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NUCLEAR SUBSIDIES

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January 2012

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26th January 2012

Executive summary[1]

This report identifies seven main types of subsidy enjoyed by nuclear power in the UK:

- *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 the risk 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 borne 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 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.

With regard to proposed new nuclear power stations in the UK, they may receive support via loan guarantees, tax breaks, or other financial instruments and there is concern that, directly or indirectly, such support may be provided for the building of nuclear power stations in the UK.

Several of these subsidies are so large that withdrawal of just one of them would make nuclear power entirely uncompetitive. For example, 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.

Several possible justifications for subsidising nuclear power are considered, and all of them are rejected. In particular:

- There is good evidence from a variety of reputable sources that there are more than enough renewable sources of power to meet the UK's needs for energy, not just electricity, now and for the foreseeable future. There is a range of reports showing how the world's economies may be decarbonised without using nuclear power.
- There is a wide range of load-balancing techniques that can ensure security of supplies with 100% renewables. Nuclear power is a poor answer to the load-balancing problem because of the disproportionately disruptive effect when a

[1] An electronic version of this document, with live links, may be downloaded from http://www.mng.org.uk/nsubsidies.

nuclear power station fails and because nuclear power cannot easily be increased or decreased to meet peaks and troughs in demand.

- Far from being an answer to the problem of CO_2 emissions and climate change, the building of new nuclear power stations would be a mis-allocation of resources, making things worse by diverting funds away from alternatives that are better, cheaper, quicker to build, and providing greater security.

The report reviews some of the evidence that there are more than enough good alternatives to nuclear power and provides pointers to further sources of information. And the report considers a range of distortions in energy markets, including subsidies for nuclear power, and makes recommendations about how those distortions may be corrected.

1 Introduction

Notwithstanding the misleadingly low figures for the cost of nuclear power that are put out by the nuclear industry and repeated, apparently without critical examination, by other organisations, it is now well established that nuclear power is one of the most expensive ways of generating electricity.[2] Bearing in mind that there are now several reports showing how to decarbonise the world's economies without nuclear power,[3] that nuclear power is far from being zero carbon,[4] that there are more than enough alternatives,[5] and that those alternatives are quicker to build and have none of the headaches of nuclear power,[6] there is absolutely no case for new nuclear power plants anywhere in the world. In terms of the fight against climate change, money spent on nuclear power is a mis-allocation of resources. The alternatives are quicker and cheaper.

The purpose of this report, prepared by the Energy Fair group,[7] is to highlight the several subsidies for nuclear power, many of which are hidden from view. As detailed later, calculations by actuarial specialists show that withdrawal of just one of those subsidies (limitations on liabilities) would increase the price of nuclear electricity to levels that would make it entirely uncompetitive. Withdrawal of the other subsidies identified in this report, would add substantially to the cost of nuclear electricity.

For an industry that has been established for many years, has already received large amounts of subsidy[8] and should now be commercially viable without the need for support, the existence of these subsidies, both in the UK and elsewhere, is a clear breach of the principle of fair competition.

Although the nuclear industry has been pressing for even more subsidies and the UK government appears willing to oblige (see Section 2.10), there is no case for providing them. Instead, we should be aiming to *wind down the arms race of subsidies, reserving them for where they are really needed* (see Section 6).

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[2] Information on that point, with links to relevant sources, may be seen at www.mng.org.uk/gh/nn.htm#subsidies.
[3] See Section 0 and http://www.mng.org.uk/gh/scenarios.htm.
[4] See http://www.mng.org.uk/gh/nn.htm#CO2.
[5] See Section 0 and http://www.mng.org.uk/gh/energy.htm.
[6] See http://www.mng.org.uk/gh/nn.htm.
[7] See http://www.nonukes.org.uk.
[8] "More than half of the subsidies (in real terms) ever lavished on energy by OECD governments have gone to the nuclear industry." From "Nuclear power out of Chernobyl's shadow", *The Economist*, print edition, May 6th 2004.

In Section 2, next, we review the main subsidies that are enjoyed by the nuclear industry, focussing mainly on the situation in the UK. Section 3 examines possible justifications for subsidising nuclear power and concludes that none of them are valid. Section 4 considers how subsidies for nuclear power may be withdrawn. Section 5 reviews some of the evidence showing that there are more than enough alternatives to meet the UK's current and anticipated future needs for energy, not just electricity. Section 6 describes distortions in energy markets and how they may be corrected.

2 The subsidies

Most of the subsidies described in this section take the form of exemptions from costs that businesses are normally required to cover. The exemptions have the effect of pushing costs on to the Government, or the public at large, including people in other countries or people who are not yet born. Although they may be disguised, the subsidies are real.

We will consider the subsidies as they are now and any proposals by the UK government for changes in the future.

2.1 Limitations on liabilities

> *From the U.S. to Japan, it's illegal to drive a car without sufficient insurance, yet governments around the world choose to run over 440 nuclear power plants with hardly any coverage whatsoever.* Washington Post, 21 April 2011.[9]

Nuclear power is only required to pay a small fraction of the cost of insuring fully against claims from a Chernobyl-style disaster, or worse. For example:

- "... in the United States, the Price-Anderson Act limits the nuclear industry's liability in the event of a catastrophic accident to $9.1 billion, which is less than 2% of the $600 billion guaranteed by the Congress. In any case, $600 billion is considered to be a gross underestimate ..." [CALD2006, p 32] and "In France, if Electricité de France had to insure for the full cost of a meltdown, the price of nuclear electricity would increase by about 300%. Hence, as opposed to conventional wisdom, the price of French nuclear electricity is artificially low." [*ibid.*][10]
- The Union of Concerned Scientists, writing about their report into subsidies for nuclear power in the USA, says that "Government subsidies to the nuclear power industry over the past fifty years have been so large in proportion to the value of the energy produced that in some cases it would have cost taxpayers less to simply buy kilowatts on the open market and give them away."[11]

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[9] "As Fukushima bill looms, nations weigh dilemma: nuclear plants viable only when uninsured", Washington Post, 2011-04-21, http://www.washingtonpost.com/business/as-fukushima-bill-looms-nations-weigh-dilemma-nuclear-plants-viable-only-when-uninsured/2011/04/21/AFrwGDHE_story.html.

[10] Regarding the 300% figure, Appendix J of the report "Environmentally harmful support measures in EU member states" says "Scenario B, in which all liabilities are covered at the upper damages estimates, results in premiums of 5.0 c€/kWh. This insurance scenario would thus lead to a tripling of current total generating costs." (p 132). The report, which was commissioned by the DG Environment of the European Commission, 2003, can be downloaded from http://www.mng.org.uk/gh/resources/EC_env_subsidies.pdf (PDF, 1.1 MB).

[11] See "After 50 years, nuclear power is still not viable without subsidies, new report finds" (Union of Concerned Scientists, press release, 2011-02-23, http://www.ucsusa.org/news/press_release/nuclear-power-subsidies-report-0504.html). The report itself is "Nuclear power: still not viable without subsidies" (Union of

2.1.1 Limitations on liabilities in the UK

In the UK, the Paris/Brussels Conventions are implemented by the Nuclear Installations Act 1965, with amendments. The Conventions have been revised periodically, the last time in 2004. The UK government intends to increase the cap on liabilities to €1.2 billion from its present level of £140 million.[12] The majority of the insurance is provided by a pool of UK insurers comprising 8 insurance companies and 16 Lloyds syndicates—Nuclear Risk Insurers.[13] Beyond £140 million, the current Paris/Brussels system applies, with government contribution to Special Drawing Rights 300 million (about €360 million).[14]

In addition to the limitations on the sums of money that may be paid out, compensation rights are extinguished under both the Paris and Brussels Conventions if an action is not brought within ten years. Since it can take at least that long for radiation-induced cancers to develop, that limitation on liabilities represents yet another subsidy for the industry.[15]

2.1.2 The cap on liabilities is far too low

With these caps and restrictions, nuclear operators are largely protected from the real costs of a nuclear disaster. For example, it has been estimated that, for the Fukushima nuclear disaster, the cleanup costs alone could be as high as $250 billion (€175 billion).[16] There are many other costs arising from this catastrophe.

The UK government's proposed new cap on liabilities for nuclear operators ($1.7 billion) is also much less than the $41 billion that BP has set aside to cover claims arising from the Gulf of Mexico disaster.[17]

As touched on in the introduction, research by Versicherungsforen Leipzig GmbH,[18] 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[19] (see also Section 2.11).

Concerned Scientists, February 2011, http://earthtrack.net/documents/nuclear-power-still-not-viable-without-subsidies).

[12] See "Seven-fold increase in liability for nuclear sites announced", DECC press release, 2011-01-24, http://www.decc.gov.uk/en/content/cms/news/pn11_007/pn11_007.aspx.

[13] See http://www.nuclear-risk.com/.

[14] This information comes from "Civil liability for nuclear damage" from the World Nuclear Association, http://www.world-nuclear.org/info/inf67.html.

