Executive Summary

The Renewable Energy Review

Executive Summary

This review of renewable energy was commissioned by the Government in the May 2010 Coalition Agreement. It requested that we advise on the scope to increase ambition for energy from renewable sources. This has important implications for the sector investment climate and Government policy.

In September 2010 we summarised our analysis of 2020 renewable energy ambition in a letter to the DECC Secretary of State. We argued that the Government's 2020 ambition is appropriate, and should not be increased. Instead the focus should be on ensuring that the existing targets are met: this requires large-scale investment over the next 10 years, supported by appropriate incentives.

Our overall conclusion in this review is that there is scope for significant penetration of renewable energy to 2030 (e.g. up to 45%, compared to 3% today). Higher levels subsequently (i.e. to 2050) would be technically feasible. Equally however, it would be possible to decarbonise electricity generation with very significant nuclear deployment and have limited renewables; carbon capture and storage may also emerge as a cost-effective technology.

The optimal policy is to pursue a portfolio approach, with each of the different technologies playing a role. In the case of renewable technologies such as offshore wind and marine, this will require the resolution of current uncertainties and the achievement of cost reductions. Therefore the message in our previous letter is reinforced: new policies are required to support technology innovation and to address barriers to uptake in order to suitably develop renewables as an option for future decarbonisation.

In this review we do four things:

- We set out new analysis of technical feasibility and economic viability of renewable and other low-carbon energy technologies.
- We present scenarios for renewable energy deployment to 2030 and beyond, and assess whether it is appropriate now to commit to increased ambition for renewable energy in the 2020s.
- We consider implications of these longer-term scenarios for ambition to 2020.
- We assess the key enabling factors for investment in renewable energy technologies, suggesting high-level policy options as appropriate to deliver ambition in 2020 and beyond.

Box 1: Summary of findings of the renewables review

Electricity generation

- A range of promising options exists for delivering decarbonisation of the power sector by 2030 at reasonable cost. This includes renewables, nuclear and carbon capture and storage (CCS).
- A portfolio approach to technology support is appropriate.
- Firm commitments on support for offshore wind and marine generation through the 2020s should be made now.
- These should be implemented through the new electricity market arrangements.
- If renewable energy targets for 2020 can be met in other ways, a moderation of offshore wind ambition for 2020 could reduce the costs of decarbonisation.
- Ambition for offshore wind to 2020 should not be increased unless there is clear evidence of cost reduction.

Heat

- Further funding will be required to support renewable heat in the period 2015-20 and in the 2020s.
- Approaches to renewable heat and energy efficiency (i.e. the Renewable Heat Incentive and the Green Deal) should be integrated.
- Accreditation of installers is crucial if supply chain bottlenecks are to be avoided and consumer confidence improved.

Transport

- A cautious approach to the use of biofuels in surface transport is appropriate until and unless sustainability concerns are resolved.

Renewable energy scenarios

- The Government's plans for renewable energy deployment to 2020 as set out in the Renewable Energy Strategy are broadly appropriate.
- Our scenarios for renewable energy penetration in 2030 include a share of 30% (460 TWh) in a central case, rising to a maximum of 45% (680 TWh). These illustrate the order of magnitude for likely and possible renewable contributions to economy-wide decarbonisation.

Specific conclusions on power generation, renewable heat and transport (Box 1) are:

Power generation

- **The need for sector decarbonisation.** It is crucial in the context of economy-wide decarbonisation that the power sector is almost fully decarbonised by 2030. Options for sector decarbonisation include nuclear, CCS and renewable generation.
- **Current uncertainties.** The appropriate mix of low-carbon generation technologies for the 2020s and 2030s is uncertain. Key factors are: the ability to build nuclear to time and cost; whether CCS can be successfully demonstrated at scale for coal and gas; the extent to which the planning framework will support further investment in onshore wind generation; and the costs of renewable generation, especially offshore wind and marine.
  - **Nuclear power** currently appears to be the most cost-effective of the low-carbon technologies, and should form part of the mix assuming safety concerns can be addressed. However, full reliance on nuclear would be inappropriate, given uncertainties over costs, site availability, long-term fuel supply and waste disposal, and public acceptability.
  - **CCS technology** is promising but highly uncertain, and will remain so until this technology is demonstrated at scale later in the decade. In the longer term, storage capacity may be a constraint.
  - **Onshore wind** is already close to competitive, although investment has been limited by the planning framework, and is limited in the long term by site availability.
  - **Offshore wind** is in the early stages of deployment and is currently significantly more expensive than either onshore wind or nuclear. However, the existence of a large-scale natural resource, reduced local landscape impact compared with onshore wind and the potential for significant cost reduction make it a potentially large contributor to a low-carbon future.
  - **Marine** technologies (wave, tidal stream) are at the demonstration phase and therefore more expensive again, but may be promising, given significant resource potential and scope for cost reduction.
- **A portfolio approach.** Given these uncertainties, a portfolio approach to development of low-carbon generation technologies is appropriate.
  - This should include market arrangements to encourage competitive investment in mature technologies such as nuclear and onshore wind generation.
  - It should also include additional support for less mature technologies including CCS, offshore wind and marine, where there is potential for the UK to drive these technologies down the cost curve. This is in contrast to solar PV, where the pace and scale of development will be determined outside the UK.

- **Commitments for the 2020s.** As part of a portfolio approach, the Government should commit now to an approach for supporting offshore wind and marine in the 2020s. The approach should avoid stop-start investment cycles and provide confidence to supply chain investors of a long-term business opportunity beyond the next decade.
- **Firm commitments.** Given the need to provide investor confidence, support should be provided through firm commitments. Such commitments should be implemented through the new electricity market arrangements. For example, within the Government's proposed Contracts for Differences for low-carbon generation, a proportion of these could be targeted at supporting less mature renewable technologies.
- **Illustrative 2030 scenario.** We set out an illustrative scenario in which commitments on support for offshore wind and marine through the 2020s are broadly in line with planned investment and supply chain capacity to 2020. Together with ongoing investment in onshore wind, this would result in a 2030 renewable generation share of around 40% (185 TWh). Sector decarbonisation would then require a nuclear share of around 40% and a CCS share of 15%, along with up to 10% of generation from unabated gas.
- **Key deployment barriers** to be addressed include finance and planning:
  - Notwithstanding new market arrangements, there is a potentially important role for the Green Investment Bank (GIB) in financing offshore wind projects. Unless it can be demonstrated that risks of a shortage of finance to 2015/16 can be mitigated, allowing the GIB to borrow money from its inception should be seriously considered.
  - Planning approaches should facilitate investments in transmission that are required to support investments in renewable and other low-carbon generation. In addition, a planning approach which facilitates significant onshore wind investment would reduce the costs of meeting the 2020 renewable energy target, and of achieving power sector decarbonisation through the 2020s.

Renewable heat

- **Indicative 2030 ambition.** There is a set of low-carbon heat technologies that are mature but that need to be demonstrated in a UK context. Given successful demonstration, increasing the share of renewable heat from currently very low levels to around 35% of energy demand (210 TWh) by 2030 is likely to be both feasible and desirable. This will require consumer understanding and acceptance of the technologies, along with a willingness to accept the disruption and hassle costs of house retrofit.
- **Developing renewable heat options.** The approach over the next decade should focus on removing barriers and developing options that would allow significantly increased ambition in the 2020s. To facilitate this, approaches to renewable heat and energy efficiency (the Renewable Heat Incentive and Green Deal) should be integrated. Success will also require accreditation of installers, alongside financial support provided under the Renewable Heat Incentive. Firm targets should be set and funding commitments made for the period beyond 2020 as and when current uncertainties are resolved (e.g. between 2015 and 2020).

