The Generation Gap

Scenarios for UK Electricity in 2020

Alex Evans

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Executive Summary

Introduction

By 2020, the UK is projected to lose a sizeable proportion of its current electricity generating capacity. Most of Britain's ageing nuclear power stations are due for retirement by 2020, when only three are scheduled still to be open. To make matters more difficult, many of the UK's coal power stations will also be phased out over the same period because of the effects of the EU Large Combustion Plant Directive, which will force coal power stations to install expensive equipment in order to reduce emissions that cause air pollution and acid rain. In many cases, it will be cheaper for plant owners to close the power stations rather than install the necessary technology.

This raises the question of what – if anything – the Government should do about Britain's looming electricity 'generation gap'; this is, in many ways, the central issue facing the Government in its forthcoming energy White Paper. This report seeks to answer the question by examining four different scenarios for what the UK's electricity generation sector might look like in 2020. The four scenarios – *Business as Usual*, *The Nuclear Option*, *Clean & Green* and *Fortress Britain* – are designed to illustrate the consequences of decisions that the Government must make in the energy White Paper such as the level of political commitment to energy efficiency and renewables, whether the UK needs a new generation of nuclear reactors and where the balance between state and market should lie.

The Scenarios

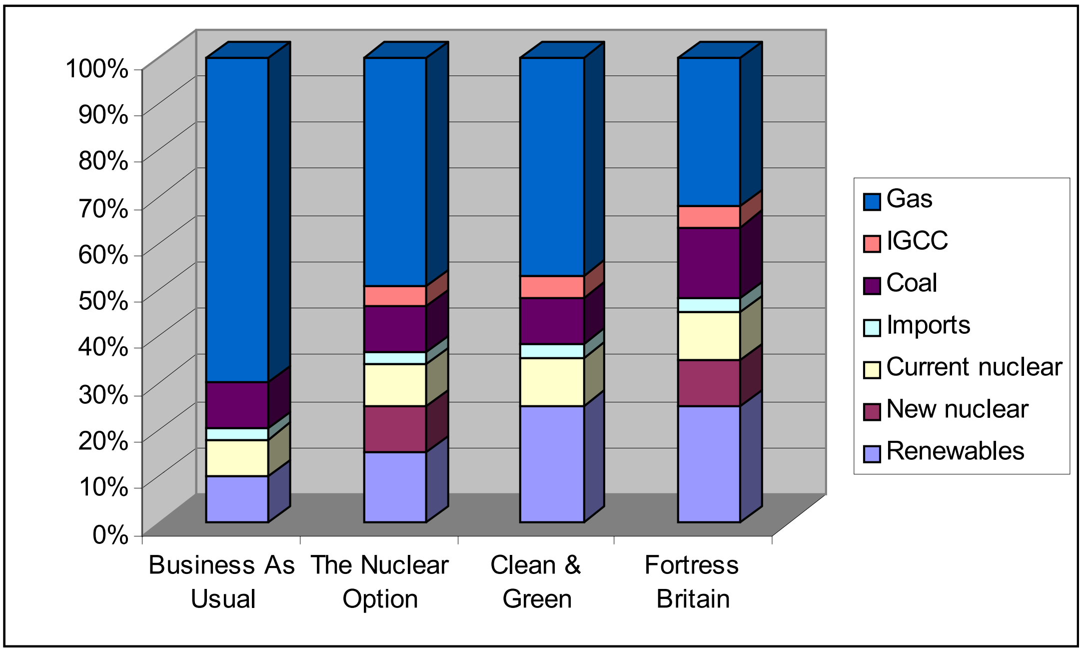
"Business as Usual" sets out an energy future in which energy decisions are left almost entirely to the market. The scenario results from high concern for maximising competition and minimising state intervention in the electricity sector, and low concern for both emissions reductions and dependence on imported gas. Accordingly, the scenario exhibits high demand for electricity at some 500 terawatt hours (TWh) per year, an increase of 25 per cent on present levels. In this scenario, most of the 2020 electricity generation gap is filled by default with gas-fired generation; there is no programme of new nuclear build, and a low commitment to renewables (which provide just 10 per cent of 2020 electricity generation).

"The Nuclear Option" sets out a future that takes emissions reductions and gas import dependency levels seriously, but is sceptical of how much can be achieved through renewables and energy efficiency. Electricity demand in The Nuclear Option is 444TWh; renewables provide 15 per cent of this. As the name implies, the scenario includes an extensive programme of new nuclear build (10 per cent of electricity generated) in order to plug the generation gap whilst also limiting emissions and dependence on imported gas. The scenario hence assumes a willingness to intervene in the market to create a framework for new nuclear.

"Clean and Green" similarly assumes the need for serious emissions reductions, a medium level of gas import dependence and a limited willingness to intervene in the market in order to pursue policy objectives beyond the purely economic. Here, though, new nuclear is ruled out as a result of a strong commitment to environmental sustainability. Instead the scenario shows a high level of commitment to renewables (which provide 25 per cent of electricity generated) and energy efficiency (overall demand is limited to 384TWh, the effect of successfully implementing the target proposed by the Performance and Innovation Unit of a 20 per cent efficiency improvement by 2010 with another 20 per cent by 2020).

“Fortress Britain” is, as the name implies, concerned primarily with minimising gas import dependence. Accordingly, the scenario assumes both the sustained programme of new nuclear build set out in “The Nuclear Option” (which provides 10 per cent of electricity) *and* the policies to support renewables (25 per cent) and energy efficiency (with demand at 384TWh) set out in “Clean and Green”. Accordingly, this scenario is characterised by very high willingness on the part of Government to intervene in the market.

All Scenario Fuel Mix Comparison
(n.b. total electricity demand levels vary across scenarios)



Scenario Methodology and Findings

The key variables used in constructing the scenarios are as follows:

- **The extent of emissions reductions sought from the power generation sector**. It is assumed that in order to remain on track for a 60 per cent CO_2 reduction target by 2050 (as suggested by the Royal Commission on Environmental Pollution), electricity sector emissions will need to be 40 per cent below 1990 levels by 2020. The scenarios themselves show reductions ranging from 25 per cent (Business as Usual) to 50 per cent (Clean & Green and Fortress Britain; The Nuclear Option has a 40 per cent reduction).

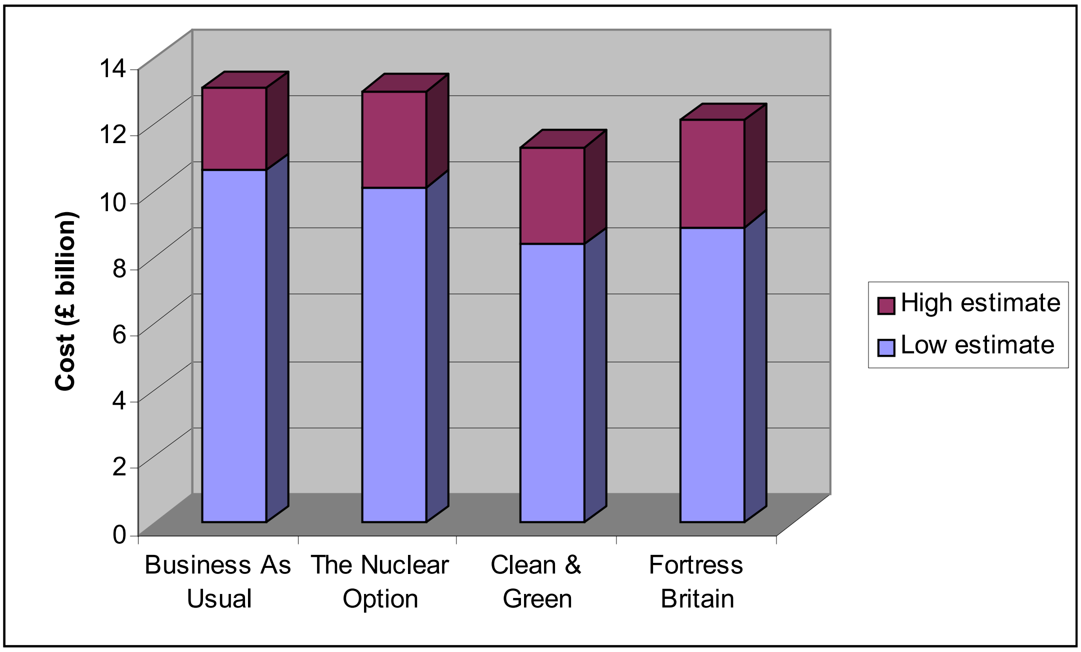
- **The extent to which concern over gas import dependency is a high political priority**. The level of gas used in fuel mix ranges from 348TWh in Business as Usual to 219TWh for The Nuclear Option, 180TWh in Clean & Green and just 122TWh in Fortress Britain. The most important determinant of the level of gas used in fuel mix depends less on alternative generating technologies and more on the level of Government commitment to catalysing the roll-out of energy efficiency technologies.

- **The extent to which a strong competitive market element is favoured**. The 'leave it to the market' scenario, Business as Usual, shows a very low level of state involvement in the energy market, as a result of which electricity demand levels show strong growth from today's levels, new nuclear is kept out of the market, and renewables achieve poor market penetration. The Nuclear Option and Clean & Green both show a median level of state involvement (involving either strong commitment to nuclear new build and some energy efficiency improvements and renewables, or alternatively no new nuclear generation and a strong commitment to renewables and energy efficiency).

Since the Government's stated objectives in energy policy are competitive markets, security, diversity and sustainability, **the use of the above variables in the scenarios implicitly represents the consequences of different orders of priority that can be applied to the four objectives when they are traded off against one another**.

However, it should be noted that the variables do not tell the whole story: for there is more to environmental sustainability than reducing emissions and there is more to security of supply than managing levels of gas import dependency (see below).

All Scenario Cost Comparison

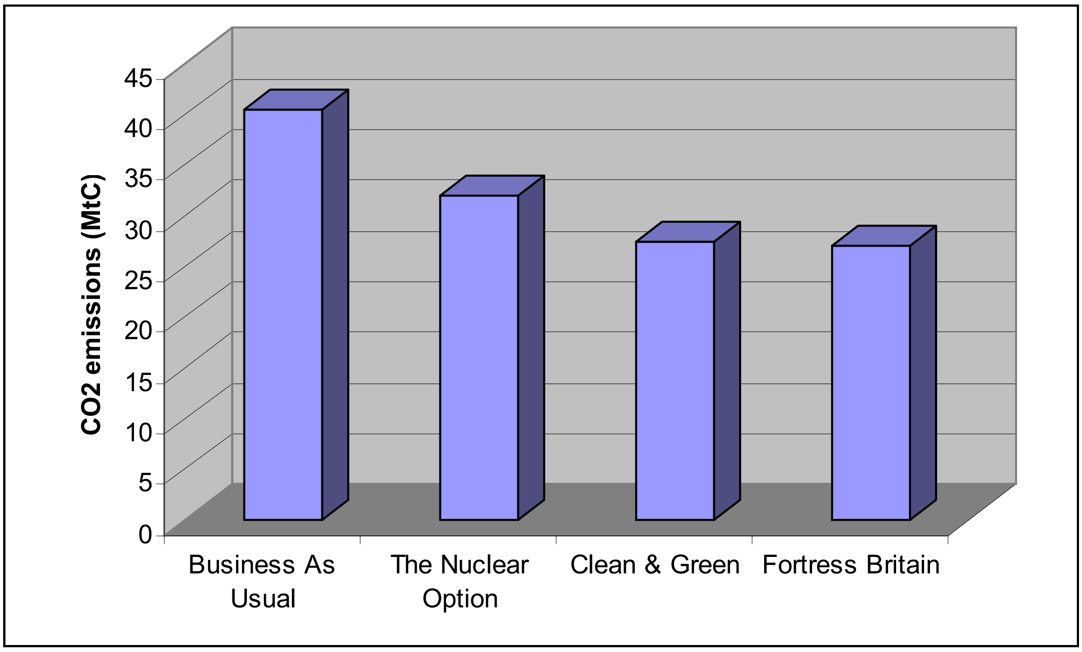


Key Conclusions

1. Before becoming embroiled in the relative merits of different technologies, the first and most important conclusion to note is that the scenarios suggest **it is possible to remain on track for complying with a 60 per cent UK emissions reduction commitment by 2050 whilst ensuring security of supply and without compromising affordability. In short: it can be done**.

2. Making a choice about which of the scenarios is most preferable depends on the question of what the Government is trying to achieve with its energy policy. Another of the key findings of this report is that the Government's stated energy policy objectives (security, diversity, sustainability and competitive markets) do not always point the same way. **Given the overwhelming importance of climate change, the report argues that the Government should use the White Paper to clarify the order of priority that applies to its four energy policy objectives by defining the goal of energy policy as the "secure transition to a low carbon economy at least cost"**.

All Scenario CO_2 Emissions Comparison

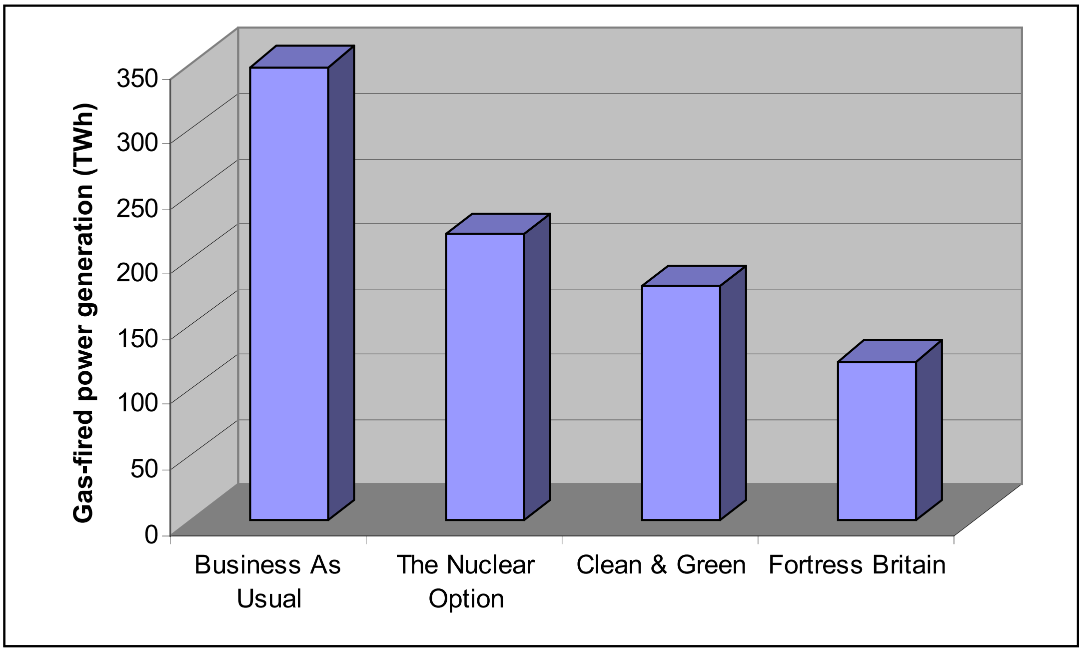


3. **However, achieving the goal of a secure and affordable transition to a low carbon economy will require a revolution in political commitment. Above all, it will be action taken on the energy efficiency front that will be of most importance to achievement of *all* of the Government's objectives in energy policy**. The most significant variance in total energy costs, CO_2 emissions and gas import dependency between the four scenarios is accounted for by total electricity demand levels. This finding gives support to the PIU's emphasis on the overriding importance of effecting demand reductions. Yet whilst there are many potential energy efficiency improvements to be made that can, on balance, save rather than cost money, this does not mean that they will necessarily happen. **There are formidable barriers to the roll-out of state of the art energy saving technologies, especially in the domestic sector; overcoming them will be a national challenge**.

