Briefing February 2011

The Cost of Nuclear Power: Why nuclear will cost us more than the alternatives.

Executive Summary

The Government admits that there are uncertainties in estimating the cost of nuclear power and that it has relied mainly on industry estimates. The Government's conclusion that nuclear power stations will yield economic benefits is not a robust for that reason.

The recently announced cost of $4,260/kW for the proposed Hinkley C nuclear power station is more than double the $2,000/kW estimated by the Government in 2008.

Cost estimates for new reactors in other parts of the world have reached $6,000/kW or more. In the US estimates have gone from $1,500/kW in 2005 to $7,500/kW or more today.

The Government says it believes nuclear electricity will become the cheapest form of low carbon electricity but experience from around the world suggests nuclear costs will continue to escalate making nuclear power the least cost effective method of carbon abatement. Meanwhile the costs of many of the alternatives are going down. Thus a new nuclear programme will damage efforts to tackle climate change by achieving less carbon saving per pound spent than alternative methods of abatement.

Current estimates of the cost of electricity from new nuclear reactors are around 9.3p/kWh compared with 8p/kWh from onshore wind, 15p/kWh from offshore wind, and 6p/kWh for gas-fired electricity. But if construction costs do turn out to be closer to $6,000/kW than $4,000/kW, nuclear electricity costs could reach as high as 20-25p/kWh.

The Government's Electricity Market Reforms which is intended to boost low carbon electricity production particularly nuclear power is expected to see the cost of electricity increase from 11.8p/kWh to 17.9p/kWh (plus inflation) over the next twenty years. If this proves insufficient to pay for nuclear electricity the increases could be even greater. On the other hand the costs of electricity from offshore wind, solar, and other renewable are expected to continue falling as we gain experience in these new technologies.

Preface

There are a number of ways to calculate nuclear electricity generation costs involving a dizzying number of variables. The first step is to estimate how many kilowatt hours (kWh) the plant will produce each year. Next we need to calculate the production costs which include operation and maintenance and fuel costs, the cost of decommissioning and managing the nuclear waste. Then we have to account for the plant's capital costs. The loan lifetime and the interest rate for the borrowed money are the key factors. There may also be costs for grid upgrades, and finally transmission and distribution costs need to be included. (1)

Unlike fossil fuelled generating facilities, where the cost of fuel is a major determinant of the cost of electricity, fixed costs – the costs incurred whether or not the plant is operated - are much more important in determining the cost of nuclear electricity. The usual rule-of-thumb for nuclear power is that about two thirds of the generation cost is accounted for by fixed costs. (2) There are three main elements to the fixed cost per kWh: the construction cost; the cost of capital - how much it costs to borrow the money; and the plant's reliability, which determines how much saleable electricity there is over which to spread the fixed costs. The cost of borrowing is the largest element of the unit cost of power from a nuclear power plant. In the past the interest rate was assumed to be low because of the monopoly status of electricity utilities, but this has now increased in importance because of liberalization of the market. (3) If the sector is a regulated monopoly, the real cost of capital could be as low as 5-8 % but in a competitive electricity market, it is likely to be at least 15%. Clearly doubling the largest element of the cost of electricity from a nuclear power plant will severely damage the economics of nuclear power. (4)

To allow comparisons between reactors with different output capacities, costs are often quoted as a cost per installed kilowatt (kW). Thus, a nuclear power plant with an output rating of 1200 Megawatts (MW) (1MW = 1,000kW), quoted as costing £2000/kW would have a total construction cost of £2400m (or £2.4bn). These costs are often quoted in US dollars to allow comparisons between countries. Conventionally, quoted construction costs include the cost of the first charge of fuel but often do not include the interest incurred on borrowings during the construction of the plant, usually known as interest during construction or IDC. (5) A delay in construction will increase costs, if only because 'interest during construction' on the capital borrowed will increase. Therefore delays in construction will have a significant impact on the economics of nuclear power. (6)

Obviously construction costs given in £/kW or $/kW do not tell the whole story, what we really want to know is the cost of electricity produced in p/kWh. Costs are often given as £/MWh, for example the Government's May 2007 consultation document, "*The Future of Nuclear Power*" estimated that nuclear electricity would cost between £31/MWh and £44/MWh. (7) This is easily converted to p/kWh by dividing by 1000 i.e. in this case 3.1p/kWh-4.4p/kWh.