Renewable transport

- **Electric vehicles.** Significant growth in the number of electric vehicles will increase the share of renewable energy in transport, to the extent that batteries are charged by renewable power generation. In our fourth budget scenario, electric vehicle penetration reaches around 60% of new cars and vans by 2030. Although electric vehicles may still account for a considerably smaller share of total miles in 2030, this will increase significantly in the 2030s as the vehicle stock turns over.
- **Biofuels.** It is currently inappropriate to plan for significantly increased penetration of biofuels in surface transport beyond 2020, given concerns over sustainability (e.g. the tension between biofuels and food production, uncertainties about true lifecycle emissions and biodiversity risks) and competing claims on scarce bioenergy supplies from other sectors (e.g. aviation, industry). Under a cautious assumption of 11% (30 TWh) biofuels penetration in 2030, the total renewable transport share – including renewable electricity used in electric vehicles – would be around 15%.

Renewable energy ambition

- **2030 possible contributions.** Adding across our sectoral scenarios, the share of renewable energy penetration is 30% (460 TWh) in our central scenario[1]. Higher levels of ambition (e.g. up to 45%, 680 TWh) are technically feasible and might be economically desirable, depending on the evolution of relative costs and the development of supply chains. Analysis of maximum feasible levels suggests that:
  - **Power generation.** Renewable penetration of up to 65% (300 TWh) would be technically feasible. How much is economically desirable will depend on the evolution of the relative costs of renewables, nuclear and CCS.
  - **Heat.** Renewable penetration of up to 50% (275 TWh) might be technically feasible and desirable by 2030, depending on availability of bioenergy and ability to rapidly develop supply chains and overcome other barriers.
  - **Transport.** With optimistic assumptions over the availability of sustainable biofuels, up to 25% (60 TWh) of transport energy demand could be met by renewable energy in the form of biofuels.
- **2030 ambition.** The precise level of appropriate ambition will become clear over time. We recommend that the Government keeps ambition for renewable energy under review and revisits this as uncertainties over the economics of different low-carbon technologies are reduced (e.g. in 2017/18 when the first new nuclear plant and CCS demonstration plant are due).
- **2020 ambition.** Renewable energy ambition to 2020 as set out in the Government's Renewable Energy Strategy (RES) and as required under the EU Renewable Energy Directive (RED) would sufficiently develop options for increased ambition in the 2020s.
- **Maintaining flexibility.**
  - The composition of 2020 ambition as set out in the RES is broadly appropriate. The current level of ambition for offshore wind (13 GW capacity installed by 2020) remains appropriate given uncertainties about the feasibility of increasing ambition on other lower-cost options (e.g. onshore wind).
  - If, however, increases in onshore wind (or other low-cost) ambition were achievable and politically acceptable, a slight reduction in 2020 offshore wind ambition would reduce the costs of meeting the RED target.
  - Conversely, the 2020 ambition for offshore wind should not be increased, unless there is clear evidence that costs have fallen significantly.

[1] The total does not exactly equal the sum of the parts due to accounting complexities (as set out in Chapter 5).

We summarise the analysis that underpins our key messages in four sections, and provide more details in the full report:

1) Technical and economic analysis of renewable electricity generation

2) Delivering renewable heat ambition to 2020 and beyond

3) The role of renewable energy in surface transport

4) Scenarios for renewable energy ambition

The broad context for the review is set out in Box 2.

Box 2: Context of the renewables review

The **current share** of renewables in the UK energy mix is around 3% (Table B1).

Table B1: Share of renewables in UK energy consumption (2004-2009)

	2004	2005	2006	2007	2008	2009
Heating and cooling	0.7%	0.9%	1.0%	1.2%	1.4%	1.6%
Electricity	3.5%	4.1%	4.5%	4.8%	5.4%	6.6%
Transport	0.1%	0.2%	0.5%	0.9%	2.0%	2.5%
Total	**1.1%**	**1.4%**	**1.6%**	**1.8%**	**2.4%**	**3.0%**

Source: *DUKES* 2010, Table 7.7.

By 2020, the 2009 EU Renewable Energy Directive (RED) sets a target for the UK to provide 15% of (gross final) energy consumption from renewable sources – consistent with a share of 20% across all EU Member States. The Committee advised in a letter in September 2010 that the UK's current plans for meeting that target are broadly appropriate.

By 2030, the Committee has previously recommended (in our advice on the fourth carbon budget) a reduction in economy-wide emissions of around 60%, requiring that the power sector is largely decarbonised by that date.

The Committee will publish a full **bioenergy** review later in 2011. Given concerns over sustainability and questions over the best long-term use for this limited resource, in this report we adopt a holding position that assumes no increase in bioenergy use in the power or transport sectors beyond 2020.

1. Technical and economic analysis of renewable electricity generation

Our assessment of renewable electricity generation covers two areas:

i) Supporting renewable electricity generation as part of a portfolio approach

ii) Enabling factors and policy implications

i) Supporting renewable electricity generation as part of a portfolio approach

The technical and economic analysis in this review has identified a potentially significant, but uncertain, contribution from renewables to required power sector decarbonisation (Table 1).

- **Power sector decarbonisation.** Deep cuts in power sector emissions through the 2020s are feasible, cost-effective and desirable. Analysis for our fourth budget report suggested the need for 30-40 GW of low-carbon capacity in the decade from 2020, to replace ageing capacity and to drive down average emissions intensity to around 50 gCO_2/kWh.
- **Diversity.** Given current uncertainties over either the deployability or the costs of nuclear and CCS (see below), there is a value in developing other options for power sector decarbonisation. This suggests a potentially important role for renewable generation technologies.
- **Resource.**
  - There is abundant UK renewable resource, as regards wind, marine and solar energy.
  - Nuclear generation is unlikely to be subject to a fuel resource constraint for at least fifty years although this may become an issue in the longer term. In the medium term, availability of sites may become a binding constraint.
  - There is a long-term constraint on cost-effective CCS storage capacity. This could limit medium-term deployment of CCS in power generation, given the likely need for long-term use of CCS in energy-intensive industries.
- **Technical feasibility.** There is an issue about how the system copes with intermittent renewables (i.e. keeping the lights on when the wind does not blow). Our analysis suggests, however, that a high level of intermittent renewable generation is technically feasible, as long as options for providing system flexibility are fully deployed.
  - A range of options exist to address intermittency (demand-side response, interconnection, balancing generation) at a cost that is likely to be low relative to the costs of generation even up to very high penetrations. For example, analysis that we present in Chapter 1 suggests that even for renewable shares up to 65% in 2030 and 80% in 2050, the cost is only up to 1 p/kWh of additional intermittent generation.

– Given the potential to deploy these options, an assessment of achievable build rates suggests that it would be technically feasible to achieve renewable generation penetration of 65% in 2030.

- **Economics.** It is likely that a wide range of low-carbon generation technologies (renewables and others) will be cheaper than fossil-fired generation (Figure 1), given a carbon price compatible with overall progress to a low-carbon economy (e.g. around £70 per tonne in 2030):

  – Nuclear appears likely to be the lowest-cost low-carbon technology with significant potential for increased deployment; it is likely to be cost-competitive with gas CCGT at a £30/tCO_2 carbon price in 2020. As such, it should play a major role in decarbonisation, provided that safety concerns are addressed (Box 3).

  – The economics of CCS generation are likely to remain highly uncertain until this technology has been demonstrated at scale.

  – Onshore wind has a comparable cost to nuclear and is therefore also likely to be cost-competitive with gas CCGT by 2020.

