Energy Fair

THE FINANCIAL RISKS OF INVESTING IN NEW NUCLEAR POWER PLANTS

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Many thanks to Peter Field for the following cartoon.

Executive summary[1]

Since most of the cost of nuclear electricity is in the capital cost of nuclear plants, since build times can be 7 years or more, and since payback times can be 30 years or more, investors in new nuclear plants are exposed to financial risks from inaccurate estimates and from changes in markets in the future.

There is increasing recognition in the business world that investing in new nuclear power stations is commercially risky.

This report describes five major types of risk for any investor considering putting money into new nuclear plants, with particular emphasis on the situation in the UK:

- *Market risk.* By the time any new nuclear plant could be built in the UK (2020 or later), the market for its electricity will be disappearing, regardless of any possible increase in the overall demand for electricity. The rapidly-declining cost of photovoltaics (PV) with the falling costs of other renewables, and the likely completion of the European internal market for electricity with the strengthening of the European transmission grid, will be transforming the market for electricity in the UK, and throughout the rest of Europe and beyond. Consumers, large and small, will be empowered to generate much of their own electricity (on their own sites or elsewhere) or to buy it from anywhere in Europe, and this without the need for subsidies. Explosive growth of PV is likely to take much of the profitable peak-time market for electricity. And there will be stiff competition to fill in the gaps left by PV, from a range of renewable sources, many of which are better suited to the gap-filling roll than is nuclear power.
- *Cost risk.* There is good evidence that, contrary to the often-repeated claims that nuclear power is cheap, it is one of the most expensive ways of generating electricity. The inflation-adjusted cost of building new nuclear power stations has been on a rising trend for many years. The introduction of new safety measures after the Fukushima disaster will push up prices further. Meanwhile, the cost of most renewable sources of power is falling.
- *Subsidy risk.* Although nuclear power is a long-established industry which should be commercially viable without support, it depends heavily on subsidies. This is a clear breach of the principle of fair competition. At any stage, some or all of the subsidies may be withdrawn, either via formal complaints to the European Commission (Energy Fair has already submitted a complaint about subsidies for nuclear power), or via the European Court of Justice, or via decisions made by politicians. All state aid which is deemed to be illegal must be repaid. Consumers may refuse to pay surcharges on electricity bills. There is additional subsidy-related risk arising from the great complexity of government proposals in this area, with its potential for unexpected and unintended consequences.
- *Political risk.* Apart from the risk that politicians may decide to withdraw some or all of the subsidies for nuclear power, it is vulnerable to political action arising from events like the nuclear meltdowns in Fukushima. That disaster led to a sharp global shift in public opinion against nuclear power and it led to decisions by politicians in several countries to close down nuclear power stations and to accelerate the roll-out of alternative sources of power. The next nuclear disaster—and the world has been averaging one such disaster every 11 years—is likely to lead to even more decisive actions by politicians, perhaps including the closing down of nuclear plants that are still under construction or are relatively new.

[1] An electronic version of this document, with live links, may be downloaded via bit.ly/yLM7y4.

- *Construction risk*. The delays and cost overruns in the Olkiluoto and Flamanville nuclear projects are just recent examples of nuclear projects where actual build times and actual costs greatly exceed what was estimated at the outset. But the extraordinary complexity of nuclear power stations—which is likely to increase, after Fukushima, with the added complexity of new safety systems—means that construction risk will remain a major hazard for investors for the foreseeable future.

There is abundant evidence from reputable sources that, in general, renewables can be built much faster than nuclear power stations, they are cheaper than nuclear power (taking account of all subsidies), they provide greater security in energy supplies than nuclear power, they are substantially more effective in cutting emissions of CO_2, there are more than enough to meet our needs now and for the foreseeable future, they provide diversity in energy supplies, and they are largely free of the several problems with nuclear power.

Around the world, solar power and wind power are growing fast, while the number of operational nuclear reactors in the world is shrinking.

1 Introduction[2]

Since most of the cost of nuclear electricity is in the capital cost of nuclear plants, since build times can be 7 years or more,[3] and since payback times can be 30 years or more [KPMG2011], investors in new nuclear plants are exposed to commercial risks from inaccurate estimates and from changes in the future.

This report provides evidence for significant risks for investors in nuclear power in five main areas: the changing markets for electricity, the high and rising cost of nuclear power, the heavy dependence of the industry on subsidies and the risk that some or all of these may be withdrawn, the risk that political sentiment may move against nuclear power, and the risks of overruns in times and costs in the building of nuclear power stations. Any one of these provides good reasons to be cautious.

As we shall see, next, there is already recognition that it is commercially risky for investors to put money into nuclear power.

The intended audience for this report is, primarily, any investor considering putting money, directly or indirectly, into the building of new nuclear power plants in the UK. But the report is also relevant to the financial aspects of new nuclear plants elsewhere and should be of interest to anyone concerned with energy policies in the UK or abroad.

2 Recognising the risks

There is increasing recognition in the business world that investing in new nuclear power stations is commercially risky:

- Some companies have withdrawn from their involvement with the building of new nuclear power stations or seem likely to withdraw:
    - Dutch utility Delta and its partners EDF and RWE have postponed plans to build a second nuclear power plant in the Netherlands, ostensibly because of the poor investment climate and low electricity prices.[4]

[2] An electronic version of this document, with live links, may be downloaded via bit.ly/yLM7y4.
[3] Judging by the evidence of the Olkiluoto and Flamanville nuclear projects.
[4] See "Dutch utility puts off plan for nuclear power plant", Reuters, 2012-01-23, bit.ly/wiDdlx.

- Siemens has been reducing its involvement in the building of nuclear power stations for several years.[5]
- Scottish and Southern Energy is leaving a consortium of companies planning to build new nuclear plants in the UK.[6] Construction risk is one of the reasons given by the company for pulling out.[7]
- Both RWE and E.ON have withdrawn from what appeared previously to be their serious intention to build new nuclear power plants in the UK.[8]
- GDF Suez has expressed doubts about the economics of its proposal to build a new nuclear plant in Cumbria.[9]
- Bulgaria has decided not to build the proposed new nuclear plant at Belene.[10]
- Constellation Energy Group Inc. pulled out of a consortium with EDF to build a nuclear reactor in Maryland, USA.[11]

- A report by the Texas Institute found that, while the announcement of an intent to build a new nuclear reactor had no measurable impact on a utility's credit rating, the actual construction of a new nuclear plant carried, on average, an almost 70 per cent probability that the utility would experience a rating downgrade.[12] One news report suggests that investment in new nuclear plant may lead to a downgrade in credit rating,[13] and another suggests more specifically that ratings agencies could downgrade French energy giant EDF and British Gas owner Centrica if they decide to build four reactors in the UK.[14]
- A report by consultancy Candole Partners concludes that there is only a 46% chance of a proposed nuclear project at Temelín in the Czech Republic breaking even over its lifetime, whereas investors would normally seek 95% certainty that such long-term projects will give a profit.[15]
- It has been reported that plans for a third nuclear power station at Heysham in Lancashire have been put on ice[16] but this has been denied.[17]
- The Fukushima disaster has prompted a commercial shift towards renewables.[18]

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[5] See, for example, "Siemens quits the nuclear game", World Nuclear News, 2011-09-19, on.ft.com/wHhNVq; "Siemens drops Rosatom nuclear plant ambitions", Financial Times, 2011-09-18, on.ft.com/wHhNVq; "Siemens saves face as Rosatom tie-up fades away", Financial Times, 2011-09-19, on.ft.com/wCtfBr.
[6] See, for example, "SSE pulls out of UK nuclear consortium", Reuters, 2011-09-23, reut.rs/zcxzfd.
[7] See "SSE reveals reasons for new nuclear pull out", New Civil Engineer, 2011-11-09, bit.ly/wUUZED.
[8] See, for example, "Wylfa B nuclear plant: firms pull out of plans, reports say", BBC News, 2012-03-29, bbc.in/Hq9fyK). See also "RWE and E.On halt UK nuclear plans at Wylfa and Oldbury", BBC News Business, 2012-03-29, bbc.in/HraM68).
[9] See "GDF Suez's nuclear reservations hit government energy policy", The Guardian, 2012-04-16, bit.ly/HMgQeE.
[10] See, for example, "Bulgaria quits Belene nuclear power plant project", Novinite.com, 2012-03-28, bit.ly/GWi5IS).
[11] See, for example, "Constellation drops nuclear plant, denting EDF's U.S. plans", Bloomberg, 2011-10-10, bloom.bg/xvIo90.
[12] See, for example, "New Texas Institute study on nuclear power projects financing", Texas Institute press release, 2011-09-13, bit.ly/Ac6dNr.
[13] See "New nuclear electricity costs hit utility ratings—Moody's", ICIS Heren, 2012-03-27, bit.ly/HfsgCE. See also "Nuclear electricity investment could risk utility credit ratings—analysts", ICIS Heren, 2012-03-20, bit.ly/GDkTKX.
[14] See "UK nuclear programme is at risk in Moody's credit alert", This is Money, 2012-04-07, bit.ly/ImuIuT.
[15] See "ČEZ fails to make economic case for expanding Temelín, study says", Czechposition.com, 2012-01-17, bit.ly/vZ20XU. But see also "Westinghouse moves on Temelin-3, -4 bid as project financing in question", Independent Nuclear News, 2012-01-30, bit.ly/zE5cu8.
[16] "Third nuclear power station at Heysham plans on ice", BBC News, 2012-03-14, bbc.in/GDnDaW.
[17] "EDF Energy statement regarding Heysham grid connection", EDF Energy statement, 2012-03-15, bit.ly/GCMbvv.