"The Future of Nuclear Power" consultation document stresses the uncertainties involved in estimating the costs of nuclear electricity, and admits that it has relied mainly on industry estimates. (8) Dr Mark Diesendorf from the Institute of Environmental Studies at the University of New South Wales recently detailed common problems and errors in estimating nuclear costs. These included accepting manufacturers' cost estimates; choosing an unrealistically low discount rate; using accounting methods that shrink capital cost; overestimating operational performance; ignoring subsidies and other life cycle costs. (9)

In a November 2009 report entitled: "*New Nuclear – the economics say no*", (10) Citigroup explain that there are five major areas of risk faced by developers of new nuclear power stations. These are:

(1) The risk of delays in the planning application process
(2) The risk of sudden and unexpected cost escalations for dealing with nuclear waste management and decommissioning.
(3) The risk of escalation in construction cost;
(4) The risk that power prices are not high enough to cover the very high fixed costs - it was a sudden drop in power prices that drove British Energy to the brink of bankruptcy in 2003;
(5) The risk that operational unrealiability leaves the plant with insufficient income.

The UK Government has announced measures to limit the two least significant of these risks – the Planning risk, and the risk associated with decommissioning and waste management costs. The Government introduced a fast-track planning process with the Planning Act 2008[1], and it is proposing to adopt a "pay as you go" approach for waste management and decommissioning costs, effectively limiting the risk faced by the developers and leaving the taxpayer bearing that risk. (11)

That still leaves three major risks which Citigroup describes as the corporate killers - risks that are so big and significant that if they go wrong, the developer (even the biggest utilities) could be financially damaged beyond repair.

Indeed, at no time, anywhere in the world, has a utility built a new nuclear power station and taken the full Construction, Power Price, and Operational Risk. In a foretaste of what was to come Citigroup concluded that:

[1] For an update on how the Localism Bill will affect the Planning Act (2008) and the abolition of the Infrastructure Planning Commission see: http://www.bdb-law.co.uk/blog/anguswalker/198-localism-bill-effect-infrastructure-planning-explained

"*...it is extremely unlikely that private sector developers will be willing or able to take on the Construction, Power Price, and Operational risks of new nuclear stations. The returns would need to be underpinned by the government and the risks shared with the taxpayer / consumer. Minimum power prices (perhaps through capacity payments), support for financing, and government backed off-take agreements may all be needed to make new nuclear viable*."

Introduction

French-owned EDF Energy is expected to launch a project to build two European Pressurised water Reactors (EPRs) at Hinkley Point in Somerset early in 2011. It estimates the cost of the two reactors will be £9bn ($14bn). The proposed reactors would have a combined rating of 3,260MW, which puts the cost at £2,760/kW ($4,260/kW). EDF has an EPR under construction at Flamanville in Normandy. The cost of this reactor was estimated in 2008 at €4bn ($5.2bn), but it is now running at least €1bn over budget and two years late. (12) The only other EPR being built in Western Europe is Olkiluoto in Finland. The original contract price for this reactor was reported to be €3bn in 2004. By August 2010, Areva NP, the company building the reactor, acknowledged that the estimated cost had reached €5.7bn. (13) This puts the cost of the first two EPRs at $4-$5,000/kW

In 2008, when the UK government revisited nuclear economics, it assumed the construction cost would be around £1,250/kW ($2,000/kW), so the cost has more than doubled in two years. (14) As we will see the estimated cost of new reactors in some parts of the world has now reached as high as $6000/kW or more. Clearly there is a huge degree of variance in estimated costs from forecast to forecast, and a huge variance in the assumptions made for the parameters important in determining the cost of nuclear generated electricity. Stephen Thomas, Professor of Energy Policy at Greenwich University says many of the quoted construction cost forecasts should be treated with scepticism. The most reliable indicator of future costs has often been past costs.

Yet the UK Government says it believes new nuclear will become the least expensive form of low carbon electricity generation. (15) It says cost overruns and delays at Olkiluoto have arisen partly because of changes made to the design during construction. The Generic Design Assessment[2] process, being run by the Nuclear Installations Inspectorate and the Environment Agency, should mean design issues are resolved early in the process, rather than addressed during construction, when resolution may be more complex, costly and time consuming. (16) However, experience suggests that nuclear costs will continue to escalate making nuclear power the least cost effective method of carbon abatement. Meanwhile the costs of many of the alternatives are going down. Thus a new nuclear programme will damage efforts to tackle climate change by achieving less carbon saving per pound spent than alternative methods of abatement.