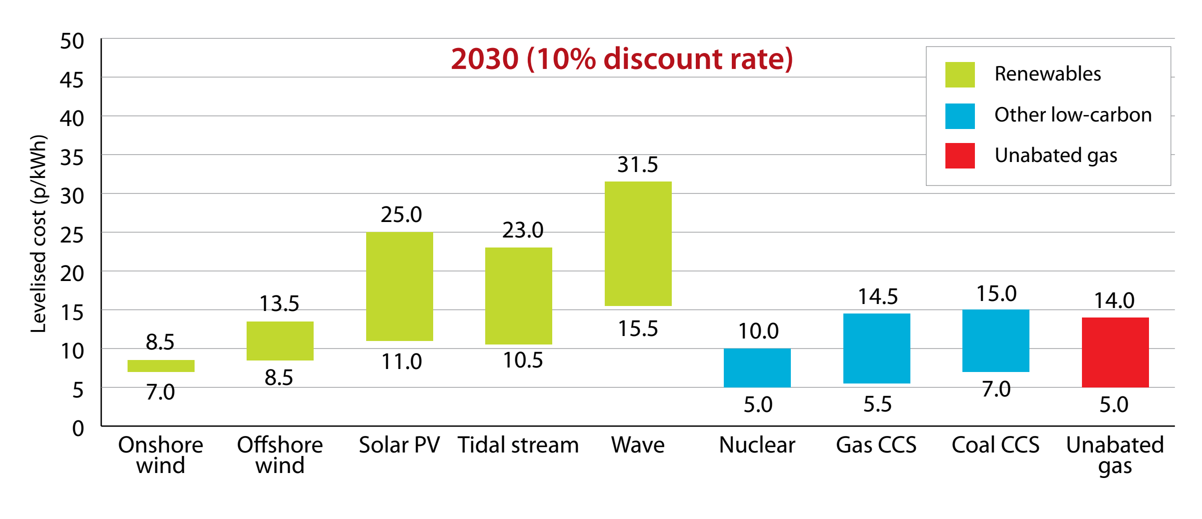
  – Most other renewable generation technologies currently appear relatively expensive and are likely to remain so until at least 2020, and in some cases considerably later.

  – By 2030, however, there are plausible scenarios where these other renewable technologies (e.g. offshore wind, marine, solar) have become cheaper than fossil-fired generation at a carbon price of £70/tCO_2 and to different extents have become competitive or close to competitive with nuclear.

  – Our conclusions on cost are based on a 10% real discount rate for annualising capital costs. Whilst some emerging technologies may currently apply a higher discount rate, we consider 10% to be a suitable basis for longer-term cost comparisons in the power sector, with new market arrangements in place and with wider deployment. Depending on the extent to which technology uncertainties are resolved, and with a supportive policy environment, a lower discount rate may be appropriate (e.g. 7.5%), in which case the low-carbon abatement options are even more attractive against conventional generation (Figure 2).

- **UK role in technology development.** As set out in our 2010 innovation review, the UK should support those technologies where we have a comparative advantage, and where we have the opportunity to be a leader internationally. These include offshore wind, for which the UK has a very favourable resource and a developing industry, and marine, for which the UK is in the lead in developing and demonstrating the technology and has a large share of the world's most promising sites.

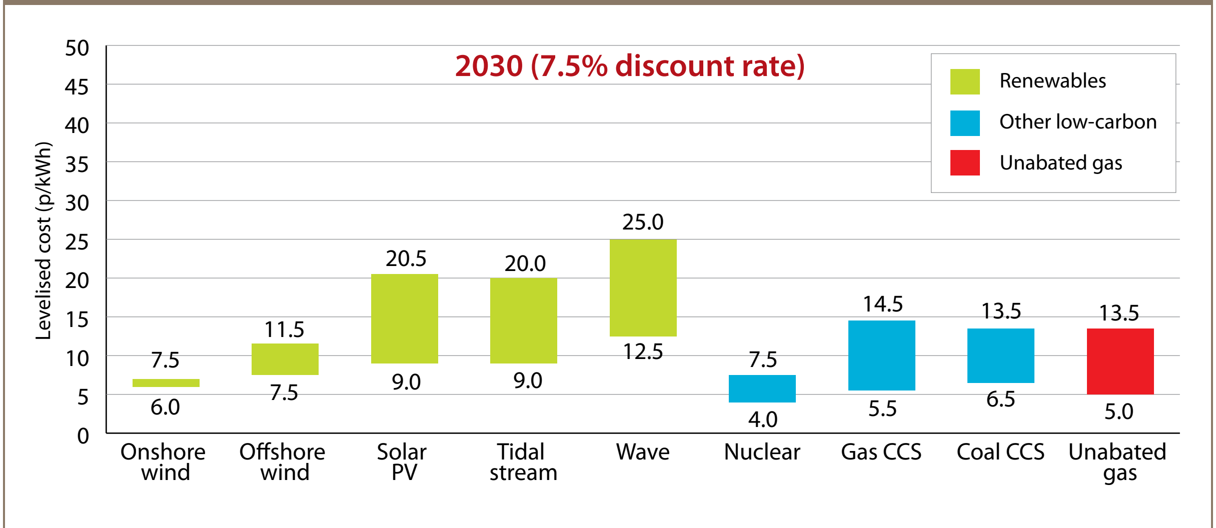
Figure 1: Estimated cost ranges for low-carbon power technologies (2030)



Source: CCC calculations, based on Mott MacDonald (2011) *Costs of low-carbon generation technologies.*

Note(s): 2010 prices, using 10% discount rate, for a project starting construction in 2030. Unabated gas includes a carbon price. Excludes additional system costs due to intermittency, e.g. back-up, interconnection. These ranges take into account capital cost and fuel/carbon price uncertainty, but do not cover all possible eventualities (e.g. they assume that CCS is successfully demonstrated).

Figure 2: Estimated cost ranges for low-carbon power technologies at 7.5% discount rate (2030)



Source: CCC calculations, based on Mott MacDonald (2011) *Costs of low-carbon generation technologies.*

Note(s): As Figure 1, with 7.5% discount rate.

Box 3: The Fukushima nuclear plant and implications for the UK

Events in Japan at the Fukushima Daiichi nuclear plant have raised the issue of nuclear power safety internationally. The UK has launched a review, which will deliver preliminary findings in May. We note that whilst the specific circumstances in Japan differ significantly from those for new nuclear in the UK, in principle this could affect the potential for nuclear power to contribute to decarbonisation in the UK (e.g. the National Policy Statement for nuclear has been delayed to take account of the review, and any tightening of safety requirements may increase costs).

- Nuclear safety was considered at length in the 2008 White Paper on Nuclear Power and associated consultation document. This concluded that the safety risks associated with new nuclear power in the UK are very small:
  - There have been no civil nuclear events with off-site consequences or where all the safety barriers that are an inherent part of the design were breached in the UK.
  - The consultation document cites analysis for the European Commission suggesting that the risk of 'a major accident – the meltdown of the reactor's core along with failure of the containment structure' is of the order of one in a billion per reactor per year in the UK.
  - More broadly, the White Paper found that the safety risk associated with new nuclear in the UK is not comparable with older plant where accidents have occurred overseas because regulatory scrutiny of reactor designs and operations is far more rigorous in the UK today.
- Those conclusions are likely to be robust to events in Japan:
  - Events in Japan were the result of an enormous earthquake and tsunami. These affected back-up power and thereby compromised cooling of some reactors. Subsequently there has been overheating, exposure and radiation release from spent fuel ponds.
  - The likelihood of natural disasters of this type and scale occurring in the UK is extremely small.
  - Plant designs allowed under the UK's Generic Design Assessment have benefited from considerable technological improvement since the 1960s Boiling Water Reactors used at Fukushima, including the incorporation of secondary backup and passive cooling facilities.

- However, the Committee has not undertaken a detailed review of all possible implications for nuclear in the UK.
  – DECC has commissioned such a review from the chief nuclear officer, Dr Mike Weightman. This will report preliminary findings in May, with a final report due in September 2011.
  – A full review is required to ensure that any safety lessons are learnt and to restore public confidence in the safety of nuclear power.

Should the review suggest limiting the role of nuclear generation in the UK in future, then a higher renewables contribution would be required. Alternatively if the review leads to a significant tightening of safety regulations, nuclear costs may be increased, which would improve the relative economics of renewable technologies and argue for potentially increasing their role.

