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Financing the Nuclear Renaissance

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Abstract This paper considers the key economic risks associated with nuclear power. The authors observe that the bulk of the risks of a nuclear power station project fall during the roughly five year period of plant construction. This window of risk follows a lengthy siting process and comes before power station operations lasting up to sixty years. As a consequence of the nature of the economic risks, operational nuclear power plants are more attractive targets for initial investment than new build projects. The authors suggest that the first glimmers of a US nuclear renaissance were visible in 2000 when dramatically higher prices were achieved for second-hand nuclear power plants following a period of depressed prices in the 1990s. The paper closes with a consideration of the prospects for nuclear new build in both Europe and the United States and the key financial and economic factors that could drive such developments differently in each case.

Keywords Finance, Nuclear Power, Electricity Generation, Economic Risk, Energy Policy

JEL Classification G31

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1. Introduction

There is much talk about, and some action towards, a nuclear renaissance in Europe and North America. Elsewhere in the world, particularly in East Asia, the development of nuclear energy has been a story of continuous growth and expansion. In the west, the growth of nuclear energy largely stalled in the late 1980s. In this paper we shall consider the financing of a possible return to the building of new nuclear power plants (NPPs) in Western European and the US.

Several factors contributed the turning away from nuclear energy following the optimism, even hubris, of the 1960s and 1970s. Key factors included:

- The accidents at Three Mile Island, Pennsylvania in 1979 and Chernobyl, Ukraine in 1986.
- The growth of effective single issue pressure groups and widespread concern on issues such as the environment, the Cold War and nuclear weapons
- The availability of major reserves of non-OPEC oil and natural gas
- The development of highly efficient closed cycle gas turbines (CCGTs) for electricity generation

and most importantly, in the context of this paper:

- Policy pressure towards liberalized electricity markets and a consequent increase in the risk and so required return on investment in generation assets.

2. The Cost Structure of Nuclear Power

While much has changed since the 1980s, certain things remain the same and one key reality is that the lifetime-levelised costs of nuclear electricity production are dominated by capital costs. The cost breakdown is roughly: 66% capital investment, 20% operations and maintenance and 14% fuel-related costs [1]. These figures assumed a discount rate of 10% real post-tax [2]. The fuel cost comprises much more than the price of the uranium yellowcake (U_3O_8) produced from the milling of uranium ore. That stage of refinement is perhaps analogous to a prepared fuel intermediate between power station anthracite and refined fuel oil. In the nuclear case however, for most modern NPPs, the uranium in the yellowcake must be enriched, formed into oxide fuel pellets and carefully canned and prepared in fuel assemblies appropriate to the reactor type. As such, for a Pressurised Water Reactor operating a "once-through" fuel cycle only roughly one quarter of the fuel costs relate to the yellowcake precursor [3]. In this way lifetime levelised costs are only very weakly sensitive to fluctuations in uranium market prices. This is in complete contrast to natural gas fuelled CCGTs for which fuel costs represent roughly two thirds of total generation costs. The development of the CCGT in the 1980s provided emerging liberalised electricity markets with a perfect technology – a flexible, modular, relatively small scale power-plant that could be built quickly and for which the marginal costs of electricity production were high. As the presence of this new technology grew in the market (especially in the UK via the "dash for gas") gas and electricity prices became more strongly correlated (and the gap between them - the "spark spread" became a useful concept). With a relatively stable spark spread a greater proportion of the economic risks of electricity production could be passed through to final electricity consumers [4]. That is generators could pass through the costs of high priced gas through the sale of high priced (but competitive priced) electricity. In contrast risks of poor reliability of individual nuclear power plants (low load factors) could not necessarily be covered by increasing revenues for the company elsewhere in the electricity market.

Nuclear energy, and renewables, however, present a wholly different risk profile to the market. In both cases the marginal cost of operating the installation is very low, and may, in-extremis, even be negative for short periods. In the case of a new NPP the following aspects are noteworthy in the countries of concern to us: first the plant could be expected to operate for 60 years far beyond the horizon of any conventional calculations of net present value. Second, between the decision to proceed and the first sale of a unit of electricity there would typically be a gap of at least ten years. The first five years is not especially troubling to the project developers, as during this phase safety and environmental approval is obtained. It is essential that the developers should incur no major costs at this initial stage and that they should preserve the ability to abort the project without significant loss in the event that the necessary approvals are not granted. It is the period from five to ten years that is most daunting to the project developers as it at that this stage that the greatest costs are incurred (in construction). It is in this phase that engineering risks, political risks and project finance risks become most acute, because a partly completed power station is almost worthless and any time delay is very expensive because of the capital sunk in the project. The consequence of these realities is that the financial attractiveness of nuclear energy, and of new NPPs, is revealed to be very different things. We shall consider this matter further in section 4.