Construction delays around the world

None of the UK's Advanced Gas-cooled Reactors (AGRs) were completed on time and there were huge cost overruns. Dungeness B was the first AGR plant to be ordered in 1965. At the time it was expected to be operational by 1970-71, but it did not produce commercial energy until 1989. Even the final two stations, Torness and Heysham B, were over a year late. Delays caused budget overruns, and when completed the majority failed to perform to their designed output, further reducing income. (17)

The Government seems to think the UK can avoid the construction delays experienced in UK reactor programmes in the past and recent delays seen in Finland and France, but problems are not confined to Europe, or consigned to the past. Country after country has seen nuclear construction programmes go considerably over budget - for example, completion costs for the last ten Indian reactors have been 300% over budget. (18) China's Tianwan project began commercial operation in June 2007, more than two years later than planned. The Chinese regulator halted construction for almost a year on the first of two Russian-designed reactors while it examined welds in the steel liner for the reactor core. In Taiwan, the Lungmen reactor project is five years behind schedule. Difficulties include welds that failed inspections in 2002 and had to be redone. The rising cost of steel, concrete and other commodities has gutted subcontractors' profits, causing

[2] See http://www.no2nuclearpower.org.uk/news/id_gda.php for more information

them to stop work to renegotiate fixed-price contracts. (19) The World Energy Council says construction times for new reactors have risen from 66 months in the mid-1970s to 116 months - nearly ten years - for completions between 1995 and 2000. The unproven designs being proposed for the UK are likely to lead to more potential delays. (20)

EPR design is in crisis.

The planning application for Hinkley Point C is expected to be received by the Infrastructure Planning Commission (IPC) in the winter of 2010/11, (21) and for Sizewell C in Suffolk on 1st June 2011 (22). Both of these applications will be made by EDF Energy, so the first four proposed reactors applying for planning permission will be EPRs. Horizon Nuclear Power, which is a joint venture between the two German utilities, EoN and RWE, (23) is expected to submit an application to build two or three reactors at Wylfa on the Island of Anglesey in the first quarter of 2012 and an application (24) for two or three reactors at Oldbury in Gloucestershire in the second quarter of 2014. (25) Both of the Horizon proposals could comprise of either two 1,650MW Areva EPR reactors or up to three 1,100MW Westinghouse AP1000 reactors, so at this stage the reactor type is uncertain. (26)

As well as construction going dramatically wrong at Olkiluoto and Flamanville, the price the EPR is being offered at is so high that all contests where it has been bid have either been abandoned (South Africa and Canada) or the contract has gone to a much lower bid from a competitor (UAE). Potential markets such as USA and Italy all look problematic and reactor orders, if placed at all, will be much later than expected. (27)

The Finnish and French authorities' decision to allow construction to start before full generic approval had been given looks particularly ill-judged. But the process of obtaining safety approval in UK (and France and the USA) is incomplete and, even if successful, the features needed to achieve regulatory approval may add significantly to costs. One nagging issue for reactor builders is that contractors are inexperienced. They will be getting asked to work for an industry that has been dormant in most of Europe and the U.S. for 20 years. (28) The Sussex University Energy Group's submission to the Government's October 2007 consultation on the future of nuclear power concluded that the Government's view that "*nuclear power stations would yield economic benefits"* was not a robust conclusion because it did not properly acknowledge the uncertainties involved in introducing novel reactor designs into the UK and the high level of technologically-derived risk to capital cost estimates. The simple answer to the question 'what are the economics of nuclear power', the group concludes, is: we don't know. (29)

The costliest private projects ever undertaken?

The claim that nuclear power is or could be cost competitive with alternative technologies has been based on hope and hype, according to Dr Mark Cooper, senior fellow for economic analysis at the Institute for Energy and the Environment at Vermont Law School. (30) At the start of the so-called nuclear renaissance around 2001 – 2004, vendors, academics and government officials in the US were coming up with some very low cost estimates (around $1,000/kW to $2,500/kW). But by 2009 Wall Street and Independent Energy Analysts were producing much higher estimates – up to four times higher than the initial projections (around $5,000/kW to $10,000/kW). Cooper has analysed three dozen recent cost projections, and concluded that the likely cost of electricity from new reactors would be 12-20 cents per kilowatt hour (c/kWh) (7- 12p/kWh at June 2009 exchange rates) - considerably more expensive than the average cost of energy efficiency and renewable energies. Cooper says:

"We are literally seeing nuclear reactor history repeat itself. The 'Great Bandwagon Market' that ended so badly for consumers in the 1970s and 1980s was driven by advocates who confused hope and hype with reality. It is telling that in the few short years since the so-called 'Nuclear Renaissance' began there has been a four-fold increase in projected costs."

