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CONCEPTS OF INVESTMENT RISKS AND STRATEGIES IN ELECTRICITY GENERATION

J. de Joode

M.G. Boots

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Acknowledgement/Preface

This report is an output of the EZS project ‘Midterm investment strategies in electricity production’ (ECN project number 77591). Related to this project and report, a (simple) quantitative model, applying the real options approach, is developed by Steven Kluiters (ECN Clean Fossil Fuels Unit), which will be published during the course of 2005. Another output of this project was a workshop organised jointly with another EZS project on ‘Clean coal power technologies’ (ECN project number 77585). The workshop, entitled ‘Clean Coal Power Technologies and Investment Risks; The Nature of Future Electricity Supply in the Netherlands’ was held on 11 November 2004 in Amsterdam. See http://www.electricitymarkets.info/ws-ccpt04/index.html for details on this workshop.

Abstract

This report deals with the specific investment risks in electricity generation. We discuss the problems associated with energy investments in general and focus on the additional or changing risks resulting from electricity market liberalisation. The focus is on 1) risks under the control of the electricity company, and on 2) market risks, such as the risk of price changes. Ultimately, we discuss some of the approaches and strategies that enable electricity producers to counter or mitigate these risks.

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Introduction

Electricity markets are currently in the spotlights of European policy makers. In the spirit of the larger EU-goal of a single market for the free movement of people, goods and capital, former national monopolistic electricity markets are liberalized. With the accomplishment of energy market liberalisation, concerns about untimely investments in power generation capacity became prominent. Prior to the liberalisation of energy markets, most of the risks associated with investments in generation capacity were of no direct concern for the energy company. The integrated monopolies could pass on all costs of investments as increased prices to the electricity consumers, i.e., there was little market risk. As a result, companies had no incentive to take account of such risks when making investment decisions. Liberalisation profoundly changed the environment in which electricity producers take their investment decisions. While at the same time some disadvantageous specific energy market characteristics, already present in the pre-liberalisation era, remain.

The most fundamental change affecting the value of investments in liberalised markets is the uncertainty about electricity prices (IEA, 2003a). Borenstein (2001) identified the fundamental problem with electricity markets as follows: "In nearly all electricity markets, demand is almost completely insensitive to price fluctuations and supply faces binding constraints at peak times. Combined with the fact that unregulated prices for homogenous goods almost always clear at a uniform (or near uniform) price for all sellers - regardless of their costs of production - these attributes necessarily imply that short-term prices for electricity are going to be extremely volatile. Problems with market power and imperfect locational pricing only exacerbate the fundamental trouble with electricity markets."

Since decisions about investments in power generating capacity depend on expected returns and costs, price uncertainty is a problem. Forward contracts can give an indication of the expected price (and thus of returns), however, these contracts usually have a limited duration (about 3 years), while the investments are made for a longer period, or they do not exist at all. Therefore, electricity volume, demand growth and development of supply (including import and interconnector capacity) are important indicators for an investor. Nevertheless, the structural aspects of the (spot market) price remain a relevant indicator. In a well-functioning energy-only market[1], prices will tend to equal marginal costs of production. However, in periods with super-peak loads, the price will be higher because of limited supply, creating scarcity rents.

In this context peaking plant require special attention[2]. These plants tend to set the market price and are generally dispatched only a few hours per year. As a result, many argue that they will never be able to earn the fixed costs of power generation. The plants can bid for higher prices than their marginal costs in the spot market in order to cover their fixed cost. This will result in price spikes that are generally considered by regulators as exercise of market power. Other constraints for the peak plant to cover their fixed costs are price caps on wholesale markets. Risk-averse investors would try to refrain from this niche in the market due to the uncertainty the peak plants face.

Therefore, there is legitimate concern for failure of the wholesale electricity market 1) to reflect scarcity rents that are high enough to cover all the fixed costs of peaking plants, and 2) to ensure that the average market price tends towards the integral (long-term) costs of a base load plant. As a result, current markets may fail to generate a proper level of investment in both base load and peaking plants.

1 The energy-only market refers to a market situation where producers' revenues only depend on the kWh price.
2 For this example, as well as the remainder of this report, our point of departure is the individual owner of a specific power plant.

Therefore, the implementation of certain mechanisms that would avoid capacity shortages is considered in the Netherlands (and elsewhere). Possible options are the introduction of reliability contracts or capacity markets. The baseline is that the demand for reserve capacity becomes explicit (see e.g. de Vries, 2004), i.e. apart from an energy (MWh) market, a capacity (MW) market may be created.