It is clear that nuclear power plants are expensive items, but there are relatively few examples where the financing has been sufficiently transparent and simple that a price paid (as opposed to a price quoted) can be determined. The 2003 MIT Report on nuclear power presents data from new build projects in Japan from the 1990s and early 2000s. These data (in 2003 USD) yield an NPP price of roughly $2,500/kWe, equivalent to €2,250/kWe capacity at a 2003 USD to EUR rate of 0.90 [5]. At the 2008 BP Forum meeting in Madrid it was suggested that in 2008 new build NPPs in Europe should be expected to cost roughly €2,500/kWe capacity. This is roughly consistent with the earlier Japanese experience, and the 2003 MIT report, allowing for inflation and currency fluctuations. We note however that rising global commodity prices are having a strong effect on nuclear power plant construction cost estimates. In the United States HIS CERA have announced a 69% rise in US nuclear power plant construction costs since 2005 [6].

Since the nuclear dark days of the early 1990s much has changed to prompt a renewed interest in nuclear energy. Plausible claims have been made by NPP design companies that their newer designs will be simpler, quicker and cheaper to build although such improvements are unlikely to be dramatic for the earliest projects in any renaissance. Perhaps the most important change has been the rise in concern for climate change and the growing consensus that something must be done to reduce harmful greenhouse gas emissions. Notwithstanding several published claims to the contrary, nuclear energy and its full associated fuel cycle is indeed a low-carbon energy technology with emissions roughly comparable to certain renewables such as wind power [7]. Increasingly, in the markets of concern to us, a price is now being applied to greenhouse gas (GHG) emissions from fossil fuel power plants and, as such, the relative economics of low carbon electricity generation options is favoured. In Europe the key instrument is the EU Emissions Trading Scheme. An effectively functioning mechanism for pricing carbon is an important part of the case for any nuclear renaissance in Europe, but the volatility of the associated permit prices has caused some concern to those planning major capital investments such as, in particular, new NPPs.

Even if carbon prices turn out to be low or the ETS is not continued, a continuing high price of oil (and hence gas) and coal would provide an economic case for NPPs. But that case is far stronger if the cost of fossil fuel based generation includes the carbon dioxide emitted (see figure 1).

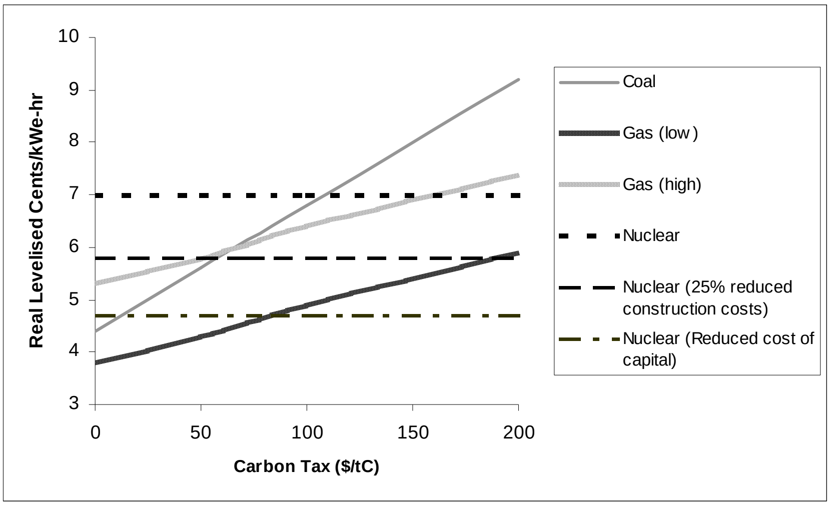

Figure 1. Real levelised lifetime costs of major electricity generation technologies as a function of applied carbon price (tax) as estimated by MIT in 2003. Linearization of data presented in the MIT Report [5]. The analysis assumed returns of 12% to equity investors for coal and gas investments and 15% for nuclear investments. The low and high gas price scenarios were $3.50/MBTU and $4.50/MBTU respectively. In terms of carbon pricing, fossil fuel costs and nuclear construction costs much has changed since these data were assembled in 2003. With thanks for Fabien Roques for preparing this figure.

