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FROM MARKET UNCERTAINTY TO POLICY UNCERTAINTY FOR INVESTMENT IN POWER GENERATION: REAL OPTIONS FOR NPP ON ELECTRICITY MARKET

SUMMARY

In the electricity sector, market participants must make decisions about capacity choice in a situation of radical uncertainty about future market conditions. Sector is characterized by non-storability and periodic and stochastic demand fluctuations. Capacity determination is a decision for the long term, whereas production is adjusted in the short run. Paper looks on the main contributions in investment planning under uncertainty, in particular in the electricity market for capital intensive investments like NPP. The relationship between market and non-market factors (recent UK policy example) in determining investment signals in competitive electricity markets was analysed. Paper analyse the ability of competitive electricity markets to deliver the desired quantity and type of generation capacity and also investigates the variety of market imperfections operating in electricity generation and their impact on long-term dynamics for generation capacity. Paper analyses how price formation influences investment signals. Number of factors (including market power, wholesale price volatility, lack of liquidity in the wholesale and financial market, policy and regulatory risks etc.) contribute to polluting the price signal and generating sub-optimal behaviour.

Key words: power generation, nuclear power plant, electricity market, market uncertainty, investments, generation capacity

1 INTRODUCTION

The recent high volatility in fuel markets, combined with environmental regulation policies, has introduced major uncertainties into the planning of generation capacity expansion. These uncertainties make generators' decisions to invest in new capacities more difficult.

Volatile fuel prices, concerns about the security of energy supplies, and global climate change are coinciding to strengthen the case for building new nuclear power generation capacity.

There is an emerging consensus that there is no obvious “silver bullet” for addressing the global energy and climate challenge - the solution will be comprised of a variety of technologies on both the supply and demand side of the energy system. In addition to energy efficiency and low-carbon renewable options, two technologies that could do much of the heavy lifting in the future are carbon capture and storage (CCS) and nuclear power (NP). However, the views on NP and its potential role in meeting the projected large absolute increase in global energy demand, while mitigating the risks of serious climate disruption, are highly divergent. Part of the continuing controversy is due to the large risks and uncertainties underlying the cost elements of NP and electricity market price. These risks and uncertainties are reflected in the wide range of cost estimates. The cost overruns and schedule delays of Finland’s new Olkiluoto plant and French Flamanville, are rekindling old fears about NP being far too complex and costly, and raising new questions about the viability of new nuclear plants, especially in deregulated electricity markets. Indeed, the costs of nuclear power stations (and large coal-fired power stations, particularly those with carbon capture and storage) remain uncertain. On the other hand, the fact that countries seem keen to build nuclear power stations suggests that their relative cost compared to low-carbon alternatives still seems attractive to at least some potential investors.

Proponents argue that in relation to the objectives of electricity supply security, resource efficiency, and mitigating the threat of climate change, NP performs very well. NP represents a well-established technology for generating electricity that produces no carbon or other climate- relevant emissions; NPP is amenable to significant scaling-up and thus can provide large amounts of power; and NPPs uses a natural resource (uranium) with advanced technologies, it could provide enough fuel to meet the world’s electricity needs for several centuries. Sceptics claim that NP is costly and technically complex. It involves the use of highly toxic materials that must be kept secure from attack or theft. Moreover, a viable technology for the permanent disposal or reprocessing of spent nuclear fuel has not yet been fully demonstrated. Finally, even in a carbon-constrained world, NP may be less economically attractive than a host of decentralized energy efficiency and distributed generation technologies.

2 INVESTMENT AT ELECTRICITY MARKET

In several industries, market participants must make decisions about capacity choice in a situation of radical uncertainty about future market conditions and decide on the level of output to be produced after the state of nature has unravelled. These industries are normally characterised by non–storability and periodic and stochastic demand fluctuations. In these cases capacity determination is a decision for the long term, whereas production is adjusted in the short run.

In the electricity sector, generation must takes place just in time, and ought to ensure second by second supply demand balance, but capacities need to be installed well in advance, at times when companies face considerable demand and cost uncertainty when choosing their capacity. For electricity markets it is moreover well-known that demand fluctuates systematically over each day, month or year. It is natural to expect that companies try to anticipate those patterns when they make their investment decisions. Electricity generation is generally considered the typical example of an activity that is most effectively carried out by establishing a competitive market.

But also investment in new power is essential for a well-functioning electricity market. Still, today decisions pertaining to investment in new capacity are surrounded by considerable uncertainties about the future economics of the projects. One reason is that in a deregulated market private investors typically have to bear a greater portion of the investment risk compared to a monopoly utility in a regulated market. This favours flexible investment alternatives with short-lead times and low capital requirements. Moreover, energy and climate policy – with feed-in tariffs for RES or green certificate system and the European emission trading systems for CO_2 (EU ETS) - may add to investment uncertainties. Delayed and uncertain permitting processes also increase investors' risks.

3 SECURITY OF SUPPLY ON ELECTRICITY MARKETS

Security of electric power supply become recently very important issue in energy policies but the adaptation of command and control rules that entailed a certain level of security of supply in the monopolistic context to a state of competition has not been trivial. It has represented the transition from a monopolistic organisation to a competitive one. This normally means an increase (rather than reduction) in the level of complexity in the market structure and regulation.

