Conclusions

Meeting the carbon emission reduction target requires a wholesale transformation of the energy system – a formidable challenge, but essential if the UK's statutory carbon targets are to be met.

These conclusions emerge as robust across all the sets of model runs described in the UKERC Research Report that accompanies this briefing paper.

The runs are unanimous that the technologies to meet the challenge exist, and deploying them is a much lower cost option than the damages from climate change, estimated elsewhere, that will ensue if the UK and other countries fail to rise to it.

Further reading

Paul Ekins, Ilkka Keppo, Jim Skea, Neil Strachan, Will Usher, and Gabrial Anandarajah 2013 '*The UK Energy System In 2050: Comparing Low-Carbon, Resilient Scenarios*', A Research Report from the UK Energy Research Centre, UKERC/RR/ESY/2013/001

Notes

[1]MARKAL is a well established linear optimisation,energy system model, developed by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA) in the 1970s, and since used by the IEA and many research teams round the world.

UUK MARKAL has been used for a number of major modelling exercises of different projections of the UK energy system to 2050: for UKERC in 2007-08, for the Committee on Climate Change (CCC) in 2010, for the Department of Energy and Climate Change (DECC) in 2011, and again for UKERC to update the earlier scenarios in 2012.

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insight

An energy briefing paper

Low-carbon, resilient scenarios for the UK energy system in 2050

Executive Summary

- There is a need for greatly increased energy efficiency and conservation in all sectors
- All buildings, new and existing, will have to become much more energy efficient
- No low-carbon technology is clearly preferred on cost grounds
- There is no scope for a new 'dash for gas' to substitute for coal after 2030 - because after 2030 there is no coal-fired generation (without CCS) in low-carbon scenarios
- The CO_2 intensity of power generation in 2030 must be less than 100 gCO_2/kWh if carbon targets are to be met cost effectively
- Residential heating by 2050 uses almost no natural gas – but electricity instead (directly or through heat pumps), supplemented by biomass and solar thermal

Executive summary continued

- There is little gas-fired generation after 2030 in low-carbon scenarios, but substantial gas capacity used as back-up to renewables generation
- The contribution of bioenergy to carbon reduction is still very uncertain
- The internal combustion engine will likely cease to be the main vehicle technology of the 21st Century – instead, mass entry of different low-carbon, highly efficient vehicle technologies will mean people are able to travel further, with reduced fuel use and lower carbon emissions
- Meeting the carbon emission reduction target therefore requires a wholesale transformation of the energy system.
- Given the findings, the authors advise that there is little reason not to include a 2030 decarbonisation target in the 2012 Energy Bill, and that doing so would give investors in low-carbon generation assurance of the UK energy system's direction of travel, and the policy commitment necessary to achieve it, as well as acting as a litmus test of the government's determination to meet the reductions in carbon emissions to which the UK is currently statutorily committed

Introduction

This briefing draws out the key messages from the UKERC report ***The UK Energy System in 2050: comparing low-carbon resilient scenarios,*** – which describes and compares a series of model runs, implemented through the UK MARKAL[1] modelling system, which was developed through UKERC with funding from the Research Councils' Energy Programme. This has revealed some consistent patterns showing how the UK energy system might develop in future, which are discussed in detail in the full report.

The need for caution

Comparisons between model runs, even of the same model, need to be drawn with care. Various assumptions, including cost and other data inputs to the model, were changed between the model runs, to reflect policy and other developments, and to incorporate new information. Some of the technology representations in the model were also improved. However, where consistent patterns emerge across the different runs, despite the different inputs and the fact that the runs were carried out by different modellers and modelling teams, then more confidence may be placed in these patterns as likely features of the future UK energy system under the constraints applied, the principal constraint being reductions in carbon dioxide (CO_2) emissions from the UK energy system, according to the provisions of the UK Climate Change Act of 2008.

Policy implications of the analysis

Three sectors – electricity, residential and transport – are currently the largest carbon emitters and are the key to meeting the UK's carbon targets. Industry may reduce its emissions through greater efficiency, CCS and the use of bioenergy, but unless electricity is effectively decarbonised soon after 2030, and buildings and transport by 2040, the carbon target for 2050 will not be met. Given the length of time it will take to transform these sectors, policies now and through to 2020 are of critical importance.