- The Economist writes that "For France, nuclear power has long been a source of national pride .... But since the nuclear accident at Fukushima in Japan, potential buyers have been having second thoughts ..."[19] and "... the economics of nuclear power are thorny. Though the fuel is inexpensive, building facilities is pricey. Their cost has risen more than that of other power plants; their scale, complexity and scarcity make it hard to economise. ..."[20] And more recently: "Nuclear power will not go away, but its role may never be more than marginal."[21]
- In a special report, the Financial Times has suggested that "Even before the Japanese earthquake and tsunami of March 11, prospects for nuclear construction were looking difficult in most of the developed world, mostly because of shaky economics."[22]
- An article in the Wall Street Journal describes several risks of investing in new nuclear power stations, including the capital-intensive nature of nuclear plants, long build times and the associated risk that markets may change while the plant is being built, the risk of cost overruns, dependence on subsidies, and more.[23]
- A report by Citigroup [CITI2009] says "Three of the risks faced by developers—Construction, Power Price, and Operational—are so large and variable that individually they could each bring even the largest utility company to its knees financially. This makes new nuclear a unique investment proposition for utility companies." It has been reported that Peter Atherton of Citigroup has said that the investment environment for nuclear power is "dire" and that "The risk-reward balance for public equity market investors [in nuclear power] is massively negative and I can't see a way of making it attractive at all."[24]
- A report by KPMG [KPMG2011] identifies a range of risks for investors including construction risk, market risk, regulatory risk, legal and political risk, environmental risk, and operations risk.
- It is reported that David Simpson, global head of mergers and acquisitions at KPMG, has said that the huge costs and risks associated with nuclear construction mean that plants will only be built with public support in the form of long-term power purchase agreements, that he expects the UK government to offer 35-year contracts, and that such contracts could be illegal state aid under European Union competition rules.[25]
- A report by Ernst & Young [EY2010] identifies a range of risks in the building of new nuclear plants, including those arising from the regulatory environment, lack of planning, and lack of experience.
- The Financial Times quotes James Stettler at UniCredit as saying "From a shareholder point of view, nuclear is a risky business and the margins are now potentially lower."[26]
- It has been reported that "Centrica should 'not touch with a barge pole' the new nuclear build (NNB) joint venture with EDF to build four new plants in Britain, argues Lakis Athanasiou, utilities analyst with Evolution Securities. 'Centrica is a minority holder in a

[18] See, for example, "Nuclear disaster prompts rise in renewable deals", The Independent, 2012-01-30, ind.pn/z4idQY.
[19] "Under pressure: France wants to export nuclear reactors. Who will buy them?", The Economist. 2011-12-17, econ.st/zZGQgp.
[20] "Nukes of hazard", The Economist, 2011-10-15, econ.st/yzZXRB.
[21] "The dream that failed", The Economist, 2012-03-10, econ.st/y69ULl.
[22] "Nuclear: enthusiasm for reactor investment cools", Financial Times, 2011-09-28, on.ft.com/zrVwTa.
[23] "The business case against nuclear power", Wall Street Journal, 2011-03-24, on.wsj.com/w2vHLp.
[24] See "UK nuclear investment environment "dire"—Citigroup", Reuters, 2011-07-06, reut.rs/zhZmHx.
[25] See "Questions over funding for nuclear expansion", Professional Engineering, 2011-10-03, bit.ly/wKu5bg.
[26] "Siemens saves face as Rosatom tie-up fades away", Financial Times, 2011-09-19, on.ft.com/wCtfBr.

technology in which it has no institutional understanding, and where, as emphasised by Flamanville, construction risk is notorious. Centrica should not progress new nuclear further, particularly if [the] government is unwilling to take construction risk,' he says."[27]

- Problems with nuclear projects, mainly in the USA, are detailed on bit.ly/zrpzcJ. They include delays, negative financial indicators, rapidly rising costs, design problems, fraud and mis-appropriation of funds, failed legislation, and the cancellation or suspension of projects.

3 Market risk

It is unlikely that any new nuclear power station could be completed in the UK before 2020 (see Section 3.2, below). By that time, the market for electricity in the UK is likely to be transformed by the falling price of renewables and the probable completion of the European internal market for electricity. Even allowing for possible increases in the demand for electricity for space heating and the electrification of road transport (see Section 3.2.2, below), it is likely that much of the market for nuclear electricity in the UK will be disappearing.

3.1 How electricity markets are changing

3.1.1 The falling price of renewables

The cost of photovoltaics (PV) is tumbling and the cost of other renewables is also falling. Here is some of the evidence:

- A report by the European Photovoltaics Industry Association [EPIA2011] shows that, because of rapidly falling prices, photovoltaics (PV) is likely to become a competitive source of electricity in the UK by 2019, without subsidies—not just for householders paying domestic retail prices but also for wholesale generators and large commercial and industrial consumers. In sunnier countries like Spain, Italy, and Greece, PV will become competitive earlier, perhaps as soon as 2013 [EPIA2011].
- A report by Ernst & Young [EY2011], and another by McKinsey,[28] reach similar conclusions.[29] Ernst & Young suggest that, by 2020, it is likely that commercial and industrial consumers in the UK will be able to generate their own electricity using PV at a cost, without subsidies, that is competitive with buying it from the grid.
- Greg Barker MP, Minister of State for Climate Change, has said "There is the potential for solar power to become competitive with fossil fuels without subsidy within the lifetime of this parliament [before May 2015]. Solar has gone from being one of the most expensive forms of renewable energy to one of the cheapest."[30]
- It is reported that, already (early in 2012), "... [in Germany] solar now generates electricity at levels only a few cents above what consumers pay. The subsidies will disappear entirely

[27] See "City presses Centrica to cancel plans for building nuclear power plants", The Guardian, 2011-07-25, bit.ly/nCiTu2.
[28] See "McKinsey: solar will be cost competitive within a decade", Business Green, 2012-04-18, bit.ly/I4zVYr.
[29] See also "Price of solar panels to drop to $1 by 2013, report forecasts", The Guardian, 2011-06-20, bit.ly/ywxxFb.
[30] See "Energy minister Greg Barker says decision to cut feed-in tariffs was justified by fall in cost of solar panels", The Guardian, 2012-02-08, bit.ly/zrm2K3.

within a few years, the German BSW solar association says, when solar will be as cheap as conventional fossil fuels."[31]

- Many other news reports highlight the rapidly-falling cost of solar power.[32] Rising prices for other kinds of energy, such as those seen recently in the UK,[33] will hasten the day when PV becomes competitive without subsidies. It appears that there is still considerable potential for reductions in the cost of PV.[34]
- The Offshore Valuation Report shows that the levelised costs of offshore wind is likely to decrease to around £70-£80/MWh by 2030, compared to £140-£150/MWh today [OVG2010].
- Connie Hedegaard, the EU climate change commissioner, has said that offshore wind power is *already* cheaper than nuclear power.[35]
- According to WWF,[36] Siemens has stated that offshore wind power could be fully cost competitive globally between 2020 and 2025.
- It is reported that E.ON expects to cut costs for building offshore wind farms by about 40 percent by 2015.[37]
- The Government has established an industry-led task force to drive down the cost of offshore wind power.[38]

3.1.2 Buying electricity from anywhere in Europe

By 2020, it is likely that consumers of electricity, including large commercial and industrial consumers, will be able to buy electricity from anywhere in Europe:

- *European internal market for electricity*. Completion of the European internal market for electricity, which should be in place at least by 2020,[39] will mean that any consumer in the UK will be able to buy electricity from any supplier, anywhere in Europe. There is already a single market for electricity within the UK and the UK government supports the further integration of the European internal market for electricity.[40]

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[31] See "Falling solar prices good for climate, bad for firms", AlertNet, 2012-02-01, bit.ly/xdRmtc.
[32] See, for example, "Solar closes in on grid parity", RenewableEnergyWorld.com, 2011-10-13, bit.ly/xLmcCv; "Low-cost imports from China fuel boom in solar panels", The Observer, 2011-10-02, bit.ly/ABsSAi; "Solar is the 'fastest growing industry in America' and made record cost reductions in 2010", Climate Progress, 2011-09-16, bit.ly/z3KXcs; "Solar is ready now: 'ferocious cost reductions' make solar PV competitive", Climate Progress, 2011-06-09, bit.ly/zu3yEP; "How China dominates solar power", The Guardian, 2011-09-12, bit.ly/z27w6g.
[33] See, for example, "Britain holds summit over rising energy bills", Reuters, 2011-10-17, reut.rs/wx3UhK.
[34] See, for example, "Twin Creeks unwraps new tool, process to slash silicon solar PV costs", RenewableEnergyWorld.com, 2012-03-13, bit.ly/xfiIld.
[35] See, for example, "Wind power cheaper than nuclear, says EU climate chief", The Guardian, 2011-03-17, bit.ly/yMo6mu.
[36] See "Clean energy future 'within our grasp'", WWF press release, 2011-10-25, bit.ly/zzwvXO.
[37] "EON to cut costs of building offshore wind farms 40% by 2015", Bloomberg, 2012-03-14, bit.ly/GEcZL4.
[38] "Electricity market reform: keeping the lights on in the cheapest, cleanest way", press release from the Department of Energy and Climate Change, 2011-07-12, bit.ly/wxoxaZ.
[39] See, for example, "European energy giants call for EU single energy market", Globe-Net, 2011-02-11, bit.ly/wWBPQx.
[40] "... the Government fully supports further integration of the EU electricity market ...", [WP2011A, para. 9.2.1].