4. The report's findings also suggest that **a strong commitment to renewable energy will pay substantial dividends in reducing emissions and gas import dependency.** The Performance and Innovation Unit cost figures

employed to price each scenario also show that renewables are likely to be more cost effective than new nuclear build (see below). The report therefore recommends that **the Government should use the energy White Paper to announce a target of 25 per cent of electricity to come from renewable sources by 2020**.

All Scenario Comparison of Gas Contribution to Fuel Mix



5. Although nuclear can obviously contribute to reducing emissions and limiting gas import dependency, the report argues that in the broader context its environmental sustainability and contribution to security remain low. Whilst the report sees a case for using plant life extensions on existing reactors which are already in place, **the report argues that three factors mitigate strongly against new nuclear build**:

- The unproven nature of the new reactors proposed by the nuclear industry, combined with a cost case predicated on building an entire series of new power stations, suggests that **by committing to a new build programme the UK would leave itself vulnerable to plant shutdowns potentially affecting the whole series of reactors**;

- **The vulnerability of nuclear installations to attack in the changed security environment** suggests that it would be deeply unwise to commit to the technology for another generation; and

- **The continuing lack of any progress towards a solution to Britain's long-term radioactive waste management strategy** calls any claims to environmental sustainability seriously into question**.**

1. Introduction

As the Government moves into the final phase of the process leading to the publication of its long-anticipated energy White Paper, one question stands out as one of the most important in the document, and probably also the most contentious. What sort of power generation capacity is required to help replace both Britain's present ageing nuclear capacity and many of its coal-fired power stations that are also due for retirement? Or, to put it another way, how can the Government keep the lights on whilst also keeping costs to a minimum and complying with the UK's CO_2 emissions reduction commitments?

Whilst environmentalists and advocates of specific low carbon technologies such as wind power or energy efficiency have been effective advocates for the potential of energy efficiency and supply side options such as renewable energy, there has been relatively less work on how non-nuclear low carbon options might fit together into a complete energy mix. This paper aims to contribute to the debate by assessing four scenarios for energy technology and power generation fuel mix in the year 2020 – two with new nuclear power, and two without.

This paper, which is an interim publication on the way to a major report on the UK's climate change strategy due to be published in autumn 2003, begins by discussing how the Government's stated objectives in energy policy of security, diversity, sustainability and affordability can be made to fit together. It then conducts a brief assessment of the relative merits of the different technologies and how much each might contribute to the UK's energy system in 2020 before sketching out the four 2020 scenarios. These scenarios are then assessed against each of the Government's energy policy objectives to see how they perform relative to each other.

1.1 The Government's energy policy objectives

An obvious place to start our exploration of the future of UK energy policy is with the simple question – what are we actually trying to *do* in the context of energy policy? The Government's current answer to this question is expressed as four linked objectives: sustainability, security, diversity and competitiveness.

Sustainability

At the fore of the Government's thinking is the challenge of global climate change and the resulting need to move towards a low carbon economy. Currently nuclear power stations account for about 23 per cent of the UK's generation capacity. Yet by 2020, almost all of them will have reached the end of their working lives. At present, the likeliest contender to replace them would be coal-fired generation, which is currently the most competitive form of power generation under the New Electricity Trading Arrangements on short term marginal cost (gas-fired power is more competitive on new entrant cost). With this additional coal, the UK's CO_2 emissions would rise significantly, in turn raising serious questions about the UK's ability to meet its Kyoto target of reducing emissions of greenhouse gases to 12.5% below 1990 levels by 2010, as well as the Government's own domestic target of a 20 per cent CO_2 emissions reduction by the same date.

This consideration will be particularly important if the Government adopts an aspirational target of reducing the UK's CO_2 emissions by 60 per cent below 1990 levels by 2050 (as recommended by the Royal Commission on Environmental

Pollution, which calculated the emissions reductions that the UK would need to make under an example 'Contraction and Convergence' scenario). The challenge of climate change places the spotlight squarely on the respective future roles of low or zero carbon technologies including energy efficiency, renewable energy, natural gas (which although a fossil fuel emits substantially less CO_2 than coal), Combined Heat and Power (CHP) plant and nuclear power.

However, environmental sustainability is not limited to climate change alone. Other factors are also highly significant – a consideration that will be returned to later in the report.

Security and Diversity

Two more of the Government's stated objectives are achieving both security and diversity in energy supply. Security refers essentially to maintaining assurance that Britain's lights will not go out. However, the simplicity of the term obscures the number of factors at play in ensuring that lights stay on: from the most upstream level (such as mining coal or extracting natural gas that can then be transported by tanker or pipeline to the UK National Transmission System for use in power stations) to the most local level of a 66 kV local distribution network.

This report concentrates on the more upstream levels of the energy sector, and especially on electricity generation. In particular, the report is not intended as an assessment of security issues further downstream such as 'pinch points' in the National Grid or questions of demand management in local distribution networks.

Perhaps the most widely discussed element of security of supply in recent months has been the question of the UK's approaching dependency on imported gas. Whilst Britain has hitherto been largely self-sufficient for its gas as a result of UK Continental Shelf (UKCS) reserves, these fields are now becoming depleted and will have been largely used up by 2020. However, not all commentators agree that this is a cause for concern; the Performance and Innovation Unit Energy Review, for example, took a markedly relaxed approach to questions of gas import dependency. This area is discussed further in section 2.3.

However, as we shall see, just as sustainability is about more than just CO_2 emissions, so security of supply is also about more than assessments of projected levels of gas import dependency. The report argues that too little has been done to assess the vulnerability of the UK's energy system to terrorist attack – a factor that is especially significant in the context of nuclear energy.

Diversity – having a diverse mix of different power generation sources in fuel mix – can in this sense reasonably be regarded as perhaps better described as a *factor* in energy security and reliability rather than as a wholly discrete objective in its own right.

Competitiveness

Finally, the Government has also set itself the objective of maintaining competitive energy markets. Energy markets do seem at first glance to have become more competitive in recent years. Domestic consumers now have the ability (enjoyed by businesses for some years previously) to change their energy suppliers – although so far few have chosen to do so. Aiming to rectify this, a small army of door-to-door salesmen armed with clipboards and contracts roves the country seeking converts to new electricity supply companies; so competitive is their approach that electricity misselling is increasingly coming to be regarded as a real problem.

Prices have also become more competitive – at least for wholesale customers such as electricity supply companies and energy intensive industrial sites. Prices have fallen by 20 per cent since the introduction of the Government's widely discussed New Electricity Trading Arrangements (NETA) in 2001, following an earlier 20 per cent fall from 2000. Most, though not all, commentators agree that the main reason that prices have fallen is because there is overcapacity in the UK electricity generation sector. This overcapacity is itself largely a legacy of the 1990s 'dash for gas' – the scramble to build cheap and profitable gas-fired power stations that followed the first wave of liberalisation of the UK's energy sector.

Despite the 40% fall in wholesale power prices since 2000, however, domestic consumers have for the most part felt little benefit. Ofgem, the energy regulator, maintains that consumers have experienced an average price reduction of about 10 per cent; energywatch, the consumer watchdog, estimates the figure to be closer to 2 per cent. Some commentators have called for Ofgem to force supply companies to pass on more of the price reductions to consumers. Others, though, have suggested that the transition to a low carbon economy and for increased security of supply will not come cheap, and hence that it would be pointless to effect short term price cuts that will only need to be reversed in the near future.

Sequencing the objectives?

Of course, the Government's four objectives raise an obvious question. The Government's energy policy objectives – competitiveness, sustainability, diversity and security – are clear. Yet it is equally clear that they can and do point in different directions. The greenest energy will by no means always be the cheapest; nor will the energy source that gives greatest independence from imports necessarily be the most environmentally sustainable. So what happens when the Government's energy objectives clash with one another?

One of the findings to emerge from the process of calculating the scenarios in this report has been that in the absence of a clear order of priority to apply to the Government's stated energy policy objectives, there is no obvious basis on which to make decisions about energy. Energy policy is not, alas, made mostly of 'win-wins'; nor can it ever be values-free.

With this in mind, it is as well to be clear at the outset about the values and priorities that underpin the analysis set out in this report, and in particular the assessments made of how the four scenarios perform. Set out below, then, are the core value judgements that lie at the heart of this report: whilst some of them will appear to be no more than common sense, they are set out anyway in order to be completely explicit about what should happen when energy policy objectives trade off.

- ippr agrees with the contention made in the Performance and Innovation Unit Energy Review that where economic and environmental goals conflict, the latter will "tend to take precedence". Questions of environmental sustainability raise fundamental questions of long term responsibility to future generations. Furthermore, given the sheer scale of the damage costs projected to take place if climate change is allowed to continue unchecked, there is in the end a highly robust economic case for prioritising climate change.

- Within the environmental sustainability 'box', this report views climate change as the most pressing of all environmental challenges in the energy sector. The report is (for reasons argued later) highly sceptical of claims made that nuclear power is environmentally sustainable, principally because of the still unsolved questions of radioactive waste management. However, reacting to climate change is regarded as a relatively higher priority than getting out of nuclear as quickly as possible.

- However, the report also regards energy reliability as a fundamental prerequisite for any effective energy policy. Whilst the report does not take this as a basis for an aggressively pessimistic approach to gas import security, it is nevertheless obvious that the Government cannot afford to take chances on (for example) levels of spare capacity. Citizens sitting in the dark as a result of an ineffective energy policy are unlikely to be greatly mollified by the knowledge that costs and emissions have been kept to a minimum. Energy reliability is thus taken as the highest priority in this report.

- Finally, the report places "competitive energy markets" in third place. There is clearly no point in attempting to provide energy to consumers at the least possible cost for an indefinite period of time if the low price externalises all of the costs of reliability and sustainability: this would be a false economy indeed. Shifting to the low carbon economy will cost real money; but this is a price that must be faced up to.

- The report assumes that wherever possible, it is preferable to employ broad, market-based frameworks such as the EU's forthcoming emissions trading scheme rather than more interventionist approaches. However, given that international emission targets continue to be set on relatively short term target periods, the report also accepts that there will be cases where a degree of state intervention is necessary in order to ensure that appropriate low carbon technologies become available in a timely manner.

These considerations can be synthesised together by proposing an overall goal for the Government's energy policy of a "secure transition to a low carbon economy at least cost".

1.2 The looming generation gap

In recent months, much attention has been focussed on the problem of overcapacity in power generation. The UK currently has around 23 per cent more power generation capacity than it uses. This level of spare capacity has existed since the 1970s, when the Central Electricity Generating Board 'gold-plated' levels of generating capacity. More recently, the existence of substantial amounts of spare capacity has continued as a result of the 'dash for gas' that occurred after electricity liberalisation and before Labour came to power in 1997, as power generators built cost-effective new Combined Cycle Gas Turbine (CCGT) power stations. This shift from coal to gas in power generation fuel mix is also the principal reason why the UK has initially found itself on course to achieve its Kyoto obligation of reducing greenhouse gas emissions to 12.5 per cent below 1990 levels by 2010 with relative ease. Figure 1.1 below shows the relative contribution of different fuel types in UK energy mix in 2001.

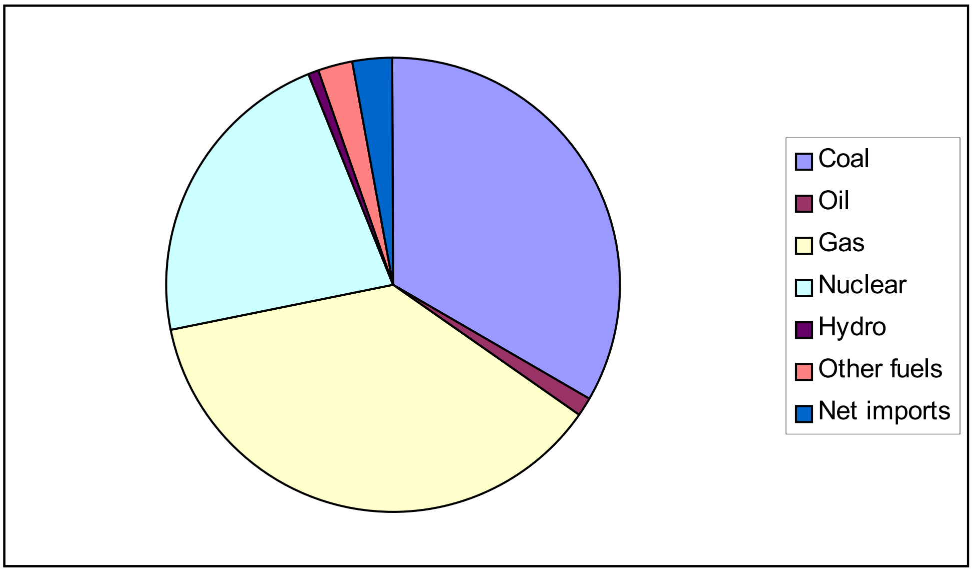
The introduction of the Government's New Electricity Trading Arrangements (NETA) in spring 2001, combined with still more significant earlier developments such as the exposure of CCGT to a more competitive market in 1998, have put the problem of overcapacity squarely into focus. Wholesale power prices fell by 20 per cent after NETA's introduction, following an earlier 20 per cent fall before NETA went live. These price falls ultimately played a significant role in the problems of British Energy, in the failure of the US-owned electricity supply company TXU Europe and in the continuing travails of the Combined Heat and Power (CHP) sector.[1]

Ironically, however, Britain also faces a longer term challenge: the need to install significant amounts of new capacity by 2020. This is for two reasons.

First, most of the UK's current nuclear capacity – which accounts for 22 per cent of current UK generation capacity – will be progressively phased out between now and 2020. The older Magnox series of reactors will all have retired by 2010, and almost all of the newer Advanced Gas-Cooled Reactors are scheduled to undergo decommissioning by 2020, by which time on planned timescales only three nuclear power stations will still be open: Heysham and Torness (both 1,300MW and due to close in 2023) and the UK's single Pressurised Water Reactor at Sizewell in Suffolk (1,250MW and due to close in 2035).

Secondly, it is also likely that a significant proportion of the UK's current coal-fired stations will have been retired by 2020. This is partly because many of the least efficient coal power stations in the UK are due for retirement anyway. For instance, Powergen has announced its intention either to mothball or to retire two of the three coal power stations that it acquired from TXU Europe (Drakelow and High Marnham, together accounting for about 2GW of generating capacity) later this year.

Figure 1.1: electricity available by fuel type 2001



	TWh
Coal	125.4
Oil	4.7
Gas	139.4
Nuclear	83

[1] For a fuller discussion of overcapacity in the UK electricity market, please see the separate ippr research paper *The Failure of British Energy: Crisis or Opportunity?*

Hydro	3.2
Other fuels	9.6
Net imports	10.4
Total	**375.6**

Source: DTI – DUKES 2001

More fundamentally, however, many coal power stations are also likely to be closed by the end of 2015 at the latest because of the projected effects of the EU Large Combustion Plant Directive (LCPD). The Directive will from 2008 impose demanding limits on emissions of sulphur dioxide (SO_2), followed in 2016 by stringent additional limits on nitrogen oxides (NO_x). In order to comply with the Directive, owners of coal-fired power stations face a choice. One option is to fit expensive end-of-pipe treatment such as Flue Gas Desulphurisation (FGD) to the power stations by 2008 in order to meet the earlier SO_2 target. Currently only two coal power stations in the UK – Drax and Ratcliffe-on-Soar – have FGD fitted; West Burton will have the technology fitted by October this year. The other option is to make use of the Directive's "limited life derogation" which would allow plant owners to escape the emission limits as long as the power station runs for no more than 20,000 hours from 2008 – and, critically for the question of future UK energy capacity, as long as the power station also closes by the end of 2015. From 2016 onwards, the introduction of NO_x limits will require coal power stations to be fitted with another expensive technology, Selective Catalytic Reduction (SCR), in order to comply.