[15] Under new rules that were supposed to come into effect in 2006 but are not yet in force, nuclear companies will have to increase the amount of cover they have in place, to €700 million (£620 million) per site, while the time frame for claims will be extended from ten to 30 years. New types of cover will also be required, including protection against "economic losses" resulting from an accident, damage to the environment, and loss of use and enjoyment of the environment, as well as the cost of preventing contamination of new areas. However, it is likely that these new limits will still fall far short of the real cost of a nuclear disaster, and it appears that the UK government is making arrangements to take on these additional costs (see "UK taxpayer may be forced to take on nuclear risk after insurers refuse to offer cover.", The Times, 2009-09-09, http://business.timesonline.co.uk/tol/business/industry_sectors/natural_resources/article6826650.ece.

[16] See "Fukushima cleanup could cost up to $250 billion", Weather-tech, 2011-05-31, http://www.myweathertech.com/2011/05/31/fukushima-cleanup-could-cost-up-to-250-billion/.

[17] See "Court order halts BP talks with Rosneft", The Guardian, 2011-02-01, http://www.guardian.co.uk/business/2011/feb/01/bp-loss-gulf-oil-spill-resumes-dividend.

[18] See http://www.versicherungsforen.net/fs/vfl/de/index.jsp.

[19] The report from Versicherungsforen Leipzig GmbH, and associated documents, may be downloaded via links from http://www.energyfair.org.uk/reports#liabilities where press reports and other information may also be found.

2.1.3 The subsidy

Since nuclear operators are paying much less than the true cost of insuring against nuclear disasters, they are enjoying a large subsidy, without which they would not be commercially viable (Section 2.11).

Since, for the UK and other countries in Europe, the Paris and Brussels conventions are involved, it may be argued that limitations on liabilities for the nuclear industry cannot be touched. But the principle of fair competition is very well established and should over-ride particular arrangements for a specific industry, especially since the reasons for those arrangements are no longer valid.[20]

2.2 Underwriting of commercial risks

The nuclear industry, like the banking industry, enjoys a commercial environment in which risks are socialised but profits are privatised.[21] In the case of nuclear power, it is, for political reasons, necessary for national governments to underwrite most of the commercial risks of nuclear power, as evidenced by the way the UK government had to bail out British Energy in 2005 at a cost of about £5 billion[22,23,24] and how the Japanese government has had to bail out the Tokyo Electric Power Company (TEPCO) at a cost of $13 billion.[25] More specifically, the Nuclear Decommissioning Authority in the UK, under the Energy Act (2004), is able to bail out future private nuclear operators if they fail to fund their liabilities fully.[26,27] In the USA, federal loan guarantees for nuclear power represent a substantial subsidy to the industry.[28]

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[20] Much of the original motivation for establishing the nuclear industry, and for international treaties designed to put limits on the industry's liabilities for nuclear accidents, was because of its role in the creation of nuclear weapons. With the end of the cold war and with growing worries about the proliferation of nuclear weapons, any such justification for protecting the nuclear industry has completely disappeared. See also Section 4.

[21] See, for example, "New capitalism: old capitalism except taxpayer money is at risk", Sunday Herald, 2009-07-06, http://www.sundayherald.com/oped/opinion/display.var.2518209.0.new_capitalism_old_capitalism_except_taxpayer_money_is_at_risk.php. See also "Boiling the frog slowly: nuclear optimism hides the true costs till it is too late," Energy Economy Online, 2009-07-24, http://energyeconomyonline.com/Boiling_the_Frog.html.

[22] See "Ministers 'wrote blank cheque' to bail out nuclear power group", The Guardian, 2006-03-17, http://www.guardian.co.uk/business/2006/mar/17/nuclearindustry.politics.

[23] See also "Waste not, want not", John Sauven writing in The Guardian, 2007-08-21, http://www.guardian.co.uk/commentisfree/2007/aug/21/wastenotwantnot.

[24] We believe this example is relevant because it demonstrates the general point that, ultimately, national governments have no choice but to underwrite the commercial risks of nuclear power. However it appears that the state aid for the rescue and restructuring of British Energy and BNFL were allowed by the EC in 2004 and 2006 respectively. The case reference documents are in the Register and here: Register Search page: http://ec.europa.eu/competition/state_aid/register/ . Moreover, the restructuring of Magnox Electric in the early 1990's was similarly approved by the EC. Once the Commission has approved an aid, it is difficult to do anything to overturn this. In high-politics high-stakes state aid cases, the Commission tends to fudge outrageous subsidies. General information about EC State Aid control is here: http://ec.europa.eu/competition/state_aid/overview/index_en.html.

[25] See, for example, "Japan's stricken nuclear operator set for $13 billion bailout", Reuters, 2012-01-26, http://uk.reuters.com/article/2012/01/26/us-tepco-idUKTRE80P04B20120126.

[26] On 15 January 2004 Lord Whitty told the House of Lords (Column GC170) that "There may again be circumstances in which a private sector operator cannot meet its nuclear obligations … we must retain the possibility of the Government meeting such costs".

[27] See "Waste not, want not", The Guardian, 2007-08-21, http://www.guardian.co.uk/commentisfree/2007/aug/21/wastenotwantnot.

[28] See "The real cost of new US nuclear reactors", Bulletin of the Atomic Scientists, 2009-08-21, http://www.thebulletin.org/web-edition/op-eds/the-real-cost-of-new-us-nuclear-reactors.

With regard to the bail out of British Energy, Ian Jackson writes: "The government was forced to step in and implement a complex financial restructuring that effectively renationalised British Energy back into majority public ownership. *This included the government underwriting financial responsibility for £14 billion of decommissioning and spent fuel liabilities that it thought it had privatised in 1996.* … British Energy makes payments into a government-backed Nuclear Liabilities Fund—essentially a pension fund for reactor clean-up—and *any future shortfall will be picked up by the taxpayer*." [NUKEN2008, p 10, emphasis added].

The Fukushima disaster provides another example of the way the commercial risks of nuclear power are inevitably underwritten by national governments. Although, in Japanese law, electric power firms are in principle responsible for nuclear accident compensation, there has always been a loophole in the event of "an extraordinarily grave natural disaster", and now it appears that the law will be revised so that the Japanese government, not TEPCO, will bear most of the cost of compensating victims.[29]

The way in which the commercial risks of nuclear power are, for political reasons, underwritten by national governments represents a substantial subsidy to the industry even though no actual money may change hands. If the industry were to obtain that kind of underwriting from normal commercial sources, it would cost a lot of money. The subsidy is an unfair subsidy because there is nothing equivalent for renewables.

2.3 Protection against terrorist attack

Nuclear plants are vulnerable to terrorist attack,[30] as are trains and ships carrying nuclear fuel or nuclear waste. Although some protection is provided by the Civil Nuclear Constabulary (paid for by the nuclear industry), there is good evidence that the public is *not* being fully protected against the risks of terrorist attack. For example, in 2006, a reporter from the *Daily Mirror* newspaper managed, very easily, to plant a fake bomb on a train carrying nuclear waste.[31] Despite the well-known risks now posed by pirates to international shipping off the coast of Somalia and elsewhere, the protection provided for ships carrying nuclear materials is only partial.[32]

The fact that protection against terrorist attack for nuclear plants and nuclear transports can only ever be partial represents a cost to us all arising from the corresponding risks. Since there is nothing equivalent for renewable sources of energy, these costs represent an unfair subsidy for the nuclear industry.

2.4 The short-to-medium-term costs of disposing of nuclear waste

The Energy Act 2008 requires operators of new nuclear power stations to have in place arrangements for managing and disposing of nuclear waste and to meet the associated costs. However, there is considerable uncertainty about the eventual cost of disposing of

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[29] See, for example, "Nuclear redress law vague about responsibility for Fukushima crisis", The Mainichi Daily News, 2011-08-01, http://mdn.mainichi.jp/mdnnews/news/20110801p2a00m0na019000c.html.

[30] Since 9/11 it has been clear that crashing planes are a means for terrorists to mount an attack. Even without terrorists, crashing planes are a significant risk for nuclear plants (see "Nuclear risk from plane crashes is higher than estimated, inquiry shows", The Guardian, 2011-02-21, http://www.guardian.co.uk/environment/2011/feb/21/nuclear-risk-plane-crashes?&CMP=EMCENVEML1631).

[31] See "We plant 'bomb' on nuke train", Daily Mirror, 2006-07-21, Hhttp://www.mng.org.uk/gh/re/daily_mirror_nukes2.htmH.

[32] See "Nuclear fuel fleet arms up", The Scotsman, 2009-04-14, Hhttp://news.scotsman.com/latestnews/Nuclear-fuel-fleet-arms-up.5166539.jpH.

nuclear waste. There is also considerable debate about the levels of charges to the operators of nuclear plants and how much of the risk should be born by the Government.