Table 1: Summary: Importance of low-carbon generation technologies in UK decarbonisation strategy

Technology	Cost at commercial (10%) discount rate (p/kWh)[2] 2020	2040	2040 cost at a social (3.5%) discount rate (p/kWh)	Importance of UK deployment for reducing costs
Unabated gas	5.0-11.0	6.0-16.5	5.5-16.0	Reference technology
Technologies that are likely to play a major role in future UK mix				
New nuclear	5.5-10.0	4.5-9.5	2.5-4.5	Equipment costs likely to be driven by global deployment, with some potential for local learning-by-doing.
Onshore wind	7.5-9.0	6.5-8.0	4.0-5.0	Technology is already well-established and is being deployed globally. UK impact on costs therefore likely to be limited.
Offshore wind	10.0-15.0	7.5-12.0	5.0-8.0	UK deployment likely to be important to reducing costs, given significant capability already established and a large share of the global market. Also a requirement for specialised local infrastructure (e.g. ports).
Technologies that could play a major role in the future UK mix, where deployment in the UK is important in developing the option				
CCS	6.0-15.0 (gas) 7.5-15.0 (coal)	5.5-14.5 (gas) 6.5-15.0 (coal)	5.0-13.5 (gas) 5.0-11.5 (coal)	UK deployment will be important alongside global efforts towards cost reductions. UK has existing strengths (e.g. in CO_2 storage and transportation, subsurface evaluation and geotechnical engineering, and in power plant efficiency and clean coal technologies) and likely to be an early deployer internationally.
Tidal stream	12.5-25.0	9.0-21.5	6.0-14.0	UK has an important role. UK companies have significant marine design/engineering experience and already have a sizable share of device developers and patents. UK resource also a large share of the global market.
Wave	19.0—34.5	12.5-29.0	7.0-15.0	As for tidal stream, UK has an important role.
Technologies that could play a major role in the future UK mix, with limited role for UK deployment in developing the option				
Solar PV	17.5-33.0	8.0-19.5	4.5-11.0	Limited role for UK deployment (though UK does have research strength). Technology development likely to be driven by international deployment or by research in the UK that is not dependent on UK deployment.
Tidal range[3]	23.5-41.0	20.5-39.5	8.5-16.0	Limited scope for cost reductions as an established technology, and limited sites to apply any learning from early deployments.
Severn barrage[4]	21.0-31.0		7.5-11.0	

[2] Costs are for a project starting construction in that year. Estimates take into account capital, fuel and carbon price uncertainty. Additional system costs due to intermittency (e.g. back up, interconnection) are not included.
[3] CCC calculations based on Mott MacDonald's assessment of 2 GW site.
[4] Cost estimates for Severn barrage (Cardiff -Weston scheme) from DECC (2010) *Severn Tidal Power Feasibility study*. High end of costs is represented by the Feasibility Study estimate including Optimism Bias (OB), Risk Assessment (RA) and Compensatory Habitat payments. Low end includes Compensatory Habitat payments but not RA and OB.

UK practical resource[5] (i.e. potential to contribute to long-term decarbonisation)	Other considerations	Conclusion: Future role in UK mix and strategic attitude to technology development
		Limited role for building new unabated gas (or coal) beyond 2020, given rising carbon costs and availability of (lower-cost) low-carbon alternatives.
In theory could be very large. In practice may be limited by sites – 8 currently approved sites could provide over 20 GW (e.g. 175 TWh per year)[6].	Mature technology, globally deployed. Waste disposal and proliferation risks. Public attitude and safety concerns.	Given maturity and relatively low cost, likely to play a major role at least to 2050. Potential constraints and wider risks/considerations suggest it would not be prudent to plan for a low-carbon mix entirely dominated by nuclear.
Around 80 TWh per year, depending on planning constraints.	Intermittency. Possible local resistance.	Relatively low cost, therefore likely to play a significant role, within the constraints of suitable sites. Large amounts of other technologies will also be required, given limited site availability.
Very large – over 400 TWh per year.	Lower visual impact (less local resistance). Intermittency.	Promising long-term option, given large resource and potential for cost reductions. Given potential UK impact on global costs, warrants some support to 2030 to develop the option.
May be limited by availability of fuel and storage sites.	Dispatchable. Exposed to fossil fuel price risk.	Future role currently highly uncertain given early stage of technology development. Likely to be valued in a diverse mix, given different risks compared to nuclear and renewables and potential to operate at mid-merit, given lower capital intensity.
Potentially large – 18 to 200 TWh per year.	Intermittency (with possible benefits in wind-dominated mix).	Currently at an early stage therefore will have a limited role in the period to 2020. Important role for UK globally in developing the option to 2030. Given potentially large resource and scope for cost reduction, could play significant role as part of a diverse mix in 2030 and beyond.
Limited – around 40 TWh per year.	Intermittency (with possible benefits in wind-dominated mix).	Currently at an early stage therefore will have a limited role in the period to 2020. Important role for UK globally in developing the option to 2030. Given scope for cost reduction, could play role as part of a diverse mix in 2030 and beyond, but limited by practical resource.
Large – around 140 TWh per year (on the basis of current technology) with more possible with technology breakthroughs.	Intermittency (with possible benefits in wind-dominated mix).	Given current high costs and limited UK impact on global costs, role in the short term (i.e. to 2020) should be limited. Option to buy in from overseas later, and to have a major role in the longer term (subject to significant cost reductions).
Limited – around 40 TWh per year (of which almost a half from the Severn).	Intermittency (with possible benefits in wind-dominated mix).	Given limited opportunities to reduce costs with deployment, should not be pursued where sufficient lower-cost options are available. Should be triggered as an option if relative costs improve or if there are tight constraints on roll-out of lower-cost technologies (e.g. wind, nuclear).

5 See Chapter 1, section 2. Numbers here are considered 'practical' resource, i.e. taking into account environmental and proximity constraints.
6 175 TWh per year in 2030 would require 22 GW, including all current developer plans for 7 sites (18 GW), existing plant expected still to be in operation (1.2 GW) and 2 more reactors (3.2 GW) at the remaining site, or additional at the other 7 sites.

The implication of our technical and economic analysis is that energy and technology policy approaches should promote competition between the more mature low-carbon technologies, while providing support for technologies that are currently more expensive but with a potentially important long-term role. Support is required for technologies at the early deployment phase (e.g. offshore wind) and those at the demonstration phase (e.g. marine). This raises questions about whether it is appropriate to commit now to a specific level of ambition for these technologies in 2030 and if so what the level should be.

Committing now to technology support in the 2020s

The likely scale of investment in the less mature renewable technologies (e.g. offshore wind, marine) during the 2020s is very uncertain. This reflects their currently high costs, and the lack of policy commitment to providing support for new investments beyond 2020.

This uncertainty would be resolved by committing now to a minimum level of deployment or support in the 2020s, therefore underpinning required supply chain investment over the next decade.

A decision on whether to go beyond a minimum commitment, including a decision on the possible contribution from a Severn barrage project, could be taken when better information is available on relative costs and any barriers to deployment (e.g. in 2017/18, when there will be more confidence about costs and performance of offshore wind, marine, nuclear and CCS).

The minimum commitment should also hold only if supply chain investment envisaged to 2020 is delivered in practice.

In order to provide investor confidence, technology support should be provided through firm commitments, to be implemented through new electricity market arrangements (see section 1(ii) below).

An illustrative scenario for technology support

In determining the appropriate level of any such commitment the relevant factors are the level of supply chain investment required, the degree of commitment required to support this investment, and the need to keep the impact on electricity bills at an acceptable level.