- *Cascading principle*. Owing to the *cascading principle*,[41] solar power generated in sunny regions can be available immediately to consumers throughout the UK, even with the European transmission grid as it is now.
- *Transmission links are quick to build*. Any possible bottlenecks in transmission, as for example in transmission links across the English Channel, may be corrected quite fast. For example, the recently-completed BritNed link between the UK and the Netherlands was installed in about 18 months.[42] It is likely that, by 2020, the European transmission network will have been significantly strengthened.[43]
- *PV revolution throughout Europe*. The PV revolution will not be confined to the UK. Throughout Europe, there is likely to be rapid uptake of the technology, with many countries catching up with or overtaking the impressive lead that Germany enjoys at present.
- *Desertec and related initiatives*. In addition, there is likely to be explosive growth of PV, concentrating solar power (CSP) and wind power in North Africa and the Middle East, with imports of 'desert' electricity into Europe under the Desertec,[44] Medgrid,[45] 'Mediterranean Solar Plan',[46] and other initiatives that are taking shape now.

3.1.3 A superabundance of renewable sources of power

Renewables will not only be cheap, they will be very plentiful:

- A report from the Tyndall Centre [TYN2002] suggests that the practical potential of PV in the UK is 266 TWh/yr, about two thirds of the UK's overall usage but a much higher proportion of peak-time usage because the power is delivered during the daylight hours when demand is greatest. However, that estimate is certainly an under-estimate because it focuses on PV on buildings and excludes the very considerable potential of ground-based installations on brownfield sites and PV in association with roads and railways.[47]
- A report by the Offshore Valuation Group estimates that, for five offshore electricity generating technologies—wind with fixed and floating foundations; wave; tidal range; and tidal stream—the full practical resource is 2,131 TWh/year, nearly six times current UK electricity demand [OVG2010].
- A report by JDS Associates [JDS2011] says that a micro-CHP unit in a standard house in the UK produces on average 2860 kWh of electricity per year, which is more than 80% of the 3,300 kWh/yr used by a typical household in the UK.[48] There would be a good

[41] In some ways, a transmission grid is like a lake: when a tanker of water is added at one end, another tanker of water may be extracted from the other end, as if the water had been transmitted down the length of the lake. But the water which is extracted is not the same water that is added. In a similar way, solar power produced in sunny regions is, in effect, immediately available to consumers throughout Europe. It is not necessary for electrons to travel all the way from the generator to the consumer. For more information, see bit.ly/A3vwWU.
[42] See, for example, bit.ly/xrNCew.
[43] See, for example, "Energy infrastructure priorities for 2020 and beyond: a blueprint for an integrated European energy network", European Commission, 2011-10-19, bit.ly/z1jUkp.
[44] See Desertec Industrial Initiative (www.dii-eumena.com/), Desertec Foundation (www.desertec.org/), and Desertec-UK (www.desertec-uk.org.uk/).
[45] See, for example, "Medgrid to study developing a Mediterranean power grid for solar energy", Bloomberg, 2010-12-10, bloom.bg/wfcwKj.
[46] See, for example, bit.ly/x5z1Yk.
[47] An interesting idea is to install PV above railways, as is being done on Blackfriars Bridge in London (see "Work starts on solar bridge at Blackfriars station" (The Guardian, 2011-10-04, bit.ly/z9OoG0). We have estimated that the potential is about 18 GW or about 22% of the UK's peak generating capacity. Similar things could be done with roads.
[48] "Typical domestic energy consumption figures", Ofgem, 2011-01-17, bit.ly/A8acII.

seasonal fit between the output from micro-CHP (greatest in the winter) and the output from PV (greatest in the summer), and the technology is available now.[49] Large-scale CHP is also available for district heating and for commercial and industrial buildings.

- A report by the European Environment Agency shows that the "economically competitive potential" of wind power in Europe is 3 times projected demand for electricity in 2020 and 7 times projected demand in 2030. Offshore wind power alone could meet between 60% and 70% of projected demand for electricity in 2020 and about 80% of projected demand in 2030 [EEA2009]. The UK is one of the windiest parts of Europe.

There are now many reports showing how to decarbonise the world's economies without nuclear power. Details, with download links, may be found on www.mng.org.uk/gh/scenarios.htm.

There are good solutions to the supposed problem of variability of renewables, as described in Appendix A. It is clear that renewables can provide supplies of power that are robust and reliable, and can respond to constantly-changing demands for electricity.

3.1.4 Speed of development

Apart from the prospect that renewables will be plentiful and cheap, they can be built very much faster than nuclear power stations:

- PV is quick and simple to install. In just one year (2010), Germany installed 8.8 GW of PV,[50] producing, overall, about the same amount of electricity as a 1 GW nuclear power station but, more importantly, producing up to 8.8 times as much electricity as that nuclear power station during the profitable daylight hours when the demand is greatest. Instead of just one year to install 8.8 GW of PV power, it is likely to take 7 years or more to build that 1 GW nuclear power station.
- A report by WWF [WWF2011] shows how renewable energy could supply nearly 90% of the UK's electricity demand by 2030.
- Research by Mark Jacobson and Mark Delucchi [JD2011, JD2009] shows that it is technically feasible to decarbonise the world's economies by 2030.

The trends are already here: the average annual growth of wind power around the world in recent years has been about 27%[51] and the annual growth in solar power has been about 30%.[52] The PV capacity that was added in 2010 brought cumulative, global solar PV power to nearly 40 GW, up an impressive 70 per cent from nearly 23 GW in 2009.[53]

3.2 Implications for nuclear power

Although the Government has suggested that the first of their planned new nuclear power stations might be ready by 2018,[54] it looks as if there will be delays in investment decisions[55] and other delays, so that, bearing in mind that, in recent experience, it can take 7 years or more to build a nuclear power station, it seems unlikely that any new nuclear plant would be operating in the UK before 2020.

[49] See, for example, the Ecosystem from British Gas, bit.ly/ABKhFl.
[50] See, for example, "Germany leads the PV market - for now", IEEE Spectrum, 2011-02-01, bit.ly/wQ5bld.
[51] See "BTM forecasts 340-GW of wind energy by 2013", RenewableEnergyWorld.com, 2009-03-27, bit.ly/A5fWmx.
[52] See "Solar energy market growth", Solar Buzz, 2011-01-26, bit.ly/zFs1W1.
[53] See "Global solar power growth doubled in 2010: study", Reuters, 2011-02-14, reut.rs/wWhSoi. Notice that the rate of growth doubled, as stated in the headline, but the actual capacity increased by 70%, as noted in the main text.
[54] See, for example, "Nuclear power stations 'to open from 2018'", The Independent, 2010-08-09, ind.pn/zD5H3C.
[55] See, for example, "Nuclear timetable allowed to slip", Financial Times, 2011-08-07, on.ft.com/y79Lpo.

From the perspective of any investor in nuclear power, this is bad timing. Any new nuclear plant in the UK would come on stream when much of its potential market will be disappearing:

- *Rapid uptake of PV*. By 2019, when PV becomes competitive in the UK, uptake of this technology is likely to be rapid:
    - It is very quick to install (Section 3.1.4).
    - Small and large consumers in the UK will be able install PV wherever there are suitable roofs, walls or areas of ground. Naturally, they will use their own electricity before anything else. IKEA is already planning to install PV on 10 of its stores in the UK, with more to follow.[56]
    - Apart from price competitiveness by 2019, PV will have the attraction for domestic, commercial or industrial consumers that it will reduce their exposure to the risk of rising prices of electricity from external suppliers in the future. It will also help to insulate consumers from poor service from those suppliers.[57]
    - Paradoxically, at least one of the proposed new subsidies for nuclear power[58](discussed in Section 5) is likely to have the effect of boosting the uptake of PV and other renewables. This is because the subsidy will be added to consumer's bills, providing an incentive for domestic, commercial and industrial consumers to install PV, and other renewables, and reduce their dependence on external suppliers.
    - Consumers may also club together to install PV in community schemes, something that is already happening.[59]
    - With further falls in the cost of PV and other renewables, their roll-out is likely to accelerate.
- *Buy your own wind farm.* Apart from PV, large commercial and industrial consumers, and communities of householders, may buy their own wind farms. IKEA's new wind farm in Scotland will produce 30% of the company's electricity consumption in the UK.[60]
- *Buy electricity from anywhere in Europe.* With the likely completion of the single European market for electricity (Section 3.1.2), consumers may also buy electricity from PV and other renewable sources via any appropriate supplier, anywhere in Europe.
- *Another dash-for-gas?* The UK government has set out proposals for another 'dash-for-gas'.[61] But even before that announcement, a new dash-for-gas appears to be going

[56] See "IKEA UK invests in more measures to create renewable energy", IKEA press release, 2011-07-29, bit.ly/zEoErN.
[57] See, for example, "Energy firms accused of treating clients with contempt as complaints leap", The Guardian, 2011-12-09, bit.ly/wU3Kgo.
[58] In particular, the proposed "feed-in tariff with contracts for difference" (FiT CfD) described in [WP2011A] and discussed in [EMR2011].
[59] See, for example, "Bolstered renewables fund extends from Cornwall to Devon", The Guardian, 2011-09-27, bit.ly/Ayof1D.
[60] See "IKEA UK invests in more measures to create renewable energy", IKEA press release, 2011-07-29, bit.ly/zEoErN.
[61] See "'Dash for gas' plans anger campaigners", The Guardian, 2012-03-17, bit.ly/GDqpgx.

ahead anyway.[62] These developments will further erode the market for nuclear electricity.

