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Applying Real Options Theory in the Electrical Energy Sector

SUMMARY: Real options theory is the newest expansion of standard investment evaluation methods and one that is at the same time suitable for eliminating most of their inadequacies. Similarly to financial options, the possession of real options –rights not obligations – means that operational or production hedge mechanisms complementing the management tool-kit with flexibility and the capability to respond to the environment are acquired by means of interpreting options inherent to financial products for physical assets. This study aims to analyse how real options took root in investment evaluation theory, along with the types of real options and the valuation procedures available for them, moreover to illustrate real options analysis in the course of individual level investments in the electrical energy sector. By describing binomial pricing as completed for 10 power generation technologies in detail, my goal was not primarily to grasp strategic value identified through real options, much rather to describe the pricing steps themselves. Based on the results, real options theory outperforms conventional investment valuation procedures both in terms of uncertainty and managing flexibility.*

KEYWORDS: real options, binomial pricing, uncertainty, flexibility
JEL CODES: G31, G32

REAL OPTIONS THEORY BASICS

The expression real options was first used by *Stewart Myers* in 1977, when he investigated the possibilities of applying options pricing in the non-financial, primarily property investment valuation domain, by which he meant flexibility and as an added value, the phenomenon of deferred learning. A real option can be considered the option to defer and adjust investments and production decisions with the purpose of dispelling uncertainty (Triantis, 2000). Economists were quick to realise that options theory created for analysing financial options can offer notable added value for decisions about real investments (Black – Scholes, 1973; Merton, 1973).

This subject first caught the moderate attention of academics in the 80s and 90s; widespread dissemination, however, was yet to come. In the mid 90s, real options provided the transition from restrained, specialised interest in options theory to the mainstream generally accepted by science and the profession itself (Borison, 2005).

Easy to apply, instructive discount cash-flow based approaches assume a passive management approach (Kogut – Kulatilaka, 1994); they make the implicit assumption whereby a project will begin immediately and operate continuously until the end of anticipated useful life even if the future is uncertain. As a consequence,

* Research was implemented with support from the European Union and Hungary, in the scope of the priority project entitled *"National Excellence Program–Nationwide Program for the Development and Operation of a System for Providing Domestic Student and Researcher Personal Support"* (identifier: TÁMOP 4.2.4.A/1-11-1-2012-0001).

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discount cash-flow procedures disregard the added value that can be incorporated in a project by means of the management's flexible adaptation and innovation, i.e. they systematically underestimate the value of investment projects (Dixit – Pindyck, 1994, 1995; Trigeorgis, 1993; Kemna, 1993; Kumar, 1995; Van Putten – MacMillan, 2004). The undervaluation of investment alternatives may lead to underinvestment, and to losing competitive position (Dean, 1951; Hayes – Abernathy, 1980). An efficient project valuation procedure takes both uncertainty and active decision-making – essential to the success of a strategy – into account (Luehrman, 1998).

REAL OPTIONS TYPES

Real options were typically created along the lines of two dimensions: concentrating on timing, and along project size. Within that, one may distinguish a relatively narrower and a more diverse typologisation of real option types depending on the degree of freedom project operators are given when managing the asset or project. These categories include, but are not limited to, the following: wait/deferment real option, real option to abandon, real option to shut down/restart within the temporal dimension; real option to expand, real option to contract, switching real option, growth real option, combined real option, exploration real option, outsourcing real option, rainbow options within the project size dimension (Trigeorgis, 1997; Amram – Kulatilaka, 1999; Benaroch, 2002; Copeland – Antikarov, 2003). As useful as the language of options may seem for the qualitative description of fields of play for action at companies, the strategic significance of real options and the possibility to line them up behind a long-term corporate goal is best emphasised by *Copeland and Keenan's* categorisation (1998), who differentiate real options for growth, learning and insurance.