Anticipating such mechanisms that are initiated at the level of public policy, ultimately we intent to develop a (simple) model that accounts for (the risks of) investments in generation capacity. Such a model can indicate when new capacity is required (and profitable), taking into account the CO_2-emissions trading regime and risk considerations of investors. The size, the timing and the technology of an investment, as well as the identity of the entity willing to invest, will emerge. The main focus is on new investments in generating capacity in the Netherlands in the period 2005-2015. However, before actually modelling the issue of investments, we need to have a clear understanding of the different factors that affect private investment behaviour, such as risk perceptions, possibilities to finance the investment, etc. Moreover, investment risks should be quantifiable.

Therefore, in Chapter 2 the issue of risk and risk perception in electricity generation is addressed. Electricity investment risks are to be distinguished between risks for private parties and risks for society as a whole. Risks for the society as a whole mainly amount to the sufficient availability of electricity to meet total demand and the costs at which this is accomplished, in other words the security of energy supply. However, our prime focus is on risks relevant for the investor in electricity generation, i.e. the private risks. Chapter 3 describes a number of approaches and strategies that may mitigate private investment risks in the power sector. However, the main purpose of this report and the core of Chapter 3 consist of an assessment of methods that quantify (some of) the investment risks in order to be able to make a proper investment decision.

Investments in electricity generation are typically capital intensive, irreversible and dependent on other parts in the electricity chain. Changes in financial markets, such as a change in interest rate, have a substantial impact on capital-intensive electricity projects. Moreover, they suffer from significant investment cycles in which high prices induce more and more investments until excess capacity is created and prices plummet again, thereby discouraging further investments. Assets in the electricity industry have a high degree of specificity and investments have a long lead-time resulting in uncertain future revenue streams. This requires a risk-premium on investment projects: the expected benefits need to outweigh the costs by more than just the interest rate. The profitability of many investment projects is largely determined by other investment projects higher or lower in the electricity chain. For instance, in deciding on the construction of a new power plant, the investor will keep a close eye on the present and anticipated infrastructure need for transportation of both input (possibly gas) and output (electricity, and in case of a cogeneration plant also heat).

1. PRIVATE RISKS IN THE ELECTRICITY SECTOR

This section aims to shed light on the risks present in the electricity sector. First, we shortly elaborate on the concepts involved when studying the risks associated with electricity generation investment; the concepts of risk and uncertainty. Second, we give a description of the environment surrounding the investment decision by discussing the major determinants. Third, we link these investment determinants to the potential risks involved and give an indication of importance of each of these risks.

1.1 Concepts of risks and uncertainty

Within economic analysis, much cited definitions of risk and uncertainty are those of Knight (1921). In Knight's interpretation, *'risk'* refers to situations where the decision-maker can assign mathematical probabilities to the randomness that he is faced with. In contrast, '*uncertainty'* refers to situations where this randomness cannot be expressed in terms of specific mathematical probabilities. However, this definition has been subject to a long debate within uncertainty theory, mainly regarding the question whether people are not able to attach probabilities in the uncertain case, or just withhold of estimating probabilities[3].

A certain decision is risky when probabilities on the future possible states are known. In contrast, a decision is uncertain when the probabilities are not precisely known. The crucial distinct between risk and uncertainty therefore lies in the degree by which probabilities are known[4]. This distinction proves to be useful when quantifying risks, however in this report there is no strict separation between risk and uncertainty and both terms are used interchangeably.

In the next section we turn to the environment surrounding the investment decision. We continue with the concepts described above in Section 2.3, where the types of risk and uncertainty are discussed.

1.2 The investment environment

In order to provide more background to the private risks associated with investments in electricity generation, we devote this section to the investment environment in general. Here we briefly describe the (potential) determinants that together make up this environment and consecutively give an indication which role each of these determinants plays in our case of electricity generation investment. Determinants in the investment environment can be internal or external to the firm.

1.2.1 Determinants internal to the firm

Internal determinants are mainly related to financing, organisation and technological know-how. Moreover, electricity-generating companies will also take account of the current size and diversity in its investment programmes and the mix in electricity generating techniques.

A firm's financial capability constrains both number and size of any investment program. In the electricity sector in general, it is not common for firms to commit themselves to a large number of investment programmes at the same time.

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3 Camerer and Weber (1992) provide a review of various definitions and formalisations.

