Nuclear subsidies (Hinkley Point C)

Energy Fair

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1 Introduction

These notes contain observations and arguments relating to the finding by the Directorate General for Competition of the European Commission (hereinafter "EC") that, with regard to the proposed new nuclear power plant at Hinkley Point in south west England (HPC), "the package of measures notified by the UK involves State aid which, as amended by the commitments provided, is compatible with the internal market pursuant to Art 107(3)(c) TFEU" [EC2014, p. 75].

The notes may be useful in the preparation of a legal case against state aid for HPC, by the Austrian government or otherwise.[1]

To avoid prejudging legal issues, the informal words "subsidy" or "subsidies" will normally be used in this document instead of "state aid". But we believe that many of the things we describe as subsidies are likely to qualify as state aid under the Treaty on the Functioning of the European Union (TFEU). However, for certain purposes, such as demonstrating the high cost of nuclear power (Section 4.2), it is merely necessary to recognise that subsidies represent costs, and that these costs can have a bearing on such issues as whether or not HPC may promote "an objective of common interest".

It appears that some key arguments and conclusions in [EC2014] are false. And it appears that the errors in these arguments and conclusions arise largely from seriously deficient understandings of technical aspects of nuclear power and technical aspects of electricity supply systems.

Because of the apparent importance of those technical issues, much of this document is devoted to them. Then, in Section 14, we aim to demonstrate that key arguments and conclusions in [EC2014] are false, drawing on facts and arguments presented in earlier sections.

Throughout this document there are frequent references to "renewables". That word is intended as a shorthand for what would otherwise be described with the rather cumbersome expression: "renewable sources of energy, with conservation of energy".

2 Our formal complaint to the EC about subsidies for nuclear power

It is pertinent to mention that, in December 2011, Energy Fair submitted a formal complaint to the EC about subsidies for nuclear power [EF2011]. We have not yet received a response.

Appendix C gives a summary of the main elements of the complaint.

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[1] "Austria to launch lawsuit over Hinkley Point C nuclear subsidies", The Guardian, 2015-01-21, http://bit.ly/1zwoG78.

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Possibly the most important part of the complaint is that "the cap on liabilities for nuclear accidents of the Paris/Brussels Conventions constitutes state aid in the sense of Article 107 of the TFEU. Since Article 351 of the TFEU requires EU Member States to adapt and align their pre-existing Treaty obligations to be compliant with EU law ...".

This cap on liabilities for nuclear power is a very substantial subsidy for the industry (Section 4.2) but it is barely mentioned in [EC2014]. Nevertheless, it could be a part of any legal case against subsidies for HPC. Likewise for other elements of [EF2011].

3 A broad-brush case against subsidies for HPC

As a possible aid to thinking about subsidies for HPC, Appendix A presents a broad-brush case against such subsidies. It is essentially what we submitted to the EC on 2014-03-23,[2] which is itself a revised and updated version of our Open Letter, which we sent to the EC in December 2013.[3]

In summary, *there is no valid justification for any kind of subsidy for nuclear power*. The alternatives are better and cheaper.

As the Washington Post has written in connection with President Obama's pro-nuclear negotiations with India: "It no longer makes sense for any country to install a technology that can create a catastrophe such as Chernobyl or Fukushima—especially when far better alternatives are available. Technologies such as solar and wind are advancing so rapidly that by the time the first new nuclear reactors are installed in India, they will be less costly than nuclear energy. Most importantly, the alternative technologies are cleaner and safer."[4]

4 Costs

This section aims to demonstrate that, with proper accounting, nuclear power is ***very*** much more expensive than any of the alternatives. As discussed later, this may have a bearing on such issues as whether or not HPC may promote "an objective of common interest".

4.1 The very high and rising cost of nuclear power

In [EC2014] and other documents relating to subsidies for HPC, the main focus is on the proposed "Contract for Difference" (CfD),[5] "Credit Guarantee" (CG), and "Secretary of State Agreement" (SSA).[6] But HPC, if it were to be built, would benefit from several other subsidies, several of them large, and most of them not widely recognised.

Taking account of all the subsidies that HPC would enjoy, it is clear that *the real cost of HPC would be **very** much higher than is generally recognised and **very** much higher than the*

[2] "Comments on "State aid SA.34947 (2013/C) (ex 2013/N)—Investment Contract (early Contract for Difference) for the Hinkley Point C New Nuclear Power Station: Invitation to submit comments pursuant to Article 108(2) of the Treaty on the Functioning of the European Union", bit.ly/1s9dtWn.

[3] This may be seen online with its 47 signatories via bit.ly/1bpwTwc, with 110 letters of endorsement at bit.ly/OH5xtB.

[4] See "Why Obama should stop pushing nuclear energy on India", Washington Post, 2015-02-02, wapo.st/1yvHYob.

[5] A CfD is "a contract between two parties, typically described as 'buyer' and 'seller', stipulating that the seller will pay to the buyer the difference between the current value of an asset and its value at contract time (If the difference is negative, then the buyer pays instead to the seller).", Wikipedia, retrieved 2015-02-04, bit.ly/1CYWolz.

[6] The SSA "provides that if, following a political shutdown, the Counterparty Body was to default on compensatory payments to NNBG's investors, the Secretary of State would pay the agreed compensation to the investors." [EC2014, p. 13].

alternatives to nuclear power. And the cost of nuclear power has been on a rising trend for several years.

Our report on *Nuclear Subsidies* [NSUBS2011] identifies seven main types of subsidy enjoyed by the operators of nuclear plants in the UK (all of which would be available to HPC):

- *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 attacks 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:* In UK government proposals, the Government is likely to bear much of the risk of cost overruns in the disposal of nuclear waste.
- *Subsidies in 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 born by future generations, but they will receive no compensating benefit.
- *Underwriting the cost of decommissioning nuclear plants:* In UK government proposals, the Government is likely to bear much of the risk of cost overruns in decommissioning nuclear plants.
- *Institutional support for nuclear power:* the UK government is providing various forms of institutional support for the nuclear industry.

And our report *Subsidies for nuclear power in the UK government's proposals for electricity market reform* [EMR2011] identifies four other subsidies that would be available to HPC:

- *Exemption from tax*. Uranium is exempted from the tax on fuels used for the generation of electricity now established in the Finance Act 2011 [FA2011].
- *Feed-in tariffs with contracts for difference*, now known as CfD.
- *Capacity mechanism*. The UK government's proposals for a 'capacity mechanism' as a backstop for the power supply system are now in place and appear to provide unjustified support for nuclear power.
- *Emissions Performance Standard*. Although nuclear power emits between 9 and 25 times more fossil carbon than wind power, it appears that 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.

4.2 Estimating the true cost of nuclear power

As mentioned above, HPC would benefit from all of the eleven subsidies outlined above. How big are these subsidies? In several cases, it is difficult to make estimates. But with the cap on liabilities for nuclear disasters, research by Versicherungsforen Leipzig GmbH, a company that specialises in actuarial calculations, shows that 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].

From these figures, we can begin to estimate the real cost of nuclear power:

- The strike price agreed for HPC is £92.50.[7] This is roughly twice the current market price for electricity in the UK.
- If we take the minimum of the figures mentioned above (€ 0.14 per kWh), this equates with €140/MWh or £104/MWh.
- If we ignore all other subsidies, then, as a **very** conservative estimate, the generation cost for nuclear power is 92.50 + 104 = £196.50/MWh, which is considerably more than the £140/MWh generation cost for offshore wind power,[8]—which is itself considered to be one of the most expensive forms of renewable energy.

But this is only the beginning:

- *Short-to-medium-term costs for the disposal of nuclear waste*. As described in Section 1.4 of [NSUBS2011], it is very difficult to estimate the short-to-medium-term costs of disposing of nuclear waste but, for commercial and political reasons, it is very likely that charges made by the UK government for the disposal of nuclear waste will be lower than the real cost of disposal and very much lower than commercial rates that could be charged for disposal.
- *The long-term cost of disposing of nuclear waste*. As mentioned earlier, the 'high level' categories of nuclear waste will remain dangerous for thousands of years. It is commonly assumed that this kind of waste can be disposed of by burying it underground, and it is commonly assumed that it may then be forgotten.

  Shortcomings in the "bury-and-forget" philosophy for the disposal of nuclear waste are highlighted by the fact that the Waste Isolation Pilot Plant, near Carlsbad, New Mexico, designed to last tens of thousands of years, had two leaks of airborne radioactive materials in February 2014.[9]

  On long timescales, what appears to be solid rock deforms like butter [RAN1995, K1978]. We know far less about the movements of rocks and water underground than we do about the weather, those movements are at least as unpredictable as the weather, and they are likely to have a considerable impact on any dangerous nuclear waste that has been stored underground.

  Thus, under all foreseeable scenarios, the storage of dangerous categories of nuclear waste will give rise to risks and associated costs, and the costs of managing the waste, for thousands of years.[10] Such costs are likely to be far greater than the total value of the electricity generated by any nuclear plant.

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[7] "Initial agreement reached on new nuclear power station at Hinkley", GOV.UK, 2013-10-23, bit.ly/XY2X81. The strike price would be reduced to £89.50 if the Sizewell C nuclear plant were to be built.

[8] See "Offshore wind power cost 'could fall one-third by 2020'", The Guardian, 2012-06-13, bit.ly/1yN0MTd).

[9] See "Nuclear and radiation accidents and incidents", Wikipedia, retrieved 2015-02-04, bit.ly/1yFSiKa.

[10] The idea that nuclear waste may be disposed of by converting it into nuclear fuel and then "burning" it in nuclear power plants has proved to be far more difficult than was anticipated (see "Revealed: £2bn cost of failed Sellafield plant", The Independent, 2013-06-09, ind.pn/15VcmjI). It is very unlikely to provide a solution to the problem of long-lived nuclear waste.

- *The cost of decommissioning nuclear plants*. As described in Section 2.6 of [NSUBS2011], the uncertainties associated with the decommissioning of nuclear plants mean that it is *impossible* for the UK government, or any other government, to shed its responsibilities for the decommissioning of nuclear power stations by passing everything over to the nuclear operators. This kind of underwriting of decommissioning costs by national governments is, almost certainly, a substantial subsidy for the nuclear industry.

Taking account of all the costs of nuclear power, including what appear to be the very large hidden costs just described and the several other hidden costs mentioned earlier, it is clear that the real cost of nuclear power plants, including HPC, is ***very*** much higher than is acknowledged by the nuclear industry or the UK government.

Taking account of the costs arising from nuclear waste that will be dangerous for thousands of years, it is entirely possible that the true costs associated with any nuclear plant, including HPC, will be greater than the total value of the electricity that it may produce.

4.3 The high cost of HPC

In connection with an early £16bn estimate for the cost of HPC, it has been reported[11] that Peter Atherton and Mulu Sun of Liberum Capital have said:

- "We are frankly staggered that the Government thinks it is appropriate to take such a bet and underwrite the economics of this power station. We are flabbergasted that it has committed future generations of consumers to the costs that will flow from this deal."
- That HPC's construction costs of £8bn per reactor make it "the most expensive power station in the world", other than hydroelectric schemes, on a per-unit basis.
- And that "For the cost of £16bn for the 3,200MW to be built at Hinkley, the UK could build 27,000MW of new gas-fired power stations, solving the 'energy crunch' for a generation."

But that early estimate of the cost of HPC—attracting comments like those above—is now dwarfed by a more recent estimate of the cost of HPC. It has been reported[12] that EU regulators have estimated that HPC will cost at least £24.5bn and that "Joaquin Almunia, the EU Competition Commissioner, disclosed that the total cost [of HPC] could be as high as £34bn".