What, then, are the options for plugging the UK's looming electricity generation gap? The next section discusses the practical feasibility of gas, CHP, renewables and nuclear for filling this gap, together with an assessment of the potential of energy efficiency measures to play a role. These technology assessments are then collated into four scenarios, which are then tested against the Government's energy objectives.

2. The Options

This part of the report assesses the relative merits of a range of different electricity generation and efficiency technologies, assessing in particular:

- Energy efficiency
- Combined Heat and Power (CHP)
- Natural gas
- Coal and clean coal
- Renewables
- Nuclear

Within each technology section is a short introduction to key debates about the technology and a section on the estimated costs associated with it. Table 1.1 below may act as a useful summary of the costs associated with a range of the technologies discussed.

Table 2.1: selected PIU technology cost estimates

Technology	2020 cost	Confidence	Cost trend to 2050
End use efficiency	Low (usually cost effective and below costs of supply to final user)	High	Decrease, but variable (technology cost will fall but lowest cost potential will be progressively deployed)
Large CHP	Less than 2p/kWh	High	Limited decrease
Micro CHP	2.5 – 3.5p/kWh	Moderate	Sustained decrease
PV	10-16p/kWh	High	Sustained decrease
Onshore wind	1.5 – 2.5p/kWh	High	Limited decrease
Offshore wind	2.0 – 3.0p/kWh	Moderate	Decrease
Energy crops	2.5 – 4.0p/kWh	Moderate	Decrease
Wave	3.0 – 6.0p/kWh	Moderate	Uncertain
Fossil fuels with CO_2 capture & sequest.	3.0 – 4.5p/kWh	Moderate	Uncertain
Nuclear	3.0 – 4.0p/kWh	Moderate	Decrease
CCGT	2.0 – 2.3p/kWh	High	Limited decrease
Coal (IGCC)	3.0 – 3.5p/kWh	Moderate	Decrease

Source: Performance and Innovation Unit Energy Review, 2002

2.1 Energy efficiency

Introduction

A great deal could in principle be achieved on energy efficiency, particularly in the domestic sector and the commercial built environment. Policy options for pursuing this goal include: tightening building regulations and/or widening their coverage; imposing tougher standards on product energy efficiency; imposing additional efficiency obligations on electricity supply companies; using emissions trading; and using demand management tools at distribution network level.

Figure 2.1: UK Electricity Consumption by Sector

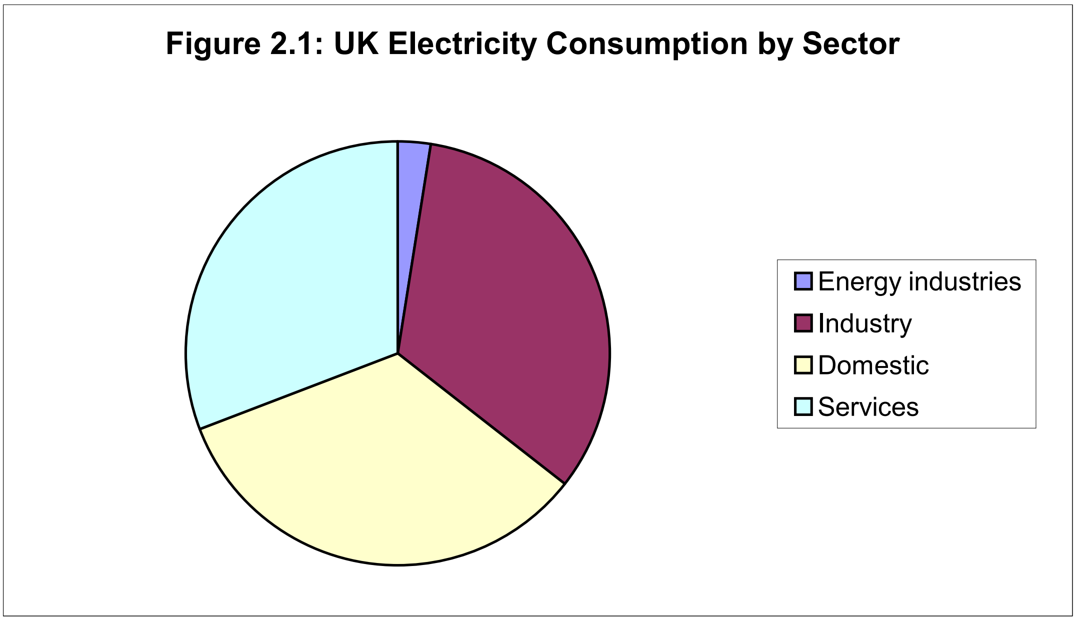


Table 2.2: UK electricity consumption 1970 - 2001

	1970	1980	1990	1999	2000	2001
Energy industries	8.2	8.5	10.0	8.0	9.7	8.5
Industry	81.1	88.6	100.6	112.3	114.9	113.6
Services	42.4	58.4	80.0	101.5	104.0	106.0
Domestic	77.0	86.1	93.8	110.3	111.8	115.3
Total	**208.7**	**241.6**	**284.4**	**332.1**	**340.4**	**343.4**

Source: DTI - DUKES 2001

The Cabinet Office Performance and Innovation Unit (PIU – now the Strategy Unit) Energy Review called for a “step change” in energy efficiency and argued for a target of a 20 per cent improvement in domestic energy efficiency by 2010 and a further 20 per cent by 2020. The effect of whether or not this target is achieved will, in the PIU’s estimation, be dramatic. Whilst around half of current generating capacity (36GW) is expected to have retired by 2020, uncertainty over demand levels in 2020 means that the amount of new capacity that will be needed to replace it could be as little as 25GW or as much as 50GW.

Domestic energy efficiency is at present rather underweight in policy terms within the UK Climate Change Programme, and the potential exists for much more to be done. The current Energy Efficiency Commitment (EEC) on electricity suppliers is relatively unambitious compared to what could be done, for instance, and some commentators have suggested that the last review of the Building Regulations also fell short of what could have been achieved.

However, whilst the PIU was bullish about the potential for increasing energy efficiency in the UK, other voices have been more sceptical about how much can be achieved. Some critics point for example to the poor historical record of improving energy efficiency in the UK and argue that there is no reason to suppose that it will fare better in future. Advocates of energy efficiency reply that “we have barely tried and we have only made small efforts in the past, but these efforts have been extremely successful” (Lehmann, 2001).

The cases of other countries seem to show what can be achieved with real policy commitment. Whilst many commentators in the UK bemoan the anecdotal evidence of the difficulty of persuading consumers to take up condensing boilers, for example (observing that boilers tend to be replaced only when they break down and that engineers called in may be biased against condensing boilers), the technology has achieved market shares of 75 per cent and 40 per cent in the Netherlands and Germany respectively. In the UK, by contrast, market penetration of condensing boilers languishes at just over 10 per cent.

Cost

There is no real doubt that the PIU’s proposed energy efficiency improvement targets could be achieved given the political will to do so, and that this would make supply side objectives such as reducing CO_2 emissions and achieving least possible dependence on imported gas consequently easier to achieve. The real question is how much achieving the PIU targets would cost – and here there is lively debate.

Advocates such as the Energy Saving Trust argue that many energy efficiency measures have a negative cost (in that the cost of the energy saved exceeds the cost of installing the measure), and that energy efficiency savings are among the lowest cost ways to reduce emissions in the economy. Indeed, the Energy Saving Trust has argued that “the cost of reducing carbon emissions to 2010 through domestic energy efficiency is negative at -£150 per tonne” (EST 2002b). Some evidence bears out this claim: the National Audit Office, for example, found that Energy Efficiency Standards of Performance (EESoP) schemes saved electricity at a cost of 1.8p/kW – less than half the cost of supplying electricity to domestic customers.

However, there are also reasons to be cautious of some of the claims made of energy efficiency. Whilst there is little doubt that many savings are economically justified, there are also barriers other than the purely economic. Many consumers are arguably not strongly aware of their energy use patterns and are unlikely to behave as purely rational economic actors.

Dieter Helm has suggested the need for a degree of scepticism about how much uptake there will be of ostensibly positive Net Present Value (NPV) projects (i.e. projects that effectively cost nothing as the energy savings more than make up the cost of the energy efficiency equipment) or projects with NPVs just above zero. This, he argues, is because:

- Consumers lack the necessary information;
- The calculations may use very high discount rates, which would place a relatively high value on consumption reductions achieved a long way into the future rather than more immediately;
- The costs of investing exclude transaction costs, hassle costs etc.;

- They do not trust the sellers of the equipment, and believe that the savings will be lower;

- They expect energy prices to fall; and

- There are barriers to take-up such as access to credit markets and landlord / tenant relationships.

Consequently, Helm argues that there is reason to suppose that while there are many projects with either a positive or nearly positive NPV, not all of them are likely to be taken up by consumers.

Apart from the points Helm raises, there are at least two more reasons for a wary approach towards energy efficiency. One is that in the real world, the energy savings allowed by the installation of energy efficiency equipment will often be taken as increased comfort rather than as actual reductions in demand for electricity. Secondly, there are also challenges in the way that the energy efficiency industry is organised. Consumers face a dearth of ‘one-stop shops’ to which they can turn for energy efficiency improvements to their home; entirely different sets of people install (say) condensing boilers and loft insulation.

The above factors could also constitute a rationale for a degree of mistrust towards claims that the best way of pursuing emissions savings within the domestic and commercial built environment is to use broad price-based market instruments such as emissions trading. Whilst such measures can play a highly valuable role in stimulating lower carbon technologies in electricity generation, two factors should lead to a degree of caution towards their imposition on the domestic sector:

- One is the high transaction costs often associated with built environment energy efficiency projects in both the commercial and domestic built environment. The development of the projects entry route to the UK Emissions Trading Scheme (UKETS), for example, has at times been hallmarked by a lack of interest on the part of many building companies. In their view, CO_2 emissions prices as low as £6-£10 per tonne frequently fail to justify the transaction costs and management time of investing in energy efficiency.

- The other problem is the lack of robust baseline methodologies by which to calculate the emissions savings made by energy efficiency projects, a factor that has been another cause for concern within the Department of Environment, Food and Rural Affairs (DEFRA) throughout the process of developing the UKETS projects entry route (formally announced in November 2002, although without great clarity of detail on the methodologies to be employed).

As a result many measures undertaken to promote energy efficiency to date have tended to see parties other than the actual beneficiaries paying for energy efficiency improvements, for instance through grants from the government or obligations imposed on energy supply companies such as the Energy Efficiency Commitment. Whilst such measures are ultimately paid for by consumers through general taxation or higher electricity bills, this is a less direct route that will be less economically efficient than a purely rational price-based approach.

Conclusions

It is clear that there are reasons for a degree of caution about some of the claims made for energy efficiency. Dieter Helm calls for the following conclusions to be tested before relying heavily on energy efficiency in the White Paper (Helm 2002b):

- "Hard empirical evidence on elasticities undermines much of the energy efficiency lobby's case"

- "The use of high discount rates to 'demonstrate' large-scale potential for energy savings has no theoretical or empirical foundation"

- "Many policies can assist in meeting the CO_2 and security of supply objective, and there is no hard empirical evidence to suggest that at a significant scale, energy efficiency is the dominant policy"

- "Some aspects of energy efficiency have the major advantage of some social benefits, but, again, empirical evidence is largely absent"

Helm concludes that "while demand-side measures are important, and especially in the short term when the capital stock is fixed, their contribution in the longer-term remains more of an assumption than a well-researched empirical proposition".

This last point is probably a fair assessment on Helm's part. Predicting energy futures is necessarily and always a highly uncertain business: when ten new Pressurised Water Reactors were envisaged in the 1980s, no-one foresaw the 'dash for gas' of the 1990s that would change the British energy landscape so markedly. What Helm could perhaps emphasise more strongly, however, is that similar levels of uncertainty apply to almost every other technological option that could play a role in the UK power sector in 2020. It is impossible to say on a "well-researched, empirical basis" whether increasing levels of gas import dependence will lead to security of supply shocks; whether carbon sequestration or indeed nuclear fusion will prove to be technically workable and financially affordable; or when affordable and reliable energy storage systems will become available on a large scale so as to offset the intermittency problems associated with renewables.

Indeed, in contrast to the uncertainty associated with emerging technological options, energy efficiency enjoys one significant advantage. Energy efficiency's uncertainty is not primarily about technical or cost considerations: what is technically achievable with energy efficiency is well known. The PIU's recommendation of a 20 per cent efficiency improvement by 2010, with a further 20 per cent by 2020, is also supported by the Inter-Agency Analysts Group (IAG) and by DEFRA. Instead, the uncertainty associated with energy efficiency is primarily *political*. Achieving the PIU's recommended energy efficiency improvements can be done – but it will require a revolution in levels of political commitment. And, because of the barriers to roll-out of energy efficiency measures, ultimately a more interventionist approach than simply putting a price on carbon. In this sense, there can be few if any "objective" assessments of energy efficiency's potential: any such assessment will necessarily entail a prescriptive element in defining the extent of political commitment that should be applied to the issue. The question of the contribution that energy efficiency can make under different 2020 energy scenarios is returned to in part three.

2.2 Combined Heat and Power (CHP)

Another significant technological option that must be taken into account in any assessment of energy mix scenarios in 2020 is Combined Heat and Power (CHP), also often called cogeneration or cogen, which as the name implies generates both heat and electricity at effective efficiencies of up to 80 per cent. Although CHP is often thought of as a type of natural gas-based power station, it is more accurately described as a particular type of energy efficient technology, partly because it can run on fuels other than gas and partly because it can arguably be seen as an energy efficiency measure as much as a supply side measure.

CHP's efficient handling of heat is a highly significant attribute. Heat is the single most important energy service provided by Britain's non-transport energy system, either for space heating, industrial processes or heating water. Yet the largest *losses* of heat in the UK are of waste heat from the generation of electricity; indeed, so extensive are heat losses through energy conversion that the amount lost exceeds the entire heat requirements of the UK. As an IPPR report by Chris Hewett pointed out, "it is this inefficient provision of heat that lies at the heart of Britain's energy problems" (Hewett 2001). Heat inefficiency, combined with additional inefficiencies in the transmission system, mean that (as the PIU observed), "in the electricity sector it takes on average 100 units of primary energy to make 39 units of final energy". CHP is one of the core technologies that can help to address this challenge and thus assist the Government's objectives of security, diversity and sustainability

Unfortunately, however, CHP installation in the UK has recently ground almost to a complete halt. In 2001, CHP capacity in the UK grew by just 1 per cent (38MWe), while electrical output from CHP fell by some 17 per cent. Installed capacity now stands at 4,763MWe, less than half of the Government's 2010 target. This has been due partly to the effect of high gas prices, themselves caused by the opening of the UK's gas interconnector with the continent. Other factors include the linking of gas prices with oil prices in the European market and the opportunities for arbitrage using the interconnector. Lastly, the effects of the Balancing and Settlement Code (BSC) introduced under the New Electricity Trading Arrangements (NETA) have also had an impact: the BSC provides for penalties to be levied against generators which fail to deliver the promised amount of electricity on schedule as agreed; because of the unpredictable nature of heat loads (since they depend largely on weather conditions).

Although the Government has a target to have 10,000MW of "good quality" CHP installed in the UK by 2010, the target is very unlikely indeed to be met on the basis of present policies. This has led the CHP industry to call for a CHP Commitment, a possibility already legislated for under Section 70 of the Utilities Act 2000, which the industry argues would give the Government's 2010 CHP target a higher chance of being achieved. In the longer term, estimates suggest that CHP could reach between 17 and 21 GW of installed capacity if the potential for community heating were also included.

Cost

Large scale CHP is one of the more cost-effective technological options for energy generation in 2020 according to the PIU Energy Review, which costed large CHP at "less than 2p/kWh" compared to 2.-4p/kWh for biomass and 3-4p/kWh for new nuclear power. Micro-CHP is estimated to be more expensive, at 2.5-3.5p/kWh in 2020, although here it should also be borne in mind that micro-CHP will also reduce demand for gas used for domestic heating requirements.

