NUCLEAR ENERGY FOR A ZERO-CARBON ECONOMY

A report by

ENVIRONMENTALISTS FOR NUCLEAR ENERGY (EFN) UK

April 2006

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Dear Sir or Madam,

The British government is currently deciding the future shape of energy in this country. Environmentalists for Nuclear are an organization devoted to the use of safe, clean nuclear energy. We believe that a massive expansion in nuclear power is the only way to meet our CO2 goals and set an example to the rest of the earth, thus preventing 'dangerous' climate change.

A large amount of additional generation capacity needs to be built anyway in the UK (and in other major economies including China). Renewables require massive subsidies whilst only producing small amounts of energy. Intermittency costs, and the danger of surges in supply to the grid, also count against wind. At present prices, nuclear is price competitive with fossil fuel alternatives such as gas.

To promote new build, the government needs to provide a stable regulatory environment. The Renewables Obligation should be extended to a Non-Carbon Obligation including new nuclear. Guaranteed minimum electricity prices could be offered to investors or a 'capacity payment' reintroduced.

The government should provide a 'bank' of suitable nuclear sites, based on the existing British Nuclear Group and British Energy nuclear sites, but also including the initiation of planning procedures on new sites. Perhaps two rival consortia would emerge with plans based on the Westinghouse AP1000 and the European Pressurized Water Reactor.

The UK should build 100 (1GW) new nuclear reactors over the next 10-20 years, to account for electricity needs plus requirements currently satisfied by fossil fuels such as transport. The first few reactors of each type should attract a subsidy to account for first-of-series regulatory and other costs.

Apart from these initial subsidies, the transfer to a near zero-carbon economy would be relatively costless. It would, however, require a transfer of resources towards domestic capital investment and away from the import of natural gas. Finally we need to educate and train at least 20,000 new nuclear engineers.

For the sake of the future of the earth's future and that of the plants animals and humans upon it, we urge you to seriously consider this report.

Yours Sincerely,

Stephen Stretton

Environmentalists for Nuclear Energy (EFN) UK

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I. Executive Summary

1. Climate scientists predict significant and irreversible environmental consequences unless immediate, sustained, and significant action is taken to curtail the global emission of greenhouse gases (GHGs) such as carbon dioxide (CO2). These consequences include the shutting down of the North Atlantic Current, the collapse of the Amazon rainforest and the irreversible melting of the Greenland icesheet (Warren). All environmental non-governmental organisations, and all three major British political parties, accept the importance of the warnings of climate scientists and the relatively short window of opportunity (perhaps one decade) to turn around global habits and avoid 'dangerous' climate change. Such global action should be consistent with, but not limited by, the 1997 Kyoto agreement on climate change.

2. The Kyoto Protocol commits the EU to average emissions in the period 2008-2012 of 92% of 1990 levels (the UK's target is a reduction of 12.5% on 1990 levels). The UK will probably meet its Kyoto commitments due to the large scale switch in the 1990s from coal to gas-fuelled electricity generation. Further reductions must involve both using less energy and a large scale switch to a carbon-free sources of electricity. Environmentalists for Nuclear (EFN) believe that effective action to slow down climate change to 'safe' levels is impossible without a significant expansion in the nuclear industry. In Britain, renewable sources are too intermittent, uneconomic, or are inappropriate to our geographic conditions, and so cannot generate the large part of energy needs.

3. EFN suggests that a large and sustained growth in nuclear generation over the next 20 years is necessary so that nuclear power accounts for almost all the baseload electricity needs of the UK (c.75% of total electricity generated, compared with the current level of c.20%) by 2025.

4. Electricity generation and aviation should be part of the EU carbon-trading scheme. There should be a preference for non-carbon emitting sources of energy (rather than simply renewable), enacted in a 'Non-carbon obligation'. EFN supports energy savings in the home and wind turbine generation in windy areas. Energy efficiency could be encouraged by reductions in tax on highly efficient appliances.

5. The UK government has indicated that any new nuclear build will take place within the private sector. The England and Wales electricity generation and supply industry was one of the first to be deregulated and is one of the places where deregulation has developed the furthest. The decision over nuclear is therefore not one of command and control, rather it is one of appropriate regulatory framework. Such a framework should properly account for society's concerns over emissions and security of supply and should aim to minimise price risk to both consumers and producers of electricity. Important measures to limit such risk may include long term price guarantees, forward-looking carbon taxes, and the reintroduction of so called 'capacity payments' within the electricity market.

6. The UK should ensure that the regulatory hurdles and financial risks for first-of-series build are minimised. It should ensure the safety regulation process is efficient, and should liase with European and US licensing authorities to ensure consistency. It should set in process the planning procedures to provide a 'bank' of suitable nuclear sites (mostly where there are existing nuclear facilities), for both British Energy and other potential investors. It should provide financial help to pay for the costs of 'first of series' build, perhaps in the form of tax credits payable in the first few years of generation. Universities and the nuclear industry should be given a clear statement of intent to increase the training of nuclear engineers and so to avoid skills bottlenecks.