When President George Bush signed the Energy Policy Act of 2005 into law, fulfilling many of the industry's key legislative ambitions including the provision of unlimited federal loan guarantees to cover up to 80% of project costs for new reactors, the American Nuclear Energy Institute was estimating construction costs at $1,100/kW to $1,500/kW. By June 2007, the Keystone Center, a Colorado-based energy think tank, published another report, funded in part by the industry, which suggested costs, based on hard data from reactors built in Asia, would be about $3,000/kW to $4,000/kW. In October 2007, Moody's Investor Services projected that new reactors would cost $5,000/kW to $6,000/kW. But as staggering as their estimates were at the time, those who did the calculations for Keystone and Moody's have concluded, based on newer data, that they were not high enough. Moody's now thinks $7,500/kW is more realistic. (31)

Another relatively recent US study, by a leading expert in power plant costs, Craig A. Severance, estimates that total all in costs for building a new reactor are likely to be between $8,900 and $10,500/kW. (32) This would put the costs of electricity from new nuclear plants at 25 to 30 c/kWh — triple current U.S. electricity rates! (33) These estimates put new reactors among the costliest private projects ever undertaken. Most renewable and efficiency projects will be well below these costs, so on an economic basis alone should be implemented first. (34)

The US Government's own Energy Information Administration (EIA) has reported that the capital costs of building a new generation of reactors have shifted markedly in the past year, while solar capital costs have dropped. (35) The EIA has published a special report (36) detailing the changes it will make in its assumptions on the cost of new power plants in its Annual Energy Outlook 2011. EIA found that capital costs for new nuclear and coal-fired power plants are 25-37% higher than those reported in its previous Annual Energy Outlook. The increase reflects higher global commodity prices, the small number of firms able to engineer complex projects such as a new nuclear or advanced coal facility, and the general trend of increased costs of capital-intensive projects in the power sector. EIA found the capital costs for a new dual-unit 2,236MW nuclear plant were $5,335/kW. However, solar capital costs fell markedly. Solar thermal capital costs dropped by 25%, while photovoltaic costs were down 10%. Solar projects are extremely diverse, and the EIA gave a range of costs. A 100MW solar thermal plant's cost of capital is about $4,692/kW, while a 7MW photovoltaic installation could cost $6,050/kW.

Nuclear Capital Cost Escalation, USA, 2003 - 2009

Study	Capital Cost (US$/kW)	Energy cost* (US c/kWh)
MIT (2003)	$2000+IDC	6.7-7.5
Keystone Center (2007)	$3600-$4000	8.3-11.1
Harding (2007)	$4300-$4550	10.0-12.5
MIT (2009 update)	$4000+IDC	8.4
Moody's (2008)	$7500	-
Severance (2009)	$7400 $10500 projected	17.5-21.0 25-30

*cost of energy depends on assumed discount rate and capacity factor
IDC = Interest During Construction. (37)

The escalation of construction costs is not restricted to The West. According to Citigroup, the first AP-1000 unit under construction, in SanMen China, is running significantly over its $1,000/kW construction cost target and is expected to be over $3,500/kW target on current estimates. (38)

Load Factors

Construction cost escalations are not the only problem for potential investors in new reactors. A key aspect of the economics of new nuclear plants is the assumed and achieved load factors that a plant is expected to reach. EDF is targeting an availability factor of 85% for its existing operational nuclear plants. But in the past 5 years has consistently reported load factors below 80%. (39)

UK Nuclear Costs

The UK government, in its 2008 white paper on nuclear power, "*Meeting the Energy Challenge*", assumed nuclear plants would cost £1,250/kW ($2,000/kW). In 2009 it confirmed that it was still working on that assumption. (40) The Government's most recent consultations, however, on Electricity Market Reforms, (41) use a June 2010 UK Electricity Generation Costs Update by Mott MacDonald for the Department of Energy and Climate Change. This gives the capital cost for nuclear (not including IDC) as £3812/kW ($5968/kW) for the first of a kind plant and £2,966/kW ($4643/kW) for later plant. (42) So already costs have more than doubled since 2008. This compares with EDF's estimate for the cost of Hinkley C at £2,760/kW ($4,300/kW)

The Future of Nuclear Power consultation document in 2007 estimated that nuclear power would cost between £31/MWh and £44/MWh (3.1p/kWh-4.4p/kWh). The document stressed the uncertainties involved in estimating the costs of nuclear electricity, and admitted that it mainly relied on industry estimates. (43) It concluded:

"*Based on this conservative analysis of the economics of nuclear power, the Government believes that nuclear power stations would yield economic benefits to the UK…*"

The 2008 Nuclear White Paper estimated the cost of nuclear electricity at between £32/MWh for a 7% discount rate and £42/MWh for a 12% discount rate, so costs had changed little over the year. (44)