4 Although people don't know the precise probabilities in the case of uncertainty, they usually do have some beliefs or expectations of these probabilities. If this is not the case, economists use the term 'complete ignorance'.

Especially smaller companies tend to invest in only one (large) project at a time. Partly, the financial constraint depends on a firm's creditworthiness (in case investments need to be financed with internal as well as external capital).

Organizational determinants in relation to capacity investments refer to a firm's goal or mission, or stated differently, its core business. In fact there are two contrasting views on investing outside your core business. One states that investments in unfamiliar fields are more risky simply because of inexperience and lacking knowledge. Initial setbacks in construction and operation are more likely to occur. On the other hand, investment outside your field of expertise or main market decreases exposure to negative developments in its main market. This is a simple diversification strategy (of which we will come to talk about later on). For example, a distribution network owner will exhibit different risk-valuing behaviour concerning an investment in a power plant than an extension of the network. The former would indicate a strategic move upstream, whilst the latter indicates an extension of current activities. At the same time, this move will turn company profits less vulnerable to slumps in the demand for transport capacity.

The third determinant, technological know-how, is somewhat related to the previous. Investments in power generating capacity all have a different dimension regarding the technology involved. An electricity generating company owning several coal plants will have a comparative advantage in operating a coal plant compared to a competitor owning nuclear plant. Entering another market (in the sense of generating techniques) might prove unfavourable due to a lack of technological understanding and experience. An example in this case might be a 100% 'grey' electricity generator who has reservations on entering the renewables electricity market.

Although appearing to be somewhat contradictory to the above-mentioned determinants, companies will always find a certain degree of diversification favourable. This means that from a diversification perspective it might be good to move upstream or downstream in the electricity chain (vertical integration), enter another market (horizontal integration), or add a different generation technique to the portfolio. Therefore, it is also necessary to look to the firm-external determinants.

1.2.2 Determinants external to the firm

External determinants that influence investment decisions are the market, government policies, consumers' preferences and exogenous technological developments.

One of the foremost determinants for the go-ahead of investment projects is the market condition (and forecasts) at any point in time. Low demand growth potential and fierce competition will give rise to low prices, thereby making large-scale investments unattractive. In the same vain, market power will also give some sense of safety regarding potential investment projects. After all, a dominant firm will not need to anticipate moves of smaller competitors, since they hardly affect the return on considered investment.

Governments influence decisions on investing in electricity generating capacity in several ways and in various policy fields, such as, competition, security of supply, environment and technology. Regulation on competition prohibits certain integration, horizontal or vertical, in the electricity chain, thereby reducing potential investment targets. Security of supply on the other hand, might force companies to over invest, as is the case when certain reserve capacity is enforced in order to guarantee electricity delivery. Another major field of government policy is environmental policy. The emissions trading scheme, for example, influences the merit order for generation techniques. On a smaller scale, the construction and/or safety permits that are needed to develop a power plant in a certain region also determine when, where and how investments will materialise.

Another external determinant in energy companies' investment decision are consumer preferences[5]. A less obvious determinant in the investment environment is exogenous technological progress. That is, improvements in the level of technology and efficiency of certain generation techniques. Examples of this kind of developments are improvements in nuclear waste conservation, efficiency of green power generation or cleaner techniques to process fossil fuels.

1.3 Private risks

1.3.1 Relating investment determinants to private risks

The various determinants in the last section all relate to (a set of) particular risks. This section gives an overview of these risks. An electricity generating company faces the following types of risk: financial, operational, construction, market, macro-economic, contract and regulatory. These risks are related to the determinants as shown in Table 1.1.

Table 1.1 *Risk typology*

Determinants	Internal/ external	Type of risk involved	Example
Financial capacity	Internal	Financial risk	Unanticipated interest movements
Organisation capacity	Internal	Operation risk	Unsatisfactory plant performance
		Construction risk	Cost overruns/project delay
Technological capacity	Internal	Market risk	
Market condition / market structure	External	Market risk	Increase in fuel cost
			Lower than expected demand
		Operation risk	Insufficient infrastructure
		Macroeconomic risk	Adverse interest/inflation movement
Government policy	External	Regulatory risk	Change in policy
Technological progress	External	Market risk	Efficiency improvement in other technique

From this table, it can be observed that certain types of risk are associated with more than one type of determinant. For example, the reason for plant operations to be below the expected level of achievements can be either internal (bad supervision/management) or external (a physical problem within the infrastructure that causes delays in the delivery of raw materials).