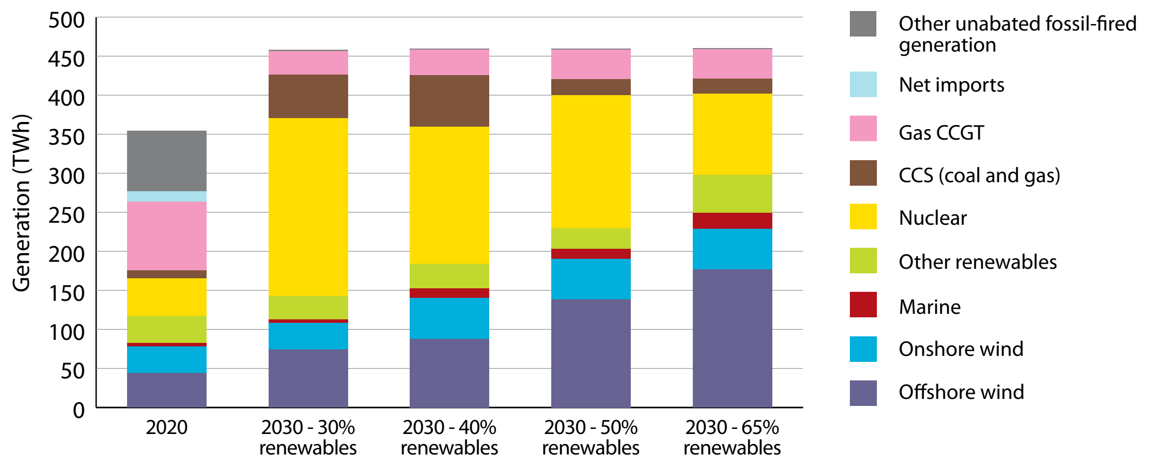
We set out a range of scenarios in this report (Figure 3), of which the 40% (185 TWh) renewable penetration scenario currently appears likely to be the most appropriate. This scenario includes:

- **Offshore wind.** There is investment in offshore wind through the 2020s at levels consistent with planned investment levels to 2020 (as set out in the Government's Renewable Energy Strategy).
- **Marine.** Tidal stream and wave investments proceed in line with rates planned for 2020.

- **Onshore wind.** Our cost estimates suggest that onshore wind is likely to be one of the cheapest low-carbon options. There are however questions over the scale at which it can be deployed given uncertainties relating to site availability and planning, in turn reflecting public concerns about the local visual impact. Our assessment is that over 6 GW (generating 20 TWh a year) could be added in the 2020s.
- **Biomass.** Given sustainability concerns and demands from other sectors we assume no new investment in biomass in the power sector beyond 2020.
- **CCS.** This scenario includes investment in a further 9 GW of CCS, largely coming on to the system in the second half of the 2020s.
- **Nuclear.** Given that nuclear is likely to be relatively low cost, it should have a crucial role, provided safety concerns can be addressed (see Box 3 above). In this illustrative scenario, there is investment on all eight currently approved sites, with around 18 GW new nuclear added to the system through the 2020s, resulting in around a 40% share (175 TWh) in 2030.

In practice, the precise renewables share (including any contribution from other renewables, e.g. solar PV and geothermal) will be determined through a combination of technology support for those currently more expensive technologies, and competition between more mature renewable technologies and other low-carbon alternatives, to be implemented through new electricity market arrangements.

Figure 3: Renewable generation scenarios to 2030



Source: CCC calculations, based on modelling by Pöyry Management Consulting.

Note(s): All 2030 scenarios achieve a comparable level of emissions intensity (around 50 g/kWh) and security of supply.
Includes losses, excludes generator own-use and autogeneration. Other renewables include hydro, biomass (including anaerobic digestion), geothermal and solar PV.

Offshore wind ambition to 2020

In our September 2010 letter to the Secretary of State for Energy and Climate Change, we suggested that the ambition to 2020 for offshore wind was broadly appropriate.

In this report, we have returned to the question of 2020 ambition, and considered whether this could be reduced whilst still providing required technology support to 2030.

The context for this is the electricity price impact of offshore wind ambition, which involves a cost penalty roughly double that of onshore wind generation (as reflected in the current subsidy payment for offshore wind of 2 ROCs[7] per MWh, compared to 1 ROC for onshore wind).

Given the very aggressive pace of investment to 2020 under the Government's plans, ideally this would be smoothed in the context of a 2030 commitment (i.e. by reducing ambition to 2020 to reduce costs, whilst committing to further investment in the 2020s given the long-term importance of offshore wind).

One way to achieve this whilst still meeting the UK's renewable energy target under the EU Renewable Energy Directive would be to increase ambition for onshore wind. This would require that society (and specific communities) accept greater landscape impact in return for slightly reduced electricity bills.

There may also be scope to increase ambition for other options to meet the renewable energy target, including renewable heat, imported renewable energy or renewable energy credits.

Therefore, if evidence emerges that other, lower-cost, options can be delivered at higher levels than currently envisaged, the offshore wind ambition for 2020 could be slightly reduced, even while stretching ambitions for 2030 are maintained.

The level of 2020 offshore wind ambition should not be increased unless there is clear evidence of significant cost reduction. Increasing ambition would adversely impact consumers without any clear offsetting benefits in terms of technology innovation.

ii) Enabling factors and policy implications

Amongst the key enabling factors to deliver 2020 ambition that we consider in the review are the Electricity Market Reform, the role for a Green Investment Bank in financing offshore wind investment, and the planning framework.

The Electricity Market Reform

We have previously highlighted the risks to investment in low-carbon generation under current electricity market arrangements, and the need for new arrangements based on long-term contracts to ensure that investments are made at least cost to the consumer. The Government recently made proposals consistent with this recommendation.

[7] Renewable Obligation Certificates (ROCs) are tradable certificates that electricity suppliers buy from developers of renewable generation projects.

Ideally these arrangements would be technology-neutral, with the range of low-carbon technologies bidding against each other for contracts. However, in practice this would result in investment focused on mature technologies, and not in those currently more expensive technologies that have a potentially important longer-term role.

Therefore, given our conclusion above that a portfolio of low-carbon technologies is desirable, the new market arrangements should be designed to provide additional support for those promising technologies at an earlier stage of development.

For example, the minimum commitments recommended above could be implemented through reserving some of the available contracts for less mature renewable technologies. This would have to reflect different costs across the technologies and be subject to certain conditions (e.g. a declining reserve price in contract auctions) in order to ensure cost reductions and a falling electricity price penalty for consumers.

More mature renewable technologies (i.e. onshore wind and hydro) would then compete with other mature low-carbon technologies (i.e. nuclear) for contracts. This would provide a least-cost investment programme for sector decarbonisation, and could also reflect considerations around diversity of the generation mix (e.g. it may be appropriate to pay more for technologies that diversify the mix and reduce security of supply risk).

The expectation is that the less mature technologies that would at first need support (e.g. offshore wind, marine and CCS) would ultimately also be able to compete for contracts without additional support.

Transitioning from current support arrangements

There is an important issue of the transition from current arrangements (the Renewables Obligation) to new arrangements, with the risk that the change causes an investment hiatus. To mitigate this risk, existing arrangements need to be effectively grandfathered and available until new arrangements are clear. This could require extending the RO beyond the date (2017) proposed in the Electricity Market Reform consultation.

The Green Investment Bank

Even if greater revenue security is provided through new electricity market arrangements, there will still be significant uncertainties around cost and performance of offshore wind. Therefore new electricity arrangements may not fully address current concerns over availability of equity and debt finance for required investments.

If finance is constrained, there is a potentially valuable role for a Green Investment Bank (GIB), both in terms of providing comfort to investors and providing an additional pool of capital for risk sharing.

The GIB could best fulfil this purpose if it is indeed a bank, rather than a fund, as announced in the March 2011 Budget.

However, as currently proposed, the GIB would only be able to borrow money from 2015/16. This is potentially problematic given that a crucial window of opportunity for the GIB is precisely the period before 2015/16 – as new electricity market arrangements will still be uncertain and there will be few proven examples of offshore wind projects in successful operation. Around £20 billion of investment finance is needed for offshore wind alone in this period, when risks are at their highest.

Therefore, unless it can be demonstrated that risks can be mitigated, allowing the GIB to borrow money from its inception should be seriously considered.

The planning framework for onshore wind and transmission

Planning approval rates for onshore wind projects have historically been low (e.g. less than 50%), and the period for approval long (e.g. almost two years). This reflects an implicit social preference for investment in more expensive renewable technologies, given concerns (held by some but not all people) about the visual impact of onshore wind developments.

However, further approvals will be required in order to deliver the onshore wind ambition in the Government's Renewable Energy Strategy.

