Oxera

Discount rates for low-carbon and renewable generation technologies

Prepared for the Committee on Climate Change

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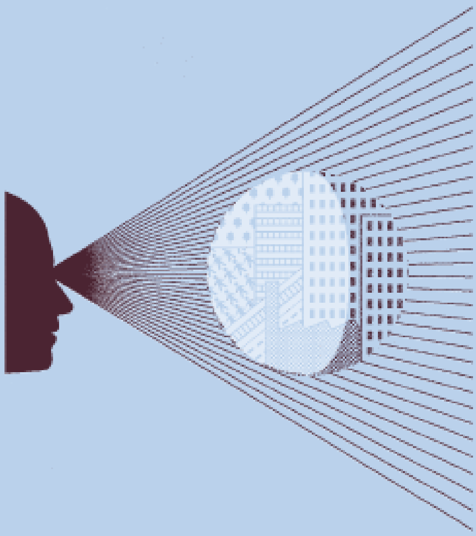

Executive summary

The main objective of this report is to identify and assess the main drivers of discount rates for low-carbon generation projects, taking into account both technological and market risks. The primary findings from this study are estimates of the discount rates for a range of low-carbon generation technologies for 2011, 2020 and 2040.

While the capital asset pricing model (CAPM) is the most commonly used method for estimating the cost of equity, in many instances it may not provide an accurate estimate of firms' or investors' required returns ('hurdle rates'), for a number of reasons: its underlying assumptions may not be appropriate in certain contexts; its use of historical (as opposed to purely forward-looking) data; and its relatively poor results in empirical testing. Moreover, investors that are not able to build a fully diversified portfolio may require compensation for certain unsystematic risks—for example, for large projects that take up a significant proportion of a firm's capital resources. In addition, given that investment in low-carbon generation projects may have a high degree of project-specific risk that is also largely unsystematic, this may make the CAPM unsuitable to the extent that investors require compensation for idiosyncratic risk.

As a result of these methodological considerations, the discount rate estimates presented in this report rely on evidence reported in the available literature, supplemented by estimates reported by industry participants in a survey conducted by Oxera. The main challenge in aggregating evidence from both sources relates to the inability to control for differences in risk preferences, and the future expectations or technical expertise of the various authors of the sources already available in the public domain or of the survey respondents. Despite these limitations, the evidence gathered from these sources provides insight when identifying the relevant risk factors and the relative overall risk perceptions across the range of technologies. It is important to note that the survey on which this report is partly based was completed prior to the earthquake on March 11th 2011 off the eastern coast of Honshu, Japan, and before the impacts of the subsequent tsunami on the Fukushima Daiichi nuclear power plant were known. As such, and because the full impacts of the events are not yet clear, it has not been possible to assess what, if any, impact this natural disaster may have on risk perceptions or discount rates for nuclear power and other low-carbon generation technologies in the UK.

A wide range of factors can be expected to affect discount rates for low-carbon technologies, some of which are outside the control of a particular low-carbon generation developer (eg, wholesale electricity prices and government policy); others appertain to a particular type of technology (eg, load factor, cost structure, or technology maturity). Overall, the maturity or deployment of a given technology appears to be the dominant intrinsic factors that define the overall risk perception for that technology. Furthermore, all low-carbon technologies are exposed to policy risk, to such an extent that several survey participants responded to the effect that they were unable to rank the risk factors due to the uncertainty surrounding future energy policy.

According to the survey respondents, the impact of removing policy risk is at least as important as the actual risks that would be mitigated by a particular policy. Also, a policy designed to remove wholesale electricity price risk would most benefit technologies with a 'lumpy' investment, such as nuclear.

The target discount rate is expected to vary across different types of project sponsor as a result of influences on capital structure and investment strategy, among other factors. While the marginal investor has not been identified for each type of technology, these are implicitly embedded within the discount rate ranges presented in the report.

The discount rate estimates for low-carbon technologies are subject to a significant degree of uncertainty, as indicated by the relatively wide ranges presented. The estimates presented in this report are consistent with the relative risk rankings: not only are higher discount rates associated with riskier technologies, but also the corresponding range estimates are wider.

The approach for estimating the future evolution of discount rates relies on high-level policy scenarios. Under a specific scenario, the level of risk associated with technologies supported by the policy is assumed to be perceived as declining over time. This is reflected in the discount rate range through an adjustment in the cost of equity, debt premium and gearing. Furthermore, discount rate estimates were adjusted for all technologies in order to reflect expected movements in the real risk-free rate. According to this approach, the discount rate for technologies that are supported by a policy could be as much as 2–3% lower over the next decade, and could fall by a further 1–2% by 2040.

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1 Introduction

The Committee on Climate Change (CCC) commissioned Oxera to research the investment conditions for low-carbon power plant technologies, including renewable generation, nuclear power, and carbon capture and storage (CCS).[1] This report provides an assessment of the drivers for discount rates across these technologies, together with an outlook for how these rates are likely to evolve, based on a survey of investors, project sponsors and financial analysts. The survey results are supplemented by a review of the literature, as well as analysis of capital markets data.

The main objective of the research is to identify and assess the main drivers of discount rates for low-carbon generation projects, taking into account both technological and market risks. The primary findings from this study are discount rate estimates for a range of low-carbon generation technologies for 2011, 2020 and 2040.

It is important to note that this research has been completed during a period when the UK energy sector is experiencing a number of significant challenges, as follows.

– **A highly uncertain macroeconomic outlook**—the unprecedented strength of the monetary policy response, both internationally and in the UK, to the financial crisis in 2008, together with the uncertainty surrounding the future impacts of the fiscal policies adopted in the UK and elsewhere, highlight the challenges faced by international investors when assessing the opportunities for investing in low-carbon generation. These factors suggest that the range of plausible outturns for macroeconomic growth (an important driver of electricity demand and the prices of energy-related commodities such as oil, gas, coal and carbon), inflation, interest rates, and exchange rates is very wide, which would be expected to have a material impact on investors' expected returns and perception of risk.

– **Uncertainty over the impacts of deployment of significant renewable generation capacity in Great Britain**—there continues to be considerable uncertainty about the full costs of intermittent renewable generation necessary to meet existing, legally binding commitments under the April 2009 EU Climate and Energy Package.[2] In particular, due to the impact of renewables on price formation and volatility, measures to meet the legally binding target of a 20% reduction in emissions of greenhouse gases (GHGs) in the EU by 2020 are likely to affect the value of all generating plants participating in the GB wholesale electricity market. The implication is that the value of new generation capacity could also become more uncertain, even in the absence of new policy measures.

– **Uncertainty over the technical viability of certain low-carbon generation technologies**—the limited experience of certain low-carbon generation technologies, such as CCS and offshore wind, would be expected to reinforce the challenges associated with valuing future investment opportunities. This would be due partly to the potential implications for price formation of new, unproven generation technologies, and partly to the challenges of assessing the probability of these technologies being technically and commercially proven.

[1] This is part of a wider programme of work led by Mott MacDonald that is investigating the potential evolution of the costs of low-carbon generation technologies.

[2] European Commission (2009), 'Commission welcomes adoption of climate and energy package', April 23rd.

– **Consultation on Electricity Market Reform (EMR)**—the EMR consultation published in December 2010 by the Department of Energy and Climate Change (DECC) sets out the government's motivation for several wide-ranging proposals for reform of the UK's primary renewables support mechanism, as well as the electricity trading arrangements.[3] In addition, it poses the question of the extent to which the government should attempt to influence explicitly the contribution of different technologies to the low-carbon generation mix.[4] As a result of the uncertainty surrounding the outcome of the EMR consultation, and the challenges of assessing the full impacts of specific proposals on existing generation portfolios as well as new investments (due to the lack of detailed design of key policies), the outlook for returns to low-carbon generation remains unclear.

– **Implications from international events**—on March 11th 2011, a major earthquake hit the eastern coast of Honshu, Japan, resulting in a tsunami. This was followed by a nuclear accident at the Fukushima Daiichi nuclear power plant. It is important to note that this report is based on evidence from before the earthquake and before the impacts of the nuclear accident were known. As such, and because the full impacts of the events are not yet clear, it has not been possible to assess what, if any, impact this natural disaster may have on risk perceptions or discount rates for nuclear power in the UK.

Taken together, the above uncertainties and challenges imply that estimating investors' forward-looking required returns on low-carbon generation investments based exclusively on past realised returns is likely to be inappropriate. This would be expected to apply to technologies, such as CCS, that are unproven, as well as those, such as nuclear generation, for which there is no recent experience of new-build projects in Great Britain. Moreover, a bottom-up analysis of realised returns to estimate the costs of capital for low-carbon generation projects in other jurisdictions would not be expected to capture the impact of GB-specific market factors (or, indeed, proposed reforms to GB market arrangements) on investors' required returns. Consequently, this study has undertaken a survey of market participants supplemented by findings from a literature review. Oxera has also made use of market evidence on key parameters relevant to assessing the costs of debt and equity in order to develop discount rate estimates that are consistent with current capital market conditions and market expectations.

A key finding from the survey is that the expectations and risk perceptions of investors and project sponsors differ significantly, and so the required returns, or hurdle rates, for individual low-carbon generation technologies vary widely. That said, there is a relatively consistent ranking of the risks and required returns among the low-carbon generation technologies that were the subject of the survey. It is important to emphasise that the survey responses should be treated with an appropriate level of care given that market participants (some of which may have responded to Oxera's survey) may be actively discussing details of policy measures with DECC that would be expected to have a material impact on the economics of future investment projects. As a result, this research provides, at most, a high-level guide to the appropriate discount rates for low-carbon generation projects, since the range of feasible discount rates is potentially very wide.

To obtain discount rate range estimates, a four-stage approach was followed (see Figure 1.1 below).

– **Stage I: Input gathering**. Data on discount rates for various technologies was gathered from various academic studies and from discussions with market participants contacted as part of the survey described in section 2.

[3] Department of Energy and Climate Change (2010), 'Electricity Market Reform. Consultation Document', December.

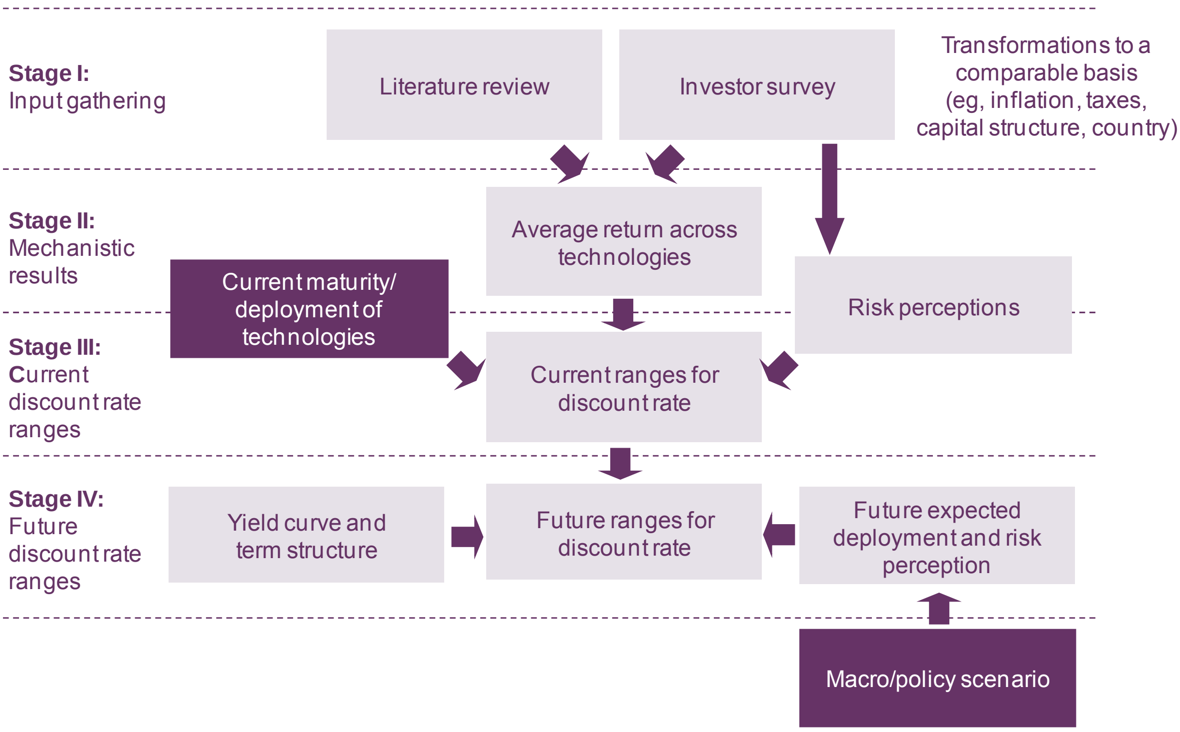
[4] As outlined in DECC's discussion of the issues associated with technology-specific auctions. Department of Energy and Climate Change (2010), op. cit., p. 116.