2.4.1 Levels of charges

Writing in *Nuclear Engineering International*, Ian Jackson says that:

> *... a fully commercial price would make disposal far too expensive, killing the prospects of any new nuclear build programme in Britain …. The bottom line is that nuclear energy utilities probably need fixed waste disposal 'prices' for repository disposal capped somewhere in the range from £12,200 to £24,400/m^3, but the NDA's* [Nuclear Decommissioning Authority's] *true marginal 'cost' is nearer to £67,000/m^3, and the commercial 'value' of the repository asset could approach £201,000/m^3 if operated as a fully private sector venture.".*[33]

He expands on these points in [NUKEN2008, pp 61-63]. With regard to the commercial value of the disposal service, he says:

> *Because the NDA is already charging foreign nuclear utilities a premium of 647 per cent profit margin for disposal of substituted intermediate-level wastes, then logically this market premium should be the disposal pricing benchmark for British nuclear utility investors too. Commercially speaking, it is hard to justify charging British utility customers a lower price for geological disposal than overseas utility customers paying for disposal space in the same repository. It would also risk accusations of giving preferential state aid subsidies to nuclear energy utilities investing in Britain, that are potentially illegal under European state aid competition law.* [NUKEN2008, p 61]

In short, it appears that, if the Government wishes to ensure that new nuclear plants will be built, it will be necessary for charges for the disposal of nuclear waste to be lower than the real cost of disposal and very much lower than commercial rates that could be charged for disposal. Such under-charging for disposal would be a subsidy for the industry.

2.4.2 Transfer of risk

It has been recognised for some time that the Government is likely to take on much of the commercial risk arising from the disposal of nuclear waste:

- Dieter Helm, Professor of Energy Policy at New College, Oxford, says about the system proposed for handling nuclear waste: "It's a fixed-price contract for the Government to take the waste. The Government absorbs the final-end risk."[34]
- Irwin Stelzer, writing in *The Spectator*, says "… in what the government calls 'extreme circumstances', it is prepared to help meet the massive decommissioning

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[33] See "Buried costs", *Nuclear Engineering International*, April 2008, http://www.greenpeace.org.uk/files/pdfs/nuclear/Nukenomics-Jackson.pdf. See also "Waste cost threat to UK nuclear plans", *Financial Times*, 2008-03-26, http://www.ft.com/cms/s/0/08f7bbc2-fb66-11dc-8c3e-000077b07658.html#axzz1U9FP708A, and http://www.greenpeace.org.uk/media/press-releases/taxpayers-facing-nuclear-missile.

[34] See "Key advisor says that UK's new nuclear policy is flawed", The Times, 2008-01-28, http://business.timesonline.co.uk/tol/business/industry_sectors/utilities/article3261571.ece.

and waste disposal costs—knowing full well that such extreme circumstances almost always attend decommissioning and waste disposal."[35]

In [DECC2010A], the Government proposed a 'Fixed Unit Price' (FUP) for the disposal of nuclear waste. However, careful analysis by Greenpeace showed that, under this scheme, the Government would bear much of the risk of cost overruns.[36]

In [DECC2010B], the Government replaced the proposed FUP with a proposal for a more flexible system involving a 'Waste Transfer Price' (WTP). Here, some of the uncertainty about the cost of waste disposal would be reduced by waiting for a period of up to 30 years after the start of nuclear reactor generation before deciding the level of the WTP. There would also be a cap or ceiling on the price that could be charged for disposal of each unit of waste.

In [FUPSIMF2011], Ian Jackson argues that the WTP proposal introduces two subsidies for nuclear generation:

- A subsidy from the price cap, which means that the Government takes on the risk of cost over-runs.
- A subsidy arising from his assessment that the Department of Energy and Climate Change has underestimated the cost of disposal.

We feel it is appropriate to add that waiting for up to 30 years before setting the price of waste disposal has the psychological effect of kicking the issue into the long grass, reducing the incentive to get things right now and dumping the problem—and the bills—on governments in the future.

2.4.3 How to ensure that nuclear operators pay a proper price for waste disposal?

It is true that the Government proposes to charge a "Risk Fee" for providing a cap on liabilities [DECC2010B, para. 1.15] and it may be argued that that removes any element of subsidy in the cap. But, as with the cost of disposal, it appears likely that costs will be underestimated and that the size of the fee will be too low.

To overcome problems of bias in Government estimates and to ensure that operator of each nuclear plant pays the full cost of disposal of nuclear waste, something like the following measures are needed:

- There should be no cap on the price of disposal (as recommended in [FUPSIMF2011]).
- The operator of any nuclear plant should be required to establish a fund (a 'waste disposal fund') to pay for the disposal of nuclear waste.
- In addition, the operator of any nuclear plant should be required to take out insurance against cost overruns in the disposal of nuclear waste, whatever those costs may eventually turn out to be.

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[35] See "Go nuclear, but keep your hand on your wallet", *The Spectator*, 2008-03-12, http://www.spectator.co.uk/the-magazine/features/553546/part_3/go-nuclear-but-keep-your-hand-on-your-wallet.thtml.

[36] See "Greenpeace response to the Consultation on a methodology for determining a Fixed Unit Price for waste disposal and updated cost estimates for nuclear decommissioning, waste management and waste disposal", Greenpeace, June 2010, http://www.mng.org.uk/gpnwaste, and "Hidden subsidies and new nuclear", Greenpeace, June 2010, http://www.greenpeace.org.uk/files/pdfs/nuclear/gpuk-fup-briefing.pdf.

- The premium should be paid in equal annual instalments over a period of, say, 20 years, well within the likely lifetime of the plant, and *starting when the plant begins operation*.
- The operator of any nuclear plant can reduce the risk of cost overruns—and thus the size of the insurance premium—by increasing the size of the waste disposal fund.
- If, for any proposed new nuclear plant, insurance cannot be obtained from commercial sources, then the building of the plant should not be permitted. However, this should never happen since, as just noted, the size of any insurance premium can be reduced by increasing the size of the waste disposal fund.

Removing the price cap, and the insurance requirement, should protect the Government from taking on risks that properly belong to the nuclear operators.

The requirement that insurance premiums should be paid from the beginning of the lifetime of the plant should avoid the cost issue being kicked into the long grass by deferring decisions about price for up to 30 years from when the plant first goes into operation.

2.5 The long-term costs of disposing of nuclear waste

On a long-term perspective, the 'high level' categories of nuclear waste will remain dangerous for thousands of years. The costs arising from the dangers of the waste and the need to manage it will be born by future generations but they will receive no compensating benefit.

Since these are costs that are created by the nuclear industry but are not paid for by the industry, they represent yet another subsidy to the industry, even though no actual money changes hands. The subsidy will be paid by people who are not yet born. Of course, there are no equivalent costs with renewable sources of power.

2.6 The cost of decommissioning nuclear plants

The Energy Act 2008 requires the operators of new nuclear power stations to have plans for decommissioning, including plans for how decommissioning will be financed, and that these plans must be approved by the Government.

This suggests that the operators of nuclear plants will take full responsibility for decommissioning and that the Government will be protected. But this really is not possible given the long timescales and large uncertainties:

> *Perhaps more than any other technology, nuclear power has the habit of making any government the prisoner of past decisions. The economic impact of nuclear energy decisions made in the 1950s and 1960s are still being felt by taxpayers today. … Investing in nuclear technology uniquely captures governments in a lengthy cycle of expenditure that once started, will take a century to exit…. Few other technologies have the capacity to bind government spending for a 100 years. As a result, the long-term costs of nuclear power can only really be estimated and estimates are only as good as the economic assumptions on which they are based.... accurately forecasting the total cost of front end nuclear build and back end nuclear clean-up still remains more of an art than a science.* [NUKEN2008, p 3].

And:

> *Decommissioning has been described as rather like a Chinese puzzle box in which new problems are revealed the deeper one looks, as successive layers of complexity are revealed. Each year the decommissioning management contractors tend to look a little deeper at what needs to be done and then cost the clean-up tasks accordingly from the bottom up. As a result, the Nuclear Decommissioning Authority's three-year near-term cost projections are reasonably accurate but forecasts of the total lifecycle cost for taxpayers remain highly speculative. It is these difficult long-term cost projections that are rising by 9 per cent annually. In September 2007 the National Audit Office, which formally audits the Nuclear Decommissioning Authority's annual accounts, commented: "It is not possible to quantify reliably the impact on the Nuclear Decommissioning Authority's future financial results of the settlement of these liabilities."* [NUKEN2008, p 25].

In 2006, it was reported that Gordon Brown's estimate of the cost of cleaning up the UK's nuclear legacy would be €132.5bn (£90bn).[37] It may be argued that this huge sum is simply "water under the bridge" and is not relevant now, with the UK government's declared intention that nuclear power should be commercially viable without any subsidies.

The key point here is that it is *impossible* for the UK government, or any other government, to shed its responsibilities for decommissioning of nuclear power stations (and for nuclear waste and other aspects of nuclear power) by passing everything over to the nuclear operators. There will *always* be the risk of cost overruns and there will always be a risk that nuclear companies may fail.[38,39]

As with the general commercial risks of nuclear power (Section 2.2), this kind of underwriting of decommissioning costs by national governments is a substantial subsidy for the nuclear industry. And it is an unfair subsidy because there is nothing equivalent with renewables.

As with the disposal of nuclear waste (Section 3.4.3), we believe that, for any proposed new nuclear plant:

- There should not be any cap on the cost of decommissioning.
- A 'decommissioning fund' should be established to pay for decommissioning (in line with Government proposals).
- In addition, the operator of any nuclear plant should be required to take out insurance against cost overruns in decommissioning, whatever those costs may eventually turn out to be.
- The premium should be paid in equal annual instalments over a period of, say, 20 years, well within the likely lifetime of the plant, and *starting when the plant begins operation*.