- *Combined heat and power (CHP).* Many domestic, commercial and industrial consumers are likely to generate much of their own electricity using CHP.[63]
- *Holding down the price of power*. The generation of cheap electricity in sunnier regions will hold down the price of electricity throughout Europe [TRANS-CSP2006, Chapter 4 and Annex 1].
- *Negawatts*. The widespread of use of LED lighting—much more efficient than traditional incandescent lighting and significantly more efficient than compact fluorescent lamps, and expected to dominate the market for lighting by 2015—is likely to cut overall demand for power.[64]

Since payback times for nuclear reactors are 30 years or more [KPMG2011], a shrinking market for nuclear electricity is bad news for investors.

3.2.1 Filling in the gaps?

In a world where consumers have been empowered to choose where their electricity comes from, and are likely to favour PV with other renewables, the outlook for nuclear power does not look good:

- *Filling in the gaps.* Instead of the comfortable world where there was an assured market for all the 'base load' electricity they could produce, nuclear power stations would lose much of their market. PV is likely to take much of the profitable peak-time market for electricity. With load balancing (Appendix A), the potential is greater. Nuclear would be left to fill in the gaps.
- *Competition in the gaps*. In those gaps, nuclear power would be competing with other sources of power that work when there is no sun: wind power, thermal power stations fuelled by biofuels or fossil gas, CHP, power from tidal streams, from tidal lagoons and from waves, enhanced geothermal systems (EGS), hydropower and pumped storage devices in the UK, Norway, the Alps, and elsewhere, and CSP with heat storage and backup sources of heat. There is a particularly good seasonal fit between wind power—which is strongest in the winter—and solar power—which is strongest in the summer.[65]
- *Competition in load-balancing*. Since nuclear power stations cannot easily be turned up or down to meet variations in demand, and can themselves fail, often with little warning, they

[62] See, for example, "Gas power construction is 'twice government predictions'", The Guardian, 2012-03-14, bit.ly/AuDwZB; "UK green energy projects fall by wayside in dash for gas", The Guardian, 2011-12-04, bit.ly/zwAwux; and "The peak oil brigade is leading us into bad policymaking on energy", The Guardian, 2011-10-18, bit.ly/xPlaqY.

[63] See "Distributed energy delivers big, green results in London", Forbes, 2012-01-13, onforb.es/wFurr6.

[64] See, for example, "LEDs offer a brighter future, says report", BBC News, 2011-12-16, bbc.in/wIQDrk; "LifeBulb: an LED that can match a 60W incandescent?", The Guardian, 2011-12-13, bit.ly/xhzvn3. See also Zeta LED Technology, bit.ly/y1Zcu5.

[65] See "Seasonal optimal mix of wind and solar power in a future, highly renewable Europe", Dominik Heide and others, *Renewable Energy* 35, 2483-2489, 2010, bit.ly/yBw2dZ. "[In Europe,] wind power generation is much stronger in winter than in summer. The opposite is true for solar power generation. In a future Europe with a very high share of renewable power generation those two opposite behaviors are able to counterbalance each other to a certain extent to follow the seasonal load curve. The best point of counterbalancing represents the seasonal optimal mix between wind and solar power generation. It leads to a pronounced minimum in required stored energy. For a 100% renewable Europe the seasonal optimal mix becomes 55% wind and 45% solar power generation. ..."

are not well suited to filling in the gaps left by PV (see Appendix A). They would be competing with other sources of power that have the necessary flexibility: gas-fired power stations (using biological or fossil gas, or hydrogen generated from excess renewable power), power from solid biomass, EGS, CSP, tidal lagoons managed as pumped storage devices, hydropower and pumped storage devices in the UK, Norway, the Alps, and elsewhere, and a range of other storage systems.[66]

In a world that is dominated by renewables, the idea that nuclear power is needed to provide 'base load' is out dated. Much more important are techniques and technologies for balancing supply and demand (Appendix A).

3.2.2 Any answers for nuclear power?

There may be alternative options for new nuclear power stations in the UK but they do not look promising:

- *Meeting increased demands for electricity?* The Government has suggested that "by 2050 electricity demand is set to double", mainly because of expected increases in demand for electricity for space heating and the electrification of road transport.[67] Assuming that is true, which may be disputed,[68] this may suggest that nuclear power might escape the problems described above. But even if all 8 of the nuclear power stations envisaged by the Government were to be completed, the problems for nuclear power that we have described would remain. The potential of renewables in the UK alone greatly exceeds the generating capacity of those nuclear power stations, and consumers may also be buying PV-generated electricity, and electricity from other renewables, from anywhere else in Europe. As before, nuclear power would lose much of the profitable peak-time market, and at other times it would be competing with a range of other sources of power, many of which are much better suited to the gap-filling role.
- *Selling into Europe?* The proponents of new nuclear power stations in the UK may argue that they may by-pass the problems described above and sell electricity into mainland Europe. But most of the rest of Europe is likely to be ahead of us in the renewables revolution, with the same discouraging implications for nuclear power.
- *Government intervention?* Perhaps new subsidies for nuclear power, as described in [EMR2011], will save the situation? Although that is possible, it seems unlikely that they could compensate for the loss of a large part of the market for nuclear electricity. And as outlined in Section 5, some of them are probably unlawful under EU competition law, and they are vulnerable to political action. As noted at the beginning of Section 3, at least one of the proposed new subsidies for nuclear power is likely to have the effect of encouraging consumers to reduce their dependence on UK nuclear power supplied via traditional suppliers in the UK.

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[66] See bit.ly/xxIrav.

[67] "Electricity market reform: keeping the lights on in the cheapest, cleanest way" (DECC press release, 2011-07-12, bit.ly/wxoxaZ).

[68] The Government appears to be assuming that there will be widespread use of electrically-driven heat pumps for space heating. But this overlooks the very large untapped potential of super-insulation and other measures for reducing or eliminating the need for heating that is additional to passive solar heating, waste heat, body heat and so on. It has been estimated that 73% of global energy use could be saved by practically achievable design changes to 'passive systems' (eg ensuring that buildings are well insulated) [CUL2011]. This reduction could be increased by further efficiency improvements in 'conversion devices' (engines, generators etc). Also, the population may not grow as much as the Government thinks—because of political sensitivities about immigration.

4 Cost risk

Contrary to the often-repeated claim that nuclear power is cheap, it is one of the most expensive ways of generating electricity. And, while the cost of nuclear power is increasing, the cost of most renewables is coming down.

4.1 The high cost of nuclear power

It appears that, where claims are made that nuclear power is cheap, the evidence has come, directly or indirectly, from the nuclear industry itself.[69] It appears that such claims can only be made with some or all of the following optimistic assumptions: no overruns in the times or costs of building nuclear plants (Section 7), ignoring all the subsidies for nuclear power (Section 5) and assuming that capital costs have been paid off.

If nuclear power was as cheap as is claimed, then it should be able to compete unaided, especially since it is a long-established industry. But nuclear companies have said repeatedly that they need additional support from the Government.[70]

Reports about the high cost of nuclear power may be downloaded via links from www.mng.org.uk/gh/nn.htm#subsidies. For example:

- As noted in Section 2, a report by consultancy Candole Partners has cast doubt on the commercial viability of a proposed nuclear project in the Czech Republic.
- A report from the New Economics Foundation [NEF2005] shows that a kilowatt-hour of electricity from a nuclear generator would cost more than 2.5 times as much as claimed by the industry, once realistic construction and running costs are factored in—and that's without taking account of the subsidies described in Section 5.
- A report by the Union of Concerned Scientists [UCS2011] says that "Government subsidies to the nuclear power industry over the past fifty years have been so large in proportion to the value of the energy produced that in some cases it would have cost taxpayers less to simply buy kilowatts on the open market and give them away."
- A report by the Insurance Forum, Leipzig, a company that specialises in actuarial calculations, shows that, if the current cap on the liabilities of nuclear operators was to be removed, full insurance against nuclear disasters would increase the price of nuclear electricity by a range of values—€ 0.14 per kWh up to € 2.36 per kWh—depending on assumptions made [VL2011].
- A report by Mark Cooper of the Vermont Law School [MC2009] shows that recent estimates of the cost of building new nuclear power stations have been about one-third of what one would have expected, based on the nuclear reactors completed in the1990s.
- As noted earlier (Section 3.1.1), Connie Hedegaard, the EU climate change commissioner, has said that offshore wind power is cheaper than nuclear power.

[69] See, for example, "Why Britain must take the nuclear path", Financial Times, Vincent de Rivaz, 2010-01-07, on.ft.com/xhj1mY.

[70] See, for example, "EDF Energy wants Britain to fix the market if it builds nuclear plants", The Times, 2009-11-07, bit.ly/yh2MYN; "Families face nuclear tax on power bills", The Guardian, 2009-10-19, bit.ly/wSWqTU; "Consumers to pay for new nuclear power plants", Daily Telegraph, 2009-08-18, tgr.ph/AqNLkG; "Energy firms in secret talks on nuclear 'levy'", Sunday Times, 2009-08-16, bit.ly/xX3bXT; "UPDATE: UK nuclear industry seeks equal terms with renewables", Easy Bourse, 2009-06-10, bit.ly/yTdsN7; "EDF calls for support for nuclear industry", Financial Times, 2009-05-25, on.ft.com/wiJkx5.

4.2 Nuclear power is getting more expensive ...

Most of the cost of nuclear electricity comes from the cost of building nuclear plants, and, in inflation-adjusted terms, those costs have been rising consistently since at least the 1970s [GRU2010, IIASA2009, MC2010]. Cost overruns with the Olkiluoto and Flamanville plants (Section 7) show that nuclear plants can turn out to be unexpectedly expensive.

