A bright future

Friends of the Earth's electricity sector model for 2030

March 2006

Friends of the Earth

Friends of the Earth inspires solutions to environmental problems, which make life better for people

A bright future

March 2006

This report was written by Robin Webster and Germana Canzi, with editing by Adam Bradbury; modelling work was carried out by Neil Crumpton, Edwin Wall, Nick Rau and Mike Childs, all of Friends of the Earth. Lesley James provided further comments.

Friends of the Earth received comments from 12 experts, of whom seven were from industry, one from a consulting firm and four from the academic sector. Some reviewed the whole model in detail, others focused on specific aspects. We have tried to incorporate most of their comments. Those agreeing to be mentioned include: Dr Dave Elliott of Open University, Robert Gross of Imperial College, Bridget Woodman of Warwick Business School, Dr Mike Farley of Mitsui Babcock, Graham Meeks and Gaynor Hartnell of the Renewable Energy Association. Ian Calvert and Syed Ahmed of the Combined Heat and Power Association (CHPA) provided input with regard to the future scenarios for CHP based on detailed work commissioned by the Government.

Friends of the Earth wishes to thank the reviewers for their time and help. Participation in the review does not necessarily mean endorsement of all the findings or recommendations in this report.

Full data sets and graphs illustrating the model can be found in *Friends of the Earth's electricity sector model for 2030: Data*, available at http://www.foe.co.uk/resource/reports/bright_future_data.pdf

For further information, contact:
Germana Canzi, Neil Crumpton or Nick Rau at Friends of the Earth.

Contents

Executive summary 3

1.1 The Energy Review 4

1. Climate change and UK Government policy 4

1.2 The power sector 5

1.3 Will the lights really go off? Security of supply 5

2. The model 6

2.1 What the model does 6

2.2 Policy futures and fuel mix scenarios 7

2.3 Results 8

3. Conclusions and recommendations 11

Annex 1: Assumptions and further details about the scenarios 13

Technology estimates 14

References/notes 16

Executive summary

The Prime Minister Tony Blair announced in November 2005 that there would be a review of the Government's energy strategy, and a formal consultation was launched in January. The review investigates how the UK should meet its future energy needs, and specifically asks whether or not the UK should build a new generation of nuclear power stations. This report and the accompanying model demonstrate that Britain's electricity needs can be met and that we can make massive cuts in carbon dioxide without resorting to nuclear power at the same time as reducing our use of fossil fuels, including natural gas.

Burning fossil fuels to generate electricity is a highly polluting – and often inefficient – process that releases large amounts of gases into the atmosphere. The electricity sector currently produces 37 per cent of the world's greenhouse gas emissions through the burning of fossil fuels.

Some argue that we cannot meet our climate and energy policy goals without constructing new nuclear power stations. Some have gone as far as saying that the lights will go out. Friends of the Earth's model has been reviewed by academics and representatives from industry. It illustrates that we can fulfil the need for electricity supply and reduce emissions from the sector in line with Britain's long-term climate change targets without embarking on a new nuclear programme.

The aim of this modelling exercise was to create realistic and transparent scenarios for future development of the energy sector, using credible industry assumptions concerning the development of renewable technologies and the impact of policy on current major electricity generation methods. In many cases industry assessments have been adjusted downwards, in order to make sure our estimates were conservative enough.

As a result, Friends of the Earth has identified six possible outcomes that would help reduce emissions by large amounts and help achieve secure energy supplies. **In all six scenarios, demand was met, and the electricity sector achieved a 48-71 per cent reduction in emissions of carbon dioxide (from 1990 levels) by 2020** in the electricity sector without needing to replace decommissioned nuclear power stations with new ones.

Under all but one of our scenarios natural gas consumption by the power-generating sector would see only marginal growth with subsequent decline.

Our model does not include carbon capture and storage (CCS) on a large scale – only two pilot projects. However, Friends of the Earth does think this may have a role to play in the future, under certain conditions. Meanwhile, it may be a sensible insurance policy to ensure all new and upgraded fossil-fuel plants are built as "capture-ready". This could help meet emissions reduction targets in case some of the other technologies in the model do not grow as fast as needed.

The model is transparent, and is made publicly available for anyone who wants to understand how Friends of the Earth has reached its conclusions or use it to create alternative scenarios.

1. Climate change and UK Government policy

The Labour Government has pledged in three successive election manifestos (in 1997, 2001 and 2005) to reduce carbon dioxide emissions to 20 per cent below 1990 levels by 2010. It has also pledged to achieve a long-term cut of CO_2 emissions of 60 per cent by 2050. On the international stage, Tony Blair has taken a position of leadership on the issue, prioritising work on climate change at the G8 Summit in Gleneagles in July.

Unfortunately the commitment to the issue seen in international negotiations has not been reflected in actions at home. Since 1997 carbon dioxide emissions in the UK have risen by 5.5 per cent and the UK is no longer on track to meet its 2010 target.[1] The publication of the Climate Change Programme Review setting out the Government's strategy was originally due to be published in mid 2005. It has been repeatedly delayed. Policy on climate change has remained piecemeal and contradictory.

Friends of the Earth is running a campaign, The Big Ask, for the introduction of a new law that would require the Government to monitor the amount of carbon dioxide being released annually by the UK and reduce those emissions by 3 per cent every year.[2] Emissions reductions will have to come from many different sectors across the economy – from industry to transport, aviation to housing.

