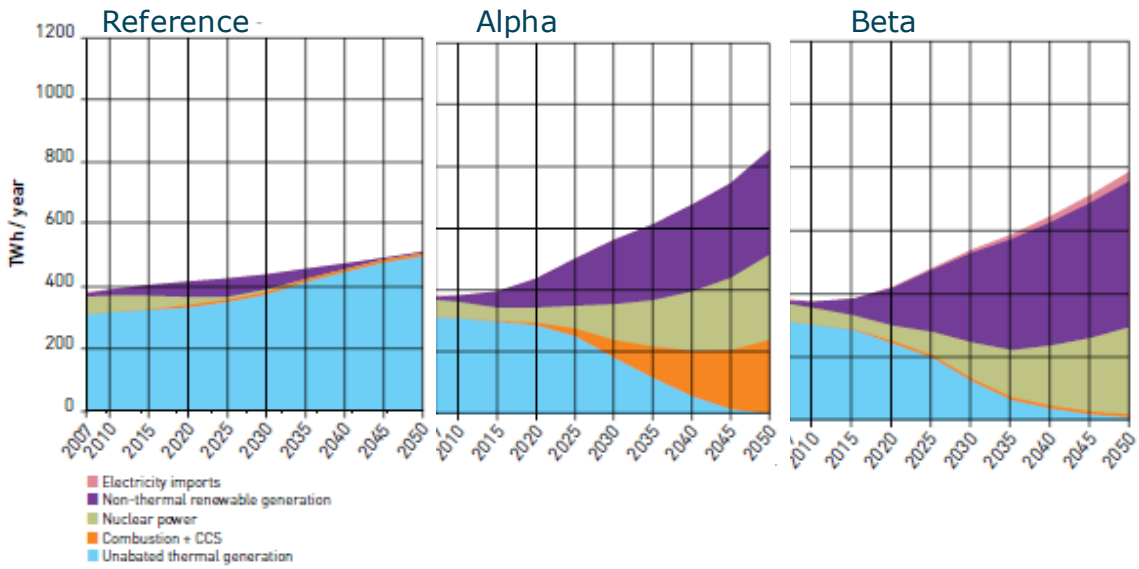
[9] The UK has a commitment to reduce its greenhouse gas emissions by at least 80% by 2050 relative to 1990 levels. Source: DECC (July 2010) 2050 Pathways Analysis, p 6

[10] Figure 2.1 sets out the reference case and two pathways defined as follows: "***Pathway Alpha*** *illustrates a pathway with largely balanced effort across all sectors, based*

or no action to reduce carbon emissions, future electricity generation is dominated by unabated thermal generation. By contrast, under pathway alpha there is no unabated thermal generation by 2045. Under this pathway, the dominant generation sources are non-thermal renewable, nuclear power, and renewable. Pathway beta is characterised by the absence of CCS.

Figure 2.1: Electricity generation in 2050 under reference case, and alpha and beta pathways[11]



2.22. Uncertainty in the future electricity generation mix and capacity requirement has a knock-on effect on network development. The capacity and configuration of the electricity transmission network will depend on, inter alia, the dominant generation technology (e.g. relative dominance of nuclear and wind), the relative scale of onshore and offshore connected renewable generation, as well as the degree of interconnection with other European markets.

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on physical and technical ambition. In this pathway, there would be a concerted effort to reduce overall energy demand; an equivalent level of effort from three large scale sources of low carbon electricity (renewables, nuclear, and fossil fuel power stations with carbon capture and storage); and a concerted effort to produce and import sustainable bioenergy. ***Pathway Beta*** *looks at what could happen if we were not able to generate electricity using carbon capture and storage technology.* ***The reference case:*** *this pathway assumes that there is little or no attempt to decarbonise, and that new technologies do not materialise. This pathway does not meet the emissions targets and would not ensure that a reliable and diverse source of energy was available to meet demand – it would leave us very vulnerable to energy security of supply shocks."* See: DECC (July 2010) 2050 Pathways Analysis, p.16.