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[37] See "Nuclear costs to hit £90bn, warns Brown", The Observer, 2006-06-04, http://www.guardian.co.uk/business/2006/jun/04/theobserver.observerbusiness.

[38] None of these problems are solved by the UK government's present proposals that the operators of nuclear plants should put forward plans for decommissioning and that those plans should be vetted by a 'Nuclear Liabilities Financing Assurance Board'.

[39] See "Nuclear decommissioning", Nuclear Spin, September 2008, http://www.spinprofiles.org/images/b/ba/Nuclear_Decomm.pdf.

- The operator of any nuclear plant can reduce the risk of cost overruns—and thus the size of the insurance premium—by increasing the size of the decommissioning fund.
- If, for any proposed new nuclear plant, insurance cannot be obtained from commercial sources, then the building of the plant should not be permitted. However, this should never happen since, as just noted, the size of any insurance premium can be reduced by increasing the size of the decommissioning fund.

2.7 Institutional support for the nuclear industry

It appears that various institutions, offices and staff that are needed to support the nuclear industry in the UK are paid for, at least in part, out of public funds. Since, in most cases, there is nothing equivalent for renewables—because renewables are inherently safer, cleaner and less complex—these expenditures are an unfair subsidy for the nuclear industry. Here are the kinds of facilities that have been or are being provided to support the nuclear industry in the UK:

- The National Nuclear Laboratory (NNL).[40]
- A "nuclear academy" in West Cumbria.[41,42]
- The UK government has an Office for Nuclear Development (OND), apparently paid for out of public funds.[43] To be fair, there is now an Office for Renewable Energy Deployment (ORED) but, arguably, there should be an office equivalent in size to the OND for each of wind power, wave power, tidal power, the DESERTEC concept, and so on.
- The newly-established Nuclear Institute is likely to be in receipt of public money.[44] As with the OND, there appears to be nothing equivalent for any of the several renewable sources of power and the same remarks apply.
- According to a report in *The Times*,[45] the Nuclear Decommissioning Authority,[46] "consumes around half of the Department of Energy and Climate Change's £3 billion budget" and that "58 per cent of [the NDA's] £2.78 billion budget comes from taxpayers".

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[40] See "Appointments to the National Nuclear Laboratory", DECC press release, 2009-08-19, http://nds.coi.gov.uk/Content/Detail.aspx?NewsAreaId=2&ReleaseID=405971&SubjectId=2.
[41] See "Minister Ed Miliband opens West Cumbria's £20m nuclear academy Energus", Times & Star, 2009-06-19, http://www.timesandstar.co.uk/news/politics/minister_ed_miliband_opens_west_cumbria_s_20m_nuclear_academy_energus_1_570178?referrerPath=news/education.
[42] See "National skills academy for nuclear launches flagship centre for skills training", PersonnelToday.com, 2009-07-01, http://www.personneltoday.com/articles/2009/07/01/51220/national-skills-academy-for-nuclear-launches-flagship-centre-for-skills-training.html.
[43] See Office for Nuclear Development (OND), http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/office/office.aspx.
[44] See "Nuclear Institute launched", The Whitehaven News, 2009-03-18, http://www.whitehaven-news.co.uk/news/nuclear_institute_launched_1_528306?referrerPath=news/.
[45] See "Nuclear Decommissioning Authority pledges action on million-pound bonuses", The Times, 2009-07-17, http://business.timesonline.co.uk/tol/business/industry_sectors/utilities/article6717198.ece.
[46] See http://www.nda.gov.uk/.

- The planned Nuclear Advanced Manufacturing Research Centre (NAMRC) will receive £15 million from the Government and the Manufacturing Advisory Service (MAS) will receive £4 million.[47]
- Other nuclear bodies that appear to depend, at least in part, on public funds include the Nuclear Legacy Advisory Forum,[48] the Nuclear Directorate of the Health and Safety Executive,[49] the UK Safeguards Office,[50] the Office for Civil Nuclear Security (OCNS),[51] and the International Atomic Energy Agency.[52]

It should be possible to obtain information about public funding of these various bodies under the UK's Freedom of Information Act 2000.[53]

For comparison, it would be very useful to obtain information about institutional support that may (or may not) be provided for renewable sources of power and the amount of public money that is devoted to it. In case anyone objects that renewables are receiving subsidies via feed-in tariffs and the Renewable Obligations scheme, there are good reasons for this which do not apply to nuclear power (See Section 3.3).

It appears that the UK government is keen to provide yet more institutional support for the nuclear industry, witness its recent statement that it "will provide capital investment of up to £15 million in order to establish a Nuclear Advanced Manufacturing Research Centre consisting of a consortium of manufacturers from the UK nuclear supply chain and universities."[54]

2.8 Capital subsidies

Unlike the subsidies discussed earlier, capital subsidies are less to do with existing nuclear plants and more to do with possible new nuclear plants in the UK.

The Olkiluoto nuclear plant which is under construction in Finland is being financed, in part, by a loan to the Finnish company TVO, with loan guarantees from the French government, administered by the French company COFACE.[55]

Prompted by two complaints, the European Commission investigated whether the loan guarantee might constitute unlawful state for the project but concluded otherwise.[56] It argued that:

- The guarantee would confer no advantage to TVO because:

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[47] See "£19m pledge for nuclear updates", Professional Engineering, 2009-07-29, http://www.profeng.com/archive/archive+2009/2213/22130004.htm.
[48] See http://www.nuleaf.org.uk/nuleaf/home.asp?r=4483&NavPosition170=0&NavInUse170=1&LastSelectedItem=2.
[49] See http://www.hse.gov.uk/nuclear/nsd1.htm.
[50] See http://www.hse.gov.uk/nuclear/safeguards/index.htm.
[51] See http://www.hse.gov.uk/nuclear/ocns/.
[52] See http://www.iaea.org/.
[53] See http://www.opsi.gov.uk/Acts/acts2000/ukpga_20000036_en_1.
[54] See "UK Low Carbon Industrial Strategy", July 2009, page 7. The document may be downloaded from http://interactive.bis.gov.uk/lowcarbon/.
[55] "Compagnie Francaise d'Assurance pour le Commerce Extérieur".
[56] See "State aid: Commission concludes that French state guarantee for Finnish nuclear power plant operator TVO does not constitute aid", press release from the European Commission, 2011-09-26, http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1400.

- TVO had sufficient access to financial markets to finance the whole project without any state intervention, so the financing of the project was not dependant on the state guarantee.
- The guarantee premium paid by TVO to the French Government was not below the market price.

- The state intervention did not allow TVO to obtain cheaper finance.
- TVO had selected the AREVA NP/Siemens consortium before the COFACE guarantee was granted.

Despite the negative result in this case, it is clear that loan guarantees can be used to subsidise nuclear projects (eg in the USA).[57]

Since EDF is a state-owned French company and is the leading member of a consortium that is proposing to build a new nuclear power station at Hinkley Point in the UK, there is concern that the French government may choose to subsidise that project, or others in the UK, via loan guarantees or other financial instruments.

2.9 Other subsidies for nuclear power

Taxpayer support for nuclear power comes in many forms. Here is a selection of other subsidies:

- When a nuclear power station fails, a relatively large capacity is lost and the loss is normally quite sudden and without much warning.[58] If new nuclear power stations are built as proposed by the Government, this will mean that the annual cost of providing so-called Large Loss Response will rise from £160m a year to £319m. But the costs will be shared equally across all electricity providers. This is a cross-subsidy to nuclear power from renewable sources of power.[59]
- The following forms of support for the nuclear industry have been recorded in Hansard as answers by the UK government to parliamentary questions in June 2010:
  - **£11 million** on research expenditure to the Nuclear Decommissioning Authority (NDA) in 2010-11.
  - **£10.2 million** for the Engineering and Physical Sciences Research Council's (EPSRC) current nuclear research portfolio since 2008-09 on eight projects directly relevant to long-term nuclear waste management and facility decommissioning.
  - **£3.553 million** for the Natural Environment Research Council (NERC) for nuclear decommissioning and radioactive waste management research covering 2009-11.

[57] See, for example, "Maximising US Federal loan guarantees for new nuclear energy", Bulletin of the Atomic Scientists, 2009-07-29, http://www.thebulletin.org/web-edition/features/maximizing-us-federal-loan-guarantees-new-nuclear-energy.
[58] By contrast, variations in wind power are much more gradual and there is normally several hours warning.
[59] See "Exclusive: Will wind farms pick up the tab for new nuclear?" (Business Green, 2010-08-24, http://www.businessgreen.com/business-green/news/2268599/exclusive-wind-farms-pick-tab).