II. Reaching UK Carbon Emissions Targets

The United Kingdom government has committed to a reduction of national CO2 emissions of at least 60% (from 1990 levels) by 2050. Significant progress should be made by 2020. To achieve these targets, the polluter must pay the environmental costs of his emissions. Price increases in carbon dioxide-emitting energy sources will lead to improvements in efficiency and encourage movement to non-polluting alternatives. With appropriate regulatory changes, the UK can ensure a low-cost, early, secure, and orderly transition to a low-carbon economy, enhancing the UK's prosperity and international competitiveness. This document will argue for:

a) the proper taxation of the environmental costs of carbon-based generation technologies,
b) a clear and consistent regulatory framework that has incentives consistent with the interests of society as a whole for a secure and reliable electricity generation, and that aims to reduce risk to consumers and producers of electricity,
c) a sympathetic approach to the initial hurdles faced by renewed nuclear build such as regulatory compliance and first-of-series costs.

Environmentalists for Nuclear Energy (EFN) believe in a large and increasing role for nuclear. Nuclear power stations generate a secure, carbon-free, constant and reliable supply of electricity for 24-hour-a-day ('baseload') UK needs. The UK should make plans for:

(1) the replacement of existing coal and nuclear baseload plant with new nuclear capacity
(2) additional expansion so that all baseload needs, or approximately three-quarters of total electricity requirements, are produced through nuclear;
(3) in the medium term, a future growth in nuclear generating capacity concurrent with the transformation of other energy systems (industry, domestic heating, transport and storage technologies) to use clean, emissions-free, nuclear energy.

Such a plan, adopted in the UK and the other major economies, is the most practical and low-cost route to avoiding 'dangerous' climate change.

There have been a number of government environment instruments designed to support non-carbon emitting technologies. After privatisation, a levy was imposed on electricity produced from fossil fuel. From 2002, the fossil fuel levy was replaced by the Renewables Obligation (RO), a system of tradable permits obligating electricity distributors to buy a certain proportion of their energy from renewable sources. A long-term ‘Non-Carbon’ Obligation, including new nuclear build, would reduce the risks and therefore the funding costs for new investors. A level playing field across all non-carbon power sources would allow us to reach our goals at lowest cost.

The European 'Emissions Trading Scheme' (ETS) is designed to cap total emissions so that the EU reaches its Kyoto targets. Once granted, permits to emit can be traded. This system ensures economic efficiency and, depending on the mechanisms of allocation, can avoid disruptive financial transfers. The ETS has been applied in the UK to industrial users of fossil fuels, with domestic users and electricity generation exempt at present. All parts of the economy should in principle be covered by either the ETS or an equivalent carbon taxation scheme. In particular, ETS should be extended to aviation, and CO2-emitting electricity should fall under the ETS or similar domestic 'carbon tax'.

With the full application of appropriate taxation/permitting, the cost of CO2-emitting energy, as seen by final users, will rise. The demand for such energy would therefore fall, reducing overall UK emissions. Revenues from the ETS or energy tax could be used to efficiently subsidise non-carbon generating energy sources, so that industry is close to financial balance (on energy-related payments) with the government. The electricity regulator should also make sure that domestic and commercial energy consumers always have the ability to choose a low-carbon energy supplier and should take the lead in choosing such suppliers within the public sector.

III. Delivering Secure Energy

Electricity supply remains a complex industry where regulatory structure is critical to final outcome. Over the last two decades, the England and Wales electricity generating market has been privatised and deregulated. Between 1990 and 2001 the electricity 'Pool' existed to balance supply and demand. Energy prices were based on the cost of generation at the marginal power station plus a payment for available capacity. In 2001, the 'New Electricity Trading Arrangements' (NETA) were put in place, with a system of bilateral contracts between generators and distributors/consumers.

The United States provides an important example of the potential pitfalls of deregulation. The last few years have seen a number of interruptions, imposing huge costs on consumers, industry and the US economy as a whole. The state-by-state process of deregulation has now ground to a halt, some states having been 'deregulated', others remaining in the prior state. Whilst excess demand exists mainly in the deregulated states of the eastern seaboard of the US, the building of new electricity capacity has mostly been in regulated states of the mid-west.

One important lesson is that, although deregulation has reduced energy costs for consumers, it may not ensure sufficient capacity in the long term. It is interesting to note that even now the UK imports some electricity from France, the country with the largest nuclear sector and with the lowest electricity prices in Europe. The economics of new build, in particular of baseload plants such as nuclear, are more favourable with the certainty, and lower funding costs, of a more stable, regulated market environment.

The UK has traditionally generated electricity from a variety of fuels – primarily coal and gas (historically, produced domestically) and uranium (produced by geopolitical allies). This will change if, as currently projected, the UK switches to a reliance on imported natural gas. In addition to being used in industry and the home, natural gas presently supplies about 40% of UK electricity. This is projected (DTI) to rise to 60% by 2020. Future natural gas requirements cannot be met from the remaining North Sea gas reserves alone: the UK, like the rest of Europe, will need to import gas from Russia, Algeria or Central Asia, areas not noted for their geopolitical stability. The potential economic and human costs associated with withdrawal of the major energy source are very significant indeed.