1.1 The Energy Review

Over recent years the UK Government has produced a series of reports, including publications from the DTI, the Royal Commission and an Energy White Paper[3], investigating how it is going to meet the energy challenge. All of these investigations pointed to the enormous, and currently largely untapped, potential within the renewable energy industries for supply, and promotion of energy-efficiency measures for reducing demand.

Despite the fact that there has not been enough time to implement the recommendations of these reports, and that slow implementation has been largely a result of Government inaction, Tony Blair announced on 29 November 2005 that there would be a review of the Government's energy strategy. The review, he said, would investigate how the UK should meet its future energy needs, and specifically ask whether or not the UK should build a new generation of nuclear power stations.

On 23 January the Government announced a formal public consultation on UK energy policy. Although the Review's stated intention is to look at the energy system as a whole, including transport and heating, the underlying debate is on the electricity generation sector – which is why Friends of the Earth has chosen to issue this energy model on the electricity sector. Friends of the Earth frequently makes recommendations to the Government on steps to be taken to reduce emissions in other sectors as well.

1.2 The power sector

Burning fossil fuels to generate electricity is a highly polluting – and often inefficient – process that releases large amounts of gases into the atmosphere.[4] The power sector currently produces 37 per cent of the world's greenhouse gas emissions through the burning of fossil fuels. In addition, global energy needs may rise very rapidly in the absence of policies to keep this growth under control through an ambitious deployment of energy-efficient technologies.[5]

The electricity market has been through many changes over the years. Twenty years ago the UK's electricity was generated and supplied by just one Government-controlled company. In the late 1980s the sector was completely overhauled by liberalisation policies.[6]

In the 1990s the power sector swung away from coal power and towards gas as a result of availability of North Sea gas and Government policies. Fortuitously for the Labour Government, this "dash for gas" resulted in significant reductions in greenhouse gas emissions and emissions of other pollutants, as gas-fired generation is far less carbon-intensive than coal-fired.

More recently, the trend appears to have reversed. High gas prices, relatively lower prices of imported coal and weakness of other environmental policies such as the emissions trading scheme, meant that coal use in the power sector, and with it emissions, have started to rise again.

Some say the planned closure of decommissioned nuclear power stations and many old polluting coal-fired power stations creates a potential "generating gap". However, this can also be seen as a very significant investment opportunity for companies that can develop new energy generating (and energy conservation) technologies and export them to the rest of the world.

1.3 Will the lights really go off? Security of supply

Some argue that we cannot meet this challenge without constructing new nuclear power stations. Some have gone as far as saying that the lights will go out. Others have claimed we will become vulnerable to countries like Russia that are large exporters of natural gas. At the moment the UK is importing small amounts of natural gas, but this amount is set to increase. Although gas will come from several sources, the UK's chief supplier of piped gas for the coming decades will be Norway, which has recently signed a long-term supply contract with the UK. New import terminals and pipelines are being built to allow a wide diversity of sources of gas in the future.[7]

It is also worth noting that the UK does not have domestic supplies of uranium, and that large volumes of oil and coal are imported as well.

The UK is going to have to import natural gas in the future no matter what happens in its electricity fuel mix, because natural gas is used in large quantities for heating. So, what can be done? Making sure our homes and offices are better insulated would be quicker and cheaper than building nuclear power stations. In the electricity sector the key priority is making sure that the natural gas we do use, we use in the most efficient way possible – and whenever possible, we also use it to produce heat (for example through the use of Combined Heat and Power, CHP).

Friends of the Earth's model for the electricity sector up to 2030 illustrates some options on how we could fulfil the need for electricity supply and reduce emissions from the sector without a new nuclear programme, a technology that creates very serious problems of security, nuclear proliferation, waste disposal, costs and delays for construction, decommissioning, etc. Friends of the Earth has published separate briefings about nuclear power and its drawbacks, so this issue will not be dealt with in detail here.[8]

2. The model

Friends of the Earth published a report and a mathematical model in *Tackling electricity without nuclear power* in 2003. This report and the accompanying model update and improve on that work. In publishing this new model, we have also carried out consultations with representatives from industry and academia.

The first key finding of this work is that it is possible to meet demand and achieve a 48-71 per cent reduction in carbon dioxide emissions in the electricity sector by 2020 without needing to replace decommissioned nuclear power stations.

The second key finding is that in under all but one of our scenarios natural gas consumption by the power-generating sector would see only marginal growth with subsequent decline. The heat sector would also have a further large potential for reducing emissions and gas use further through energy efficiency policy, although this potential cannot be included in this model which is only about the electricity sector.

2.1 What the model does

Friends of the Earth has created this model in order to investigate the potential for reducing emissions of carbon dioxide while maintaining supplies of electricity up to 2030, without the need to replace old nuclear power stations. The aim of this exercise was to use credible assumptions made by industry concerning the development of different technologies and the impact of policy on current major power generation methods to create realistic scenarios for future development of the energy sector. In many cases industry assessments have been adjusted downwards in order to make sure our estimates and assumptions were conservative enough.

As a result Friends of the Earth has modelled six future scenarios to identify the range of possibilities in terms of total demand, moves towards gas or coal generation and progress towards actual deployment of alternative energy sources and energy conservation technologies. The scenarios identified the scale of carbon dioxide emission reductions we considered possible and the scale of implementation of various technologies to achieve such emission reductions and achieve secure energy supplies.