In addition, note that every type of risk (financial, operation, market, etc.) indeed consists of a quantifiable (risk) and non-quantifiable (uncertainty) part. Certain fuel price movements can be expected and thus anticipated on, while probabilities on changes in regulatory policy are more uncertain-like.

1.3.2 Ranking private risks

The attitude of investors towards the risks they face will differ per risk type. For example, they might value the risk associated with advancement of competitive generation techniques less high than the risk associated with financing of the investment.

[5] However, one could argue that consumer preferences can be at least partially influenced via advertising.

In theory one could construct a ranking of private risks for every investment opportunity. Assuming that these investment opportunities are mutually exclusive (in the case of limited finances for example), the investor will prefer the investment with the lowest total risk exposure, with each type of risk 'weighted' with the importance he attaches to it.

Since this 'weighted risk' approach will differ with every investor and so too with the circumstances in which the decision is taken, there is not much to say to the general ranking of private risks. For electricity generators in specific, however, one could point to the fact that in the short run the 'spark spread' (i.e. the difference between the fuel price and the electricity price) is of detrimental importance. Consequently, the market risk (e.g. fuel risk, lower demand, competitor moves) is assumed to be very important.

Another approach towards the risks presented is their suitability to be quantified and incorporated into a model. The focus in this respect needs be on the risks that are completely internal to the electricity or energy market. For this purpose we regard the market risks surrounding fuel price development, development of electricity demand and the market structure (e.g. number of competitors) the most suitable to quantify. In addition, regulatory risk are partially quantifiable, e.g. when they are related to taxation in the energy sector or to interest rate movements. Risk related to internal determinants, such as organisation structure and financial capacity are rather too ambitious for our purposes.

2. DEALING WITH RISKS IN INVESTMENTS

In principal, there are two ways to take account of risk when considering investment. First, one can mitigate the risk by straightforward methods such as mid-term contracting, insuring or hedging. Second, one could use an approach that implicitly takes account of risks when potential investment proposals are quantified on their costs and revenues. These two methods are considered consecutively.

2.1 Risk mitigation methods

2.1.1 Diversification

One of the ways to deal with risk exposure of investment projects is to 'never put all of your eggs in one basket'. This is in fact a method adopted from finance theory, more specific portfolio theory (Markowitz, 1952). In short, this theory states that by investing in different company stocks with different rates of return and risk characteristics, the overall rate of return and risk on your portfolio can be enhanced significantly. The potential application of this method to the electricity generation context is manifold. An electricity producer might construct a portfolio considering different generation techniques, different suppliers of fuel inputs, different geographic locations and different business activities (see organisational hedging).

This method might seem as a common sense thing to do. However, its usefulness with regard to the degree of risk exposure of total investments is limited. Firstly, because one can never mitigate all the risk involved. Secondly, there might be significant returns to scale involved in applying this method. For example, a small electricity producer with a limited availability of capital (and thus a limited capability of carrying investment risk) may have to settle for only one investment project (one location, one generation technique and so on) at a time. Therefore, this approach should always be adopted in combination with another risk reducing approach.

2.1.2 Long-term contracts

A widely recognised method to deal with risks in the energy industry is (mid or long-term) contracts. For example, it was intensively used in the building of gas pipeline networks. The signing of contracts is potentially applicable to a large range of energy business risks, from infrastructure investments to fuel deliveries and even regulatory uncertainty, e.g. product sharing agreements (PSA)[6].

Contracts with suppliers and consumers can significantly reduce both fuel and price risk. However, this instrument is only limited in scope since it not only covers downward risk, but also excludes upward risks. That is, if the spot price of gas is lower than negotiated in the contract with the gas supplier, gains are foregone. Another disadvantage of this approach is the fact that one always has to search for a counter party. Whilst this is unambiguous in some cases (signing a contract with a industrial customer in which electricity price is fixed), it might prove difficult, if not impossible, in others. In addition, when using long-term contracts some amount of transaction costs is always incurred.

6 These kinds of agreements are often used when large dedicated investments in emerging countries are involved. By signing a PSA, an investor hedges the risk of the national or local government changing its tax or resource rent regime. Shell, for instance, signed a PSA with the Russian and local government in 2000, before deciding to invest in the Sakhalin project in the Far East.