Not only is HPC exceptionally expensive, but the subsidies for it that have been offered by the UK government are exceptionally generous: at £92.50/MWh, it is about twice the current market price for electricity in the UK and it is index-linked for the exceptionally long period of 35 years.[13]

4.4 Other evidence

Even without taking account of the hidden costs described above, it has been recognised for some time that the cost of nuclear power is high and rising:

- Jeff Immelt, the chief executive of General Electric—one of the world's largest suppliers of atomic equipment—has said (in July 2012) that nuclear power is so expensive compared with other forms of energy that it has become "really hard" to justify.[14]

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[11] See "New power station deal 'threatens higher energy prices for decades to come'", The Telegraph, 2013-10-30, bit.ly/1ytPobu.
[12] See "Hinkley Point nuclear plant to cost £24.5bn", The Telegraph, 2014-10-08, bit.ly/1seOJL9.
[13] See, for example, "Hinkley Point C contract terms", World Nuclear News, 2014-10-08, bit.ly/1DPKybY.
[14] See, for example, "Nuclear 'hard to justify', says GE chief", Financial Times, 2012-07-30, on.ft.com/MtFwLy.

- Cost overruns are a familiar feature of nuclear construction projects. For example, by December 2012, the cost of the Olkiluoto nuclear plant in Finland had risen to €8.5 billion from the original estimate of €3.3 billion,[15] and there are similar figures for the Flamanville nuclear plant in France.[16]

- 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 ..."[17] 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. ..."[18] And more recently: "Nuclear power will not go away, but its role may never be more than marginal."[19]

- 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."[20]

- 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.[21]

- 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."[22]

- 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.

[15] See "Olkiluoto nuclear power plant", Wikipedia, retrieved 2015-02-02, bit.ly/1uR9nzo.
[16] See "Flamanville nuclear power plant", Wikipedia, retrieved 2015-02-02, bit.ly/1yviDus.
[17] "Under pressure: France wants to export nuclear reactors. Who will buy them?", The Economist. 2011-12-17, econ.st/zZGQgp.
[18] "Nukes of hazard", The Economist, 2011-10-15, econ.st/yzZXRB.
[19] "The dream that failed", The Economist, 2012-03-10, econ.st/y69ULl.
[20] "Nuclear: enthusiasm for reactor investment cools", Financial Times, 2011-09-28, on.ft.com/zrVwTa.
[21] "The business case against nuclear power", Wall Street Journal, 2011-03-24, on.wsj.com/w2vHLp.
[22] See "UK nuclear investment environment "dire"—Citigroup", Reuters, 2011-07-06, reut.rs/zhZmHx.

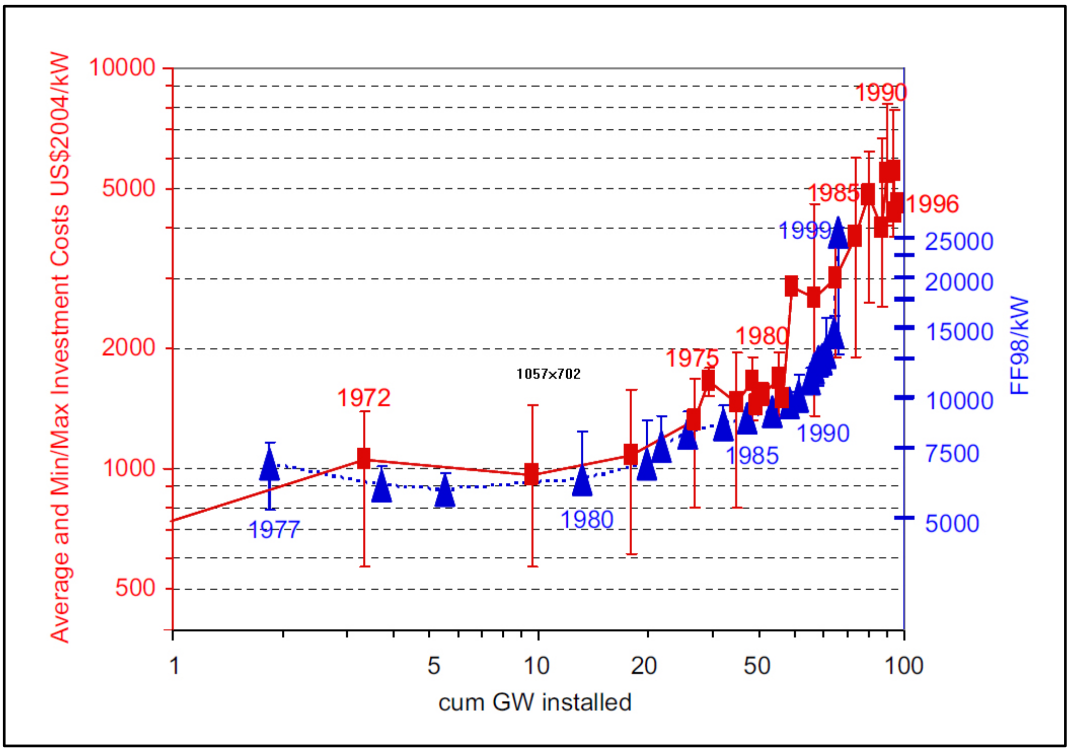

Figure 1. Average and min/max reactor construction costs per year of completion date for US (red rectangles) and France (blue triangles) versus cumulative capacity completed.[23]

4.5 The relatively low and falling cost of renewables

It is clear that, without subsidies, the cost of renewable sources of power is very much less than any realistic estimate of the cost of nuclear power, those costs are, in general, falling, and in some cases they are close to the current market price for electricity.

As mentioned in Section 4.2, the generation cost of offshore wind power, generally considered to be one of the most expensive sources of renewable energy, is about £140/MWh. As mentioned in that section, this is very much lower than the very conservative estimate given there of the true cost of nuclear power (£196.50/MWh).

Here is more evidence for the relatively low and falling cost of renewables:

- 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,[24] reach similar conclusions.[25] 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.

[23] Reproduced from Figure 13 in [GRU2010].
[24] See "McKinsey: solar will be cost competitive within a decade", Business Green, 2012-04-18, bit.ly/I4zVYr.
[25] See also "Price of solar panels to drop to $1 by 2013, report forecasts", The Guardian, 2011-06-20, bit.ly/ywxxFb.

- Greg Barker MP, former 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.”[26]
- Prime Minister David Cameron MP is reported to have said (April 2012) that renewables can be one of the cheapest forms of energy within years.[27]
- As far back as early 2012, it was reported that “... [in Germany] solar now generates electricity at levels only a few cents above what consumers pay. The subsidies will disappear entirely within a few years, the German BSW solar association says, when solar will be as cheap as conventional fossil fuels.”[28]
- Many other news reports highlight the rapidly-falling cost of solar power.[29] It appears that there is still considerable potential for further reductions in the cost of PV.[30]

- 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].
- According to WWF,[31] 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.[32]
- The Government has established an industry-led task force to drive down the cost of offshore wind power.[33]

5 A superabundance of renewable sources of power

It is clear from many formal studies and reports that, with technologies that are available now, there is potential to generate far more renewable electricity than anyone could ever use, and there is very considerable potential for “negawatts”—meeting our energy needs, in part, via the conservation of energy.

In this connection, it is pertinent to mention that we use other forms of energy besides electricity. But:

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[26] 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.
[27] See “Green energy ‘cheap within years’, says ‘passionate’ PM”, BBC News, 2012-04-26, bbc.in/IdWZq4.
[28] See “Falling solar prices good for climate, bad for firms”, AlertNet, 2012-02-01, bit.ly/xdRmtc.
[29] 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.
[30] See, for example, “Twin Creeks unwraps new tool, process to slash silicon solar PV costs”, RenewableEnergyWorld.com, 2012-03-13, bit.ly/xfiIld.
[31] See “Clean energy future ‘within our grasp’”, WWF press release, 2011-10-25, bit.ly/zzwvXO.
[32] “EON to cut costs of building offshore wind farms 40% by 2015”, Bloomberg, 2012-03-14, bit.ly/GEcZL4.
[33] “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.

- Electricity is the main focus of this document because that is the form of energy produced by nuclear plants.
- While it is true that planes, for example, cannot at present be powered with electricity, it appears that there is potential to create jet fuel, for example, from renewable supplies of electricity or renewable supplies of heat, or both.[34]

Here is some of the evidence for the very large potential of renewables:

- A network of land-based 2.5-megawatt (MW) turbines restricted to nonforested, ice-free, nonurban areas operating at as little as 20% of their rated capacity could supply more than 40 times current worldwide consumption of electricity and more than 5 times total global use of energy in all forms. There is additional potential in offshore wind farms [XI2009].
- 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].
- For five offshore electricity generating technologies—wind with fixed and floating foundations; wave; tidal range; and tidal stream—the full practical resource in UK coastal waters, estimated to be 2,131 TWh/year, is nearly six times current UK electricity demand [OVG2010].
- Renewable energy technologies can provide 100 percent of the world's energy (not just electricity) and it is technically feasible to make the transition by 2030 [JD2011a, JD2011b, JD2009]. This research by Mark Z. Jacobson and Mark A. Delucchi is exceptionally thorough and authoritative.
- Using the proven technology of concentrating solar power (CSP), less than 1% of the world's deserts could produce as much electricity as the world is using. Less than 5% of the world's deserts could produce electricity equivalent to the world's total energy demand.

  Using low-loss HVDC transmission lines, it is feasible and economic to transmit electricity for 3000 km or more. It has been calculated that 90% of the world's population lives within 2700 km of a desert. In fact, owing to the "cascading principle",[35] there is considerable potential for long-distance transfers of electricity without the use of HVDC transmission lines.

  These calculations, which are quite conservative, are based on very thorough research from the German Aerospace Centre (DLR) [MED-CSP2005, TRANS-CSP2006].
- PV, which is very quick and simple to install, could generate about 266 TWh/yr in the UK—about 66% of the UK's present electricity demand [TYN2002]. 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.
- *Negawatts*. 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). This reduction could be increased by further efficiency improvements in 'conversion devices' (engines, generators etc) [CAM2012]. It has also been estimated that,

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[34] See, for example, "Desertec and industrial processes", retrieved 2015-02-07, bit.ly/1LYDYFM.
[35] See "The cascading principle", Desertec-UK, retrieved 2015-02-03, bit.ly/1AnyXCZ.

by the use of energy conservation measures, EU energy demands may be cut by two thirds [BMU2012].