The model is publicly available for anyone who wants to understand how Friends of the Earth has reached its conclusions or use it to generate alternative scenarios. Different annual terrawatt-hour per year (TWh/yr) outputs can be typed into the "demand" and "technology" rows and the resultant CO_2 emissions will be calculated automatically – as would any under- or over-generation for that year. The specific emission factors can also be varied to test sensitivity of the figures assumed by Friends of the Earth.

Further information on assumptions and methodologies used in the model can be found in Annex 1.

2.2 Policy futures and fuel mix scenarios

Using this model Friends of the Earth has selected scenarios that show what could be achieved over the next 25 years by Government policy that is genuinely committed to providing a regulatory framework aimed at reducing emissions from the power sector.

First, we gathered assessments from a range of sources on the potential growth for renewables and CHP.

Second, we investigated two possible policy futures, illustrating two different rates of implementation of policy encouraging the reduction of emissions through energy efficiency, and investment in renewable energy and in CHP.

The two policy futures were:

- **"good progress"** – this is what could be achieved if policy development showed good progress and all market conditions were favourable.
- **"slow progress"** – this is what happens if policy implementation is less effective, though still reflective of some commitment from Government. This outcome accepts that there are significant uncertainties. Even with good commitment from Government problems may occur in putting all the relevant measures into practice because of adverse market conditions, for example.

We chose not to model "business as usual" scenarios, because there are plenty such scenarios already available against which to compare our work, including the DTI's emission projections and many industry scenarios.

Third, we used the model to identify the likely scale of outstanding demand caused by the phase-out of much of the existing nuclear and coal stations.

Fourth, we identified three possible scenarios where, in addition to the growth of renewable energy and energy conservation technologies, there would be a growth of a different mix of natural gas and upgraded or rebuilt coal-fired power stations. In all scenarios new technologies are used to reduce emissions as much as possible from fossil-fuel generation.

Encouraging a switch from coal to gas in the power sector is a proven way to reduce emissions, and the regulatory environment of the next few years should continue to promote this shift, for example through the emissions trading scheme which should make it more expensive to burn coal. However, in a liberalised market with fluctuating energy prices it is not possible to predict with absolute certainty to what extent market conditions will favour gas or coal-fired generation.

The three alternative fuel-mix scenarios for meeting the outstanding demand are:

- **"gas":** in this scenario, old coal-fired stations and nuclear stations are replaced mainly by the construction of the next generation of advanced gas power stations with increased efficiencies.
- **"mix":** here, outstanding demand is met by some new advanced gas power stations. In addition to these, the market develops coal-fired power stations that are completely upgraded with the newest technologies to improve efficiency and that allow for co-firing 20 per cent biomass.
- **"coal":** in this case a new generation of coal plants or upgraded ones are built on the sites of the old, inefficient ones, including an upgraded plant at Drax and new advanced coal. Gas-fired generation grows far less than in the other scenarios, and gas is almost solely burnt in efficient CHP schemes of various sizes.