[11] Source: DECC (July 2010) 2050 Pathways Analysis, pp 17, 19, & 29.

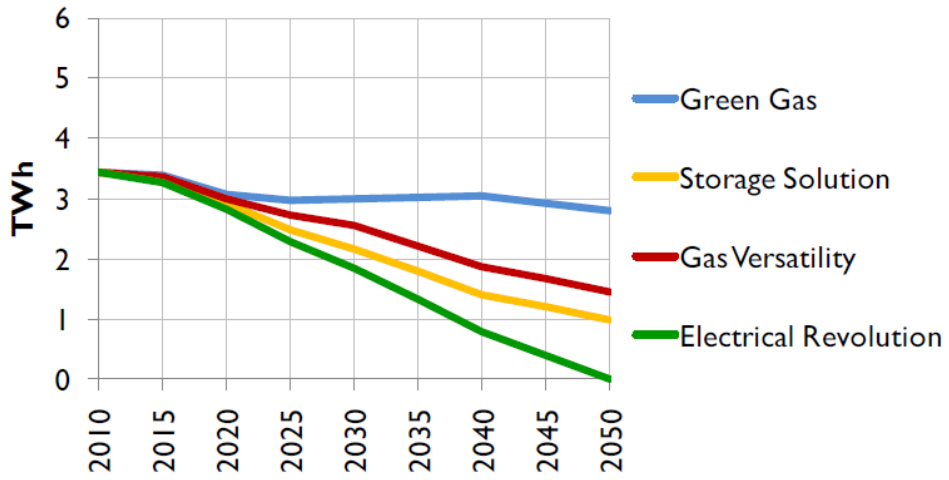
2.23. Uncertainty in relation to the development of the electricity transmission network is also reflected at the distribution level, e.g. the uncertainty with regard to the electrification of the transport sector and demand-side response measures will affect the level of required capacity in electricity distribution. There is also uncertainty in relation to the development of smart network technologies which could provide alternative and more flexible ways to meet future network capacity requirements.

2.24. In the gas sector, the potential to meet domestic heat and hot water energy needs through renewable electricity could lead to a reduction in the use of natural gas and in the utilisation of gas transmission and distribution networks. Equally, there are also future scenarios where natural gas, as well as biogas, could continue to play a major ongoing role in the UK energy mix. Recent studies by the government, industry, and by Ofgem all point towards uncertain future gas network use.[12]

2.25. For example, a recent report commissioned by the industry outlined a set of four plausible but diverse scenarios with very different implications for the future use of gas networks. Under their "green gas" scenario, characterised by the commercialisation of carbon capture and storage technologies (CCS) but the absence of commercially successful electricity and heat storage technologies, the report suggests that annual gas flows on the gas distribution networks will be approximately constant over the period from 2010 to 2050. By contrast, under the "electrical revolution" scenario, characterised by the slow development of CCS but the emergence of electricity heat and storage technologies, the report suggests that annual gas flows would fall to zero by 2050. (See Figure 2.2)

[12] See for example: DECC (July 2010) 2050 Pathways Analysis; Redpoint (October 2010) Gas Future Scenarios Project – Final report; Ofgem (February 2010) Project Discovery – Options for delivering secure and sustainable energy supplies. http://www.ofgem.gov.uk/markets/whlmkts/discovery/Documents1/Project_Discovery_FebConDoc_FINAL.pdf

Figure 2.2: Peak day gas demand by scenario[13]



Conclusion

2.26. Academics and practitioners have expressed concern with the static nature of NPV analysis for more than 20 years. The inability of NPV analysis to value options embedded in different investment strategies can lead to poor investment decision-making, particularly where the environment is characterised by uncertainty and managerial flexibility.

2.27. The expected decarbonisation of the energy sector has created additional uncertainty in relation to the future generation mix and level of capacity, which in turn affects network investment. The magnitude of the uncertainty suggests that there is a potential value in investment strategies which provide future flexibility, and we need a methodology to value such flexibility.