6 Many reports show how to decarbonise the world's economies without using nuclear power

Apart from the reports mentioned in the previous section, there is now a large number of reports showing how to decarbonise the world's economies without using nuclear power. Details of these reports, with download links, are given on www.mng.org.uk/gh/scenarios.htm. Here are some examples:

- "Scientists have developed a comprehensive computer model that simulates German energy supply and demand, in a bid to establish whether it is feasible for Germany to rely on renewable energy sources to power its economy and meet its carbon dioxide emission reduction targets. ... Using real data from 2011 and 2012, the researchers have run millions of simulations to optimize the model. They say they have demonstrated that there are several economically viable ways to achieve a low-carbon future, using existing technologies."[36]
- "This meta-study builds on related existing modelling work (i.e. the study 'energy [r]evolution, a sustainable EU 27 energy outlook' by Teske et al. (2012a), published by Greenpeace and the European Renewable Energy Council) and on an extensive literature-review. In a first step the literature review includes prestigious studies on meeting long-term climate, renewable energy source (RES), and/or energy efficiency targets. In a second step related aspects (RES, energy efficiency, infra-structural prerequisites) are covered and examined for derivable implications at the European level, focusing on supply and demand for electricity. Third, legal aspects of a nuclear power phase-out until 2030 in the EU are analysed. The study ends with a derivation of recommendations for practical policy implementation in accordance with the above mentioned European targets."[37]
- "The International Energy Agency (IEA) has released a report in which it concludes that the integration of large amounts of renewable energy can be achieved by any country at only a small increase on whole system costs, compared with the current fossil-fuel heavy electricity systems. Making the conclusion even more startling is that the IEA used present-day costs for solar PV and wind, with the two most widely-deployed renewable energy technologies set to provide the bulk of the generating capacity in these transformed electricity systems."[38]
- **"**Today WWF launched a new report—*Putting the EU on Track for 100% Renewable Energy*—which shows where Europe needs to be by 2030 in order to reach a fully renewable energy system by 2050. **...** By 2030, the EU could be reducing its energy use by more than a third and generate almost half of the remainder from renewables. The post-2020 climate and energy policies needed to deliver this vision would help the EU to reduce its €573bn external fossil fuel bill and cut its greenhouse gas emissions in half."[39]

[36] "Plan outlines low-carbon future for Germany", New York Times, 2014-11-30, nyti.ms/1vBW85B.
[37] "Phase out of nuclear power in Europe: from vision to reality", Global 2000, March 2014, bit.ly/1BCyj2m.
[38] "IEA says wind and solar can carry bulk of energy transformation", RE New Economy, 2014-02-27, bit.ly/1mIkziq.
[39] "New policy can put the EU on track to reach 100% renewable energy", WWF, 2013-02-13, bit.ly/1EtGdij.

7 Security of energy supplies

This section aims to demonstrate that, contrary to popular belief, nuclear power is bad for energy security, and that, contrary to popular belief, renewables can provide plentiful, diverse, robust, reliable, and responsive, supplies of energy—and they can be built much faster than nuclear power.

The next section aims to demonstrate that nuclear power is also bad for other aspects of security. Most of those other aspects have implications for the security of energy supplies.

A key part of energy security is ensuring that supplies of electricity on the grid are in balance with demands for electricity, bearing in mind that those demands are quite variable, depending on the time of day, weather conditions, commercial breaks in popular TV programmes, and other factors.

As we shall see, nuclear power is a hindrance, not a help, in balancing supply and demand on the grid.

7.1 Contrary to popular belief, a nuclear plant is an intermittent source of power

It is commonly assumed that each nuclear power plant operates for 24 hours each day, and for 365 days a year. But, like all kinds of equipment, nuclear plants fail. Because of unscheduled failures or because of routine maintenance, they may stop working altogether, or they may operate at reduced capacity.

In this connection, relevant measures are *capacity factor*—the ratio of a power plant's actual output over a period of time to its potential output if it were possible for it to operate continuously, at full nameplate capacity, over the same period of time; and the closely-related *load factor*—the average load divided by the peak load in a specified time period.

With nuclear plants, these factors are often 75% or lower. For example, for power producers identified as "major", the UK government gives the following figures for the load factors of nuclear plants [DECC2014, p. 143]: 65.6 (2009); 59.3 (2010); 66.4 (2011); 70.7 (2012); 73.8 (2013). Also, during its 35 years of operation, Hinkley Point A had a lifetime load factor of 34%.[40]

A survey of press reports over the three years up to December 2014 shows that, taken as a whole, the UK's nuclear reactor fleet was not reliable [NFLA2014]. In that period, there were at least 62 unplanned shutdowns, detailed in the report. Towards the end of November 2014, only 43% of the UK's nominal nuclear electricity capacity was available, because of shutdowns.

It has been argued that a significant part of the rise in the UK's emissions of CO_2 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."[41]

7.2 Sudden loss of a large amount of power, with little warning

When a nuclear power plant fails, it normally does so suddenly and with little warning. Because nuclear power plants are normally large (HPC would be an example), the failure of any one plant is exceptionally disruptive on the grid. For that reason, it is considered necessary for there to be special provision of alternative supplies of electricity—called the "Large Loss Response"—to fill

[40] See "Hinkley Point A nuclear power station", Wikipedia, retrieved 2015-02-02, bit.ly/1LDsdEz.
[41] From "Leaping UK carbon emissions deliver two red-hot lessons", The Guardian, 2012-02-07, bit.ly/1A5VUdQ.

the electricity supply gap when a nuclear plant fails.[42] As we shall see (Section 7.5), renewables are largely immune to this problem.

A new nuclear plant may have a higher load factor or capacity factor than those quoted above, perhaps as high as 90%, but that figure is likely to fall as the plant ages. And higher figures do not eliminate the disruptive effect of sudden failure of a large amount of power, with little warning, and they do not eliminate the need to provide the Large Loss Response. For each nuclear plant, the size of the Large Loss Response that needs to be provided is related to the size of the plant, not its capacity factor or load factor.

It has been reported that the increase in the number of nuclear power stations in the UK that is envisaged by the UK government would mean that the annual cost of providing the Large Loss Response would rise from £160m a year to £319m. The costs just mentioned would be shared equally across all electricity providers. Naturally, the renewable generators are not pleased about this.[43]

7.3 A nuclear plant is an inflexible source of power

The current generation of nuclear reactors, which would include what is planned for HPC, are relatively uneconomic if their output is constantly varied.[44] This means that, normally, they would provide little assistance in balancing supply and demand on the grid.

7.4 The concept of "baseload" is obsolete: what is needed are sources of power that are dispatchable

Because of its inflexibility, it is often suggested that the role of nuclear power is to provide "baseload", with the implication that this is some kind of advantage. But:

- As we have seen (Section 7.1), nuclear plants are often out of service or are working at reduced capacity. This undermines the claim that they are suitable as a source of baseload electricity.
- In terms of balancing supply and demand on the grid, the most useful sources of electricity are those that are "dispatchable", meaning that they can deliver power-on-demand—when it is needed and not otherwise.
- In that connection, several renewable sources of power have that feature. These include: hydropower; enhanced geothermal system (EGS); power from biomass; concentrating solar power with heat storage; and tidal lagoons that are managed in such a way that they can provide pumped-storage facilities as well as tidal generation.
- In short, *the concept of baseload is obsolete*. It may once have made sense in the days of the UK's Central Electricity Generating Board, but it is not appropriate for the energy world that is now developing. For reasons given below, energy supplies in the not-too-distant future will undoubtedly be dominated by solar power and wind power. Then what will be needed are complementary sources of power that are truly dispatchable, with techniques for balancing the grid, as described in Appendix B.

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[42] See "Exclusive: Will wind farms pick up the tab for new nuclear?" (Business Green, 2010-08-24, bit.ly/1zG1l3K); and "Renewable energy providers to help bear cost of new UK nuclear reactors" (The Guardian, 2013-03-27, bit.ly/1yTe5S9).

[43] See "Exclusive: Will wind farms pick up the tab for new nuclear?" (Business Green, 2010-08-24, bit.ly/1zG1l3K); and "Renewable energy providers to help bear cost of new UK nuclear reactors" (The Guardian, 2013-03-27, bit.ly/1yTe5S9).

[44] See "Nuclear in France—what did they get right?", 2009-06-22, bit.ly/15PkS3S.

In connection with the last point:

- There is no possibility that nuclear power could supplant the dominant role of solar and wind power in the future. This is because of its very high and rising cost (Section 4.1), the relatively low and falling cost of renewables (Section 4.5), the superabundance of renewables (Section 5), the speed with which solar and wind power are growing (Section 11.2), the shrinkage of nuclear power (Section 11.1), and the exceptionally long build times for nuclear plants (Section 11.1).
- As renewables come to dominate the energy scene, it will become increasingly clear that inflexible nuclear plants will be an embarassment as they will continue to churn out power regardless of whether it needed.[45]

7.5 Diversity

As argued in Section 9.2, nuclear power can actually reduce the diversity of sources of power.

7.6 Nuclear power is not a "home grown" source of power

It is sometimes argued that nuclear power promotes energy security because it is "home grown". It is true that the South Terras Mine in Cornwall was mined for uranium from 1873 to 1903 and that there are uranium deposits on Orkney.[46] But all UK supplies of uranium are currently imported, undermining the argument that nuclear power is home grown.

By contrast with nuclear power, the "fuel" for all renewables based in the UK, including negawatts, is not only free but entirely local, thus eliminating the risk that imports might be cut off.

7.7 Renewables can provide plentiful, diverse, robust, reliable and responsive supplies of electricity—and sooner than nuclear power

As we have seen, there is a superabundance of renewable sources of energy (Sections 5), and there are many reports showing how to decarbonise the world's economies without using nuclear power (Section 6). As we shall see (Section 11), renewables can be built much faster than nuclear plants. And there is considerable diversity amongst renewables, including negawatts (Section 8). Those things should help to persuade us that renewables can provide secure and diverse supplies of energy, without the use of nuclear power, and sooner than nuclear power.

7.7.1 Gradual and predictable variations

By contrast with the disruptive effect when a nuclear plant fails (Section 7.2), it is virtually impossible for there to be an unexpected and sudden large fall in the output from renewables: variations in their output are almost always relatively gradual, and such variations are normally predictable; and, via the provision of alternative routes, transmission grids may be designed to be robust against failures.

7.7.2 Negawatts don't fail suddenly with little warning

It should not be forgotten that the most reliable source of power is negawatts: reductions in the need for energy that may be achieved by conservation measures. All such power has a capacity factor or load factor of 100%, without any possibility of a sudden and unexpected large loss of

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[45] This kind of problem has already appeared in Germany, as described in "Renewable power cuts into baseload in Germany", Renewables International, 2012-04-04, bit.ly/1zRNGkN.

[46] "Uranium mining by country", Wikipedia, retrieved 2015-01-30, bit.ly/1tFvDAM.

power. And, as we have seen (Section 5), the potential for savings in energy is very large [CAM2012, BMU2012]

7.7.3 Demonstrations

A demonstration of the way that renewables can provide a reliable and responsive source of electrical power is the "Combined Power Plant" which links and controls 36 wind, solar, biomass and hydropower installations spread throughout Germany.[47] It has proved to be just as reliable and powerful as a conventional large-scale power station.[48]

Research at the University of Delaware has shown that a mix of offshore and onshore wind, along with contributions from solar power, could provide reliable and cost-effective power flow during all but a handful of days in a hypothetical four-year period under study.[49]

7.7.4 Techniques and technologies for balancing supply and demand on the grid

Of course, the wind does not blow all the time and the sun does not shine at night. So how is it possible for renewables to provide robust, reliable, and responsive, supplies of power? The answer is that there is a wide range of techniques for balancing variable supplies of electricity with variable demands for electricity. Some of those techniques are described in Appendix B. Also relevant is how renewables can provide a backstop against all contingencies, as described next.

7.8 A backstop against all contingencies

It is sometimes argued that nuclear power would be a useful backstop if other sources of power are not available. But if such a backstop is needed, it can be provided very much more cheaply and effectively like this:

- Maintain a strategic reserve of biogas or biomethane. Alternatively, it may be acceptable in terms of CO_2 emissions to use conventional gas, since the backstop would be used relatively rarely and the corresponding emissions would be relatively small.
- Maintain a strategic reserve of gas-fired power stations that are near the ends of their working lives but still in working order.
- Use these two resources to provide electricity if or when all other sources have failed.
- Because gas-fired power stations are normally much smaller than nuclear plants, the strategic reserve would comprise several such plants, helping to reduce the disruptive effect is any one plant should fail.

8 Other aspects of security

As mentioned above, nuclear power is also bad for other aspects of security besides security of energy supplies. But most of those other aspects also have implications for the security of energy supplies.

[47] "The combined power plant", Kombikraftwerk 2, 2007, bit.ly/1yJT6MW.

[48] See also "The US city that has decided to go 100% renewable", RE New Economy, 2014-10-29, bit.ly/1LpKfu2.