– **Stage II: Mechanistic results**. Inputs were averaged across each technology to provide preliminary discount rate ranges, on a pre-tax real basis. In certain cases where inputs were presented under different bases, assumptions for key parameters were used to obtain comparable estimates (eg, inflation, taxes, gearing).

– **Stage III: Final views on discount rate ranges**. The final discount rate ranges were formed using the output from stage II, in combination with risk perceptions obtained from survey responses and views from Mott MacDonald on the current deployment of various technologies.

– **Stage IV: Deployment scenarios**. Forward-looking discount rate ranges for 2020 and 2040 were obtained according to the deployment assumption of each technology under three macro scenarios. The discount rates are adjusted according to i) a term premium, which reflects the expected increases in the risk-free rate over the relevant period; ii) a 'deployment premium'; and iii) a change in capital structure and debt premium. Each adjustment is explained further in section 4.

Figure 1.1 Process for establishing discount rate ranges



Note: Dark-shaded boxes denote input provided by Mott MacDonald.
Source: Oxera.

The report is structured as follows:

– section 2 sets out the methodology, including a discussion of reasons why the minimum required return, or hurdle rate, may differ from traditional estimates of the cost of capital, as well as an overview of the survey methodology;
– section 3 outlines the main drivers of the discount rates associated with investments in low-carbon generation, and the associated risks;
– section 4 presents discount rate estimates for investment in low-carbon generation;
– section 5 concludes.

A copy of the survey and references to the literature are provided in Appendices 1 and 2, respectively.

2 Methodology

The aim of this report is to assess the drivers of discount rates for low-carbon generation projects. Financial analysis of the cost of capital as implied by the costs of debt and equity in capital markets requires assumptions to be made about the appropriate asset pricing model, and typically also requires data on returns to financial instruments that have broadly comparable risk profiles. This may not be possible in the case of low-carbon generation technologies because they may be nascent and not yet available for commercial deployment. Even if they are deployed commercially, there may not be sufficient data available on their cost of capital due to the lack of comparators (ie, traded equity securities and debt instruments) with which to assess the risks and required returns of particular technologies in specific market contexts or regulatory jurisdictions. Moreover, investors' hurdle rates frequently deviate from theoretical predictions of asset pricing models such as the capital asset pricing model (CAPM) for a variety of reasons that would also be expected to apply to low-carbon generation technologies.

Accordingly, this section of the report sets out the theoretical framework underlying the determination of discount rates for investment in low-carbon generation, and discusses reasons why the minimum required return, or hurdle rate, may differ from traditional estimates of the cost of capital.

This section also describes Oxera's survey methodology; a copy of the survey is provided in Appendix 1.

– Section 2.1 presents an overview of the cost of capital and the CAPM.

– Section 2.2 discusses reasons why the CAPM may not provide an accurate estimate of hurdle rates.

– Section 2.3 provides a brief review of the hurdle rate literature.

– Section 2.4 describes the survey methodology used to gather views from market participants.

– Section 2.5 summarises the key points in this section.

2.1 Cost of capital and the CAPM

Discount rates are often estimated on the basis of the weighted average cost of capital (WACC). The WACC gives an estimate of the cost to a firm of raising capital, which is equivalent to the approximate return required by potential creditors and equity investors. The WACC reflects the opportunity cost of making an investment—that is, the return that could have been earned on an alternative investment with similar risks. Although the WACC is a forward-looking concept, intended to reflect the risk inherent in future cash flows, it is typically estimated using historical prices (and therefore returns) on traded debt instruments and equities. Specifically, the WACC is calculated using the following formula:

$$\text{WACC} = k_d \cdot g + k_e \cdot (1 - g)$$

where k_d represents the cost of debt, k_e is the cost of equity, and g is gearing (the proportion of debt in the firm's capital structure).

A common approach for measuring the required return to equity investors is to apply the CAPM, which predicts that the risk premium applicable to any security is a linear function of the risk premium on the market portfolio, as in the following equation (this relationship is based on a number of assumptions that are discussed further in section 2.2):[5]

$$E(R_i - R_f) = \beta_i \cdot E(R_m - R_f)$$

where $E(R_i - R_f)$ denotes the expected return on a particular security over and above the risk-free interest rate (ie, the expected 'excess return' on a security); $E(R_m - R_f)$is the expected excess return on the market portfolio; and β_i is the coefficient that captures the exposure of the security to 'systematic risk'—that is, the risk that arises from exposure to the risks inherent in the market as a whole.

In this framework, investors are compensated for their exposure to systematic risk only. This is a consequence of the assumption that risks that are not correlated with the market (termed 'non-systematic' or 'idiosyncratic' risks) can be diversified away at no additional cost.

2.2 The CAPM in the context of hurdle rates

The CAPM is widely understood, relatively easy to implement, transparent, and is commonly used by public authorities and regulators. However, the CAPM has performed poorly in empirical tests,[6] which reflects the fact that the model relies on a number of assumptions that may not hold in practice. For example:

– the CAPM estimates returns over a single period (eg, a year), whereas investors may have longer-term or staged investment horizons that incorporate multiple 'strategic' objectives;

– due to transaction costs and other capital constraints, investors generally may not be able to diversify their portfolio sufficiently to eliminate all idiosyncratic risks;

– investors do not all have identical information, expectations and risk preferences;

– the practical implementation of the CAPM through the 'market model' necessitates the use of proxies, such as historical realised returns in place of forward-looking expected returns; historical variance in place of forward-looking volatility; and a national stock market index in place of a truly representative market portfolio;

– the CAPM relies on the assumption that investors maximise expected utility, and that expected utility is determined solely by expected level and variance of financial returns, without consideration of other statistical properties of returns such as skewness (ie, the potential for asymmetry of returns) and kurtosis (ie, 'fat tails' in the distribution of returns that would make the frequency of outliers greater than predicted by the normal distribution).

Perhaps reflecting these and other imperfections of capital markets, investors and companies' financial officers do not necessarily rely exclusively on CAPM estimates to determine their hurdle rate targets for particular projects when allocating capital. Reasons that may be used to justify such departures from finance theory include the following.

– The tendency to project over-optimistic scenarios for their future cash flows, or 'optimism bias'.

– Uncertainty in estimating the WACC may lead to the need for a 'safety margin' to be applied to the discount rate.

[5] The market portfolio is one containing all marketable assets in equal proportions to those in the market.

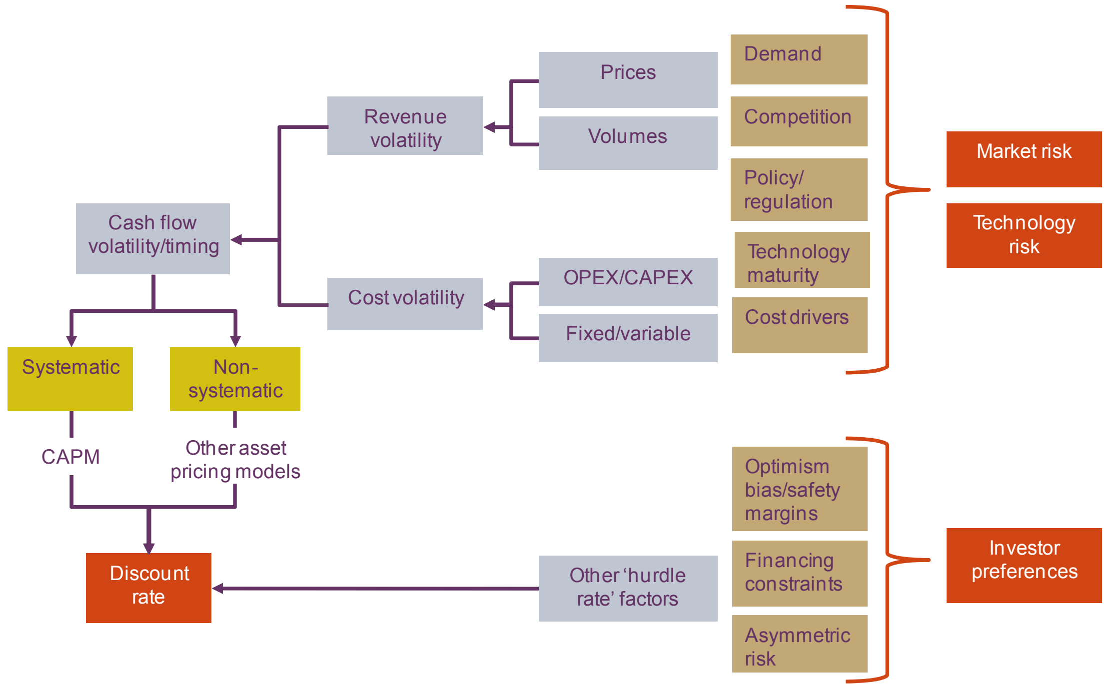
[6] For example, see Fama, E. and French, K. (2003), 'CAPM: Theory and Evidence', University of Chicago CRSP Working Paper no. 550.

– Asymmetric risks—where the downside risk (ie, the risk of financial distress or failure) is not offset by sufficient upside risk—could be exacerbated by the lack of credible commitment by policy-makers to stated policies such that losses borne by investors in some future states of the world may not be offset by higher returns in others (perhaps due to concerns that abnormally high returns could be clawed back through windfall taxes or other, functionally equivalent, policies).

– Investment constraints resulting from human resource constraints, and/or concerns over limited access to capital markets in certain circumstances that may increase the expected cost of financial distress.

Figure 2.1 summarises a number of factors that may affect the discount rate used to assess the profitability of an investment. It illustrates that, while systematic risk factors that increase the cost of equity according to the CAPM feed into the discount rate, non-systematic risk, as well as other factors, can contribute to a hurdle rate which differs from that obtained using the CAPM.

Figure 2.1 Determinants of investor hurdle rates



Note: This illustration abstracts from the impact of debt on the hurdle rate, and can be considered as applicable to an asset that is fully financed by equity.
Source: Oxera analysis.

It is important to note that the cost of capital for a stand-alone project does not typically correspond to the overall cost of capital of the company undertaking the investment. Indeed, the risks associated with some low-carbon generation projects could perhaps be expected to vary greatly from firms' (or investors') overall operations seen as a portfolio of projects, especially if they involve large capital expenditure (CAPEX) that is also 'lumpy' (eg, nuclear new build), or based on unproven, nascent technology. Given the large and diversified operations of some of the companies operating in the GB electricity market, it may not be feasible to estimate the marginal impact of individual projects on the firm-wide cost of capital in order to infer the discount rate for a specific project on a stand-alone basis.[7]

[7] Indeed, it should be recognised that because the application of a firm-wide discount rate is likely to increase the risk of inefficient capital allocations, firms would be expected to differentiate discount rates somewhat according to administrative guidelines that may not be publicly available, thereby making it difficult (if not impossible) to infer what discount rates are applied

2.3 Hurdle rate literature

A number of studies have investigated hurdle rates used for investment in practice. Some have compared CAPM-based discount rates with investor hurdle rates, primarily based on surveys of companies' financial officers, and found significant differences between the hurdle rate and the WACC. In light of these findings, alternative approaches have been proposed for estimating hurdle rates. One such study found that the average real hurdle rate used by the CEOs of US Fortune 1000 was typically more than 3% higher than their real cost of equity. Moreover, it found that investor hurdle rates are uncorrelated with risk proxies, such as the CAPM beta, used to estimate firms' cost of equity.[8]

Another study conducted in 2006 found that companies tended to use hurdle rates 5% higher than their cost of capital.[9] Through econometric analysis, the authors determined that this premium was partly due to required compensation for unsystematic risk. A significant percentage of survey respondents attributed the need for this premium to optimism bias, limited access to capital markets, and limited human resources. Notably, almost 30% of respondents stated that project-specific risk, which is unrelated to the state of the economy, was a 'very important' factor for them in determining or changing the hurdle rate.[10]

It has been shown that the ability to make intermediate decisions, such as a decision to expand or cancel a project depending on the circumstances at specific milestones, can decrease the required return on a project.[11] Conversely, the risk of 'irreversible' investment decisions may lead investors to require a higher return than that implied by the CAPM. An alternative valuation method incorporating the impacts of these intermediate decisions is a 'real options' framework. Real options valuation involves simulating cash flows by making assumptions on the probability distributions across all possible scenarios. With those probabilities it is then possible to incorporate the value of 'options' to, say, expand or cancel a project. This is in contrast to simpler investment appraisal frameworks based on modelling a single stream of expected cash flows (without multiple intermediate decision points or stages) and applying a single discount rate that reflects the uncertainty.

2.4 Survey methodology

As mentioned in section 1, Oxera surveyed investors, project sponsors and financial analysts to gain a better understanding of the following issues.