Matters related to security of supply can be defined in many different ways, and the term Security of Supply can mean different things in different countries and in a variety of contexts. It also includes a number of different concepts.

Security of supply incorporates the sufficiency of supply sources and/or production capacity to meet peak demand at a reasonable cost (*Supply Adequacy*). It also includes the availability of flexible and reliable import, transmission and production capacity to deliver energy when and where it is required (*Reliability*). Finally, security of supply also takes into consideration the ability of the system to mitigate the risk of one or more sources of supply becoming restricted or very expensive (*Diversity*).

The definitions that are used in the sector for issues related to Reliability and Security of supply [1].

- Supply Adequacy is a measure of the capacity of the power system to serve the aggregate electric power and energy requirements of the customers within the quality standards (voltage limits and ratings) of the system and taking into consideration planned and unplanned outages of the system components.
- Reliability of the system means in general, the ability to deliver at each point in time and at each location of the network, within a specified safety standard, the amount of power desired.
- Security of supply covers a wide range of measures of power system ability to withstand sudden disturbances (such as electric short circuits or unanticipated losses of system components). Security of power supply is a complex concept that involves a number of actions necessary to guarantee system integrity. It includes supply adequacy, reliability and diversity.

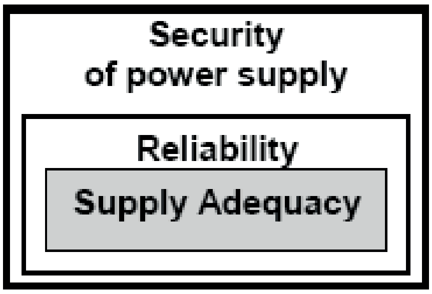

Figure 1 Security of power supply, Reliability, Supply Adequacy [2]

3.1 Supply adequacy issues in electricity markets

Investment decision under uncertainty in energy markets has attracted significant attention in recent years, and policy makers in many countries are debating whether competitive wholesale electricity markets are providing appropriate incentives to stimulate adequate investment in new generation capacity. Looking at the evidence deriving from different markets shows that organised wholesale markets are currently failing to support investment in generation capacity, mainly because of the inefficiency of price signals during peak hours.

One idea to solve this problem is Capacity payments that maybe will be able to restore efficient investment incentives. Some recent policy contributions highlight that policy intervention may have a significant effect on the quantity (and type) of additional capacity installed.

Non-storability and the periodic fluctuation of demand and supply have a major impact on the economic behaviour of markets presenting these characteristics.

In the last century, the electricity supply has been designed mainly in two variants:

- A vertically integrated public monopoly; or
- Different local monopolies for the distribution-retailing phase for small customers and a national company in the production-transportation phase, integrated by a long-term contractual relationship.

The opening up of the network system imposes a new organisational style based on competition between producers. According to this new model there are phases in which competition is possible, and others characterised by monopolies. The distribution and transportation networks are considered natural monopolies, thus controlled by a regulating body that has to ensure access to every company, whereas the production and the selling (wholesale and retail) are free activities based on competition. With the liberalisation process of the electricity market, regulated monopolists have been transformed into competing companies.

Competitive wholesale markets for electricity and energy often fail to provide adequate net revenues to attract investment in generation to meet reliability criteria. In addition, it is also argued that short-term price volatility is more extreme and frequent than in other commodity markets, because storage for electricity is too costly for commercial application.

Lastly, another factor that is considered crucial when evaluating the adequacy of new capacity investment is the possibility, for the policy makers, to change market rules and market institutions.

Impacts to investment decision can be market based and policy based risk factors.

Impacts of *typical market based factors* to electricity investment are:

i) large variations in demand over the year;
ii) the need to balance physically the supply and demand and supply at every point of the network;
iii) non-storability of electric power;

iv) inability to control power flows to most individual consumers;
v) limited use of real time pricing by retail consumers;
vi) necessity to rely on non-price mechanism (blackouts) to ration imbalances, because markets cannot clear quickly enough to do so.

In this context in order to make sure that an economic signal (price of the electric power and ancillary services) reaches the market it should exist mechanism which is able to make consumers' preferences explicit to suppliers.

Policy based risk factors are those related to the various forms that policy intervention may take in energy markets in order to minimise the effects of the specific features of the energy market on consumers. It is possible to distinguish between "ordinary" market uncertainties and uncertainties that are induced by policies. Market and other external uncertainties such as fluctuations in fuel prices and reservoir levels can to some degree be perceived as easier to manage than the uncertainties that stem from various policies. However, policy uncertainty either encourages investors to adopt a - wait and see strategy or increases the risk premium they require on their investments. Both can increase costs for consumers by pushing up market prices. At the same time environmental policies may require additional investments to meet tighter standards, or for some capacity to close.

The problem is particularly acute for investments such as nuclear, carbon capture and storage (CCS) and renewables that rely not on a tangible commodity that consumers need (energy), but on markets created by government to reflect benefits to society (carbon reduction). They typically consist in price restrictions, regulatory uncertainty and regulatory intervention.