According to the real option for growth, a given investment may be the precursor or basis for starting a chain of interconnected projects, thereby opening up future growth prospects (for instance, the implementation of new projects, new processes; new market penetration; strengthening of base competencies) (Kester, 1984). Sources also refer to these as *strategic growth opportunities* or *innovation options.* In many cases, the purpose of real options for growth is not or not just immediate value generation, much rather to create future business opportunities. For management, growth options represent the starting point for realising profit from positive developments in the economic environment by virtue of supplementary projects or expanding existing resources. The better part of value is determined by uncovered opportunities, i.e. the possibility to leverage future profit potential through reinvestment. From the options perspective, one may think about growth options as buy options for the capital value of any supplementary projects (Courtney, 2001; Hungenberg, 2001). In corporate practice, such options may be based on the specialised human capital, technological know-how or dominant market position of a company (Witt, 2003). The difficulty in analysing real options for growth lies in identification, moreover the valuation of growth opportunities that *Drews* (2003) called "surprise potential".

Insurance options uncover the possibility to respond to unfavourable demand or price developments for management in the shape of shutting down, as well as and/or operative adaptation. In contrast with growth options, insurance real options provide protection for a company against potential loss risks in a manner whereby they can avoid dips in their cash-flow (Copeland – Hove, 2002).

Depending on insurance logic, they may be call or put options. The option for a company to switch to an alternative production process represents a call option, while a potential factory sale can be modelled as a put option. Expand/contract (i.e. scaling) options are typical real options for insurance, where a real option to expand reflects the opportunity for the scope of a good investment project being able to boost the value of an additional investment in the case of a good market situation and favourable profitability; while in the case of a real option to contract the enterprise has to consider possibilities for limiting project size and scope of effect (when it generates a loss). Switching real options are also listed among insurance real options, and allow project operators to switch to another operational model in the wake of market requirements regarding the asset – next to the payment of a certain premium (Margrabe, 1978; Kensinger, 1987). When the price of the manufactured product or demand for it changes, the factory owner may change the plant's basket of production or provide the same output from changed raw materials (Hommel, 2000). Finally, real options to shut down and restart can also be found among the insurance options. When market conditions are bad, a company may stop production. Once the market situation improves, it can execute investment aimed at restarting production. Essentially, real option to shut down and restart are just two options linked to each other. An option for freezing investment in case of unfavourable market conditions if cash-flow from the project is unable to cover variable costs, then – in case market circumstances turn for the better – the second option, i.e. restarting the investment, can be called-off (McDonald – Siegel, 1985; Brennan – Schwartz, 1978).

According to Copeland and Keenan's (1998) categorisation, a real option to learn is the third real option group, which enables the investment decision to be postponed, reducing the risk of management making irreversible decisions based on incomplete information and thus suffering unfavourable consequences. As a result, the value of an option to learn can be derived from the option to defer an irreversible investment when given uncertainty factors are present, i.e. from the value of waiting (out). In other words, it is equivalent to a call option, the object of which is the decision itself (Brach, 2003; Pritsch, 2000). This includes the real option to defer. A company that already has the capability and flexibility to time investments is justified in expecting financial compensation for waiving this flexibility in the case of prompt implementation instead of waiting for new information (Blyth et al., 2007). Delaying an investment represents value for the investor prior to the making of the initial cash-flow (Dixit – Pindyck, 1994; Ingesoll – Ross, 1992; McDonald – Siegel, 1986). The higher the uncertainty surrounding the decision, the more company executives prefer deferring project implementation, maintaining the option to implement the project at a future date (Myers, 1977). Since activities that determine the availability of production or later production cannot be postponed indefinitely, the deferral strategy frequently goes hand in hand with a next level of exercising management flexibility, i.e. splitting the decision into consecutive stages (sequencing real option) (Trigeorgis, 1996). In the case of the real option to abandon, likewise of the learning type, management can decide to permanently stop production in the given project or operating the project if market circumstances deteriorate permanently and significantly, liquidating the assets that are included in it, then utilising amounts realised through liquidation elsewhere (Myers – Majd, 1990; Hubbard, 1994). The option to abandon only exists if full irreversibility of the investment project is not validated. In other words, the partial reversibility of investments will be one consequence of the existence of the option to abandon. Choosing the optimum date to abandon represents the greatest challenge related to the valuation of options to abandon.