- **£180,000** for the Environment Agency for grant in aid on regulatory research relevant to nuclear waste and decommissioning in 2009-10 (approximately 25% of the research costs in that year).
- **£0.95 million** annual subscription to the OECD Nuclear Energy Agency (NEA) & the NEA's Databank, which contains technical information from other NEA members.
- **£5 million** provided by the NDA in 2007-08 million to support the establishment of Energus (formerly referred to as The Nuclear Academy) as a centre of excellence for skills, training and business support.
- **US$ 9.3 million** and **€16.4 million** respectively to the United Nations' atomic watchdog, International Atomic Energy Agency (IAEA) for 2010, with a similar sum, but allowing for inflation, exchange rate differences, and the likely outcome of current ongoing budget negotiations among member states and the agency, has been set aside for 2011.
- **€116.95 million** and **US$ 84.42 million** paid by UK to the IAEA over the past 10 years.
- **£3 million**, DECC's Office for Nuclear Development, total budget for 2010-11. This does not include the cost of DECC's wider work on policy associated with nuclear security, safety and non-proliferation.

- OECD export credits for nuclear power.[60]
- "Sweetners" for companies taking over the management of Sellafield.[61]
- The cost of incentives to persuade people to accept a dump for nuclear waste in their area.[62]
- The Government exposed to unlimited liabilities for the costs of accidents at Sellafield.[63,64]
- The Government paying nuclear consultancy fees.[65]
- Payments by the Government to directors of BNFL.[66]
- Subsidies provided to support the sale of British Energy.[67]

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[60] See "OECD lays out nuclear export credits", Nuclear Engineering International, 2009-06-29, http://www.neimagazine.com/story.asp?sectionCode=132&storyCode=2053426.
[61] See "IoS investigation: official plotted Sellafield cover-up", The Independent, 2009-01-04, http://www.independent.co.uk/news/uk/politics/ios-investigation-officials-plotted-sellafield-coverup-1224473.html.
[62] See "Windfall for nuclear waste site", BBC News, 2008-12-22, http://news.bbc.co.uk/1/hi/england/cumbria/7795162.stm.
[63] See "MP's anger as state bears cost of any Sellafield disaster", The Guardian, 2008-10-27, http://www.guardian.co.uk/environment/2008/oct/27/sellafield-deal-nuclear-economy.
[64] See "Why did government use emergency procedure over Sellafield clean-up bill?", The Guardian, 2009-03-10, http://www.guardian.co.uk/politics/blog/2009/mar/10/sellafield-emergency-procedure.
[65] See "Taxpayer foots the bill for nuclear bonuses", The Times, 2009-04-22, http://business.timesonline.co.uk/tol/business/industry_sectors/utilities/article6144016.ece.
[66] See "BNFL's 'expensive failures' earn £1m payoffs from taxpayer", The Guardian, 20080-12-11, http://www.guardian.co.uk/world/2008/dec/11/nuclear-executive-salaries.
[67] See "Could nuclear sell-off be another taxpayer bail-out?" The Guardian, 2008-11-11, http://www.guardian.co.uk/environment/2008/nov/19/edf-nuclear-energy-sellafield-drigg.

- Bonuses paid to civil servants.[68]
- Direct financial support for the nuclear industry.[69]

2.10 New subsidies?

As if these subsidies were not enough, the nuclear industry has repeatedly called for more support for the industry in the UK.[70]

Now, in [WP2011], the UK government has indeed proposed new subsidies for nuclear power. Our analysis may be seen in [EMR2011].

2.11 Other sources of information

There is more information about subsidies for nuclear power in the following sources:

- Other hidden subsidies identified by Dr David Lowry.[71]
- Subsidies identified in Pete Roche's *NuclearSpin* briefing: *Nuclear costs and financing*, October 2008.[72]
- Subsidies identified in Pete Roche's *No2NuclearPower.org.uk* briefing, *Nuclear Subsidies – how the market is rigged in favour of dangerous nuclear electricity*, January 2007.[73]
- Subsidies identified in *The Economics of Nuclear Power*, by P. Bradford, A. Froggatt, D. Milborrow and S. Thomas, Greenpeace International, May 2007.[74]
- Subsidies for nuclear power in the USA described in *Nuclear power as taxpayer patronage: a case study of subsidies to Calvert Cliffs Unit 3* (PDF, 285 KB, Doug Koplow, Earth Track Inc., July 2009) [75] and other reports from Earth Track.[76]

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[68] See "Cumbria nuclear workers handed £11k bonus by NDA", Carlisle News & Star, 2009-04-23, http://www.newsandstar.co.uk/news/cumbria_nuclear_workers_handed_11k_bonus_by_nda_1_544942?refererPath=/1.50001.

[69] See "£19m pledge for nuclear updates", *Professional Engineering*, 2009-07-29, http://www.profeng.com/archive/archive+2009/2213/22130004.htm.

[70] See "EDF Energy wants Britain to fix the market if it builds nuclear plants", The Times, 2009-11-07, http://business.timesonline.co.uk/tol/business/related_reports/the_future_of_energy/article6907099.ece, "Families face nuclear tax on power bills" (The Guardian, 2009-10-19, http://www.guardian.co.uk/environment/2009/oct/19/nuclear-tax-on-power-bills), "Consumers to pay for new nuclear power plants" (Daily Telegraph, 2009-08-18, http://www.telegraph.co.uk/news/newstopics/politics/6044394/Consumers-to-pay-for-new-nuclear-power-plants.html), "Energy firms in secret talks on nuclear 'levy'" (Sunday Times, 2009-08-16, http://business.timesonline.co.uk/tol/business/industry_sectors/utilities/article6797809.ece) , "UPDATE: UK nuclear indus seeks equal terms with renewables" (Easy Bourse, 2009-06-10, http://www.easybourse.com/bourse-actualite/marches/update-uk-nuclear-indus-seeks-equal-terms-with-renewables-682055), "EDF calls for support for nuclear industry" (Financial Times, 2009-05-25, http://www.ft.com/cms/s/0/1369ae48-4972-11de-9e19-00144feabdc0.html?ftcamp=rss), "Slash renewables target to protect nuclear, says EDF" (ENDS Report Bulletin, 2009-03-12, http://www.mng.org.uk/gh/resources/ends_report_bulletin_2009-03-12.html).

[71] See "The nuclear industry's secret subsidies", The Guardian, 2008-09-04, http://www.guardian.co.uk/commentisfree/2008/sep/04/nuclear.nuclearpower.

[72] See http://www.mng.org.uk/gh/resources/Nuclear_Costs_and_Finances.pdf.

[73] See http://www.no2nuclearpower.org.uk/reports/Nuclear_Subsidies.pdf.

[74] See http://www.greenpeace.org.uk/files/pdfs/nuclear/nuclear_economics_report.pdf.

[75] See http://www.mng.org.uk/gh/resources/Koplow_CalvertCliffs3_july_2009.pdf

[76] See http://www.earthtrack.net/earthtrack/index.asp?page_id=151&catid=74.

2.12 What is the real cost of nuclear power?

Because subsidies for nuclear power are, for most part, not transparent, estimating the sizes of the several subsidies is not straightforward. However, it should be possible to calculate the sizes of the several subsidies using well-established actuarial and accounting methods.

For one of the subsidies that we have identified—limitation of liabilities (Section 2.1)—this has now been done. As mentioned earlier, recent research by Versicherungsforen Leipzig GmbH,[77] 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.[78]

An alternative estimate in Appendix A suggests that, without limitations on liabilities, the cost of nuclear electricity would be more than 25 US cents per kWh.

Whichever estimate we take, nuclear power would not be competitive if it was required to pay proper levels of insurance against the cost of a nuclear disaster.

The cost of nuclear power would be substantially higher again if the industry had to pay all the other costs that have been identified in Section 2: the cost of underwriting the commercial risks of the industry, the cost of protection against terrorist attacks, the short-, medium- and long-term costs of disposing of nuclear waste, the cost of decommissioning nuclear plants, institutional support for the nuclear industry, and a range of other subsidies.

Without the subsidies that the nuclear industry enjoys now, it would certainly not be commercially viable. Notwithstanding the existence of all those subsidies, the industry has said that it needs even more subsidies in order to go ahead with the building of new nuclear plants (Section 2.9).

3 Justifications for nuclear subsidies?

Some people may acknowledge the existence of subsidies for nuclear power but argue that those subsidies are justified. This section examines arguments of this sort and concludes that none of them are valid. Notice that, in all parts of this main section except Section 3.2, the word 'justification' has its ordinary non-technical meaning, not the narrow technical meaning considered in that subsection.

3.1 The 'public benefit' argument

From time to time, right up to the present, people have attempted to justify nuclear power as a public benefit for the following reasons:

- The original justifications for the limitation of liabilities for nuclear power, and other forms of support, were two-fold:
    - Nuclear power was considered to be necessary because of its role in the production of nuclear weapons.

[77] See http://www.versicherungsforen.net/fs/vfl/de/index.jsp.
[78] The report from Versicherungsforen Leipzig GmbH, and associated documents, may be downloaded via links from http://www.bee-ev.de/3:720/Meldungen/2011/AKW-nicht-versicherbar-BEE-verlangt-ehrliche-Kostendebatte.html. The documents may also be downloaded via links from http://www.energyfair.org.uk/reports#liabilities where press reports and other information may also be found.

- As a means of generating electricity, it was one of the few alternatives to coal or other fossil fuels.