The Electricity Market Reform (EMR) to be implemented through the Energy Bill 2012 will need to incentivise either the large-scale deployment of new nuclear power, or an intensification of the rate of deployment of new renewables, or both.

Investors in low-carbon power generation technologies will need reassurance of government commitment to long-term decarbonisation by the inclusion in the Energy Bill of a maximum average electricity carbon intensity for 2030 of 100 gCO_2/kWh.

The Gas Strategy must make clear the difference between gas capacity and the extent to which it can be used. The capacity payment component of the 2012 Energy Bill will need to re-assure prospective investors in new gas-fired generation that they will continue to receive reasonable returns even as gas changes through the 2020s from providing base load to acting more as backup to the increased renewables capacity on the grid.

There should be substantial efforts to develop electricity storage technologies, in order to reduce the level of back-up gas capacity required.

There is no scope for a new 'dash for gas', if what is meant by this term is the construction of new gas-fired stations that will generate significant levels of electricity without CCS beyond 2030. New gas-fired stations will be required before 2030 to replace closing coal and nuclear stations, but they will be operated increasingly as back-up capacity beyond 2025 and arrangements to remunerate gas generators for their construction should make this clear.

Three sectors – electricity, residential and transport – are currently the largest carbon emitters and are the key to meeting the UK's carbon targets

New initiatives to promote the commercial demonstration of CCS will need to proceed far more effectively than their predecessors, and this demonstration will need to be successful for the envisaged level of decarbonisation to be compatible with the continued large-scale use of gas.

The Green Deal and the Energy Company Obligation (ECO) will need greatly to increase the rate of uptake not just of relatively simple energy efficiency measures, like loft and cavity wall insulation, but also of more difficult and expensive measures such as solid wall insulation, while ensuring that associated ventilation provisions keep buildings healthy.

The behaviour of consumers will be critical for the take-up of low-carbon technologies in both buildings and vehicles. Currently, consumer behaviour does not readily lead to the adoption of efficiency technologies in buildings or low-carbon vehicles, like battery electric vehicles. But if low-carbon heating technologies are to be able to keep buildings warm cost-effectively, it is essential that they are deployed in energy-efficient homes, with around 50% lower energy demand for the same internal temperatures than at present.

Battery electric vehicles and fuel cell electric vehicles will need to be strongly promoted through subsidies, and taxes on high-carbon alternatives, if the gap between the low-carbon aspirations shown in the scenarios and current practice are to be bridged.

The need for greatly increased energy efficiency and conservation in all sectors

Producing low-carbon energy is costly and politically controversial, whatever technologies are deployed. The more efficiently it can be used, and the less that is required to satisfy the desired level of energy services, the easier it will be to deliver the necessary low-carbon supply. All the model runs show that it is cheaper to achieve large reductions in energy demand through efficiency and conservation technologies than to provide an equivalent level of supply. However, just because it is cheaper does not mean that it is politically easy to achieve. Making UK buildings more efficient, especially, remains a major policy challenge.

> Onshore wind is currently the cheapest non-biomass low-carbon option

Key uncertainties – which technology?

There are three main classes of large-scale low-carbon technologies on the supply side: nuclear; renewables (the most important of which in these model runs are wind and bioenergy, with marine being added towards 2050); and carbon capture and storage (CCS). Nuclear, wind and CCS are wholly or mainly electricity-related technologies, which is therefore the focus in this section.

On the demand side there are energy efficiency and conservation, which reduce the quantity of energy required to meet a given level of energy service demand, and a range of other end-user technologies (such as heat pumps, biomass boilers, solar thermal and PV) which supply energy. These are more decentralised, mainly using the lower-voltage distribution system where they generate electricity.

There is a great deal of uncertainty which of these technologies, if any, will become dominant because it is the cheapest. In all the low-carbon runs (80 or 90% reduction in CO_2 emissions from 1990's level), all the main low-carbon technologies (nuclear, renewables, CCS) make a significant contribution to generation, although changing the assumptions in different runs changes the mix between them.