With the current market structure, wholesale electricity prices are subject to the volatility of the price of gas. In recent times, the price of gas has risen significantly, driving up the price of electricity too. Individuals or companies who might be able to use either, in reality have little ability to diversify when energy prices are high. Thus in the deregulated, gas-dominated, scenario, considerable supply and price risk is faced by UK fuel consumers.

In the present regulatory framework, the risks for a potential investor in new gas capacity are low, compared to the risks in baseload power plants, such as coal or nuclear. For any business, risks are minimised if revenue streams are well matched with costs. This is the case with gas, since revenues from wholesale electricity sales on spot markets are volatile but well correlated with the cost of gas. Significantly, due to the nature of limited liability companies operating in rapidly changing markets, the long term benefits of secure energy supply are not fully captured by free-market mechanisms.

Society as a whole can be fairly sure of its need for reliable carbon-free energy over the next 45 years. Arguably, there is a significant negative externality associated with the dominance of imported gas in UK electricity supply. The most straightforward way of internalising this cost would be to impose an additional tax on electricity produced by gas relative to that produced from (more securely sourced) coal and nuclear. Since gas emits approximately half as much carbon dioxide as that produced through coal, a simple (but admittedly fairly arbitrary) measure would be to raise the tax per kWh on electricity produced by burning gas to the same level per kWh as that imposed on electricity from coal. A non-carbon obligation expanded to include new nuclear capacity would also have the effect of limiting the dominance of gas.

Natural Gas is a premium fuel which can be expected to rise in price over coming decades.

IV. Issues Specific to Nuclear Energy

A nuclear power station supplies energy reliably, at almost-fixed costs, for its lifetime of four or more decades. With its stability and high energy density (in contrast to say natural gas), many months- or years-worth of unenriched Uranium can be stored safely and easily. Such a strategic reserve can be easily be converted to nuclear fuel domestically when required. A nuclear-dominated electricity industry would allow low and stable electricity prices, and provide energy diversity for industrial and domestic consumers. An initial nuclear build should aim to replace the retiring nuclear and coal generation with new nuclear power stations. In the medium term, nuclear energy can cover all baseload electricity demand.

Nuclear energy has in general *low* fluctuation in its cost of generation. Fuel costs are only a small part of generating costs, and operation and maintenance costs are fairly predictable. Nevertheless, the potential investor faces *high* risks in a deregulated and short-term market place, because capital costs are high and revenue streams potentially volatile. The government is itself also the source of many of the perceived risks associated with new nuclear build and could mitigate such concerns by detailed work with potential investors. The government could also guarantee minimum prices or investigate other ways to encourage very long-term electricity contracts.

Great engineering improvements have been made in recent years in both reactor design and use. Such improvements mean that the nuclear industry is now globally competitive. Reactors of the Westinghouse AP1000 or European pressurised water reactor (EPR) types have already achieved regulatory approval in countries such as the US and Finland. They have a modular design and include 'passive' safety features, reducing both cost and complexity. The UK should set in train the regulatory approval of these reactors to avoid late modifications to design. Typically, any first-of-series new reactor will be significantly more expensive than nth-of-kind. The removal of these uncertainties justifies significant government help for the first-mover, perhaps in the form of a production tax credit payable by the government over the first few years of generation. (c.f. MIT 2003)

The costs of decommissioning are becoming clearer with the experience gained from the decommissioning of the Magnox generation of nuclear reactors. Future decommissioning costs are likely to fall, with efficiency gains coming with experience and those for new reactors much lower, because of the simplifications of 'passive safety' designs.

The management of nuclear waste is the responsibility of the government. At present a long-term solution has not yet been found to the problem of high- and intermediate-level nuclear waste. Nevertheless, political decisions, costs, and security requirements for this solution are mostly independent of decisions regarding renewed nuclear power plant construction. The variable costs and risks of storing extra nuclear waste in a repository are small compared to the fixed and (effectively) already sunk costs and risks of having to set up such a repository.

Great Britain already has a network of nuclear sites (where future reactors would be built) and an existing infrastructure for transporting and storing nuclear material. British Energy now runs some of these nuclear sites; others remain in government hands. The government should set up a 'bank' of approved sites for potential new investors in nuclear.

In order for a 'nuclear renaissance' to take place, a large number of nuclear engineers (more than 20,000) must be trained. This requires university and on-the job training. Skills could prove the main constraint to nuclear expansion. The government should immediately put in place a system of university ‘sponsorship’ of young engineers, similar to that used to train engineers for the armed forces. A clear statement of intent would allow universities and the nuclear industry sufficient time to act to avoid bottlenecks.

Nuclear power has traditionally suffered from a negative public perception due to its association with the awesome destructive power of the atom bomb. Yet the civil nuclear industry has an enviable safety record in this country, with no major incidents in its history.

The strong and well-engineered containment buildings of the current generation of reactors (metres-thick reinforced concrete), along with the small size of the reactor building and other security measures, provide very solid protection against terrorism. The transport of nuclear materials similarly takes place in very secure containers.