2.1.3 Insurance

Another method to counter specific investment risks is insurance. In this case the investor approaches a counter party and agrees to pay a specific amount in turn for a fully or partially recovery of incurred costs when the insured event occurs. This seems straightforward at first, but it has some prominent drawbacks. A major drawback is the fact that a fully developed insurance market is only present for a limited number of risks. For example, it is possible to take an insurance against accidents at construction sites or costs (project delays) incurred due to bad weather, but it is impossible to take up an insurance against the quicker than expected large-scale introduction of fuel-cells (in case this negatively affects the value of current assets or investments). For this kind of event, one needs to turn to other mitigation strategies such as hedging or diversification.

2.1.4 Financial hedging

A common way to reduce or even annihilate certain risk exposure is hedging through transactions on the financial market. Financial hedging instruments such as futures and forwards markets are important in creating an efficient electricity market. However, in the era of vertically integrated, (partially) state-owned electricity companies, there was little need for this kind of hedging instruments. It is only since the gradual introduction of liberalisation that financial hedging techniques have emerged for the electricity market.

Theoretically, these techniques could be very efficient in creating an efficient electricity market, but there are some caveats. First of all, the market should have a considerable size (in volumes traded). If this is not the case, electricity market players have little confidence in the market giving a good representation of the 'true' price. This is related to the second potential caveat; market power. In an illiquid market, there is a potential for large players to 'rig' the market by exerting its influence. The chance of such occurring is quite high in 'emerging markets'. Most of the electricity markets around Europe can indeed be labelled as such. In fact, the only electricity markets considered being large enough and efficiently working are the British and Scandinavian[7]. A third, and more fundamental caveat, is the limited liquidity of more longer-term futures and forwards. The Scandinavian electricity market for futures does not offer contracts for more than three years ahead. For a power generator wishing to hedge the risk of investing in a 20-year operating power plant, this does not give much comfort.

2.1.5 Organisational hedging

A practical strategy to mitigate certain risks is organisational hedging. This form of hedging encompasses the acquiring of companies up or downstream in the chain. The result is that some risks such as input price (fuel) or deliverability risks are now under internal control; the risk is internalised. Indeed, the scope of this strategy is limited by the degree that the risks exposed to are caused by developments up- or down the chain. Risks external to the electricity chain (such as macroeconomic risk or regulatory risk) cannot be hedged via this strategy. A common phenomenon in the electricity industry is the fusion of parties in different levels of the electricity or gas chain. The IEA (2003b) describes the lines along which energy companies tend to integrate in more detail. In general, there is convergence between the electricity and gas industry.

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[7] The ratio of traded amount to actual demand shows a relatively high liquidity in Scandinavia in comparison with the French and German spot market (Montfort, 2003).

2.2 Quantifying investment risk

2.2.1 Traditional NPV methods

Traditionally, large companies use the net present value (NPV) as their primary valuation tool in investment decision. The basic steps of the NPV methodology, as explained by Magnusson (2002), are:

1. To calculate the present value of the expected stream of cash that the investment will generate (discounted cash flow DCF). The discount rate usually consists of two parts: the time value of money and a risk premium. The time value is the return on a nominally risk-free investment while the risk premium is present to compensate for the risk inherent in the investment opportunity[8].
2. To calculate the present value of the stream of expenditures required to undertake the project.
3. To calculate the difference between the two, which is the NPV of the investment. When NPV is positive the corporation will go ahead with the investment. When NPV is negative the corporation is better off not making the investment.

Instead of calculating the NPV of an investment at an assumed discount rate, it is also common practice to calculate the internal rate of return (IRR), i.e. a discount rate that would set the NPV of the investment to zero. The IRR is then compared with the cost of capital; if the IRR is larger than the cost of capital, the investment project should be undertaken.

Thus, decisions about investments in power generating capacity depend on expected future returns and costs. However, in case of liberalised energy markets, there is uncertainty about electricity and fuel prices (IEA, 2003a). Forward contracts can give an indication of the expected price (and thus of returns and costs), however, these contracts usually have a limited duration, while the investments are made for a longer period. Therefore, electricity volume, demand growth and development of supply, including import and interconnector capacity, are important indicators for an investor. A widely accepted costing method that accounts for (some of) these issues is the Levelised Cost Methodology (LCM). "This approach reflects the reality of long-term financing, passing on costs to the (captive) customers, known technology paradigms, a predictable place in the merit order, a strong increase in consumption and a short build-up time for selling the output of a new plant." (IEA, 2003a).