- What are the factors affecting risks to cash flows for low-carbon generation projects?
- How do the risks and discount rates of different low-carbon generation technologies compare?
- If current market arrangements were modified to eliminate specific sources of risk, how might discount rates for various technologies be affected?

in which circumstances. Applying a firm-wide discount rate in the presence of a diverse set of projects with different risk characteristics would be expected to result in underinvestment in low-risk projects whose expected returns would not meet the company-wide hurdle rate, but which have stand-alone costs of capital below the expected return. Equally, there would also be the risk that the firm over-invests in high-risk projects whose expected returns are in excess of the hurdle rate, but which actually have stand-alone costs of capital above the expected return.

[8] Poterba, J. and Summers, L. (1995), 'A CEO Survey of U.S. Companies' Time Horizons and Hurdle Rates', *Sloan Management Review*, Fall, pp. 43–53, as cited in Driver, C. and Temple, P. (2009), 'Why do hurdle rates differ from the cost of capital?', *Cambridge Journal of Economics*, **34**, pp. 501–23.

[9] Meier, I. and Tarhan, V. (2007), 'Corporate investment decision practices and the hurdle rate premium puzzle', Working Paper. Available at SSRN: http://ssrn.com/abstract=960161.

[10] Ibid. p. 50.

[11] Gutiérrez, O. (2005), 'Real options and the Jorgensonian user cost of capital', *Investigaciones Económicas*, **XXIX**:3, pp. 625–30.

All responses were treated in confidence and Oxera undertook to present aggregated results only or otherwise to make the findings anonymous, and not to attribute any comments to individual respondents.

To understand how market participants perceive the decision to invest in low-carbon generation, Oxera contacted approximately 80 relevant market participants and stakeholders. Overall, the response rate was slightly in excess of 10%. Of the responses received, some were submitted in writing while some respondents preferred not to submit a formal written response. For the former, Oxera followed up with clarification questions as necessary and to explore specific issues raised in the written responses. For the latter, Oxera conducted detailed interviews, by telephone or in face-to-face meetings, structured around the same survey as reproduced in Appendix 1.

Given the sample size and the response rate, it is important to emphasise that it is unclear whether the findings presented in this report are representative of the views of the 'average' investor or project sponsor currently pursuing or considering investments in low-carbon generation technologies in Great Britain. For this reason, no detailed statistical analysis has been undertaken using the survey responses.

That said, the detailed nature of the responses received did allow some conclusions to be drawn. In particular, a key finding from the survey is that the expectations and risk perceptions among investors and project sponsors differ significantly, and so the discount rates for individual low-carbon generation technologies vary widely. Notwithstanding the variation in discount rates reported, there was a fairly consistent ranking of the *relative* risks and required returns *among* low-carbon generation technologies. The technologies that were included in the survey are listed in Table 4.1 of the survey (see Appendix 1 of this report).

2.5 Summary

While the CAPM is the most commonly used model for estimating the cost of equity, in many instances it may not provide an accurate estimate of firms' or investors' hurdle rates. This is partly because its underlying assumptions may not be appropriate in certain contexts, and also due to its use of historical (as opposed to purely forward-looking) data, as well as its poor results in empirical testing. Moreover, investors that are not able to build a fully diversified portfolio may require compensation for certain unsystematic risks—for example, for large projects that take up a significant proportion of a firm's capital resources. In addition, given that investment in low-carbon generation projects may have a high degree of project-specific risk that is also largely unsystematic (eg, construction costs in the case of nuclear, or the level of wind resource available in a particular locality over the life of a wind farm investment), this may make the CAPM unsuitable to the extent that investors require compensation for idiosyncratic risk.

As a result of the methodological considerations described in this section, Oxera's discount rate estimates relied on evidence reported in the available literature, which have supplemented estimates reported by industry participants in a survey conducted by Oxera. As explained above, the main challenge in aggregating evidence from both sources related to the inability to control for differences in risk preferences, future expectations, or the technical expertise among the various authors of existing publicly available sources or survey respondents. Despite these limitations, the evidence gathered from these sources provided insight when identifying the relevant risk factors and the relative overall risk perceptions across the range of technologies, as described later in this report.

3 Implications for investors and project sponsors

This section outlines the main qualitative findings concerning the factors that are likely to be relevant in the assessment of discount rates for low-carbon generation technologies. In particular, four issues are discussed: whether the discount rate varies by jurisdiction, technology, market arrangements, or with the identity of the capital provider or project sponsor.

These four issues are explored as follows in this section:

– section 3.1 outlines the main jurisdiction- and technology-specific factors likely to influence low-carbon generation discount rates, given the existing energy policy framework in Great Britain;
– section 3.2 describes how these risk factors map onto different types of low-carbon generation discount rates;
– section 3.3 examines the possible effect of alternative market arrangements on discount rates across technologies with certain economic characteristics;
– section 3.4 discusses whether and how low-carbon generation discount rates are expected to be influenced by the type of investor or capital provider;
– section 3.5 summarises the key findings from the above analysis.

3.1 Risk factors for low-carbon technologies

A wide range of factors would be expected to affect discount rates, some of which are applicable to any new investment in a particular jurisdiction and others which would be specific to low-carbon generation investment. Drivers of risk perception—such as currency risk, the legal system, the design of the electricity market, as well as certain political and regulatory risks—would be examples of the former, whereas the technology characteristics—such as cost structure, load factor, and technology maturity—could be examples of the latter. While all these factors may be expected to differ between countries and regions, this analysis is concerned with low-carbon generation investments in Great Britain.[12]

3.1.1 Does the discount rate depend on the jurisdiction and market factors?

From the point of view of a low-carbon generation developer, the jurisdictional characteristics that would have specific relevance to the electricity sector (ie, risk factors that are broadly 'extrinsic' to a specific low-carbon generation technology) include the following.[13]

– **Wholesale electricity price levels and volatility**—the average level of electricity prices would normally be expected to affect the annual revenue that can be generated by generating plants. In addition, the volatility of electricity prices would be expected to make it more challenging for investors to manage investment risks and to assess the viability of some investments. These challenges are likely to be particularly acute for assets that have large upfront capital outlays that must be recovered over several years or decades, and technologies with long construction lead times.

[12] Country risk premia may be introduced by some investors or project developers when assessing an investment that is not in their country of domicile, although it is often not clear what the precise basis is for such adjustments to the discount rate. In this context, one survey respondent highlighted that electricity investments in Great Britain would require at least a 1.5% higher discount rate than the company-wide cost of capital, which suggests that country-specific factors could be significant.

[13] Some of these risk factors would be expected to be influenced by the totality of low-carbon investments expected over the long term (eg, due to the impact of more intermittent generation capacity), and, in this sense, they are not entirely exogenous. However, from the point of view of any individual low-carbon generation project, these factors would be expected to be treated as external drivers.

– **Carbon price levels and volatility**—given that carbon prices are typically reflected in electricity prices, due to their impact on the marginal costs of some thermal generating plants (especially coal- and gas-fired generation) the level of the carbon price would be expected to provide an economic incentive in support of low-carbon generation. As with volatile electricity prices, volatility in the carbon price can also make it more challenging for investors to manage investment risks and to assess the viability of some investments. Unlike some marginal plants that are also price-setting, low-carbon generation capacity is typically infra-marginal. As such, revenues, contributions to remunerate fixed costs, and ultimately investment returns would be significantly affected by carbon price levels and their volatility.

– **Electricity demand**—growth in electricity demand and the adoption of energy-saving measures would be expected to have a direct influence on wholesale prices. Moreover, factors such as the adoption of demand-side response measures could also have an impact on electricity price volatility.

– **Policy risk**—uncertainty over the future direction of energy policy would be expected to have a significant impact on risk perceptions, in relation not only to overall structure of future market arrangements, but also to specific aspects, such as the tax treatment of investments in various technologies.

– **Value of subsidies and other support**—the risk that there may be changes in the support mechanisms currently in place, such as Renewables Obligation Certificates (ROCs), would be expected to affect those technology groups that currently benefit from, or depend on, these mechanisms.

– **Public perception**—there is a risk that public opinion and acceptance of a particular generation technology could result in changes to the government's energy policy.

3.1.2 Does the discount rate depend on the type of technology?

In addition to the extrinsic factors identified above that influence the discount rate for low-carbon generation technologies, there are likely to be several technology-specific (or 'intrinsic') factors that help to determine the appropriate discount rate. Factors listed in the survey that were related mainly to the specific technological characteristics of different low-carbon generation technologies include the following.

– **Plant load factor**—the average annual utilisation of a generating plant operating in the wholesale market would be expected to have a significant impact on risk perception since it would enable fixed costs to be spread over a greater electricity output in a given period.

– **Technical availability 'on demand'**—the availability of a generating plant at times of peak demand, and flexibility in responding to capacity requirements due to variations in demand and intermittent generation, would enable the plant to capture higher prices, thereby affecting investment returns.

– **Cost structure**—the cost structure of a generating plant, including CAPEX, OPEX and input prices, can amplify exposure to a range of other risk factors.

  – **Capital costs**—investment in technologies that are characterised by high up-front and fixed costs would be expected to be more sensitive to cost or revenue shocks. Variations in volumes and electricity prices affecting plants with high levels of operational gearing would be expected to result in profit margins that are more volatile, and, hence, more risky returns.

  – **Operating costs**—variations in the price of fuel or other inputs (eg, gas, biomass, carbon, uranium) would be likely to translate into profit variability. Plants that provide marginal electricity outputs and act as price-setters may benefit from a natural hedge to movements in input prices.

– **Construction lead times**—longer lead times for the commissioning and construction of plants increase the risk that market movements may materially affect the viability of generating plants relative to investors' expectations at the start of a development, thereby potentially raising risk perceptions.

– **Deployment and maturity**—early-stage technologies that have not been deployed successfully could be perceived as risky investments with relatively high hurdle rates. Several attributes of early-stage technologies are likely to account for this, including the uncertainty about whether they will become technically or commercially feasible.

Section 3.2 considers how these extrinsic and intrinsic risk factors would be expected to influence the overall risk perception of low-carbon generation technologies.

3.2 How do risk factors map onto various technology types?

To assess the relative risk exposures of the various technologies, it is helpful to consider how each risk factor described in section 3.1 maps onto each technology type. In the survey, Oxera asked respondents to state whether a number of extrinsic and intrinsic risks associated with different low-carbon technologies were perceived to be of low, medium, or high importance. Table 3.1 summarises the main survey findings.

Table 3.1 Summary of survey respondents' views on the importance of extrinsic and intrinsic risk factors for different low-carbon generation technologies

Risk factor	**Conventional, mature** (eg, combined cycle gas turbine, CCGT)	**High capital/low marginal cost, intermittent** (eg, wind)	**High capital/low marginal cost, lumpy investment** (eg, nuclear)	**Early stage** (eg, wave, tidal stream)
Extrinsic				
Wholesale electricity price level and volatility	Medium	Medium	High	Medium
Carbon price level and volatility	Medium	Low	Medium	Low
Electricity demand	Medium	Low	Medium	Low
Policy risk	Medium	High	High	High
Value of subsidies	Low	High	Low	High
Public perception	Low	High	High	Medium
Intrinsic				
Plant load factor	Medium	Low	Medium	Low
Technical availability on demand	Medium	Medium	Medium	Low
CAPEX	Medium	High	High	High
Operating costs (including input prices)	Medium	Medium	Medium	Medium/low
Construction lead times	Medium	Medium	High	High
Deployment and maturity	Low	Medium	Medium	High

Note: 'Low', 'medium', and 'high' represent averages of survey responses. To calculate these averages, responses for 'low', 'medium', and 'high' were converted to numbers 1, 2, and 3 respectively. These averages were rounded, and converted back to 'low', 'medium', and 'high' using the same 1–3 scale.
Source: Survey responses.

Key technological characteristics that affect the discount rate include the level of CAPEX required; the technology's 'maturity' (assumed in this report to be directly related to the extent of deployment in Great Britain and elsewhere); and operational factors such as technical performance. Table 3.1 shows that respondents consider a number of important risk factors to differ across technology types, which affects the risk perception and required return. In particular, the following survey findings are worth noting.

– Important technology-related risk factors for early-stage technologies, such as wave and tidal stream, included CAPEX and size of investment, construction lead times, payback period, technological maturity, as well as risks associated with subsidies and other support mechanisms, such as ROCs.

– Technologies characterised by high capital cost, low marginal cost, and lumpy investment (eg, nuclear) were regarded as having the greatest exposure to carbon price volatility and liquidity risk, with responses averaging slightly above 'medium'. The majority of risk factors were deemed higher than 'medium' for this category of technology, with public perception, wholesale electricity prices, and policy or regulatory risk all deemed high risk by all respondents. Overall, similar risks were ranked as important as those for early-stage technologies, except for technological maturity, which was ranked as being of greater importance for early-stage technologies.