Onshore wind is currently the cheapest non-biomass low-carbon option, but experiences political opposition to its large-scale deployment; new-generation nuclear is still uncertain in cost and in the ability of the UK to deploy it at scale, and is also not politically popular; the commercial and technical viability of CCS at scale, and the scale of subsidy required for its deployment, are not yet proven; large-scale offshore wind, while it can be built to time and on budget, is still expensive; and the UK is not best placed for the most decentralised renewable technology with the most potential, solar photovoltaics (PV), which is also still expensive.

How the costs and various other problems associated with these technologies will evolve and be resolved is still very uncertain. In the model runs different combinations of these technologies are chosen depending on the (especially cost) assumptions made. Quite small changes in assumptions can produce quite large changes in outcomes. It therefore seems wise to continue to develop and seek to deploy all of them until these issues are clarified and either a clear best choice among them, or something resembling an optimal mix between them, becomes apparent.

Decarbonisation of the UK electricity system

An absolutely consistent result to emerge from all the model runs (as shown in Table 1) is that, if the UK is to meet its GHG emission reduction target for 2050 cost effectively, the UK electricity system needs to be decarbonised by 2030 by at least 80% (a CO_2 intensity of around 100 gCO_2/kWh or less, compared to 500 gCO_2/kWh in the year 2000).

The low CO_2 intensity means that, as shown in Table 1, there is little room in the electricity mix for gas-fired generation without CCS even in 2030. This conclusion is very little changed by the lower gas price UKERC2: LC-GAS RUN, which has only a little more gas generation in 2030 than the higher price UKERC2: LC.

> If the UK is to meet its GHG emission reduction target for 2050 cost effectively, the UK electricity system needs to be decarbonised by 2030 by at least 80%

However, this does not mean that there is no gas capacity (without CCS) in 2030 and 2050. On the contrary, all the 90% emission reduction runs have more gas capacity in 2050 than they do in 2030, but the generation column shows that this capacity is little used. It is there to act as peaking and balancing capacity for the increasing quantity of variable renewables (wind and marine) in the electricity system. This points to the importance of having adequate incentives in place for this back up capacity to be built, when it will be little used.

Finally, it is sometimes said that new gas-fired generation can help reduce carbon emissions by substituting for coal. These scenarios show that this is not true for the UK post-2030, because none of the low-carbon scenarios in Table 1 have any non-CCS coal-fired generation by 2030, and the emission performance standards in the 2012 Energy Bill will ensure that no new coal-fired power stations will be built before then. Whether gas-fired generation substitutes for coal in existing power stations before 2030 depends on the difference between gas and coal prices and the level of the carbon price.

Table 1: CO_2 intensity and gas capacity and generation in 2030 and 2050 in the main low-carbon model runs

Model run	CO_2 reduction in 2050	CO_2 intensity (gCO_2/kWh)[1]		Gas without CCS[2]			
				Capacity (GW)		Generation (PJ)	
		2030	2050	2030	2050	2030	2050
Energy 2050: CAM	80%	75	31	13	26	61	0[3]
CCC: C80	80%	109	-7	41	29	178	0
UKERC2: LC	80%	-3	-16	33	29	84	0
UKERC2: LC-GAS	80%	-3	-16	34	30	92	0.5
Energy 2050: CSAM	90%	33	8	13	39	61	0
CCC: C90	90%	5	-32	24	37	41	0
CCC: C90+	90%	-1	-29	29	47	31	0
AEA: DECC-1A	90%	91	-19	24	33	128	8
AEA: DECC-1A-IAB-2A	90%	62	-2	26	37	67	0

[1] The CO_2 intensity of UK electricity in 2000 was around 500 gCO_2/kWh
[2] In 2000 the capacity and generation of gas-fired electricity were 22GW and 460 PJ respectively
[3] 0 in this column means less that 0.5 PJ

Electrification of heat

All buildings, new and existing, will have to be much more thermally efficient: much less energy will be needed to heat them, and by 2050 it will not be natural gas, but electricity, perhaps driving heat pumps, and bioenergy, perhaps with district heating, with or without CHP, and solar thermal panels.