- *Price restrictions* - A price cap is sometimes required to protect consumers against excessive prices in times of scarcity. This is normally a regulatory intervention with high distorting power when it comes to investment decisions because it is difficult to determine the optimal level of an efficient price cap. As a consequence it is typical to have a long-run average shortage of capacity and too little reliability in most electricity system.
- *Regulatory uncertainty* – Investment risk is significantly affected by regulatory intervention. These factors are considered among the main drivers for inadequate generation capacity. Policies intervention may cause prices in electricity not to raise high enough to support new investments, particularly because regulators will be unwilling to allow prices to spike during periods of system tightness due to concerns surrounding market power.

4 THE IMPACT OF LIBERALIZATION OF MARKETS ON INVESTMENT CHOICES IN NUCLEAR POWER

Since future investments in nuclear power generation capacity will be made within this new market context, it is interesting to see the impact of this modification on investments choices made by electricity producers. In particular it is question if electricity generators who will have chosen this production means will continue to prefer large capacity units as they did in the past, to optimize the benefit of the size effect and thus enjoy attractive production costs, or if the uncertainty related to the competitiveness of electricity markets will encourage them to choose smaller units to reduce the risk. In other words, how to choose between the flexibility of the modular investment and the efficiency of the high capacity unit due to increase in economy of scale?

Intuitively, the solution offered by modular power plants would appear to be most suitable for a competitive environment with strong uncertainties about the supply and the price of electricity. Because of the irreversibility of the investment in the high capacity unit, it is optimal for the producer to invest only if the market price of electricity is high enough compared to the cost of electricity. The option of making sequential decisions when several medium sized nuclear modules are used enables the producer to be more aggressive in its investment strategy by initiating the construction of the first unit at a smaller critical price of electricity.

The presence of uncertainties of future returns and costs are amongst the more critical factors affecting the willingness to invest.

In the context of a liberalized market environment, investment in power generation comprises a large and diverse set of risks. These business risks include [3]:

- factors that influence the demand for electricity and impact the supply of capital and labour;
- regulatory controls (economic and non-economic) and political risks that generally affect revenues, costs, and financing conditions;
- price and volume risks in the electricity market;
- fuel price and supply risks; and
- risks arising from the financing of investment.

The presence of uncertainties of future returns and costs are amongst the more critical factors affecting the willingness to invest. There is however little consensus in the economic literature on how and to what extent policy uncertainty connected to carbon pricing specifically (e.g., emissions trading schemes) will affect investment behaviour in the power sector suggests that climate policy will not add any significant uncertainties for electricity investors in the future, and even stimulate firms' investment incentives, at least if the policy is consistent over a longer time period. The main obstacle for investors is instead the fuel price. Thus, it is important to analyse how the implementation of a specific policy affects the behaviour of the investor.

4.1 Market uncertainty and NPP

The actual competitiveness of NPP must be analysed in a wider perspective. It cannot only rely on the analysis of greenhouse gas emissions; since nuclear is a very complex and expensive technology and many more aspects come into play. The liberalization of electricity markets shows that the fate of nuclear is strongly affected by energy market structure. The loss of some main favourable conditions (governmental support, certainty of demand, a price regime based on recovering the production cost increase by charging higher prices to consumers, etc.), lead to a drop of the number of nuclear plants built from 1990 to 2005 to only 1.7 nuclear plants per year (mainly in developing countries) compared to 17 nuclear plants per year built in the period 1970-1990. In liberalized electricity markets decisions about energy technologies are driven by the expected returns, taking into account the risks (afforded by the company, rather than by consumers as in a monopoly regime) linked to costs and revenues. Moreover, nuclear energy has to face new competitors such as renewable source technologies, characterized by a lower carbon content, better environmental footprint, increased population acceptance and higher growth rates favoured by cost reduction driven by technological innovation.

5 ECONOMIC AND FINANCIAL RISKS OF NUCLEAR POWER

From a strictly economic point of view three main risk factors are must be considered: (a) construction time, (b) investment costs and (c) variability of operating costs. Most of the existing plants have been built under a monopolistic regime, with governmental guarantees and controlled market prices, low capital costs and low investment risk. The investment risk, and the capital cost increased with deregulation of energy markets and were charged to electrical companies, penalizing capital intensive investments projects with long time return on investment and low technological flexibility [4]. Instead, investments in alternative power sources, like combined cycle gas turbine plants and smaller renewable plants have been favoured [5]. In such a context, investments on nuclear sector became uncertain and very variable. Considering a large size nuclear plant (1000-1600 MW), construction costs are up to 10 or 15 times higher than those required for the construction of a natural gas plant (100-700 MW). The projected costs also tend to increase due to the extension of construction time (cost overruns). Finally, costs for nuclear plants decommissioning are estimated as about 25% of the original investment costs. The total costs of a nuclear plant can be split into about 60-75% *fixed* costs (capital repayments, interest allowed, decommissioning costs) and 25-40% *variable* costs (for instance, the cost of uranium and labour). Unlike gas and carbon plants, the share of nuclear fuel cost on total production costs is small.

While the cost of electricity uncertainty factors related to security aspects, licensing, escalation of decommissioning costs, radioactive wastes disposal, might contribute to increase the financial risk perceived from private investors and, consequently, the level of expected return. Rogner and Langlois [6] highlight that the future of nuclear power depends on the competitiveness strategies that industries, supported by technological innovation, will adopt to guarantee the economic and financial sustainability and reduce the safety risks. Such targets require strong political support to the nuclear industry. For instance, the problems related to waste disposal and safety involves suitable technological solutions and communication, able to achieve social consensus. Therefore, an energy policy which includes the use of nuclear power among its energy sources will have to handle three problems: overcoming the scarcity of public funds, choosing the best nuclear technology available, and finally conducting a cost-benefit analysis to compare nuclear with others renewable sources [7].

