

Transforming the UK's Energy System

Policies for the 2020 Renewables Target and Beyond

A report for Friends of the Earth

Dr Jim Watson, Dr Ivan Scrase, Dr Lee Stapleton
Sussex Energy Group, SPRU,
University of Sussex.



US

University of Sussex

Sussex Energy Group

SPRU – Science & Technology Policy Research



Transforming the UK's Energy System

Policies for the 2020 Renewables Target and Beyond

Foreword	3
Executive summary	4
1. Taking stock after two decades of renewables policy	6
1.1 Introduction.....	6
1.2 UK commitments.....	7
1.3 The UK's starting position, and how we got here.....	8
1.4 Why deliberately transform the energy system?	12
2. How achievable is the 2020 commitment, and what comes after that?	13
2.1 How achievable is 15% by 2020?	13
2.2 How did the outgoing Government propose we will get there?.....	17
2.3 Looking beyond 2020.....	19
3. Are we still locked in to a centralised, high carbon energy system?	23
3.1 Lock-in: explaining inertia.....	23
3.2 Addressing lock-in: scale, infrastructure and industrial policy.....	26
Section 4. Policies to meet ambitious renewables targets	33
4.1 Promoting renewable energy at many scales	34
4.2 New energy network infrastructures	36
4.3 Implementing an Activist Low Carbon Industrial Policy	39
References	42

Friends of the Earth

Friends of the Earth believes the environment is for everyone. We want a healthy planet and a good quality of life for all those who live on it. We inspire people to act together for a thriving environment. More than 90 per cent of our income comes from individuals so we rely on donations to continue our vital work. For further information visit www.foe.co.uk <<http://www.foe.co.uk>> .

Sussex Energy Group

The Sussex Energy Group is based at SPRU – Science and Technology Policy Research, University of Sussex. The Group undertakes academically rigorous, inter-disciplinary research that engages with policy makers and practitioners. The aim of this research is to identify ways of achieving transitions to sustainable, low carbon energy systems whilst addressing other important policy objectives such as energy security. SEG's team includes 25 social scientists and doctoral students. The majority of SEG's research is funded by UK research councils and government departments, with co-funding from a variety of other sources. Through the Group, the University of Sussex is a core partner of the Tyndall Centre for Climate Change Research and the UK Energy Research Centre.

Acknowledgements

The authors would like to thank Robin Webster, Ed Matthew, Dave Timms and Tony Bosworth at Friends of the Earth and Gaynor Hartnell of the Renewable Energy Association for extensive comments on previous drafts of this report. The research leading to the report was funded by Friends of the Earth and the Economic and Social Research Council.

Foreword

For too long the UK has been in the European slow lane on renewable energy, despite having some of the continent's greatest potential for producing clean power. Despite UK Government support for renewable energy R&D since the 1970s and financial assistance for deployment since 1990, renewables' contribution to national power remains small.

We welcome the Coalition Government's commitment to meeting our EU Renewables Directive target of producing 15 per cent of energy from renewables by 2020. The challenge now is to deliver a package of measures to ensure we meet this commitment.

Friends of the Earth commissioned research from the University of Sussex's Science and Technology Policy Research department (SPRU) to inform the debate and clarify the key policy decisions needed to make sure we achieve our EU target.

Welcome progress is being made on large-scale energy generation, such as offshore wind. And the recent introduction of the Clean Energy Cashback

scheme – following a successful campaign led by Friends of the Earth – has provided a vital boost for small-scale generation. But the central recommendation of this report is that a much greater focus is needed on community-scale energy generation. Without this, the 2020 target will be much harder to achieve.

As part of our Get Serious About CO2 campaign, Friends of the Earth is calling for local carbon budget legislation to be introduced in this session of Parliament. Local carbon budgets would drive ambitious emissions cuts by helping local authorities lead effective carbon reduction strategies across their local areas. The system would drive a coordinated approach to increasing local areas' capacity to produce renewable energy – including community and small-scale schemes.

Friends of the Earth hopes this report's recommendations will be considered – alongside our proposal for local carbon budgets – in developing a strategy to meet the 2020 renewables commitment.

Andy Atkins
Executive Director
Friends of the Earth

Executive summary

This report addresses the UK's commitment to increase the amount of renewable energy we produce to 15 per cent of energy demand by 2020. It examines the scale and nature of opportunities and challenges we face, the reasons for slow progress to date, and proposes additional policies to increase the chances that the 15 per cent target will be met. These policies would also help to ensure that the 15 per cent target is not a destination, but a staging post on the way to a greater share of renewables beyond 2020.