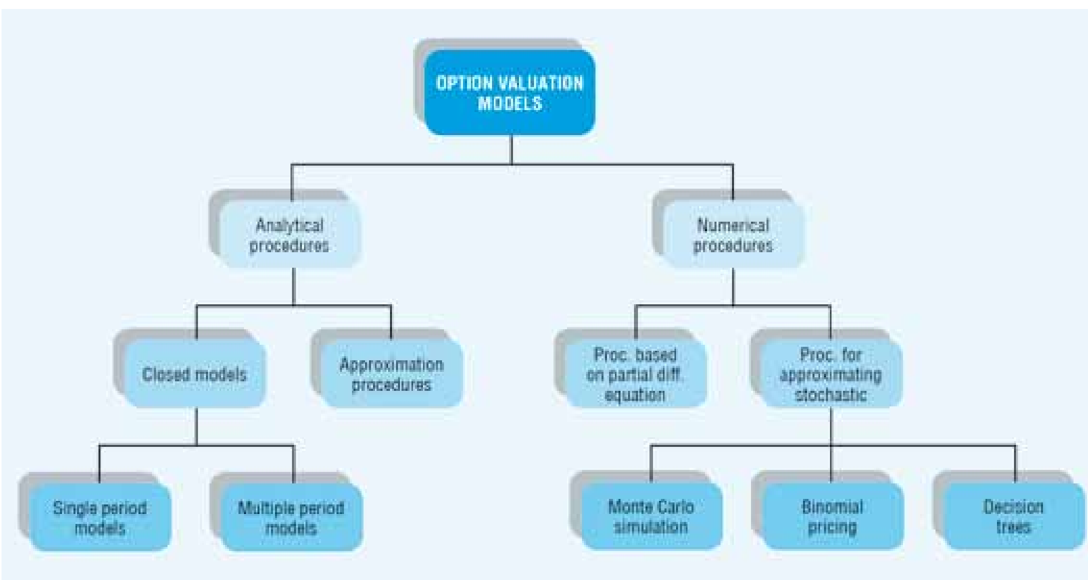
VALUATION OF REAL OPTIONS

Once options theory, and within that real options are selected as the investment decision support methodology, the question of what specific option valuation procedure should be applied arises. *Chart 1* shows the systemic sorting of real option valuation methods. These valuation procedures may have unique pros and cons in the given decision situation. This is why it is important to contemplate which method is best suited for providing decision support to the given project. The most important requirements of valuation procedures include transparency, accuracy of valuation, the versatility of the valuation process, lowest possible complexity, along with the least possible preliminary skill requirements on behalf of those who will apply them.

The profession and practice has split into two in answering the question about which – *Cox, Ross* and *Rubinstein's* (1979) binomial pricing or *Fisher – Black and Myron – Scholes'* model published in 1973 – proves more useful. Practitioners tend to favour the B/S model for the most part (Courtney et al., 2001), while the majority of academic publications apply and recommend the binomial procedure. Without a doubt, the B/S model surpasses the binomial procedure regarding the requirement of simple applicability (Amram – Kulatilaka, 1999); at the same time it is important to note that the complex modelling of real options relies on programming languages and, consequently, assumes a relatively high level of methodological know-how (Dörner, 2003).

Chart 1

CLASSIFICATION OF OPTION VALUATION PROCEDURES



Source: based on own editing (Bockemühl, 2001, p. 141; Hommel – Lehmann, 2001, p. 124; Rózsa, 2007)

This is the very complexity that makes adapting the B/S formula's rigid structure and assumptions impossible as it were in the case of tangibles (Copeland–Antikarov, 2003), i.e. the binomial procedure proves dominant in the field of model transparency. Although the binomial procedure often loses out to the B/S model in terms of precision, its results qualify as sufficiently accurate for value-driven corporate governance and easy to illustrate, and this option of graphical representation improves model transparency and accessibility.

REAL OPTIONS IN THE ELECTRICAL ENERGY SECTOR: EMPIRICAL RESEARCH

The following section will examine opportunities for using real options theory regarding investment projects in the electrical energy sector at an individual investment valuation level. Upon examining the valuation of electrical energy projects, the planning of electrical energy composition, the investment projects typical to the sector, and the sum total of projects one has to deal with a problem complex from multiple aspects. The valuation difficulties deriving from the particularities of investments in the sector (irreversibility, uncertainty, long range), moreover the features of the sector itself (numerous players with varying preferences and risk attitudes, changing regulatory and market environment, the special nature of electric power as a product) result in the complexity of investment related decision-making.