2.28. In the following section, we set out two stylised applications of the real options framework in network investment decision-making.

[13] Redpoint (October 2010) Gas Futures Scenario Project, p. 31. See: http://www.northerngasnetworks.co.uk/documents/a1.pdf

3. Real options in energy networks

Chapter Summary

In this Section we set out examples of the application of a real options approach in the energy sector.

Question 1: Do you have any views on the practical applications of real options analysis 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 improve decision making?

Introduction

3.1. Real options have been applied to a range of investment decisions in the energy sector (and most commonly the non-regulated sectors), for example, in relation to helping with investment decisions in generation assets and storage facilities. As a regulatory tool, energy regulators in Australia and New Zealand require the application of real options in network investment decisions, and we discuss their approach in relation to the scale and timing of energy network investments below.[14] As a second example of real options as a regulatory tool, we set out the incorporation of real options into the pricing of interruptible contracts in the gas distribution sector based on work we have undertaken in the context of the current gas distribution network (GDN) price controls.

Network investment: an expansion option

3.2. Investment in transmission networks is subject to high irreversible costs and often uncertainty with respect to future load requirements. There also competing investment strategies which offer different degrees of flexibility. These characteristics suggest that we should apply a real options approach in considering the optimal scale and timing of investments.

3.3. In this section, we set out how real option analysis can be applied to a decision between undertaking a large scale transmission network investment, and alternatively, a smaller network investment, with a subsequent option to expand.

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[14] Real options approaches have also been used in other regulated sectors. For example, telecommunications regulators have considered real options in relation to pricing access to new generation networks. See for example: NERA (October 2011) A Real Options Approach to Estimate the Risk Premium for an FTTH Investment, A Presentation. Available at: http://www.infraday.tu-berlin.de/typo3/fileadmin/documents/infraday/2011/presentations/Regulation%20II%203.pdf

This stylised example draws on similar examples set out by the Australian Energy Regulator (AER) and the New Zealand Energy Commission (EC).[15]

3.4. Consider the requirement to meet incremental load growth that can be met through one of two network schemes: a 400 kV line that is sufficiently large to cover all possible future levels of demand, and a 220 kV that can only meet load requirements under certain future demand outcomes but includes an option to expand. Essentially, the investment decision depends on a trade-off between the economies of scale associated with the larger scheme versus the value of a wait-and-see strategy associated with the smaller scheme.

3.5. To help understand the trade-off, we set out a numerical example of the value of the economies of scale and the future pay-offs to the expansion option (which determines the option value). [16]

3.6. Let's assume the single 400kV network option has a cost of £10m, and the small scale 220kV option £5m (for the first stage), and a further £7m to provide the equivalent capacity as the full scale network. That is, there is a loss of economies of scale from undertaking the smaller 220 kV upgrade then the expansion option of £2m.

3.7. With regard to future payoffs, we assume there are two future states-of-the-world with respective payoffs of £22million (high) and £0 million (low) which can occur with equal probability. We assume the cost of capital is 10%.[17]

3.8. Drawing on this example, we can calculate the value of the option using a simple decision tree. (See Figure 3.1.) As set out in this example, in the full scale network upgrade, we incur an investment cost of £10 million in the first period, with pay-offs in period 2 of £22m or £0m. The NPV is zero. By contrast, in the small scale network option, we incur an initial investment cost of £5m, and retain the option to undertake a further investment of £7m to meet future demand conditions if required.