– Electricity price risk (such as price level, price volatility and market liquidity) was generally regarded as a medium risk for technologies with high capital cost, low marginal cost and intermittency of output (such as wind power). This technology type was primarily associated with high CAPEX, public perception and policy risk.

– More established, conventional technologies, such as CCGT, were generally less exposed to the risk factors considered above. The main exceptions relate to the exposure to carbon prices, electricity demand and load factor, which are all ranked higher than for early-stage technologies or technologies with intermittent output, such as wind.

In particular, two risk factors—technology maturity (intrinsic) and policy risk (extrinsic)—appear to have a dominant influence on the overall risk perception across technology types.

– **Technology maturity**. Several survey respondents have indicated that the maturity of a technology tends to outweigh other intrinsic risk factors, so that, on the whole, mature technologies tend to have lower hurdle rates than early-stage and unproven technologies.

  While not directly related to the degree of maturity of the technology itself, some survey respondents noted that discount rates for new assets (irrespective of the technology) would be higher than for existing assets, suggesting that risks related to new build are significant (eg, the potential for overruns in relation to capital costs and commissioning timescales, and actual operating performance). It is possible that these risks also account for some of the differences in discount rates between different low-carbon generation technologies.

– **Policy risk**. Survey respondents associated a high degree of policy risk to all low-carbon technologies, suggesting that this particular factor is at least as significant as any other when considering an investment in low-carbon generation. This is consistent with a report by the Green Investment Bank Commission, which emphasises political and regulatory risk as an impediment to investment in low-carbon and renewable technologies.[14]

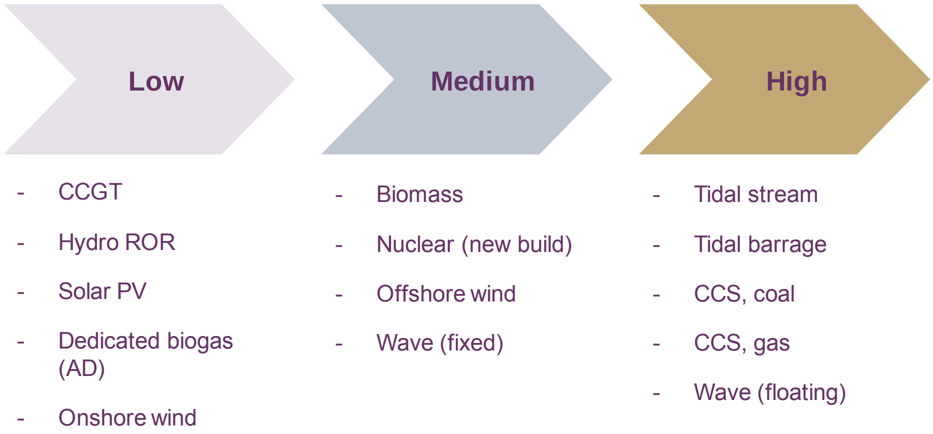
[14] Green Investment Bank Commission (2010), 'Unlocking investment to deliver Britain's low carbon future', June.

Overall, there appears to be a view among survey respondents that, owing to political risk, it is very difficult to quantify risk appetite for investment in electricity generation at this time. This is consistent with the finding that the removal of political risk would have the highest impact on the discount rate across all non-conventional technologies (see section 3.3).

Respondents also frequently highlighted the interactions between technological characteristics and the design of the wider market framework, especially the presence of renewable support mechanisms. Moreover, the extent to which market arrangements may augment or mitigate specific risk factors—such as exposure to carbon price levels and volatility, electricity prices and their volatility, and balancing arrangements—may vary significantly across technologies. The effects of market arrangements on risk perceptions and discount rates are discussed in section 3.3.

On the basis of these findings, each technology was ranked according to an overall risk perception, intended to encompass all risk factors. The overall ranking of the various technologies, as perceived under current market arrangements, is shown in Figure 3.1.

Figure 3.1 Overall risk perception for conventional and low-carbon technologies



Note: ROR, run-of-the-river; PV, photovoltaic; AD, anaerobic digestion.
Source: Oxera analysis, based on evidence from survey responses and literature.

The relative risk perception from survey respondents is generally consistent with findings from the literature review. For example, most survey respondents qualified CCS as a high-risk technology, largely reflecting its early-stage nature. Al Juaied (2010) discusses risk factors relevant to CCS, including unexpected increases in the costs of construction and CAPEX, difficulties with permit requirements, and the risk of power prices being insufficient to cover the high initial costs.[15]

While biomass is a relatively mature technology, and is therefore not subject to 'early-stage' risk, it is subject to risks associated with emissions control, as noted by energy consultant KEMA.[16] Also, the United Nations Environment Programme (UNEP) notes that a significant risk associated with biomass, which has prevented projects from securing financing, is resource supply risk.[17] These are broadly consistent with the views of survey respondents, who regarded biomass as a 'medium'-risk technology.

[15] Al Juaied, M. (2010), 'Analysis of Financial Incentives for Early CCS Deployment', Discussion Paper 2010-14, Energy Technology Innovation Policy Discussion Paper Series, Harvard Kennedy School, October.
[16] KEMA (2009), 'Renewable Energy Cost of Generation Update', prepared for the California Energy Commission, August.
[17] United Nations Environment Programme (2004), 'Financial Risk Management Instruments for Renewable Energy Projects', pp. 26–7.

In contrast, hydro ROR is considered a relatively low-risk technology by most survey respondents. This is also consistent with UNEP's assessment of the technology:

> Large scale hydro is a well developed, long-term proven, technology with low maintenance expenses and few operational risks or barriers. From a financing and risk management perspective, small-scale hydro installations benefit from a general understanding of the technology.[18]

3.3 Does the discount rate depend on market arrangements?

Market arrangements can be designed to mitigate the exposure to certain risk factors for a range of technologies. Given the absence of evidence in the literature reviewed on the effect on risk of various market arrangements for low-carbon technologies, the analysis in this section relies mainly on evidence from the survey responses.

The survey asked about the importance of risks relating to the value of subsidies or other support mechanisms, whereby the design and operation of schemes such as the Renewables Obligation, their overall cost, and their public acceptability were considered. Respondents ranked the risks relating to the value of subsidies as highest across all but conventional/mature generation technologies.

Survey respondents were also asked to rank the discount rate impact that would result if selected risk factors were transferred away from the capital provider. A summary of responses is reported in Table 3.2.

Table 3.2 Impacts of mitigating selected risk factors through market support arrangements

Risk factor	**Conventional, mature** (eg, CCGT)	**High capital/low marginal cost, intermittent** (eg, wind)	**High capital/low marginal cost, lumpy investment** (eg, nuclear)	**Early stage** (eg, wave, tidal stream)
Wholesale electricity price level	Medium	Medium	High	Medium
Wholesale electricity price volatility	Medium	Low	Medium	Low
Carbon price risk and volatility	Low	Low	Medium	Low
Load-factor risk	Low	Medium	Medium	Medium
Balancing risk	Low	Medium	Medium	Medium
Policy and regulatory risk	Medium	High	High	High

Note: Numerical responses for zero, <1% and ≥1% were converted into 'low', 'medium', and 'high' respectively.
Source: Survey responses and Oxera analysis.

Some of the results in Table 3.2 are explored in more detail below.

– Removing risk from the wholesale price level would affect most technologies, but would have the largest impact on technologies with high capital costs, such as nuclear. This suggests that relatively small variations in wholesale prices could cause large fluctuations in the return on an investment in nuclear generation, which is perhaps to be expected given that the large up-front investment required in a nuclear plant must be

[18] United Nations Environment Programme (2004), 'Financial Risk Management Instruments for Renewable Energy Projects', pp. 26–7.

recovered from sales of electricity over several decades.[19] This is consistent with the responses reported in Table 3.1.

– Removing risk from wholesale price volatility would have less impact than removing the risk from the average price level, but this risk is still relatively more important for technologies with lumpy investments, such as nuclear. This is also consistent with the responses reported in Table 3.1.

– Policy risk is important for all low-carbon technologies. Removing policy risk (which could partly be achieved by having a clear long-term policy in place) appears to be at least as important as the actual risks that could be mitigated through a given policy. This is also consistent with the responses reported in Table 3.1.

– The impact of removing the various risks is ranked similarly for early-stage technologies and for intermittent technologies (eg, wind). This result, which might appear counterintuitive at first glance, could be a reflection of the importance of a technology's maturity to its overall risk exposure. In other words, if maturity is the driver of investors' overall risk perceptions, the net effect of removing a particular risk factor would be relatively small for early-stage or less-developed technologies.

Some general qualifications should also be considered alongside these findings. For example, the role of private contract arrangements in mitigating certain risks—such as price volatility, load factor, and balancing risk—should not be underestimated despite not being mentioned explicitly by the respondents. A policy designed to eliminate those risks that are 'hedgeable' would have less impact than if it were targeted at other 'non-hedgeable' risks. Importantly, removing the policy risk itself could provide enough clarity to allow companies to adopt certain hedging strategies.

When results from Tables 3.1 and 3.2 are compared closely, certain inconsistencies become apparent. For example, survey respondents identified load factor as a relatively important risk factor for CCGT (ranked 'medium' in Table 3.1), but at the same time perceive that removing this risk would have a low impact on the discount rate. A similar inconsistency can be observed for balancing risk (eg, technical availability on demand) for CCGT. These conflicting results may reflect respondents' ability to hedge those risks: if a hedge is in place for a particular risk, the removal of the same risk through targeted market support may have a limited impact on the discount rate, even though the risk is considered important.

3.4 Does the discount rate depend on the ownership or contracting arrangements?

An important question to consider when assessing discount rates is whether the type of investor or the mode of ownership would be expected to influence them. This issue has a number of potentially far-reaching public policy implications, many of which were discussed by the Office of Fair Trading (OFT) in its recent 'stock take' study of infrastructure ownership in the UK.[20]

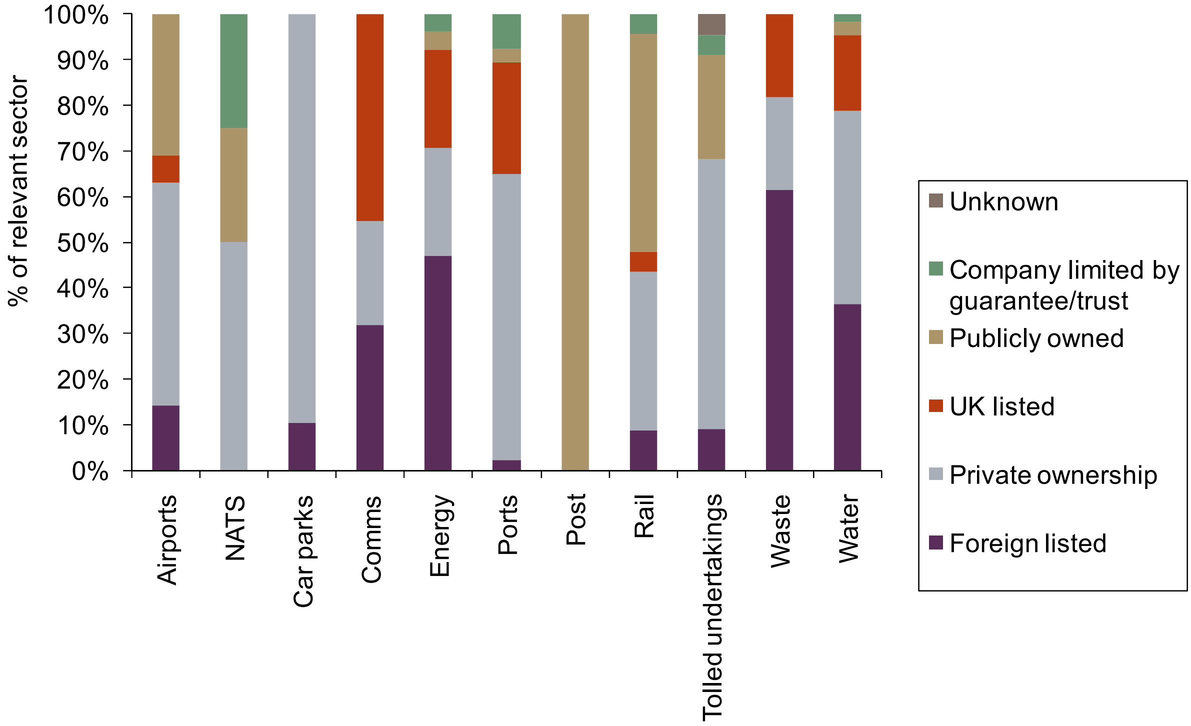
As seen in Figure 3.2 below, the dominant mode of ownership of UK infrastructure assets at present is publicly listed companies, which collectively hold about 42% of shareholdings of infrastructure assets. While this is mirrored in the energy sector, it does highlight that different ownership models could at least be possible, and that competition among different

[19] In the case of nuclear, the relevant risk factor is the long-term volatility in electricity prices, which can translate into annual cash-flow volatility. In contrast, the intra-day volatility in prices may be of less importance, as nuclear plants can be expected to run at baseload.