Additional approvals beyond this level offer scope for reducing the cost of meeting the 2020 renewable energy target and the cost of power sector decarbonisation through the 2020s (e.g. our analysis suggests scope to add over 6 GW of onshore wind capacity through the 2020s).

In addition, planning approval will be required for transmission investments to support increased renewable generation and sector decarbonisation.

International experience suggests that approaches which achieve community buy-in to onshore wind projects through sharing financial benefits have helped support high levels of investment; it is appropriate that such approaches will be tested in the UK.

However, even with such approaches, there is a significant risk that onshore wind and transmission investments will not gain local public support, given high levels of resistance from some groups.

Achieving higher rates of approval for onshore wind projects and for required investments in the transmission network is therefore likely to require central government decisions in line with national priorities as defined by carbon budgets, possibly under new planning legislation that explicitly sets this out.

2. Delivering renewable heat ambition to 2020 and beyond

We summarise our analysis of renewable heat in two sections:

i) Renewable heat scenarios to 2030

ii) Implied 2020 ambition, barriers and responses

i) Renewable heat scenarios to 2030

We set out detailed analysis of options for renewable heat investment and scenarios to 2030 as part of our advice on the fourth carbon budget.

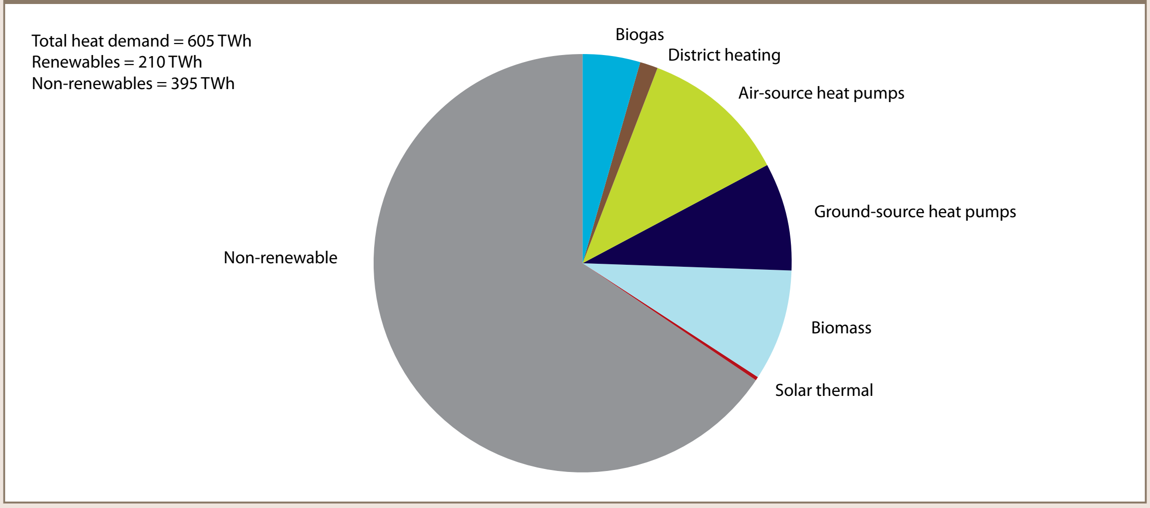
We considered the full range of renewable heat options (Box 4). We showed that these could be competitive given potential for cost reductions and a carbon price rising to £70/tCO_2 by 2030 (Figure 4).

Box 4: Renewable heat technologies

Renewable heat technologies in our fourth budget scenario included heat pumps, biomass and biogas (Figure B4).

- **Heat pumps (air-source and ground-source):**
  - Heat pumps use electricity to extract heat from the surrounding environment (e.g. the ground or air) and transmit this for space and hot water heating. One unit of electricity from heat pumps can generate between 2.5 and 4.5 units of heat, with the extra heat generated classed as renewable.
  - Energy efficiency improvement is a necessary condition for effective deployment of electric heat pumps. Otherwise heat pumps and the associated radiator system need to be significantly larger (and more expensive), and in extreme cases would not be able to provide adequate levels of warmth.
  - While there is currently limited deployment of heat pumps in the UK, these are a relatively mature technology and are widely used in other countries (e.g. France, Sweden). Widespread roll-out in the UK requires buy-in from householders and businesses, which will need effective policy to overcome existing and perceived barriers.
- **Biomass:** There is a range of potential uses of biomass to produce heat, including biomass boilers in residential and non-residential buildings, CHP for community and larger-scale district heating and process heat for industry. The key issues are the level of sustainable biomass that is available and where this is best used.
- **Biogas:** Biogas can be used to produce high-grade heat and can therefore be used as a substitute for fossil fuels in residential, non-residential and industrial sectors.

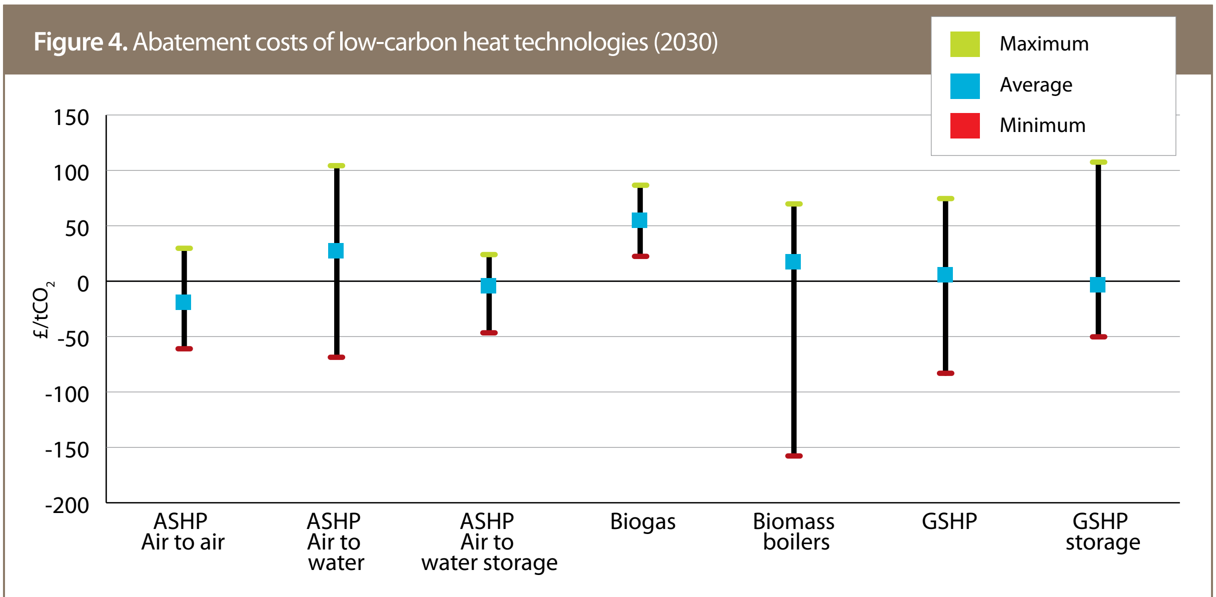
Figure B4: Fourth budget Medium abatement scenario: heat technologies (2030)



Source: CCC modelling.

Note(s): Figure includes all heat demand from buildings and industry.

Figure 4. Abatement costs of low-carbon heat technologies (2030)



Source: CCC modelling; NERA (2010).

Note(s): Cost ranges reflect different demand segments (e.g. the highest cost ground-source heat pumps with storage are in new build detached properties replacing gas). All costs are calculated based on central fossil fuel price projections and do not include a carbon price. ASHP = Air-source heat pump, GSHP = Ground-source heat pump.

We proposed a central scenario for renewable heat penetration reaching around 35% (210 TWh) in 2030, with renewable heat as one of the main contributors to economy-wide emissions reduction required through the 2020s.

In designing appropriate policies to support development of renewable heat options, four considerations are important:

- Renewable heat technologies are relatively mature, and are already widely deployed in some countries.
- Investment cycles for renewable heat are short compared to those for renewable power generation, implying scope for later decisions on commitments to technology support in the 2020s.
- The challenge is to demonstrate the technologies in a UK context, addressing current technical, economic and social barriers.
- Success here is of crucial importance, both because renewable heat technologies are promising from technical and economic perspectives, and because of a lack of alternatives for heat decarbonisation, which is required to meet the UK's 2050 target of an 80% emissions reduction.