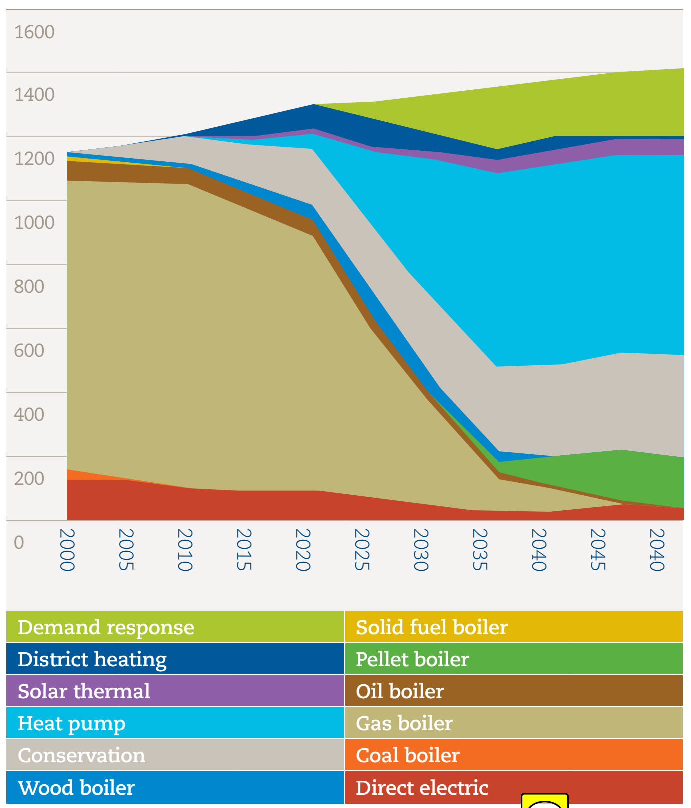
All the model runs show some electrification of heat, using the largely decarbonised electricity discussed in the previous section, but the degree of electrification differs markedly across the runs, as do the technologies which are deployed. It is clear, as shown in Figure 1, that heat will no longer be provided on a large scale by individual gas boilers. By 2050 electricity (directly or through heat pumps) makes a major contribution to heating in all scenarios, supplemented by biomass and solar thermal, while conservation and demand response reduce the amount of heat that actually needs to be supplied.

The widespread diffusion of electric heating technologies in buildings and/or transport (see below) will require active management of the electricity grid both to prevent the exacerbation of peak demands (if everyone were to try to heat their buildings or re-charge their vehicles at the same time), and to take advantage of the possibilities to store electricity at times when variable renewables (such as wind) were available at times of low electricity demand. There are a number of possibilities for more active management of the electricity grid to match supply to demand better, reduce the peakiness of demand, and store surplus power for when it is needed, but all need some combination of the development and deployment of new technologies, institutional planning and management, and changes in consumer behaviours.

The end of the internal combustion engine?

The internal combustion engine (ICE) was one of the iconic inventions of the 20th century. The 21st, if it is to be low carbon, will very likely see its demise as the major vehicle technology. By 2050 transport is no longer mainly provided in any scenario by vehicles using ICEs and conventional petrol and diesel but by low-carbon substitutes for these technologies. In the years to 2050, first they will become more efficient; then they will be hybridised with electric motors, driven by batteries, which in due course will be able to be plugged in to the power grid for a re-charge; then they will be replaced by all-electric battery vehicles, or fuel cell vehicles, probably fuelled by hydrogen, or some combination of the two. Those ICEs that remain are largely driven by biofuels. However, the low-carbon scenarios do not depict worlds in which everyone stays at home. The distance travelled in all the scenarios increases considerably between 2000 and 2050, facilitated by the very great increase in the efficiency of the vehicles used.