According to the assumptions of the 2003 MIT report, new NPPs were uneconomic when compared to both gas and coal based electricity. In Europe this relative weakness may be overcome via moves towards carbon pricing, most notably in the form of EU-ETS traded permits. The United States has thus far refused at a Federal level to formalise the status of carbon dioxide as an atmospheric pollutant and as a consequence moves towards carbon pricing in the US has been slow and patchy.

The final factor that is driving renewed interest in nuclear energy is the security of supply of key fossil fuels and in particular the risks associated with international fuel trading in a world of evolving geopolitical risks (including from non-state actors), geographical concentration of fossil energy resources and the rise in power of national oil companies and their gas analogues. Nuclear power with its inexpensive high energy-dense and easily stored fuel (available from numerous stable parts of the world) is by comparison increasingly perceived as a secure source of electricity; perhaps in some western markets, excessively so. But for these concerns to translate into economic incentives for private investors in NPP, governments would need to set up a mechanism that rewards lower risk energy or promotes diversity. Such mechanisms are in conflict with liberalised markets though and countries like the UK it is not clear how an energy policy based largely on market forces could accommodate these strategic concerns.

To summarise: those planning a new NPP must confront the following significant economic risks, which can be divided into those during the construction phase and those during the operating phase:

Risks during construction phase:

i. Overrun of construction schedule (lost time is lost money)
ii. Changes of safety or environmental regulation during planning and construction
iii. Political risk and public acceptance problems, especially arising from events in other countries after construction has started

Risks during operating phase:

i. Uncertainty over future electricity prices (as for any power technology), which will in many cases be set by the price of gas, which is linked to oil
ii. Risk of a low carbon price
iii. Poor plant reliability in operational phase (low load factor)

The upshot of these is that private investors will expect relatively high rates of return *ex ante*, especially during the construction phase when a lot of capital is committed but the timing of revenues is uncertain. The history of NPP construction in the US especially is a very discouraging one and investors will need to be convinced that plants can be built to time and budget with minimal risk of regulatory or political intervention after construction has started.

Once a plant is commissioned the risk drops significantly, and it should be possible to re-finance the capital invested in the project at a much lower return, in line with experience in other capital intensive industries.

It is important to stress that several factors are of only minor importance:

i. Decommissioning costs (40-60 years in the future)
ii. Fuel costs (raw U_3O_8 is only a few % of total costs)
iii. Geopolitical risks (fuel is easily stored and is usually regarded as “domestic” for energy security purposes)

3. First Signs of the Renaissance

In the preceding sections we have argued that new NPPs represent a daunting undertaking for participants in liberalised electricity markets. In the early days of the new electricity markets new nuclear build appeared to be an impossibility, however in recent years certain key factors have started to alter.

If our understanding of these issues is correct then one should expect that the electricity industry would indicate an interest in already completed NPPs before any interest is shown in building new plants. This is because most of the key risks are associated with the construction and licensing phase. Pre-existing plants have the advantage that these difficult hurdles have already been passed.

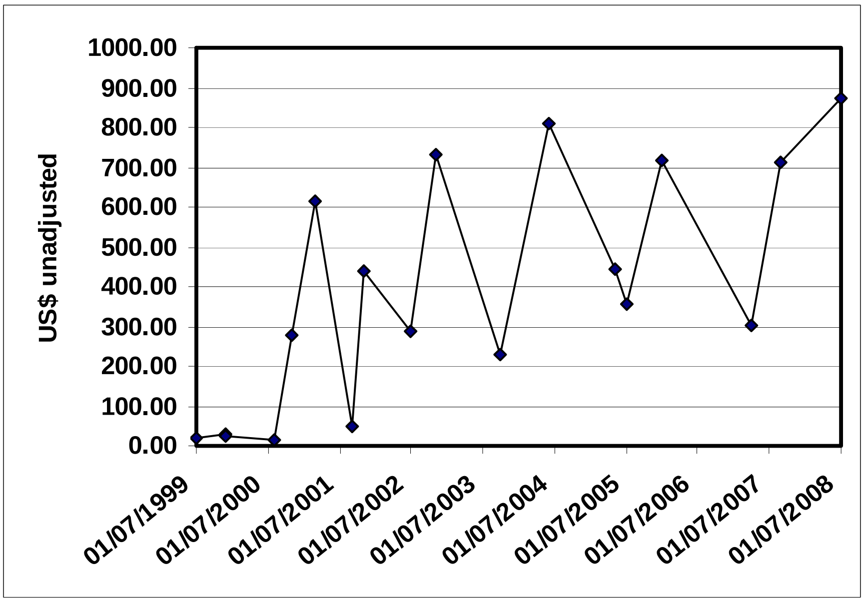

Figure 2 Prices paid per unit of rated capacity for already completed US NPPs. Data source: World Nuclear Association [6 Appendix 1]