In liberalized markets investments are profit motivated, with the choice of technology left to the market. The redistribution of risk among the different stakeholders is likely to make nuclear generation unattractive for an investor, even when its levelized costs are similar to the levelized costs of the dominant technology, for several reasons.

First, investors have a strong preference for a shorter payback period, which makes investments with short lead time more attractive. Nuclear lead times (5 years in the most optimistic scenario given the historical record) are, for engineering and licensing reasons, much longer than CCGT lead times (2 years).

5.1 The challenge of financing nuclear power

With its capital intensity and cautionary experiences of engineering difficulties and regulatory creep during construction, new nuclear build is likely to require a substantial risk premium over competing technologies.

Given all these challenges to new nuclear build, what explains the 2004 decision to build a new nuclear power unit in Finland? The large capital costs of the plant have been financed by very long-term power purchase agreements. Interest in such long-term agreements, which are rare in liberalized markets, has been triggered by the specificities of local industries that have very long investment cycles and are extremely sensitive to the price of electricity. The Finnish electricity company Teollisuuden Voima Oy (TVO) is a cooperative grouping of local utilities and large industrial consumers, which are mainly paper makers with a very long investment cycle (over 40 years). Each shareholder will enjoy electricity at production cost during the life of the plant (60 years), i.e. at a very stable price, in proportion to its share, as well as holding a useful option on the future carbon price.

These long-term power purchase agreements enabled financing at low cost, which substantially improves nuclear economics. The Finnish case is therefore in many ways reminiscent of the institutional environment that made nuclear a competitive technology in the days of regulated monopoly (at least for certain fuel price configurations), through the transfer of investment and operation risks to consumers via contractual arrangements.

The Finnish example reminds us that low discount rates are obtainable in liberalized markets when the risks have been adequately mitigated, in this case by very long-term effectively fixed price power purchase agreements with large, credit-worthy consumers who necessarily (given their involvement in the forest industry) must take a very long-term outlook. It is not impossible to identify such consumers in other liberalized markets, but the dominant assumption is that electricity consumers are generally uninterested in hedging their risk exposure to electricity price fluctuations.

Vertically integrated companies with both generation and retailing can effectively internalise the risk of wholesale power price volatility without an explicit contract, and are thus well placed to hedge wholesale price risks.

5.2 The potential financial benefits of nuclear power

There are potentially two attributes of nuclear power generation that could make it more appealing to investors. First, nuclear generation costs are insensitive to both gas and carbon prices (as are most renewables). Therefore, rising gas prices and carbon trading or carbon taxes will make nuclear more competitive against CCGTs and coal-fired plants. Second, investing in nuclear can be thought as a hedge against the volatility and risk of gas and carbon prices for a (large) generating company. The uncertainty over the evolution of gas and carbon prices implies that there is an option value associated with being able to choose between nuclear power and other fossil fuel technologies in the future. Moreover, the hedging value of a nuclear power investment to a company is not restricted to the insensitivity of this plant to gas and carbon price risks. For a company already operating some fossil fuel generation plants, investing in a nuclear plant reduces the company's overall exposure to fossil fuel and gas prices.

While most valuation studies of competitive generation technologies take account of different gas and carbon prices through sensitivity analysis, as far as the authors know, there is no published study valuing nuclear as a hedge against uncertain gas and carbon prices from a company perspective. Assessing the economics of a nuclear or CCGT power plant investment from a company perspective requires taking into account the complementarity of the risk-returns profiles of the different technologies that the company operates.

6 INVESTMENT IN ELECTRICITY GENERATION - THE UNCERTAIN FINANCIAL AND ECONOMIC FUTURE

If nuclear power is relevant to future energy needs, several factors must be taken into account. While electric growth in developed countries has been very low over the last decade, there is no assurance that this trend will continue. Even growth that is quite modest by historical standards would mandate new plants. Replacement of aging plants will call for still more new generating capacity.

In addition to the slowdown in electric load growth, power plants also have been cancelled and deferred due to the widely acknowledged deterioration in the financial condition of utilities.

Looking ahead, the prospects for substantial numbers of new central station power plants appear fairly uncertain. The prospects for more nuclear plants appear even more uncertain.

The ratio between electricity growth rates and GDP growth rates has indeed dropped.

Future growth of GDP is a major source of uncertainty, both because income and industrial production are assumed by economists to have major impacts on electricity demand, and because of some deep uncertainties about the future direction of the economy. Even the fairly narrow range of GDP growth rates of 2 to 3 percent that has been assumed by the major electricity demand projections implies a range of electricity demand growth rates of about 2 to 3 percent over the long run if electricity demand follows the income response patterns identified in recent the past.

Future electricity prices and their impacts are a second source of uncertainty about electricity demand growth. This is both because there is disagreement about future change in electricity prices and because there is uncertainty about how electricity demand responds to electricity prices.