Figure 1: Demand Served by Residential Heating End-Use Technologies



Source: AEA 2011a (model run DECC-1A-IAB-2A)

The internal combustion engine (ICE) was one of the iconic inventions of the 20th century. The 21st, if it is to be low carbon, will very likely see its demise as the major vehicle technology

The proportions of the fuels and technologies vary across the different runs. Figure 2 shows one possible mix of the demands for different fuels in 2050. The mix of technologies, and the timescale over which they will be deployed, is very uncertain. Because they require very different re-charging infrastructure, the choices between them cannot be put off indefinitely.

The future of the UK gas grid

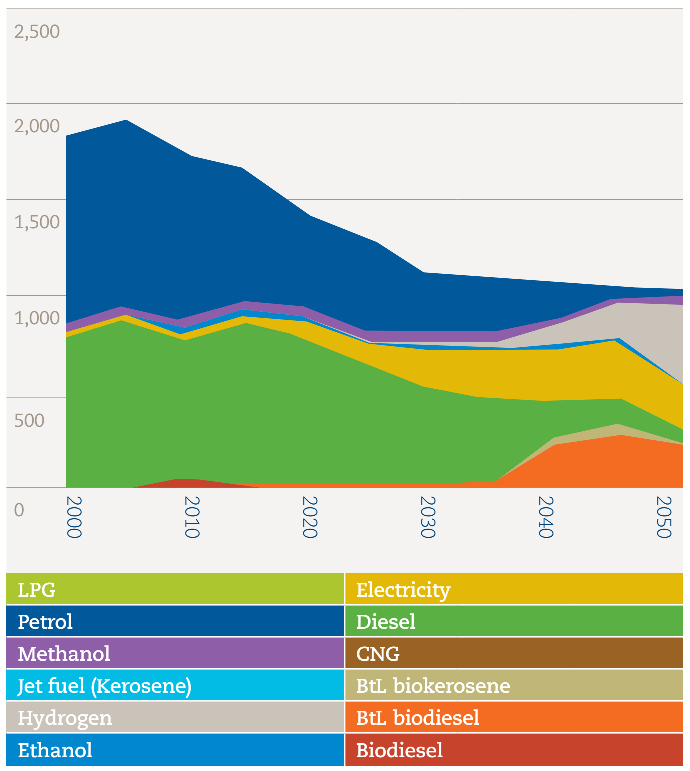
Currently, the main use of the gas grid is to transport and distribute natural gas to buildings for heating (and, to a much lower extent, cooking) purposes. As noted above, heating buildings in this way on a large scale will not be consistent with reaching the carbon emission reduction targets. But that does not necessarily mean the UK gas grid will gradually become redundant. There are two main low-carbon options for the gas grid: transporting either bio-gas (methane derived from biomass, which is assumed to be zero or near-zero carbon because it takes from the air while growing the carbon that it emits to the air when burned); or hydrogen produced in low-carbon ways (from biomass gasification, renewable electricity or nuclear power). These options are currently expensive, and none emerge at scale in the low-carbon model runs. This is an indication of the challenges that need to be addressed if the gas grid is to have a purpose in a low-carbon UK, and not become a 'stranded asset'.

Bioenergy has many different possible uses, but its sustainable availability is not clear

Bioenergy may be used to produce electricity (through dedicated power stations or co-firing with coal), heat (for example, through biomass boilers linked to district heating) and transport (through biofuels). Using biomass for power generation with CCS offers the attractive prospect of 'negative' emissions. All the sets of model runs use some bioenergy, but in very different amounts and for different purposes. This not only reflects uncertainties about the costs of these different uses, but also the amount of bioenergy likely to be available to the UK: land for growing it is limited, and this and land elsewhere has many other demands on it, including food production, the maintenance of biodiversity, and recreational activities

There are also questions about the extent to which bioenergy really is a 'low-carbon' energy source. It is clearly not zero-carbon, as it is currently accounted, and it is clear that under some modes of production it can be as high-carbon as some fossil fuels. But the analytical and governance systems are not yet in place systematically to distinguish between low and high-carbon bioenergy, and only produce and use the former.

Figure 2: Energy Consumption in the Transport Sector in DECC-1A-IAB-2A



BtL is a technology that turns biomass to liquid fuel
Source: AEA modelling for DECC

Electricity decarbonisation via CCS can provide the bulk of a 40% reduction in CO_2 by 2050