Figure 2 presents data corresponding to the prices paid for pre-existing US NPPs in the period July 1999 (Entergy purchase of Pilgrim) to July 2008 (Duke NCEMC expected purchase of Catawba). The “market” for second hand nuclear power stations in the US was very much a buyers one in the late 1990s. Ownership of NPPs was fragmented and several minority owners were happy to sell their stakes at low prices. Companies such as AmerGen (a joint venture between PECO and British Energy) and Entergy spotted the potential for consolidating ownership and improving performance, at a time when the conventional wisdom was that NPPs were liabilities rather than assets [7, p.101].

Figure 1 shows that four deals were made in the period July 1999 to August 2000 at prices below USD 30.00 per kWe of rated capacity before in the autumn of 2000 prices started to rise significantly. In September 2000 Dominion paid USD 1.3 billion for the Millstone NPP in Connecticut, equivalent to USD 660 per kWe [7, p.123]. Was this the very first tangible sign of the nuclear renaissance? Incidentally “nuclear renaissance” is a phrase first coined in 1990 by Charles Venyvesi writing in US News and World Report. However the phrase really started to take hold after it was used by Mark Yost in the Wall Street Journal on 13 September 1999 when he wrote:

Not long ago, nuclear energy looked headed for extinction. Those days are over. With production costs dropping and regulations for fossil-fuel-burning plants rising, there's a renaissance taking place in nuclear power that would have been unthinkable five years ago.

We suggest that the seeds of renaissance were indeed sown at the turn of the millennium and now as we approach the end of the first decade of that millennium the renaissance is truly taking shape.

Figure 2 neglects to include an important consideration concerning the purchase of used NPPs – the number of licensed years of operation remaining. Some plants are simply too elderly to have much residual value. Figure 3 corrects for this consideration.

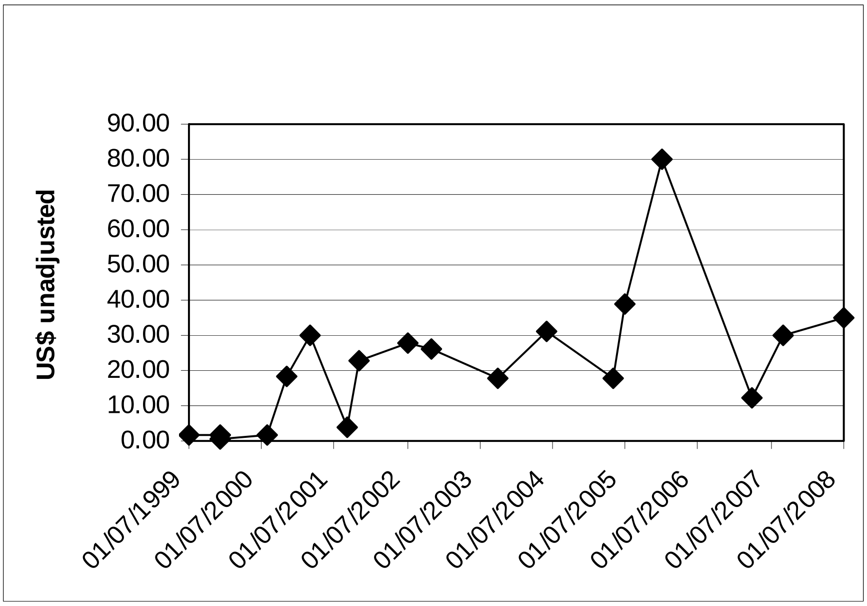

Figure 3 Prices paid used US nuclear power plants per unit of rated capacity per licensed year remaining. Data source: World Nuclear Association [6 Appendix 1]

The notion that prices for nuclear assets rose in the autumn of 2000 is still visible in the data shown in figure 2. It is, however, somewhat overshadowed by the $80/kWe/year paid by Entergy for the Palisades plant in Michigan in July 2006. However shortly after the plant was purchased it secured a twenty year life extension – a fact not represented in the data of figure 2 where only the less than four years of remaining life at the time of the deal are used for the calculation of the data.