Whilst the Coalition Government has reaffirmed the UK's commitment to the 15 per cent renewables target, there is a long way to go to meet it. The contribution from renewables is small at around 3 per cent of energy demand. Renewable electricity generation, which has seen some growth, has only increased from 2 per cent to 7 per cent of electricity in the last 20 years. During this period there has been no shortage of policy initiatives and reviews to speed up progress. Renewables policy has been punctuated by periods of optimism that reforms would accelerate progress, only for this to seep away again as projects failed to get off the ground in sufficient numbers.

This report explains how the UK arrived at its current position. It draws particular attention to the 'lock-in' to a centralised, fossil fuel energy system which has been accompanied by weak support for renewable technologies and a lack of attention to systemic barriers to progress. While this places the UK at a particularly challenging starting point, this report also finds that many of the mechanisms of lock-in are beginning to weaken or to be addressed. Industrial policy has been rehabilitated – how far the new Government pursues this agenda will be a key test of its ability to deliver.

The conditions for a more tailored policy approach that recognises the varied status of different renewable technologies are better than in the

last two decades. However the report notes that several of the conditions that have prevented successful deployment of renewables in the past remain unchanged, and current policy proposals do not fully address certain dimensions of lock-in – principally missed opportunities due to a high degree of centralisation, and other features of the energy system that continue to act as barriers to renewables.

The report concludes with five key policy recommendations.

First, there is a clear case for bolder policy intervention to maximise the chances of hitting our 2020 target and to boost the renewables capacity beyond 2020. This does not mean the Government should micro-manage renewables. However, it does mean that stronger intervention is needed to overcome problems in several key areas as set out below.

Second, better financial incentives are needed to attract vital investment for developing renewable electricity. Shortcomings of the current incentive scheme – the Renewables Obligation (RO) – have contributed to the slow progress recorded to date. Recent reforms to the RO will help mitigate these, but it is not yet clear if they will have a significant impact on investor risks. A better approach would be to replace the RO with a feed-in tariff (FIT) that delivers a more certain return.

We therefore support the new Government's plan to expand the application of FITs, and to allow larger renewable plants to benefit from FITs. When implementing this policy, it will be important to ensure the levels of FIT are high enough to make renewables attractive to investors. But it will also be important to include incentives for efficiency and cost reduction, for example by lowering the FIT rate over time. Regarding renewable heat, the Renewable Heat Incentive should be implemented as planned in April 2011.

Third, it is crucial that we focus on what we have called ‘meso-scale’ renewables. This middle level of renewables falls between large scale investments (e.g. offshore wind farms) and small scale generation (e.g. in homes and schools). Unlike in many other northern European countries, the UK has almost no recent tradition of energy generation at this meso scale. If the potential for investment in towns, cities and other communities across the UK is ignored, the 2020 target will be much harder to meet. The role of Local Authorities is vital. Policy reforms are needed so they can become more active players, such as by raising finance for local renewable energy projects.

Fourth, widespread changes in network infrastructures – the pipes and wires that enable our energy system to function – are needed to cope with a rapid growth of renewables. Investment should be prioritised in three key areas: the extension of high voltage electricity grids to new locations (e.g. to connect offshore wind farms), the development of new heat grids in areas of high heat density, and the early demonstration of ‘smart’ electricity distribution grids (including an accelerated roll out of smart meters).

Infrastructure UK, which was established by the previous Government, could handle more co-ordinated financing of these network infrastructures. But policy needs to go further. We support the creation of a Green Investment Bank,

but only if it has a clear defined focus and enough resources to make a difference. We argue that its primary focus should be on co-financing energy networks since these play an important enabling role for both generators and consumers.

Fifth, the return of industrial policy in the energy sector is welcome, as is the commitment of the coalition Government to couple the low carbon agenda with job creation in the UK. We know what the Government’s priority areas of renewables technology are (including wind, wave and tidal). Within this, it is important that support for technologies that will help us meet the 2020 target is balanced against more nascent options that could make big contributions beyond 2020. A robust, independent programme of monitoring and evaluation of government support programmes is also required as a matter of urgency to prevent capture by industry lobbies – and to inform decisions to adjust or even withdraw funding in the light of experience.

The Government must ensure that robust action is taken in coming months and years to ensure the UK meets its 2020 renewable energy target – and to enable further growth of renewables beyond 2020. This will also help set the country on the right course to meet emissions reduction targets under the Climate Change Act, and build a strong low-carbon economy.