The LCM involves the calculation of (see IEA, 2003a):

1. the present value of the stream of estimated costs, including capital costs, operating and maintenance costs, and fuel costs,
2. the present value of the stream of estimated average annual electricity production,
3. the ratio of the costs and electricity output to obtain a levelised cost of power production.

The investment project with smaller levelised cost is less expensive.

Risks can be incorporated more effectively in these static methods when different scenarios or sensitivities are being considered, e.g. with respect to the future development of electricity prices or using a scope of discount rates. Components are discounted according to their degree of riskiness, using a probabilistic assessment (expected value) of key uncertain factors. EIA (2002) presents an example of simulating the NPV of an investment in a combined-cycle generator. Electricity and natural gas prices are varied based on historical volatilities, resulting in a probability distribution of NPV. The project has a single positive NPV of $ 2 mln, whereas the distribution of NPV indicates that there is an 83% probability that the projects' NPV would be at least zero.

[8] As a result of using questionable risk-adjusted discount rates, NPV analyses penalise projects that have a high level of uncertainty surrounding their future cash flows by applying a very high discount rate.

The static NPV method assumes an irreversible investment decision, which tends to rely on single estimates of fuel and electricity prices. In reality however, investors can sometimes postpone investing until they have more information or they can turn the power plant on and off on individual dates and hours (e.g. convert gas to power only when the relative prices are right). The real option approach can account for the different flexibility options.

2.2.2 Real option approach

The real option approach measures the value inherent in the plant operator's ability to dynamically react to changing market conditions. It is therefore an important tool in the financial valuation of generation assets such as peaking plant and hydroelectric generators with storage (Frayer and Uludere, 2001). By definition, peaking plant depend on high electricity prices that only appear for a small number of hours to cover the investment costs. Volatile fuel and power prices create opportunities as well as risks for investors in peaking plants. For base load power plants, price volatility is less important. Frayer and Uludere (2001) give an overview of the level and area of optionality of different types of generation assets, which we copy in Table 2.1.

Table 2.1 *Optionality of generation assets*

Asset type	Applicability of real options	Area of optionality
Existing gas/oil	High	Very flexible, able to exploit volatility of spark-spread
New peaker single-cycle gas turbines	High	Low start costs; high operating flexibility
Hydro (storage)	High	Storage capacity; operating flexibility
Mid-merit coal	Medium	Profit more dependent on price volatility than baseload stations
New baseload combined-cycle gas turbines	Medium	Able to benefit from electricity and gas volatility
Hydro (conventional)	Medium	Limited storage may generate some options value
Baseload coal	Low	Not flexible
Nuclear	Low	Not flexible

Source: Frayer and Uludere (2001).

The real options approach is founded on the fact that most investments are irreversible (sunk cost) and that the investor has the option to wait, i.e. delay the investment to a later date (Dixit and Pindyck, 1994). A firm with an opportunity to invest is holding an 'option' analogous to a financial call option.[9] A firm has the option to spend money (the exercise price) now or in the future, in return for an asset[10] of some value. When the firm makes an irreversible investment expenditure, it exercises, or 'kills', its option to invest. This lost option value is an opportunity cost that must be included as part of the cost of the investment.

9 A call (put) option is a contract that entitles the buyer/taker to buy (sell) a fixed quantity of commodity at a stipulated basis or striking price at any time up to the expiration of the option, regardless of the market price of that commodity. The buyer (of the option) pays a premium to the seller. Note that a European option can be exercised only on one particular day whereas an American option can be exercised on or at any time before the exercise date.

10 A real asset as opposed to a financial asset.

Apart from the most general real option, i.e. the option to invest, Magnusson (2002) distinguishes other, specific types of real options, including the option:

- to wait, i.e., to deter the investment to a later date,
- to stop temporarily, for example in reaction to fluctuations in input and output prices or to mothball a power plant,
- to abandon, i.e. sell equipment and/or knowledge,
- to switch input, output or risky assets, for example in power plant valuation,
- to develop, e.g., R&D projects and start-ups,
- to expand or upgrade, implying an extension of activities,
- to grow, e.g., strategic acquisitions or multiple-generation product development.

In evaluating investments in electricity generation, the spark spread model is often used, i.e. the option to stop temporarily. The real option approach takes account of future uncertainty in prices using the observed volatility. The value of the power plant then becomes a series of (European) call options for each hour during which the power price or the fuel price can vary. The plant has the right, but not the obligation, to burn fuel and produce electricity, which it can then sell into the wholesale power market.