Before the liberalisation of the electric power market, the use of options theory was not typical during the investigation of power plant investment decisions. This is due to the procedure's profit-orientation, which is foreign to the electrical energy sector's earlier investment decision focus. According to *Crousillat* (1989), the objective of profit maximisation led to the same result as cost minimisation given the unchanging and certain nature of demand prior to liberalisation. All this cannot be achieved under competitive or imperfect market circumstances where prices are not created through equilibrium. The lack of investment flexibility in regulated markets can be a further argument for rejecting the procedure.

The simplest way to understand real option valuation is to view real options as an analytic tool similar to net present value. What is more, calculating the real option value of a given project is not much different than the conventional discounted cash-flow procedure. Under certain circumstances, the two procedures can even lead to identical results based on mostly identical input data. One crucial difference, however, is that real option valuation also identifies strategic value inherent to a project. Real option value is actually the sum of net present value and this strategic value, where real option value may never be less than net present value; moreover a project may carry value regardless of its net present value being negative or equal to zero.

Strategic project value appears if some degree of the combination of uncertainty and flexibility is typical to the project, and will be the greater the more this is so. It is important to note at this point that the presence of uncertainty in itself will not result in strategic value for an investor without flexibility being present in the given project, thus enabling the management of uncertainty. From the real options perspective, this flexibility is an option, which – in the electrical energy sector – may be the option to defer power plant investment, shut down a power plant, switch combustibles, geographically relocate the power plant, choose technology, go to market, or speed up amortisation.

Strategic value can be created if flexibility is unequivocally typical to an uncertain project; mere uncertainty in itself, however, is unable to generate value. Project flexibility is an investment characteristic that is able to generate added value irrespectively of uncertainty. I analysed the flexibility of postponement, expansion, as well as abandoning.

In the following section, I will perform the real option valuation of 10 electrical power generation technologies that can potentially be included in Hungary's composition. The first step of real option analysis involves selecting the valuation procedure itself. The binomial procedure will be applied during my empirical research. Specifying model parameters is required to perform real option valuation.

Basic Product The value of the project itself is the basic product of the real option, and it is none other than the present value of cash-flows realised after the given technology is deployed. Examining whether or not the various scenarios pertaining to how present values shape up were taken into account in the course of their calculation is important in the interest of specifying the value of the basic product. In case no scenario analysis is performed explicitly when calculating the present value of future cash-flow, the value of the basic product will be the sum of the free cash-flows[1] that can be realised over the useful life of the various power plants as specified using the discounted cash-flow method. *Table 1* presents the results of the net present value and internal rate of return calculations for the various technologies,[2] with the assumption of a hypothetical power consumption of 3.6 TWh for the sake of the comparability of technologies.

The table shows investment cost for installing capacity that would be required to meet hypothetical demand. Based on the data, the construction and installation of a solar energy park (comprised of more than 230 elements based on average block size) costs more than six times what building and

Table 1

THE 1ST STEP OF REAL OPTION ANALYSIS – NPV AND IRR DATA FOR ELECTRICAL POWER GENERATION TECHNOLOGIES ASSUMING A CONSUMPTION OF 3.6 TWH

Technology	NPV $	IRR %	Capacity to be installed MW	Investment cost $	FCF
COAL	2,032,082,150	31.74	495	1,074,501,000	3,106,583,151
Crude oil	1,924,823,959	41.55	790	698,103,267	2,622,927,226
CCGT	1,868,057,620	60.32	520	441,769,856	2,309,827,476
Natural gas CHP	1,204,207,142	32.70	1,027	663,013,699	1,867,220,840
Nuclear LRW	1,576,445,222	21.71	457	1,576,445,222	3,152,890,445
Biomass	1,151,905,594	20.26	535	1,405,341,433	2,557,247,027
Onshore	1,651,547,521	21.51	1,135	1,911,162,651	3,562,710,172
Solar PV	– 3,020,621,690	3.57	1,422	6,831,260,166	3,810,638,476
Solar thermal	– 2,694,051,361	4.30	1,532	6,763,027,267	4,068,975,906
Geothermal	1,799,968,049	24.79	479	1,496,078,187	3,296,046,236

Source: own calculations

outfitting a (medium size) coal burning power plant costs in order to satisfy the required demand.