An average airhostess receives a higher level of radiation than her colleague in the nuclear industry. The nuclear industry implicitly values human life more highly than almost any other industry. It is important that the government ensures that public is well informed on these issues.

V. Other Low-Carbon Technologies

There are a number of other potential technologies (apart from nuclear) that provide energy while emitting little if any carbon dioxide. These include renewable energy and technologies for storing carbon dioxide underground (sequestration).

Given the geography of Britain and the present costs of the various renewable technologies, wind is seen as the main alternative to fossil fuels and nuclear. Yet wind turbines produce energy only when weather conditions are in its favour. The overall costs of generating electricity through wind are high, because the vicissitudes of the weather necessitate a large amount of 'back-up' capacity (gas). However, an electric generator cannot be turned on with a snap of the fingers. It must be brought up to speed and synchronized with the grid before it can be thrown on-line. This takes time. In order to meet the back-up requirements of a field of wind turbines, the back-up generator must already be turning and synchronized. This is sometimes called a "spinning reserve". Under NETA the costs of intermittency are explicitly considered and the government now pays a substantial subsidy towards wind energy.
Wind projects capable of generating only a relatively small amount of electricity have encountered massive local resistance. Offshore wind, whilst preserving the natural aesthetic, is even more expensive than onshore wind, and interferes with the UK’s coastal radar. Even on the most optimistic projections, wind will account for less than 10% of total energy usage by 2020.

Other renewable sources of energy include hydroelectricity; wave power; (conventional) solar thermal (e.g. for water heating) and solar photovoltaic cells (PV); tidal power and biomass. Hydroelectricity is not a serious option except in Scotland where it is already used. Wave energy is also a presently undeveloped technology, currently not at a level where it could be used in a widespread fashion. Solar electricity in general is less suited to the UK, than countries closer to the equator. Photovoltaic cells (PV cells) in particular are an immature technology with costs per kWh far greater than conventional alternatives and require significant amounts of energy in their fabrication.
There is one suitable site for tidal power, the Severn Estuary, which is worthy of serious consideration. Such a project faces similar issues to renewed nuclear build (financing costs, regulatory framework, uncertainty over future electricity prices). However, since the planning and construction issues are different, and the electricity supply changes periodically with the tides, this project would not be a direct competitor to renewed nuclear build.

Vegetable oil could help at the margins as a fuel for transport, and wood could potentially be burnt to generate electricity. (Trees at the edges of motorways would also reduce noise.) However, there are energy costs in growing, harvesting, transporting, and extracting such fuels, as well as pollution of other forms. This subtracts from their environmental attractiveness. Cost and, ultimately, land constraints will prevent biomass from being the major source of energy in this country, although it could be deployed elsewhere where conditions are suitable.

In general renewable sources are presently incapable of providing significant electricity supply to allow us to fulfil our CO2 emission targets in the UK.

In the short-to-medium term, electricity produced by gas and coal will remain an important part of the UK energy mix. Technologies are currently being developed to store CO_2 underground, in porous rocks with non-porous caps such as those previously containing natural gas. Such technologies will only become economic, if at all, when generators of electricity pay the costs of emissions. EFN believes in a level playing field for all non-carbon generators. If, and when, it can be demonstrated that carbon capture is permanent and that CO_2 will remain underground for the next few centuries, then electricity produced with CO_2 captured, should attract no carbon tax. Additional help on regulatory issues and first-time costs would also be justified.

Globally, it makes economic sense to invest in improving technologies early, so as to reap the technological improvements possible as technologies mature. Furthermore it is sometimes possible for a country to develop particular expertise and competitive advantages in certain industries. Nevertheless, it is important to keep in sight the definite goals the UK has set itself. Renewable subsidies could potentially be huge in the current decade, without avoiding dangerous climate change. Nuclear energy, with very low life-cycle carbon emissions, could single-handedly generate most of our electricity by 2020-25. With the lower costs of established reactor designs, it could subsequently start to replace fossil fuels in other sectors.

VI. Domestic Heating

It is important that each house is adequately heated, and that the vulnerable in society are protected, especially in winter. Yet this need not conflict with a general rise in carbon-based energy prices. Efficiency improvements are likely to be 'spent' on further energy use unless they are accompanied by price rises (see below). Government income transfers to the needy can help cushion the pain of higher carbon-based energy prices.

For domestic users, there has been a political need to assuage concerns over fuel poverty. Fuel prices have been kept low, with Value Added Tax (VAT) at a reduced rate of 5% domestic energy supplies. It would be natural that some or all of the money raised by the increase in energy taxes be used to mitigate poverty particularly for pensioners. Any such assistance should be made in terms of a general increase in payments to all poor pensioners (such as an increase in pensions or in the ‘cold weather’ winter payment), rather than a rebate on energy bills. Further tax concessions could be offered on energy-efficient devices and home insulation and regulations improved on new and existing houses. The government and local authorities should ensure each house is as well insulated as possible.