Option pricing recognises that the possible gains and losses from an investment are not symmetrical[11] (i.e. that investments are irreversible). The recognition is that an investment will usually have a fixed downside. The more uncertain (higher σ2) the future cash flows the more valuable the option because the firm has full exposure to the upside but only limited exposure to the downside. Disregarding this asymmetry is probably the largest shortcoming of the NPV-method. A practical consequence of this is that NPV says that greater uncertainty over e.g. electricity prices should lead to less investment in underdeveloped generation capacity whereas option valuation says that it should lead to more (Magnusson, 2002).

Table 2.2 *Variables affecting a (real) call option*

Explanation of the variable		Application to electricity (=underlying asset)	Correlation with call option value
(Present) value of the underlying asset	S	Expected price of electricity	Positive
Exercise or strike price	X	Expected variable cost of production, e.g. fuel cost	Negative
Time to maturity	t	Each hour in the plant's useful life	Positive
Risk-free discount rate	r	Interest rate on Treasuries (government bonds)	Positive
Uncertainty or volatility of the value of the underlying asset	σ^2	Volatility in spark spread	Positive

Sources: Magnusson (2002) and Frayer and Uludere (2001)

11 Equivalently it recognises that investments are irreversible. If the asset rises in value, the net payoff from investing rises. If it falls in value, the firm need not invest, and will only lose what it spent to obtain the investment opportunity (Dixit and Pindyck, 1994).

Table 2.2 distinguishes the five variables that affect the value of a simple call option according to the Black-Scholes formula:

$$N(d_1) \cdot S - N(d_2) \cdot PV(X)$$

Where:
$N(\cdot)$ denotes the normal probability density function

$$PV(X) = \frac{X}{(1+r)^{-t}}$$

$$d_1 = \frac{\ln(S / PV(X))}{\sigma\sqrt{t}} + \frac{\sigma\sqrt{t}}{2}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

Frayer and Uludere (2001) applied the real options methodology, evaluating the optionality (i.e. the value of flexibility) of a mid-merit coal unit and a gas-fired peaking unit in the US. However, as Frayer and Uludere (2001) indicate, 'pricing of an option brings out the mathematical complexities and the realistic shortfalls of the methodology'. First and foremost, the source of uncertainty must be traded. Although electricity is traded, long-term contracts, i.e. future prices, are limited available in electricity. Therefore, observed historic volatility in electricity prices are generally used. When market data is unavailable or incomplete, proxy input parameters can be established using econometric techniques and Monte Carlo simulation (Frayer and Uludere, 2001).

In addition, the Black-Scholes option pricing model assumes that prices are random, i.e. unpredictable, and that volatility is constant. There are however unique characteristics of electricity and fuel prices that make application of the Black-Scholes option pricing model more complex:

- Part of electricity price changes is non-random, depending on season and time of day.
- Mean reversion: electricity and fuel prices tend to move towards their long-run marginal cost. As a result, price volatility changes stochastically over time.
- Prices differ across regions as a result of varying generation capacity across regions and congestion in transmission.
- The spark-spread principle assumes full flexibility in operations and in fuel use, i.e. perfect fuel arbitrage and electricity trading. However, a peaking plant may be unable to capture this full flexibility due to the structure of its fuel contract, thus the option value may be overestimated.
- On the other hand, the value may be underestimated due to other options not incorporated, such as the option to expand on site.

2.2.3 Portfolio theory

Portfolio theory is yet another approach dealing with uncertainty that stems from finance theory. The general idea is that a portfolio of assets provides the best means of hedging future risks, assuming that risk reduction is attained by diversification of assets. Applying it to the electricity sector, a portfolio is a mix of power generation plants, e.g. a mix of gas-fired and coal technologies. Clearly in this example the fuel price risk is of main concern.