Taking calculated NPV and IRR values as the basis, the given procedure's decision-making rules allow for ranking technologies according to value generation, moreover anticipated yield in addition to and expected yield, i.e. to specify an order of inclusion in a new composition *(merit order).*

At this point, I felt it necessary to make another adjustment for the sake of comparability: to screen out differences resulting from the different useful lives of the technologies, and to outline what are known as replacement chains. I considered the useful life data of the technology with the longest lifespan included in the study to be the benchmark (nuclear 50 years), and based on the useful lives of the various power plant types I determined how many times they each need to be implemented to be able to meet stable and constant demand for 50 years.

This is where I need to call attention to the limitations of the conventional discounted cash-flow procedure indicated in the preceding tables, and now also used in practice. This analysis performs a deterministic risk estimation, where it uses a risk premium in addition to the risk-free rate (Teisberg, 1995). The stochastic nature of price developments is not taken into account with this procedure. One may not accept this assumption for a sector characterised by fast technological development and numerous forms for the manifestation of market uncertainty (output and input price, carbon cost). Even though the simplicity of integrating risk analysis with a discount rate adjusted for just one unique risk is enticing, the disadvantages derived from failure to comprehend new risk factors and any incorrect approach will – with absolute certainty – outweigh the benefits of simplification.

Strike price The strike price of the option is the next required parameter for carrying out real option analysis. For electrical energy investment projects, this is the present value of outgoing cash-flow realised during the implementation period (column five in Table 1 shows the present value of investment cost for the power plant or power plant pool meeting 3.6 TWh consumption).

Term I assumed (skip) periods between one and five years for the different types of real options and in the course of the binomial calculations serving as the basis for pricing.

Discount rate We need the risk-free rate in the course of real option analysis. I used the 8 per cent yield of the Hungarian government bond available with the longest term (mark 2028/A)[3] for my calculations.

Volatility After defining the value of the basic product, I started dealing with identifying and quantifying project uncertainty. According to *Reedman* et al. (2006), it is expedient to model the market price of electrical power, the price of combustibles, carbon price (cost), and project value among the uncertainty factors of electrical energy investment projects. The modelling process of these selected uncertainty factors involves studying the electrical energy market, moreover volatility calculation performed after obtaining the historical data required for the analysis. Estimating this volatility is, by any means, the most difficult task in real option analysis. The price of financial options is derived from the value of the financial products serving as their basis. As a consequence, one can derive option volatility based on the historical development of the underlying instrument's market price or with the help of the B/S model built around the option's market price. Estimating volatility for a real option is a much more difficult task, since historic yield data or current market price of the basic product is not available.

Frayer and *Uludere* (2001) approached real option volatility using the price spread of (futures) contracts with a term nearly identical to the useful life of a given power plant. According to Copeland and *Antikarov's* (2003) proposal, real option volatility can be approximated to risk estimation reached as the result of Monte Carlo simulation for the project's assumed value without options (NPV-).

Choosing between volatility approximation procedures is not the goal of this study, so from this point on I will carry out volatility estimation for the various power plant investment projects using the MC simulation procedure, as it is the one most often used in sources, entails no aversion even among hands-on specialists, and – not in the least – is in synch with my methodological qualities.

I determined the probability distribution, average value and spread of selected uncertainty factors with the help of the Oracle Crystal Ball™ application. Since all uncertainty factors are prices, one may assume that they cannot take a negative value. Once we accept that the tendency of prices to gravitate back to fundamental value exists, this results in returning to the average in the long term, in other words to some degree of predictability of prices, instead of their accidental movement. All of this, combined with non-negativity, made it expedient for me to use log-normal distribution during my calculations, as this has the characteristic of pulling back towards the average.