The cost of existing and new nuclear plants will be increased by, for example, the demand for higher safety standards after a disaster like that at Fukushima.[71] One news report says "The Court of Auditors in France has ... published a report revealing that the cost of producing nuclear energy is set to surge in France as old plants need updating and new safety standards put in place."[72]

A commentary in Nature magazine says "Whatever happens in the long term, the French plans have an immediate benefit: they raise the post-Fukushima safety bar for other countries. Those governments, regulators and companies that have yet to propose anything close to such far-reaching measures must now explain why not."[73] Another news report says "... French Prime Minister François Fillon has promised to ensure that nuclear operators will conform to all of the safety requests made by [nuclear authority] ASN. Given voter concern over the dangers of nuclear energy, the French government can do little but enforce new safety regulations and other governments across the world will also need to follow suit."[74]

The way in which the cost of building nuclear power stations has been rising in the USA and in France can be seen graphically in Figure 1.

[71] See, for example, "French nuclear plants told to prepare for disasters", Reuters, 2012-01-03, reut.rs/zKILKl.
[72] See "French nuclear set to become more expensive than wind power", European Wind Energy Association. 2012-02-03, bit.ly/xEipjK.
[73] See "Get tough on nuclear safety", Nature, vol 481, p 113, 2010-01-11, bit.ly/y13erg.
[74] See "Europe's reliance on nuclear energy a costly obstacle to green power", The National, 2012-01-14, bit.ly/wRslwQ.

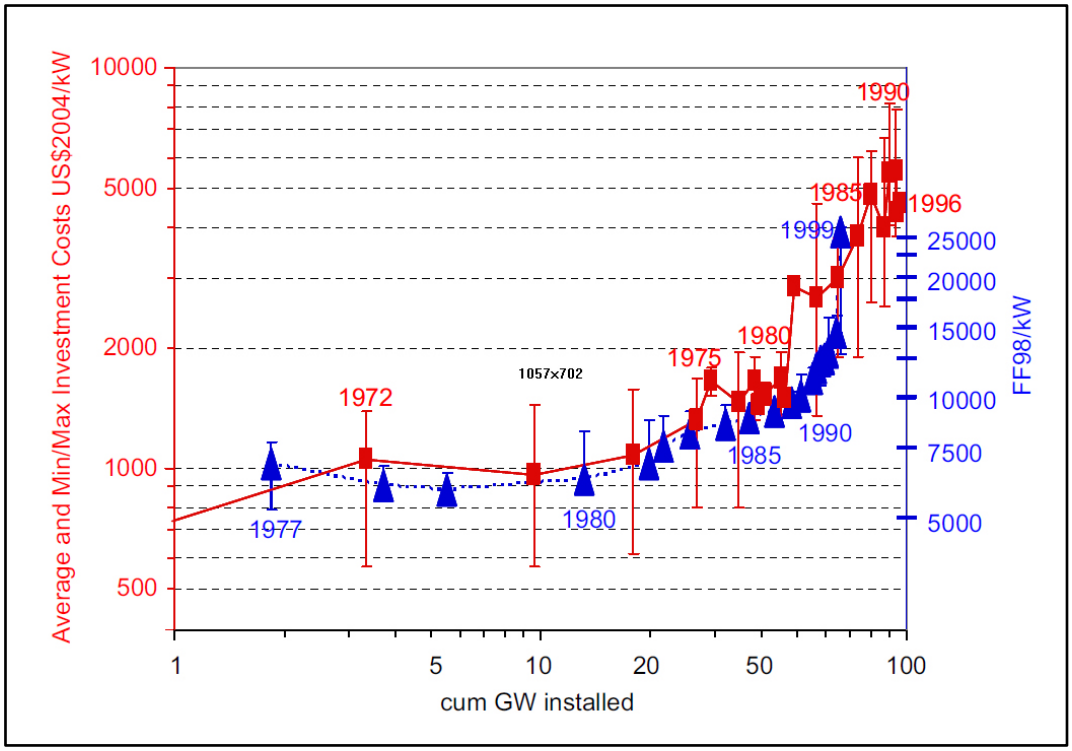

Figure 1. Average and min/max reactor construction costs per year of completion date for US (red rectangles) and France (blue triangles) versus cumulative capacity completed.[75]

4.3 ... while renewables are getting cheaper

By contrast, as we saw in Section 3, the cost of most renewables is falling. With the exception of hydropower, most renewable sources of power are relatively new. Like all new technologies, costs are brought down via economies of scale, refinements in the technologies themselves, and refinements in manufacturing processes.

The cost of modern wind turbines has declined dramatically since they were first introduced and there is still potential for further reductions in cost, especially for offshore wind power [MJ2009, RUK2011].

As described in Section 3, sharp falls in the cost of PV are likely to have a considerable impact on energy markets.

Other renewable energy technologies—power from tidal streams, tidal lagoons, wave power, EGS, and CSP—are still finding their feet commercially and are likely to get progressively cheaper as volumes increase.

Speaking at the Solar2010 conference, Mark Diesendorf said: "... the costs of nuclear energy have been escalating very rapidly since 2002. The lowest cost renewables, appropriately sited, are already competitive with nuclear. Several more expensive renewables could be competitive with nuclear by around 2020. Furthermore, most renewable energy technologies are capable of much faster growth than nuclear energy ..."[76]

[75] Reproduced with permission from Figure 13 in [GRU2010].

[76] "Comparing the economics of nuclear and renewable sources of electricity", paper presented by Mark Diesendorf at Solar2010, the 48th AuSES Annual Conference, bit.ly/zzoR0m. See also "Nuclear miracle is plagued by fast-rising reactor costs and cheap renewables", Nuclear Power Daily, 2010-09-14, bit.ly/xZB9Ru.

5 Subsidy risk

Nuclear power depends heavily on subsidies but investors cannot assume that those subsidies will always be available. Any or all of them may be removed as a result of complaints to the European Commission, or they may be challenged in the courts, or politicians may decide to remove them.

Several of the subsidies involve the transfer of risk from nuclear operators to taxpayers or members of the general public, and their quantification requires actuarial expertise. Where the necessary calculations have been done, the subsidy is large (see Section 5.1). It seems likely that most of the other subsidies that have been identified are also large.

5.1 Existing subsidies for nuclear power

As noted earlier, a report by the Union of Concerned Scientists [UCS2011] has shown that nuclear power is not viable without subsidies. This report is based mainly on the situation in the USA but much the same is true elsewhere. A report by the Energy Fair group [NSUBS2011], focussing mainly on the UK, has identified seven main categories of subsidy enjoyed by nuclear power plants in the UK today:

- *Limitations on liabilities:* The operators of nuclear plants pay much less than the full cost of insuring against a Chernobyl-style accident or worse.
- *Underwriting of commercial risks:* The Government necessarily underwrites the commercial risks of nuclear power because, for political reasons, the operators of nuclear plants cannot be allowed to fail.
- *Subsidies in protection against terrorist attacks:* Because protection against terrorist attack can only ever be partial, the Government and the public are exposed to risk and corresponding costs.
- *Subsidies for the short-to-medium-term cost of disposing of nuclear waste:* Operators of nuclear plants are paying much less than the full cost of disposing of nuclear waste, and the Government underwrites the risk of cost overruns.
- *Subsidies for the long-term cost of disposing of nuclear waste:* With categories of nuclear waste that will remain dangerous for thousands of years, there will be costs arising from the dangers of the waste and the need to manage it. These costs will be borne by future generations, but they will receive no compensating benefit.
- *Underwriting the cost of decommissioning nuclear plants:* the Government bears the risk of cost overruns in decommissioning nuclear plants.
- *Institutional support for nuclear power:* the Government is providing various forms of institutional support for the nuclear industry.

As described in [NSUBS2011], the size of the subsidy arising from the cap on liabilities has been calculated by the Insurance Forum, Leipzig. They estimate that full insurance against nuclear disasters would raise the price of nuclear electricity by a range of values—€ 0.14 per kWh up to € 2.36 per kWh—depending on assumptions made. With even the lowest of these rises, nuclear electricity would become quite uncompetitive. It appears that most of the other subsidies are also large.

5.2 Proposed new subsidies for nuclear power

Despite the existing subsidies for nuclear power, the UK government is introducing new measures which are or may potentially be additional forms of support for nuclear power [EMR2011]:

- *Exemption from tax*. Uranium is exempted from the tax on fuels used for the generation of electricity. As described in [EMR2011], this so-called "carbon price floor" may result in windfall profits for nuclear companies, estimated by the Government as £50 million per year, and by WWF and Greenpeace as £3.43 billion between 2013 and 2026—which equates to £264 million per year.
- *Feed-in tariffs with contracts for difference*. Although nuclear power is a mature technology that should not need subsidies, and, as described above, it lacks the flexibility to work effectively alongside renewables, nuclear power would be eligible for the same system of subsidies as is proposed for renewable sources of power. As noted in Section 2, it is already recognised that long-term contracts for nuclear companies may breach EU competition rules.
- *Capacity mechanism*. The Government's proposals for a 'capacity mechanism' as a backstop for the power supply system are not yet finalised. However, there is potential for the proposed mechanism to be used to provide unjustified support for nuclear power.
- *Emissions Performance Standard*. Although nuclear power emits between 9 and 25 times more carbon than wind power [JD2011], the effect of the proposed new standard would, for the foreseeable future, be to lump them together as if they were equivalent in their carbon emissions.