There is generally less agreement about the impact of electricity prices on electricity demand than there is about the impact of changes in GDP. Most analysts agree that the short-run response of electricity demand to an increase in electricity prices is very limited.

The combined effect of uncertainty about future electricity and natural gas (and oil) prices and uncertainty about how electricity demand responds to changes in electricity prices is enough to explain a range of uncertainty in electricity demand from very slow growth to quite rapid growth.

Power companies' executives contemplating the construction of long lead time power plants must contend with considerable uncertainty about the probable future growth rates in electricity demand.

In summary - the need for new power plants depends on both the growth rates in electricity demand and on the need for replacement of existing generating capacity.

7 NUCLEAR POWER GENERATION: COST–BENEFIT ANALYSIS UNDER UNCERTAINTY

Few years ago started so called nuclear renaissance that could be attributed to:

- An extremely strong record of global nuclear operations, with no high-profile incidents, for over two decades helped shift the perceptions about the environment and health risks of the nuclear energy.
- There was a fading memory of the Three Mile Island and Chernobyl accidents.
- High volatility in the fossil fuel prices called for an increased diversity in electricity generation, and

- Increased public concern over the greenhouse gas emissions meant that nuclear energy was one of the leading candidates to shoulder the increased future energy demands.

The events in Fukushima however derailed the onset of a nuclear renaissance with the focus back on the safety of NPP. These events are likely to cause major regulatory changes thus further increasing the uncertainties in already uncertain economics of the nuclear industry. It can be argued that the nuclear renaissance began faltering even before the unfolding of events at Fukushima. This was due to the concerns over the large risks and uncertainties underlying the cost elements of nuclear power. These risks and uncertainties were reflected in the wide range of cost estimates for nuclear power plants. The cost overruns and schedule delays of Finland's new Olkiluoto plant and France's Flamenville plant are rekindling old fears about nuclear power being far too complex and costly. This raises new questions about the viability of new nuclear plants, especially in deregulated electricity markets.

Negative wholesale prices have become more common as European countries turn to renewables, particularly Germany with its forced march away from nuclear power, known as the *Energiewende*. Neighbours such as Poland and the Czech Republic complain that power surges from Germany are playing havoc with their grids [8]. Across Europe a strange consequence of subsidised renewables is that some governments now want to pay power companies to maintain the capacity to produce electricity from fossil fuels to ensure that backup power is available. More perversely, Europe is burning more heavily polluting coal at the expense of cleaner and more flexible gas. This is because coal is cheap, the gas market is far from liquid and the carbon-emissions systems broken [8]. Therefore, in the longer term, increasing concerns about the CO_2 emissions added to the need for electricity in bulk without intermittency may imply stronger prospects for nuclear power. The future of nuclear power depends on resolving the issues of safety of operations, safe management of radioactive wastes and measures to prevent proliferation [9]. However, in a deregulated electricity market, the economics of NPPs will also be an important determinant of nuclear energy's role in the future global energy mix.

Current electricity price on Power Exchanges (Figure 2 show recent prices of electricity and CO_2 allowances on EEX and HUPX power exchange and base price for next year) are so low that no new Power plant can be competitive on electricity market and that almost all investment will be in renewable energy sources because of support schemes (feed-in tariffs or Green certificates).

New nuclear generating capacity would give rise to direct costs as well as a range of external costs and benefits. These would call for the valuation of the following:

- environmental benefits - reduced GHG emissions to be gained from adding nuclear rather than coal- or gas-fired generating capacity;
- fuel mix diversification value of nuclear power as a hedge against uncertain fossil fuel and carbon prices;

- costs of radioactive waste disposal;
- risks associated with radioactivity release from all fuel cycle activity;
- risks of proliferation from the nuclear fuel cycle; and
- financial liabilities arising from the back-end activities of the nuclear fuel cycle-e.g., decommissioning and waste management.

It must be stated at the outset that it is difficult to quantify the costs and risks related to nuclear safety and especially to nuclear proliferation. It should also be noted that the original risk analysis of nuclear power might have underestimated the true probability of reactor meltdown. And while modern reactors are claimed to achieve a very low risk of serious accidents, this needs to be assessed as it is dependent on “best practices” in construction and operation.