Citigroup presented a scenario in November 2009. Assuming everything goes according to plan and a 1600MW nuclear plant is built for €5bn (£4.25bn – not that different to EDF's recent estimate of £9bn for two EPRs). This works out at €3,125/kW (£2,650/kW), and that within 5 years the nuclear plants reach their maximum availability potential, Citigroup estimated that power prices need to be at €65/MWh (£58.5/MWh) for investors to earn a reasonable positive return. This compared with power prices in July 2009 of around €45/MWh. (45)

More recently, Peter Atherton told the House of Commons Energy & Climate Change Committee that using a 10% cost of capital, the required revenue to meet that cost of capital for an EPR would be just under £70/MWh, including an assumption of pay as you go for nuclear waste, but at a 15% cost of capital, which is far more realistic, it would be about £93/MWh. (46) He said this compares with £150/MWh for offshore wind; £80/MWh for onshore wind and about £60/MWh for a Combined Cycle Gas Turbine plant. But if capital costs do turn out to be closer to the $6,000/kW being discussed in the US, according to Professor Steve Thomas electricity costs will be closer to £140/MWh - £210/MWh depending on the discount rate, and using a more realistic figure for the discount rate for waste and decommissioning costs than is used by Mott Macdonald could increase this number to £250/MWh. (47)

Atherton said it would be extremely unlikely that there would be the investment appetite to build the 16GW of new nuclear capacity which the Government wants unless it deals with the risk of construction cost escalation and the risk that power prices won't be enough to cover costs:

"*The industry has said to the UK Government, "We aren't going to do it," which is why they are asking for carbon price floors, capacity payments and so on. What is that about? It is transferring risk from the developer to the consumer...*"

Market Reforms

The government unveiled plans for energy market reforms on 16th December, predicting the package of measures would lead to a huge increase in investment for renewable, nuclear and carbon capture and storage (CCS) projects. The reforms propose the introduction of four new measures, all designed to strengthen the investment case for low-carbon technologies. Central to the package are plans for a carbon floor price set out in a consultation by the Treasury. (48) But the report does not determine the precise level at which the carbon floor price would be set, instead setting out a range of proposals that would see the carbon price in 2020 stand at £20, £30, or £40 a tonne. The Department of Energy and Climate Change (DECC) is running a separate consultation on electricity market reform which proposes that the existing Renewable Obligations (RO) subsidy mechanism is phased out by 2017 and replaced by a new form of feed-in tariff, whereby the government agrees "*clear, long-term contracts*" that result in a top-up payment to low-carbon generators if wholesale energy prices are low. (49) It also outlines plans for a capacity mechanism that will provide additional payments to energy firms that construct reserve plants and invest in energy-saving measures, and sets out proposals for a "back-stop" to limit the level of emissions from fossil fuel power stations.

The reforms are likely to raise power prices by more than 50%. Chris Huhne says his plans to subsidise nuclear power and renewable energy schemes will only increase average bills by £160 a year - an increase of 32 per cent, but the unit price of electricity will rise from £118/MWh to £179/MWh over 20 years. On that basis, electricity bills would rise on average by £255 a year to £748. When inflation is factored in, electricity bills would double to about £1,000. This is because Mr Huhne's calculation assumes households will cut consumption by 12.5% over the next 20 years. None of these numbers appear to take into account the increasing use of electric vehicles or switching from gas to electric heating. (50) The Government expects electricity demand to double by 2050 as electricity provides more of our heating and transport needs. (51)

It is widely agreed that energy prices will increase over the next 20 years whatever we do, (52) which make it all the more important that whatever reforms are implemented pay due regard to the needs of the 4.5 million households living in fuel poverty. Yet one estimate calculates that the Government's reforms will add another million household to those in fuel poverty. (53)

The Government says its "Green Deal" is a key element of its policy to improve household energy efficiency. (54) But it is still unclear whether the Green Deal will deliver the promised energy efficiency savings to households on low incomes. The "Green Deal" is supposed to give every household the right to have home energy efficiency improvements of up to £6,500 in value with the cost of the work paid back through the household's energy bills. The cost of repaying the loan should be less than the savings arising from a more energy-efficient home. The trouble is that for some of the more expensive measures, such as solid wall insulation, savings might not be enough to pay back the loan, especially if householders are taking some of the savings in the form of extra heat. (55) And it is the fuel poor who tend to live in older properties with solid walls. (56)

Andrew Warren, Director of the Association for the Conservation of Energy points out that utilities have spent the last decade installing the most cost-effective energy saving items - loft and cavity wall insulation – at a heavily subsidised price, yet there are still many people who haven't taken up the offer. The Green Deal expects people to pay the full unsubsidised rate, plus interest on the loan, so it is difficult to see how this will boost take-up. (57)