Every citizen should be careful not to overheat his home. A 1°C increase in temperature corresponds to a 7% increase in heat consumption, a fact that could be conveyed to the public in information campaigns. Current temperature regulations should be enforced and guidelines for domestic homes made clearer.

A major program aimed at replacing gas heating by heatpumps is a top priority for EFN. A heatpump produces the same amount of heat as a gas boiler but requires 2 to 5 times less energy. There are several relevant technologies (air/air, air/water, water/water). In all cases there is a drastic reduction in energy consumption, and an even more dramatic reduction in CO_2 emissions (so long as the electricity is produced with nuclear energy, as EFN recommends). A house with a water/water heatpump in a country where baseload electricity is nuclear consumes 5 times less energy and emits 20 to 50 times less CO_2 than the same house heated by natural gas. In new buildings, gas heating should be made so expensive (by additional taxes on gas furnaces and/or the price of gas), or heatpumps made so cheap (by tax credits on their installation) that owners/builders will prefer the more environmentally friendly option.

In conclusion the key steps are: (1) To convert electricity production to nuclear as quickly as possible, until all base load power (at least) is nuclear and (2) replace the use of carbon fuels whenever possible by electricity in all sectors including: (a) heatpumps for natural gas in house and office heating; (b) electric batteries for petroleum in private transportation.

The conversion of electricity production to nuclear is the single most important step to reaching our CO_2 targets. Without this, both electric cars and heatpumps would still contribute to global warming. It will take at least 10 years before new nuclear plants are complete (due to planning and construction delays). Nevertheless, moves to convert heating and transport should be started immediately, in order that the technology and infrastructure are mature and pervasive once new nuclear capacity comes on line.

VII. Energy Efficiency

There is clearly great potential to improve energy efficiency in UK and other countries. Energy efficiency may be a relatively inexpensive way of reducing emissions. Yet the most effective way to encourage efficiency in a market-based strategy is a general rise in the price of CO2-emitting energy. In the industrial and domestic sectors, subsidies for energy efficiency may also be required.

Measures to improve efficiency are likely to be ineffective without price rises, as technological efficiency improvements may 'rebound' or even 'backfire'. Some or all of energy savings from better efficiency are often spent in increased energy use. (See Kazzhoom 1980. Also c.f. Jevons 1865/1871: “It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth… Every…improvement of the [steam] engine, when effected, does but accelerate anew the consumption of coal”.)

Transport provides an important example of this principle. Improvements in the fuel efficiency of aeroplanes may lead to a reduction in the price of aviation and therefore more people flying. Large-scale reductions in emissions are therefore impossible without higher taxation or permitting using the ETS.

There has been a wish to keep large carbon-emitters such as heavy industry in the EU, rather than to see these industries migrate to countries in the developing world with much less stringent environmental considerations. Current environmental obligations are not thought to cause significant 'leakage'. However, if the rate at carbon taxation were to rise significantly (e.g. to, say, £160/tC = £20/bbl in order to reach the UK's CO2 goals), this might become a concern for industry. The effect of higher energy prices could be mitigated in the following ways: (a) Taxation would occur only on CO2 emitting energy sources. Industrial consumers would have an alternative to fossil fuels in nuclear-generated electricity and might be able to negotiate favourable long-term contracts for such energy. Carbon taxation would likely rise over time, but industrial consumers would have sufficient time to migrate; (b) 'Grandfathering', and other similar approaches to emissions permitting, would encourage people to make reductions in emissions while avoiding large scale net financial transfers; (c) Experience in the Nordic states suggests it is possible to employ different taxation rates for industrial and service sectors.

Typically, energy is not a large part of costs in service industries. However, companies would be encouraged to improve energy efficiency by an increase in the costs of energy, as well as by information campaigns. The government could introduce certain standards (including turning off electronic equipment overnight) implemented alongside health and safety regulations. An energy-efficient company might consider it good public relations to be recognised as such.

Finally, very long-term electricity contracts for the public sector’s requirements may be a way to guarantee price stability, as well as helping the electricity industry develop. Schools, hospitals, prisons, civil service offices each have a responsibility to ensure that they are as efficient as possible in their use of energy.

VIII. Transmission & Distribution

New nuclear plants would be built at existing sites in first instance. These are well distributed across the UK, although they tend to be on the coast (for cooling water) and away from major centres of population. Existing transmission networks would need to be maintained and improved. Upgrading the distribution grid is an essential consideration in planning future energy supply.

IX. International Linkages

Avoiding dangerous levels of climate change will require huge and concerted global action on a number of fronts simultaneously. One way of looking at the required change in behaviour is the concept of a 'stabilization wedge' (see Socolow and Pacala in Defra 2006). Each 'wedge' represents 1 Gigatonne (billion tonnes) less Carbon emitted per year by 2055. It requires seven such wedges (in addition to present trends) to keep CO2 emissions at current levels and thus stabilise atmospheric CO2 concentrations at the ‘safe’ level of 500 ppm. Socolow and Pacala provide 15 such ‘wedges’, all technically feasible. For example: a) stopping deforestation, and doubling the rate of new tree plantation; b) halving car use; c) adding 50 times the current capacity of wind turbine. One ‘wedge’ would be provided by merely doubling nuclear energy world-wide (an additional 700GW of capacity).