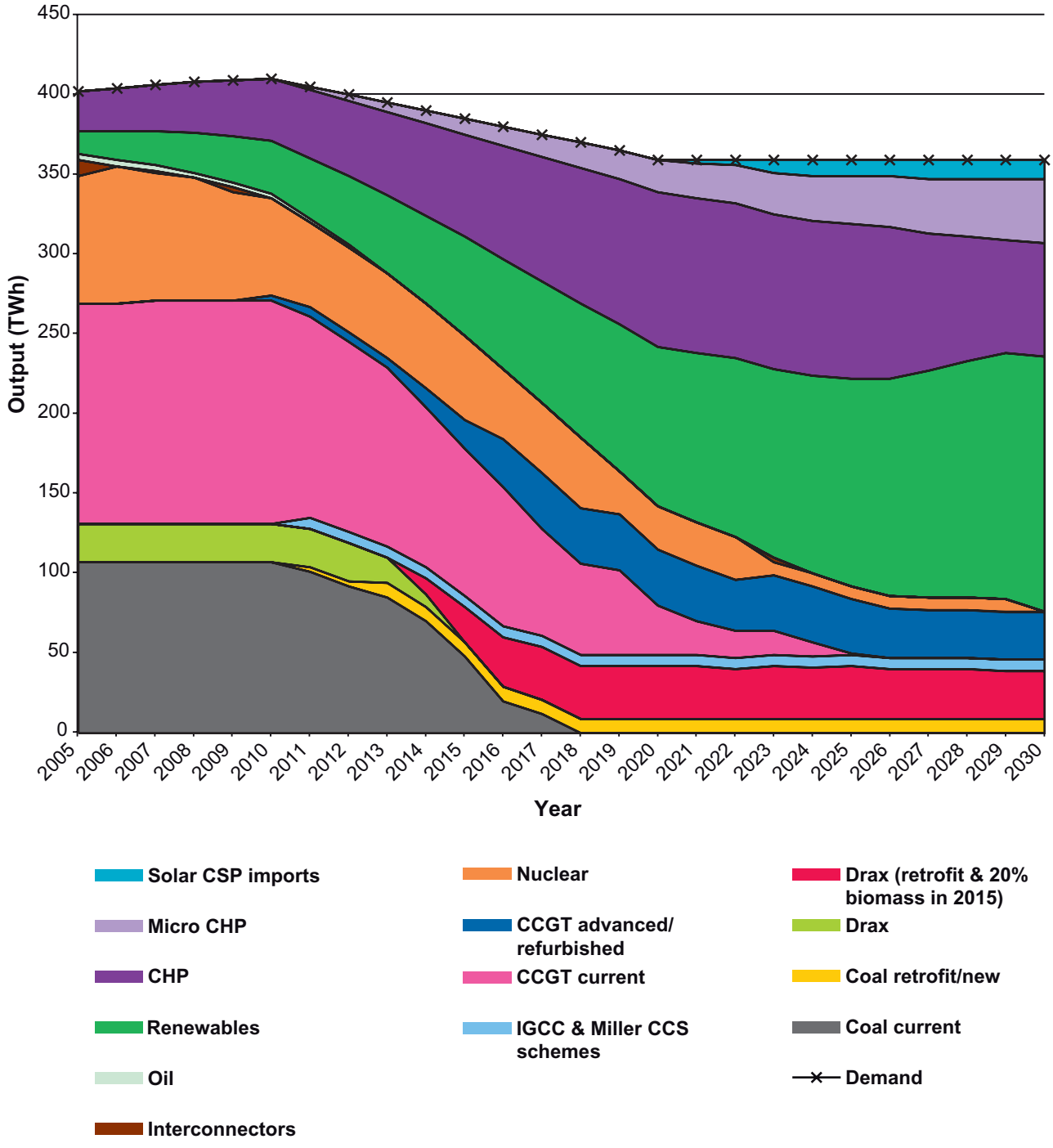
2.3 Results

In all six scenarios electricity demand is met and emissions of CO_2 are reduced by 2020 by at least 48 per cent ("slow coal" scenario) from 1990 levels, reaching 71 per cent in the "good gas" scenario.

Scenario	Emissions reductions by 2020 (per cent)	Emissions reductions by 2030 (per cent)
"good gas"	71	77
"slow gas"	59	64
"good mix"	67	75
"slow mix"	53	57
"good coal"	65	73
"slow coal"	48	53

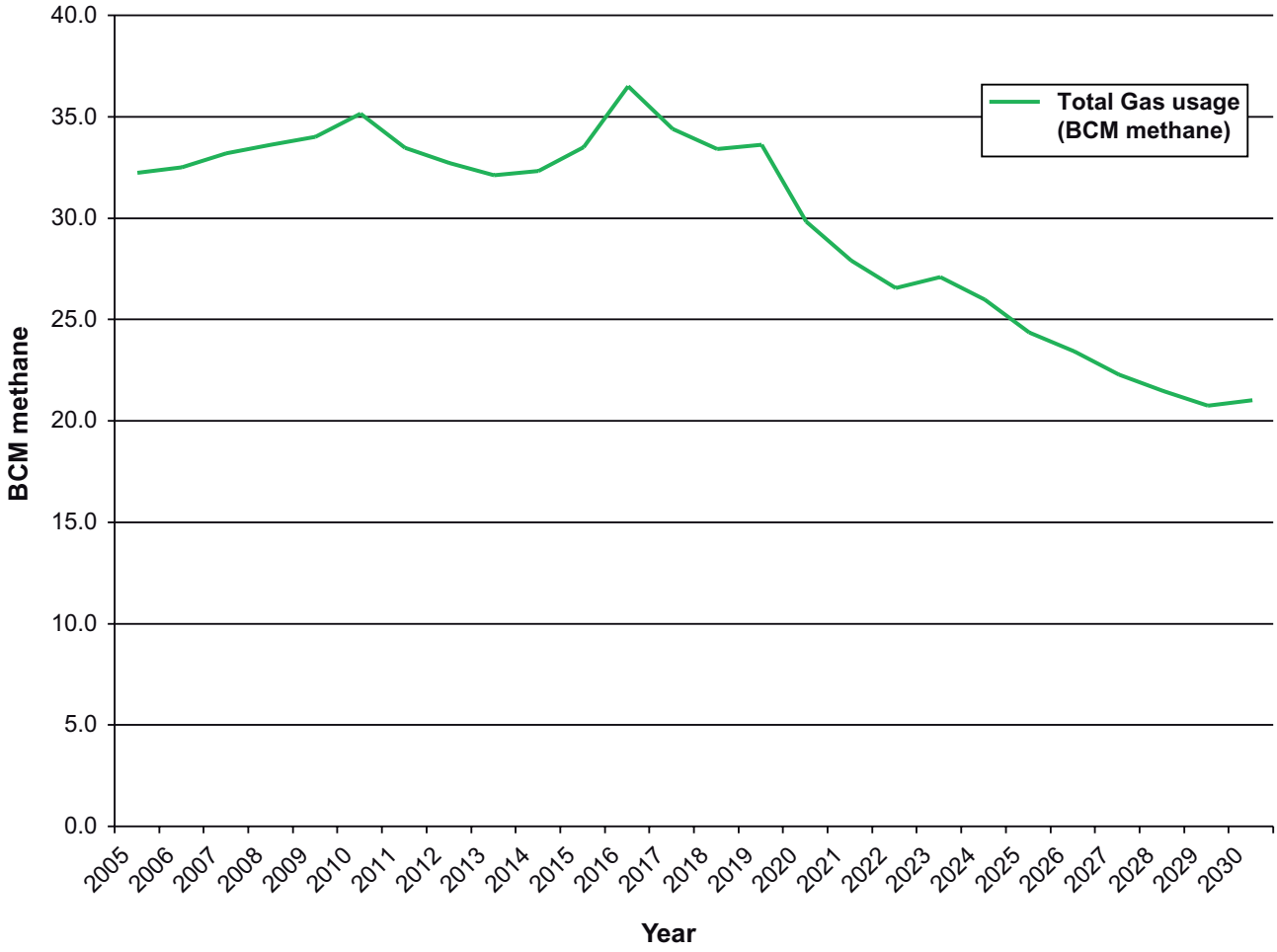
In all but one of the scenarios ("slow gas") after modest growth, gas demand is stabilised and then begins to decline leading to reductions in gas consumption in electricity generation from present levels.