- It is often claimed, quite wrongly, that nuclear power is cheap.
- Today, nuclear power is promoted as part of the answer to the problems of CO_2 emissions and climate change.
- It is sometimes argued that nuclear power helps to improve security of supplies of electricity.
- Nuclear power may be justified as a public benefit because it can be used to destroy some of the unwanted stockpiles of plutonium.
- It is sometimes argued that nuclear power is needed because a supposed 'energy gap' cannot be plugged quickly enough using renewables.

As detailed in the following subsections, none of those arguments are sound.

3.1.1 Military and diversity justifications

Although nuclear power was seen as necessary for the production of materials needed in nuclear weapons, the cold war is now over and many people would like nuclear weapons to be phased out.[79]

At the time of the miners' strike in 1984-5, Mrs Thatcher saw nuclear power as a useful alternative to coal as a means of keeping the lights on. Now, as described in Section 5, there are more than enough alternatives that are cheaper and better than nuclear power.

3.1.2 Cost

Contrary to the often-repeated claim that nuclear power is cheap, it is one of the most expensive ways of generating electricity.[80] Cost is a negative for nuclear power, not an advantage.

3.1.3 Climate change

Far from being an answer to the problem of CO_2 emissions and climate change, *nuclear power would be a mis-allocation of resources*, making things worse by diverting funds away from better and cheaper alternatives:

- As noted in Section 3.1.2, when environmental and hidden costs are factored in, nuclear power is one of the most expensive ways of generating electricity.
- There are more than enough alternatives that have none of the headaches of nuclear power.[81]
- Several reports show how it is possible to cut CO_2 emissions and enhance energy security, without using nuclear power.[82]
- There is a range of techniques for balancing supplies with constantly-varying demands, ensuring security of supply with 100% renewables.

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[79] See, for example, "US and Russia to scrap 2000 nuclear weapons", The Scotsman, 2009-07-07, http://news.scotsman.com/latestnews/US-and-Russia-to-scrap.5433732.jp.
[80] See Section 2.11 and http://www.mng.org.uk/gh/nn.htm#subsidies.
[81] See Section 5 and www.mng.org.uk/gh/energy.htm.
[82] See www.mng.org.uk/gh/scenarios.htm.

- Bearing in mind that the nuclear cycle is far from being zero-carbon,[83] we get bigger cuts in CO_2 for a given amount of money, and we get them sooner, if we choose renewables with energy conservation—and without using nuclear power. We certainly don't need both.

3.1.4 Security of supplies

Nuclear power is sometimes promoted as 'base load' power with the implication that it can be relied on 24/7. But all sources of power are liable to fail and nuclear power is no exception. Failure of a nuclear power station is normally quite disruptive because, normally, it means a relatively sudden loss of a relatively large amount of power.[84]

The inflexibility of nuclear power is an embarrassment. The output cannot be increased quickly to meet peaks in demand and the output cannot easily be reduced when supplies exceed demand. In general, the most valuable sources of power are those that can respond quickly to changes in demand, as for example, hydropower, geothermal power, tidal lagoons managed as pumped storage devices, thermal plants fired with biofuels, and concentrating solar power with heat storage and backup sources of heat.

As described in Section 5, there are more than enough renewable sources of power to meet our needs for energy, not just electricity, now and for the foreseeable future. And, as discussed in Section 5.1, a wide variety of techniques is available for balancing supplies of electricity with constantly-varying demands to ensure security of supplies with 100% renewables.

3.1.5 Other aspects of security

Nuclear power is not a 'home grown' source of power in the UK since all uranium is imported. It is true that stockpiles of plutonium may be processed into MOX fuel, with depleted uranium. But although MOX core loadings up to 100% are theoretically possible, no commercial nuclear reactor has ever been licensed to operate at that level. Where MOX is used, it normally provides only about 30% to 50% of the fuel of a nuclear power station, with the rest provided by Low Enriched Uranium (LEU). [NUKEN2008, p 89].

Most of the decarbonisation scenarios mentioned above[85] provide for greater security of energy supplies than with nuclear power, with its associated worries about all aspects of security, including the security of supplies of uranium, terrorist attacks on nuclear plants or nuclear materials in transit, the creation and detonation of 'dirty' bombs, and the proliferation of nuclear weapons.

The superabundance of renewable sources of power in the UK and its home waters means that the country could, if it wished, be a self-sufficient energy fortress. But in the absence of hostile neighbours, energy security is best served by integrating the UK's electricity supply system with the emerging large-scale supergrids—so that any shortfall in supplies

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[83] The nuclear cycle results in 9 to 25 times more carbon emissions than wind energy, in part due to emissions from uranium refining and transport, and from the construction of reactors [LEN2008, SOV2008]. See also detailed discussion in [CALD2006].

[84] See, for example, "Exclusive: Will wind farms pick up the tab for new nuclear?" (Business Green, 2010-08-24, http://www.businessgreen.com/business-green/news/2268599/exclusive-wind-farms-pick-tab). The expected increase in the number of nuclear power stations in the UK will mean that the annual cost of providing so-called Large Loss Response will rise from £160m a year to £319m. But the costs will be shared equally across all electricity providers. As one might expect, generators of non-nuclear electricity say that is not fair.

[85] See http://www.mng.org.uk/gh/scenarios.htm.

may be met from elsewhere. Of course, such integration would also allow the UK to be a net exporter of renewable electricity.

3.1.6 Destruction of plutonium

It is clear that at least some of the UK's unwanted stockpile of plutonium may be destroyed by processing it into MOX fuel and then 'burning' that fuel in appropriately-designed or adapted nuclear plants.

If we set aside the several practical problems associated with this course of action [NUKEN2008, Chapter 4], it looks like an attractive option: we reduce a storage-and-pollution problem and we get some electricity as well.

How does this relate to the issue of subsidies for nuclear power? According to Ian Jackson [NUKEN2008, p 84], MOX fuel is nearly 50% more expensive than LEU. If the argument were to be accepted that nuclear power has a role in "plutonium disposition", then it would be legitimate for the government to pay the *additional* cost of the MOX, without those payments being classified as subsidies.

But the plutonium disposition argument does ***not*** justify all the other subsidies that have been described in Section 2 or tolerating all the other problems with nuclear power.[86]

Since some kind of solution must eventually be found to the problem of storing or disposing of the UK's legacy of nuclear waste and, since plutonium stockpiles can participate in that solution, there is no case at all for building new nuclear power stations *purely* as a means of reducing the quantities of stored plutonium. Any new nuclear power stations must be commercially viable as power generators, *without* the subsidies that have been identified.

3.1.7 Speed of construction

It is sometimes argued that there will be an 'energy gap' and that nuclear power is needed because renewables cannot be built fast enough to plug the gap. But in general, renewables can be built much faster than nuclear power plants. For example, in 2010, Germany installed 8.8 GW of photovoltaic solar panels, producing about the same amount of electricity as a 1 GW nuclear plant. But it would take much longer—seven years or more—to build that nuclear plant.

3.2 Detriments to health and 'justification' for nuclear power

On the website of the UK's Department for Business, Innovation and Skills (BIS)[87] it says:

> *The concept of Justification is based on the internationally accepted principle of radiological protection that no practice involving exposure to ionising radiation should be adopted unless it produces sufficient net benefits to the exposed individuals, or society, to offset any radiation detriment it may cause.*

and on the website of the UK's Department of Energy and Climate Change (DECC),[88] it says:

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[86] See http://www.mng.org.uk/gh/nn.htm.
[87] See http://www.berr.gov.uk/.
[88] See http://www.decc.gov.uk/.

Justification is a requirement of EU law under which before any new class or type of practice involving ionising radiation can be introduced it must first undergo a high-level, generic assessment to determine whether its overall benefit outweighs any associated health detriment.

Here, the concept of 'justification' is much narrower than it is in the 'public benefit' considerations discussed above. Even if one were to conclude that the net benefits of nuclear power outweigh "radiation detriment," this would fall a long way short of demonstrating that the several subsidies for nuclear power are justified.

Most of what has been said about possible justifications in terms of public benefit applies to 'justification' in this relatively narrow sense: there are no good reasons for exposing people to the undoubted risks from radiation, including risks from a Chernobyl-style accident or worse.

3.3 Subsidies for renewables

If may be argued that subsidies for nuclear power are justified because renewables are receiving subsidies, either directly via grants or tax breaks or indirectly via Renewable Obligation Certificates (ROCs) or feed-in tariffs.

At present, renewables need protection or support mainly because of distortions in the energy market summarised in Section 6. If those distortions were to be corrected then, as described in that section, support for renewables may be reduced or removed.

3.4 Withdrawal of subsidies

As was indicated in the introduction, the subsidies that are enjoyed by nuclear power are a clear breach of the principle of fair competition. They invite legal challenge or direct action by politicians to remove these distortions in the market place.