[49] "Solution to renewable energy's intermittency problem: more renewable energy", Scientific American, 2012-12-12, bit.ly/1BylyU8.

8.1 The threat of attack by terrorists

Nuclear power plants, deposits of nuclear waste, and the system for transporting nuclear fuel and nuclear waste, are vulnerable to attack by terrorists:

- In July 2006, a reporter from the Daily Mirror newspaper managed, very easily, to plant a fake bomb on on a train carrying a cargo of nuclear waste.[50]
- The new generation of drones may be used for surveillance of nuclear plants, or to plant bombs where nuclear plants are vulnerable, by-passing fences and other traditional forms of security.[51] Deposits of nuclear waste are also vulnerable to attack.
- There is potential for cyber attacks on nuclear plants.[52]
- According the UK's security service, MI5, "The current threat level from international terrorism for the UK is assessed as **SEVERE**".[53]

8.2 Nuclear power is dangerous

With worldwide experience of nuclear power over a period of several decades, it is now unambiguously clear that nuclear power is dangerous:

- Between 1952 and 2011, there were 26 nuclear power plant accidents and incidents with multiple fatalities and/or more than US$100 million in property damage.[54] These include the Windscale fire in1957 (rated 5 on the International Nuclear Event Scale[55]), the Three Mile Island accident in 1979 (rated 5), the Chernobyl disaster in 1986 (rated 7), and the Fukushima disaster in 2011 (rated 7) .
- Other serious accidents or incidents with nuclear reactors or related facilities include:[56]
    - A partial meltdown in 1952 at the NRX nuclear reactor at the Chalk River Laboratories in Ontario, Canada.
    - A core meltdown at the EBR-I nuclear reactor in Idaho, USA, in 1955.
    - Criticality accidents in 1953, 1957, 1958, and 1968, at the Mayak nuclear plant in the former Soviet Union.
    - The Kyshtym disaster in 1957 at a facility at Mayak for, amongst other things, the reprocessing of nuclear fuel.

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[50] "We plant 'bomb' on nuke train", Daily Mirror, 2006-07-21, bit.ly/1EuxD2S. See also "An atomic time bomb", Daily Mirror, 2006-07-21, bit.ly/1632xAh; and "Toxic cargo is a perfect terror target", Daily Mirror, 2006-07-21, bit.ly/1Keszhi.

[51] See, for example, "More drones spotted over French nuclear power stations", The Guardian, bit.ly/13pawH3. See also "Most French nuclear plants 'should be shut down' over drone threat", Newsweek, 2015-02-24, bit.ly/18hOnNL; "TERROR THREAT ALERT: UK's nuclear plants are at SERIOUS risk of terrorist drone strikes", Daily Express, 2015-02-23, bit.ly/1vpysHc; "Britain's atomic power plants 'could be attacked by drones' ", The Independent, 2014-12-21, ind.pn/1ArLKmc.

[52] See, for example, "Stuxnet", Wikipedia, retrieved 2015-02-03, bit.ly/1zxJbha; and "Cyber-attacks on South Korean nuclear power operator continue", The Guardian, 2014-12-28, bit.ly/1EDOfGl.

[53] See bit.ly/1jk0kkb.

[54] See "Nuclear and radiation accidents and incidents", Wikipedia, retrieved 2015-02-04, bit.ly/1yFSiKa.

[55] See "International Nuclear Event Scale", Wikipedia, retrieved 2015-02-04, bit.ly/1z9jm3w.

[56] See "Nuclear and radiation accidents and incidents", Wikipedia, retrieved 2015-02-04, bit.ly/1yFSiKa.

- Several accidents with nuclear reactors between 1957 and 1964 at the Santa Susanna Field Lab near Los Angeles, including a core meltdown. There was also a partial meltdown in 1969.
- Core meltdowns at:
    - The Fermi 1 nuclear reactor in Michigan, USA, in 1966.
    - The Chapelcross nuclear power plant in Scotland in 1967.
    - The Saint Laurent nuclear power plant in France in 1969 and also in 1980.
    - The A1 plant at Jaslovské Bohunice, Czechoslovakia, in 1977.
- In 1984, the Fernald Feed uranium processing facility Ohio, USA, released millions of pounds of uranium dust into the atmosphere, causing major radioactive contamination of the surrounding areas.

Also:

- In late July 2006 there was an accident at Sweden's Forsmark nuclear power station which was described as a near-meltdown by Lars-Olov Hoglund, a Swedish nuclear expert.[57]
- In 2002, there was a near catastrophe at the Davis-Besse nuclear plant in Ohio.[58]
- In 1993, at the Narora nuclear power plant in India, there was a near meltdown: " 'In our Narora station there was a major fire, which got that reactor pretty close to meltdown, frankly,' says A. Gopalakrishnan. He was head of India's Atomic Energy Regulatory Board at the time."[59]

It is sometimes argued that nuclear accidents like those described above are not dangerous. But:

- It can decades for radiation-induced cancers to develop.
- Nuclear exclusion zones established at the sites of nuclear disasters such as those at Chernobyl[60] and Fukushima[61] confirm that the relevant national authorities consider that the associated releases of radioactive materials are dangerous.

8.3 Proliferation of nuclear weapons

There is little doubt that the creation and distribution of nuclear fuels and nuclear waste creates opportunities, via theft or bribery, for terrorists or national governments to obtain materials for the construction of dirty bombs, atomic bombs, or even hydrogen bombs (see also Section 8.1).

The Campaign for Nuclear Disarmament writes:[62]

> "The proliferation of nuclear weapons is inextricably linked to nuclear power by a shared need for enriched uranium, and through the generation of plutonium as a by-product of spent nuclear fuel. The two industries have been linked since the very beginning and a nuclear weapons free world requires a non-nuclear energy policy."

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[57] See Spiegel Online, 2006-08-07, bit.ly/1DFlxQP; and report in the International Herald Tribune, 2006-08-04, bit.ly/1xgvT4x.
[58] See "US nuclear safety in spotlight", Financial Times, 2011-03-22, on.ft.com/1xgxGqh; see also "Davis-Besse nuclear plant comes close to disaster as lax regulator places company interests ahead of public safety", Nuclear Information and Resource Service, 2001-03-13, bit.ly/1yHjbNN.
[59] See "Japan's nuclear crisis stokes fears in India", NPR, 2011-04-05, n.pr/1zJFVkF.
[60] See "Chernobyl exclusion zone", Wikipedia, retrieved 2015-02-04, bit.ly/1DxlshQ.
[61] See "Japanese reaction to Fukushima Daiichi nuclear disaster", Wikipedia, retrieved 2015-02-04, bit.ly/1Kr3ZtN.
[62] Campaign for Nuclear Disarmament, retrieved 2015-01-30, bit.ly/1yM9Djq.

9 Diversity of supplies

It is sometimes argued that nuclear power would add to the diversity of energy supplies. But this is more than a little misleading, as discussed in the following two subsections.

9.1 Diversity in renewables

Renewables are already very diverse: PV, concentrating solar power, onshore wind power, offshore wind power, tidal lagoons, tidal stream generators, the Severn barrage, wave power, enhanced geothermal power (EGS), power from biomass, hydropower, and of course a diversity of techniques for generating negawatts.

There is really little to be gained from any additional diversity, certainly not enough to outweigh the many disadvantages of nuclear power (summarised in Section 13).

9.2 Nuclear power can reduce diversity

Since funds for the development of energy infrastructure are not unlimited, subsidies for nuclear power necessarily reduce the funds available for renewables. This can mean that some types of renewable sources of power may fail to get the support they need, thus reducing the diversity of electricity supplies.

Although the UK has not yet started to build new nuclear plants, it appears that renewables may already be suffering from what appear to be the excessively pro-nuclear policies of the UK government, with discrimination against renewables. Apparent examples include:

- It has been reported that several offshore wind farms proposed for the UK may be scrapped owing to a budget cap on subsidies by the UK government.[63]
- More generally, it appears that cuts in subsidies for solar and wind power are potentially damaging for the development of those industries.[64]
- It has also been reported that there has been persistent blocking by the UK government of planning permissions for new onshore wind farms.[65]
- The recent failure of the pioneering wave energy company, Pelamis.[66] It appears that the company has not received the support it needs, despite the inevitable difficulties in opening up a new source of power.
- The failure of the proposed Severn barrage project[67] to get the support it needs. It has been estimated that the Severn barrage could produce as much as 5% of the UK's electricity needs.[68]

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[63] See "Offshore wind farms may be scrapped due to budget cap, Scottish Power warns", The Telegraph, 2014-10-30, bit.ly/1rXxN8y.

[64] See, for example, "Renewable energy sector reacts with anger to subsidy funding plans", Click Green, 2014-07-24, bit.ly/1CHnhMi; and "UK cap on renewable subsidies harms solar, says industry", PV Magazine, 2014-07-24, bit.ly/1KBeNWl.

[65] See, for example, "RenewableUK condemns Pickles' 50th intervention in a wind farm application", RenewableUK press release, 2014-09-24, bit.ly/1Cg5WqJ.

[66] See "Jobs go after no buyer found for Pelamis wave business", BBC News, 2014-12-20, bbc.in/1K7k2Pj.

[67] See "Severn barrage", Wikipedia, retrieved 2015-02-06, bit.ly/1zXj7Ou.

[68] See "Severn barrage: power generation potential", Wikipedia, retrieved 2015-02-06, bit.ly/1zXj7Ou.

- Slow progress in exploiting the large potential for tidal stream generation in the Pentland Firth, between Orkney and the mainland of Scotland. It has been estimated that tidal stream generators in the Pentland Firth could produce 43% of Scotland's electricity.[69]
- Slow progress in exploiting the large potential of tidal lagoons.[70] It has been estimated that tidal lagoons could produce as much as 8% of the UK's electricity needs.[71]
- Slow progress in exploiting the potential of enhanced geothermal power (EGS) in the UK. It appears that, to date, there is only one project in that area (the Eden Deep Geothermal Plant),[72] despite the estimated potential of EGS to supply 10% of the UK's electricity for 200 years.[73]
- Failure of the UK government's "Green Deal" scheme to have any significant impact on emissions from UK buildings.[74]
- Another indication of bias in policies of the UK government towards old energy technologies and away from renewables is that the UK Export Finance (UKEF) department has, in the five years up to May 2015, given financial support worth just £3.6m to green energy projects around the world, compared with £1.13bn for fossil fuel projects.[75] And it has been reported that the UK is spending 300 times more on fossil fuels than clean energy.[76]

10 Cutting emissions: renewables yield deeper cuts, and sooner

It is often claimed that nuclear power is a "low carbon" source of electricity and that, for that reason, it should be supported as a means of cutting emissions of CO_2. But peer-reviewed research shows that:

> "... nuclear energy results in 9-25 times more carbon emissions than wind energy, in part due to emissions from uranium refining and transport and reactor construction (e.g., Lenzen, 2008; Sovacool, 2008), in part due to the longer time required to site, permit, and construct a nuclear plant compared with a wind farm (resulting in greater emissions from the fossil-fuel electricity sector during this period; Jacobson, 2009), and in part due to the greater loss of soil carbon due to the greater loss in vegetation resulting from covering the ground with nuclear facilities relative to wind turbine towers, which cover little ground." [JD2011a, p. 1156; see also J2009].