We discuss policies to support UK demonstration in the next section, where one of our conclusions is that there will be a need for commitments on financial support for renewable heat in the 2020s, which in turn will require setting of renewable heat targets. Our central scenario shows the order of magnitude of ambition that currently appears appropriate, with the precise ambition to be determined as current uncertainties are resolved (e.g. between 2015 and 2020).

ii) Implied 2020 ambition, barriers and responses

The level of ambition for 2020

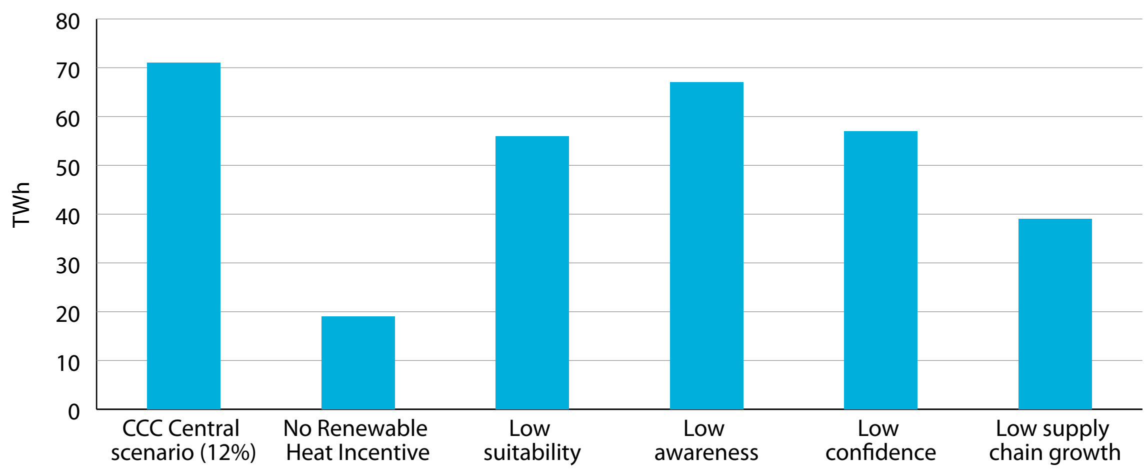
Our 2030 scenarios require significant deployment of renewable heat over the next decade. This will support technology development, build up a supply chain, and improve consumer confidence in technologies where there has been very limited deployment to date in the UK.

Specifically, our 2030 scenarios build in renewable heat penetration of around 12% (70 TWh) in 2020. This will be sufficient in terms of providing critical mass for required deployment in the 2020s, and is consistent with the Government's renewable heat ambition in its Renewable Energy Strategy.

Barriers and responses to achieving ambition

In this report, we present new analysis of barriers to renewable heat deployment to 2020, both financial and non-financial. This analysis suggests that key deployment barriers are likely to include lack of financial support, supply chain constraints, and lack of consumer information and confidence (Figure 5).

Figure 5: Impact of barriers on renewable heat penetration in 2020



Source: CCC analysis based on modelling by Element Energy.

Note(s): 'Low suitability' reduces the number of buildings suitable for renewable heat deployment (e.g. because energy efficiency is not improved as required); see Figure 3.4 in Chapter 3 for other notes.

In assessing financial barriers, our main conclusions are that:

- Current funding commitments for renewable heat are appropriate, but further support will be required in future.
  - The overall level of support provided under the Renewable Heat Incentive (RHI) to 2014/15 is appropriate and the support for specific technologies is broadly in line with expected costs.
  - However, significantly increased funding will be required in the second stage (i.e. after 2014/15), at a level to be finalised in the context of a broader strategy to meet the 2020 renewable energy target.
  - Further support will also be required in the 2020s, either in the form of an extension of the RHI, or the introduction of a carbon price for heat.
- It will be important to ensure that there is disbursement of the RHI across the range of technologies in order that a portfolio of technologies for deployment in the 2020s is developed; lack of deployment in particular niches (e.g. residential heat pumps) would be problematic in this longer-term context.

Non-financial deployment barriers could be addressed through three key policy levers:

- **Accreditation of suppliers.** The analysis highlights the crucial role of supply chain expansion in supporting investment in renewable heat over the next decade, and within this the importance of ensuring that there are sufficient numbers of accredited installers. Therefore it will be important to have arrangements in place both for training and accreditation of installers. Together with validation of equipment, this could also help to increase consumer confidence.

- **Integration of renewable heat and energy efficiency policies.** Separate mechanisms for promoting renewable heat and energy efficiency risk complicating the delivery landscape and confusing consumers. The RHI and Green Deal should therefore be integrated. Integration would help to increase the number of suitable buildings, improve consumer confidence, and information, and provide a possible source of financing for up-front investment costs.
  - **Suitability.** Given that renewable heat technologies work better in well-insulated houses, linking renewable heat and energy efficiency policies would increase the number of suitable houses. This could be achieved by requiring a minimum energy efficiency rating to qualify for payment under the RHI, and through marketing renewable heat as part of the Green Deal (e.g. by including renewable heat technologies in energy audits and follow ups).
  - **Consumer confidence.** Marketing renewable heat as part of the Green Deal would enhance consumer confidence, both because it would ensure deployment in suitable buildings, and because it would offer an opportunity to provide customers with better information. It would also allow reduction of transaction costs if implementation of energy efficiency and renewable heat measures were to form part of a whole-house or one-stop-shop approach.
  - **Financing up-front costs.** These are potentially significant (e.g. around £6,000 to £10,000 for an air-source heat pump in the residential sector) and prohibitive for some applications. Financing constraints could be addressed by integration – allowing financing under the Green Deal for renewable heat investment.
- **Zero-carbon homes.** Renewable heat deployment in new homes does not face as many barriers as retrofit to existing homes. This highlights the opportunity offered by new homes and importance of defining zero-carbon homes in such a way as to promote renewable heat.

It will be important that both financial and non-financial barriers are addressed by the RHI and other policies in order that significantly increased investment in renewable heat occurs over the next decade. This is required, in turn, for longer-term heat decarbonisation in the context of the 2050 economy-wide emissions target.

3. The role of renewable energy in surface transport

Electric vehicles

We set out a detailed assessment of scope for increased penetration of electric vehicles (including plug-in hybrid and fuel cell vehicles) in our advice on the fourth carbon budget. Based on technical and economic analysis, we suggested that it is appropriate to aim for electric vehicle penetration of around 60% of new cars and vans by 2030.

While electric vehicles would account for a smaller share of miles and energy use in 2030, this will increase significantly in the 2030s as the vehicle stock turns over. Electric vehicles would be renewable to the extent that they are powered by renewable electricity.

Biofuels

Our approach to appropriate biofuels ambition is cautious, reflecting concerns about sustainability:

- There is a tension between the use of land for growth of food versus bioenergy feedstocks. The risk is that with high growth of bioenergy feedstocks, there would be limited land available for growth of food, resulting in high prices and supply shortages. This risk is more pronounced given the significant projected increase in global population over the next four decades, and moves to more land-intense diets as incomes increase.
- There are concerns around emissions reductions associated with biofuels when lifecycle emissions including from land use impacts and from growth and processing of feedstocks are accounted for.

Given a scarce supply of bioenergy, this should be used in sectors where there are limited alternatives for decarbonisation (e.g. aviation, industry) as opposed to surface transport, where decarbonisation through electrification is likely to be technically feasible and economically viable. Specifically, we have accepted the findings of the Gallagher Review, which suggested it would be appropriate to plan for biofuels penetration of around 8% by energy in 2020[8].

8 We show in Chapter 4 that with the electric vehicle roll-out assumed in our scenarios this would still meet the EU 10% renewable energy sub-target for transport, given the specific accounting rules for that target.