It is important to stress that several factors came together to drive prices for existing NPPs lower during the early 1990s. First and foremost fossil fuel energy prices were low and stable following the 1991 Gulf War. Although climate change was a live scientific issue it had not yet started to impact seriously on either business or public policy. During this period several US states were liberalising their electricity markets and in several cases utilities were able to argue that legacy NPPs represented "stranded assets", that is, investments made in good faith during the period of rate of return regulation which would not be profitable in the new liberalised markets.

Compensation agreements for these apparently unprofitable NPPs provided a convenient exit for the utilities which owned them [10].

Finally the market in this period had not yet fully realised the significant improvements in plant operations being achieved by US NPP operators. Engineering reliability of NPPs has improved enormously since the mid 1990s and has acted to boost the value of such plants over this period. The average load factor for the US improved from 68% in 1991 to 90.7% in 2001, mainly owing to much shorter refuelling outages. US aggregate nuclear output increased about 40% over the period, despite minimal additions to capacity [8]. In a high fixed cost industry, extra output implies a sharp increase in operating revenue and profit.

Another story revealing the emerging renaissance well before any plans for actual new build is the decision made in 2002 to restart Browns Ferry unit 1 in Alabama USA [5]. The background to that story is: Browns Ferry Unit 1 is a Boiling Water Reactor operational from 1973. It was shutdown by fire for one year in 1975. The fire prompted much general concern about fire safety across the US nuclear industry and beyond. Brown's Ferry was forced into extended safety-based shutdown from 1985. But following the 2002 decision, and after major investment, the unit restarted in 2007. A plant came back from the dead – perhaps a true renaissance.

4. New Build is back on the Agenda

The progress of the nuclear renaissance in Europe and the United States is following two different financing paths. The US is moving towards a nuclear renaissance, but via methods very different to those seen in the EU, and most especially in the UK where government has adopted the axiom for new NPP project: "No Subsidy".

The US Energy Policy Act of 2005 includes a "production tax credit" of US 1.8¢/kWe for the first 6000 MWe of new capacity paid over the first eight years of operation [11]. To be eligible the new plant must be operational before 2021. the production tax credit will be awarded by the Secretary of the Treasury in consultation with the Secretary of Energy. In the event that there is substantial interest then allocations may be partial and, for example, a plant rated at 1000 MWe might receive an allocation of 750MWe of tax credit. Such a credit would then be paid proportionate to rated power (1000MWe) not to the tax credit level (750MWe). That is a plant that achieved only 500 MWe output would receive only 1/2 of the benefit to which it is entitled, not 2/3rds.

It is not the purpose of this short paper to seek to provide another ab-initio assessment of the financing of new NPPs. Several thorough assessments already exist and they have been brought together in a meta-analysis by the World Nuclear Association [8]. That meta-analysis is summarised in Table 1.

	MIT(2003)	DGEMP	T&L	RAE	UofC	CERI

	$	(2003) euros	(2003) euros	(2006) £	(2004) $	(2004) Can $
Capital cost per kW						
Nuclear	2000	1280	1900	1150	1500	2347
Gas	500	523	600	300	590	711
Coal	1300	1281	860	820	1189	1600
Construction period - years						
Nuclear	5	5	5	5	5	5
Gas	2	2	2	2	2	2
Coal	4	3	3	4	4	4
Cost of Capital or D rate %						
Nuclear	11.5	8	5	7.5	12.5	8
Gas	9.6	8	5	7.5	9.5	8
Coal	9.6	8	5	7.5	9.5	8
Gas price	3.50/MBTU	3.30/MBTU	3.00/GJ	2.18/GJ	3.39/MBTU	6.47/Mcf
Electricity price per MWh						
Nuclear	67	28	24	23	51	53
Gas	38	35	32	22	33	72
Coal	42	34	28	25	35	48
Electricity price, nuclear = 100						
Nuclear	100	100	100	100	100	100
Gas	57	125	133	96	65	136
Coal	63	121	117	109	69	89

Table 1. WNA comparative study of studies concerning the costs of new nuclear power. For explanation of acronyms and for a summary of assumptions made please refer to the original source [8]

It is noteworthy that at the end of 2007 UK forward month exchange or spot gas contract prices were reported at roughly US$ 8.00 per Million BTU [12]. Coal has also risen to record highs [13]. UK Wholesale electricity prices are shown in comparison to the FTSE 100 share index in figure 4 [14]. Since the spring of 2007 electricity prices have risen again. Such high prices, which might not be sustained, greatly favour a growth in nuclear generation compared to the scene as surveyed by the major studies summarised in Table 1. These high fossil fuel prices together with increased capital costs, sustained non-zero emisions costs, moves to wards more imaginative project finance and the current weak US dollar all conspire to greatly alter the relative economic position of nuclear energy. There is therefore an urgent need for an authoritative updating of relative nuclear economics. The MIT report data illustrated in figure 1 are now looking increasingly dated and hence are now of limited use.