The project value volatility of the real option model can be characterised with a project value risk spread. During the MC simulation, I calculated the applicable project value yields for 5,000 uncertainty factor value pairs. I adhered to *Mun's* (2006) procedure, so the first simulation step involved determining annual project yield based on previously quantified cash-flow data as the logarithmic function of the PV_1 and PV_0 quotient, in which PV_t stands for the present value of future cash-flow market value from year (t+1) until year T, according to the following (assuming continuous interest bearing):

$$PV_t = \sum_{k=t+1}^{T} FCF_k \times e^{-r\times(k-t)}$$

FCF_t stands for free cash-flow during period number t of overall useful life *(T)*,

r stands for expected yield.

Accordingly, the project's present value in period number t (V_t) is the sum of the present value of future cash-flows PV_t) and free cash-flow during period number t (FCF_t):

$$V_t = PV_t + FCF_t$$

Let z be a random variable standing for the project's continuous yield interpreted between period number t and period number (t+1). In this case the estimate function of project yield distribution simulates the spread of

$$z = 1n\left[\frac{V_{t+1}}{V_T}\right]$$

Copeland and Antikarov's (2003) V_1 and V_0 difference logarithm, with the assumption that the expected value of V_0 is constant. Thus a project's volatility will be the distribution of the

$$z = 1n\left[\frac{V_1}{E[V_0]}\right] = 1n\left[\frac{V_1}{E[PV_0]}\right]$$

expression. Assuming the denominator to be constant, I first performed the simulation of the numerator in order to derive project yield frequency distribution, and the spread of this distribution is actually the project value risk required to model top and bottom branch risk behaviour in real option pricing.

The real option valuation process

During real option analysis, I applied the Cox, Ross and Rubinstein (1979) binomial model, with the assumption, that project value may take a value of Vu with a probability of p, and a value of Vd with a probability of $1–p$ in every Δt period, in which

$$u=e^{\sigma\sqrt{\Delta t}},$$

$$d=\frac{1}{u}, \text{ and}$$

$$p=\frac{1+r-d}{u-d}$$

(σ is project volatility). Binomial real option pricing can estimate option value more accurately the smaller time intervals we assume between "*jumps*"; therefore I took the quarterly occurrence of branch-offs as the starting point when drawing-up the binomial trees, i.e. a one-year term real option is comprised of five branches after four branch-offs, while a five year term real option of 21 branches after 20 branch-offs. *Table 2* provides a summary of the input data used during the binomial pricing of the various real option types, jump parameters, as well as calculated risk-neutral probability.

The results of fossil technologies are modified significantly if we include environmental uncertainty in the study. Project value volatilities reflecting the combined effect of the three uncertainty factors increase drastically (data set in italics in *Table 3*), and thereby the parameters for binomial pricing are also modified.

Real option to defer

I first assumed the possession of options to defer. I took options to defer for terms of one, two, three, four and five years as the starting

Table 2

INPUT PARAMETERS FOR THE BINOMIAL PRICING OF REAL OPTIONS

	COAL	Crude oil	CCGT	Nuclear LRW	Onshore wind	Biomass	Natural gas CHP	Solar PV	Solar thermal	Geo-thermal
Present value of basic product, m$	3,107	2,623	2,310	3,153	3,563	2,557	1,867	3,811	4,069	3,296
	2,361	*1,987*	*1,908*	*3,153*	*3,563*	*2,578*	*1,434*	*3,811*	*4,069*	*3,269*
Investment cost of basic product, m$	1,075	698	442	1,576	1,911	1,405	663	6,831	6,763	1,496
Option term (years)	5	5	5	5	5	5	5	5	5	5
Number of intervals	20	20	20	20	20	20	20	20	20	20
Risk free rate, %	8	8	8	8	8	8	8	8	8	8
Spread, %	35	33	31	18	28	29	32	32	28	31
	48	*51*	*52*	*18*	*28*	*33*	*54*	*32*	*28*	*31*
Option parameters	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
u	1.191	1.179	1.168	1.094	1.15	1.156	1.174	1.174	1.15	1.168
	1.27	*1.29*	*1.30*	*1.09*	*1.15*	*1.18*	*1.31*	*1.17*	*1.15*	*1.17*
d	0.839	0.848	0.856	0.914	0.869	0.865	0.852	0.852	0.869	0.856
	0.79	*0.77*	*0.77*	*0.91*	*0.87*	*0.85*	*0.76*	*0.85*	*0.87*	*0.86*
Risk free p	0.512	0.517	0.524	0.585	0.534	0.531	0.521	0.521	0.534	0.524
	0.48	*0.47*	*0.47*	*0.59*	*0.53*	*0.52*	*0.47*	*0.52*	*0.53*	*0.52*