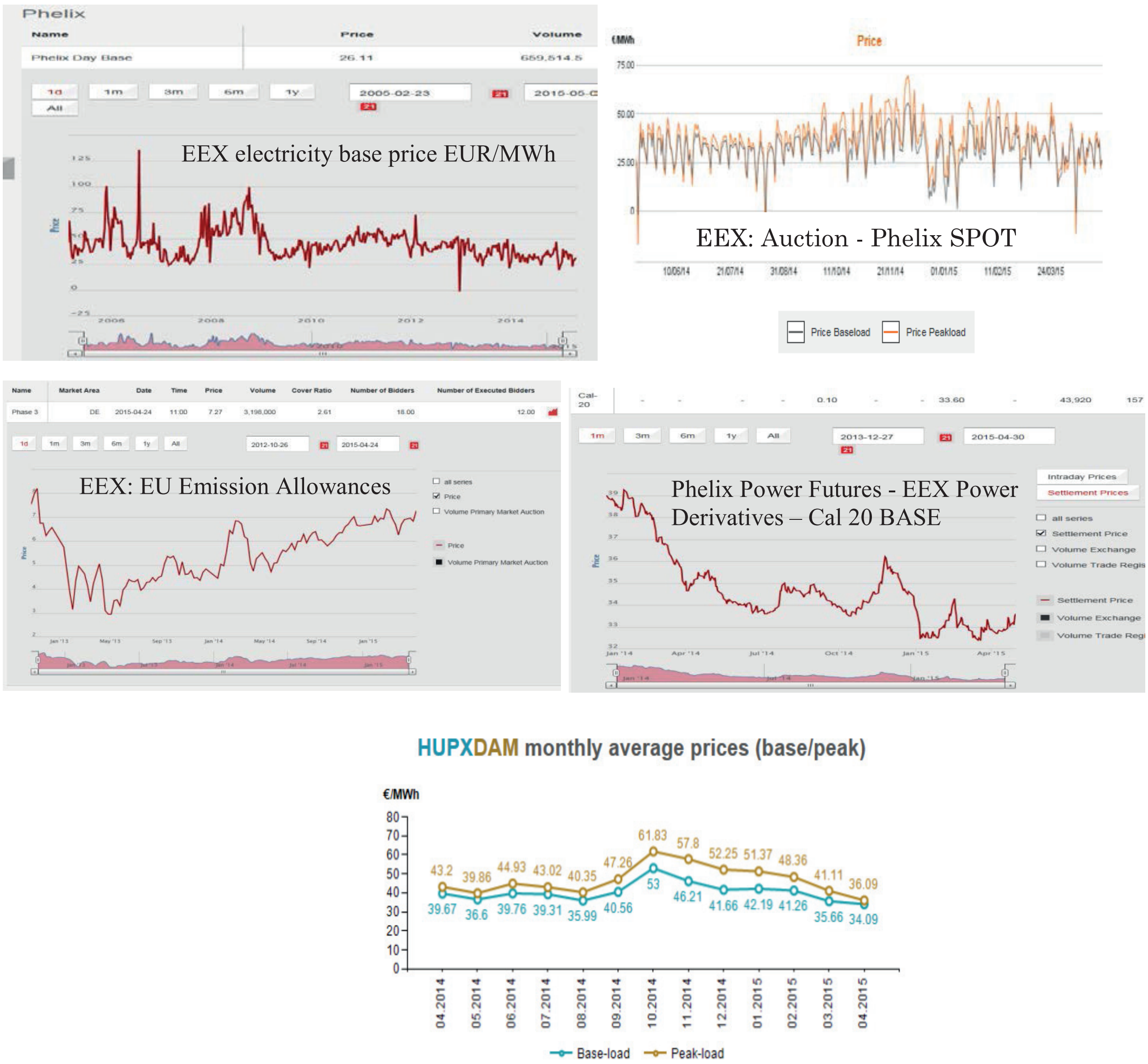

Figure 2 Market prices of electricity and CO_2 on EEX (Phelix) and HUPX

8 ALTERNATIVE CONTRACTING AND OWNERSHIP PRACTICES FOR NEW NUCLEAR POWER PLANTS

Innovative financing techniques have been investigated to disentangle the high construction risks from the lower operation risks of new nuclear build. Whether it involves project finance or corporate finance, the financing arrangements of a nuclear power plant are likely to involve refinancing once the plant has started production.

Countries embarking on a nuclear program, as well as countries whose programs have been dormant for extended periods of time, have expressed a number of common challenges that include the availability of the required human resources, securing financing, and managing waste. Some alternative contracting and ownership schemes, such as Build-Own-Operate ("BOO"), Build-Own-Operate-Transfer ("BOOT") models, and regional ownership approaches might address these common challenges. These structures have been used in non-nuclear power projects and in other industries successfully for decades and although they have been discussed within the nuclear industry community, they have not been used for nuclear power plants until the recent announcement of the Akkuyu project in Turkey.

8.1 Overview of classical contractual and ownership structures

Previously, governments have used public sector funds either using tax revenue or electricity tariff subsidies to finance nuclear power. This enabled transfer of the risks and development costs to a regulated customer base. Whether local industry could provide the nuclear technology or whether such technology had to be purchased from abroad, the end result traditionally has been that owner/operator of the NPP was either government owned and/or regulated through the regulated customer base that it serviced.

However, the recent trend shows that globally governments are increasingly looking for investors to finance new infrastructure investments. Prior and current development of NPPs has occurred either through sovereign or corporate-based structures. This development history is one of leadership by public entities in a regulatory environment that enabled transfer of the risks and development costs to a regulated customer base. As markets have liberalized there is now less opportunity to cover development costs through the regulated customer base. Instead, potential NPPs in those regions must be assessed on the strength of the underlying economics of the project within a competitive market structure.

Traditionally, project structures have favoured the presence of a national or regional utility that has served as the owner/operator. This owner/operator, either on the strength of its own balance sheet or through the support of sovereign funds or guarantees, has provided the equity component for these NPPs with debt financing (both commercial lending and Export Credit Agency financing). Such structures imply that a knowledgeable, well-capitalized entity (most likely, a national or regional utility) will serve as the owner/operator as well as develop the project. In many cases this development is with extra-national assistance for the nuclear technology via Engineering, Procurement, and Construction (EPC) contracts that may include operational assistance as well.