5.3 Subsidies for nuclear power may be withdrawn at any time

Investors in nuclear power cannot assume that existing or proposed new subsidies for nuclear power are set in concrete. Some or all of them may be removed at any time:

- Nuclear power is a well-established industry and should be commercially viable without subsidies. By contrast, many of the renewable energy technologies are relatively new, have not yet reached the bottom of their cost-reduction curves, and need public support until they are mature.
- The subsidies for nuclear power are a clear breach of the principle of fair competition, and at least some of them may prove to be illegal under EU competition law. Energy Fair has already submitted a formal complaint to the European Commission about subsidies for nuclear power.[77]
- There is potential for further action by any organisation, at any time, either via the European Commission or via the European Court of Justice.
- The ECJ has held that all illegal state aid must be repaid. There are only very rare, exceptional cases where recovery would not be ordered.
- Given increasing recognition of the subsidies enjoyed by nuclear power, politicians may decide, at any stage, to reduce or remove any or all of those subsidies.[78] There have been calls already for a windfall tax on nuclear companies, to claw back excess profits arising from the Government's proposed 'carbon price floor'.[79] And the Engineering Employers Federation (EEF), representing manufacturers in the UK, has called for a rethink of the so-

[77] See, for example, "UK 'subsidising nuclear power unlawfully'", BBC, 2012-01-20, bbc.in/yd65t1; "Anti-nuclear campaigners plan legal challenge to new British power stations", The Guardian, 2012-01-19, bit.ly/wDJqQz; www.energyfair.org.uk/actions.

[78] See, for example, "Lib Dem MPs set to rebel against nuclear power 'subsidy'", The Guardian, 2011-07-01, bit.ly/xdNuTb; "UK breaks promise on nuclear power subsidies, say MPs", BBC News, 2011-05-16, bbc.in/xKOPNc; "Call to abolish carbon floor price", Financial Times, 2011-09-11, on.ft.com/xzv6l2.

[79] "Centrica, EDF face rising windfall atomic tax risk, analysts say", Bloomberg, 2011-09-21, bloom.bg/AnFRKv.

called "carbon price floor" (see "Exemption from tax", above) on the grounds that it is likely to harm the competitiveness of UK manufacturers.[80] There has been a similar warning from Tim Yeo MP, Chair of the UK's Energy and Climate Change Committee.[81]

- Ofgem, the UK energy regulator, is already considering a revision of access charges to the grid which, if adopted, would mean less money for new nuclear power plants in the UK.[82]

5.4 Consumers may refuse to pay surcharges

The UK government's proposals for electricity market reform [WP2011A, WP2011B] include forms of support for nuclear power [EMR2011]. These kinds of support for nuclear power will be paid for directly or indirectly via surcharges to the bills of electricity consumers.

Already, numbers of consumers have declared that they will not pay such surcharges,[83] and those numbers may grow substantially if the measures are put in place and start to have an impact on consumers' bills.

5.5 Uncertainties arising from complexity in government proposals

Apart from the risks just described, there are subsidy-related risks for investors arising from the extraordinary complexity of the UK government's proposals for electricity market reform [WP2011A, WP2011B]. The ways in which the proposed mechanisms may interact are legion and the potential for unexpected and unintended consequences is large. This is a minefield for investors trying to assess whether or not they should risk their money on new generating capacity, especially nuclear capacity with its very large upfront costs that are committed for 40 years or more.

6 Political risk

Apart from the risk that politicians may decide to withdraw some or all of the subsidies for nuclear power (Section 5.3), it is vulnerable to political action arising from events like the disaster in Fukushima:

- It is said that a nuclear power plant is likely to produce a nuclear disaster only once every 10,000 years. But with more than 400 such plants operating in the world today, we may, on average, expect a nuclear disaster once every 25 years or less. Counting only the Three Mile Island disaster in 1979, Chernobyl in 1986 and Fukushima in 2011—and excluding the near-disasters at the Narora nuclear plant in India in 1993, the Davis-Besse plant in Ohio in 2002, and the Forsmark plant in Sweden in 2006—we are actually averaging one nuclear disaster every 11 years.[84]

[80] See, for example, "Industry calls for re-think on damaging carbon price proposals", EEF press release, 2011-02-15, bit.ly/wzBBvI.
[81] "UK carbon tax will leave British companies uncompetitive, warns Energy Select Committee chairman Tim Yeo", The Telegraph, 2012-03-18, tgr.ph/GDlQCL.
[82] See "Ofgem study 'undermines' case for nuclear", BBC News, 2011-11-13, bbc.in/AiZvhD.
[83] See the "Nuclear Pledge", www.nuclearpledge.com/page0.html.
[84] Joseph Romm, of the Center for American Progress, has said "There is simply no other power source that can go from being a multibillion dollar asset to a multibillion liability in a matter of hours."

- "Nuclear plants are mutual hostages: the world's least well-run plant can imperil the future of all the others." Robert Socolow and Stephen Pacala, 2006.[85]
- An opinion poll from Ipsos MORI says that 62% of citizens in 24 countries across the world oppose the use of nuclear power, with a quarter of those having changed their minds after the Fukushima disaster.[86] Another poll conducted for the BBC has found a similar global shift in opinion against nuclear power.[87] However, in the UK at least, it appears that there has been something of a rebound later.[88]
- Fukushima has led to the decision by Germany to close all its nuclear plants by 2022 and not to build any more,[89] and it has led to decisions by Belgium,[90] Bulgaria,[91] Italy,[92] Switzerland,[93] and Taiwan,[94] to phase out nuclear power, and it seems likely that Japan will do the same.[95] Thailand has frozen its plans to build new nuclear power stations.[96] And opposition parties in France say that, if they win power, they will close many of France's nuclear reactors.[97]
- A commentary in *Nature* says "The world's main nuclear operators have an interest in establishing the causes of the [Fukushima] disaster and learning the lessons—they know too well that if another major accident were to occur, then in many people's eyes the already-struggling industry would be finished."[98]
- As noted in Section 4.2, demands for higher safety standards after a disaster like that at Fukushima has the effect of raising costs for both existing and new nuclear plants.[99]
- In a "Draft Opinion" of the Committee on the Environment, Public Health and Food Safety of the European Parliament, it is proposed that there should be a minimum tax rate for nuclear fuel rods used for the production of electricity.[100] The justifications for the proposal include the externalities associated with the use of nuclear power, the potential risk in the event of a nuclear accident, and the requirement for a level playing field between different energy sources.

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[85] From "A plan to keep carbon in check," by Robert Socolow and Stephen Pacala in the *Scientific American*, September 2006, p 33.
[86] See "Citizens across world oppose nuclear power, poll finds", The Guardian, 2011-06-23, bit.ly/ynbeGG.
[87] "New poll: opposition to nuclear grows in most countries", Nuclear Engineering International, 2011-11-28, bit.ly/zVEXR3.
[88] See, for example, "Battle against emissions gives nuclear a new chance", The Independent, 2012-02-26, ind.pn/wn71Xb.
[89] See, for example, "Germany: nuclear power plants to close by 2022", BBC News, 2011-05-30, bbc.in/xlCxF7.
[90] "Belgium plans to phase out nuclear power", BBC News, 2011-10-31, bbc.in/wBLF5z.
[91] See, for example, "Battle against emissions gives nuclear a new chance", The Independent, 2012-02-26, ind.pn/wn71Xb.
[92] See, for example, "Italy says goodbye to nuclear energy", Environment News Service, 2011-06-15, bit.ly/xU3wZd.
[93] See, for example, "Swiss to phase out nuclear power", BBC News, 2011-05-25, bbc.in/ziXeYK.
[94] See, for example, "President rules out license renewal for existing nuclear plants", Taiwan News, 2011-11-04, bit.ly/xTYUNN.
[95] We have been informed by a Japanese journalist that Japan has not yet formally decided to phase out nuclear power. But some reports suggest otherwise, as for example: "Japan nuclear power expansion plans abandoned", The Guardian, 2011-05-11, bit.ly/wnT3Yz.
[96] See "Thailand freezes nuclear power plant plans", Eco-Business, 2011-03-17, bit.ly/yJpC61.
[97] See, for example, "Parties clash over future of nuclear power in France", BBC News, 2011-11-17, bbc.in/y7JVLr.
[98] See "Get tough on nuclear safety", Nature, vol 481, p 113, 2010-01-11, bit.ly/y13erg.
[99] See, for example, "French nuclear plants told to prepare for disasters", Reuters, 2012-01-03, reut.rs/zKILKl.
[100] See "Draft Opinion of the Committee on the Environment, Public Health and Food Safety for the Committee on Economic and Monetary Affairs on the proposal for a Council Directive amending Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity (COM(2011)0169 – C7-0105/2011 – 2011/0092(CNS)), 2011-10-06, bit.ly/xaEl6x.

- A court in Germany has ruled that Germany's proposed tax on uranium fuel is constitutional.[101]

The next disaster is likely to have an even bigger impact on public opinion and political opinion than Fukushima. Bearing in mind that there is a growing public awareness of the potential of renewables,[102] any future nuclear disaster is likely to lead to widespread calls to close down nuclear plants, perhaps including those that are still under construction or are relative new. This could mean substantial losses for investors.