Several of the subsidies for nuclear power are quite subtle and removing them is not simply a matter of forbidding the payment of certain sums of money. For example:

- With regard to the limitations on liabilities for nuclear power (Section 2), it may not be possible to find any insurance company or consortium of companies that would be willing to take on the risk.[89] However, that in itself does not provide a reason for exempting the industry from relevant costs.
- The way in which national governments must necessarily underwrite the commercial risks of nuclear power (Section 2.2) and the costs of cleaning up after the nuclear industry (Section 2.6), is a subsidy for the nuclear industry even though there may be no direct payment from the government to any nuclear company. But that does not mean that the subsidy should not or cannot be withdrawn.
- Again, the fact that people who are not yet born are providing a subsidy for the nuclear industry (Section 2.5), does not exempt the industry from paying relevant costs.

In broad terms, the subsidies we have identified provide support for nuclear power in either or both of two ways:

[89] Although, as mentioned earlier, the website of the World Nuclear Association says that, contrary to what is often said, the insurance industry is willing to take on insurance for nuclear disasters, see http://www.world-nuclear.org/info/inf67.html.

- The operators of nuclear plants are exempted from paying costs that businesses of a similar kind would normally be required to pay.
- Risks and corresponding costs are transferred from the operators of nuclear plants to the Government and members of the public.

Thus, in general, these subsidies may be stopped in the following way:

- Operators of nuclear plants should be required to pay the full costs of running their businesses.
- Where there are risks that may result in costs falling on the Government or members of the public, the operators of nuclear plants should be required to take out full insurance from commercial insurers, without any cap or ceiling.

Any insurer or group of insurers should be able to demonstrate that they could cover the kinds of claims that may arise from a Chernobyl-style accident or worse.

If commercial insurers are unwilling to provide the necessary insurance for any proposed new nuclear plant, then the plant should not be built. If commercial insurers are unwilling to provide the necessary insurance for existing nuclear plants, those plants should be closed down as soon as possible.

In Section 2.4.3, we have made more specific proposals about how to ensure that the operators of nuclear plants pay the full cost of disposing of nuclear waste.

With regard to limitations of liability (Section 2.1), it is sometimes argued that, with careful engineering, the risk of disaster can be reduced to a level where it can be ignored. Our response is that the question of whether or not the risk is small enough to be ignored is not for the nuclear industry to judge. The best way of assessing that risk and associated costs is to require the operators of nuclear plants to obtain full insurance against disaster.

4 There are more than enough renewables to meet our needs

There is no question that renewable sources of power can meet the UK's present demands for energy (not just electricity), and anticipated future demands as outlined in Section 5.3 below. There is a range of techniques for balancing supplies of electricity with constantly-varying demands to ensure security of supplies with 100% renewables. Renewable power sources are in general quicker to build than nuclear power stations. And, without distortions in energy prices (Section 6), renewables are cheaper than nuclear power.[90]

Here is some of the evidence that renewables can meet our needs:

- **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.** See "Global potential for wind-generated electricity", Xi Lua, Michael B. McElroya, and Juha Kiviluomac, *Proceedings of the National Academy of Sciences of the United States of America*, June 22, 2009, doi: 10.1073/pnas.0904101106.[91]

[90] See Section 2.11 and http://www.mng.org.uk/gh/nn.htm#subsidies.
[91] Download via http://www.pnas.org/content/early/2009/06/19/0904101106.full.pdf+html.

- **The "economically competitive potential" of wind power in Europe is 3 times the projected demand for electricity in 2020 and 7 times the projected demand in 2030. Offshore wind power alone could meet between 60% and 70% of projected European demand for electricity in 2020 and about 80% of projected demand in 2030.** See "Europe's onshore and offshore wind energy potential", European Environment Agency, 2009.[92] The UK is one of the windiest parts of Europe.
- **For five offshore electricity generating technologies—wind with fixed and floating foundations; wave; tidal range; and tidal stream—the full practical resource, estimated to be 2,131 TWh/year, exceeds current UK electricity demand six times over.** See "The Offshore Valuation: A valuation of the UK's offshore renewable energy resource", The Offshore Valuation Group, May 2010.[93]
- **Renewable sources of power can provide 100 percent of the world's energy (not just electricity) and it is technically feasible to make the transition by 2030.** See "A path to sustainable energy by 2030", Mark Z. Jacobson and Mark A. Delucchi, *Scientific American*, November 2009, pp 58-65,[94]This article reviews research showing that there are more than enough renewable sources of energy to meet all of the world's energy needs, not just electricity. In the scenario described in the Scientific American article, wind supplies 51 percent of the demand worldwide, provided by 3.8 million large wind turbines (each rated at five megawatts). Although that quantity may sound enormous, it is interesting to note that the world manufactures 73 million cars and light trucks every year. An interesting conclusion of this research is that, because there would be much less wastage of energy in a renewables scenario, total world demand for power in 2030 would be 11.5 terawatts, using renewables, compared with 16.9 terawatts if we were to stick with conventional sources of energy.
- **Photovoltaics (PV) could generate about 266 TWh/yr in the UK—about 66% of the UK's present electricity demand**. See "Renewable Energy and Combined Heat and Power Resources in the UK", Tyndall Centre, 2002.[95] PV is quick and simple to install.
- 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.** These calculations, which are quite conservative, are based on research from the German Aerospace Centre (DLR).[96] Although it would be possible to obtain all the world's energy from deserts, **there are several reasons why Europe**

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[92] Download via http://www.mng.org.uk/gh/resources/Europes_onshore_and_offshore_wind_energy_potential.pdf.
[93] Download via http://www.mng.org.uk/gh/scenarios/offshore_vaulation_full.pdf.
[94] See http://www.stanford.edu/group/efmh/jacobson/sad1109Jaco5p.indd.pdf. An interactive online presentation about this research may be viewed via http://www.scientificamerican.com/article.cfm?id=powering-a-green-planet.
[95] Download via http://www.tyndall.ac.uk/sites/default/files/wp22.pdf.
[96] Relevant reports may be downloaded via http://www.trec-uk.org.uk/reports.htm.

and the UK (and other regions and countries) **should use a variety of renewable sources of power**, as described in the TRANS-CSP report from the DLR.[97]

- **There are several other reports on how to decarbonise the world's economies via renewables and the conservation of energy, without using nuclear power**. A more comprehensive list, with notes and download links, is on www.mng.org.uk/gh/scenarios.htm.

4.1 Variability

The variability of sources such as wind power is much less of an issue than is sometimes suggested, as described in a report by independent consultant David Milborrow.[98]

Electricity transmission networks in the UK are *already* designed to cope with variability arising from the failure of power stations and from variations in consumer demand, and that, for a small additional cost, wind power could provide up to 40% of the UK's electricity. Further increases in the level of wind penetration are feasible and do not rely on the introduction of new technology.

National Grid have confirmed that variations in wind power can be accommodated on the grid.[99]

Contrary to what is often suggested, *all* sources of electricity are intermittent because all kinds of generators can and do fail. When a nuclear power station fails, it is particularly disruptive because it removes a relatively large amount of capacity from the grid and it normally does so quite suddenly and often without much warning. By contrast variations in wind power are much more gradual and there is normally several hours warning.

The disruptive effect when a nuclear power station fails is described in "Exclusive: Will wind farms pick up the tab for new nuclear?".[100] The expected increase in the number of nuclear power stations in the UK will mean that the annual cost of providing so-called Large Loss Response will rise from £160m a year to £319m. But the costs will be shared equally across all electricity providers. Naturally, the renewable generators are not pleased about this.

Keeping generating plants on 'spinning reserve' in case other generating plants fail is a wasteful 'last century' practice. Now, there is a range of techniques for matching supplies of electricity to variable demands.[101] These include:

- *Large-scale 'HVDC' transmission grids*, smoothing out variations in supply and demand across a wide area.
- *Renewable sources of electricity that can provide 'power on demand'*: enhanced geothermal systems (EGS), hydropower, thermal power stations fuelled with biofuels, tidal lagoons with pumped storage, and concentrating solar power with heat storage and backup sources of heat.
- *Vehicle-to-grid technologies*, providing storage from electric and hybrid vehicles.

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[97] Download via http://www.trec-uk.org.uk/reports.htm.
[98] "Managing Variability", David Milborrow, commissioned by Greenpeace, WWF, RSPB, Friends of the Earth, July 2009, http://www.trec-uk.org.uk/reports/milborrow_managing_variability_final_July_2009.pdf.
[99] "National Grid report says it can handle variable wind power", National Grid press release, 2009-06-22, http://www.energyefficiencynews.com/policy/i/2193/.
[100] Business Green, 2010-08-24, http://www.businessgreen.com/business-green/news/2268599/exclusive-wind-farms-pick-tab.
[101] See http://www.desertec-uk.org.uk/elec_eng/supply_demand.html.

- A variety of methods for the *storage of power* via pumped storage, compressed air, hydrogen and more.
- A variety of *methods for managing demand.*
- *Provision of spare capacity*, such as gas power stations, fired with biogas.
- *Methods for predicting variations in supply and demand.*

It is sometimes said that nuclear power is needed to provide 'base load' because wind and solar power are variable. But:

- In matching supplies of electricity to variable demands, power engineers do not need 'base load', they need 'power on demand'—the ability to respond flexibly to peaks and troughs in demand. Nuclear power lacks that flexibility. Much more useful are renewables that can provide that kind of flexibility (see above).
- As mentioned above, nuclear power stations can and do fail and special provision is needed to safeguard against the disruptive effect of those failures.