Historically, nuclear power development occurred either (i) as part of a national nuclear power program that has been led by the host government (e.g., France, India, the People's Republic of China), or (ii) by national or regional utility companies that have been able to recover project costs through a regulated rate base (e.g., the current U.S. nuclear fleet). The following are the three basic NPP financing structures: *Sovereign-based model, Corporate-based mode, Project-based model.*

Figure 3 shows the relationship between the different models relative to risk, measured by the following parameters that discuss allocation of risk:

- Degree of market unbundling and market liberalization: The project model scores highest against this parameter, with the sovereign and corporate model scoring lower.
- Amount of risk transferability (from public to private sector): The corporate model scores the highest against this parameter, followed by the project model, then the sovereign model.
- Degree of recourse on shareholders: The corporate and sovereign model score the highest against this parameter (note the government being viewed as a shareholder), followed by the project model.

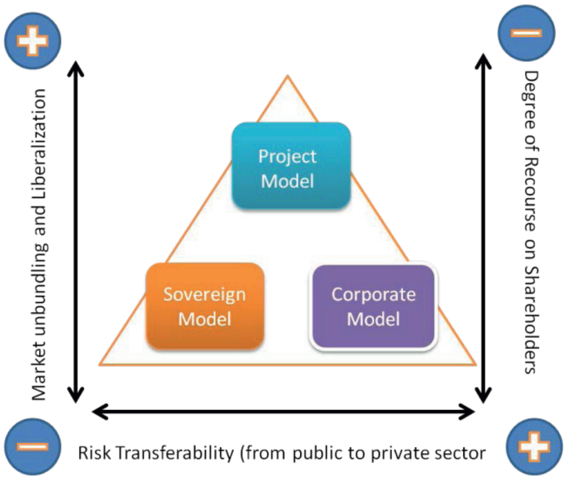

Figure 3 Different Contracting Models and Financing Techniques [10]

8.2 Description of the BOO(T) Concept

In a BOO or a BOOT structure (Figure 4), a private or non-private whereby an entity (called the Developer) is granted the right by the public sector or host government to develop, finance, build, own, operate, and maintain a facility for a specified period during which the entity owns the project and retains revenue and associated risk. Under a BOOT, at the end of the period, ownership of the facility is transferred to the host government. BOO and BOOT structures have been used successfully in a variety of infrastructure projects, but the Akkuyu project in

Turkey is the first in the nuclear industry. Under such structures, the Developer is responsible for bringing together project development capabilities, to include: technology; engineering, procurement, and construction; fuel supply; operations; and financing. As such, these types of contractual arrangements are a package deal since all of the project components of developing a nuclear power plant are included. Very simply, the BOO(T) structure places the responsibility for delivering the project on the Developer.

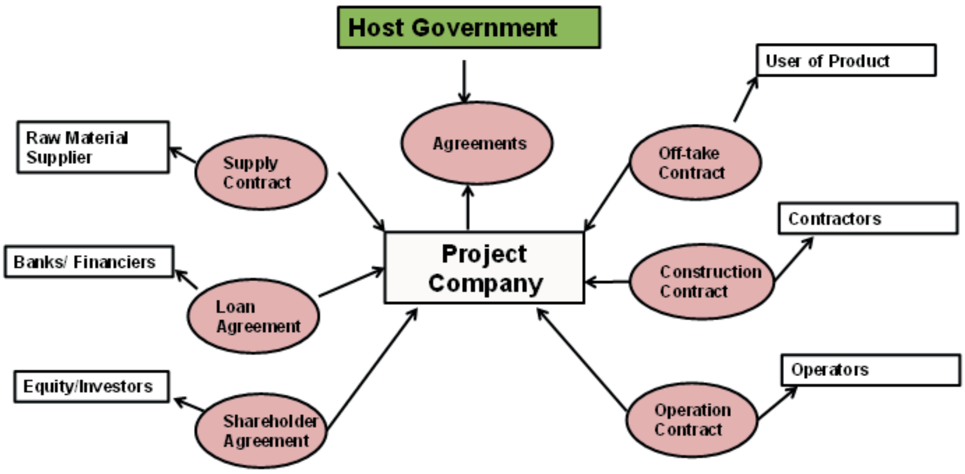

Figure 4 Typical structure for a BOO(T) Project [10]

This is normally achieved by creating a project company, which is a cooperative venture between the private and non-private entity, built on the expertise of each partner, which best meets clearly defined public needs through the appropriate allocation of resources, risks, and rewards. It undertakes the development, financing, construction and operation of a facility.

While Developer concerns will focus, to a large extent, on the linkage between the aggregate costs to develop the project and the sale price of electricity (and the period over which such price might be guaranteed by the host government), the Developer will also look to the many issues in assessing the risks associated with a particular project.

It is important to note that, while a BOO(T) structure could envision a situation whereby the licensed operator could be responsible for both spent fuel and decommissioning, the host government will have to establish the framework under which such tasks are performed.

9 CONCLUSIONS

The purpose of this paper was to analyse how increased uncertainty affects investment projects in the power sector with focus on nuclear power plants. Investment timing and technology choice are of principal interest to not only to policy-makers but also to the various market participants. Due to the non-storage characteristics of electricity, investments are crucial in order to balance supply with future demand expectations and its timing can therefore strongly affect the power price. Furthermore, there exist a limited number of alternative technologies available for power production. Each technology is associated with different cost structures and uncertainties in input price, power price and policy formulations, which together with the irreversibility of the investment affect the investment behaviour.