[20] Office of Fair Trading (2010), 'Infrastructure Ownership and Control Stock-take', Final Report: Main findings, December.

capital providers for investment opportunities could also feature for some technologies in the low-carbon generation sector.[21]

Figure 3.2 Ownership models by sector for UK infrastructure assets in 2010



Note: Energy assets included in the OFT's stock take consist mainly of energy networks (including electricity and gas, transmission and distribution) and interconnectors. Tolled undertakings include bridges, tunnels and roads. Source: OFT ownership database, available at: http://www.oft.gov.uk/OFTwork/markets-work/infrastructure-ownership.

In this context it is worth considering briefly whether ownership would, at least in theory, be expected to matter for the key drivers of the discount rate (see Box 3.1).

Box 3.1 Does ownership matter for the discount rate?

In theory, ownership does not matter—it should not affect a firm's capital structure, its financing and investment decisions, or its value.

As a starting point, Fisher's separation theorem suggests that the preferences of a firm's owners will not affect the firm's investment decisions.[1] Furthermore, the Modigliani–Miller (MM) capital structure irrelevance propositions suggest that the value of the firm remains unaffected by how the firm is financed or its dividend policy:

> the value of the firm should not be affected by the share of debt in its financial structure or by what will be done with the returns—paid out as dividends or reinvested (profitably).[2]

However, such theory maintains a number of idealised assumptions on the efficiency of capital markets, tax neutrality, symmetric access to capital markets, and perfect information. There are two steps to thinking about how ownership could, in theory, influence outcomes:

– if Fisher separation does not hold, owners' preferences *at the margin* could influence investment and financial decisions;
– if the MM irrelevance propositions do not hold, financial decisions (influenced by owners'

[21] Notwithstanding the fact that the energy assets included in the OFT's stock take consisted of energy networks (including electricity and gas, transmission and distribution) and interconnectors, not generation assets. See the OFT's ownership database, available at: http://www.oft.gov.uk/OFTwork/markets-work/infrastructure-ownership.

preferences) might affect the risk (and value) of assets.

By relaxing the assumptions that underpin the standard theoretical frameworks, a number of mechanisms emerge whereby ownership can influence outcomes. The implications for low-carbon generation assets could be as follows.

– **Influence on capital structure**—if alternative ownership models permit access to funding on different terms or rates—eg, due to imperfect capital markets or to the assumption of liability guarantees by capital providers—then ownership can affect capital structure, in particular through incentives to increase gearing.

– **Influence on investment strategy**—the investment strategy of the ultimate owner may influence the firm's focus on long-term CAPEX, especially in cases where capital programmes are not prescribed by a regulator (as would be expected to be the case in low-carbon generation).

Notes: [1]The theorem states that there is separation implied between a firm's investment and the preferences of its owners. This is because the owners can combine their investment decisions with a decision about how much to borrow or lend in capital markets, thereby achieving their desired profile of cash flows over time.
Source: Fisher, I. (1930), 'The Theory of Interest, As Determined by Impatience to Spend Income and Opportunity to Invest It', first published New York: Macmillan. [2] The MM proposition is summarised in Modigliani, F. (1980), introduction in Abel, A. (ed), 'The Collected Papers of Franco Modigliani'.

In practice, investment in low-carbon generation can be undertaken by a variety of capital providers and project sponsors, including:

– large, vertically integrated energy companies with interests across several regions internationally, such as the 'big six' incumbent electricity and gas companies in Great Britain;

– energy companies or independent generators with a more limited geographic reach and/or breadth of assets and operations, some of which may have recently entered the GB electricity market by acquiring or developing selected generation assets;

– investment funds and private commercial owners, including managed investment structures such as private equity and infrastructure funds.

For the reasons set out in Box 3.1, it may be reasonable to expect that these capital providers would differ in ways that could influence their capital structures and investment strategies. If it is assumed that some of the standard theoretical assumptions concerning the efficiency of capital markets can be relaxed then this could also imply that the appropriate discount rate would be set by the 'marginal' investor or project sponsor, which may also be capital-constrained (as opposed to all capital providers having the same discount rate and not experiencing any limit to additional debt and equity issuance).[22]

However, it is unclear whether it is possible to identify objectively which type of investor would, in practice, be the marginal source of funds since this would depend on an assessment of the capabilities (including knowledge of different technologies and familiarity with specific markets), resources (financial, managerial, and otherwise), existing asset portfolios, and business strategies of a range of capital providers in the UK and elsewhere.

An important feature of the strategy or business model adopted by different project sponsors is the method of contracting and the form of industrial organisation employed. For example, a

[22] In principle, firms should not experience capital constraints if they have reasonable access to debt and equity markets, and provided that investors are willing to fund all profitable projects. In practice, firms may experience capital constraints if, for example, they adopt a policy of maintaining a particular credit rating and if opportunities for further equity issuances are limited. Provided that there are other firms that are not bound by such restrictive treasury management policies, and assuming that investors are willing to fund profitable projects, these policies should not affect the discount rate for low-carbon generation. However, if there are other factors also limiting the ability of other firms to invest in certain technologies (perhaps due to a lack of technical expertise or a limited track record of successful deployment of a technology) then capital constraints may have an impact on the deployment of low-carbon generation, in terms of either the amount of capacity eventually deployed or the timing of these investments.

range of possibilities would seem to be available to different low-carbon generation developers, as follows.

- Fully 'merchant' generation, whereby generation capacity is developed on a stand-alone basis. In this model, the economics of the plant would be dependent on prevailing market prices for inputs and electricity generated. A particular feature of this model is that the risks associated with generating plant are significantly affected by market liquidity and price volatility, since these drive key investment risks and the costs associated with managing these through traded contracts and other hedging instruments. This model is reliant on access to liquid commodity and capital markets, including real-time, spot and forward markets.

- As an alternative to relying solely on market-intermediated risk management, merchant generators may engage in long-term contracts negotiated on a bilateral basis to manage key investment risks. For example, power purchase agreement (PPAs) are a relatively flexible tool with which to manage certain price and volume risks, and some survey respondents highlighted that their investment in low-carbon generation in Great Britain would be predicated on being able to enter into such contracts on reasonable terms. This model is therefore reliant on there being sufficient numbers of credible counterparties to enable long-term contracting relationships to be developed efficiently;

- Joint ventures (or development consortia) are another means by which firms may be able to overcome perceived capital constraints by enabling costs and associated risks to be shared among a wider set of developers and/or investors. For example, joint ventures have recently been established by a number of energy utilities to facilitate nuclear new build in Great Britain.[23]

- Vertical integration is another form of industrial organisation that is commonly used to manage risks associated with the development of highly specific assets with large sunk costs. Such assets (which are likely to include low-carbon generation) may be subject to 'hold up' problems (ie, the risk that the asset value could be significantly reduced following completion of the investment due to a change in bargaining power between the asset owner/operator and either upstream suppliers or downstream customers). Vertical integration enables a firm to internalise this ex post coordination problem, and, in the context of the electricity market, may enable certain wholesale and retail market exposures to be managed more efficiently. For example, the extent of vertical integration in the electricity and gas sectors generally suggests that it may be an efficient response to the risks that are predominant in wholesale and retail markets (including certain policy risks).

These strategies illustrate the variety of strategic responses open to the different types of capital provider and project sponsor identified above. To the extent that these strategic responses enable risks (systematic or otherwise) to be mitigated—thereby potentially allowing discount rates to be lower than would otherwise be the case—this highlights the challenges of identifying what configuration of investors, project sponsors, mode of ownership, and contracting structure would be most likely to be marginal.

This study has not differentiated the discount rate across various types of potential investor. As an alternative, section 4 presents discount rate range estimates that are intended to capture the diversity of views submitted by the survey respondents, which would be expected to account for some or all of the strategic issues raised above.

[23] NuGen is a UK-based consortium comprising GDF Suez, Scottish & Southern Energy, and Iberdrola (see http://www.nugeneration.com/index.html); Horizon Nuclear Power is a joint venture between E.ON UK and RWE npower (see http://www.horizonnuclearpower.com/contact.php); and Lake Acquisitions is a joint venture between EDF and Centrica (see http://www.centrica.co.uk/index.asp?pageid=39&newsid=1783).

3.5 Summary

A wide range of factors can be expected to affect discount rates for low-carbon technologies. Some of these, such as wholesale electricity prices and government policy, are extrinsic, in that they are outside the control of a particular low-carbon generation developer. Other factors—such as load factor, cost structure, or technology maturity—are an intrinsic part of, or inherent in, a particular type of technology. Overall, it appears that the maturity or deployment of a given technology is the dominant intrinsic factor that defines the overall risk perception for that technology. Furthermore, all low-carbon technologies are highly exposed to policy risk, to such an extent that several survey respondents commented to the effect that they were unable to rank the risk factors due to the uncertainty surrounding future energy policy.

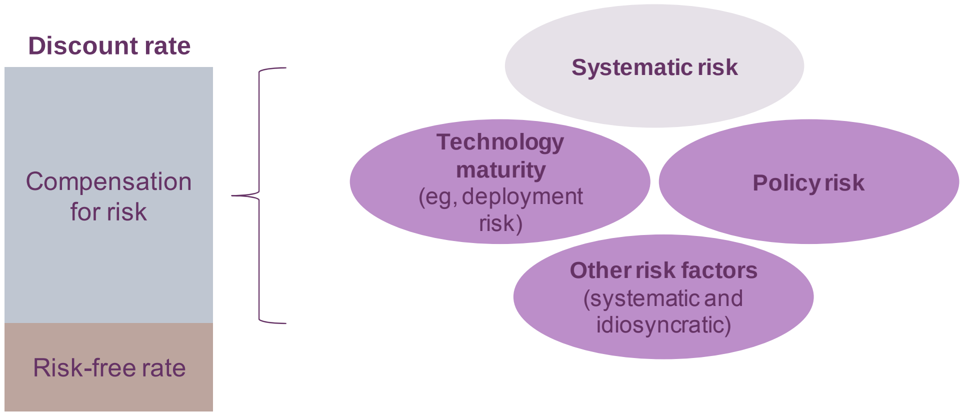
According to survey respondents, the impact of removing policy risk is at least as important as the actual risks that would be mitigated by a particular policy. Also, a policy designed to remove wholesale electricity price risk would most benefit technologies with a lumpy investment, such as nuclear. However, this study has not explored the specific policy designs that could be implemented to mitigate certain risk factors.

Lastly, the target discount rate is expected to vary across different types of project sponsor as a result of influences on capital structure and investment strategy, among other factors. While the marginal investor has not been identified for each type of technology, these are implicitly embedded in the discount rate ranges presented in section 4.

4 Discount rates for low-carbon generation technologies

As noted in the introduction to this report, the primary findings from this study are discount rate estimates for a range of low-carbon generation technologies for 2011, 2020 and 2040. Furthermore, and as discussed in section 2, finance theory dictates that the expected return on an asset is directly linked to its exposure to market risk. Despite the wide use and theoretical underpinnings of the CAPM, this study has not attempted to implement it in order to quantify discount rates for low-carbon and renewable technologies, largely as a result of data limitations.

Figure 4.1 Determinants of the discount rate for low-carbon electricity generation technologies



Source: Oxera.

This section brings together the evidence to present the final estimates for discount ranges across various technologies, and is structured as follows.

– Ranges for discount rates applicable to low-carbon and renewable technologies are presented in section 4.1.

– The mechanisms by which these ranges are adjusted to account for various future deployment scenarios are described in section 4.2.

– The implications of possible future market arrangements for discount rates are outlined in section 4.3.

– Section 4.4 summarises the main findings of the above analysis.

4.1 Ranges for discount rate applicable to low-carbon and renewable technologies

On the basis of information reviewed in stages I and II (see Figure 1.1), initial ranges were obtained from mechanically aggregating the evidence gathered from the literature review and survey responses.[24] A key observation from the aggregated evidence is that the gap between the lowest and highest reported discount rates for a given technology is greater for riskier technologies than for technologies perceived as being lower risk. This suggests that

[24] To ensure comparability, the data obtained from the literature and the survey was converted such that all discount rate estimates were translated into real, pre-tax terms.

the uncertainty about the precise level of discount rate increases with risk perception. However, the mechanistic results also highlight some internal inconsistencies. For example, the maximum discount rate for wave (fixed), which is perceived as medium risk, is higher than for CCS (coal), which is perceived as high risk.