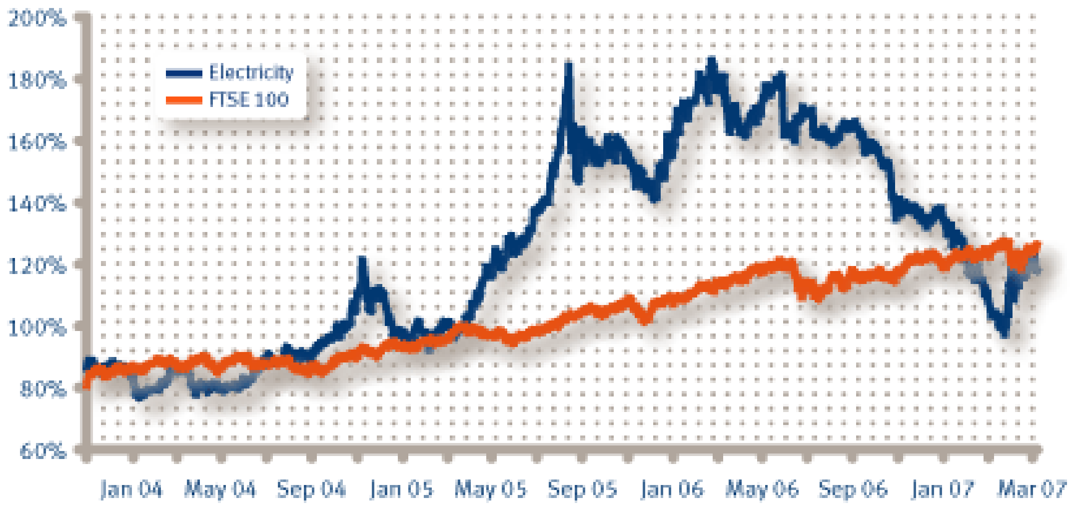

Figure 4 Comparison of UK wholesale electricity prices and the FTSE 100 share index. Source: EDF Energy [14].

5. Conclusions

We conclude that the first steps towards a nuclear renaissance are being taken in Europe and North America, but it is too early to predict the scale and geographical scope of such developments. We observe that in both the United States and Europe new nuclear power plants can be built in liberalised markets but that, so far, support beyond that available in the 1990s has been required. In Europe the most important factor has been the EU Emissions Trading Scheme with the associated cost burden placed upon competing fossil fuelled electricity generation options. In the United States a direct subsidy approach has been adopted including a production tax credit. If the US approach is to generate a sustained re-emergence of nuclear power then either today's high fossil fuel-based energy prices must persist, either as a consequence of global market dynamics or because of the internalisation into prices of the harm caused by Greenhouse Gas emissions.

As always when comparing policy interventions in a market there is a need to consider both the policy's economic efficiency and its effectiveness. While in principle economic theory would appear to favour the European approach as an efficient and sustainable approach to generation investments in liberalised markets it is also possible that the US approach will be more than sufficient to prompt a sustained renaissance of nuclear power.

In each case a fully liberalised electricity market should not be expected to be a 100% natural gas electricity market as we expect that mature markets will be diverse markets in terms of generation technologies. It is essential that liberalised markets can deliver new generation investments based upon a range of technologies and fuel types.

It is sometimes argued that nuclear power plants are simply too large and too economically risky for the commercial capital markets. We would dispute this view and would argue that major capital markets have been used to underwrite far larger and similarly capital intensive projects in transport and other critical infrastructures in the past [15]. The key is for private actors to be able to trust that the rules of the game (whatever they are) will be stable and that no nasty engineering surprises lurk around the corner. In both of these respects the track record of nuclear power is not good, but there are real and important signs that it may now be improving. We are confident that private finance will have a strong role to play in any European or North American nuclear renaissance.

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