The nuclear power industry is facing a period of extreme uncertainty. The conclusion that results from review of many studies worldwide is a *uncertain* scenario about the majority of aspects of nuclear energy development. Nuclear development scenarios seem to be associated to higher costs and prices than in the past. Shortages in the nuclear supply chain as well as the indefinite state of spent fuel worldwide could create additional barriers. Significant *uncertainties* are also linked to environmental impacts (uncertain GHG emission estimates, scarce knowledge of the contribution to other impact categories); to financial analysis (nuclear investment in competitive market is penalized compared to renewable sources and gas-fired generation, as it is characterized by high capital costs, long time return on investment and low flexibility; these factors contribute to increase the financial and economic risk for investors) as well as to macroeconomic analysis (it is uncertain the role that nuclear could have in addressing energy security; since gas-fired generation is the major competitor of nuclear in a cost-benefit perspective, the potential benefit of new nuclear is strongly affected by gas prices, carbon prices and nuclear costs).

In particular, when "facts are uncertain, values in dispute, stakes high and decisions urgent", the concept itself of “feasibility” must be converted from “technical and economic feasibility” into a more complex framework, shift from the expert community to an "extended peer community" consisting of all those affected by an impact who are ready to enter into dialogue on it. They bring in alternate points of view, that include local knowledge and expertise not generally accounted for in normal scientific reports.

Now the carbon policy uncertainty has significant impact on power generation investments. At the market level, carbon policy uncertainty incentivizes excess capacity investment in both fossil and renewable technologies, which over long run, given electricity demand is to some degree elastic, can be beneficial for both consumers and generating companies. At the economy wide level sufficient long run policy stringency and certainty is needed in carbon policy to meet near and long term emission reduction targets, with a carbon price of $100/t for carbon dioxide equivalent emission or more.

Despite recent revived interest in nuclear power, the prospects for merchant nuclear investment in liberalized industries without government support do not seem promising. The reason is relatively simple: quite apart from overcoming any regulatory and public opinion difficulties, the economic risks of nuclear power have been adversely affected by liberalization. High capital cost, uncertain construction cost, and potential construction and licensing delays are likely to lead private investors to require a substantial risk premium over coal and gas fired power plants to finance at least the first new nuclear units. Recent cost estimates reveal both the large underlying nuclear cost uncertainties and different interpretations of the impact of liberalization on the cost of finance and hence investment choices.

These results imply that there is little private value to merchant generating companies in retaining the nuclear option in risky European electricity markets with gas and carbon prices.

Because difficulties for financing new nuclear power plants new financing models have been developed like BOO/BOOT structure, Contract for difference in UK or "*Mankala*" model in Finland (whereby a limited liability company is run like a zero-profit-making co-operative for the benefit of its shareholders).

In a BOOT structure, a private or non-private entity is granted the right by the public sector to develop, finance, build, own, operate, and maintain a facility for a specified period during which the entity owns the project and retains the revenue and associated risk. The Developer is the entity that takes the responsibility for delivering the project (i.e., commissioning a nuclear power plant). Under a BOOT, at the end of the period, ownership of the facility is transferred to the public sector or host government. BOO is like BOOT, except the original entity owns the project outright and retains the revenue and associated risk in perpetuity [10].

Recently on the opposite the U.K. Government clearly accepts that there is a social or consumer value in *'keeping the nuclear option open'* as this has formed a part of U.K. government policy [12, 13]. The Finnish experience shows that if well-informed electricity-intensive end users with long time horizons are willing to sign long-term contracts, then nuclear new build can be a realistic option in liberalized markets.

Climate change policies can easily distort market signals, insulating renewables generation from market dynamics. This in turn reduces the proportion of the market that is effectively opened to competitive forces. When renewable support policies are undertaken, investments in conventional technologies suffer (especially in capital intensive investment like in nuclear power plant). This produces distorting effects on the generation mix. Policy intervention, rather than market forces, is able to select artificially winners and losers, thus potentially undermining, in the long run, the necessary diversity of the energy mix.

Carbon policy uncertainty has significant impact on power generation investments and that these impacts can be different depending on which level of investment decision making is being considered. At the firm level, carbon policy uncertainty creates path dependency in resources acquisition with the result that new investment decisions depend on the existing power generation assets and how they interact with the carbon policy risk.

At the market level, carbon policy uncertainty incentivizes excess capacity investment in both fossil and renewable technologies, which over long run, given electricity demand is to some degree elastic, can be beneficial for both consumers and generating firms. At the economy wide level, our results show that sufficient long run policy stringency and certainty is needed in carbon policy to meet near and long term emission reduction targets, with a carbon price of $100/t for carbon dioxide equivalent emission or more.

Currently nuclear power plants present too many financial risks as a result of uncertainties in electricity market, electric demand growth, very high capital costs, operating problems, increasing regulatory requirements, and growing public opposition. However, enough utilities have built and building nuclear reactors within acceptable cost limits, and operated them safely and reliably to demonstrate that the difficulties with this technology are not insurmountable.

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