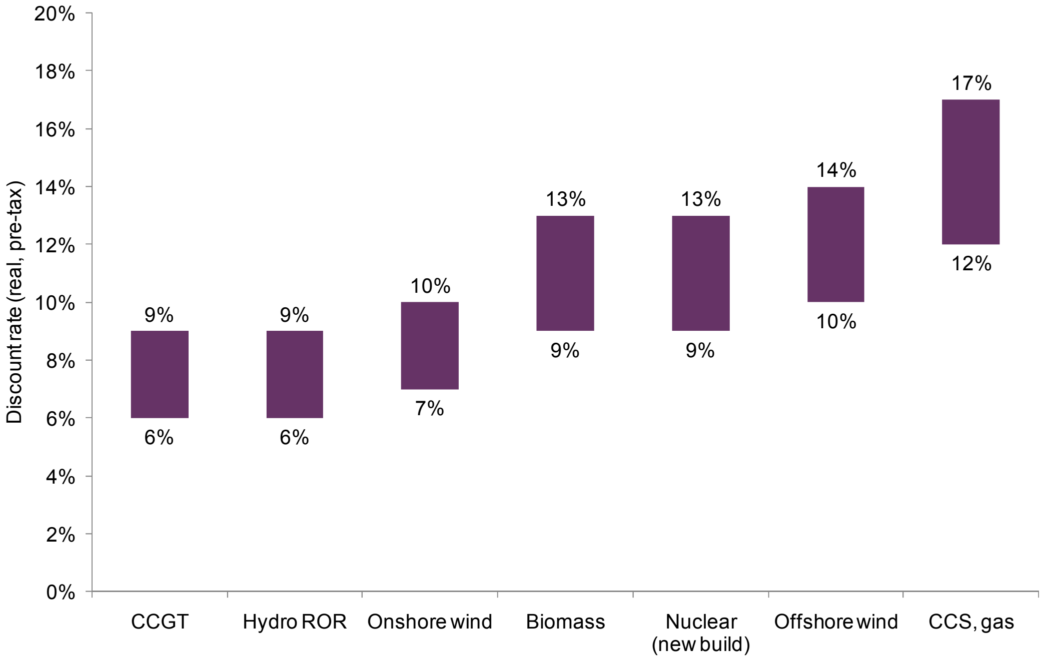
Given the inherent uncertainty about the actual discount rates for any technology, stage III of the approach (described in section 1) consisted of aligning the mechanistic ranges to preserve consistency with risk perceptions and relative range sizes, while removing outliers. The resulting indicative ranges for discount rates attributable to the technologies of interest are reported in Table 4.1 and Figure 4.2 below.

Table 4.1 Current discount rate ranges across technology types

		Discount rate (real, pre-tax) (%)	
Technology	**Risk perception**	**Low**	**High**
Conventional generation			
CCGT	Low	6	9
Low-carbon and renewable generation			
Hydro ROR	Low	6	9
Solar PV	Low	6	9
Dedicated biogas (AD)	Low	7	10
Onshore wind	Low	7	10
Biomass	Medium	9	13
Nuclear (new build)	Medium	9	13
Offshore wind	Medium	10	14
Wave (fixed)	Medium	10	14
Tidal stream	High	12	17
Tidal barrage	High	12	17
CCS, coal	High	12	17
CCS, gas	High	12	17
Wave (floating)	High	13	18

Note: This table presents indicative ranges for the discount rate based on the assumptions and methodology described in this report.
Source: Oxera analysis, based on various publicly available sources (references provided in Appendix 2), and survey responses.

Figure 4.2 Discount rate ranges for selected technologies



Note: This figure presents indicative ranges for the discount rate based on the assumptions and methodology described in this report.
Source: Oxera analysis, based on literature reviews, survey responses, and technology deployment data from Mott MacDonald.

The discount rates presented above are consistent with evidence from the literature review. The range for offshore wind (10–14%) is consistent with Ernst & Young, which reports a discount rate of 12% (nominal post-tax).[25] This translates into a discount rate of approximately 12–14% (pre-tax real) depending on the assumptions used for inflation and taxes. The range presented for CCS (gas and coal) (12–17%) is consistent with the Al Juaied (2010) study, which reports a 19.5% (nominal post-tax) cost of equity and a 7% (nominal pre-tax) cost of debt. This translates into a pre-tax real WACC of approximately 14–16%, depending on the gearing, tax and inflation assumptions used.[26] The range for nuclear of 9–13% is consistent with those used in studies by the University of Chicago (2004) and MIT (2009), which translate into pre-tax real discount rates of approximately 10–11%.[27].

The discount ranges reported in this section are also consistent with the overall risk perception for each technology, as reported by survey respondents. Lower-risk technologies, such as CCGT and solar PV, have a lower discount rate than early-stage technologies, such as CCS, tidal and wave. Furthermore, the discount rate range associated with less mature technologies tends to be wider, perhaps reflecting greater uncertainty over the feasibility and future deployment of these technologies.

The relativity across discount rate ranges is also consistent with evidence from the literature and from the Oxera survey. For example, the main risk characteristics for CCS investments reported by Al Juaied (2010)—in particular, construction cost risk—are similar to the risks generally associated with technologies characterised by high initial capital investment, such

[25] Ernst and Young (2009), 'Cost of and financial support for offshore wind', report for the Department of Energy and Climate Change, April.
[26] Al Juaied, M. (2010), 'Analysis of Financial Incentives for Early CCS Deployment', Discussion Paper 2010-14, Energy Technology Innovation Policy Discussion Paper Series, Harvard Kennedy School, October.
[27] Reported figures were adjusted to reflect UK-specific tax rate and inflation figures, as well as a gearing estimate consistent with other medium-risk technologies examined in this study. University of Chicago (2004), 'The Economic Future of Nuclear Power', August; and Du, Y. and Parsons, J. (2009), 'Update on the Cost of Nuclear Power', MIT Center for Energy and Environmental Policy Research, May.

as nuclear new build.[28] However, given the relative immaturity of CCS technology compared with nuclear, a finding that CCS is associated with greater risk and therefore a higher discount rate appears sensible. Likewise, the low range for hydro ROR reflects the relatively low risk associated with this technology, which is consistent with UNEP's view (reported in section 3).[29] This is also consistent with the reported range for this technology being at the low end of all reported ranges.

As noted in section 3, the reported results do not explicitly depend on the identity of the capital provider; rather, the reported ranges intend to capture the hurdle rate of the marginal investor in each technology.

Furthermore, the ranges reported above should not be interpreted as precise or 'scientific' estimates of discount rates. In particular, there is considerable uncertainty with respect to:

– the distribution of returns for each technology, which is uncertain not only for early-stage technologies but also across the range of technologies since it is partly dependent on future government policy and support mechanisms;
– the correlation between various cost and revenue drivers, which is also affected by future policy and market outcomes;
– the probability of future take-up or deployment of early-stage technologies.

Furthermore, the aggregation of responses across survey respondents implicitly relies on a uniform set of preferences and expectations, but this is unlikely to hold in reality.

Lastly, it is possible that discount rates for low-carbon generation may change over time as the detailed design of policy mechanisms contained in the EMR is finalised and implemented, and as deployment for key technologies increases.

4.2 Future evolution of discount rates

Investments in renewable and low-carbon technologies undertaken five, ten or 20 years in the future could be characterised by very different risk–return trade-offs. First, changes in government policy are likely to make some technologies riskier and others less risky, depending on the market support mechanisms implemented. Also, as discussed in section 3, technology deployment is a key factor that feeds into investors' risk perceptions.

4.2.1 Approach

A high-level approximation of the future discount rate for various technologies can be obtained on the basis of the expected evolution of risk perceptions according to various development scenarios, combined with the evolution of market returns on riskless assets (ie, government bonds). In particular, the following high-level approach was adopted to estimate changes in future discount rates (illustrated in Figure 4.3 below).

– For each technology, the current discount rate range estimate has been used as a starting point.

– A **term structure** premium was added to reflect expected changes in the risk-free rate between now and 2020 and 2040.

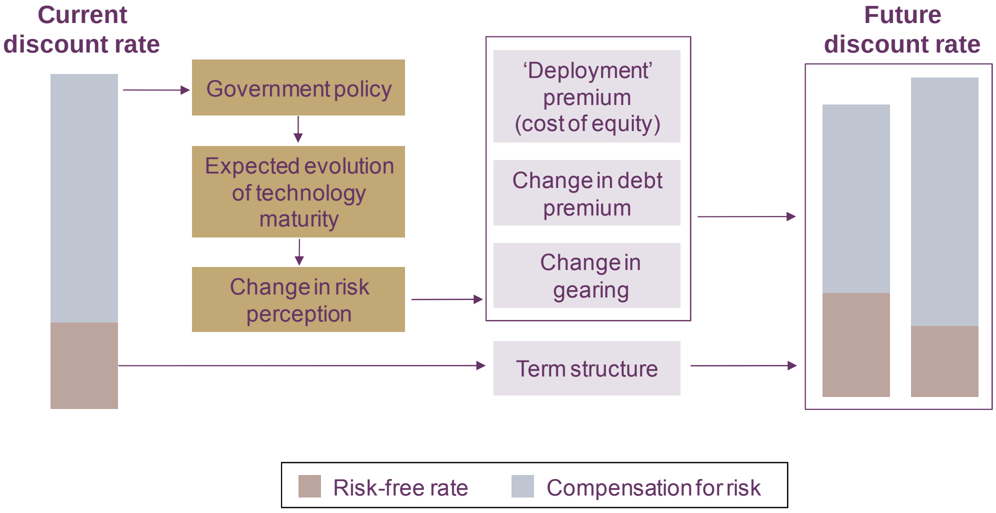
– The **risk perception** for each technology in 2020 and 2040 was adjusted depending on the expected effects of various policy scenarios on the risk perceptions for individual technologies (three high-level policy scenarios developed by Mott MacDonald are

[28] Al Juaied, M. (2010), 'Analysis of Financial Incentives for Early CCS Deployment', Discussion Paper 2010-14, Energy Technology Innovation Policy Discussion Paper Series, Harvard Kennedy School, October.
[29] United Nations Environment Programme (2004), 'Financial Risk Management Instruments for Renewable Energy Projects', pp. 26–7.

described in Box 4.1 below). For example, a policy that provides significant support to renewable technologies would be assumed to reduce the risk perception for this type of technology. The following parameters were adjusted to reflect any reduction in risk perception:

– the cost of equity was reduced by a ‘**deployment premium**’;
– **gearing** was increased to reflect the increased accessibility to debt capital;
– the **debt premium** was reduced to reflect an expected improvement in credit rating.

Figure 4.3 Evolution of future discount rates for renewable and low-carbon technologies



Source: Oxera.

Box 4.1 Policy scenarios

Three scenarios were provided by Mott MacDonald to illustrate the impact of possible macroeconomic or policy scenarios on future deployment across technology types.

– **Balanced scenario**. This scenario broadly follows the UK National Renewable Energy Action Plan (NREAP) until 2020, and then, except for some diversification away from wind, continues along the same trends. The scenario assumes significant development of nuclear and CCS programmes, with strong solar PV and bioenergy programmes.

– **High renewables scenario**. This scenario assumes policy intervention to reduce demand growth and encourage investment in all types of renewable energy and CCS. It also assumes low investment in nuclear generation.

– **Least-cost compliance scenario**. This scenario assumes policy intervention to reduce demand growth, with strong support for nuclear and selected cost-effective renewable technologies (eg, onshore wind, biomass and solar).

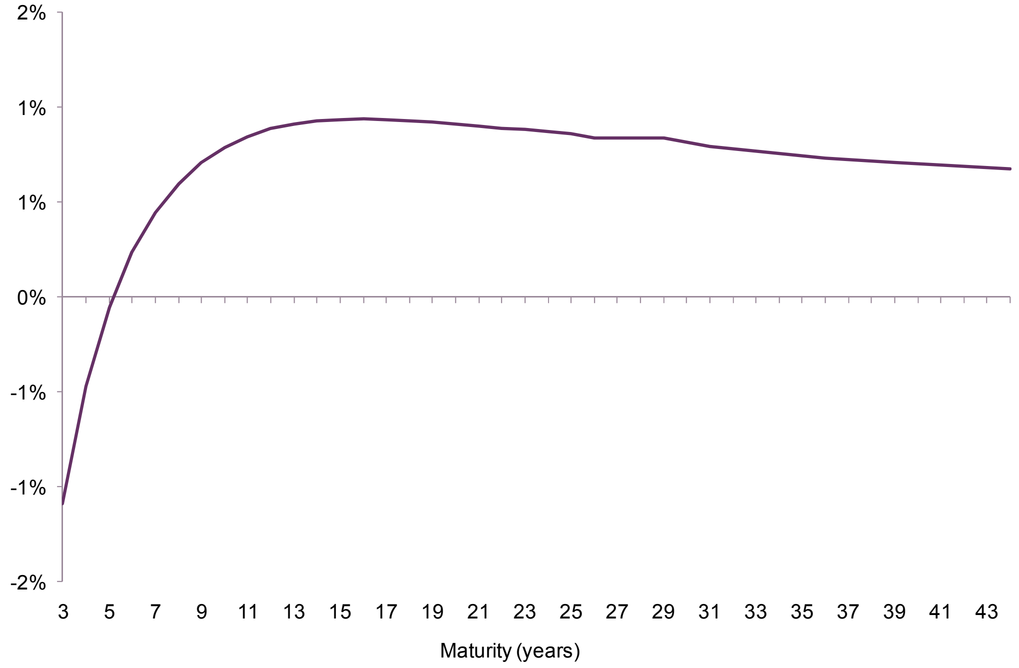
Source: Mott MacDonald.