EFN argues for a much greater use of nuclear power, so that it provides the majority of the electricity supply in the major economies (G8 + China and India) over the next 50 years.

The main stumbling block to international agreement on climate change has been the US’s reluctance to engage in international agreements that it cannot easily keep. If there were significant investment in nuclear power plants, it might find easier to agree to a successor to the Kyoto protocol. The US has an aversion to central environmental taxes. However, it has a long history of industrial innovation and appropriate regulation of free market activities. Parts of the deregulated US market have been based on the UK model. In the absence of American leadership on climate change, it falls to the others to take the lead on this issue. The UK has a key role to play to show that it can be in the self-interest of a nation to facilitate new nuclear power plants and in the interest of market investors to build them, even in the absence of new international agreements. By ordering one of the new reactor designs (such as the Westinghouse AP1000) this would reduce uncertainties for future investors in nuclear energy in the UK and US, and therefore potentially make a big difference to the final extent of global warming.

China will require a vast amount of electricity (perhaps 1000GW of capacity) over the next decades. At present, China has 4GW of nuclear on order, but is desperate to secure further energy supplies to further its expansion needs. India is also building a small number of new reactors. Given global concerns over climate change and proliferation, it is important that the US and EU maintains strong relations with China and India and that the technology used is of the most up-to date design.

The European Union has recently begun an energy review of its own. Recently, Finland has become the first Western country to begin a new nuclear reactor. France provides a good example of a clean, safe, and efficient nuclear industry providing the majority of electricity needs, and also has plans to build the European Pressurized water Reactor (EPR). If the UK were to support this new reactor, then this might lead to an overall change in behaviour across Europe. (For example, Sweden too has recently adopted a reduction of 60% in CO2 emissions by 2050.)

A well-funded domestic nuclear energy industry would be on balance more secure and more likely to contribute positively to international stability than either a declining sector or the absence of a nuclear industry in this country. In terms of international linkages it is important to develop technologies that can be exported safely to the other major world economies, and to consult on such matters with our partners in continental Europe and America. Reactor regulation could be done on a Trans-Atlantic and/or pan-European basis. The UK should be relaxed towards civil nuclear technology transfer within the major economies.

The UK has a strong internationalist outlook and has consciously taken on this issue in recent residencies of the G8 and EU. By re-embracing nuclear power now, the UK could both meet its long-term targets and send out an influential and timely message to the leaders of the other major economies.

X. New Technologies in Transport and Heat Generation

Electricity production is currently only 35% of total carbon dioxide emission. In order to reach our target of a more than 60% reduction in overall CO_2 emission, we also need to consider the other parts of the economy. Given that there exist sectors with little prospect of becoming carbon-free (e.g. aviation, heavy road transport and some parts of industry), electricity generation needs to emit almost no carbon dioxide, and other sectors should, where possible, be largely carbon-free.

Aeroplanes, cars and heavy goods vehicles impose further significant external effects on other users of both urban and rural areas. In particular, these forms of transport cause noise, congestion, local air pollution, and require infrastructure that is often unsightly. A shift to low-carbon forms of transport (new high-speed rail lines for intercity and long distance travel, enhanced mass transit systems for suburban and commuter lines, and electric cars for rural and other travel) would also mitigate these other problems. Electric cars rather than carbon-fuel cars could be encouraged by tax credits on electric cars and by waiving urban parking fees and congestion charges (and increasing the cost for non-electric cars, so that the net financial balance with the government is zero).

In general, the domestic transport sector (cars, buses and trains) should be run using carbon-free energy, where possible. Trains should be almost completely electrified, buses replaced by trams where possible. It is more likely that cars will be powered by batteries rather than hydrogen fuel cells, especially for short distances of up to 200 km per day. Batteries can be recharged by nuclear electricity overnight, when there is little other demand. To the extent that hydrogen fuel cell cars are developed at all, the hydrogen will be produced by nuclear energy using electrolysis or thermochemistry.

The laws of thermodynamics require that all conversion processes produce heat as a by-product; often at low temperature and not very useful. ‘Combined cycle power generation’ produces electricity and high-grade heat (that is, at high temperature and therefore useful). Such heat is useful in chemical processes, in heating and ventilation and elsewhere, thus saving coal, oil, and natural gas, which are in principle too valuable to be dissipated in mere combustion.

The transfer to a near zero-carbon economy can be relatively costless. It does, however, require a large transfer of resources towards domestic capital investment and away from the import of scarce supplies of oil and natural gas.

If by 2040 75-80% of the electricity production is nuclear, half or two thirds of the heating of buildings is done by heatpumps (water/water when possible in new builds, and air/air in most cases in renovations) and half of the road use takes place using clean electric vehicles, then the ultimate goal of a 60% decrease in CO_2 emissions will be met 10 years in advance on the 2050 deadline. If not, a few minor additional measures such as a last-decade push on energy conservation, a little more public transportation... will then suffice to meet the 60% target in CO_2 reduction.