Based on the mean-variance portfolio theory developed by Markowitz (1952), the expected portfolio return is related to the total portfolio risk. Both expected portfolio return and portfolio risk are weighted averages of the individual expected returns and risks. However, portfolio risk is tempered by the correlation coefficient between the individual returns.

$$E(r_p) = \sum x_i E(r_i)$$
$$\sigma_p = \sqrt{\sum_i \sum_j x_i x_j \rho_{ij} \sigma_i \sigma_j}$$

Where:

$E(r_p)$	Expected portfolio return
x_i	Proportions of asset I in the portfolio
$E(r_i)$	Expected return for asset i. The mean of all possible outcomes, weighted by the probability of occurrence: $E(r_i) = \Sigma p_n r_n$ where p_n is the probability that outcome n will occur and r_n is the return of that outcome.
σ_p	Portfolio risk
ρ_{ij}	Correlation coefficient between the individual return streams
σ_I	Standard deviation of the periodic (historic) returns to asset I

A portfolio effect arises when two assets within a portfolio are less strongly correlated (lower correlation coefficient). As a result of combining the two assets, a significant risk reduction is obtained relative to a decrease in returns.

Awerbuch and Berger (2003) show that, using portfolio theory, a range of efficient (optimal) portfolios is determined, with the minimum variance portfolio as lower bound. Investor's preferences and risk aversion then determines the choice for a risk-return combination. It is also explained that adding risk-free but lower-yielding assets (e.g. Treasuries) to the portfolio produces the same expected return while reducing the risk of the portfolio.

In the portfolio analysis, market or historic cost risk is measured on the basis of the historic variation and covariation between cost components of the technologies considered. Costs are the only relevant input, i.e. (variations in) the electricity market prices are left out of the analysis, avoiding questions regarding the appropriate electricity price to use (and avoiding additional risk to the portfolio). Cost is translated to return by taking the inverse, for example, assumed (levelised) cost for renewables of 0.12 $/kWh translates into a return of 0.08 kWh/$ct. The principle output of the portfolio optimisation analysis is an efficient frontier indicating the location of all optimum portfolios in the portfolio return - risk space.

Awerbuch (Awerbuch, 2000) has applied the portfolio theory to the US case with a simplified portfolio of three generating technologies: gas, coal and renewables. Focusing only on fossil fuel risk, renewables are assumed risk-free in terms of fuel risk. In an extension to EU generating mixes, Awerbuch and Berger (Awerbuch and Berger, 2003) have extended the model to more technologies and several cost components. Fuel risks, as well as risk of O&M and construction period costs are incorporated. In a recent portfolio study (Awerbuch and Jansen, 2004) energy planning portfolio mixes for Mexico, Morocco and India were analysed.

Awerbuch applies the approach to socially optimal portfolios. This can easily be applied to firm-level portfolio decisions, but only for large generators. Small generators simply lack the scale for relevant portfolio analysis. Moreover, investments in generating assets are not easily liquidated (irreversible) and individual capacity additions are quite lumpy. By definition portfolio theory assumes a broad approach, i.e. large companies, national portfolios or large service territories.

3. SUMMARY AND CONCLUSION

Electricity investment risks are to be divided into risks for private parties and risks for society as a whole. Risks for the society as a whole mainly amount to the security of energy supply. However, our prime focus is on risks relevant for the investor in electricity generation, i.e. the private risks. An electricity generating company faces the following type of risks: financial, operational, construction, market, macroeconomic, contract and regulatory risks.

A wide variety of determinants affect the investment decision in power generation. Some determinants, such as financial position, organisation and technological know-how, are in the control of the firm, i.e. they are internal to the firm. Contrary, external determinants affecting investment decisions, such as the market circumstances, governmental policies and exogenous technological developments, are usually not controllable by the firm.

A number of approaches and strategies that take account of and mitigate private investment risks in the power sector have been discussed. The main purpose of this report is to establish an inventory and assessment of methods that quantify (some of) the investment risks in order to be able to make a proper investment decision. In principal, there are two ways to take account of risk when considering investment. First, one can mitigate the risk by straightforward methods such as mid-term contracting, insuring or hedging. Second, one could use an approach that implicitly takes account of risks when potential investment proposals are quantified based on their costs and revenues, such as net present value methods, a real option approach or portfolio analysis.

While traditional net present value methods are simple and straightforward, and have been used extensively for evaluating investments, their ability to account for flexibility options of investments is small. The real option approach is better suited to investment opportunities that have high degree of uncertainty. It measures the value inherent in the plant operator's ability to dynamically react to changing market conditions. However, pricing of an option is mathematically complex and often has to rely on data that is either hard to obtain or hard to predict. Portfolio theory assumes that risk reduction is attained by diversification of assets. A portfolio effect arises when two assets within a portfolio are not perfectly correlated. A combination of such two assets results in a more favourable risk and return on investment position. Applying portfolio analysis requires a sufficient level of scale, and also bears the disadvantages of complexity and sometimes unrealistic input.

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