Source: own calculations

point for the 10 selected electricity generation technologies and sought the answer to the question as to which technology is most profitable to defer in the given period. As could be expected, maximum project value *[net present value + option (strategic) value]* came about next to the longest option term, i.e. the longer one defers the implementation of a given project, the greater the value it will generate. The truly remarkable case resulted from solar power technologies with negative net present value data. For the sake of realising the positive project value of photovoltaic solar cells, one needs to take a five year deferral period as the starting point, while thermal solar units can generate (positive, if moderate) value when assuming an option to defer a period of even four years, i.e. project value turns positive in the fourth period, with the remark that needless to say the greatest project value comes about when the maximum term of the real option to defer is assumed.

When environmental uncertainty is disregarded, wind power plants create the greatest value next to all terms, and this project value exceeds the maximum value that can be realised with the implementation of any other technology even next to the four year term. The ranking of technologies was modified significantly when environmental uncertainty was included in the investigation. Fossil technologies, which are significantly afflicted with environmental burdens, lost their dominant position, and results reflect dominant value generation for two renewable energy source based technologies: geothermal and wind power. They are followed by nuclear technology in the ranking, and then by natural gas based generation processes, which are heralded as the most flexible technology by a number of sources (Declercq, 2006; Federico, 2010).

Real option to abandon

Although determining the optimum date of abandoning is the critical point in any real option to abandon – as highlighted during

Table 3

THE VALUE OF REAL OPTIONS TO ABANDON TAKING THREE UNCERTAINTY FACTORS INTO CONSIDERATION

		Value of option to abandon					
	NPV	1 year	2 years	3 years	4 years	5 years	NPV*
COAL	**1,286**	0	0.37	0.42	0.24	0.05	1,286.42
Crude oil	**1,289**	0	0.1	0.24	0.14	0.03	1,289.24
CCGT	**1,466**	0	0	0.02	0.03	0	1,466.03
Natural gas CHP	**771**	0	0.53	1.19	0.67	0.14	772.19
Nuclear LRW	**1,577**	0	0	0	0	0	1,577
Biomass	**1,173**	0	0	0.01	0	0	1,173.01
Onshore	**1,652**	0	0	0	0	0	1,652
Solar PV	**–3,020**	210.01	98.47	38.02	8.02	0.37	–2,810
Solar thermal	**–2,694**	111.39	47.38	14.29	1.89	0.04	–2,582.6
Geothermal	**1,800**	0	0	0	0	0	1,800

NPV*=NPV+max(strategic value)

Source: own calculations

the overview of theory – project valuators are faced with an even more difficult task when planning electrical energy capacity in connection with what is known as salvage value, in other words the cash-flow from the disposal or liquidation of the power plant when it is abandoned. Having regard to the large degree of irreversibility inherent to electrical power generation, during my calculations I took as the starting point the assumption that salvage value after the first year will be the realisation of 50 per cent of total initial cash-flow, which then decreased by 10 per cent increments, i.e. 40 per cent assuming a real option to abandon term of two years, 30 per cent for three, 20 per cent next to a four year term, and 10 per cent for the maximum term of five years.

Based on real option pricing, liquidation is pointless for projects that have a positive net present value; in other words, no strategic value can be mapped to the various production technologies. In the case of negative net present value projects, the sooner the investor abandons a value-destroying project and attempts to salvage a part of the otherwise irreversible investment, the greater the option value generated. It is important for us to notice that in the case of projects with a significant negative net present value, this can mean nothing more than minimising losses – both when environmental uncertainty is taken into account and when it is not – since liquidation even after one year causes significant destruction of value in the investing company's life.