3.9. As shown in Figure 3.1, we construct the second 220kV line in the upside state but we do not construct in the downside state. The value of the option to invest (C^0) in the second period is £7m, which is the present value of the future pay-offs of £15m (C^u) and £0m (C^d) discounted at the cost of capital. The value of the

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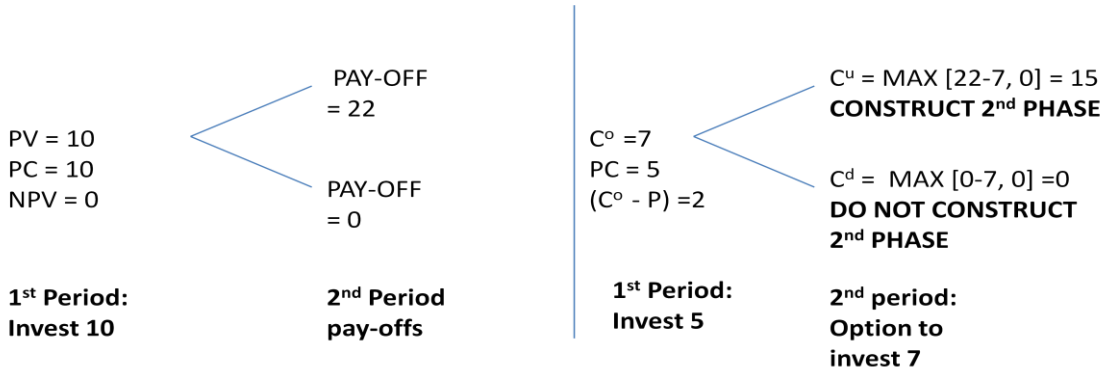
[15] See AER (June 2010) Regulatory investment test for transmission application guidelines, p. 35. For a discussion of the New Zealand Energy Commission approach, see Boyle, G., Guthrie, G., and Meade, R., (February 23 2006) Real Options and Transmission Investment: the New Zealand Grid Investment Test.

[16] Boyle, G., Guthrie, G., and Meade, R., (February 23 2006) op. cit. set out an algebraic representation of this problem.

[17] We note that we should use risk-adjusted probabilities and the risk-free rate to value options. However, in this simple example we use the cost of capital and objective probabilities. For a discussion of these terms, see Copeland, T, and Antikarov V (2003) op. cit. Chapter 4

expansion option (£7m) minus the initial investment cost of £5m, ie £2 m, is greater than the NPV of the full-scale upgrade (NPV = £0m), and can be interpreted as the value of retaining flexibility to respond to new information in the future.

Figure 3.1- Left-hand-side (LHS): Project value with full-scale network upgrade (no flexibility) and RHS: Project value with small-scale network upgrade with flexibility to invest in period 2



3.10. This is a simple example of the trade-off but could be extended to consider a larger number of periods, and a more sophisticated treatment of the uncertainty with regard to future demand.

3.11. We could also apply such analysis in considering how smart network technologies can help meet incremental load requirement in electricity distribution and transmission relative to conventional network technologies. For example, where smart network technologies involve a lower degree of sunk capital investment, they could offer a greater degree of management flexibility than conventional technologies. Such flexibility could be valuable in the context of uncertainty in the development of electricity networks to meet new load requirements. An options framework can be used to value such flexibility.[18]

Network investment: a deferral option

3.12. Network companies also consider demand-side options in order to meet increases in demand for network capacity. Demand-side options, such as agreeing contracts with large users to be interrupted in the event of a network capacity constraint, provide an option to defer a capital investment decision until a future date (a deferral option).

3.13. In the GB gas transmission sector the system operator (SO) considers a range of contractual (or demand-side) solutions in considering how to meet incremental capacity requirements. These fall into three broad categories: turn-up (where the

[18] See: Frontier (March 2012) A framework for the evaluation of smart grids, A report prepared for Ofgem

customer contracts to increase supply or demand at a given network location), turn-down (a customer contracts to decrease supply or demand) or flow-swap (increase in one location, and decrease in another).[19]

3.14. The SO holds competitive auctions to contract for such services, and compares the expected costs of the contract with the expected cost of the capital solution, ie a standard NPV approach.

