

A ZERO CARBON ECONOMY WITH NUCLEAR ENERGY

This article, first published in 2006, sets out a practical plan to decarbonize the UK energy system.

It is well known that releasing carbon dioxide (CO₂) into the atmosphere, by burning fossil fuels such as coal, oil, and natural gas, causes an overall warming of the Earth in the 'greenhouse effect'.

Scientists estimate that an increase in temperature of 2°C or more above pre-industrial levels (a common definition of 'dangerous climate change') would cause the irreversible melting of the Greenland Icesheet, raising sea levels by 7 metres, widespread desertification, and the collapse of ecosystems that store carbon, such as the Amazon rainforest. We would possibly then further huge quantities of stored greenhouse gases into the atmosphere, producing positive feedback and an even larger eventual temperature rise. On our present course, within a few years we will have committed to such a rise (IPCC 2007b).

To avoid 'dangerous' climate change, we must take immediate action to convert to a near-zero emissions economy. To stabilize the climate, global emissions need to fall to 7 billion tonnes of CO₂ per year (1 tonne CO₂ per person per year), which is the amount sequestered by the oceans each year. This compares to current UK emissions of 10 tonnes of CO₂ per person per year.

With the UK taking the necessary actions now, other countries in the rest of Europe, North America, China, and India might also make similar moves. It is feasible to move quickly to a zero-carbon economy and the required investment would have economic benefits.

1. The government should switch from taxing jobs and income to taxing carbon. This would help encourage substantial lifestyle changes aimed at using less energy, particularly in regard to road and air travel. Across the economy we need to use energy much more efficiently
2. We must construct sufficient low-emissions generation for all our energy needs. A large expansion in nuclear energy is required (in the UK, perhaps 100 nuclear reactors of 1GW capacity) using compact, passively safe, modern designs. The government must ensure the education of sufficient numbers of engineers to build these power stations.
3. Electricity price guarantees could be offered to all low-emissions electricity generators. Renewable energy should be used where practical; we must also significantly increase research into this area, and only deploy new coal plants with full carbon capture and storage.
4. We must get ready to transform domestic heating, transport and industry to use and store clean, low-cost electricity instead of burning fossil fuels (e.g. with electric cars). Any new homes must be constructed on an ecologically sound, zero-emissions basis (including heat pumps for domestic heating).

The issue is now urgent. As James Lovelock has pointed out (Lovelock 2004): "We have no time to experiment with visionary energy sources. Civilization is in imminent danger".

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Introduction

United Kingdom energy policy now needs to consider environmental impact, security of supply and cost. It will be argued that nuclear energy is by far the best option, on each of these three criteria, for the UK and for the other major economies of the world.

International agreement on Carbon Dioxide (CO₂) emissions is fraught with difficulties because we face a 'tragedy of the commons' with the private interests of countries diverging from the collective interests of the earth and its inhabitants as a whole. It might be said that countries such as the US and China are unlikely to sign agreements that will not be easy to keep in a highly competitive global economy. To solve this problem, we need an energy source that does not emit CO₂ and yet is attractive for nations that consider only the cost and local impact of generating electricity.

Renewable energy sources may be helpful, especially for those countries whose geography suits them. But due to the constraints of intermittency, land area, and cost, renewables are unlikely to provide the majority of the total energy requirements of the densely populated industrial (or industrialising) major economies.

Nuclear energy, however, can supply a large part of the energy needs of these countries over the next 40-50 years. Uranium is an abundant element on the Earth's crust, requiring little energy to extract, compared to that released in a nuclear reactor. The cost of fuel is a small part of the generating costs.

The scientific evidence concerning the risks from anthropogenic climate change now justifies massive cuts in carbon dioxide emissions. The UK should convert to a near zero-carbon economy in the next 20 years, with nuclear providing the large part of the electricity for all uses, including personal transportation and heating. If the UK were to order 100 new nuclear power stations, and train sufficient engineers to build them, the 'learning by doing' in this global industry would reduce the cost of the technology worldwide. The reduction in price of this environmentally friendly technology should align nations' private interests with the collective interests of humanity as a whole, without the need for global agreement and enforcement of treaties limiting the emission of greenhouse gases.