As indicated in the quote, this comparison takes account of the exceptionally long build times of nuclear plants (Section 11.1) and corresponding delays in cutting emissions. Since there is a limit to

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[69] See "Tidal energy: Pentland Firth 'could power half of Scotland' ", BBC News, 2014-01-20, bbc.in/1cKXxwi.
[70] It appears that, so far, there is only one significant project of that kind: "Tidal lagoon, Swansea Bay", retrieved 2015-02-06, bit.ly/1oIuY8X.
[71] See "The economic case for a tidal lagoon industry in the UK", Cebr, bit.ly/1DNtHGL.
[72] See bit.ly/1C5lZFF.
[73] See bit.ly/1EONSYu.
[74] See, for example, "Green Deal faces criticism with uptake of only 1,612 last year", City AM, 2014-01-22, bit.ly/16NWuAX.
[75] See "UK spent 300 times more on fossil fuels than clean energy despite green pledge", The Guardian, 2015-02-10, bit.ly/1uyVeMl.
[76] See "UK spent 300 times more on fossil fuels than clean energy despite green pledge", The Guardian, 2015-02-10, bit.ly/1uyVeMl. .

the amount of greenhouse gases that can be poured into the atmosphere if we are to minimise the risk of triggering dangerous climate change,[77] it is important to avoid unnecessary delays.

Other renewables have higher carbon footprints than wind power [J2009, Table 3] but they are still substantially below the emissions from nuclear power.

Although emissions from nuclear power are lower than emissions from an unabated coal-fired power station, they are still a long way from the much lower levels of emissions that are now urgently needed from the world's energy systems. Wind power and most other renewables can start cutting emissions sooner and more deeply than nuclear power.

As was mentioned in Section 7.1, it appears that a significant part of the rise in the UK's emissions of CO_2 in 2010 was due to the unreliability of nuclear power stations.[78]

In general, the claim that nuclear power should be subsidised because it is "low carbon" is very misleading. Bearing in mind that that renewables can be built much faster than nuclear plants (Section 11), that renewables can deliver much deeper cuts in emissions (this section), that they are cheaper than nuclear power (Section 4), and that renewables can provide plentiful, diverse, robust, reliable, and responsive, supplies of power (Section 7.5), there is no case for subsidising nuclear power as a means of cutting emissions.

11 Speeds of construction

As described in the following subsections, there are stark contrasts between the speeds of construction of nuclear and renewable power plants. Some of the evidence is derived indirectly via rates of growth (or shrinkage) of those two kinds of generator.

11.1 Speed of construction of nuclear plants, and shrinkage of the industry

As has been mentioned earlier, individual nuclear plants are very slow to build. Here is some of the evidence:

- It has been reported that, for Areva's last four nuclear reactors, the average time from start of construction to full grid connectivity was 17.5 years [BJPS2012b, p. 4].
- *The Olkiluoto nuclear plant*. Wikipedia says:[79] "According to [the] Financial Times in December 2014, construction of the Olkiluoto plant [Unit 3] has descended into farce as it is currently expected to open nine years late and several billions of euros over budget." Construction began in July 2005 and the plant is not now expected to start operating until 2018—more than 12 years from start to finish.
- *The Flamanville nuclear plant*. According to Wikipedia,[80] "Construction on a new reactor, Flamanville 3, began on 4 December 2007. ... EDF has ... said France's first EPR would ... start commercial operations in 2012, after construction lasting 54 months. ... In November 2014, EDF announced that completion of construction was delayed to 2017 due to delays in component delivery by Areva."

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[77] See, for example, " 'Carbon budget' talks urgent warns Lord Stern", The Guardian, 2013-09-29, bit.ly/1zuTiU8. See also "UN climate report set to establish 'global carbon budget' ", RTCC, 2013-09-20, bit.ly/1BPndol.
[78] From "Leaping UK carbon emissions deliver two red-hot lessons", The Guardian, 2012-02-07, bit.ly/1A5VUdQ.
[79] See "Olkiluoto nuclear power plant", Wikipedia, retrieved 2015-02-02, bit.ly/1uR9nzo.
[80] See "Flamanville nuclear power plant", Wikipedia, retrieved 2015-02-02, bit.ly/1yviDus.

- An indirect and partial indication of problems in this area is that global electricity generation from nuclear plants dropped by an historic 7 percent in 2012, adding to the record drop of 4 percent in 2011.[81] Worldwide, nuclear power is shrinking, not growing.

11.2 Speed of construction of renewables, and high rates of growth

It is clear that installing solar panels is very much quicker and simpler than building a nuclear power station. Although wind farms (on land) are not quite so simple to construct as solar farms, they are clearly much easier to construct than nuclear plants.

Indirect evidence for the speed with which renewables may be constructed comes from the high rates of growth of those kinds of power:

- The global total of solar PV was roughly 67 GW at the end of 2011, compared with just 1.5 GW in 2000. Over the past five years, solar PV has averaged an annual growth rate of over 50%.[82]
- As reported in the Washington Post:[83] "Futurist Ray Kurzweil notes that solar power has been doubling every two years for the past 30 years—as costs have been dropping. *He says solar energy is only six doublings—or less than 14 years—away from meeting 100 percent of today's energy needs.* Energy usage will keep increasing, so this is a moving target. But, by Kurzweil's estimates, inexpensive renewable sources will provide more energy than the world needs in less than 20 years. Even then, we will be using only one part in 10,000 of the sunlight that falls on the Earth." (emphasis added).
- Global wind power capacity was 238 Gigawatts (GW) at the end of 2011, up from just 18 GW at the end of 2000, with an average growth rate of over 25% over the past five years.[84]
- In recent years in Germany, solar power has been installed at very high rates: 7.6 GW in 2012; 7.5 GW in 2011; and 7.4 GW in 2010.[85] A possible objection is that 1 GW of solar power is not the same as 1 GW of nuclear power—because the capacity factor (or the nearly-equivalent load factor) for a nuclear plant (about 70%, see Section 7.1) is higher than the capacity factor for solar panels (about 9%).[86] But:
    - Allowing for the capacity factor, 7.5 GW of solar power will, each year, produce about $7.5 \times 365 \times 24 \times 0.09 = 5913$ GWh of electricity . For comparison, assuming that the capacity factor for nuclear power is about 70% (Section 7.1), HPC, rated at 3.2 GW, would produce $3.2 \times 365 \times 24 \times 0.7 = 19{,}622$ GWh of electricity. Thus in 4 years, solar panels may be installed producing more electricity than a nuclear plant that it is likely to take 10 years or more years to build (Section 11.1).
    - However, it is misleading to compare different sources of power purely in terms of the total amount of electricity that they can produce in a year. This is because solar power produces power in the day time, which is when it is most in demand, while nuclear power plants are normally operated so that they carry on generating power at night when demand is relatively low. That difference means that 1 GW of solar

[81] "World nuclear industry status report", Wikipedia, retrieved 2015-01-30, bit.ly/1LqCLXB.
[82] See International Energy Agency, FAQs: renewable energy, retrieved 2015-01-30, bit.ly/1kSBqOO.
[83] See "The coming era of unlimited—and free—clean energy", Washington Post, 2014-09-19, wapo.st/1AUAvjd.
[84] See International Energy Agency, FAQs: renewable energy, retrieved 2015-01-30, bit.ly/1kSBqOO.
[85] See "Germany installed record amounts of solar power in 2012, 7.6 GW of new capacity", Clean Technica, 2013-01-08, bit.ly/1DBmyth.
[86] See "Capacity factor", Wikipedia, retrieved 2015-02-03, bit.ly/1D9IHkk.

power is much more nearly equivalent to 1 GW of nuclear power than it may superficially appear.

- In 2014, 4.8 GW of wind turbines were installed in Germany.[87] With political will, much the same may be achieved in the UK. Since the load factor for onshore wind power in the UK is about 25%,[88] we may conclude that, in a year, 4.8 GW of wind turbines would produce about 4.8 × 365 × 24 × 0.25 = 10,512 GWh of electricity. For comparison, HPC would, as before, produce about 19,622 GWh of electricity. Thus it would take only 2 years to install new wind turbines producing more electricity than a nuclear plant that will probably take 10 or more years to build.
- It has been reported that renewable energy is poised to overtake nuclear power in the UK.[89]
- An interesting perspective on the potential speed of construction of renewables comes from the following observation by Mark Jacobson and Mark Delucchi [JD2009]. In their scenario, wind supplies 51% of worldwide demand, provided by 3.8 million large wind turbines, each rated at five megawatts. They say (p.61): "Although that quantity may sound enormous, it is interesting to note that the world manufactures 73 million cars and light trucks *every year*." In other words, renewables do not put exceptional demands on the world's capacity to make things.

  In that connection, we should not forget that, even if the world in the future were to rely on conventional power stations for its electricity, those power stations would need to be replaced every 30 or 40 years. With renewables, demands for the manufacture and installation of equipment would probably be no more than with conventional generating plants as they become due for replacement, possibly less.

12 Maturity of technologies

It is widely accepted that the main justification for subsidising any technology is that, while it has the potential to be commercially viable, it is not sufficiently mature to have reached the bottom of its cost-reduction curve.

Nuclear power does not fall into this category. It has been widely used for decades, it has received very large amounts of public support, it has had ample opportunity to bring costs down, but costs are on a rising trend (Section 4.1), not falling.

In connection with the levels of support that have been provided for nuclear power, *The Economist* has written that "More than half of the subsidies (in real terms) ever lavished on energy by OECD governments have gone to the nuclear industry."[90]

It is sometimes suggested that technologies such as concentrating solar power must be mature because they have a long history—CSP dates back at least as far as the 19th century, and perhaps as far as Archimedes' supposed use of the technology to set fire to Roman ships. Of course, the key difference between nuclear power and a technology like CSP is that the former has been widely used for decades, whereas CSP, for various historical reasons, is still not widely used and there is still plenty of room for cost reductions and refinements in the technology.

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[87] See "Italy rules out solar subsidies as Germany adopts auctions to dole them out", RE New Economy, 2015-02-04, bit.ly/1u9bbso.

[88] See Chart 6.5, p. 166, in [DECC2014]. These figures are for onshore wind power in the UK in the years 2000 to 2013.

[89] See "Renewable energy poised to overtake nuclear in the UK", New Scientist, 2015-02-24, bit.ly/1wCYNSZ. .

[90] From "Nuclear power out of Chernobyl's shadow", *The Economist*, print edition, May 6th 2004.

13 Summary: Renewables, including conservation of energy, are more than sufficient to meet our needs, and can do so better than nuclear power, and more cheaply

The foregoing sections all point to the conclusion that renewables, including conservation of energy, are more than sufficient to meet our needs, and can do so better than nuclear power, and more cheaply:

- *More than enough renewables*. There is a superabundance of renewables (Section 5), and many reports show how to decarbonise the world's economies without nuclear power (Section 6). See also, Sections 7.5, and 7.8.
- *Costs*. Taking account of all kinds of subsidy and hidden costs, nuclear power is much more expensive than renewables (Section 4). Even without taking account of hidden costs and subsidies, HPC is considered by commentators to be excessively expensive (Section 4.3).
- *Security of energy supplies*. Far from enhancing security of energy supplies, nuclear power actually makes things worse (Section 7). By contrast, renewables can provide plentiful, robust, reliable, and responsive, supplies of electricity (Section 7.5), and a backstop against all contingencies (Section 7.8).
- *Other aspects of security*. Nuclear power is also bad for other aspects of security, some of which have a bearing on security of energy supplies (Section 8).
- *Diversity of energy supplies*. Given the wide range of renewable sources of power, nuclear power would contribute little to diversity, certainly not enough to outweigh its many shortcomings (summarised in this section). And by diverting resources away from renewables, nuclear power may decrease the diversity of energy supplies.
- *Cutting emissions of greenhouse gases*. There is good evidence that emissions from the nuclear cycle are substantially higher than emissions from renewables (Section 8). In the quest to reduce global emissions, nuclear power is one of the last options to choose.
- *Speed of construction*. Nuclear plants take much longer to build than renewables, and, worldwide, renewables are growing very fast while nuclear power is shrinking (Section 11).