Research recently undertaken by Campbell Carr Ltd. and published by the Combined Heat and Power Association suggested that under a CHP Commitment scheme, an obligation on suppliers to source 12 per cent of their power from CHP would be needed to reach the Government's 10GW 2010 CHP target (Campbell Carr 2002). Achieving this would, the report suggested, need a buy-out price of £4.50/MWh - £8.50/MWh, which would compare favourably with the £30/MWh buy-out price under the Renewables Obligation. Costs to consumers from the introduction of a CHP Commitment would reach 0.05p/kWh – 0.10p/kWh at their highest in 2010 (as compared with a 0.7p/kWh fall in retail electricity prices since 1998), and progressively fall thereafter as the market recovers.

2.3 Natural gas

Combined Cycle Gas Turbine (CCGT) derived electricity is very well established in the UK market following the dash for gas during the 1990s. In 2001, natural gas-fired generation accounted for 37 per cent of UK electricity, making the UK substantially more dependent on gas for electricity than most other European states. Gas's contribution to UK electricity generation could be expected to grow substantially towards 2020 in the absence of government action designed to ensure greater diversity of fuel sources (and provided that gas prices do not rise sharply), to the extent that the PIU Energy Review suggested that a business as usual scenario for energy fuel mix in 2020 could see the share of gas in power generation reach as much as 75 per cent.

Gas security of supply

The key potential problem with such a scenario would be the extent of gas import dependence that it would entail. Currently, the UK is one of only two G7 countries to be a net exporter of gas. After 2010, however, total net exports are expected to fall rapidly as UK Continental Shelf (UKCS) reserves run down. This has led some commentators to argue that the UK should limit its dependence on gas imports, particularly as the use of gas in sectors besides electricity is not expected to decline markedly over the same period.

There are several levels of concern to the issue of gas security of supply:

- One regards *political risk*, suggesting that gas sources such as Libya, Algeria or Russia may decide to limit supplies of gas to the UK or other Western European countries for political reasons.

- Another level of concern regards *economic risk*, and argues that there is an especially high level of risk associated with "being on the end of a pipe", particularly in the context of an island that currently has just one gas interconnector to the continent as well as extremely limited gas storage capacity.

- Finally, an additional risk specific to the UK is the proportionately much higher contribution to *electricity fuel mix* from gas as a result of early liberalisation and the "dash for gas" during the 1990s than in other European countries.

However, there are also counter-arguments that suggest that a wide variety of options exist with which to manage the risk of increasing gas import dependency between now and 2020. For example:

- The UK currently has enough time to be able to plan a comprehensive programme of investing in both additional gas storage capacity and more interconnectors to the continental gas market such as the currently proposed Symphony pipeline to Norway

- Many continental European countries have been 70 per cent import dependent for twenty years or more without significant supply problems (although this argument must be set against the UK's higher reliance on gas for electricity generation)

- Suggestions that Russia might interrupt the westward flow of gas arguably underrate the extent to which Russia depends on earnings derived from gas exports, such that fears of a 'gas OPEC' are unfounded

- The UK depends on imports of many other commodities that could easily be considered essential, and this is not generally regarded as a problem

The PIU took a broadly relaxed approach to the question of gas security, encouraging Government to continue to keep a close eye on the issue but also noting that "there is no crisis of energy security for the UK". As ever, however, the real questions lie in the detail: in this case the exact figures of gas import dependence. The energy scenarios set out in part three offer different levels of gas in 2020 fuel mix, which are in turn largely a function of how concerned policymakers are about security of gas supply relative to other objectives such as cost and reducing CO_2 emissions.

Another dimension to the issue of gas security of supply is the question of capacity on the gas National Transmission System (NTS). Increasing proportions of gas-fired electricity generation in the UK, together with the inability of gas power stations to stockpile fuel reserves, have meant that peak demands for gas can stretch the capacity of the NTS to maintain enough supplies of gas. Whilst this problem can be ameliorated through sustained investment in additional pipeline and storage capacity, higher levels of gas in 2020 fuel mix will also require equivalently higher levels of investment in the NTS.

Costs

The PIU Energy Review cited the current capital costs of a CCGT plant at around £270/kW, and delivered energy costs at around 2.2p/kWh. The PIU also expected capital costs to continue to fall marginally for the technology, to around £260/kW by 2020. (In practice, capital costs for CCGT are at present closer to £350/kW; however, PIU costs are assumed in the scenarios in order to allow consistency in the figures assumed for operating costs.) Additional improvements in CCGT thermal efficiency (from around 55 per cent today to perhaps 60 per cent in 2020) could effectively reduce CCGT-derived electricity to around 2.0p/kWh by 2020 given today's gas prices.

2.4 Coal

As noted earlier, coal-fired generation in the UK faces a challenge in the form of the Large Combustion Plant Directive (LCPD). The three power stations that will by the end of 2003 be fitted with FGD – Drax, Ratcliffe-on-Soar and West Burton – between them account for about 7.8GW of installed capacity. These three power stations could therefore remain in use until 2015 and still be in compliance with the LCPD, whilst also (subject to the extent of other fossil fuel-based power generation) potentially keeping CO_2 emissions to a level consonant with meeting a 60 per cent

CO_2 reduction target by 2050. However, in order to remain in use all the way to 2020, the stations would also need to be fitted with SCR so as to comply with the NO_x limits that will apply from 2016 onwards.

Such a limited amount of coal-fired power in the UK would represent a historic low in the contribution from coal, and would raise questions about UK fuel mix in 2020. One is the potential impact on security of supply. Coal-fired power possesses a marked advantage over other technologies in that its fuel source can be stockpiled in close proximity to the power station, allowing fuel reserves to be built up. This advantage cannot be enjoyed by wind generation (although the development of energy storage technologies would help to address their performance in this area). Gas faces a similar challenge in that storage capacity is currently very limited in the UK.

Another security-related consideration is that coal-fired power is currently an important contributor to peak generation in the UK. Nuclear power and CCGTs are primarily suited towards baseload generation. Coal-fired power stations, by contrast, enjoy higher flexibility in their output, and can therefore be called online at short notice in order to meet peaks in demand beyond baseload levels. Whilst CCGT power stations can in principle be used for peak generation, using them as such has a negative impact on equipment, thus incurring higher maintenance levels and costs. As mentioned earlier, there are also serious questions about whether the gas National Transmission System (NTS) would be able to cope with the uncertainties in gas demand that would be entailed.

The question therefore arises as to whether it would be useful for more coal-fired power stations to be fitted with FGD and SCR (or alternatively restricted only to peak output, which can opt out of the LCPD, but must then close after 2015) in order to comply with the LCPD and hence continue to contribute to UK power generation and improve security of supply after the end of the limited life derogation in 2015. Such a strategy would not be without additional cost: indeed, generators estimate that fitting FGD and SCR could add an extra £3/MWh to a station's operating costs.

The main problem with such an approach would be its effect on the UK's CO_2 emissions. Paradoxically, whilst fitting FGD and SCR reduces SO_2 and NO_X emissions (and hence on air pollution and acid rain), it also has the effect of increasing CO_2 emissions. "Part-loading" of coal-fired stations (running them at below peak capacity so that their output can be quickly ramped up to meet peak demand) also increases relative CO_2 emissions. One of the problems with NETA is that an effect of the structuring of the Balancing and Settlement Code appears to have had the effect of increasing part-loading of coal plant, a charge that Ofgem itself acknowledges; energy consultant David Milborrow has estimated that the CO_2 emissions resulting from part-loading of coal plant may have been between 1.3 and 3.0 million tonnes last year (ENDS Report 2002b).

Even leaving aside considerations related to FGD or part-loading, coal plant performs markedly worse on climate change metrics than any other generation source: coal creates between two and three times as much CO_2 per kWh as natural gas. Any 2020 energy scenario in which meeting climate change objectives is regarded as a high priority will therefore need to limit the amount of conventional coal-fired generation in fuel mix unless carbon capture and sequestration has become a viable technology or unless frameworks exist to allow equivalent emissions permits to be purchased from other countries at a lower cost than alternative generation types.

However, although coal is disadvantaged by its climate change impacts, this problem could in some estimations be outweighed by the security advantages of fitting more coal-fired power stations with both FGD and SCR so as to keep them beyond 2015. The question of the role that coal-fired power stations might play in 2020 is returned to in part three.

Clean coal

In the longer term, clean coal may emerge as a viable technical option, possibly combined with carbon capture and sequestration (see later). The key technological option in this context are "clean coal" Integrated Gasification Combined Cycle Turbines (IGCC).

Although it is sometimes claimed that IGCC plant can achieve thermal efficiencies comparable to gas-fired CCGT plant, the evidence to date is not encouraging. One flagship IGCC pilot project achieved efficiencies of only 37 to 38 per cent, a performance so poor as to fall some 7 or 8 per cent behind the efficiencies of current coal-fired power stations fitted with both FGD and SCR. However, the performance of IGCC can be expected to improve between now and 2020.

However, IGCC currently remains a largely unproven technology, and likely costs remain highly uncertain. The PIU Energy Review estimated that the 2020 cost of IGCC-generated electricity would be between 3.0 – 3.5p/kWh, slightly lower than their estimate for new nuclear power. However, the technical uncertainties are much lower than with the new nuclear technology of the AP1000.

Some scenarios for energy in 2020 place a high emphasis on the potential of IGCC to contribute to electricity fuel mix whilst also delivering on climate change and security of supply objectives. A scenario constructed by Friends of the Earth proposed that in 2020 IGCC coal could provide just over 10 per cent of supply from IGCC and conventional coal plant together, or 6,850MW of capacity operating at a 65 per cent load factor (with some additional back-up coal capacity maintained on the system in order to provide additional security of supply insurance but not illustrated in their scenario).

The table below shows a list of clean coal plants already proposed in the UK.

Table 2.3: Proposed clean coal plants in the UK as at September 2001

Location	Company	Size
Dowlais Valley, S. Wales	Progressive Energy	400MW
Kellingley, Yorks.	UK Coal / Texaco	420MW
Wansbeck, North East	Progressive Energy	450MW
Westfield, Scotland	Global Energy	120MW
Westfield, Scotland	Global Energy	400MW
Hatfield	Coalpower	500MW
Total		**2,290MW**

Source: UK Coal, consultation response, 2001

2.5 Renewables

Introduction

The Government currently has a target for 10 per cent of electricity to be generated from renewable sources by 2010. The main policy instrument for achieving this target is the Renewables Obligation on suppliers to source a defined proportion of their power from renewable sources (the figure rises gradually to hit 10 per cent in 2010).

However, the UK is not on track to reach this target. After stalling at 2.8 per cent of total electricity since 1999, renewables' share in 2001 slid to 2.6 per cent of total generation according to published DTI statistics. This is mainly large hydro plant, together with some onshore wind and landfill gas generation. Future capacity is likely to rely increasingly on "second generation" renewables such as offshore wind and biomass power as well as additional onshore wind.

In practice, the 10 per cent target is on current trends perhaps more likely to be reached in 2013 than 2010, although policies could be implemented to bring this date forward. A variety of factors have contributed to the poor progress towards the Government's target. Planning has been a particular problem, particularly for both onshore and offshore wind projects (for different reasons in each case).

The PIU proposed a target of 20 per cent of electricity to come from renewable sources by 2020, and this proposal was supported (to varying degrees) by the two largest electricity companies in the UK, Powergen and Innogy, as well as by Shell. Indeed, several organisations – including ippr, the Sustainable Development Commission, the Renewable Power Association and AEA Future Energy Solutions, which assess renewable potential for the Government – argued that at least 25 per cent (and in some cases 30 per cent) would be achievable.

Cost

Cost estimates for renewables in 2020 differ very widely between different technologies. Some renewable technologies, such as onshore wind, are already well established and close to being competitive with fossil fuel generation sources. Other types of renewable technology are much further away from market (and much more expensive), most notably in the case of photovoltaics.

Table 1.4 below shows the PIU's estimated costs for different renewables in 2020, together with illustrative figures to show how the mix of renewables might evolve between now and 2020 (the figures in the three right hand columns indicated installed capacity in megawatts). The proportionate contributions from each type of renewable technology in 2020, together with their associated costs, are used to form the basis of the renewables contribution to the four scenarios set out in part three.

Table 2.4: Illustrative renewables installed capacity mix 2002 – 2020

Generation type	PIU cost estimates	2002 (MW)	2010 (MW)	2020 (MW)
Biomass	2.5 – 4.0 p/kWh	200	1,500	4,000
Onshore wind	1.5 – 2.5 p/kWh	500	3,500	5,500
Offshore wind	2.0 – 3.0 p /kWh	-	3,500	7,500
Landfill gas	-	400	1,000	1,000
Photovoltaics	10 – 16 p /kWh	-	100	500
Small hydro	-	100	100	100
Wave / tidal	3.0 – 6.0 p/kWh	-	50	1,000
Total		**1,200 MW**	**9,750 MW**	**19,600 MW**

Source (cost figures only): PIU Energy Review 2002

Perhaps the most contentious variable in determining whether the Government should target 20 per cent renewables or a higher figure is the question of the costs associated with intermittency. The Royal Academy of Engineering in its White Paper consultation response accused the PIU of being "hopelessly unrealistic" on the proposed 20 per cent renewables target and argued that this would require 16-19GW of conventional plant to be retained as back-up at a cost of around £1 billion. This assertion was strongly rebutted by David Milborrow, an independent consultant to both the PIU and the British Wind Energy Association, who argued that Royal Academy's estimates of intermittency costs were ten times too high (ENDS Report 2002b).

More recently, a report by Ilex Consulting commissioned by the DTI suggested that the system costs (i.e. counting balancing and network costs as well as capital and operating expenses) of reaching a 20 per cent renewables target by 2020 would be £143 – 398 milllion per year or 0.32 – 0.90 p/kWh for the additional 10 per cent of capacity. If renewables' contribution rose to 30 per cent of supply then these system costs would be from £325 – 921 million per year, with most of the additional expense being accounted for by the need to reinforce the system against intermittency risks. In both cases, the low end estimate assumes a higher proportion of biomass-fired energy (which avoids the intermittency risk associated with wind power), while the higher costs assume a higher proportional contribution from wind power in Scotland with larger sums needed to reinforce the national transmission grid.

However, a response to the Ilex report, commissioned by the British Wind Energy Association, makes a number of significant comments on Ilex's estimates of the system costs associated with higher renewables levels:

- Ilex's least cost scenario does not fully exploit the offshore wind resource in the south of England, which could be incentivised through stronger locational signals in the transmission and distribution system. The lowest costs cited by Ilex for transmission are in this sense not the "least cost" option.

- Ilex's assertion that wind is unable to contribute "firm power" to meet peak demand ignores a number of recent studies on this area, and does not provide clear evidence for the contention that low winds are often found at times of peak demand. The BWEA counters that offshore wind will further develop the ability of the technology to provide "firm power", due to both stronger winds offshore and increased geographical diversity.

- The Ilex report identifies a "capacity cost" as a significant element of the system costs of renewables. However, the BWEA charge that this is an "entirely new concept, not identified – as far as we are aware – in any other studies of this kind".

- Whilst the Ilex report compares the case of the UK to that of Denmark, it omits to set the costs of transmission and reinforcement there (estimated by the BWEA to be as little as £53 million for 3,500MW of renewables and CHP) against estimates for the UK.

- Finally, the Ilex report makes no mention of the positive impact that wind prediction techniques already in use in Denmark can make on balancing costs associated with wind power.

2.6 Nuclear

As discussed earlier, current planned timescales for nuclear power phase-out imply that all Magnox reactors will have been phased out by 2010, and all Advanced Gas-

Cooled Reactors (AGRs) by 2020 (with the exceptions of Torness and Heysham as well as the UK's sole Pressurised Water Reactor, Sizewell B). Assuming that the overall level of UK generating capacity remained level, these projected decommissionings would imply nuclear power's share of generating capacity declining from its current level of 23 per cent to 7 per cent in 2020.