A collective action problem as difficult as this one requires countries to speak to one another. It requires institutions to be cherished and developed. But it also requires a country, or group of countries to take a lead in solving the problem. The UK, the US and the European Union as a whole need to take a global lead on converting to a zero-emission economy. Nuclear power is the only viable route to such a future.

Reaching UK Carbon Emissions Targets

The United Kingdom government has committed to a reduction of national CO₂ emissions of at least 80% (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:

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

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. In addition, Concentrated Solar Power could also be used.

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 obliging 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.

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 regulated but not nationalised. 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 from the North Sea (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 the 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.

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 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 (because the electricity price is 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. (Ansolabehere et al. 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 financial risks of storing additional nuclear wastes in a repository are small compared to the fixed and (effectively) already sunk costs and financial 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 power stations.

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 air hostess 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.

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 and 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 CO₂ 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. There should be a level playing field for all non-carbon generators. If, and when, it can be demonstrated that carbon capture is permanent and that CO₂ will remain underground for the next few centuries, then electricity produced with CO₂ 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 having a serious role in 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.

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 domestic energy supplies falling under a reduced rate of Value Added Tax (VAT). 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. The government should ensure current building regulations are enforced and provide clear guidelines over the optimal temperature for domestic heating.

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. ("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". (Jevons 1879)) 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' (compensating individuals and companies for additional cost of permits, according to historical use) 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.

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.

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' (Schnellhuber & Cramer 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).

There should be 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 US' 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 decade. 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. These targets are to be commended but are probably insufficient to stop climate change.)

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.

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 CO₂ 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, some heavy freight without rail connection. 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., if the electricity comes from low-carbon sources. 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 thermo-chemistry.

‘Heat pumps’ are an important way of heating homes and other buildings. These devices move heat from outside to inside a building. This process requires between 50 and 80% less energy than direct heating. Of course if electricity is produced using nuclear, then the CO₂ emissions are reduced further still. Financial incentives could be used to encourage the wide-scale transfer to heat pump technology.

The conversion of electricity production to nuclear is the single most important step to reaching our CO₂ targets. Without this, both electric cars and heat pumps 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.

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.

Conclusions

Climate change is perhaps the biggest and most intractable problem humanity has yet faced. Scientists predict severe consequences unless immediate and sustained action is taken to limit and reduce carbon dioxide emissions. Solving this problem will require a massive and immediate expansion in the nuclear industry in the densely populated, predominantly urban, major economies. The UK has adopted a leadership role on climate change. In order to fulfil this role and have a chance of preventing dangerous climate change the UK should immediately make plans for a conversion to a ‘zero carbon economy’, with completion of this goal by 2020-2025. Nuclear is the only fuel source, which can provide the large part of our requirements. The reduction in price of the technology (due to ‘learning by doing’) would compensate for any increase in the resource prices and potentially could encourage nuclear to be adopted in the other large economies such as US and China. This course of action can prevent massive climate disruption and the resulting human and ecological damage.

Action Points

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 thermohaline circulation (Gulf Stream), the collapse of the Amazon rainforest and the irreversible melting of the Greenland ice sheet (Schnellhuber & Cramer 2006). 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 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 carbon-free sources of electricity. 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 a large part of our energy needs.
3. 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'. Energy savings should be made in the home and wind turbine generation encouraged in windy areas. Energy efficiency could be encouraged by reductions in tax on highly efficient appliances.
4. 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.
5. 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 liaise 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 EDF 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. The UK should take a full role in the research of a next generation of nuclear fission reactors including fast breeder reactors and high temperature reactors. Universities and the nuclear industry should be given a clear statement of intent to massively increase the number of nuclear engineers and so to avoid skills bottlenecks.

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