“good mix” scenario



The above graph represents the changing electricity generation mix according to our “good mix” scenario 2005-2030.

"good mix" scenario: gas consumption (billion cubic metres, BCM, methane)



The above graph represents the declining consumption of gas in electricity generation according to our "good mix" scenario 2005-2030.

More details on results and assumptions can be found in Annex 1.

Full data sets and graphs illustrating the model can be found in *Friends of the Earth's electricity sector model for 2030: Data*, available at http://www.foe.co.uk/resource/reports/bright_future_data.pdf

3. Conclusions and recommendations

This model illustrates that there is large potential to reduce emissions in the electricity sector without relying on uneconomic and unsafe nuclear power. Whatever the energy mix, the UK can easily move away from nuclear power without suffering a supply shortage, as long as efforts are made rapidly to promote other technologies.

The areas where we need more effective policies are for CHP (both large-scale and small-scale) and energy efficiency. In addition, more needs to be done to promote a variety of renewable technologies, including biomass and micro-generation. Fossil fuels will continue to be needed in the period analysed, and should be therefore be burnt with the most efficient technologies available. At the moment, the Government is not doing enough to ensure this.

Friends of the Earth will make more detailed recommendations in its submission to the Energy Review, which will include recommendations for electricity, but also for transport and housing policies. Among other things, we will recommend that the Government:

- Increase promotion of a variety of renewable energy sources through more ambitious policies than is currently the case
- Do more to achieve its stated CHP targets for the industrial sector by putting in place new policies, and develops an ambitious strategy to boost the take-up of micro-CHP
- Set strong caps in the second phase of the emissions trading scheme. A higher price for carbon will help to incentivise a switch to gas. In addition, it will incentivise coal-fired power station operators to upgrade their plants with new state-of-the art technologies that improve their efficiency and allow them to increase the amount of biomass they burn up to 20 per cent of total fuel use. Other old, inefficient coal-fired power stations that don't use these technologies should close.
- Upgraded and new fossil-fuel plants should be made ready for possible future use of carbon capture and storage ("capture ready").
- Promote increased use of sustainable biomass and biogas for electricity generation. Friends of the Earth accepts that biomass can be burnt in coal-fired power stations with current technologies despite the fact that this may not be the most efficient use of this scarce resource. However, this can be a useful mechanism to stimulate the development of a biomass market. In the longer term a market for biomass/biogas-fired CHP stations will have to be stimulated. (More efforts should also be made to promote biomass for the heat sector to reduce gas demand and emissions there).

In order to achieve the reductions modelled in our scenarios, energy-efficiency policy for industry, the commercial and retail sector and households needs to be considerably boosted as well. Under a business-as-usual scenario, demand would grow, whereas in our scenarios it continues to grow for a few years then starts stabilising or decreasing as more ambitious conservation policies start to kick in. The policies that could achieve the stabilisation or reduction in the model are feasible and would lead to net economic benefits for the whole of society.

Our modelling suggests that it would be possible to more than meet electricity demand if all available sustainable technologies were to grow according to what industry sources say is possible. This suggests that if demand did not stabilise, but were to grow, we would still be able to keep the lights on without nuclear power, although of course emissions would be reduced more slowly.

There are many illustrations of the huge potential for energy conservation, which only needs more political will in order to be tapped. At least one reviewer said our estimates for the potential to reduce demand were too conservative.

The first three years of the Government's energy-efficiency commitment policy delivered around 87 TWh of savings. This is the equivalent of more than all nuclear power supplied in the UK every year (around 80 TWh). While this indicates the programme has been successful, it also shows that far more could be done if we went further and promoted the development of energy service companies.

Studies for the European Commission, and supported by industry groups, have identified the potential to make significant cuts in electricity-use and considerable financial savings by ensuring that industry uses correctly-sized and super-efficient motor devices. These studies show a potential to reduce electricity consumption by around 6 per cent in the UK within a few years simply by encouraging a switch to more efficient motor drives.[9]

Around one large power station, or two medium-sized ones in the UK have to be kept running in order to provide power for appliances not in use and on standby mode. Replacing ordinary light-bulbs with energy-efficient light-bulbs could reduce electricity

consumption by at least 2 per cent (equivalent to one nuclear power station) by 2020. The potential is much higher if we implement a programme to replace inefficient street lighting and lighting in the commercial sector.

A detailed list of recommendations on how to achieve the energy efficiency potentials will be listed in Friends of the Earth's submission to the Energy Review. These will include fiscal incentives for the purchase of more efficient products or equipment to make homes more efficient; minimum standards for products negotiated with other European countries (the European Union is already discussing this); Government procurement standards; and measures to stimulate efficiency in the business and retail sector.

Our model does not include carbon capture storage on a large scale – only two pilot projects. However, Friends of the Earth does think this may have a role to play in the future, under certain conditions. Meanwhile, it may be a sensible insurance policy to ensure all new fossil-fuel plants are built as "capture-ready". This could help meet reduction targets in case some of the other technologies in the model do not grow as fast as needed – allowing for uncertainties over market conditions for the development of CHP, micro-CHP and energy demand patterns.