The nuclear industry has not been slow to use the projected nuclear (and coal) phase-out as a basis from which to argue for nuclear new build as a prerequisite for meeting the Government's climate change and security of supply objectives. BNFL, for example, has argued that "establishing new nuclear generation in the UK to replace existing nuclear capacity will help to ensure a secure, diverse and environmentally friendly energy supply".

At present, the leading contender for the technology to be used in any programme of new nuclear build would be the Westinghouse Advanced Passive 1000 (AP1000), which is being promoted in the UK by BNFL (which owns Westinghouse). In the longer term, an alternative could be the Pebble Bed Modular Reactor (PBMR), but this is currently significantly further away from market than the AP1000.

BNFL argue that the AP1000 enjoys a number of key advantages. It is asserted to be:

- *Passively safe*, in that it "uses the forces of nature [such as gravity, conduction, convection or natural circulation of air and steam] to assure safety without the need for operator action or the use of electrically driven devices"

- *Simple,* particularly in its lower requirement for pumps and valves than traditional reactors; BNFL contends that the AP1000 requires 50 per cent fewer valves, 35 per cent fewer pumps, 80 per cent less pipe and 80 per cent fewer heating, ventilation and cooling units, for instance.

- *Mature,* in that the design work for the series was started in the late 1980s with "1300 man years of design and testing involved"; "around 60 per cent of the design work is already completed, with over 12,000 design documents in place"

- *Proven,* in that the AP1000 is built on the Westinghouse Pressurised Water Reactor design which has some 2,250 years of operating experience

- *Modular,* in that each reactor will be comprised of 50 large modules and 250 smaller ones, with the latter able to be transported by rail. BNFL also argue that the *standardisation* of the AP1000's design brings significant cost improvements with additional reactors built in the same series (see section on cost below).

Apart from the obviously nonsensical proposition that a reactor type that has never been built anywhere in the world could possibly be regarded as either mature or proven, there are also reasons to take a sceptical view of arguments in favour of the AP1000 and suggest that in a nuclear scenario, the Pebble Bed Modular Reactor (PBMR) may in the long term be a better choice.

One is that given its smaller, modular design, the PBMR is likely to be significantly more viable for attracting private finance and hence less in need of state subsidy; the other is that the PBMR is theoretically immune to the loss-of-coolant leaks such as those experienced at Three Mile Island or Chernobyl.

Radioactive waste management

Another key consideration with nuclear power is the question of radioactive waste management. At present the UK lacks a clear strategy for dealing with its radioactive wastes: indeed, the Government has made next to no progress on this area since 1997. It is known that scenarios are being investigated for how soon a deep repository for the wastes could be constructed, but even the most heroic assumptions appear to rule this out until 2025 at the earliest. By contrast, a recent public inquiry addressed by BNFL yielded the insight that current assumptions built into nuclear industry assumptions are that no repository would be built until 2040. It may therefore be many years until a viable strategy is in place for dealing with the UK's radioactive waste stocks.

The nuclear industry itself argues that waste is not a highly significant consideration in deciding whether to embark on a programme on nuclear new build, since "waste arising from a new build programme represents only a small addition to the existing waste inventory … replacing all the current UK nuclear capacity with AP1000 reactors would only add about 10 per cent to the UK's nuclear waste inventory over their lifetime". However, what the nuclear industry's position overlooks is that whilst the AP1000 does produce a lower overall volume of radioactive waste than older reactors, this is mainly achieved through lower volumes of Low Level Waste (LLW) and Intermediate Level Waste (ILW). Indeed, the nuclear industry's own figures suggest that the AP1000 would effectively not improve at all compared to the oldest Magnox reactors when comparisons are drawn solely on the basis of production of High Level Waste (HLW). Arguments that the AP1000 series would perform much better on radioactive waste are therefore open to some question.

Nuclear security risks

One problem that could be associated with a programme of new reactor build is that it would be particularly vulnerable to plant shutdowns. The nuclear industry's own requirements for economies of scale require a series of reactors to be constructed in order to bring down capital costs over time. This implies that there would probably be at least four AP1000s and very probably more in order to make the technology more competitive than it otherwise would be.

However, the problem with this approach is that it would then place a substantial proportion of the UK's energy generation "eggs" in one basket. Were a serious fault later discovered with the AP1000 or another reactor system that was used, then in a worst case scenario all of the series might need to be taken offline while tests were carried out. This scenario is currently causing concern in Japan, where 12 of the Tokyo Power Company's 15 reactors are currently off-line, raising questions about whether the company will be able to meet its supply obligations to consumers and hence whether Tokyo's lights will ultimately stay on.

Nuclear power's other significant security downside relates to its vulnerability to terrorist attack – and the comparatively higher resilience of decentralised generation forms to attack. Policies in areas across the political agenda are currently having to be rethought within the context of the new security environment: the US has recently created a new Department of Homeland Security with a budget of $37 billion, for example, and the UK has started planning in earnest for the risk of nuclear, biological or chemical weapons attack. In this new context, at a time when a long term vision is being assembled for the UK's energy policy, it is only rational for the Government to consider the links between counter-terrorist and energy policy.

Britain's nuclear installations represent a crucial vulnerability within the energy system. The recent occupation by protesters of the Sizewell B site shows that security may be breached by an incursion much less dramatic than a hijacked plane being used to attack a site. The case of Chernobyl showed vividly how serious damage can be if a reactor core is penetrated without having first shut down safely, whilst private nuclear industry calculations are understood to have shown that the effect of a plane being flown into the Intermediate Level Waste stores at Sellafield could have been 30,000 deaths within the first two days after the attack.

Britain currently has an opportunity to wean itself off nuclear power and hence render its energy system much more resilient to attack. As discussed earlier in this section, all of the oldest Magnox reactors will have retired by 2010. Whilst this paper advocates retaining the option to use the later AGRs and PWR for as long as possible, as a purely transitionary measure, it would nevertheless fly in the face of the lessons of the new security environment to embark at this stage on a sustained programme of building new reactors.

In the opposite sense, moving as quickly as possible towards a distributed generation system based on CHP and renewables offers the potential to enhance significantly the robustness of the UK energy system from attack. Any 1,000MW power station (of any variety, but especially nuclear) will inevitably make an attractive target for terrorists. By contrast, the impact of a successful attack on a 3MW wind turbine would be miniscule. As Dan Plesch, a senior research fellow at the Royal United Services Institute, wrote in his pamphlet *Sheriffs and Outlaws in the Global Village*, "in older days, attacks by guerrillas on the economic and technical structure of society could not produce catastrophe. Societies were far more decentralised and mass-destruction weapons were not available" (Plesch 2002). Within the energy context, the decentralised option is offered by renewables and other embedded generation technologies such as CHP; nuclear reactors, on the other hand, can themselves be turned into mass-destruction weapons by attacking them in the right way.

Cost

BNFL maintains that the "total generating cost for the first AP1000 reactor in a series is £30/MWh, reducing to £22/MWh for the fourth in a series". These costs are broken down as follows:

Table 2.5: BNFL cost assumptions for AP1000

Capital costs	£18.20/MWh (1st reactor in series)
	£11.10/MWh (4th reactor in series)
Operating and maintenance	£6.90/MWh
Fuel	£3.0/MWh
Spent fuel management	£0.8/MWh
Decommissioning cost	£0.6/MWh

Source: PIU 2001

British Energy made a different but broadly similar assessment of the costs of a new reactor series of 3p/kWh for the first twin unit to around 2.5p/kWh for later twin units. However, both sets of figures were strongly called into question by a PIU Energy Review working paper entitled *The Economics of Nuclear Power* (PIU 2001).

This paper underlined that the nuclear industry's cost estimates were for "radical reductions – halving or better – in nuclear costs between the late 1980s and the present": from around 6p/kWh for Sizewell B (excluding first of a kind costs) to today's estimate 2.2-2.5p/kWh for the expected fourth unit in a new reactor series. Whilst the paper concurs that there are indeed arguments to suggest potentially great cost reductions (such as that nuclear power now faces sterner competition, that procurement is now much more efficient and that the AP1000 is a "much simpler machine" than Sizewell B), it also highlights some significant uncertainties in the appraisal. For example, the paper points to significantly different assumptions in the BNFL and BE cost estimates: the discount rates used differ by more than a percentage point; plant lifetime is cited as 20 years by BE but 30 by BNFL; and BNFL assume single units per site whilst BE assumes twin units.

Furthermore, the PIU paper points to the potential for large variations in total generating cost resulting from construction cost and operating availability. On construction costs, the paper emphasises the lack of recent construction experience and of published data, noting that "only the smaller AP600 has yet cleared the generic US regulatory process, and no full-size AP-type reactor has yet been built anywhere in the world". Accordingly, the paper continues, "neither BNFL nor BE can currently be sure that any construction contract for an AP1000 station could be at fixed price".

On operating availability, the PIU paper points out that "average current OECD lifetime performance is 75-80 per cent availability, with good units averaging 85 per cent"; whilst some units have recently achieved 90 per cent or better in recent years, "it is not yet clear that such levels can routinely be achieved over whole plant lifetimes". The paper concludes that "both BE and BNFL use figures for availability that are substantially higher than the 75-80 per cent range of recently achieved performance", and note that availability just 5 per cent poorer than that expected by BNFL would raise generating costs by some 0.2p/kWh.

In conclusion, the PIU analysis suggests that "a range of 3p/kWh to 4p/kWh is a more realistic range of likely future nuclear costs".

Plant Life Extensions

An additional factor that must be considered in the nuclear context is the possibility of plant life extensions for existing nuclear reactors. As mentioned earlier, current nuclear decommissioning timetables suggest that by 2020 only 7 per cent of the UK's electricity will be met from nuclear sources (accounted for by the AGRs at Torness and Heysham and by the PWR at Sizewell B). However, this percentage takes no account of the potential of plant life extensions to existing nuclear reactors to prolong higher levels of nuclear input to the overall 2020 generation mix, without the need for new nuclear build. Some estimates suggest that plant life extensions could lead to nuclear's contribution in 2020 standing at 18 per cent rather than 7 per cent.

To be sure, there is no guarantee that plant life extensions will be technically feasible on this scale, as any extensions would be subject to technical assessments of the strength of reactor materials that have not yet been carried out. Given the potential extent of the contribution that plant life extensions can make to overall 2020 generation mix, however, it is remarkable how quiet the nuclear industry has been about possibilities in this area. One might reasonably surmise that a nuclear industry focussed principally on new build as its lifeline for the future might see good reason to maintain a judicious silence about the possibility of prolonging the useful life of existing reactors.

2.7 Carbon capture and sequestration

Carbon capture and sequestration (C&S) is a relatively new and untested technology that involves removing the CO_2 from fossil fuels before the gas is released into the atmosphere, and instead sequestering the gas. Whilst there is a range of different ways in which CO_2 can be sequestered (for instance through planting additional forest cover, which then absorbs CO_2), sequestration is in the energy context usually geological. This is to say that the CO_2 is captured at source from the combustion of fuel for power generation and then transported to a geologically suitable repository. An example of such a repository might be a deep saline aquifer or a depleted oil reservoir.

As the PIU Energy Review stated explicitly, “the main question about the environmental impact of C&S is whether the CO_2 would stay in the ground”. Whilst it is not yet possible to assess the likelihood of this occurring, the significance of the question is hard to overstate. There are also serious safety issues since a sudden, large emission of CO_2 could cause asphyxiation to people in the area.

Whilst there is a clear rationale for assessing the potential of C&S technology, therefore, there is also a clear reason for scepticism and for taking a very precautionary approach. There is thus no basis on which to assume that C&S technology will necessarily be feasible in 2020, and the technology has therefore been excluded from all four of the scenarios presented in this report. As a result, coal-fired generation is held relatively low in all scenarios, since high levels of coal-fired generation without C&S would be irreconcilable with achieving ambitious CO_2 targets consistent with a 60% reduction by 2050 as suggested by the Royal Commission.

3. 2020 energy scenarios

This section of the report describes and assesses four scenarios for fuel mix in 2020. The scenarios are the result of identifying a small number of key variables in energy policy from now to 2020, and then synthesising different permutations of these variables into four distinct 'futures' which show what they might imply in terms of fuel mix, cost, CO_2 emissions and level of gas import dependency.

The key variables used in constructing the scenarios are as follows:

- The extent of **emissions reductions** sought from the power generation sector;

- The extent to which concern over **security of supply** and gas import dependency is a high political priority; and

- The extent to which a strong **competitive market element** is favoured;

In this sense, the scenarios take as given the Government's stated energy policy objectives of security, competitive markets and sustainability (taking the Government's fourth objective, diversity, into account through describing the technology mix in each scenario). However, the scenarios also show that energy policy cannot be as simple as targeting all of these objectives at once. As becomes clear from the four alternative futures presented, there are instances in which one of the Government's objectives is inevitably traded off against another; ensuring security of supply, for example, will not always lead to the cheapest electricity for consumers.

A principal aim of constructing these scenarios has been to emphasise that there is more to energy policy (and to sustainable development in the broader sense) than easy 'win-wins'. A clear order of priorities is needed – and this will be a central test for the White Paper. In the context of these four scenarios, the four futures presented here result from different possible orderings of the three variables set out above, and show what different priorities might mean in the real world.

Two other variables used to differentiate the scenarios are:

- Whether **new nuclear build** forms a component of energy mix in 2020; and

- Whether the scenario includes a strong governmental **commitment to renewables and energy efficiency**.

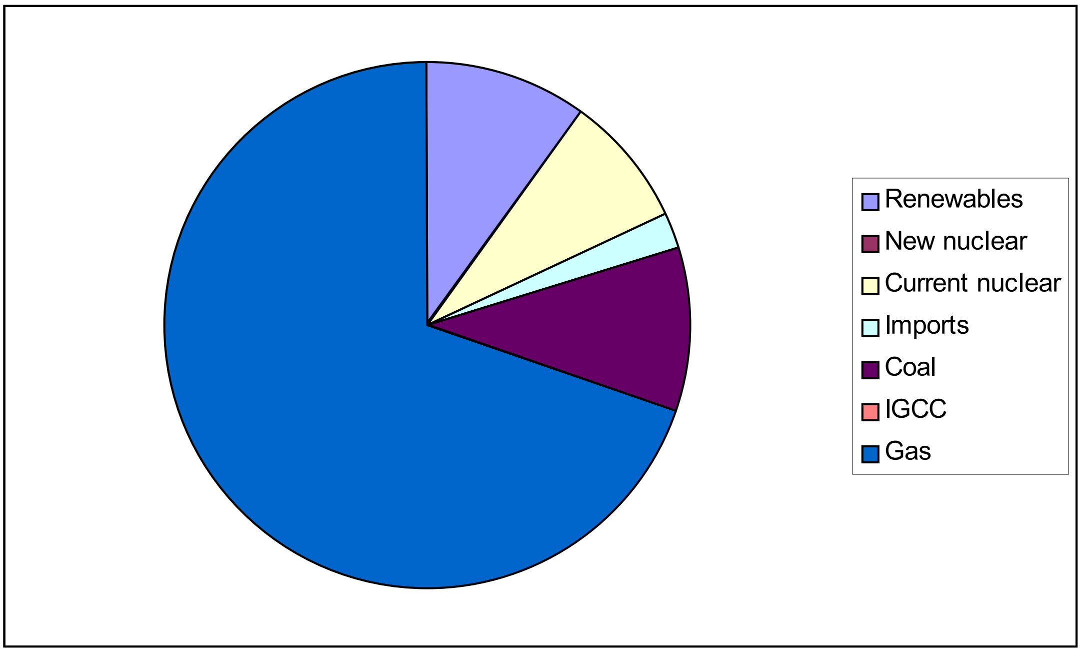
The first of these variables is more or less self explanatory, and in the context of the two scenarios that contain an element of nuclear new build has been assumed to consist of a new build programme of AP1000s for 10 per cent of total electricity generated. The second variable derives from the debates discussed in Part Two about how much can realistically be achieved through renewables and energy efficiency by 2020 (which in turn results principally from the extent of governmental commitment to improving performance in this area).