Professor of Energy Policy at Exeter University, Catherine Mitchell, says the proposed electricity market reforms and the Green Deal do not include anything that will move the UK forward in anything other than an incremental manner. What's needed is a change to the energy market to deliver a new type of energy system with regulated obligations on the scale of the transition from town gas to natural gas. Tendering for street-by-street or area-by-area contracts to make homes energy efficient would be much more cost effective. (58)

David Thorpe, author of Sustainable Home Refurbishment says we need about £60-70,000 per house, about ten times what the Government is proposing. But since the UK's 28 million houses are responsible for around 27% of greenhouse gas emissions we are going to have to do this anyway, and we need to be renovating around 700,000 houses per year in order to make the required contribution to the UK's target of reducing Greenhouse Gas emissions by 80% by 2050. (59) With combined gas and electricity bills expected to almost double from around £1,000 to £2,000 according to the price comparison website energy helpline, (60) much of the refurbishment cost could be recouped before 2050.

Opportunity Costs

As well as paying due regard to the needs of those suffering from fuel poverty, market reforms also need to ensure that scarce resources are being allocated as effectively as possible - best buys first, not the more the merrier. For each pound we spend we need to buy the maximum amount of carbon abatement possible.

Although the Government's market reforms might encourage utilities to invest in new nuclear reactors, this doesn't necessarily mean it is the best way to spend our money. Because of the seriousness of the climate change threat, it is essential that we spend our limited resources on the fastest and most effective climate solutions. If instead we spend on expensive options which are slow to implement we will, in effect, worsen climate change because each pound spent is buying less solution than it would do if it were to spent it on more effective measures such as energy efficiency. (61) Diverting investment from cheaper market winners such as combined heat and power, renewables, and efficiency, to nuclear power according to Amory Lovins, co-founder, chairman and chief scientist of Rocky Mountain Institute in Colorado means you're going to get about two to ten times less climate solution per dollar, and you'll get it about twenty to forty times slower. (62)

Lovins reports that while electricity costs from new centralised power stations, nuclear and fossil fuelled, are increasing, for renewable costs are tending to go down. Wind, combined heat and power, and end-use efficiency already provide electrical services more cheaply than central thermal power plants, whether nuclear or fossil-fuelled. This cost gap will only widen, since central thermal power plants are largely mature and getting costlier, while their competitors continue to improve rapidly. (63)

Lovins estimates that generating a kilowatt-hour of nuclear electricity would displace nearly all of the 0.9-plus kilograms of CO_2 emitted by producing a kilowatt-hour from coal. But then so would generating a kilowatt-hour of electricity with wind. Even a combined heat and power plant burning natural gas can still displace more carbon than nuclear *per dollar spent on delivered electricity*, because it costs far less. In fact CHP displaces around 1.4 kilograms of CO_2 for the same cost as displacing 0.9 kilograms of CO_2 with nuclear.

Nuclear power is, therefore, a climate protection loser, because it is just not a cost-effective way of reducing carbon emissions. Wind and CHP are around 1.5 – 3 times more cost effective, but energy efficiency is around 10 – 20 times more cost effective.

Alternatives

As we have seen, Peter Atherton of Citigroup recently put the cost of offshore wind at £150/MWh compared with £93/MWh for nuclear. Just as the Cabinet Office's Performance and Innovation Unit expected the cost of offshore wind to fall from around 5p-6p/kWh in February 2002 to 2p-3p/kWh by 2020 as a result of learning and innovation, (64) Renewable UK expects to see capital costs for offshore wind reduce by 15-20% by 2015. (65) Nuclear costs, on the other hand, will probably increase.

The Government says the UK needs 59GW of new generating capacity by 2025. Of this 33GW needs to be renewable capacity in any case in order to meet the UK's obligation to meet European Union targets. 8GW of new capacity is already under construction, so that leaves the type of generating plant for a further 18GW of new capacity still to be determined. (66) The Government says that new nuclear power should be able to contribute as much as possible to the UK's need for new non-renewable capacity. (67)

In its Appraisal of Sustainability for the Draft National Policy Statement on Nuclear Power (68) the Government assumes that if new reactors are excluded from the energy mix they will be replaced by gas-fired generation. Assuming for the sake of argument that the wind industry will be kept busy providing most of the 33GW of renewable capacity required by 2025, where else could the extra 18GW of capacity come from?