For all these reasons, and because nuclear power is a mature technology that has been widely used for decades (Section 12), *there is no valid justification for subsidising nuclear power*.

14 Responses to some arguments and conclusions in [EC2014]

As its title suggests, this section contains responses to some arguments and conclusions in [EC2014]. Sections VII, VIII, and IX, of [EC2014] are the sections in which the Commission sets out its arguments and conclusions about state aid for HPC. The main focus in this document will be on Section IX ("Assessment of the measure under Article 107(3)(C) TFEU"). We also refer to a letter from the EC to the UK government [EC2013].

Each Paragraph that is quoted from [EC2014] is shown indented and preceded by its number in brackets.

14.1 Objectives of common interest

> (196) The UK claims that it pursues the common EU objectives of decarbonisation, security of supply and diversity of supply at the lowest cost, and that it faces, like other MSs, a challenge in achieving them.
>
> (366) In the Opening Decision, the Commission questioned three of the common objectives put forward by the UK, i.e. diversification, security of supply, and decarbonisation.
>
> Paragraph 100 in [EC2013]: "The Service to be provided would be the construction of Hinkley Point C, within a specified time schedule, and operating Hinkley Point C within the framework of the Investment Contract. The UK submits that this service is required to achieve the combined general economic interest objectives of i) security of supply, ii) diversity of generation, iii) decarbonisation and iv) electricity price stability/affordability."

As argued below, none of these four things—decarbonisation, security of supply, diversity of supply, or the affordability or stability of electricity prices—provide any justification for subsidising nuclear power.

14.2 Decarbonisation

Although decarbonisation is mentioned in the two paragraphs just quoted, it receives little attention in Sections VII, VIII, and IX, of [EC2014], which are the sections in which the Commission sets out its arguments and conclusions about state aid for HPC.

For reasons given in Section 10, we believe that the objective of decarbonising energy supplies provides no justification for subsidising nuclear power.

14.3 Affordability and stability of electricity prices

> (398) The CfD openly addresses the need to provide price stability and predictability over the project's and the equity's rates of return, which are particularly important for investments of this size and duration and are therefore essential to allow the investment. In this sense, the CfD addresses the main market failures identified above.

It appears that the expression "price stability" in this paragraph has a meaning—price stability for investors—which is different from the meaning of the same expression in Paragraph 100 in [EC2013], quoted in Section 14.1. Since the latter is bracketed with "affordability", we shall assume that it refers to price stability for consumers.

With regard to affordability and price stability for consumers, it is clear that nuclear power fails on both counts and that subsidies for HPC will not help:

- As we have seen (Section 4), nuclear power is very expensive and costs are rising, while renewables are cheaper and costs are falling.
- Subsidies for HPC will not promote affordability for the consumer because they are simply added to consumers' bills.
- It is very likely that refinements in renewable technologies will mean falling prices for several years, followed by stable prices as the technologies mature. Although falling prices do not represent "price stability", we shall assume that no one is likely to object.
- The "fuel" for all kinds of renewables, including negawatts, is free. This will clearly help to promote stability in the price of electricity.

- Renewables are largely free of the very large and often unpredictable costs for the short-to-medium-term disposal of nuclear waste, long-term disposal of the more dangerous categories of nuclear waste, and the decommissioning of nuclear plants. Whether or not these costs are paid by nuclear operators or by the UK government, consumers and taxpayers will ultimately foot the bill.

14.4 Euratom Treaty

(370) As recognised in past Commission decisions, the Euratom Treaty aims at creating the "conditions necessary for the development of a powerful nuclear industry which will provide extensive energy sources." This objective is further reiterated in Art 1 of the Euratom Treaty, which establishes that "it shall be the task of the Community to contribute to the raising of the standard of living in the Member States (…) by creating the conditions necessary for the speedy establishment and growth of nuclear industries."

(371) On this basis, the Euratom Treaty establishes the Euratom Community, foreseeing the necessary instruments and attribution of responsibilities to achieve these objectives. The Commission must ensure that the provisions of this Treaty are applied.

(372) Art 2(c) of the Euratom Treaty provides that Member States shall "facilitate investment and ensure, particularly by encouraging ventures on the part of undertakings, the establishment of the basic installations necessary for the development of nuclear energy in the Community." Art 40 of the same Treaty envisages the Community publishing of illustrative programs "to stimulate investment, indicating production targets."

With regard to the Euratom Treaty and the above three clauses in [EC2014], the following points may be made:

- It appears that a case may be made that provisions of the Euratom Treaty cannot override provisions of the TFEU. One of the grounds for complaint in [EF2011] is "That the cap on liabilities for nuclear accidents of the Paris/Brussels Conventions constitutes state aid in the sense of Article 107 of the TFEU. Since Article 351 of the TFEU requires EU Member States to adapt and align their pre-existing Treaty obligations to be compliant with EU law, since relevant UK laws have not been amended in the light of that requirement, and since the cap on liabilities has not been notified to the European Commission, it is, technically, illegal under EU law."[91] It appears that similar arguments may be applied to the Euratom Treaty, even though the Treaty "forms part of the active treaties of the European Union".[92]
- In connection wit the last point, the selective promotion of one technology for the generation of electricity is entirely inconsistent with the concept of a competitive common market, a founding principle of the EU.
- The Euratom Treaty was devised when opinions in Europe, and energy supply technologies, were very different from what they are now. It would be entirely inappropriate, and inconsistent with the democratic foundations of the EU, for such a

[91] From Note 2 of a press release about [EF2011]: "Legal bid to halt nuclear construction", Energy Fair, January 2012, bit.ly/1AidtHP.
[92] See "Euratom Treaty", Wikipedia, retrieved 2015-02-05, bit.ly/16kuOlR,

treaty to dictate present-day policies on energy supplies, without a democratic re-examination of the issues.

If the EU were to be for-ever bound by outdated treaties, then, conceivably:

- It might find itself in the position of being obliged to "create the conditions necessary for the speedy establishment and growth of an industry for the transport of goods by means of horses and carts".
- Or it might be obliged to "facilitate investment and ensure, particularly by encouraging ventures on the part of undertakings, the establishment of the basic installations necessary for the development of an industry in the Community for the manufacture of quill pens."

- According to Wikipedia,[93] the Treaty "was not included as part of the *Treaty establishing a Constitution for Europe*, which sought to combine all previous treaties, over fears that including nuclear power in the treaty would turn more people against it."
- If necessary, steps should be taken to ensure that the EU does consider democratically whether or not it is still appropriate for the Euratom Treaty to be one of the treaties of the EU. That issue may be taken up directly with the EC and the Council of the European Union or, perhaps, via the European Court of Justice (ECJ).

14.5 Security of supply

(373) Based on the Commission assessment, the measure contributes to long-term security of supply, in particular based on capacity forecasts and the role which HPC's supply of electricity will play when it is expected to start operating.

With regard to this clause, the Commission's assessment needs to be made available for public scrutiny. A comprehensive case against the Commission's decision cannot be made until that assessment has been supplied.

But, from the evidence presented in previous sections of this document, it is very likely that the Commission's assessment is wrong:

- *Renewables are cheaper and better*. With regard to capacity, now and in the future, there is a superabundance of renewable sources of power (Section 5), many reports show how to decarbonise the world's economies without the use of nuclear power (Section 6), renewables can supply plentiful, diverse, robust, reliable, and responsive sources of power (Section 7.5), renewables can, in general, be built much faster than nuclear plants (Section 11), renewables are undoubtedly cheaper than nuclear plants—and they are getting cheaper while the cost of nuclear power is increasing (Section 4.5).
- *Nuclear power is intermittent*. Contrary to popular belief, nuclear power is an intermittent source of power (Section 7.1).
- *The Large Loss Response*. Like all kinds of equipment, nuclear power plants can fail. Failure of a nuclear plant normally means the sudden loss of a relatively large amount of power with little or no warning. Because such failures are exceptionally disruptive on the grid, it is necessary to make special provision—the Large Loss Response—to ensure that there are alternative sources of power when a nuclear plant fails (Section 7.2).

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[93] See "Euratom Treaty", Wikipedia, retrieved 2015-02-05, bit.ly/16kuOlR,

- *Inflexibility of nuclear power*. Nuclear power is an inflexible source of power that gives little or no assistance in balancing supply and demand on the grid (Section 7.3).
- *"Baseload" is an obsolete concept—what is need is power that is "dispatchable"*. It is suggested in [EC2014] and elsewhere, that nuclear power can provide "baseload" power, as if this was some kind of advantage. But (Section 7.4):
    - The intermittency of nuclear power means that it is not suitable as a "baseload" source of power.
    - More importantly, the concept of baseload is obsolete. A much more desirable attribute is that a source of power should be dispatchable—able to supply power on demand, if or when it is needed. Several renewable sources of power have that attribute.
- *Opportunity cost*. Given that funds for the development of energy infrastructure are not infinite, money spent on nuclear power reduces the funds available for solutions that are cheaper and better. This is an opportunity cost.
- *A backstop against all contingencies*. The cheapest and most effective way of providing a backstop against all contingencies is to maintain a strategic reserve of biogas, biomethane, or fossil gas, and a strategic reserve of soon-to-be-retired gas-fired power stations that are still in working order (Section 7.8).

Nuclear power is also bad for other aspects of security, some of which have a bearing on security of supplies. Here are the main points:

- Nuclear power is not a "home grown" source of power (Section 7.6).
- Nuclear power is vulnerable to attack by terrorists (Section 8.1).
- Without doubt, nuclear power is dangerous (Section 8.1).
- And nuclear power is likely to facilitate the proliferation of nuclear weapons (Section 8.3).

14.6 Diversity of energy supplies

> (374) The Commission therefore finds that aid measures aimed at promoting nuclear energy pursue an objective of common interest and, at the same time, can deliver a contribution to the objectives of diversification and security of supply.

There seems to be something of a non sequitur here. The (false) reasoning seems to be that aid measures aimed at promoting nuclear energy help to promote an "objective of common interest" because nuclear power promotes security of energy supplies and diversity of energy supplies. Since the former has already been discussed (Section 14.5), this subsection considers diversity of supplies.

As we have seen (Section 7.5), renewables are already quite diverse: there is really no need for any additional diversity, especially in view of the high cost of nuclear power, long build times, and other shortcomings summarised in Section 13. And since nuclear power diverts resources away from alternatives, it may actually reduce diversity of supply by killing off some of those alternatives.

14.7 Market failure?

> (378) There is merit in UK's claims that a residual market failure exists in carbon emissions in the long-run since there are no long-term price signals for carbon and a

> lack of a sufficiently precise and stable regulatory framework for carbon reductions in the long term. This argument justifies some sort of government intervention to foster low-carbon generation, which includes nuclear.

It is true that the externalities of burning fossil carbon are not properly accounted for, largely because of the failure of the EU Emissions Trading System to put realistic price on emissions. But from the evidence presented above, there are much better solutions to the problem than subsidising nuclear power: emissions can be reduced more quickly and more cheaply by investing in renewables.

> (379) In addition, the arguments that the security of electricity supply is not adequately priced in, and that private investment decisions in electricity generation may remain below the social optimum, seem to have merit.

This is entirely wrong. Far from enhancing security of supplies, nuclear power makes things worse (Section 7). Any intervention in the market should aim to encourage the development of renewables, especially those that are dispatchable (Section 7.4), with techniques and technologies for balancing supply and demand on the grid, as described in Appendix B.