Meeting climate targets will be a challenge, but it is also an investment opportunity. And there are plenty of options, as the scenarios illustrated above show.

Annex 1: Assumptions and further details about the scenarios

Nuclear:
In all the scenarios existing nuclear capacity declines according to phase-outs shown in *Energy Paper 68*[10] with the exception of Dungeness B which extends its lifetime by about 10 years according to recent announcements.

Gas-fired power:
Combined Cycle Gas Turbine (CCGT) plant already operating are considered to have an operational life of about 20 years. In the gas scenario, some new CCGT plants will be built and some old ones refurbished with higher efficiencies. In the mix scenario, some new CCGT is built as well, although at a much slower rate.

Large Combustion Plant Directive:
At the time of creating the model, complete information was not publicly available on the opt-ins and opt-outs of coal plants from the Large Combustion Plant Directive, which affects their life-time. In the gas scenario, therefore, we have assumed a complete phase-out by 2018, assuming some plant would continue for a short period beyond 2015.

Coal upgrade in the "mix" and "coal" scenarios:
Coal plants in all scenarios are made much cleaner and more efficient than the ones currently operating. They are upgraded in order to use new technologies such as Advanced-Super Critical Steam Cycle (ASCSC), which can raise thermal efficiency from around 35 per cent to around 45 per cent. ASCSC uses steam above its supercritical pressure, thereby increasing the efficiency of steam power cycles. In addition, the upgraded coal power stations in the model are assumed to have also adopted new technology that enables them to co-fire up to 20 per cent of biomass (existing plants can only manage up to 7 per cent).

Drax:
The 4 gigawatt (GW) station Drax is the most recently constructed and the largest of the coal-fired power stations in the UK. It has announced it will comply with the Large Combustion Plant Directive and is therefore planning to stay open until 2015. In the "coal" and "mix" scenarios Drax is assumed to be upgraded with ASCSC, gas-turbine feedwater heaters (GTFWH) and co-fired with 20 per cent biomass. An upgraded Drax would have a capacity of 5GWe. If such modifications are carried out at Drax then its electrical output at 70 per cent load factor would be 31 TWh/yr comprising 63 per cent from coal (19.5 TWh/yr), 21 per cent from gas (6.5 TWh/yr) and 16 per cent from biomass (5 TWh/yr).

All other coal retrofits are assumed not to have fitted GTFWH but would be co-fired with 20 per cent biomass. In the "gas" scenario, Drax is phased out by 2018, whereas in the "coal" and "mix" scenarios it continues operating as a new, upgraded plant for a longer period of time.

"Cleaner coal" technology:
Progressive Energy's Integrated Gasification Combined Cycle scheme at Teesside – in all the scenarios this scheme is assumed to be commissioned in 2011 and to generate 5 TWh/yr (800 MW at 70 per cent load factor) through to 2030. Assumed to use carbon capture and storage from the beginning, so once co-fired with biomass this plant is assumed not to produce emissions.[11]

Other low-carbon technology:
BP Miller project – in all scenarios this scheme is assumed to be commissioned in 2011 and to generate 2 TWh/yr (350MW at 70 per cent load factor) through to 2030, with carbon capture from the start.

Oil-fired power:
In all the scenarios oil-fired production declines to zero by 2015.

Interconnectors:
The UK both exports and imports electricity from mainland Europe using an interconnector. The imported electricity comes from potentially unsustainable sources, for example generated from nuclear power stations in France. In all scenarios net imports are assumed to decline to zero as renewable sources of energy come on-line. Renewable sources such as wind may lead to exports of renewable power, which could balance out any imports. We have not modelled the possible construction/use of other interconnectors.

Electricity demand to 2030:
Electricity demand differs in the "good" and "slow" progress scenarios. Both start in 2005 at 402 TWh/yr[12] and rise for a number of years (because of the implementation delay) before reducing only slightly to 400 TWh/yr in the "slow progress" future, and to 359 TWh/yr by 2020 in the "good progress" future before levelling off.[13] This figure includes auto-generation. Reviewers disagreed on whether these estimates are pessimistic or optimistic.

CHP:
In the "good progress" future the Government's CHP electricity target of 10 GWe capacity by 2010 is assumed to be missed. However, it is assumed that by 2020 a substantial proportion (17.5 GWe of capacity) of the Combined Heat and Power Association (CHPA) aspirational target of 20 GWe is met; this

target is based on the Government's own assessment of potentials for the growth of this technology. This capacity growth equates to an installation rate of less than 1 GWe per annum from a 2006 capacity of 6 GWe. Such a build rate should readily be achievable especially now that new high-efficiency CHP technology, including fuel cells, are appearing on the market. Such factors should help incentivise business interest. These estimates do not include domestic micro-CHP (mCHP) which is considered separately (see below).

Schemes at all scales (excluding domestic micro-CHP) are assumed to generate 123 TWh/yr by 2020 (17.5 GWe installed at 80 per cent load factor). Much of this capacity, possibly about 14-15 GWe (100 TWh/yr), is likely to operate in baseload mode throughout the year (eg, providing heat for continuous industrial processes). If there is other inflexible baseload generating capacity on the grid, such as nuclear stations, then there could be a conflict of over-generation during low demand in summer.

Output from biomass / biogas fired CHP is included in the renewables sector output (to avoid double counting) at a 2020 output of 25 TWh/yr (25 per cent of renewables output).