What the Appraisal of Sustainability didn't evaluate is an alternative strategy based on a high level of Government support for decentralised energy and combined heat and power. The Government's Low Carbon Transition Plan (69) expects 30% of UK electricity to come from renewables by 2020, but only 2 of the 30% would be from small-scale renewable. Yet research by the Energy Saving Trust shows that small-scale renewables and microgeneration could provide around 30-40% by 2050. (70) Similarly, the Chief Executive of National Grid, Steve Holliday, says that 15% of the country's electricity production could come from so called "embedded generation" in homes and offices by 2020 as micro generation becomes increasingly viable after the £9 billion rollout of "smart meters" for every home in Britain. (71)

A study by Pöyry Energy Consulting looked at industrial CHP and found that across the UK it could generate as much electricity as 10 nuclear power stations and halve gas imports using a combination of new and extended CHP plants. (72) Poyry reported that a ConocoPhillips industrial CHP development at Immingham, which supplies two refineries in Humberside with heat, steam and power, at a cost of around £560m, has the same electricity generating costs as Sizewell B, or around £470/kW ($736/kW)

The solar PV industry alone expects to provide 12% of electricity across Europe by 2020. The difference between this and the 2% the Government expects to be provided by small renewable would be enough to save us having to replace our nuclear reactors. (73) Solar photovoltaic system costs are projected to continue falling over the next 10 years. A group called the North Carolina Waste Awareness and Reduction Network reports that in the past year, electricity from new solar installations has become cheaper than electricity from proposed new nuclear plants. (74) The next generation of solar cells will be small, but with a huge impact. It will probably be possible to embed them in windows without obscuring the view. (75) New transparent solar cell technology could be available within about five years, according to Professor Chris Binns of Leicester University. A transparent thin film could be coated onto window glass so that windows in buildings can also become power generators. Spray-on solar cells will slash the cost of solar energy and make it easy for builders to deploy solar systems. (76)

Micro-CHP, which would replace conventional domestic central heating boilers, and produce electricity as well as how water for heating, has significant potential to reduce carbon emissions Whilst new reactors are not expected to produce any power until around 2020 at the earliest, micro-CHP can be installed 1kW at a time, producing power from day one. In terms of capacity, if all domestic gas boilers are replaced (as they reach the end of their useful life) with micro-CHP, the UK could in theory install 1.5 million units every year. That is equivalent to 1.5GWe, or not far off the size of one nuclear power station in 2010, another in 2011 etc. By 2020, we could have the equivalent of ten new reactors powered by micro CHP. And if it didn't work out for some reason, we could just stop installing them; on the other hand, with nuclear you have to commit to the whole £4.5billion (or more) price tag for a single station and if, after 10 years construction, it doesn't stack up, you have absolutely nothing to show for your money. (77) The marginal cost of a micro-CHP boiler (the extra cost over and above an efficient gas central heating boiler) would be around £600, (78) so 1.5 million would cost around £900 million or £600/kW ($940/kW) - much cheaper than a new nuclear reactor at £4.5bn.

Conclusion

The cost of building new nuclear power stations continues to escalate. When the Government re-visited the cost of new reactors in 2008 it estimated capital costs to be around $2,000/kW. EDF Energy now estimates the cost of its proposed Hinkley C reactors at $4,260. Estimates from other parts of the world suggest that $6,000/kW might be a more realistic figure, but Moody's Investor Services in the US put the number closer to $7,500/kW, while a leading US expert suggests it might even be as high as $10,000/kW.

In 2008 the Government put the cost of nuclear electricity at around £42/MWh, whereas Citigroup recently told the House of Commons Energy and Climate Change Committee that a more realistic figure would be around £93/MWh. However, if the costs being discussed in America turn out to be closer to the mark, and a more realistic discount rate is used for waste and decommissioning costs the figure could approach as much as £250/MWh.

The Government's planned electricity market reforms might be sufficient to persuade some of the larger utilities to start building new reactors despite the uncertainties surrounding the costs. This is likely to increase the cost of electricity to the consumer to unaffordable levels without simultaneously making some dramatic improvements in the energy efficiency of domestic dwellings. In any case it is generally agreed that energy costs will increase over the next decade or so. Unfortunately the Government's plans for energy efficiency and for tackling fuel poverty do not appear to be fit for purpose.

Spending on expensive nuclear electricity rather than cheaper alternatives damages efforts to tackle climate change by achieving fewer carbon savings for every pound spent.

The Government's Appraisal of Sustainability for the Draft National Policy Statement on Nuclear Power assumes that if new reactors are excluded from the energy mix they will be replaced by gas-fired generation. It fails to evaluate an alternative strategy based on a high level of Government support for decentralised energy and combined heat and power. Both the Energy Saving Trust and the National Grid have said that microgeneration could provide the necessary energy requirements beyond that already expected to be supplied by renewable energy.