> (381) There are however two market failures which are more relevant specifically to nuclear energy.
>
> (382) First, investment in nuclear energy is subject to significant risk given the combination of high upfront capital costs, long construction times and a long period of operation to recover the investment costs. The lack of market-based financial instruments, as well as other types of contracts, to hedge against such substantial risk constitutes a market failure which is specific to few technologies among which nuclear energy. The instruments currently available from the market do not provide time horizons in excess of 10 or 15 years, either in the form of long-term contracts or as risk-hedging instruments.

This line of reasoning is based on the false assumption that there is a case for subsidising nuclear power. But, as we have seen, the alternatives are more than sufficient to meet our needs, they are cheaper than nuclear power, and have none of the shortcomings of nuclear power, as summarised in Section 13.

> (383) In particular, nuclear energy production has extremely long and complex life cycles, unlike most other energy infrastructure and indeed unlike most infrastructure investments in general. It normally takes eight to ten years to construct a nuclear power plant, with costs to be incurred before any revenues are generated and with risks borne only by the investor. The 60-year operational life is characterised by the generation of revenues, but these are based on an uncertain evolution of wholesale prices. The ensuing decommissioning period can last forty years, with funds to be set aside for the shutdown of the installation. Finally, high-level nuclear waste storage and treatment is typically carried out on site before transfer to a repository, where waste is expected to be stored for thousands of years.

Again, this reasoning is based on the false assumption that there is some kind of justification for subsidising nuclear power. The problems mentioned in this paragraph all argue in favour of sources of power that are free of those problems.

> (384) Second, there is the risk of (predominantly political) “hold-up” once the investment is made and the investor is in a weaker bargaining position. Given the controversial nature of nuclear technology, successive governments can take different views on its desirability,

> which can compound uncertainty for private investors. The Commission is not convinced that this issue may qualify as a market failure, but it recognises that it can be a factor in making investment in new nuclear more difficult, in particular given the long timelines needed for constructing, operating and decommissioning nuclear power plants.
>
> (385) These issues are unique to nuclear technology. All technologies can in principle suffer from a political "hold-up", however given the longer time horizon and the greater investment size, nuclear projects can be expected to suffer more. And the impossibility of adequately sharing the risks stemming from the high investment through market instruments impacts disproportionately more on nuclear than on other technologies.

As before, these arguments depend on the false assumption that anyone should be considering providing subsidies for nuclear power.

> (392) For the reasons highlighted above, and to the extent that investment in new nuclear aims at the objective of common EU interest highlighted in Section IX.2 above, the Commission therefore concludes that the proposed State aid measures are necessary, on the basis of this specific type of new nuclear investment and on the basis of the state and functioning of financial markets observable in the UK at the time of this decision.

Once again, this paragraph, and the ones that precede it, are making the false assumption that there is a valid case for subsidising nuclear power.

14.8 Section IX.4 of [EC2014]: "Appropriate instruments and incentive effect"

> (397) The Commission has already accepted in its decision of 23 July 2014 that CfDs can be an appropriate instrument to support low-carbon technologies and in particular renewable technologies.

It appears that CfDs may indeed be an acceptable means of supporting renewable technologies. But, as indicated in Section 14.1, there is no case at all for any kind of subsidy for nuclear power as a means of cutting emissions of CO_2:

- Emissions from the nuclear cycle are much higher than from renewables (Section 8).
- Renewables can be built much faster than nuclear plants (Section 11).
- Renewables are much cheaper than nuclear power (Section 4).
- Renewables can provide plentiful, diverse, robust, reliable, and responsive, supplies of power (Section 7.5).

> (400) Given the objective of the aid measures, i.e. pursuing an investment in nuclear energy, the Commission considers that an open tender where more electricity generating technologies would participate would not have been appropriate, given the timeframe required by the UK.

For all the reasons summarised in Section 13, it is entirely inappropriate for "pursuing an investment in nuclear energy" to be an objective of any aid measures.

With regard to timeframes, renewables can meet all our energy needs (Section 7.5) and cut emissions (Section 8) very much faster than nuclear power.

Thus it is entirely inappropriate for special arrangements for nuclear power to have been negotiated with EDF. As indicated paragraph 400 of [EC2014], there should be a process of competitive bidding for levels of subsidies like those outlined in the EC's press release "State aid: Commission authorises UK aid package for renewable electricity production".[94]

In this connection, the bidding process should take account of levels of maturity (Section 12), it should take account of the fact that any one type of renewable technology may not meet all requirements but that, collectively, they can; and it should embrace technologies for balancing supply and demand on the grid, outlined in Appendix B.

> (401) Following the open call for interest launched by the United Kingdom, only EDF came forward with an investment proposal. The UK has provided evidence50 that no other project was ready to compete with HPC at the time of the negotiations with EDF. Given the specificities of nuclear technology, pre-commitment costs are substantial and a limited number of operators has the knowledge and financial strength to undertake investments of the size of HPC. The UK explained that they would have preferred to have competitive tension among bidders, but that there were no other firm offers for new nuclear.
>
> (402) The Commission recognises that nuclear energy is in general in a different situation than other technologies in terms of the requirements investors have to meet. There are simply no comparable projects to a nuclear power plant in terms of the investment lifetime and size. The HPC project is very peculiar. It is an infrastructure project of almost unprecedented scale, in energy as well as any other sector. Therefore, the Commission acknowledges that a tendering process in the case at hand would not have provided meaningful results given the constraints of the project.

For reasons like those given above, it is entirely inappropriate for there to have been a bidding process that is restricted to nuclear power. The bidding process should be much broader, it should take account of levels of maturity, and it should take account of the fact that, renewables for example, should be assessed collectively.

> (403) The Commission also believes that the provision of the CfD for new nuclear investment does not discriminate excessively against other technologies and is not more favourable to new nuclear than it is for other technologies. Indeed other technologies can be similarly supported by CfDs, with the same type of instrument being used, except for adaptations which can be considered necessary for the differences in technologies (such as the Secretary of State agreements or the opex reopeners).

There are three main problems here:

- The premise is wrong: there is no conceivable reason for providing any kind of subsidy for nuclear power (Section 13), and that includes CfD.
- That it may be appropriate to provide CfDs for other technologies, has no bearing on whether or not it may be appropriate to provide CfD for nuclear power—it isn't appropriate.
- It is clear that the very high levels of support proposed for HPC (Section 4.3) must have a damaging effect on the alternatives, both by diverting funds away from those alternatives and by artificially lowering the price of nuclear power, thus making it more difficult for alternatives to compete.

> (404) Moreover, the intermittent nature of many renewables technologies does not allow them to be a suitable alternative to a baseload technology such as nuclear energy. As

[94] This press release, dated 2014-07-23, may be seen at bit.ly/1A1epiw.

explained in point (199) above, the replacement of the capacity that is expected to be covered by the HPC project corresponds to 14GW of onshore wind or 11GW of offshore wind capacity, which is unrealistic to be provided in the same timeframe.

This is entirely wrong:

- All sources of power are intermittent, including nuclear power (Section 7.1).
- As described in Section 7.4, the concept of "baseload" power is obsolete.
- Timescales are the Achilles' heel of nuclear power (Section 11). If we are worried about the time needed to create generating capacity of a given size, nuclear power is the worst possible technology to use. Renewables can fill the gap very much faster.

(406) Within the limits of this specific case and project, therefore, the Commission concludes that the CfD, in combination with the Credit Guarantee and the Secretary of State Agreement, as structured in the notified measures, are appropriate instruments to provide aid and offer an adequate incentive effect to the beneficiary.

Again, this is entirely wrong. There is no valid justification for subsidising nuclear power (Section 13).

14.9 Section IX.5 of [EC2014]: "Proportionality"

All discussions of whether or not aid for HPC would be "proportionate" are entirely otiose—because there is no valid justification for any kind of subsidy for nuclear power (Section 13).

14.10 Section IX.6 of [EC2014]: "Potential distortions to competition and trade"

Subsidies for HPC are likely to distort competition and trade:

- Since there is not an infinitely large pot of money available for the support of energy technologies, subsidies for HPC will necessarily reduce the subsidies available for other sources of energy (Section 9.2).

  If different energy technologies had equal merit, this might not matter. But it is clear from information summarised in Section 13 that there is an opportunity cost: money spent on nuclear power would be much better spent on renewables.
- If HPC goes ahead, its 3.2 GW will compete directly with other sources of power (including negawatts), both those in the UK and—owing to HVDC connections with Ireland and continental Europe—in the rest of Europe.
- Since the project is very unlikely to go ahead without the forms of support that have been offered for it (CfD, CG, SSA), and since those subsidies will undoubtedly lower the price of electricity from HPC, it is clear that those subsidies will necessarily distort competition and trade in the energy sector.

(517) The Commission tested the extent to which EDF could have the possibility to systematically realise higher prices in the market. As explained in paragraph (11), the RP curve is based on prices one season (i.e. six months) ahead of delivery, or a 'season-ahead' price. As nuclear is a baseload technology with a steady and comparably reliable output profile, HPC could in theory sell large quantities of electricity further ahead than one season. If prices longer than one season ahead are systematically and significantly higher the season-ahead prices – the

basis of the RP curve – then on average HPC could realise a higher effective price per MWh than the strike price.

With regard to “As nuclear is a baseload technology with a steady and comparably reliable output profile”, the concept of “baseload” is obsolete (Section 7.4) and, like all other electricity generating technologies, nuclear power is intermittent (Section 7.3).

Similar comments apply to paragraphs 519, 520, 530, and 533.

14.11 Section X. of [EC2014]: “Conclusion”

We believe it is clear, from the evidence that has been presented, that several arguments and conclusions in [EC2014] are false. We believe that there is no valid justification for any kind of subsidy for nuclear power, including both the subsidies that have been offered for HPC (CfD, CG, and SSA) and the several hidden subsidies enjoyed by the nuclear industry (Section 4.1).

We believe that the EC is wrong to say that the subsidies that have been offered for HPC are “compatible with the internal market pursuant to Art 107(3)(c) TFEU”.[95]

Appendices

Appendix A. Comments on “State aid SA.34947 (2013/C) (ex 2013/N)—Investment Contract (early Contract for Difference) for the Hinkley Point C New Nuclear Power Station: Invitation to submit comments pursuant to Article 108(2) of the Treaty on the Functioning of the European Union”[96]

The proposed “Contract for Difference”, mentioned in the title of the invitation to submit comments, would not be a subsidy for nuclear power if the reference price for electricity were to be generally higher than the strike price. But with the Hinkley Point proposal, this is very unlikely to happen. The prices of electricity from onshore wind farms and photovoltaics are already approaching the current market price for electricity in the UK and both of them are likely to become cheaper in the future. Costs for other renewables are also falling. Thus the strike price of £95.50 per MWh agreed for the proposed Hinkley Point project—about twice the current market price for electricity and index-linked for the 35 years of the contract—is likely to result in a very large subsidy for the plant throughout those years. At the very least, the scheme will artificially reduce the cost of borrowing for the project.

But the contract for difference is just one of several subsidies that would be available to the Hinkley Point project. Others are:

- Loan guarantees from the UK government.
- Seven existing subsidies for nuclear power, described in “Nuclear Subsidies” (PDF, bit.ly/1bSgGhx). One of the largest of these is the cap on liabilities for nuclear disasters.
- One existing subsidy (the exemption of uranium from the tax on fuels used for the generation of electricity) and two proposed subsidies (plus the contract for difference)

[95] Paragraph 550 in [EC2014].
[96] See http://bit.ly/1s9dtWn.

described in “Subsidies for nuclear power in the UK government’s proposals for electricity market reform”, PDF, bit.ly/1de3BTE).

There is no valid justification for any of these subsidies for nuclear power. They divert resources from other options that are altogether better and cheaper. For reasons given below, they are bad for energy security, bad for the fight against climate change, bad financially for consumers and taxpayers in the UK, and bad for the development, throughout Europe, of the good alternatives which are ready to go, cheaper than nuclear power, and very much quicker to build.