In the "slow progress" future, output increases to about 100 TWh/yr in 2020 (14.3 GWe installed at 80 per cent load factor).

For the purposes of the model CHP plant has been attributed a specific emission figure of 250g/kWh-electricity to illustrate the full efficiency benefits of this technology in the electricity sector. Consequently, the heat output would give rise to average emissions expected from technologies across the heat sector.

Micro-CHP:

In the "good progress" future domestic mCHP output rises from zero in 2010 to 20 TWh/yr in 2020 and 40 TWh/yr in 2030. This is as a result of some consumer incentives to encourage the purchase of such efficient boilers and/or an equitable price for electricity exported to the local grid. New mCHP technology, particularly solid oxide fuel cells could enable higher power to hot water/heat ratios than current mCHP technologies based on Stirling engines. Depending on the cost of the cells, generation from mCHP could rise higher than the 40 TWh/yr 2030 figure estimated.

This significant contribution could be achieved either as a result of cost and reliability factors promoting consumer take-up (possibly 1 million per year) and/or a near mandatory mCHP boiler replacement policy coupled to capital grants and equitable "export" incentives. About 1 million boilers per annum is estimated to be the natural turnover for domestic boilers suitable for mCHP replacement. In the "slow progress" scenario output rises to 20 TWh/yr and assumes low incentives and poor consumer take-up of the technology.

The average output of mCHP boilers is assumed to be 3,000 kWh/yr but higher outputs are possible (and should be encouraged to reduce gas dependency and less efficient centralised CCGT generation). Two reviewers pointed out that there is ongoing research on the issue of efficiency of micro-CHP units.

Renewables:

Renewable technologies of all types, including biomass-fired CHP are included in this row. Biomass co-fired in coal power stations is not included as renewable energy. It is assumed that, by 2020, 20 per cent of demand is achieved in the "slow progress" future (ie 80 TWh/yr out of 400 TWh/yr), and that about 28 per cent of demand is achieved in the "good progress" future (ie 100 TWh/yr out of 359 TWh/yr).

The 80 TWh/yr figure is assumed to result from the current policy of incentivising a 15 per cent share by 2015 and 20 per cent by 2020 renewables output in the electricity mix. The 100 TWh/yr figure is estimated to be possible if additional incentives were implemented. Such incentives would particularly stimulate biomass production and the earlier deployment of offshore windfarms, marine current turbine arrays and possibly wave farms.

Other new technologies such as tidal lagoons (potentially generating more than 20 TWh/yr from schemes in the Severn Estuary alone, possibly by 2020) might add further to the renewables output.

Some peer reviewers have indicated that such renewables output by 2020 is over-optimistic, while others said we were being pessimistic. We believe that the growing public awareness and concern about climate change is likely to result in increasing public support for the speedy deployment of renewable schemes of all types.

Technology estimates[14]

Offshore windfarms:

10-15 GW of capacity installed by 2020. This would generate between 33 and 50 TWh/yr in 2020 at 38 per cent load factor and requiring 2,300 to 3,400 turbines of average capacity of 4.5MW.

Onshore windfarms:

As much as 12 GW of capacity is assumed to be built by 2020 in all scenarios, generating 31 TWh/yr (29.5

per cent load factor). This would require from 8,000 turbines averaging 1.5 MW capacity to 6,000 turbines averaging 2 MW capacity. There are currently about 1,300 turbines across the UK. For comparison, Germany has currently 16,000 onshore wind turbines installed.

Hence, from wind energy alone in the "slow progress" scenario, approaching 64 TWh/yr is generated by onshore and offshore windfarms, rising to around 80 TWh/yr in "good progress". It is worth noting that if this growth was not achieved, there would still be potential for achieving growth through other renewable technologies.

Biomass:

About 20 TWh/yr ("slow") to 25 TWh/yr ("good") is assumed to be generated from biomass and biogas by 2020. Co-firing may also require significant quantities of biomass. In the "slow mix" scenario about 15 TWh/yr comes from co-firing rising to 25 TWh/yr in the "slow coal" scenario. In the "good" scenarios it ranges from 7 TWh/yr to 12 TWh/yr.

The highest total electrical output from biomass fuels would be 35 TWh/yr ("slow mix") to 50 TWh/yr ("slow coal"). The Biomass Task Force estimated a UK biomass resource for electricity generation of 14.4 to 17.3 TWh/yr (excluding Municipal Solid Waste – MSW).

Consequently, significant quantities of biomass would need to be imported to the UK in most scenarios. Friends of the Earth believes we could ethically import biomass up to a share of the global or European production equivalent to our share of global and European population minus an allowance for the energy consumed in producing or transporting the biomass. These preliminary calculations suggest the UK may be able to consume between 132-182 TWh of energy from biomass every year.

Alternatively, coal stations could use CCS to reduce emissions rather than co-firing biomass. Note that CCS of co-fired biomass emissions would be carbon-negative so if sustainable sources are available there would be merit in using them.

Tidal stream and wave power:

Between about 5 TWh/yr and 12 TWh/yr by 2020 has been estimated from these technologies in the recent Future Marine Energy report from the Carbon Trust.

Others:

Landfill gas and hydro would continue to make their contributions, along with smaller contributions from coal mine methane, micro-turbines, geothermal schemes, solar PV, etc.

Summing all these renewable potentials we estimate that 80 TWh/yr to 100 TWh/yr is possible by 2020 and up to 200 TWh/yr by 2030.