3.15. In the gas distribution sector, the GDNs also hold auctions for interruptible contracts when faced with demand for incremental capacity. As part of the current gas distribution price review (RIIO-GD1), we will require gas distribution network (GDN) companies to consider the real option value associated with interruptible contracts when considering how to meet future capacity requirements.[20] 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 uncertainty with regard to the future level of demand and the requirement for new capacity will be at least partially resolved.

3.16. In the supplementary annex to this paper, we set out in more detail our proposed approach to incorporating option values within interruptible contract auctions. Below, we set out the high-level results.

Interruptible contract auctions in gas distribution

3.17. As with the above example, we can calculate the value associated with a deferral option using an event tree.

3.18. Figure 3.2 shows the event tree for a project with no flexibility, and a project with flexibility (eg based on interruptible contract). On the left-hand side (LHS), we assume that in time period one the GDN can undertake a notional investment in capacity at a cost of 100, which has a present value (PV) of 100, and therefore a NPV equal to zero. That is, we assume that the expected level of utilisation of the notional investment scheme justifies the expenditure. Drawing on our forecast volatility of the returns to an investment in incremental capacity 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.[21]

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[19] See for example, NGGT (July 2011) RIIO-T1 Business Plan, How We Will Deliver, pp. 70-75.

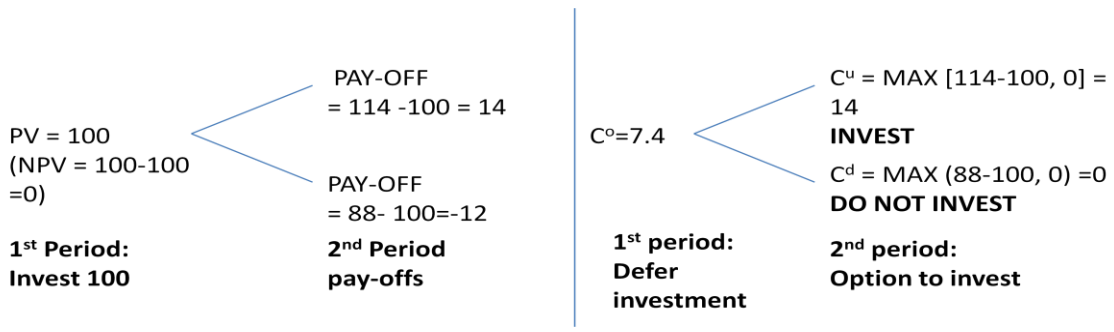
[20] See Ofgem (March 2011) Decision on strategy for the next gas distribution price control - RIIO-GD1, para. 4.35. http://www.ofgem.gov.uk/Networks/GasDistr/RIIO-GD1/ConRes/Documents1/GD1decision.pdf

[21] We explain the derivation of the volatility in Chapter 4 of the supporting supplementary annex, Chapter 3,

3.19. The right-hand side (RHS) of Figure 3.2 shows the event tree where the company defers the decision to invest to time-period 1, ie where the company 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 (C^u = 14, and C^d = 0), we calculate an option value of the project with management flexibility (C^o) of 7.4.

3.20. The value of the real option is equal to the difference in the value of the project with flexibility (RHS, Figure 3.2) and without flexibility (LHS) or 7.4 – 0 = 7.4 or around 7% of notional the project investment cost of 100.