Industrial CHP could provide the same amount of electricity as ten nuclear stations for around $736/kW. Micro-CHP could do the same, by 2020 at a marginal cost of around $940/kW, by replacing central heating boilers as and when they require replacement. Solar costs are falling rapidly and are now less than the cost of nuclear in some parts of the world, and are likely to continue falling as nuclear costs continue rising.

Energy Efficiency measures are usually the cheapest alternative to building new generating facilities. Sometimes these measures can be implemented at zero or negative cost. For example, new European regulations on the efficiency of Televisions, which may be introduced as soon as 2012 could save the equivalent of 14 nuclear power stations across Europe. (79)

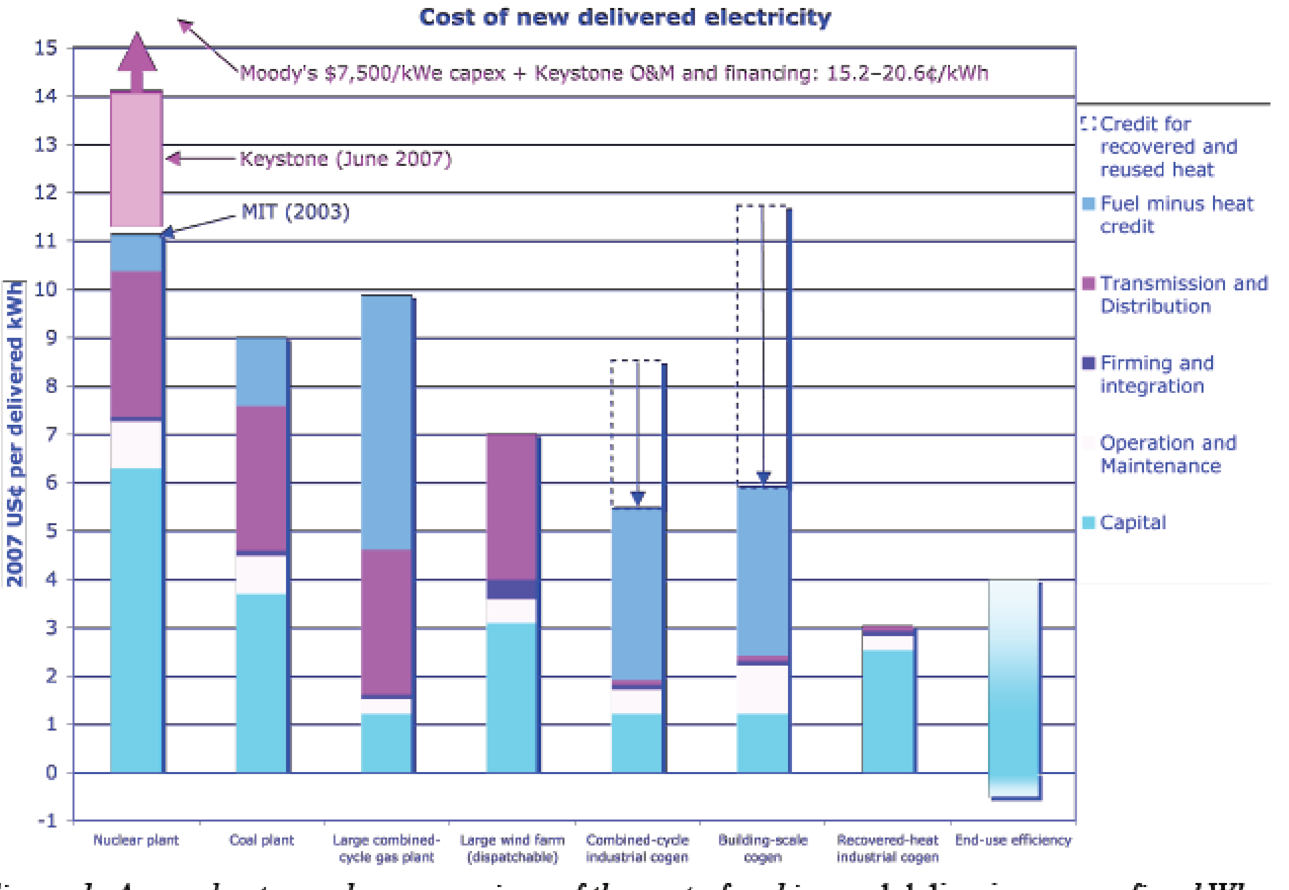

Figure 1: An apples-to-apples comparison of the cost of making and delivering *a new firm kWh of electrical services in the United States, based on empirical –2007 market costs and prices*.

From Lovins et al (80)

This briefing was funded by No Need for Nuclear http://www.noneedfornuclear.org.uk/

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