In our fourth budget advice, we set out scenarios for biofuels penetration through the 2020s:

- Our Low and Medium abatement scenarios include no increase in penetration through the 2020s from levels consistent with the Gallagher Review recommendations in 2020 (30 TWh, equivalent to around 11% penetration in liquid fuels by 2030, given falling liquid fuel use). Together with the contribution from renewable power used in electric vehicles the total renewable energy share in transport would be around 15% in 2030.
- Our High scenario includes increased penetration through the 2020s in line with the IEA's BLUE Map scenario (60 TWh, equivalent to around 25% penetration in liquid fuels by 2030).

We are currently undertaking a bioenergy review which will:

- Develop scenarios for availability of sustainable bioenergy based on analysis of global land, population growth, diet change, and scope for agricultural productivity improvement.
- Consider where available sustainable bioenergy would best be used (i.e. between power, surface transport, buildings, industry, aviation, shipping) given alternative abatement options available.

We will publish the bioenergy review before the end of 2011.

4. Scenarios for renewable energy ambition

Scenarios to 2020

Our scenarios for renewable energy ambition to 2020 are consistent with the UK's 15% renewable energy target for 2020 under the EU Renewable Energy Directive (Figure 6). Although we assume slightly lower levels of biofuels than in the Government's Renewable Energy Strategy, the overall target is still met through increased energy efficiency (e.g. improving fuel efficiency of conventional vehicles, replacement of conventional vehicles with electric alternatives).

We estimate that the cost of supporting renewable electricity to 2020 will add up to 2 p/kWh to the electricity price, increasing the average annual household electricity bill by around £50-60 in real terms.

- Around half of this cost is due to supporting offshore wind.
- There is also some cost from onshore wind, though by 2020 new projects are likely to be competitive without specific support.
- This represents around a 10% increase on what household electricity bills would otherwise be in 2020.
- It is around a 4% increase on households' total energy bills, where electricity accounts for 40% of total energy costs and gas accounts for the remainder.

There is the opportunity to offset the impact of higher prices through energy efficiency, which we estimate could reduce residential energy consumption by around 14% in the period to 2020.

This would therefore more than compensate for impacts of renewable electricity investment, and ensure that the share of expenditure on energy relative to income remains roughly flat when allowing for upward pressure on bills from rising gas and carbon prices along with expectations of rising incomes.

For non-residential consumers, higher electricity prices could lead to impacts on competitiveness of a small number of energy-intensive UK industries which compete in global markets (e.g. iron and steel, aluminium).

To the extent that there are competitiveness risks, there is a range of potential measures (e.g. tax rebates) which would help mitigate any impacts.

Delivering renewable heat ambition will not increase energy bills under the current financing approach. It could require fiscal support of the order of £2 billion a year by 2020.

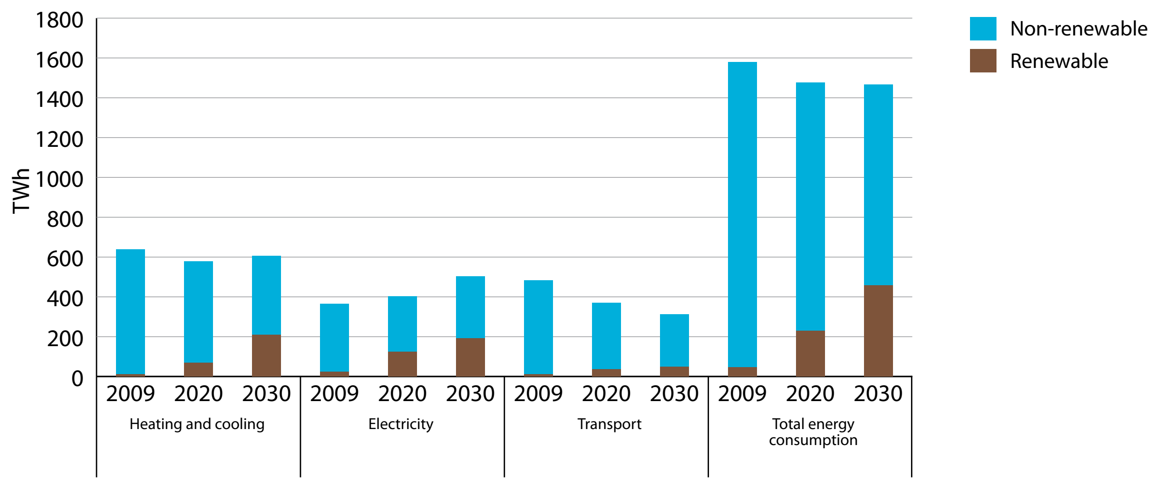
Renewable energy in transport is not expected to add to motoring costs as biofuels are expected to be a similar cost to petrol and diesel under central assumptions for the oil price. We have factored the increasing cost of electricity into our analysis of the cost effectiveness of electric vehicles and electric heat pumps.

Scenarios to 2030

Our power, heat and transport scenarios for 2030 imply a renewable energy share of up to 45% (680 TWh) in 2030.

Our illustrative scenario for power alongside our central scenarios for heat and transport in 2030 are consistent with a 30% (460 TWh) economy-wide renewable energy share (Figure 6), with the possibility of going further as uncertainties are resolved (e.g. over the relative cost of renewable power generation, or deployability of renewable heat).

Figure 6: Renewable shares in energy consumption (2009, 2020 and 2030)



Source: CCC calculations.

Note(s): Total energy consumption is gross final consumption calculated on the basis as set out in the EU Directive. Energy consumption shown in the heating sector is taken from the CCC heat model and is calculated on a slightly different basis. Electricity use is shown both in the sectors within which it is consumed and in the electricity sector; it is only counted once in total consumption. Includes autogeneration and generator own use. 2030 figures are for our illustrative central scenarios. Demand assumptions are taken from our fourth budget analysis, based on CCC's bottom-up modelling and energy projections from the DECC energy model using central assumptions for population growth from ONS and GDP growth from the Office of Budget Responsibility.

The costs associated with delivering this level of ambition are of the order of under 1% of GDP in 2030 compared to a scenario where there are no carbon constraints.

The 2030 energy bill impacts over and above those to 2020 are limited:

- **Electricity.**
  - An increasing proportion of electricity will be paid for under long-term contracts at prices below those of unabated gas with a £30/tCO_2 carbon price in 2020.
  - Whilst unabated fossil-fired generation will become more expensive with an increasing carbon price in the 2020s, this will account for a declining share of total generation (e.g. providing less than 10% of generation in 2030).
  - Whilst there will be some ongoing investment in more expensive offshore wind and marine, this will be limited unless there have been significant cost reductions.

- **Heat.** During the 2020s there is scope for some renewable heat technologies to become cost-competitive and possibly lower cost than conventional heating technologies.

The story in the 2020s is therefore likely to be one of more modest price rises than during the 2010s, and with average energy bills falling relative to income, assuming incomes continue to grow.

Developing a full range of renewable and low-carbon options for required economy-wide decarbonisation in the 2020s, and deployment at this time according to least-cost principles, could give the UK a competitive advantage in a carbon-constrained world.

There are a range of levers for addressing any ongoing fuel poverty impacts (e.g. social tariffs, income transfers) and competitiveness impacts (e.g. tax rebates, sector agreements, border tariff adjustments).

* * *

Our analysis suggests that there is both scope and need for ongoing investment in renewable energy through the 2020s as part of a least-cost strategy for meeting carbon budgets. We recommend that the Government recognises the important role of renewable energy in meeting carbon budgets by providing technology support for less mature technologies in new electricity market arrangements, and integrating the RHI with the Green Deal. The focus of policy should be on removing barriers and putting in place incentives to significantly increase renewable energy supply over the next decade – thereby developing a range of renewable energy options for decarbonisation in the 2020s and beyond. Given these options, we will be better able to meet carbon budgets at an affordable cost, resulting in a range of benefits including mitigation of climate change risks, reduced reliance on imported fossil fuels, and industrial opportunities associated with building a green economy.