7 Construction risk: build times and cost overruns

From recent news reports, it appears that the nuclear plant which is under construction at Olkiluoto in Finland, is likely to be 3 to 5 years late and likely to be between US$2.8 billion and US$4.5 billion over budget.[103]

From other reports, it appears that the nuclear plant which is under construction at Flamanville in northern France, is likely to be 2 to 4 years late and likely to be between US$3.7 billion to US$4.3 billion over budget.[104]

It has been reported that similar problems have arisen in the building of the Taishan nuclear plant in China,[105] and that "Britain's biggest single nuclear project has run into serious trouble with missed deadlines and cost overruns threatening the future of the entire nuclear reprocessing operation at Sellafield in Cumbria."[106]

These kinds of problems are not unusual in the building of nuclear plants:

- According to the BBC, "The British nuclear regulator has told Newsnight that ... no British nuclear power station had ever been built on time."[107]
- As noted in Section 4.1, it has been shown that recent estimates of the cost of building new nuclear reactors have been about one third of the actual cost of nuclear reactors completed in the 1990s [MC2009].
- In Canada, construction of the Darlington Nuclear Generating Station started in 1981 at an estimated cost of $7.4 billion 1993-adjusted Canadian dollar, and finished in 1993 at a cost of $14.5 billion.[108]

[101] See "Germany's enBW dealt legal blow over nuclear fuel tax", Lowtax, 2012-01-16, bit.ly/AeM2Bu.
[102] See http://www.energyfair.org.uk/pren and http://www.mng.org.uk/gh/scenarios.htm.
[103] See, for example, "UPDATE 1-Areva EPR bill seen at 6.6 bln eur-paper", Reuters, 2011-10-12, bit.ly/wCl2zy; "UPDATE 1-Olkiluoto 3 nuke plant may be delayed further -TVO", Reuters, 2011-10-12, bit.ly/zxNiyM; "Olkiluoto 31,600 MW nuclear power plant, Finland", Energy, 2011-01-30, bit.ly/zlBZnR; "National Green Tribunal urged to cancel Jaitapur nuclear project", bit.ly/wxFR9r; "For Australia, nuclear is the power of last resort", Sydney Morning Herald, 2011-10-09, bit.ly/x0OtgY.
[104] See, for example, "EDF postpones Flamanville nuclear plant", Break Bulk, 2011-07-21, bit.ly/yuTaA3; "EDF admits French nuclear reactor delayed but says UK projects on target", The Guardian, 2011-07-20, bit.ly/yvYCfi; "New French nuke plant beset by more delays", UPI, 2011-07-22, bit.ly/xvzIQt.
[105] See "Problems seen in Olkiluoto-type project in China", YLE.fi, 2011-10-07, bit.ly/zsfAiX. See also "Report raises concerns over safety of nuclear plants", The Independent, 2011-09-10, ind.pn/zhXkEF.
[106] See "Sellafield faces nuclear option as overspending threatens plant's future", The Independent, 2012-02-14, ind.pn/y5302z.
[107] "UK nuclear stations unlikely to be on time", BBC Newsnight, 2009-11-25, bbc.in/AktlVV.
[108] See, for example, "Why was the cost of Ontario's Darlington plant so high?", Canadian Nuclear FAQ, retrieved 2011-10-11, bit.ly/Ai2bxo.

- Vincent de Rivaz, chief executive of EDF Energy, has said that there is a "productivity challenge" that must be overcome in the construction sector in order to deliver new nuclear plants affordably.[109]

As reported in the Economist, Pierre Noël of Cambridge University Electricity Policy Research Group says that the record for building plants on time and within budget is "between horrendous and terrible."[110]

Whenever these kinds of problems occur, we are promised that lessons will be learned and that things will improve in the future. But the extraordinary complexity of nuclear power stations—which is likely to increase after Fukushima with the added complexity of new safety systems—means that construction risk will remain a major hazard for investors for the foreseeable future.

8 Alternatives to nuclear power

There is good evidence from reputable sources that, in general, renewables can be built much faster than nuclear power stations, they are cheaper than nuclear power (taking account of all subsidies), they provide greater security in energy supplies than nuclear power, they are substantially more effective in cutting emissions of CO_2, there are more than enough to meet our needs now and for the foreseeable future, they provide diversity in energy supplies, and they are largely free of the several problems with nuclear power.

Evidence in support of these assertions may be found on www.energyfair.org.uk/oppcost and in sources referenced there.

Around the world, the average annual growth of wind power in recent years has been more than 27%[111] and the annual growth in solar power has been about 30%.[112] In 2010, the worldwide growth of solar power was an impressive 70%.[113] Meanwile, nuclear power is shrinking: as of April 1, 2011, there were 437 nuclear reactors operating in the world—seven fewer than in 2002 [WWI2011]; and several countries have decided to phase out nuclear power—Germany, Switzerland, Italy, Belgium, and Taiwan—and it seems likely that others will do the same.

9 Conclusion

From the perspective of any private investor, fund manager or company with funds to invest, new nuclear power stations in the UK are a bad bet. By the time any such power stations can be built, the rapidly-falling price of PV, the falling cost of other renewables, and the likely completion of the European internal market for electricity, will provide new choices for householders and large commercial and industrial consumers, leaving a much-reduced market for nuclear electricity, with a highly-competitive market in the gaps. The cost of nuclear electricity is, in any case, high and rising, while the cost of most renewable sources of power is falling. Nuclear power depends

[109] See "EDF Energy: Construction stand-offs threaten UK nuclear delivery", The Telegraph, 2011-12-13, tgr.ph/yzyvxz.
[110] "Nukes of hazard", The Economist, 2011-10-15, econ.st/yzZXRB.
[111] See "BTM Forecasts 340-GW of Wind Energy by 2013", RenewableEnergyWorld.com, 2009-03-27, http://www.renewableenergyworld.com/rea/news/article/2009/03/btm-forecasts-340-gw-of-wind-by-2013?src=rss.
[112] See "Solar energy market growth", Solarbuzz, http://solarbuzz.com/facts-and-figures/markets-growth/market-growth.
[113] See "Global solar power growth doubled in 2010: study", Reuters, 2011-02-14, http://www.reuters.com/article/2011/02/14/us-energy-solar-idUSTRE71D4WJ20110214.

heavily on subsidies which may be withdrawn via legal or political action. Any repeat of a Fukushima-style nuclear disaster—and such events have been occurring every 11 years on average—could mean closure of many nuclear plants, perhaps including some still under construction or relatively new. And nuclear plants are notorious for overruns in building times and costs.

The commercial opportunities, now and for the foreseeable future, are in renewable sources of power.

Bibliography

[CITI2009] "New Nuclear – the economics say no; UK green lights new nuclear – or does it?", Citigroup Global Equities Online, 2009-11-09, bit.ly/Av5Abl.

[CUL2011] "Reducing energy demand: what are the practical limits?", Jonathan M. Cullen, Julian M. Allwood, and Edward H. Borgstein, Department of Engineering, University of Cambridge, 2011-01-12, bit.ly/zSOUyE.

[EEA2009] "Europe's onshore and offshore wind energy potential", European Environment Agency, 2009, bit.ly/wVIdgX.

[EMR2011] "Subsidies for nuclear power in the UK government's proposals for electricity market reform", Energy Fair, October 2011, bit.ly/zrgCQ9.

[EPIA2011] "Solar Photovoltaics competing in the energy sector – on the road to competitiveness", European Photovoltaics Industry Association, September 2011, bit.ly/z88k2L.

[EY2010] "Passing the starting line: nuclear construction risk" (PDF, Ernst & Young, September 2010, bit.ly/AgqdqA.

[EY2011] "Ernst & Young UK solar PV industry outlook: the UK 50kW to 5MW solar PV market", Ernst & Young, June 2011, bit.ly/yntgfx.

[GRU2010] "The costs of the French nuclear scale-up: a case of negative learning by doing", Arnulf Grubler , *Energy Policy*, 38, 5174–5188, 2010, bit.ly/AzJ6Dz.

[IIASA2009] "An assessment of the costs of the French nuclear PWR program 1970–2000", Interim Report IR-09-036, International Institute for Applied Systems Analysis, Austria, October 2009, bit.ly/wnMbg3.

[JD2011] "Evaluating the feasibility of meeting all global energy needs with wind, water, and solar power", *Energy Policy*, 2011, Part I (doi:10.1016/j.enpol.2010.11.040) Part II, (doi:10.1016/j.enpol.2010.11.045).

[JD2009] "A path to sustainable energy by 2030", Mark Z. Jacobson and Mark A. Delucchi, *Scientific American*, November 2009, 58-65.

[JDS2011] "Micro-CHP as an integral component of the UK's energy strategy: a strategy and policy roadmap", JDS Associates, 2011-11-09, bit.ly/z6OW6U.

[KPMG2011] "Construction risk in new nuclear power projects—eyes wide open" , KPMG, January 2011, bit.ly/zWdNSw.

[MC2010] "Policy challenges of nuclear reactor contruction, cost escalation and crowding out alternatives", Mark Cooper, Vermont Law School, September 2010, bit.ly/z76eiJ.

[MC2009] "The economics of nuclear reactors: renaissance or relapse?" Mark Cooper, Vermont Law School, June 2009, bit.ly/AgDts6.

[MJ2009] “Cost reduction prospects for offshore wind farms”, Martin Junginger, André Faaij, Wim C. Turkenburg, *Wind Engineering*, 28(1), 97-118, 2009, bit.ly/wVIbrw.

[NEF2005] “Mirage and oasis: energy choices in an age of global warming”, New Economics Foundation, June 2005, bit.ly/y9JU0C.

[NSUBS2011] “Nuclear Subsidies”, Energy Fair, October 2011, bit.ly/zIqjOB. This is a substantially revised and updated version of the document of the same name that was submitted in support of our complaint of 22nd February 2011, registered as SA.32626(2011/CP).

[OVG2010] “The Offshore Valuation: a valuation of the UK’s offshore renewable energy resource”, The Offshore Valuation Group, May 2010, bit.ly/w1b7I0.

[RUK2011] “Offshore wind: forecasts of future costs and benefits”, RenewableUK, June 2010, bit.ly/zFddxo.