Each adjustment is discussed further below.

Term premium

The discount ranges for future periods were adjusted to reflect expected changes in the risk-free rate. For example, the relevant discount rate for 2020 was increased by the difference between the long-term yield in 2020 and the current long-term yield. The long-term yield at a particular point in the future was estimated using a ‘bootstrapping’ technique on the current yield curve (see Figure 4.4).[30] Due to limitations in data availability for government bond yields with maturity greater than 25 years, data on six individual longer-term issues was used to extend the yield curve. Forward rates derived from bootstrapping imply a slight decrease in the risk-free rate between 2020 and 2040.

Figure 4.4 UK real yield curve



Note: Yields as at February 16th 2011. Yields on maturities up to 25 years are provided by the Bank of England website. Yields on individual index-linked bonds of 26-, 29-, 31-, 36-, 39-, and 44-year maturities (maturing in 2037, 2040, 2042, 2047, 2050, and 2055 respectively) are taken from Bloomberg. All other data points have been extrapolated.
Source: Bank of England, Bloomberg, and Oxera analysis.

Deployment premium and technology maturity

As noted, the future deployment of individual technologies will be heavily influenced by the government's stance on energy policy. For instance, a scenario in which government policy favours renewable energy could see solar, wind, wave and tidal technologies deployed more quickly than in a scenario in which government policy is designed to minimise the cost of achieving emission reduction targets (which could arguably favour a different mix of technologies). In turn, increased deployment of a particular technology is assumed to result in a reduction in risk perception for that technology as it becomes more developed. Lastly, it is the change in risk perception that is reflected in a deployment premium to the cost of equity, and accounts for the revised risk perception for each technology as it becomes more mature and is increasingly deployed.

As noted in section 3, the future evolution of discount rates primarily depends on policy developments as the government works towards finalising the market arrangements for the electricity markets. Assuming that this successfully eliminates the majority of policy risk, as perceived by market participants and investors, the relative discount rates across low-carbon and renewable technologies are expected to differ from those reported above.

Cost of debt and gearing

The capacity to finance an investment with debt capital can vary according to the characteristics of the asset, so that certain types of investment can be financed with a

[30] The bootstrapping technique consisted of using the current yield curve to construct future yields for specific maturities. For example, the 25-year yield in 2020 was implied from the current nine- and 34-year yields.

greater proportion of debt than others. Typically, the lending appetite from banks or other lenders is lower for riskier investments, although the precise nature of this relationship will depend on the details of contractual arrangements for the debt facility (eg, collateral, security, term, and other clauses). In the context of investments in renewable and low-carbon technologies, it can also be expected that the capacity to rely on debt financing will be greater for less risky, more established technologies. For example, a lender may be reluctant to commit large amounts of capital to a technology with no track record or whose deployment is highly uncertain.

These considerations have been reflected in the gearing and cost of debt assumptions that underlie the future discount ranges: technologies with low risk perceptions have been assumed to benefit from a higher level of gearing and a lower cost of debt compared with riskier technologies. This is consistent with the view of various survey respondents, who communicated that it may be very difficult to raise debt (even in small amounts) to finance investments in very risky technology, whereas more common technologies could be financed at gearing in excess of 50% while still maintaining an investment-grade credit rating.

This approach is generally consistent with rating methodologies applied by credit rating agencies. For example, in the context of energy utilities, Moody's states that companies with low business risk 'may have lower financial ratios and higher leverage than most peer companies on a global basis, but still maintain higher overall ratings'.[31] This would be consistent with a low-risk technology being able to benefit from both a higher gearing and lower debt premium.

In summary, the future discount rates of technologies reflect adjustments to the following parameters:

– **debt premium**, to reflect a lower implicit credit rating for less mature and riskier technologies;
– **gearing**, to reflect the lower lending appetite for technologies that are yet to be proven as feasible and are perceived as being riskier.

The combination of the debt premium and gearing adjustments act to reduce the overall discount range as a technology becomes more deployed and risk perceptions are reduced.

4.2.2 Estimates for 2020 and 2040

As discussed in section 3, changes in government policy leading to increased support for low-carbon technologies would affect investors' risk perceptions of low-carbon technologies. Similarly, improvements in a technology's maturity (which could be independent from the underlying market support) would also be expected to affect investors' risk perceptions. Lower perceived risk for a particular technology would, in turn, be expected to reduce that technology's respective discount rate. While there is a significant amount of uncertainty involved in estimating future discount rates, the methodology described in section 4.2.1 has been applied to approximate the impact on discount rates of the reductions in risk perceptions under different market arrangements scenarios. Table 4.2 presents discount rates in 2020 and 2040 assuming that the market arrangements broadly reflect those in the Balanced scenario, described in Box 4.1. (The discount rate estimates for the other scenarios are given in Appendix 3.)

[31] Moody's (2009), 'Rating Methodology: Regulated Electric and Gas Utilities', August, p. 24.

Table 4.2 Future discount rate ranges across technology types (real, pre-tax, %)

Technology	2020 range estimate		2040 range estimate	
	Low	High	Low	High
Conventional generation				
CCGT	6	9	5	8
Low-carbon and renewable generation				
Hydro ROR	6	9	5	8
Solar PV	6	9	5	8
Dedicated biogas (AD)	7	10	6	9
Onshore wind	6	8	5	8
Biomass	8	11	6	8
Nuclear (new build)	8	11	6	9
Offshore wind	9	12	7	10
Wave (fixed)	9	12	6	9
Tidal stream	11	15	9	13
Tidal barrage	11	15	8	12
CCS, coal	11	15	8	12
CCS, gas	11	15	8	12
Wave (floating)	12	16	9	14

Note: This table presents indicative ranges for the discount rate based on the assumptions and methodology described in this report. They reflect the Balanced scenario described in Box 4.1 above.
Source: Oxera analysis, based on various publicly available sources (references provided in Appendix 2), and survey responses.

In this scenario, support for low-carbon technologies is expected to reduce the perceived risks across all low-carbon technologies, leading to a reduction in their associated discount rates, as illustrated in Table 4.2. The reduction in risk perception is expected to occur gradually over time, and is particularly important for those technologies currently deemed to be higher risk (such as CCS and wave).

The risk reductions that appear likely to be achieved largely relate to those risks that are inherent across low-carbon technologies (eg, risks associated with policy and with technological maturity). While supportive government policy, higher deployment, and competitive cost structures may stimulate the development and improve the economic viability of technologies currently deemed ‘high risk’, it is not necessarily justified to conclude that discount rates will converge to a unified range. Other risk factors which are not shared across all technologies, such as the impact of climate change on wind patterns (for wind power) or the risk of increasing fuel costs (for CCS), may be more difficult to mitigate. Also, unanticipated changes in the public perception of a given technology may change the relative risk perception compared with other technologies.

Considerable additional uncertainty is associated with longer forecasting time periods. In particular, the extent of technological development and innovation over the medium term is difficult to predict. Improvements affecting the cost structure of certain technologies listed above may lead to additional reductions in the levels of risk that investors perceive. It is also possible that new low-carbon technologies will be developed, which may be more competitive than—and therefore affect the relative risks associated with—certain new technologies currently under consideration.

4.3 Impact of market arrangements on the discount rates

The survey also asked respondents to quantify the impact of eliminating the exposure to selected risk factors. The question was designed to abstract from considerations regarding the expected effectiveness and practical attributes of particular policies or support measures. Instead, it sought to focus on the impact on discount rates that might result from reallocating risk factors away from the investor.

As described in section 3, of the risks listed, most respondents identified policy and regulatory risk as having a significant impact on the risk for low-carbon technologies. This is consistent with a recurring message from survey respondents that the exercise of assessing and quantifying the risks of the various low-carbon technologies is almost impractical, as a result of the significant policy uncertainty. However, very few respondents quantified the impact of removing policy risk.

Some respondents commented that policy should focus on removing exposure to risks that an investor cannot diversify away. Others were of the view that market support should focus on developing early-stage technologies up to the point where deployment is sufficient to attract private investment.

Based on the method described in section 4.2, focused support for a particular technology could reduce the discount rate by 2–3% over the next decade for riskier technologies, and by 0–2% for less risky ones. This would be achieved through a combination of increased clarity on policy and the removal of certain risk factors, which would lead to a reduction in risk perception as expectations on future improvements in a technology's maturity and deployment are revised. Based on this analysis, a further reduction of 1–2% could be achieved by 2040. These estimates for future discount rates are highly uncertain, even more so than the estimates for current discount rates. However, the results from the approach described in this section across various policy scenarios are broadly consistent with the few survey responses that sought to quantify the impact of removing exposure to certain risk factors.

In summary, while it has proved difficult to quantify the impact of removing exposure to individual risk factors, responses to the survey suggest that clarity on the design and implementation of a government energy policy and associated market mechanisms will go a long way towards reducing investors' risk perception in relation to low-carbon technologies in general. At that point, the specific impact of eliminating investors' exposure to particular risk factors will become easier to assess and (ideally) quantify. Importantly, the removal of policy risk and possible emergence of new, unanticipated, technologies may result in a change in the relative importance of various risk factors and investors' overall risk perception.

4.4 Summary

The discount rate estimates for low-carbon technologies are subject to a significant degree of uncertainty, as indicated by the relatively wide ranges presented. The estimates presented in this section are consistent with the relative risk rankings—not only are higher discount rates associated with riskier technologies, but also the corresponding range estimates are wider.

The approach to estimating the evolution of discount rates relied on high-level policy scenarios. Under a specific scenario, the risk perception of technologies that are supported by the policy is assumed to decline with time. This was then reflected in the discount rate range through an adjustment in the cost of equity, debt premium and gearing. Furthermore, discount rate estimates were adjusted for all technologies in order to reflect expected movements in the real risk-free rate. According to this approach, the discount rate for technologies that are supported by a targeted policy could be as much as 2–3% lower over the next decade (the reduction would be lower for technologies that are currently more mature) over the next decade, and by a further 1–2% by 2040.

A1 Survey of discount rates for investment in low-carbon generation technologies

Oxera

Discount rates for investment in low-carbon generation technologies

Survey for the Committee on Climate Change

November 2010

Oxera has been commissioned by the Committee on Climate Change[1] to undertake research into the investment conditions for low-carbon power plant technologies, including renewable generation, nuclear power, and carbon capture and storage (CCS; whether applied to coal- or gas-fired power plants).[2] This study will seek to establish the factors considered by project sponsors, capital providers and lenders when assessing the appropriate discount rate for the various renewable and low-carbon technologies, and how these might change under alternative market arrangements.

This survey is aimed at understanding the following issues:

– What are the factors affecting risks to cash flows for low-carbon generation projects?
– How do the risks and discount rates of different low-carbon generation technologies compare?
– If current market arrangements were modified to eliminate specific sources of risk, how would discount rates for various technologies be affected?

All responses will be treated in confidence. Results will be presented in aggregate form only or otherwise made anonymous, and comments will not be attributed to individual respondents or organisations.

[1] The Committee on Climate Change is an independent body established under the Climate Change Act 2008 to advise the government on emissions targets and report to Parliament on progress made in reducing greenhouse gas emissions.
[2] This is part of a wider programme of work led by Mott MacDonald that is also investigating the potential evolution of costs of low-carbon generation technologies.

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We would greatly appreciate receiving your responses to the questions in this survey and any other comments or feedback by **January 27th 2011**. Please send the completed survey to:

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EC1N 2HA

Email: CCCsurvey@oxera.com
Tel: +44 (0) 20 7822 2660

Alternatively, if you would prefer to contribute to this survey by telephone, please contact Vincent to arrange a convenient time for a short (30–40-minute) interview.

Thank you.

Survey of discount rates for investment in low-carbon generation technologies

This survey is structured as follows.

– Section 1 asks for general contact information.

– Section 2 asks for background information on your expertise and experience of low-carbon generation technologies and specific geographical markets.

– Section 3 contains questions on the primary economic factors affecting risks to cash flows for low-carbon generation projects in the context of the current energy policies and market arrangements in Great Britain.

– Section 4 contains questions on the relative discount rates of various low-carbon technologies in the context of the current energy policies and market arrangements in Great Britain.