Real option to expand

When contemplating the fundamental characteristics of real options to expand, I was directed by twofold motivation. On the one hand, I saw an opportunity to include learning rates and investment cost reduction achieved as a consequence of capacity duplication in the model, on the other, to answer one of the key questions of capacity planning: should one expand or invest anew? In connection with these real options, therefore, the first step involved identifying the learning rates of the various technologies based European Union databases (ECN, 2004), after which I assumed that at the end of the fifth year after first implementation, the investor will execute a 50 per cent expansion of the given technologies next to cost reduction corresponding to 50 per cent from the learning rates in relation to the initial capital need. As the next step, I investigated duplication of technology, i.e. 100 per cent capacity expansion at the end of the individual useful life of each technology, assuming cost reduction for investment costs of a degree corresponding to the learning rates.

As a consequence of increased focus on environmental criteria, the expansion of fossil technologies – primarily coal and natural gas burning power plants – does not appear to be rational investor behaviour. The value of the real option to expand for technologies where low learning rates are typical decreased significantly as a consequence of project value risk, while the increase of risk for technologies promising significant cost reduction potential caused increases in strategic value.

CONCLUSIONS, RECOMMENDATIONS

The study looked at the strategy driven steps of applying real options, a theory said to be an alternative to conventional investment valuation procedures with the goal of familiarising the reader with the special circumstances that allow for the applicability of real options, the key real option types that are available, as well as the procedures available for their valuation. In light of the inclusion of the dominant electrical energy sector, the reader may ask whether the sector provided the theory or the theory the sector in this paper. Answering that question is by no means simple.

Without a doubt, the electrical energy sector is a particularly interesting domain for real options theory due the potential inherent to the combination of the significant degree of uncertainty surrounding its investments, moreover combining the interaction between high sunk costs and investment timing flexibility; at the same time, when the paper's empirical results were interpreted, the contribution of real options theory to optimising investments was unequivocally given a highlighted role.

All in all, the inclusion of the environmental dimension in the model created significant added value both in connection to risk identification and value generation criteria. In my opinion, real option pricing as performed allows for taking the effects uncertainty factors have on cash-flows, project risk and value generation into consideration together. I believe that real option analysis is capable of putting the yield characteristics of complex technical systems' investment alternatives to the service of investment decision-making optimal from the environmental and profit perspective alike by means of its meticulous project volatility estimation, the complexity of which will frighten off many users, moreover through its option pricing process, supported by appropriate statistical and mathematical analysis software and IT.

Notes

[1] One can divide the parameters I used for my calculations into two groups: factors derived from technology, and variables based on financial/economic estimates. I relied on 13 databases (AEO, 2008; AEO, 2011; EERE, 2008; EIF, 2010; IEA, 2010; Minicam, 2008; NREL-SEAC, 2008; Oxera, 2011; POWER SWITCH, 2003; PB, 2011; Raeng, 2004; Risto T. – Aija K. 2008; Stretton S., 2010). These databases disclose information with varying levels of detail on technological, financial/economic parameters with varying units of measure, currencies and effective dates. As a consequence, the first step in performing my calculation involved finding a "common denominator" for these data, i.e. I had to do the appropriate conversions and transposition to a common date. After that, with resulting data still showing significant variance, I calculated minimum, maximum and average values, then selected the data set to be used for each parameter, providing an appropriate explanation.

[2] The Free Cash Flow Calculation Formula:

$$FCF = \sum_{t-1}^{n} 8{,}760 \times TF \times size \times price - O\&M\ FC \times 1{,}000 \times size - O\&M\ VC \times 8{,}760 \times TF \times size - \ddot{U}A\ 8{,}760 \times TF \times size$$

in which FCF = free cash-flow; TF = load factor; *O&M VC* is variable cost for operation and maintenance; *O&M FC* is fixed cost for operation and maintenance; *ÜA* is fuel cost; price is the market price of electric power as a product;

The Net Present Value Calculation Formula:

$$NPV = \sum_{t-1}^{n} \frac{FCF_n}{(1+r)^n} - CC \times 1{,}000 \times size,$$

in which CC is cost of CAPEX.

[3] Source: http://www.akk.hu/object.67031834-75e5-46a3-9dc9-7296e536438a.ivy; Downloaded on: 13/02/2013

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