[TRANS-CSP2006] “Trans-Mediterranean interconnection for concentrating solar power”, German Aerospace Centre, 2006, bit.ly/wjsV7q.

[TYN2002] “Renewable energy and combined heat and power resources in the UK”, Tyndall Centre, 2002, bit.ly/yrQkAY.

[UCS2011] “Nuclear power: still not viable without subsidies”, Union of Concerned Scientists, February 2011, bit.ly/y3QoXk.

[VL2011] “Calculating a risk-appropriate insurance premium to cover third-party liability risks that result from operation of nuclear power plants”, Versicherungsforen Leipzig GmbH, bit.ly/AwMhax.

[WP2011A]. “Planning our electric future: a white paper for secure, affordable and low-carbon electricity”, Department of Energy and Climate Change, July 2011, bit.ly/xWnr7b.

[WP2011B] “Planning our electric future: technical update”, Department of Energy and Climate Change, December 2011, bit.ly/z8MOSK.

[WWF2011] “Positive energy: how renewable electricity can transform the UK by 2030”, WWF, October 2011, bit.ly/yNCRRg. See also “Clean energy future ‘within our grasp’”, WWF press release, 2011-10-25, bit.ly/zzwvXO.

[WWI2011] “Nuclear power in a post-Fukushima world”, Worldwatch Institute, 2011, bit.ly/xP6O7s.

Appendix A: Balancing supply and demand for electricity

All sources of electricity are intermittent—because all kinds of equipment can fail—and the demand for electricity is constantly changing. Hence, there is and always has been a need for facilities to keep supplies and demand in balance. The main options now and in the next few years are:

- *Large-scale HVDC transmission grid*. There is now considerable momentum behind the creation of a low-loss 'supergrid' of high-voltage direct-current (HVDC) transmission lines, spanning Europe, the Middle East and North Africa.[114] This development, which is taking shape now, will be—even in partial form—a powerful means of balancing supply and demand:
    - If there is a peak in demand in any one area, it can almost always be met from spare capacity in one or more other areas.
    - Excess power in any one area may be transmitted to one or more other areas where it is needed.
    - Large-scale storage facilities, such as pumped-storage systems in Norway and the Alps, may be widely shared.[115]
    - In general, peaks and troughs in supply and demand may be smoothed out over a wide area.
- *Power on demand*. One of the most useful attributes in any source of electricity is the ability to respond quickly to peaks in demand. Renewable sources of power that can provide power on demand include:
    - Concentrating solar power (CSP) plants that include provision for heat storage and backup supplies of heat when there is not enough sun.
    - Hydro-electric power stations.
    - Enhanced geothermal system (EGS) power stations.
    - Thermal generators fired by biogas or biomethane.
    - Tidal lagoons, managed as pumped-storage devices.
- *Storage of power*. There is a growing range of methods for storing power, including utility-scale technologies.[116]
- Methods for managing demand. These include:
    - *Dynamic demand*. Large cold stores, for example, may take advantage of relatively cheap surplus power when it is available and delay drawing current—perhaps for several hours—when electricity prices are high.[117]
    - *Ice in air conditioners*. Ice is made at times when electricity supply is plentiful and is used for cooling when the demand for electricity is high.[118]

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[114] See, for example, bit.ly/zXcVrw.
[115] See, for example, "Pumped storage hydropower in Norway", Statkraft, bit.ly/x1eq3i. A submarine transmission link between Norway and Scotland is planned. See, for example, "NorthConnect to seek permission for Scotland-Norway link", Global Transmission Report, 2011-09-28, bit.ly/ws8c7a.
[116] See bit.ly/xxIrav.
[117] See, for example, http://www.dynamicdemand.co.uk/.
[118] See, for example, http://en.wikipedia.org/wiki/Ice_storage_air_conditioning.

- *Storing surplus power from wind turbines*. When there is excess power from wind turbines, it is possible to store it as heat in district heating schemes and draw on it as required.[119]
- *Interruptible service*. Some large industrial customers may choose a lower-cost option of interruptable service, in which they pay a lower rate for their power in exchange for the right to have their service "interrupted"—temporarily cut off—in the event that demand elsewhere is high.
- *Time-of-use billing.* Consumers may payless for their power at a time when demand is lower, such as the middle of the night, or during a season when demand is lower.

- *The provision of spare generating capacity*. Electricity supply systems normally have 'plant margin': the provision of generating capacity over and above what is strictly required to meet demand. The most useful kinds of spare capacity are those that can be switched on or off easily, depending on demand.
- *Complementary sources of power*. In load-balancing via the grid, it is helpful if different kinds of generators have complementary characteristics, as, for example, the good seasonal fit between wind power and solar power, noted in Section 3.2.1.
- *Prediction*. Weather forecasting can normally give a few hours notice of variations in output from wind farms. This gives time for alternative sources of power to be brought on stream or taken off stream.

A demonstration of the way that renewables can provide a comprehensive and reliable source of electrical power is the "Combined Power Plant"[120] which links and controls 36 wind, solar, biomass and hydropower installations spread throughout Germany. It has proved to be just as reliable and powerful as a conventional large-scale power station.

A report by the German Advisory Council on the Environment (SRU)[121] shows in detail how renewables can provide security in electricity supplies without nuclear power. And there are several other reports showing how to decarbonise the world's economies without nuclear power.[122]

Nuclear power and load balancing

It is often claimed that nuclear power is needed because it can provide continuous 'base load' power, with the implication that it is available 24/7. But:

- Nuclear power stations can and do fail, often with little or no warning, and they are taken out of service for scheduled maintenance. Where there are technical problems, they may be run with reduced output. The capacity factor of nuclear power stations is normally about 70% and, in some cases, can be below 50%.
- Unscheduled outages of nuclear power stations are, normally, disproportionately disruptive because they usually happen quite suddenly and with little warning and because the amount of power which is lost is normally quite large. For this reason, special provision is needed, the 'Large Loss Response', to ensure that the lights stay on when a

[119] See "District heating plants to store electricity from wind turbines", 2010-09-03, bit.ly/zIp7tB.
[120] See bit.ly/xmrO8n.
[121] See "Pathways towards a 100% renewable electricity system: summary for policymakers", German Advisory Council on the Environment (SRU), January 2011, bit.ly/Ai4g5N. See also "Technoport talks: Prof. Olav Hohmeyer, Norway Europe's green battery", You Tube, 2011-10-12, bit.ly/wIFgp4.
[122] See http://www.mng.org.uk/gh/scenarios.htm.

nuclear power station fails.[123] The variability of wind power, for example, is much easier to manage because variations are gradual and, for each increase or decrease, there are normally several hours warning.

- The inflexibility of nuclear power is an embarrassment. They cannot easily be switched on or off and their output cannot easily be increased or decreased to meet variations in demand. Much more useful are supplies of electricity which can provide 'power on demand', as described above.

In general, nuclear power stations are a poor answer to the load-balancing problem.[124]

A flat calm with an increase in demand?

It is sometimes suggested that a flat calm over the UK and neighbouring countries, coupled with an increase in demand, would be a problem if we were to rely on wind power.[125] If we were to rely exclusively on wind power, that would be true. But:

- Apart from wind power, there is a wide range of renewable sources of power available to us which would not be affected by a drop in wind speeds. These include EGS power, tidal streams, tidal lagoons, wave power, hydropower, power from biomass, photovoltaics, and concentrating solar power with heat storage and backup supplies of heat.
- There is a range of techniques for matching supplies to demand, outlined above.
- There is now a large number of reports from reputable sources showing how to decarbonise the world's economies using only renewable sources of power.[126]

The weight of evidence is that renewable sources of power, with conservation of energy, can provide robust and reliable supplies of power even in the scenario outlined above.

Nevertheless, the Government has proposed a 'capacity mechanism' to address what it sees as the problem of 'resource adequacy': "... how to ensure there is sufficient reliable and diverse capacity to meet demand, for example during winter anticyclonic conditions where demand is high and wind generation low for a number of days." [WP2011A, paras. 3.2.6 and 3.2.7].

A strategic reserve capacity

Of all the many ways of providing such spare capacity, nuclear power would be one of the worst because of its high cost and because it cannot easily be turned on and off or vary its output according to need.

A much better option would be maintain a strategic reserve of gas-fired plants which are still serviceable but near the ends of their working lives, together with a strategic reserve of fuel to power them. These would provide much more flexibility than nuclear plants with a much lower capital cost. Since they would only be used occasionally, their running costs would be low.

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[123] See "Exclusive: Will wind farms pick up the tab for new nuclear?", Business Green, 2010-08-24, bit.ly/ye1WSN.
[124] In addition, it is relevant to point out that a significant part of the rise in the UK's emissions in 2010 has been due to the unreliability of nuclear power stations: "The biggest reactor in the country, Sizewell B, was offline for six months, meaning more coal and gas had to be burned to fill the electricity gap, pumping more climate-warming gases into the air. Other reactors had problems too in 2010 and more recently events as varied as a rogue school of jellyfish and winter tornadoes have closed atomic energy plants." (from "Leaping UK carbon emissions deliver two red-hot lessons", The Guardian, 2012-02-07, bit.ly/xJtIFJ).
[125] See, for example, "Will British weather provide reliable electricity?", James Oswald *et al.*, *Energy Policy*, 36(10), 4005-4007, 2008.
[126] See http://www.mng.org.uk/gh/scenarios.htm.

The fuel for those gas-fired plants could be ordinary ‘fossil’ gas but greener alternatives would be biogas, biomethane, or hydrogen generated by the electrolysis of water, using spare capacity at times when there is an excess of wind power or other renewable sources of power.