Concentrating Solar Power imports (CSP):

Several governments, including those of Germany, Italy, Spain, Morocco, Jordan and Israel, are engaged in a project aimed at producing electricity from large-scale CSP solar power plants (mirror arrays not PV) in the Sahara and to be exported to Europe. UNEP, the World Bank and the International Energy Agency are also involved.[15] Electricity is already traded throughout Europe, with plans to expand the grid into North Africa. In Spain about 1 GWe of parabolic trough or solar power CSP schemes are either under construction or have recently been proposed. The model assumes under "good progress" that the UK will be able to import some of this electricity. The cost of such imported electricity is estimated by the German Environment Ministry to cost about 4.1 pence/kWh delivered 3,500 km by high-voltage, direct-current transmission lines to mid Europe latitudes.

One reviewer pointed out that these imports may be limited because of the large distances involved. Friends of the Earth has included an estimate of the potential for concentrating solar power imports as an example of what technologies could potentially come onto the market at a later stage. However, we recognise there are some uncertainties in modelling as far out as 2030, and the potential for this technology can be considered illustrative.

Emission assumptions used (grams CO_2/kilowatt-hour):

Coal current	943
Coal retrofit with 0% biomass	745
Coal IGCC	0
Drax	910
Coal retrofit with 20% biomass	595
Drax retrofit with 20% biomass (plus GTFWH)	500
CCGT current	410
CCGT advanced	370
CHP	250
Micro CHP	250
Carbon capture costs (% of scheme output)	20%
Carbon capture rate	90%

References/notes

1 Figures for primary fuel inputs for inland energy consumption were taken from *Digest of UK Energy Statistics*, published 25/8/05. (See www.dti.gov.uk/energy/inform/dukes/) Friends of the Earth converted volumes of primary energy consumed in millions of tonnes oil equivalent (Mtoe) to millions of tonnes of carbon emissions (MtC).

2 To learn more about the Bill, visit www.thebigask.com. Text of Early Day Motion 178 and current numbers of signatures available at: http://edmi.parliament.uk/EDMi/EDMDetails.aspx?EDMID=28373&SESSION=875

3 Deparment of Trade and Industry, *New and Renewable Energy: Prospects in the UK for the 21st Century*, 1998. http://www.dti.gov.uk/renew/condoc/support.pdf; Royal Commission on Environmental Pollution, 22nd Report. *Energy: The Changing Climate*, 2000; Performance and Innovation Unit, Energy White Paper 2003.

4 The creation of energy through the burning of fossil fuels to produce electricity is an extremely inefficient process. Only 35 per cent of the energy in a traditional coal-fired power station is finally transferred to the grid, and only around 48 per cent in gas-fired stations. The rest is wasted as heat and released into the atmosphere. Further losses are made in the transmission and distribution and through the use of inefficient equipment.

5 60 per cent of that increase is predicted to be in the form of oil and natural gas. *World Energy Outlook. 2005.* http://www.iea.org/textbase/npsum/WEO2005SUM.pdf

6 RIIA, *Keeping the lights on: working paper no.3,* 2004. http://www.riia.org/viewdocument.php?documentid=4689

7 CBI, *Energy Brief, Powering the Future: Enabling the UK energy market to deliver*, November 2005.

8 For more information on this, see http://www.foe.co.uk/resource/briefings/nuclear_power_answer_climate_change.pdf

9 European Copper Institute, *Improving energy efficiency of motor-driven systems; a major contribution against climate change*, 2003. http://www.eurocopper.org/eci/archives/docs/PK%20EN%20Motor%20Challenge122003.pdf

10 http://www.dti.gov.uk/energy/inform/energy_projections/ep68_final.pdf

11 The Teesside IGCC / CCS project would be co-fired with 10 per cent of biomass or possibly more if successful. Consequently the scheme is assumed to be essentially carbon-neutral. However, two reviewers have suggested this estimate may be a bit optimistic.

12 Conforming with predictions from the Digest of UK Energy Statistics (DUKES) http://www.dti.gov.uk/energy/inform/energy_stats/electricity/index.shtml

13 The "policy evolution" scenario in Ilex's 2004 report for WWF predicted that UK electricity demand could be reduced by 0.2 per cent per annum. This was in line with the Performance and Innovation Unit's 2003 report, which estimated a potential to reduce energy demand cost-effectively in the UK by 30 per cent. This results in electricity demand of 359 TWh/yr in 2020. It was estimated for the purposes of this exercise that a slower implementation of energy-efficiency strategies would result in electricity demand of 400 TWh/yr by 2020. In both cases electricity demand levels off after 2020. ILEX Energy, *The Power To Save Our Climate. Reducing CO_2 emissions in the UK power sector*, report for WWF-UK, 2002.

14 Sources for estimates on renewable energy: British Wind Energy Association, Carbon Trust and other sources.

15 Several studies on this technology are available here: http://www.solarpaces.org/library.htm

Friends of the Earth is:

- the UK's most influential national environmental campaigning organisation
- the most extensive environmental network in the world, with around 1 million supporters across five continents, and more than 70 national organisations worldwide
- a unique network of campaigning local groups, working in more than 200 communities throughout England, Wales and Northern Ireland
- dependent on individuals for over 90 per cent of its income.

Friends of the Earth

Friends of the Earth
26-28 Underwood Street
London N17JQ
Tel: 020 7490 1555 Fax: 020 7490 0881
Email: info@foe.co.uk
Website: www.foe.co.uk

Friends of the Earth Trust company number 1533942, registered charity number 281681