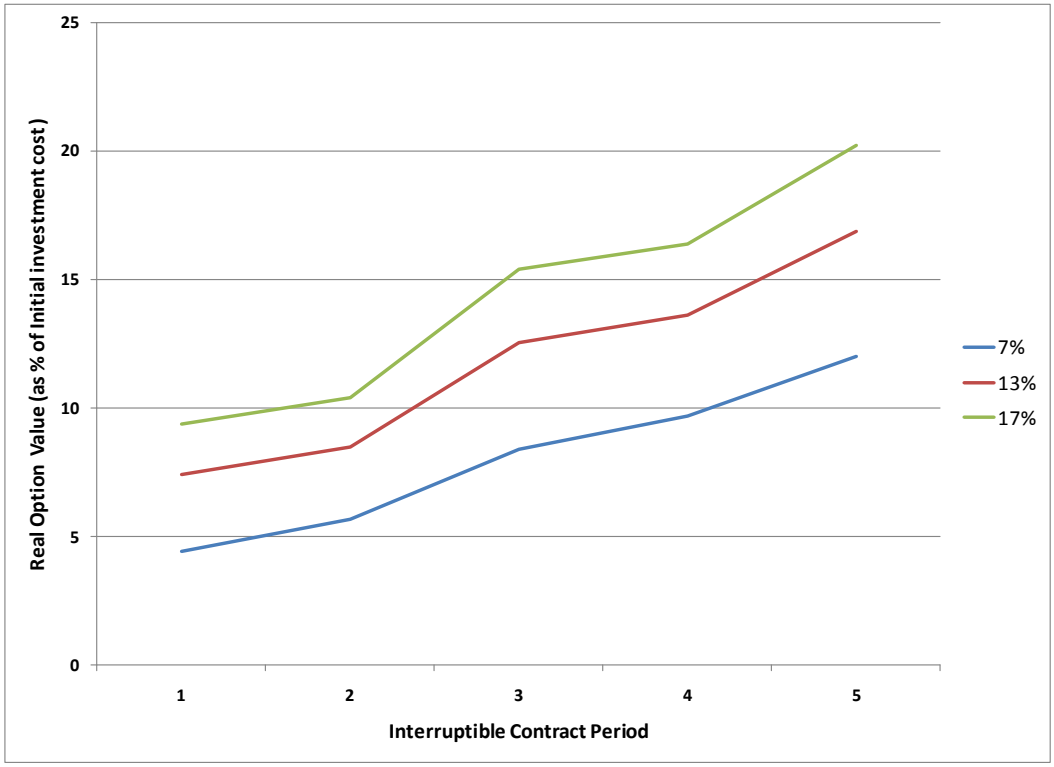
Figure 3.2(LHS): Project value with no flexibility and, (RHS): Project value with flexibility



3.21. 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 3.3 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.

3.22. The Figure shows that under our central volatility assumption of 13%, we estimate a real option value of 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 3.3: Real option values as a % of initial project investment cost



Incorporating the option value into the interruptible auction design

3.23. 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, which is an opportunity cost associated with undertaking the capital investment. The implication of including the option value is that we expect GDNs to make greater use of interruptible contracts to meet future incremental capacity requirements.

3.24. Formally, we consider the GDN should accept all contract bids (assuming the bid satisfies non-price criteria) where:

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

3.25. 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.

3.26. In our supplementary appendix, we set out how we propose to incorporate the real options analysis within the auction process in practice, and we invite respondents' views.

Table 3.1: 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%)*

4. Conclusions

4.1. In this paper, we have explained the differences between the standard NPV approach to investment decision-making and the real options approach. NPV analysis may undervalue projects by ignoring the value of flexibility embedded within many options. As a consequence, the NPV framework has a bias towards projects which do not provide flexibility (e.g. large scale capital investments) relative to more flexible options (e.g. demand-side options in the context of energy markets).

4.2. By contrast, the real options approach seeks to value such flexibility. As we have discussed, the valuation of flexibility is important where the investment climate is characterised by uncertainty, and the decision-maker faces a range of investment options which provide different levels of flexibility. These factors – uncertainty and options that provide different levels of flexibility – characterise many of the investment decisions in the energy sector today.

4.3. In this paper, we have set out two potential applications of real options analysis in a regulated setting: the choice between undertaking a full-scale network upgrade, or a smaller upgrade plus an expansion option, and the choice between a capital solution and a contract solution to meet incremental capacity in gas distribution networks.

4.4. We would welcome respondents' views on how and whether to incorporate real options analysis in our policy and investment decision-making analysis. We have set out questions in each chapter, and which are summarised in Appendix 1.