This is the plan for the UK but in fact could (and should) be applied almost identically in any other country.

XI. Appendix A: Impacts of Climate Change

From Warren, R: Impacts of Global Climate Change at different Annual Mean Global Temperature Increases (Abstract) in Defra (2006):

Based on peer-reviewed literature, climate change impacts on the earth system, human systems and ecosystems are summarised for different amounts of annual global mean temperature change (ΔT) relative to pre-industrial levels. Temperature has already risen by $\Delta T = 0.6°C$, and effects of climate change are being observed globally. At $\Delta T = 1°C$ world oceans and Arctic ecosystems are damaged. At $\Delta T = 1.5°C$ Greenland Ice Sheet melting begins. At $\Delta T = 2°C$ agricultural yields fall, billions experience increased water stress, additional hundreds of millions may go hungry, sea level rise displaces millions from coasts, malaria risks spread, Arctic ecosystems collapse and extinctions take off as regional ecosystems disappear. Serious human implications exist in Peru and Mahgreb.

At $\Delta T = 2\text{-}3°C$ the Amazon and other forests and grasslands collapse. At $\Delta T = 3°C$, millions at risk to water stress, flood, hunger and the dengue and malaria increase and few ecosystems can adapt. The thermohaline circulation could collapse in the range $\Delta T = 1\text{-}5°C$, whilst the West Antarctic Ice Sheet may commence melting and Antarctic ecosystems may collapse. Increases in extreme weather are expected.

XII. Appendix B: 'Carbon Wedges'

From Socolow, R. et al.: Stabilization Wedges: An elaboration of the concept

Wedge	***Effort by 2054 for one wedge, relative to 14 GtC/year BAU***	***Comments, issues***
Energy Efficiency & Conservation		
1. Efficient vehicles	Increase fuel economy for 2 billion cars from 30 to 60 mpg	Car size, power
2. Reduced use of vehicles	Decrease car travel for 2 billion 30-mpg cars from 10,000 to 5,000 miles per year	Urban design, mass transit, telecommuting
3. Efficient buildings	Cut carbon emissions by one-fourth in buildings and appliances projected for 2054	Weak incentives
4. Efficient baseload coal plants	Produce twice today's coal power output at 60% instead of 40% efficiency (compared with 32% today)	Advanced high-temperature materials
Fuel shift		
5. Gas baseload power for coal baseload power	Replace 1400 GW 50%-efficient coal plants with gas plants (4 times the current production of gas-based power)	Competing demands for natural gas
CO2 Capture & Storage (CCS)		
6. Capture CO2 at baseload power plant	Introduce CCS at 800 GW coal or 1600 GW natural gas (compared with 1060 GW coal in 1999)	Technology already in use for H2 production
7. Capture CO2 at H2 plant	Introduce CCS at plants producing 250 MtH2/year from coal or 500 MtH2/year from natural gas (compared with 40 MtH2/year today from all sources)	H2 safety, infrastructure
8. Capture CO2 at coal-to-synfuels plant	Introduce CCS at synfuels plants producing 30 million barrels per day from coal (200 times Sasol), if half of feedstock carbon is available for capture	Increased CO2 emissions, if synfuels are produced without CCS
Geological storage	Create 3500 Sleipners	Durable storage,successful permitting
Nuclear Fission		
9. Nuclear power for coal power	Add 700 GW (twice the current capacity)	Nuclear proliferation, terrorism, waste
Renewable Electricity & Fuels		
10. Wind power for coal power	Add 2 million 1-MW-peak windmills (50 times the current capacity) "occupying" 30x106 ha, on land or off shore	Multiple uses of land because windmills are widely spaced
11. PV power for coal power	Add 2000 GW-peak PV (700 times the current capacity) on 2x106 ha	PV production cost
12. Wind H2 in fuel-cell car for gasoline in hybrid	Add 4 million 1-MW-peak windmills (100 times the current capacity)	H2 safety, infrastructure
13. Biomass fuel for fossil fuel	Add 100 times the current Brazil or U.S. ethanol production, with the use of 250 x106 ha (1/6 of world cropland)	Biodiversity, competing land use
Forests and Agricultural Soils		
14. Reduced deforestation, plus reforestation, afforestation and new plantations.	Decrease tropical deforestation to zero instead of 0.5 GtC/year, and establish 300 Mha of new tree plantations (twice the current rate)	Land demands of agriculture, benefits to biodiversity from reduced deforestation
15. Conservation tillage	Apply to all cropland (10 times the current usage)	Reversibility, verification

XIII. Appendix C: Cost Comparisons

Britain

Source: Royal Academy of Engineering "The Cost of Generating Electricity" (2004)

Costs excluding carbon taxation*:

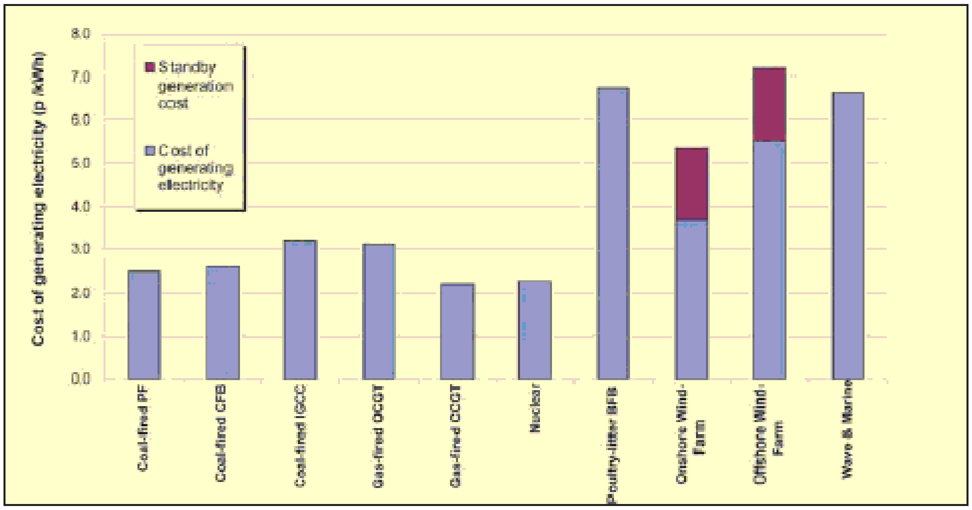

Figure 1 Cost of generating electricity (pence per kWh) with no cost of CO2 emissions included.

Costs including a small carbon tax[+]:

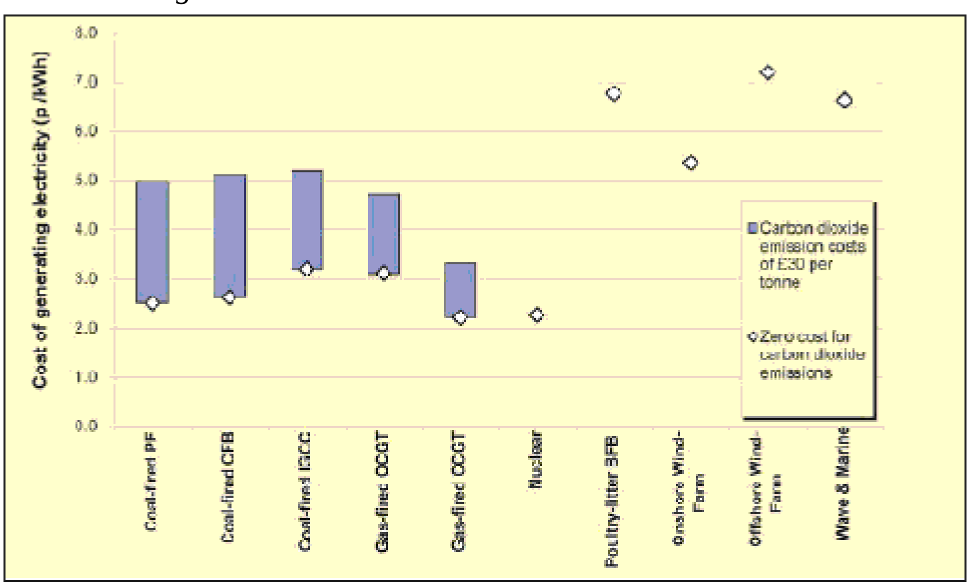

Figure 3 Cost of generating electricity with respect to carbon dioxide emission costs. (Zero to £30 per tonne)

Notes:
** Exact costs of providing backup capacity for wind due to intermittency are disputed. Gas prices have risen since survey was completed.*
[+] CO2 emissions for gas backup to wind power ignored

Industrialised Countries as a Whole (Kyoto Annex I countries)
Source: REH Sims et al. Energy Policy 31 (2003) 1314-1326

Technology	Energy source	Generation costs (c/kWh)	Emissions (g C/kWh)	Cost of C reduction ($/t C avoided)	Reduction potential to 2010 (Mt C/yr)	Reduction potential to 2020 (Mt C/yr)
CCGT	Gas	3.45	108	Baseline	Baseline	Baseline
PF + fgd + CO2 capture	Coal	7.6 - 10.6	40	610 - 2050		
CCGT + CO2 capture	Gas	4.95	17	165	2 - 10	5 - 50
Nuclear	Uranium	3.9 - 8.0	0	46 - 421	62	**181**
Hydro	Water	4.2 - 7.8	0	66 - 400	3	18
Wind turbines	Wind	3.0 - 8	0	(-43) - 92	23	61
Biomass IGCC	Biofuel	2.8 - 7.6	0	(-60) - 224	4	36
PV and solar thermal	Solar	8.7 - 40.0	0	164 - 3800	0.8	9

Notes:
My emphasis: note high carbon reduction potential of nuclear energy
Gas costs have risen since survey complete
PF: Pulverized Fuel;
Fgd: Flue gas desulphurization
CCGT: Combined cycle gas turbine
IGCC: Integrated gas combined cycle

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