The four scenarios can be summarised briefly as follows:

Business as Usual

"Business as Usual" sets out an energy future in which energy decisions are left almost entirely to the market. The scenario results from high concern for maximising competition and minimising state intervention in the electricity sector, and low concern for both emissions reductions and dependence on imported gas. Accordingly, the scenario exhibits high demand for electricity at some 500 terawatt hours (TWh) per year, an increase of 25 per cent on present levels. In this scenario, most of the 2020 electricity generation gap is filled by default with gas-fired generation; there is no programme of new nuclear build, and a low commitment to renewables (which provide just 10 per cent of 2020 electricity generation).

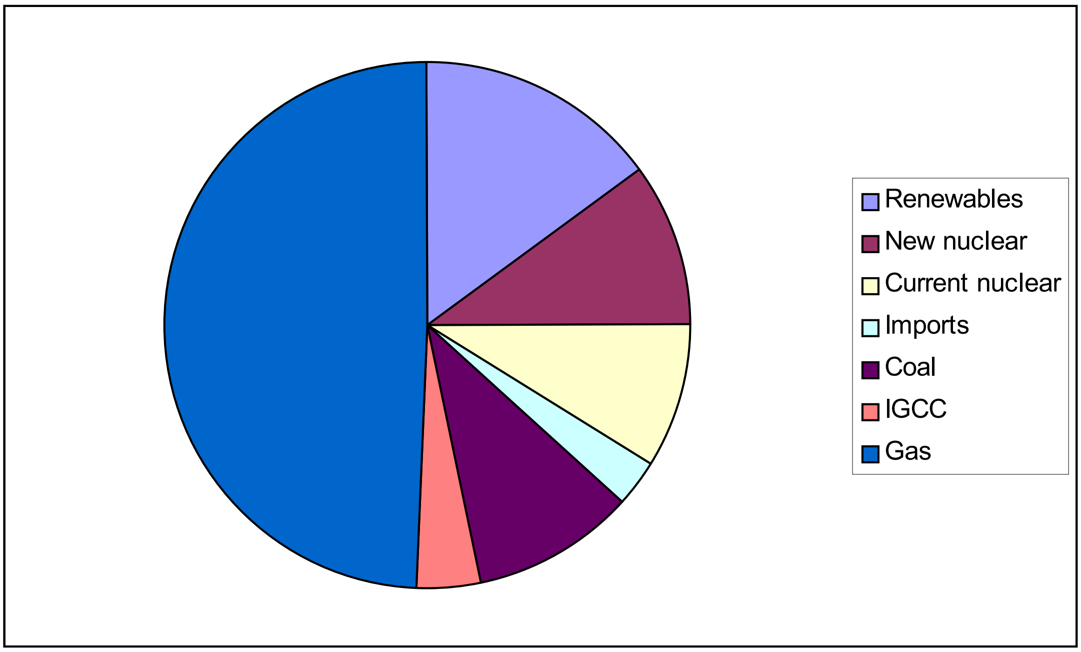
Figure 3.1: Fuel Mix – Business As Usual
Total demand: 500 TWh



The Nuclear Option

"The Nuclear Option" sets out a future that takes emissions reductions and gas import dependency levels seriously, but is sceptical of how much can be achieved through renewables and energy efficiency. Electricity demand in The Nuclear Option is 444TWh; renewables provide 15 per cent of this. As the name implies, the scenario includes an extensive programme of new nuclear build (10 per cent of electricity generated) in order to plug the generation gap whilst also limiting emissions and dependence on imported gas. The scenario hence assumes a willingness to intervene in the market to create a framework for new nuclear.

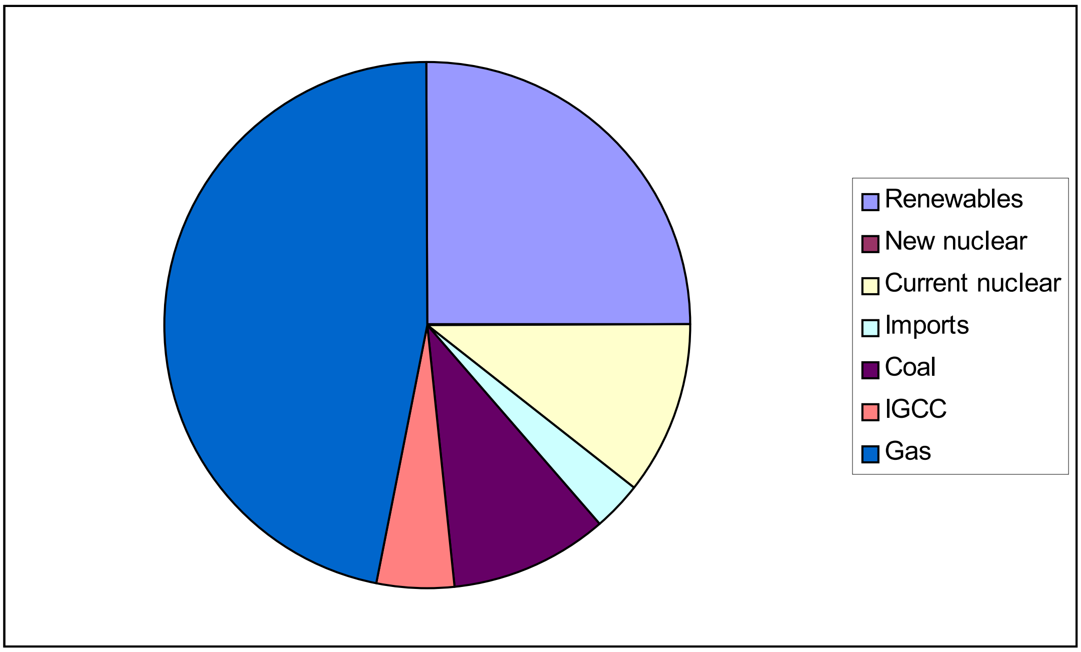
Figure 3.2: Fuel Mix – The Nuclear Option
Total demand: 444 TWh



Clean and Green

"Clean and Green" similarly assumes the need for serious emissions reductions, a medium level of gas import dependence and a limited willingness to intervene in the market in order to pursue policy objectives beyond the purely economic. Here, though, new nuclear is ruled out as a result of a strong commitment to environmental sustainability. Instead the scenario shows a high level of commitment to renewables (which provide 25 per cent of electricity generated) and energy efficiency (overall demand is limited to 384TWh, the effect of successfully implementing the target proposed by the Performance and Innovation Unit of a 20 per cent efficiency improvement by 2010 with another 20 per cent by 2020).

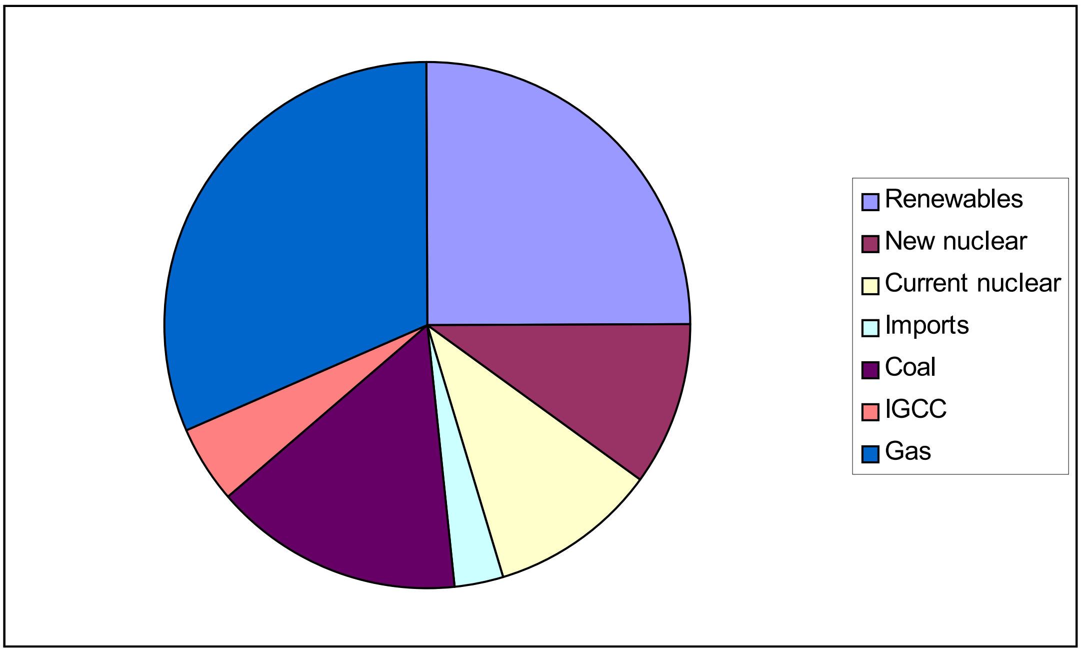
Figure 3.3: Fuel Mix – Clean and Green
Total demand: 384 TWh



Fortress Britain

"Fortress Britain" is, as the name implies, concerned primarily with minimising gas import dependence. Accordingly, the scenario assumes both the sustained programme of new nuclear build set out in "The Nuclear Option" (which provides 10 per cent of electricity) *and* the policies to support renewables (25 per cent) and energy efficiency (with demand at 384TWh) set out in "Clean and Green". Accordingly, this scenario is characterised by very high willingness on the part of Government to intervene in the market.

Figure 3.4: Fuel Mix – Fortress Britain
Total demand: 384 TWh



3.1 Scenario methodology and findings

1. Quantifying electricity demand

Each of the scenarios begins by assessing the total electricity demand in 2020. The estimates of net total demand in 2020 range from 500 TWh under Business As Usual to 384 TWh for Clean and Green and Fortress Britain, with The Nuclear Option assuming a mid range demand figure of 444 TWh. The difference in these ranges derives from the extent of measures taken to promote both energy efficiency and CHP installation.

The impact of energy efficiency is calculated through taking a rounded 2000 electricity demand baseline of 400 TWh and then applying different estimates under each scenario of electricity demand increase by 2020, ranging from a 28 per cent increase in demand under Business As Usual to just a 2 per cent increase in demand under Clean and Green and Fortress Britain. The latter figure reflects the result of successful implementation of the PIU's proposed energy efficiency targets, whilst the former is the Energy Savings Trust's business as usual estimate for 2020. The second scenario, The Nuclear Option, takes a more pessimistic view of what can be achieved through energy efficiency whilst still implementing some "low hanging fruit" energy efficiency measures, and hence assumes a mid-range demand increase of 14 per cent.

On a similar basis, higher CHP installation levels are assumed under Clean and Green and Fortress Britain than under Business As Usual and The Nuclear Option: the former two scenarios assume a demand reduction of 24 TWh through the effect of CHP, whilst the latter two assume only half this at 12 TWh.

A possible criticism of this approach to the scenarios might be that assuming different electricity demand levels for the four scenarios amounts to comparing apples with pears, given that the higher demand scenarios inevitably incur higher costs, emissions and levels of gas import dependency. However, the intention of these scenarios is principally to show the implications of four competing visions of the energy futures, and the assumptions of advocates of each vision. In this regard, it is fair to vary the levels of demand, for different advocates make different claims of what can be achieved in the field of reducing electricity demand growth.

There is no doubt that the PIU's proposed energy efficiency target can be achieved in the technical sense. What is at issue is rather the political feasibility of achieving the targets – something that (for example) some pro-nuclear advocates have viewed critically. The real issue here is the barriers to roll-out of cost-effective energy efficiency technology, which is in turn a question principally of political willingness to intervene to correct market failure. Since it cannot be assumed that the political will needed will become apparent in the next eighteen years, it is therefore reasonable to incorporate this variable into

2. Quantifying fuel mix

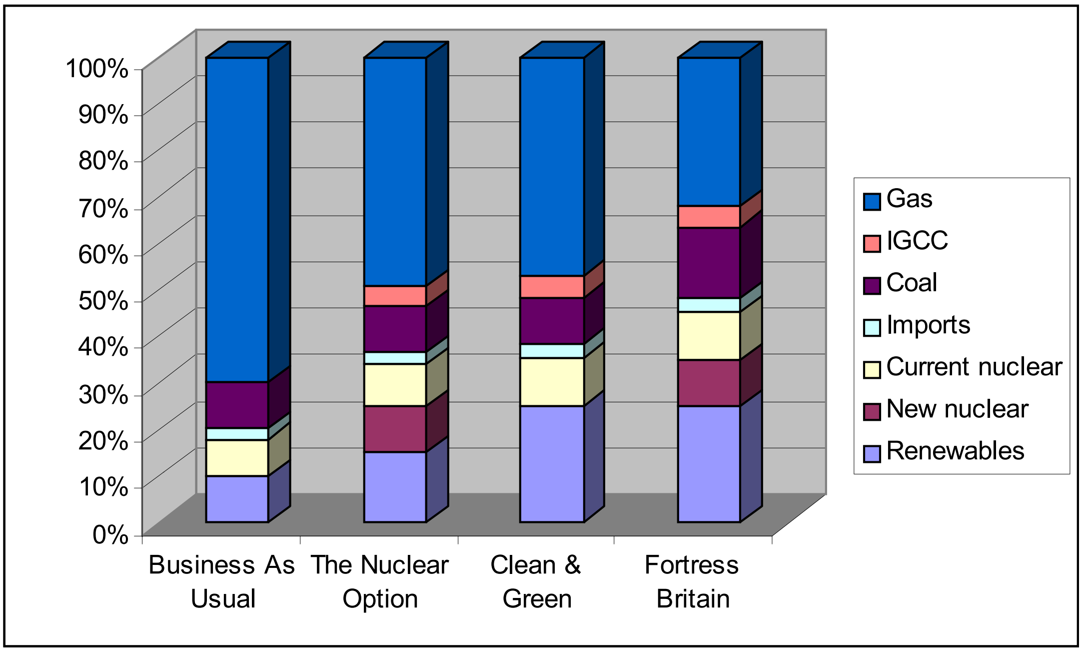
Once 2020 electricity demand has been quantified for each of the scenarios through assessing the impact of energy efficiency measures, the contribution to energy generation from different fuel and technology sources is estimated.

Renewables vary from providing 10 per cent of total electricity under the Business As Usual scenario to yielding 25 per cent of electricity under Clean and Green and

Fortress Britain; The Nuclear Option assumes a medium renewables installation figure of 15 per cent of electricity generated. (For a breakdown of the relative contributions of different renewable technologies to the renewables component of the scenarios, please see table 1.4 above.)

The 25 per cent renewables share assumed in both Clean & Green and Fortress Britain is 5 per cent more than the 20 per cent target proposed by the PIU in the Energy Review. However, there are good reasons for supposing this more ambitious target to be achievable. Numerous responses to the Government's energy White Paper consultation assented to the achievability of a 25 per cent target, including the Government's Sustainable Development Commission, IPPR's own response and (significantly) Future Energy Solutions, which undertakes assessment of the potential of renewable technologies for the Government. Moreover, there is increasing consensus that the Government's Renewables Obligation is proving to be a success story, suggesting that workable policy instruments exist with which to pursue a 25 per cent target.

Figure 3.5: All Scenario Fuel Mix Comparison
(n.b. total electricity demand levels vary across scenarios)



On *nuclear*, all scenarios assume that plant life extensions mean that existing nuclear will provide 40 TWh of electricity per year, a total contribution of between 8 per cent and 10 per cent depending on the electricity demand level in each scenario. Whilst one argument might maintain that plant life extensions would do no more than postpone real commitment to renewables, this report tends instead to the alternative view that plant life extensions would buy valuable time for the development of new technologies and for capital costs of low carbon technologies to come down. Furthermore, as discussed earlier, The Nuclear Option and Fortress Britain both also include a programme of new build of AP1000s, geared to contribute an additional 10 per cent of electricity in these two scenarios.