Appendices

Index

Appendix	Name of Appendix	Page Number
1	Consultation Response and Questions	(ix)
2	Regulatory Precedent	1
3	Feedback and Questionnaire	5

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 consider that a real options approach is useful (or not 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 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 the estimated option values for interruptible contracts in practice?

Appendix 2 – Regulatory Precedent

Introduction

1.1. The Australian Energy Regulatory (AER) and the New Zealand Electricity Commission have both set out a framework for investment appraisal to meet transmission network constraints that includes the potential application of real option theory. In this Section, we briefly describe their respective approaches.

New Zealand

1.2. In 2005 the Electricity Commission adopted a new investment appraisal framework or Grid Investment Test (GIT).[22] The GIT is applied by the Electricity Commission in developing grid reliability standards (GRS), reviewing and approving reliability and economic investments, and reviewing alternative transmission investments. Transpower (the electricity network owner) is also required to prepare its Grid Economic Investment Report (GEIR) – which comprises the proposed investments for upgrading the grid – based on the GIT.

1.3. The test consists of three key steps. First, the appraiser (ie Transpower or the Commission) identifies the market development scenarios and their associated probabilities (as agreed with the Commission). Second, the appraiser estimates the investment's net market benefits associated with each market development scenario. Third, the appraiser calculates the expected new market benefit as a probability weighted average of the scenario-specific net market benefits.

1.4. A proposed investment satisfies the GIT if the Commission is reasonably satisfied that the investment's expected net market benefit is positive and greater than that offered by any feasible alternative investment.[23]

1.5. As set out in the GIT, the expected benefits should include "*the value of any material real options associated the proposed investment or alternative project.*"[24]

1.6. The GIT also states that:

"*Either standard net present value analysis or real options analysis must be applied in assessing the expected net market benefit of a proposed investment or alternative project. The type of analysis to be used in applying the grid investment test to a particular grid investment must be whichever of standard net present value analysis*

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[22] These requirements are set out under Section 3 Part F of the Electricity Governance Rules (2003).

[23] See: New Zealand Electricity Commission (2005) *Schedule F4 – Grid Investment Test*

[24] See: New Zealand Electricity Commission (2005) *Schedule F4 – Grid Investment Test*, Article 27.10

or real options analysis is more appropriate having regard to the likelihood of occurrence of any real options during the economic life of the proposed investment or alternative project."[25]

Australia

1.7. The Australian Energy Regulator (AER) introduced the Regulatory Investment Test for Transmission (RIT-T) to govern investment appraisal. This test was first introduced in 2004 and revised in July 2010.

1.8. The test is similar to the Commission's approach: involving the identification of market scenarios, their probabilities, and investment alternatives, with the decision rule based on the investment that has the highest probability weighted average of the scenario-specific net market benefits.[26]

1.9. The GTI-T also identifies a real option as a potential market benefit:[27]

"*any additional option value (meaning any option value that has not already been included in other classes of market benefits) gained or foregone from implementing the credible option with respect to the likely future investment needs of the market."*

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[25] See: New Zealand Electricity Commission (2005) *Schedule F4 – Grid Investment Test*, Article 14

[26] AER (June 2010) Regulatory investment test for transmission, Articles 3 and 4.

[27] AER (June 2010) Regulatory investment test for transmission, Article 5f.

Appendix 4 - Feedback Questionnaire

1.1. Ofgem considers that consultation is at the heart of good policy development. We are keen to consider any comments or complaints about the manner in which this consultation has been conducted. In any case we would be keen to get your answers to the following questions:

1. Do you have any comments about the overall process, which was adopted for this consultation?
2. Do you have any comments about the overall tone and content of the report?
3. Was the report easy to read and understand, could it have been better written?
4. To what extent did the report's conclusions provide a balanced view?
5. To what extent did the report make reasoned recommendations for improvement?
6. Please add any further comments?

1.2. Please send your comments to:

Andrew MacFaul
Consultation Co-ordinator
Ofgem
9 Millbank
London
SW1P 3GE
andrew.macfaul@ofgem.gov.uk