A demonstration of the way that renewables can provide a comprehensive and reliable source of electrical power is the "Combined Power Plant" which links and controls 36 wind, solar, biomass and hydropower installations spread throughout Germany.[102] It has proved to be just as reliable and powerful as a conventional large-scale power station.

4.1.1 Providing a backstop against contingencies

It is sometimes said that a problem could arise if there was a flat calm over the UK during the winter when the demand for electricity is high.

If the UK were to rely exclusively on wind power, this might be true. But a variety of renewables with different characteristics and interconnection with emerging supergrids should ensure security of supplies.

However, a backstop may be provided quite economically by maintaining a strategic reserve of gas-fired power stations which are near to the ends of their working lives but still serviceable, together with a strategic reserve of biogas or biomethane.

4.2 Negawatts

It is often cheaper to save power than to generate it. In that connection, **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).** See "Reducing energy demand: what are the practical limits?" (report by Jonathan M. Cullen, Julian M. Allwood, and Edward H. Borgstein of the Department of Engineering, University of Cambridge, 2011-01-12).[103]

4.3 Future developments

Electrification of road and rail transport in the UK would add to the UK's demand for electricity but not as much as one might think:

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[102] See http://www.kombikraftwerk.de/index.php?id=27.
[103] Download via http://dx.doi.org/10.1021/es102641n.

- In terms of energy, about 50% more electricity would be needed (see Appendix 8 of "Energy UK"[104]). The main reason it is not more is that electric motors are very much more efficient than internal combustion engines. Much of the energy that we are using now for overland transport is simply wasted.
- In practice, any additional amount of generating capacity that may be required is likely to be less than 50%. This is for two reasons:
    - It is likely that much of the charging of electric vehicles will be done at night when there is likely to be a lot of spare capacity from sources such as wind power. To that extent, it does not add to the generating capacity that would be required.
    - The electrification of road transport will facilitate the introduction of grid-to-vehicle technologies allowing two-way flows of electricity between vehicles that are on charge and the transmission grid. This, with other techniques for balancing the grid,[105] will help to keep demands for electricity in balance with supplies, thus helping to minimise the amount of spare capacity that is required.

It seems likely that, in the future, there will be increasing use of electrically-driven heat pumps to provide space heating in buildings. But, with good insulation of buildings and the use of technologies such as inter-seasonal heat transfer,[106] residual needs for the heating of buildings should be small.

As mentioned earlier, a report from the Department of Engineering, University of Cambridge, estimates that 73% of global energy use could be saved by practically achievable design changes to passive systems and that further savings may be achieved by improvements in the efficiency of conversion devices.

With appropriate policies in place, it seems likely that the UK government's suggestion that "electricity use could double by 2050"[107] is unduly pessimistic and that little or no increase in generating capacity may be required.

5 Correcting distortions in the energy market

The reasons that renewables are, at present, needing some kind of protection or support are:

- The commercial 'playing field' is tilted against them:
    - Fossil fuels are heavily subsidised:
        - In a report published in 2004,[108] the New Economics Foundation made a conservative estimate that worldwide subsidies for fossil fuels amounted to about $235bn a year.

[104] Download via http://www.mng.org.uk/gh/resources/energy_UK3.pdf.
[105] See http://www.trec-uk.org.uk/elec_eng/supply_demand.html.
[106] See, for example, http://www.howedell.herts.sch.uk/eco_issues/sustainable_elements.pdf.
[107] See "Chris Huhne speech to the Royal Geographic Society – 'The Perfect Storm'" (DECC press release, 2011-02-17, http://www.decc.gov.uk/en/content/cms/news/RGS_speech/RGS_speech.aspx).
[108] See "Fossil fuel subsidies 'must end'", BBC News, 2004-06-21, Hhttp://news.bbc.co.uk/1/hi/sci/tech/3818995.stmH.

        - The continued existence of subsidies for oil, gas and coal, is confirmed by reports that the G20 intend to remove them.[109]
        - A report in 2010 by Bloomberg New Energy Finance showed that fossil fuels are receiving 12 times as much subsidy as renewables.[110]
    - Nuclear power is heavily subsidised as described in Section 2.
    - The price of CO_2 emissions is far too low. There is still no global cap on emissions and schemes such as the EU Emissions Trading System are not working properly.[111]
- It is widely accepted that renewables need support until they a properly established. When any particular renewable technology is well established and, *when there is a level playing field for renewables*, then there may be a case for withdrawing subsidies for that particular technology (more below).

More generally, the Stern report said that climate change is the greatest market failure the world has seen,[112] and that actions are needed to compensate for that failure.

Rather that piling subsidy upon subsidy, we should be aiming to *wind down the arms race of subsidies, reserving them for where they are really needed*:

- Ensure that a proper price is paid for CO_2 emissions.[113,114]
- Remove subsidies from oil, gas and coal, as the G20 have indicated they will do.
- Remove subsidies from nuclear power following procedures outlined in Section 4.
- Retain subsidies for renewables that have not yet reached the bottom of their cost-reduction curves.
- Remove subsidies from renewable sources of power that have reached the bottom of their cost-reduction curves and are well established.

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[109] See, for example, "G20 fossil fuel subsidy push may aid climate talks", Reuters, 2009-09-25, http://www.reuters.com/article/environmentNews/idUSTRE58O3RN20090925.

[110] The download link, with a press release is in "Subsidies for renewables, biofuels dwarfed by supports for fossil fuels", Bloomberg New Energy Finance, 2010-07-29, http://bnef.com/PressReleases/view/123. See also "Fossil fuel subsidies are twelve times renewables support", Bloomberg New Energy Finance, 2010-07-29, http://www.bloomberg.com/news/2010-07-29/fossil-fuel-subsidies-are-12-times-support-for-renewables-study-shows.html.

[111] See, for example, "EU Emissions Trading System: failing at the third attempt" (briefing from Corporate Europe Observatory, Carbon Trade Watch, April 2011, http://www.corporateeurope.org/system/files/files/article/EU-ETS_briefing_april2011_0.pdf); "EU emissions trading scheme on course to make tiny savings, says report" (The Guardian, 2010-09-10, http://www.guardian.co.uk/environment/2010/sep/10/eu-emissions-trading-savings).

[112] See "Stern: climate change a 'market failure'", The Guardian, 2007-11-29, http://www.guardian.co.uk/environment/2007/nov/29/climatechange.carbonemissions.

[113] In this connection, the nuclear cycle is far from being zero carbon, see http://www.mng.org.uk/gh/nn.htm#CO2.

[114] One of the most effective ways of ensuring that a proper price is paid for emissions of industrial greenhouse gases is to control them 'upstream', at or close to their origins. This is described in *'Upstream' reform of the EU Emissions Trading System* from the K2S group (http://www.k2support.org/home) which may be downloaded from http://www.mng.org.uk/euets.

6 Conclusion

Greater awareness of the subsidies for nuclear power may pave the way for their reduction or withdrawal. Apart from the savings to the public purse, removal of subsidies for nuclear power will help to level the commercial playing field for renewable sources of power, thus boosting their expansion and speeding the transition to the sustainable low carbon economy that is so urgently needed in the fight against climate change.

There are more than enough renewable sources of power to meet present and anticipated future needs for energy, not just electricity. They are cheaper than nuclear power, they can be built more quickly, they can provide greater security, and they have none of the other problems of nuclear power.

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8 Appendix A: An alternative estimate of the cost of nuclear power without limitation on liabilities

Here is another estimate of the cost of nuclear power without limitation on liabilities (an alternative to the figure quoted in Section 2.11):

- According to a report from the New Economics Foundation,[115] a kilowatt-hour of electricity from a nuclear generator will cost as much as 8.3 pence (13.7 US cents) once realistic construction and running costs are factored in, compared with about 3 pence (4.9 US cents) claimed by the nuclear industry—*and that's without including the cost of managing pollution, insuring against catastrophic accidents, or protecting nuclear power plants and nuclear transports from attack by terrorists.* Adjusting for inflation, the NEF estimate is 9.95 p/kWh (about 16.29 c/kWh).
- In Section 2.1, we saw that "if Electricité de France had to insure for the full cost of a meltdown, the price of nuclear electricity would increase by about 300%.", with that 300% figure backed up with evidence from Appendix J of the European Commission report "Environmentally harmful support measures in EU member states".[116] The latter source suggests that the premium required would be 5.0 c€/kWh (about 7.2 US cents/kWh). Adjusting for inflation this is 6.34 c€/kWh (about 9.1 US cents/kWh).
- On the strength of this evidence, we may conclude that, if the nuclear industry had to pay the full cost of insuring against a meltdown, the cost of power from new nuclear power stations would be 16.29 + 9.1 = 25.39 US cents per kWh—*higher than most other sources of power*.

[115] "Mirage and oasis: energy choices in an age of global warming" (PDF, 1.2 MB, New Economics Foundation, June 2005, http://www.mng.org.uk/gh/scenarios/nef_energy_june_2005.pdf).
[116] See http://www.mng.org.uk/gh/resources/EC_env_subsidies.pdf (PDF, 1.1 MB).