Coal continues to make a contribution in all four scenarios. As discussed earlier, the use of carbon dioxide capture and sequestration is ruled out. One corollary of this is that the overall contribution of coal is capped at much lower levels than today in order to comply with emissions reduction commitments: in the first three scenarios coal's contribution is 10 per cent of total electricity generated, rising to 15 per cent in Fortress Britain. All coal is assumed to be fitted with Flue Gas Desulphurisation in order to comply with the Large Combustion Plant Directive, which has the effect of raising coal's relative costs. Nevertheless, the continuing contribution of coal has the effect of enhancing security of supply, as well as of providing a buffer of capacity well suited to meeting peak demand. IGCC clean coal is assumed to make a contribution of 5 per cent or 18 TWh of electricity in all scenarios except the Business As Usual case, this is counted separately from traditional coal-fired generation.

All four scenarios assume that electricity *imports* are held more or less level with present figures, at 12 TWh (about 3 per cent) a year. Although it is entirely conceivable that more electricity interconnectors might be built between now and 2020, a conservative approach is employed so as not to risk understating the scale of the exercise.

Once the contributions from all of these sources have been totalled, the remainder of the net demand figure for each scenario is met by CCGT-derived *gas*. (In reality a proportion of this figure would be likely to be Open Cycle Gas Turbine derived, since OCGT is better suited than CCGT to peak generation; however, this is not differentiated since the difference between CCGT and OCGT has a negligible impact on cost, carbon emissions and gas import dependency.)

Given the differences in both demand and energy mix across the four scenarios, the contribution made by gas to fuel mix also differs significantly. Business As Usual sees fully 70 per cent of electricity generation derived from gas, whilst Fortress Britain manages to keep this figure down to just 32 per cent, slightly lower than today, by investing strongly in energy efficiency and alternative generation technologies. Interestingly, the level of gas in fuel mix is almost exactly the same for both The Nuclear Option and Clean and Green, at 49 per cent for the former and 47 per cent for the latter.

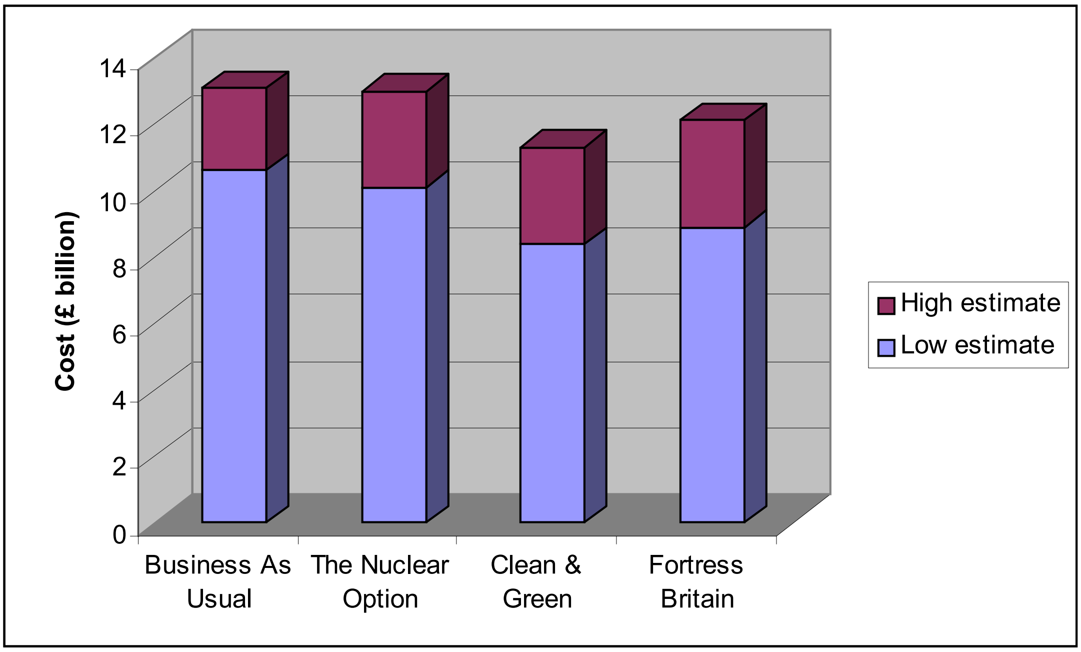
3. Quantifying generation costs

Once fuel mix for each scenario has been quantified as above, total generation costs are estimated for each one. This is achieved through a simple calculation of assuming the PIU's 2020 cost ranges in pence per kilowatt hour or the different energy technologies and then mutiplying these by the total TWh generated by each fuel source in the scenario.

The decision to use the PIU's estimates as the basis of the cost calculations in these scenarios is, of course, open to question. However, the PIU cost assumptions enjoy the advantage of being (a) geared towards 2020, the selected date for the scenarios set out in this report; and (b) comprehensive, in that they allow comparison between the full range of electricity generation technologies likely to be employed in 2020 fuel mix.

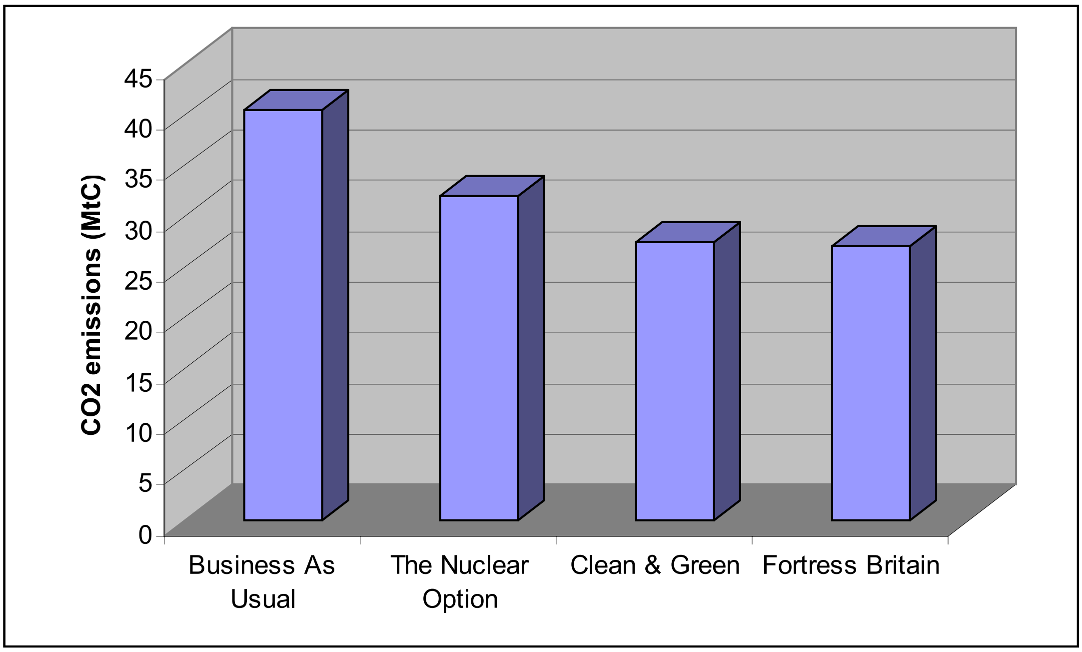
This approach is deliberately kept simple, and avoids the mutiplicity of other variables that would be incorporated into a more formal economic modelling exercise. (Not least among these is the obvious impacts that economic growth rates over the next eighteen years will have on electricity demand in 2020, together with other uncertainties such as 2020 gas prices). However, the intention of these cost estimates is not to provide a precise figure for the total cost of meeting UK electricity demand in 2020. Rather, it is to show the logical corollary of applying the PIU's cost estimates to different cases, and above all to provide a relative comparison between the four scenarios.

Figure 3.6: All Scenario Cost Comparison



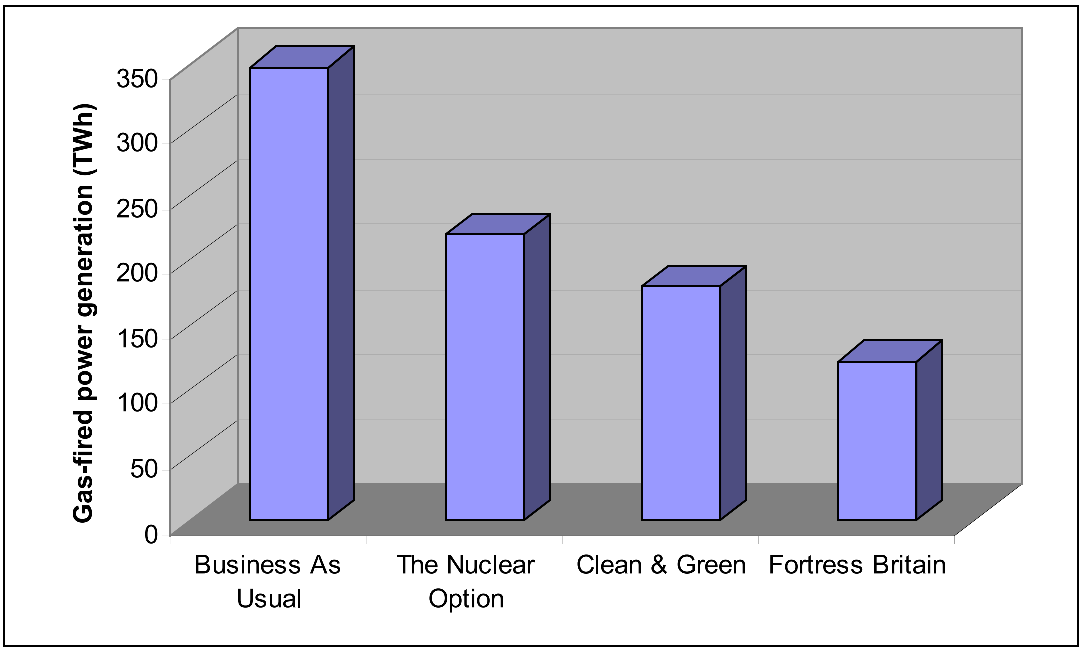
4. Quantifying carbon emissions and gas import dependency

Figure 3.7: All Scenario CO_2 Emissions Comparison



Finally, each scenario's projected CO_2 emissions and gas import dependency levels are assessed. The most important point to underline here is that the percentage increase or decrease levels for each scenario against a 1990 baseline are for the UK's electricity sector only, and hence do not take account of transport, industrial or direct heat emissions. In this regard, the projected figures can only give a partial guide as to how the UK would fare under future agreed international emissions reduction commitments (a point that is returned to in the Conclusion section). A note of the figures used for carbon intensity and load factors for each generation type is included in the *Assumptions* section.

Figure 3.8: All Scenario Comparison of Gas Share of Fuel Mix



A similar caveat applies to the estimate of gas import dependency, as here too the amount of gas used in electricity fuel mix does not represent the full UK total, mainly because of domestic and industrial gas consumption. Figures for gas use in these other areas is again held level across all four scenarios in order to provide a standard relative comparison of what levels of gas import dependency the UK might face in 2020.

3.2 Why 2020?

2020 is of course ultimately an arbitrary date to choose for the scenarios – what some might call a “suspiciously round number”. However, there were a number of reasons why 2020 seemed the most appropriate date for the scenarios:

- 2020 has been widely used as a benchmark date by other studies (not least the PIU Energy Review): retaining this date as the focus hence makes for easier comparison with other work in this field.

- By 2020, the UK will have lost most of the generation capacity currently earmarked for likely retirement, whether through planned decommissioning (as in the case of the Magnox reactors or the oldest coal stations) or because of the impact of Large Combustion Plant Directive, which will be fully in force by the end of 2015 at the latest.

- The technology cost of newer energy technologies such as renewables (or indeed new nuclear) is likely to diminish substantially beyond 2020; therefore, the two decades leading up to this date are likely to be the most challenging.

- In the case of renewables specifically, it also seems reasonable to assume that the next two decades will be the most challenging from the perspective of managing their intermittency, since energy storage systems are as yet still in their infancy.

It is worth pausing to remember once more that forecasting the future is a risky business at the best of times, and never more so than in the energy sector. Assessments of UK fuel mix in the 1980s assumed that gas-fired generation would play no significant role in electricity in 2000. One might also recall IBM's assessment in the 1960s that total worldwide demand for personal computers would be no more than six.

Accordingly, these scenarios accept the doomed nature of any claim to accuracy in their assessments, and most certainly do not present themselves as forecasts. In order to try to make the comparison between the effects of different policy decisions as clear as possible, many variables are deliberately excluded from the scenarios in order to try to minimise uncertainty. No attempt is made to forecast economic growth (apart from its implicit effect on electricity demand growth), to anticipate the technological innovations and unforeseen political events that will inevitably emerge in the next eighteen years (in particular the potential impacts of an emergent hydrogen economy on electricity demand levels and the shape and scale of future international commitments), or to go beyond the PIU's assessment of how the passage of time will help to reduce the capital costs of different energy technologies.

What the scenarios do claim is to make a little clearer the consequences of some of the competing policy options in the energy White Paper. In their different ways, the scenarios try to illustrate and quantify some of the rival visions of the energy future presented by different constituencies in the White Paper debate – and in particular, to render clearer what each of these competing visions might mean for the Government's stated energy policy objectives of security, diversity, competitiveness and environmental sustainability.

Table 3.1: 2020 Energy Scenarios

	1 Business As Usual		2 The Nuclear Option		3 Clean and Green		4 Fortress Britain	
Objective priorities								
Strong emissions reductions?	✗		✓		✓		✓	
Strong concern on gas imports?	✗		✗		✓		✓✓	
Strong competitive market element?	✓✓		✓		✓		✗	
Key technology decisions								
Commitment to renewables and energy efficiency?	✗		✗		✓		✓	
New nuclear build?	✗		✓		✗		✓	
Energy demand	**%**	**TWh**	**%**	**TWh**	**%**	**TWh**	**%**	**TWh**
Effect of efficiency measures	+28%	+112	+14%	+56	+2%	+8	+2%	+8
Effect of CHP	-3%	-12	-3%	-12	-6%	-24	-6%	-24
Net 2020 demand	+25%	**500**	+11%	**444**	-4%	**384**	-4%	**384**
Energy mix	**%**	**TWh**	**%**	**TWh**	**%**	**TWh**	**%**	**TWh**
Renewables	10%	50	15%	67	25%	96	25%	96
New nuclear	-	-	10%	44	-	-	10%	38
Current nuclear	8%	40	9%	40	10%	40	10%	40
Imports	3%	12	3%	12	3%	12	3%	12
Coal	10%	50	10%	44	10%	38	15%	58
IGCC	-	-	5%	18	5%	18	5%	18
Gas (CCGT)	**70%**	**348**	**49%**	**219**	**47%**	**180**	**32%**	**122**
Total	**100%**	**500**	**100%**	**444**	**100%**	**384**	**100%**	**384**
Energy costs	**p/kWh**	**Total (£bn)**	**p/kWh**	**Total (£bn)**	**p/kWh**	**Total (£bn)**	**p/kWh**	**Total (£bn)**
Renewables	2.2-4.0	1.1-2.0	2.2-4.0	1.5-2.7	2.2-4.0	2.1-3.8	2.2-4.0	2.1-3.8
New nuclear	3.0-4.0	-	3.0-4.0	1.3-1.8	3.0-4.0	-	3.0-4.0	1.1-1.5
Current nuclear	2.5-3.0	1.0-1.2	2.5-3.0	1.0-1.2	2.5-3.0	1.0-1.2	2.5-3.0	1.0-1.2
Natural gas (CCGT)	2.0-	6.7-	2.0-	4.4-	2.0-	3.6-	2.0-	2.4-

	2.3	8.0	2.3	5.0	2.3	4.1	2.3	2.8
Imports	2.0-3.0	0.2-0.4	2.0-3.0	0.2-0.4	2.0-3.0	0.2-0.4	2.0-3.0	0.2-0.4
Coal	2.5-3.0	1.3-1.5	2.5-3.0	1.1-1.3	2.5-3.0	1.0-1.1	2.5-3.0	1.5-1.7
IGCC	3.0-3.5	-	3.0-3.5	0.5-0.6	3.0-3.5	0.5-0.6	3.0-3.5	0.5-0.6
Total costs	**£10.3-13.1 bn**		**£10.0-13.0bn**		**£8.4-11.2 bn**		**£8.8-12.0 bn**	
	1990 % +/-	**MtC total**	**1990 % +/-**	**MtC total**	**1990 % +/-**	**MtC total**	**1990 % +/-**	**MtC total**
Electricity sector CO_2 emissions	**-25%**	**40.5**	**-41%**	**32.0**	**-49%**	**27.4**	**-50%**	**27.0**

3.3 Conclusions

Before becoming embroiled in the relative merits of different technologies, the first and most important conclusion to note is that the scenarios suggest it is possible to remain on track for complying with a 60 per cent UK emissions reduction commitment by 2050 whilst ensuring security of supply and without compromising affordability. In short: **it can be done**.