Here are the main reasons:

- **Nuclear power is a mature technology that should not require any subsidy**. Subsidies are for newer technologies that are still finding their feet commercially.
- Contrary to what the UK government suggests, nuclear power is a hindrance, not a help, in ensuring security of energy supplies:
    - Like all kinds of equipment, nuclear power stations can and do fail. Failure of a nuclear power station is normally very disruptive on the grid because a relatively large amount of electricity is lost, often quite suddenly and with little warning.
    - By contrast, variations in the output of renewables are much easier to manage because they are gradual and predictable. There are several techniques for managing that kind of variation and also variations in the demand for electricity (see bit.ly/I4E5vr). **The supposed problem of intermittency in renewables is overplayed**.
    - Nuclear power lacks the flexibility needed for balancing supply and demand on the grid.
    - Contrary to popular belief, nuclear plants are not "always on", 24/7. Apart from unscheduled failures, nuclear power stations often operate at reduced capacity or are taken out of service for routine maintenance.
- Contrary to what the UK government suggests, Nuclear power is a poor means of plugging the supposed “energy gap” or “keeping the lights on”:
    - Nuclear plants are very slow to build: they can take 17 years or more to complete. (see bit.ly/1a7idjS, p. 4).
    - In general, renewables can be built very much faster.
    - There is good evidence for a superabundance of renewable sources of energy (see bit.ly/9MKP5i).
    - There are now many reports showing how to decarbonise the world's economies without using nuclear power (see bit.ly/wRQ8ro).
- Contrary to what the UK government suggests, **Nuclear power is a poor means of cutting emissions**. Peer-reviewed research shows that **the nuclear cycle produces between 9 and 25 times more CO_2 than wind power** (see bit.ly/1afpW06). Other renewables also have much lower emissions than nuclear power.
- Contrary to what the UK government suggests, nuclear power is, taking account of all subsidies, much more expensive than the clean and safe alternatives, and likely to remain so in the future:

  - Withdrawal of just one of the present subsidies for nuclear power (the cap on liabilities) would raise the price of new-build nuclear electricity to **at least £200 per MWh**, substantially more than the unsubsidised cost of offshore wind power (about £140 per MWh and falling), itself considered to be one of the more expensive kinds of renewable energy (see bit.ly/KisjOT).
  - **The cost of renewables is falling**. Greg Barker MP, UK Minister of State for Climate Change, has said (see bit.ly/19YlI8W) "There is the potential for solar power to become competitive with fossil fuels without subsidy within the lifetime of this parliament [ie before May 2015]". This trend is confirmed by other sources of evidence. **When that tipping point is reached, there is likely to be explosive growth in solar power**. The cost of other renewables is also falling.
  - In view of the falling cost of renewables, the proposed "contracts for difference" for nuclear power is likely to be a permanent large subsidy for nuclear power throughout the proposed 35 years of the contract.
- There are many acceptable options for siting wind and solar power plants, including wind farms out at sea (where costs are coming down), and solar plants on factory roofs and in association with roads and railways. There is also great potential for importing solar power from southern Europe and beyond, and wind power from Ireland or continental Europe.
- In addition, renewables, with conservation of energy:
  - Provide more flexibility than nuclear power;
  - Provide diversity in energy supplies;
  - Are largely free of the several problems with nuclear power (see bit.ly/1bScDSg), including the significant risk of nuclear disaster and the still-unsolved problem of what to do with long-lived nuclear waste.

Evidence in support of these points is in the web page "Opportunity cost" (see bit.ly/KisjOT).

Subsidies for nuclear power have the effect of diverting resources away from technologies which are cheaper than nuclear power and altogether more effective as a means of meeting our energy needs and cutting emissions.

In terms of competition within the EU, state aid for nuclear power in the UK is entirely at odds with the coming single market for electricity in the EU and with the principle that there should be free movement of goods and services throughout the region. It is bad for the development, throughout Europe, of the good, effective alternatives—renewables with conservation of energy—which are ready to go, cheaper than nuclear power, and very much quicker to build.

Please ensure that there is no state aid for the proposed new nuclear plant at Hinkley Point, and likewise for any other proposed new nuclear plant in the UK or elsewhere in Europe. And please review all subsidies for existing nuclear plants throughout Europe.

Appendix B. Techniques for balancing supply and demand on the grid

Here are some of the techniques that can be used for balancing variable supplies of electricity with variable demands for electricity:

- *Large-scale HVDC transmission grids*. In an area like Europe, there are several potential benefits from building a 'supergrid' of highly-efficient high-voltage direct-current (HVDC) transmission lines to link existing HVAC transmission grids.[97] One of the most important benefits is that this kind of large-scale grid can make it much easier to match variable supplies with variable demands. For example, the wind may stop blowing in any one spot but it almost never stops blowing everywhere across a wide area like Europe. 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. Large-scale storage facilities, such as pumped-storage systems in Norway and the Alps, may be widely shared.

  Submarine HVDC transmission lines that have been laid between Norway and Denmark and between Norway and the Netherlands enable both pairs of countries to benefit in this way.

  Large-scale HVDC transmission grids are needed for the long-planned internal market for electricity in Europe,[98] for the more-recent initiative to create a "European Energy Union",[99] and because of the growth of offshore wind power. Several of the necessary transmission lines are already in place or under construction.[100]
- *Combining solar and wind power*. In load-balancing via the grid, it is helpful to combine solar power wind power—because there is a good fit between them. Solar power is strongest in the summer, and wind power is strongest in the winter.[101]
- *Power on demand*. One of the most useful attributes in any source of electricity is that it should be dispatchable—able to respond quickly to peaks in demand. Sources of electricity such as coal-fired power stations or nuclear power cannot respond quickly in that way. Renewable sources of power that can provide power on demand include:
  - Concentrating solar power plants[102] that include provision for heat storage and backup supplies of heat when there is not enough sun.[103,104]
  - Hydro-electric power stations.
  - Enhanced geothermal system (EGS) power stations.
  - Thermal generators fired by biofuels.
  - Tidal lagoons that are managed in such a way that they can provide pumped-storage facilities as well as tidal generation.
- An interesting possibility which is likely to become increasingly important in the next few years is vehicle-to-grid technology—the use of Plug-in Hybrid Electric Vehicles

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97 See "Electricity transmission grids", Desertec-UK, bit.ly/1DekXc5.
98 See "Third energy package", Wikipedia, retrieved 2015-02-02, http://bit.ly/1tvRDHN.
99 See "Climate action and energy", European Commission, bit.ly/1uWfFRK.
100 See "List of HVDC projects (Europe)", Wikipedia, retrieved 2015-02-02, bit.ly/1yta1o8.
101 See, for example, "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/1zG4O2i.
102 See bit.ly/1tDR4SN.
103 See bit.ly/18CmTlL.
104 See also "Keeping the lights on: why concentrating solar power is vital to tomorrow's energy mix", CleanTecnica, 2012-01-06, bit.ly/1ETyUxK.

(PHEVs)[105] or electric vehicles as a responsive source of power to help meet peaks in demand.[106]

- *Storage of power*. There are various methods for storing power[107] but one of the cheapest and most effective is the storage of solar heat in melted salts or other substances, in conjunction with the generation of electricity using concentrating solar power.[108,109] Another possibility is to use surplus electricity to create hydrogen by electrolysis of water. The stored hydrogen may be used to generate electricity when required. Yet another possibility is 'liquid air'.[110]
- *Methods for managing demand*.
    - *Dynamic Demand*.[111] Some appliances, such as televisions or computers, need power at specific times. But other appliances, such as domestic refrigerators or large-scale commercial cold stores, are much more flexible in their requirements for electricity. 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. The same is true of PHEVs[112] or electric vehicles mentioned above. If devices like that can detect when there is pressure on electricity supplies and delay their demands until supplies are more plentiful, that can be very helpful in matching variable supplies with variable demands. It turns out that a small drop in frequency in electricity supplies is a signal of pressure on the electricity supply system and that fridges and similar appliances can be equipped with devices that can detect that kind of fall in frequency and can ensure that electricity demands are delayed until more plentiful supplies are available.
    - *Phase-change materials*. The use of phase-change materials in fridges, buildings and elsewhere can provide flexibility about when power is needed and, in some cases, reduce overall power consumption. The phase-change material can absorb or release heat without changing temperature.[113]
    - *Ice in air conditioners*. A related idea is the basis for a new device, now commercially available, which integrates an ice-making function into air-conditioners. Ice is made at times when electricity supply is plentiful; air conditioning is accomplished when the weather is hot, mainly using the cold stored in the ice.
    - *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.[114]

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[105] See bit.ly/1vefCD3.
[106] See "Vehicle-to-grid technology", bit.ly/18CmWOx.
[107] See bit.ly/1KdWy9b.
[108] See bit.ly/1tDR4SN.
[109] See "Generating electricity without the sun", bit.ly/18CmTlL.
[110] See bbc.in/1wHUuyP.
[111] See bit.ly/1KdX6fc.
[112] See bit.ly/1vefCD3.
[113] See: "Vaccine fridge keeps its cool during 10-day power cut", New Scientist, 2012-01-13, bit.ly/1KdXpqt; and "Buildings and clothes could melt to save energy", New Scientist, 2012-01-05, bit.ly/1EtY9ct.
[114] See "District heating from wind: Kirkwall", University of Strathclyde, Engineering, bit.ly/161tN28.

- *Interruptible service*. Some large industrial customers may choose a lower-cost option of interruptible 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 is very high and power is needed somewhere else.
- *Time-of-use billing* is a related service in which 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. This spare generating capacity can help make good any shortfalls in supplies. The most useful kinds of capacity are those that can be switched on or off easily, depending on demand.
- *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. By contrast, when a conventional power plant fails, it normally does so without notice, giving power engineers little chance to provide alternatives.
- *Conservation of energy*. One of the most reliable sources of power is "negawatts": cutting the need for energy via conservation methods. Every megawatt or kilowatt that is saved, reduces the problem of balancing supply and demand on the grid. As we have seen (Section 5), the potential for saving energy is very large.

Appendix C. Summary of the grounds for complaint in "Alleged subsidies to nuclear power operators in the UK" [EF2011]

In summary,[115] the grounds for complaint in [EF2011] are:

- That the so-called "carbon price floor", introduced in the Finance Act 2011, is a *de facto* tax on fuels used for the generation of electricity and that the exemption of uranium from that tax is incompatible with EU state aid rules, Articles 107 and 108 of the Treaty on the Functioning of the European Union (TFEU).
- That the cap on liabilities for nuclear accidents of the Paris/Brussels Conventions constitutes state aid in the sense of Article 107 of the TFEU. Since Article 351 of the TFEU requires EU Member States to adapt and align their pre-existing Treaty obligations to be compliant with EU law, since relevant UK laws have not been amended in the light of that requirement, and since the cap on liabilities has not been notified to the European Commission, it is, technically, illegal under EU law.
- That the proposed cap on liabilities of nuclear operators for the disposal of nuclear waste falls under the definition of state aid in Article 107(1) of the TFEU; that, unless or until it is notified to the Commission, it is illegal under EU law; and that, since the measure cannot be justified (Article 107(3) of the TFEU), it should not be approved by the Commission and should not enter into force.

[115] This summary is from Note 2 in the press release "Legal bid to halt nuclear construction", Energy Fair, January 2012, bit.ly/1AidtHP.

- That the proposed "feed-in tariff with contracts for difference", as applied to nuclear power, is, under Article 34 of the TFEU, a measure having an effect that is equivalent to "quantitative restrictions on imports" and is thus contrary to EU law.

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