– Section 5 contains questions on how the reallocation of risks (through, for example, market and/or contracting arrangements) may affect discount rates for renewable and low-carbon projects.

1 Contact information

Please provide the following contact details.

Name:	
Position:	
Company or organisation:	
Contact telephone number:	

2 Background

If you are a project sponsor, capital provider or lender to low-carbon generation projects, please answer the following questions.

Q2.1 What electricity generation technologies do you invest in? In particular, please indicate whether you invest in thermal generation (eg, coal- or gas-fired generation), renewables, nuclear generation, or CCS.
Answer

Q2.2 In which countries or regions are you currently active in pursuing low-carbon generation projects?
Answer
Q2.3 In which countries or regions are you aiming to be active in pursuing low-carbon generation projects?
Answer

If you are an opinion leader, researcher or market analyst active in the electricity generation sector please answer the following questions.

Q2.4 What electricity generation technologies do you have experience or knowledge of?
Answer

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Q2.5 Which countries or regions do you cover in your research?
Answer

3 Risks for low-carbon and renewable projects under current market arrangements

Q3.1 What do you consider to be the main risk factors associated with renewable and low-carbon energy projects under current market arrangements? Please rate each potential risk factor in table 3.1 below in terms of its importance (low, medium or high) across the various technologies listed (which are grouped according to their main economic characteristics).

Please use the space below to provide any additional comments that are not reflected in Table 3.1.

Table 3.1 Importance of risk for low-carbon, renewable and conventional energy projects (low, medium or high)

Risk factor	Conventional, mature (eg, CCGT)	High capital/low marginal cost, intermittent (eg, wind)	High capital/low marginal cost, lumpy investment (eg, nuclear)	Early stage (eg, wave, tidal stream)
Revenue risks				
Wholesale electricity prices, reflecting overall demand and supply conditions for electricity (including the impact of gas price volatility on price-setting plant)				
Carbon price volatility and liquidity				
Wholesale electricity price volatility and market liquidity (ability to capture price movements)				
Value of subsidies or other supports, such as Renewables Obligation Certificates (ROCs)				
Load factor (ie, annual utilisation of generating plant as a result of economic despatch)				
Technical availability 'on demand' (ie, availability of generating plant at times of peak demand)				
Growth in annual electricity demand				
Other factors directly affecting electricity demand, such as the adoption of energy efficiency measures or short-term demand-side response to wholesale prices				
Other: please specify				
Cost risks				
Capital costs (CAPEX) of generating plant				
Operating and maintenance costs (OPEX) of generating plant				
Fuel commodity prices (eg, costs of coal, gas, oil, uranium)				
Construction lead times				
Other: please specify				
Other factors				
Size of investment and capital commitment				
Payback period (or other measure of cash-flow duration)				
Technological maturity				
Public perception and acceptance of a particular generation technology, and the risk of public opinion resulting in changes to energy policy				
Policy or regulatory risk				
Other: please specify				

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4 Discount rates for low-carbon and renewable energy projects

Q4.1 Given your areas of expertise as set out in section 2, please provide in Table 4.1 below an indication of your risk perception (low, medium or high) and range estimates for the discount rates that may be applicable for the generation projects. Please specify whether these are expressed in real or nominal terms (ie, whether they are inflation-adjusted), whether they are pre- or post-tax, and whether they refer to the discount rate attributable to debt, equity or all capital.

Please use the space below to provide any additional comments that are not reflected in Table 4.1.

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Table 4.1 Discount rates for selected generation technologies

Technology	Risk perception (low, medium or high)	Discount rate (range, %)	Inflation-adjusted?	Pre- or post-tax?	Other comments
Renewable generation					
Onshore wind					
Offshore wind					
Solar PV					
Dedicated biogas (AD)					
Biomass combustion					
Biomass pyrolysis and gasification					
Hydro ROR					
Wave (fixed)					
Wave (floating)					
Tidal stream					
Tidal barrage					
Other: please specify					
Other low carbon generation					
Nuclear (new build)					
CCS applied to coal-fired generation					
CCS applied to gas-fired generation					
Other: please specify					
Thermal generation					
CCGT gas-fired generation					

Note: See the Appendix for a full description of each renewable technology listed above.

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Q4.2 Please provide details about the main criteria that you are considering with respect to the discount rates specified in Table 4.1.
Answer
Q4.3 How would the discount rate associated with investment in an early-stage, immature low-carbon technology project (such as CCS, wave or tidal stream generation) differ if the project were undertaken once it had been proven to be technically and commercially viable (say, in 2020) rather than today (ie, before it is proven to be so)? Please indicate how the discount rate might be expected to change after the technology becomes 'proven', including a range estimate for the magnitude of the change in the discount rate that might be expected. (Again, please specify whether these rates are expressed in real or nominal terms, pre- or post-tax, and whether they apply to debt, equity, or all capital.)
Answer

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5 Risks for low-carbon projects under various market support arrangements

Q5.1 Selected risks are listed in Table 5.1 below. Assuming that these could be completely mitigated or otherwise transferred away from investors or project sponsors, how would this influence your perception of the risk of low-carbon generation projects? For each risk factor, please provide range estimates for the impact on discount rates (in %) that may be applicable across the various technologies shown in the table. The discount rate impact should be listed as an increment or reduction in discount rate that would result if the risk factor was transferred away from the capital provider, and each risk factor should be considered in isolation (in other words, impacts will not be summed to reflect impact of removing all risks).

Please use the space below to provide any additional comments that are not reflected in Table 5.1.

Table 5.1 Discount rate impact of mitigating selected risk factors through market support arrangements

Risk factor	Conventional, mature (eg, CCGT)	High capital/low marginal cost, intermittent (eg, wind)	High capital/low marginal cost, lumpy investment (eg, nuclear)	Early stage (eg, wave, tidal stream)
Carbon price risk and volatility				
Average annual level of wholesale electricity price				
Short-term volatility of wholesale electricity price (eg, daily volatility)				
Load-factor risk				
Balancing risk (ie, the risk of generating more or less at gate closure, potentially applicable to intermittent generation or technical unavailability)				
Policy and regulatory risk				
Other: please specify				

Note: The discount rate impact should be given as an increment or reduction in the discount rate that would result if each risk factor were transferred away from the capital provider.

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Appendix: Detailed specification of renewable electricity technologies

Technology	Description
Renewable generation	
Onshore wind	Onshore wind energy technology has developed in the form of three-bladed, horizontal-axis downwind turbines. Typical modern wind turbines have diameters of 40 to 90 metres and are rated between 500 kW and 3.6MW. Vertical axis devices and downwind technologies also exist on a small scale and experimentally.
Offshore wind	Offshore wind farms allow for larger scale wind turbines and higher energy capture due to higher wind speeds and no height restrictions. Turbine capacity is available up to 6MW and almost 130m diameter rotor. Further research continues to increase this capacity with 7.5MW in prototype.
Solar PV	Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semi-conductors that exhibit the photovoltaic effect. Solar photovoltaic generates electricity in over 100 countries and is the fastest-growing power-generation technology in the world. The two main types of PV panels are crystalline, which is more space-efficient, and thinfilm, which is more cost-efficient. Both types can be deployed on roof space, or they can be ground-mounted.
Dedicated biogas (AD)	Anaerobic digestion (AD) is a series of processes in which micro-organisms break down biodegradable material in the absence of oxygen, used for industrial or domestic purposes to manage waste and/or to release energy. Under biodegradable material we consider food waste, sewage sludge, manure and slurry. The process produces a methane-rich biogas suitable for energy production (in GTs or reciprocating engines). A by-product is a nutrient-rich digested material that can be used as fertiliser.
Biomass combustion	Biomass is plant- or biological matter grown to generate electricity or produce heat such as wood, waste and alcohol fuels. These biomass fuel sources are combusted through direct incineration. Typically, wood chips are used for this. Boiler types include Circulating Fluidised Bed boilers (CFBC), Bubbling Fluidised Bed boilers (BFBC) and Grate boilers. CFBC can also be used for waste-wood incineration. Sizes range from 10MW to 300MW.
Biomass pyrolysis and gasification	Pyrolysis and gasification are known as advanced combustion technologies. Pyrolysis and gasification are ways of capturing the volatile liquids and gases that are given off when biomass is heated. The advantage is that the liquid products (in the case of pyrolysis) and the gas products (in the case of gasification) can be used to fuel a more efficient power cycle than standard combustion alone. Advanced combustion technologies are usually used for smaller installations up to 3MW.
Hydro ROR	Hydro Run Of River (ROR) is a type of hydro plant where the natural flow and elevation drop of a river are used to generate electricity. Its main disadvantage is that it relies on a fluctuating resource. The available capacities for Hydro ROR are very wide, but currently the most relevant sizes in the UK context reach up to 5MW.
Wave (fixed)	Wave (fixed) refers to the extraction of energy from waves using a device that has a fixed structure (eg, overtopping device or oscillating water columns (OWC)). Overtopping: waves splash over into a reservoir above sea level and filter back down into the sea through hydro turbines. OWC: as waves impinge on the device, the water column rises and falls, causing the air column above the waves to compress and decompress, which drives a turbine at the top of the device. The device sizes in the UK range from 20kW to 2MW.

Wave (floating)	Wave (floating) refers to the extraction of energy from waves using a device that is acted on directly by the waves (most well developed is the pelamis). These devices use the motion of the ocean's surface waves to oscillate the cylindrical sections and hinged joints of the devices themselves, which then pump high-pressured fluid through hydraulic motors and drive an electric generator. Each device is rated up to 750kW.
Tidal stream	Tidal stream refers to the extraction of energy from the tide. The technology is fairly immature—around ten years behind offshore wind—and to date there is no single type of device dominating the market. The device sizes in the UK currently peak at 1.2MW (MCT SeaGen device). It is estimated that up to 34% of the UK's electricity demand could be extracted from tidal currents.
Tidal barrage	A tidal barrage refers to the extraction of energy from the tide using a number of turbines incorporated into what is essentially a dam across a tidal estuary. Water is let into the bay during high tides. It is held there until low tide where the greatest head is present, optimising power generation. High civil infrastructure costs, a worldwide shortage of viable sites and environmental issues remain the biggest challenges for this type of technology. The largest Tidal Barrage to date is on the Raft River in France, generating 240MW. The UK's largest single tidal range resource is located in the Severn estuary. (up to 13.5 GW). There are also significant sources in other estuaries like the Solway (up to 7.2 GW), Mersey (700 MW) and smaller resources in the Dee, Duddon, Wyre and Conwy estuaries in the West, and the Thames, Humber and Wash in the East.

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A3 Alternative discount rate scenarios for 2020 and 2040

Tables A3.1 and A3.2 illustrate discount rates in 2020 and 2040 under the High Renewables scenario and the Least Cost Compliance scenario, respectively.

Table A3.1 Future discount rate ranges under the High Renewables scenario (real, pre-tax, %)

Technology	2020 range estimate		2040 range estimate	
	Low	High	Low	High
Conventional generation				
CCGT	6	9	5	8
Low-carbon and renewable generation				
Hydro ROR	6	9	5	8
Solar PV	6	9	5	8
Dedicated biogas (AD)	7	10	6	9
Onshore wind	6	8	5	8
Biomass	6	9	6	8
Nuclear (new build)	9	13	8	12
Offshore wind	7	10	6	8
Wave (fixed)	7	10	6	9
Tidal stream	9	14	7	11
Tidal barrage	9	13	7	10
CCS, coal	12	17	11	16
CCS, gas	11	15	10	15
Wave (floating)	10	14	8	12

Note: This table presents indicative ranges for the discount rate based on the assumptions and methodology described in this report, and reflects the High Renewables scenario as described in Box 4.1.
Source: Oxera analysis, based on various publicly available sources (references provided in Appendix 2), and survey responses.

Table A3.2 Future discount rate ranges under the Least Cost Compliance scenario (real, pre-tax, %)

Technology	2020 range estimate		2040 range estimate	
	Low	High	Low	High
Conventional generation				
CCGT	6	9	5	8
Low-carbon and renewable generation				
Hydro ROR	6	9	5	8
Solar PV	6	9	5	8
Dedicated biogas (AD)	7	10	6	9
Onshore wind	6	8	5	8
Biomass	8	11	6	8
Nuclear (new build)	8	11	6	9
Offshore wind	10	14	9	13
Wave (fixed)	10	14	9	13
Tidal stream	12	17	11	16
Tidal barrage	12	17	11	16
CCS, coal	12	17	11	16
CCS, gas	11	15	8	12
Wave (floating)	13	18	12	17

Note: This table presents indicative ranges for the discount rate based on the assumptions and methodology described in this report, and reflects the Least Cost Compliance scenario as described in Box 4.1.
Source: Oxera analysis, based on various publicly available sources (references provided in Appendix 2), and survey responses.

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