However, **action taken on the energy efficiency front will be of critical importance to achievement of the Government's objectives** of affordability, sustainability and security of supply. Overall, the most significant variance in total energy costs, CO_2 emissions and gas import dependency between the four scenarios is accounted for by total electricity demand levels. This finding gives some support to the PIU's emphasis on the overriding importance of effecting demand reductions. If the Government can show the requisite political will to intervene to overcome market failures on energy efficiency, then it will make its job of achieving secure, affordable and sustainable energy for consumers very much easier; but it must not ignore the fact that **the scale of change demanded is nothing short of revolutionary**.

On the question of security of supply, levels of **gas import dependency** are broadly comparable between The Nuclear Option and Clean and Green (with gas's share of fuel mix at 49 per cent and 47 per cent respectively, but (as implied by the name) significantly lower under Fortress Britain, at 32 per cent. The business as usual case shows much higher gas dependency at 70 per cent of electricity fuel mix.

On **CO_2 emissions**, it could reasonably be assumed as a rule of thumb that in 2020, electricity sector CO_2 emissions would need to be approximately 40 per cent below 1990 levels in order to remain on a linear trajectory towards the Royal Commission's suggested 2050 target of a 60 per cent reduction in overall CO_2 emissions. (The Government's UK Climate Change Programme argued that electricity sector emissions would need to be 29 per cent below 1990 levels by 2010 in order to compensate for slower progress in other sectors of the economy.) On the basis of this rule of thumb, The Nuclear Option, Clean & Green and Fortress Britain would hit the required level of emissions reductions; the Business As Usual scenario would miss the target by a substantial margin. Whilst it should be noted that the assumed 2020 target of a 40 per cent reduction in CO_2 emissions takes no account of the potential to meet targets through international emissions trading, the key point is (again) that **the most important determinant of whether climate targets are**

achieved has less to do with fuel mix and more to do with whether the Government can catalyse real progress in effecting reductions in demand for electricity.

There is broad similarity in **costs** between the different scenarios, especially given the different levels of energy demand assumed from one scenario to the other. It is also interesting to note, though, that Fortress Britain (which includes new nuclear) is slightly more expensive than Clean and Green (which does not), despite the fact that demand is level across the two scenarios at 384 TWh. This is principally because the new nuclear and extra coal in Fortress Britain are more expensive than the higher levels of natural gas used in Clean and Green.

The nuclear question

Given that Fortress Britain provides substantially lower levels of gas import dependency than Clean and Green at only slightly higher cost, it might seem to make sense for the Government to pay slightly more if this will achieve substantially improved performance on its security of supply and environmental objectives. Why not take a both/and approach to renewables and nuclear rather than an either/or approach, and hence manage risks while increasing diversity?

This seems at first approach to be a hard question to answer for environmentalists. Of course, an environmentalist might reply that instead of building a new series of nuclear power stations, it would make more sense to spend the money on even more renewables, or on energy efficiency. However, this argument might well not convince all sceptics. Many of them are unsure of the feasibility of the PIU's proposed energy efficiency targets, and would hence raise eyebrows at a plan that counted on going *beyond* the PIU's targets. Likewise, they would probably argue that increasing renewables from 25 per cent of fuel mix to 35 per cent would incur much higher incremental costs, given the increased price of managing intermittency for higher levels of renewables installation. So the question still holds: even assuming that the PIU's energy efficiency target and a 25 per cent renewables target are achieved, why not build new nuclear too – especially if it will reduce emissions and gas dependency even further, and have no more than a marginal effect on costs?

However, there are three principal factors that mitigate against new nuclear which represent elements of environmental sustainability and security of supply and diversity that have not yet been considered.

The first is that whilst nuclear might be able to reduce CO_2 emissions further than would be possible under ambitious 2020 targets for renewables and energy efficiency, **there is no current basis on which to assume that the problem of radioactive waste management will have been solved by 2020**. As noted earlier, advocates of nuclear new build are technically correct to say that new nuclear reactors would produce far lower volumes of waste than earlier reactors such as the Magnox series. Yet this claim is not the whole story. A series of AP1000s would produce less Low Level Waste (LLW) than a Magnox reactor, it is true; but the level of High Level Waste (HLW) would be virtually unchanged. In this sense, it is seriously misleading to claim (as many nuclear advocates do) that the real radioactive waste problem is a Cold War legacy and that a new series of reactors would barely add to the existing stockpile. Rather, a new reactor series would represent a wilful decision to produce yet another generation of High Level Waste, at the same volumes as with existing reactors, in the continuing absence of a viable disposal route.

Second, there are also security considerations other than gas import dependency that mitigate against new nuclear. The first of these is related to **the new, post-September 11 security environment**. Whilst this report argues that there are good reasons for extending the life existing nuclear plant by some years in order to buy a little more time to achieve the transition to a low carbon economy, this is not to say that it therefore also makes sense to recommit to the nuclear generation route for another thirty to forty years into the future. A nuclear power station is inevitably, a tempting target for terrorist attack. This is a good rationale for having as few of them as possible; and for avoiding reliance on them as much as is practicable, in case future heightened security tensions mean that reactors need to be shut down. (Whilst any reactor could be a terrorist target, one that is online would produce far more damage if, say, hit by a plane than one that was offline or undergoing decommissioning.)

A series of new nuclear reactors would mean more targets and reduced flexibility for switching nuclear off temporarily or permanently if security reasons demanded it. Indeed, a more sensible approach to security considerations in energy policy would be to make haste for a more decentralised energy system (with high levels of renewables and CHP), since a more distributed generation system has fewer 'concentrations of consequence' and is thus harder to disrupt by striking at a small number of high-value targets.

The third issue with a new programme of nuclear build is that **high reliance on a single technology type could reduce security of supply**. Relying on a series of AP1000s for 10 per cent of the UK's electricity would leave it highly reliant on AP1000 technology – indeed, constructing a series of reactors of exactly the same design as each other is a central component of the nuclear industry's cost case. Yet even existing nuclear reactors have frequently continually unreliable in recent months. It would be rash to assume on the basis of no actual evidence that a series of AP1000s would prove more reliable, and as we saw earlier, the PIU has suggested that the nuclear industry's projections of plant availability might be optimistic. In a worst case scenario, what would happen if a fault were discovered that led to the suspension of generation by the entire AP1000 reactor series, leading to the temporary loss of 10 per cent of the UK's generation capacity at a stroke? As Tokyo residents (who were recently told by the Tokyo Electric Power Company that 12 out of 15 of the company's nuclear reactors are out of service, and that the lights may not stay on) can attest, diversity means not putting all your eggs in one basket.

In conclusion, then, although building a new generation of nuclear reactors would reduce emissions and gas import dependency, this does not mean that it would necessarily increase environmental sustainability or overall security of supply: indeed, the opposite might be the case.

In this sense, a key finding of the research is that the optimal scenario for achieving the Government's stated objectives in energy does not contain new nuclear build, but instead manifests a strong commitment to both renewables and energy efficiency.

3.4 The scale of the challenge ahead

However, as a concluding note to this report, it is also hugely important to emphasise the level of political commitment that will be needed in order to realise the vision set out in Clean and Green scenario.

Whilst this report agrees with those commentators that argue that there are good reasons for avoiding reliance on a new generation of nuclear reactors, choosing not to pursue new nuclear will also require a deep and sustained commitment to ensuring that renewables and (especially) energy efficiency targets are actually met.

The historical record in this area is not encouraging. On the basis of current policies, the UK is not currently on course to meet either its 2010 domestic target of a 20 per cent reduction in CO_2 emissions or its commitment to source 10 per cent of electricity from renewable sources by the same year. Nor will the UK meet its interim target of 5 per cent of electricity from renewables by 2005, or the Government's 2010 CHP target of 10,000 MWe of good quality CHP. Market penetration of energy efficiency technology remains low by European best practice standards, and rates of renewables installation are among the worst in Europe.

Although the UK can fairly at present lay claim to having played a strong leadership role on international climate policy, its continuing ability to do so rests in large part on whether the Government can demonstrate its ability to deliver domestically on internationally agreed commitments. With Kyoto, the Government was lucky: the emissions reductions required had already been largely achieved as a result of the fortunate happenstance of the dash for gas in the 1990s. This handy 'get out of jail free' card will have been played by the time future commitments have been agreed – even as worsening climate damages imply an increasingly urgent need to make more demanding global emissions reductions.

A brief foray into international climate change policy

As can be seen throughout this report, the days in which energy policy was a purely national level endeavour are well and truly over. The timing and extent of European gas liberalisation is of crucial importance to determining the UK's security of gas supply. Demand for energy technologies in other countries will have a strong impact on determining their capital costs in the UK. And the UK also has the opportunity to become a global leader in the emerging market for low carbon technology.

Above all, though, it is the worsening global damages outlook on climate change and the inevitable competitiveness issues raised by the need to reduce global emissions that provide the clearest reason why the international dimension of energy policy matters. In the not too distant future, *all* countries (including developing countries) will need to engage in reducing their emissions: action by the UK alone, or even Europe, would not be sufficient. Any transition to a low carbon economy must eventually be a multilateral endeavour. It is therefore of critical importance that the Government continues to play a leadership role in developing the next generation of international climate change policy beyond Kyoto.

Yet ensuring that climate policy is a multilateral endeavour can also help the UK to achieve its climate change targets. The scenarios presented in this paper deliberately take a conservative approach in that they do not assume that the UK will be able to use international emissions trading to help meet its targets. (Although the recently agreed European emissions trading scheme will offer countries in the EU a way to trade towards meeting their targets from 2005 onwards, there may be a constrained supply of permits if experience to date is any indication: only the UK, Germany and Luxembourg are on course to meet their Kyoto targets, and will hence have permits that they could sell up to 2012.) If the UK *did* enjoy the ability to use emissions permits purchased abroad towards meeting its targets, then its burden would be very much easier. There would be a clearer signal to the market on the desirability of low carbon technologies; at the same time, a higher level of coal could be retained in fuel mix (improving both security of supply and the level of generation capacity suited to meeting peak demand) without compromising overall environmental integrity.

The question of what international policy structure will follow in Kyoto's wake after the end of the 'First Commitment Period' in 2012 is especially germane to the Government's energy White Paper because of a coincidence of timing, for 2003 is also the year in which countries will start to debate future commitments at the United Nations. Accordingly, the energy White Paper offers a valuable opportunity for the Government to begin shaping the emerging debate.

The Royal Commission made a clear and emphatic recommendation to the Government that in its view, the best prospects for success at international level were offered by the 'Contraction & Convergence' (C&C) policy framework for international climate change policy as the basis of future negotiations; the PIU, for its part, observed that C&C was consistent with the 'leading' approach to climate policy that the Government has expressed its intention to play.

C&C is a simple global policy framework that would work as follows:

1. All countries would agree a safe global ceiling on concentrations of CO_2 in the atmosphere (such as 450 parts per million), and then calculate a global emissions budget consistent with reaching it.

2. On the question of national emissions allocations, C&C recognises that developing countries will only accept emissions targets under an emission regime that is equitable. Accordingly, national emissions entitlements would converge from current emissions levels (which are proportional to national income) to an allocation based instead on population, by an agreed 'convergence date' (such as 2040).

3. Full international emissions trading would be allowed so that countries could meet their targets flexibly and at least cost. (The existence of a global price on carbon would also provide each country with a clear incentive to reduce dependency on fossil fuels as quickly as possible, in order to reduce the number of emissions permits that have to be bought – or indeed increase the number of surplus permits to sell.)

Although it has been widely forgotten since the publication of the Royal Commission's report on energy, the widely discussed UK target of reducing CO_2 emissions by 60 per cent by 2050 is in fact derived from a scenario applying C&C (in the Royal Comission's example, with a concentration target of 550 parts per million and a convergence date of 2050).

The most important distinction between C&C and the approach taken by Kyoto is that C&C starts with the question of what global level of emissions is safe, and *only then* turns to the secondary question of how much CO_2 each country is permitted to emit. Kyoto, by contrast, began by determining national entitlements; assessing the overall level of global emissions came at the end of the process rather than at the beginning.

Interestingly, C&C meets the stated position of the Bush Administration on climate change where Kyoto does not – even though it enjoys very much higher environmental integrity than Kyoto. President Bush has consistently stated that the US desires a global policy that both includes quantified targets for developing countries, which C&C includes but Kyoto does not. Bush has also been equally consistent in emphasising that international climate policy should be consistent with the goal of stabilising atmospheric concentrations of greenhouse gases in the atmosphere (to the extent of actually including this objective in the US National Security Strategy in 2002); again, C&C offers this through its formal atmospheric concentration target where Kyoto does not.

Conclusion

For both domestic and international reasons, it is important that the Government goes beyond target setting and (as in other areas of policy) shifts its focus to delivery. It will not be easy; indeed, to realise the vision of a Clean and Green future will require a revolution in political commitment as well as in action on the ground.

Yet there are excellent reasons for the Government to make this commitment. Climate change will be the most pressing environmental challenge of the 21st century. Insurance industry data shows economic damages from extreme weather events growing at ten percent per annum, at two to three times the rate of economic growth. There can be few issues that can lay such a weighty claim to the attention of Governments.

Yet there is also an opportunity side to the situation. If fossil fuel combustion and economic growth have often seemed inseparable over the past hundred years, the next century will see a profusion of business opportunities arising from the need to decouple the two, both in the manufacture of new technologies and in the prospect of a vast new global emissions trading market.

The Government's energy White Paper could in retrospect be seen as the UK's first clear statement of intent to be a world leader in the new global low carbon economy, as a concrete example of what the Blair doctrine of global interdependence means in practice, and of how global governance can link seamlessly to effective delivery at the national level. The UK has everything to play for. The Government must use the energy White Paper to rise to the challenge.

Summary of recommendations

- The Government should make clearer the order of priority applying to its four different energy objectives by synthesising them into an overall aim of "the secure transition to a low carbon economy at least cost"

- The Government must make delivery of the PIU's proposed energy efficiency target – a 20 per cent improvement by 2010 and another 20 per cent by 2020 – a key priority, since improved energy efficiency performance will reduce costs, emissions and gas import dependency.

- The Government should commit to a 2020 target of 25 per cent of electricity to come from renewable sources.

- Achievement of both energy efficiency and renewable targets will require a revolution in levels of political commitment. There are formidable barriers to the roll-out of a low carbon economy; overcoming them will be a national challenge.

- The report argues against new nuclear build because:

    - Committing to a new build programme would leave the UK vulnerable to plant shutdowns potentially affecting the whole series of reactors;
    - Nuclear installations are especially vulnerable to attack in the changed security environment
    - There is a continuing lack of progress towards a solution to Britain's long term radioactive waste management

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