Dr Jim Watson

Dr Ivan Scrase

Dr Lee Stapleton

**Sussex Energy Group, SPRU
University of Sussex.**

1. Taking stock after two decades of renewables policy

This Section introduces the report, explains the origins of the UK's challenging starting position, and argues that the energy system needs to be deliberately transformed so as to better accommodate renewables.

1.1 Introduction

The UK has the best wind and wave power resources in Europe, skills in offshore engineering and long traditions of infrastructure building and industrial and social innovation. Renewable energy is a rapidly expanding global sector, already providing significant quantities of clean, low carbon energy. By 2050 the world will need to significantly reduce dependence on fossil fuels if dangerous climate change is to be averted.

While debates about the relevant visions for 2050 are inevitable and desirable, there is a consensus that the energy systems we have today will be transformed over coming decades. Renewable energy technologies and new ways of converting, distributing, using and saving energy that make them part of a secure, economically viable energy system will be at the heart of this innovative future. Renewables are only part of the solution to the climate problem, but making them work is central to moving the UK and the world on to a sustainable development path.

This report focuses on changes that need to start happening now in order that the UK meet its 2020 renewables target, and to place the UK in a good position to go well beyond this target in the decades that follow. This inevitably demands a high degree of generalisation and speculation – as thinking becomes more long-term the possibilities and uncertainties multiply. Where might the UK be in 2050? Visions abound, often emphasising one or a few long-term bets such as hydrogen or fusion power, or imports of renewable energy from the Sahara via super-grids. This report does not aim to add to those visions, but simply notes that the UK is well placed to become a low carbon society that gets a large proportion of the energy it needs from renewable resources. However this assumes that

renewable energy capacity will be realised much more fully than at present, using the full range of technologies. This, in turn, implies major incentives to empower people and organisations, many quite remote from Whitehall and the incumbent energy companies, to make this happen throughout the UK.

While advocating greater use of decentralised energy, this report does not argue against use of large scale facilities in principle, nor does it necessarily advocate radical decentralisation of the UK energy system as a whole. It is not contradictory to envisage a locality with its own smart 'micro-grid' for electricity, taking power from a diverse array of local sources, and for this to be fully connected into a UK national grid and further into an international super-grid. It is quite possible that in 2050 or even sooner someone in Krakow will consume a unit of electricity generated by a solar panel on a school in Bedford. The report says no more about international super-grids, but discusses investment in smart grids. These present opportunities for mobilising knowledge, innovation and energy to integrate multiple local generators, and to integrate electricity supply and demand more fully. There is also a strong role for central government, and changed roles for policy, in moving on to a low carbon development path. Major new infrastructures are needed - to extend the electricity grid within and beyond the UK's coastline, to transport heat and hot water, and in IT systems to make the grid more flexible and smarter, down to the level of the household. A truly smart grid would overcome the unhelpful distinctions that have built up between energy producers and energy consumers.

With the publication of the *Renewable Energy Strategy (RES)*, and the wider *Low Carbon Transition Plan* in 2009, the previous Government signalled its clear intention to meet its European commitment to securing 15% of its energy from renewables by 2020. This commitment has been reaffirmed by the incoming government. Indeed, the Coalition Agreement states that the

government 'will seek to increase the target for energy from renewable sources, subject to the advice of the Climate Change Committee' (HM Government 2010). The Government has also confirmed that it will continue its predecessor's commitment to a low carbon development path, with renewable energy central to the vision alongside nuclear power and carbon capture and storage (CCS). This report does not enter the debates over which of these technologies holds greatest promise, or their compatibility with one another (though these are important questions to debate). Rather the emphasis is on how the UK can meet its renewables target for 2020, and reduce the UK's carbon emissions and dependence on fossil fuels in doing so. This means not just meeting the target, but doing so as a step forwards on a robust trajectory towards an increasing share of renewables in total UK energy consumption beyond 2020.

The remainder of this section of the report outlines what the UK has already committed to achieving, discusses renewed government enthusiasm for renewables, and draws out some key lessons from history that must be taken into account if this enthusiasm is to be translated into successful attainment of the 2020 target. Section 2 then provides a quantitative analysis of the prospects for moving beyond the 2020 target. Section 3 discusses the particular challenges the UK energy system faces due to systemic features that have 'locked out' low carbon and decentralised energy provision. Finally Section 4 proposes a range of policies to help overcome these systemic barriers.

1.2 UK commitments

In March 2007 a binding EU-wide agreement was signed to raise the contribution of renewables to Europe's total energy from 6.4% to 20% by 2020. Then, in January 2008, differentiated targets were set for each Member State, and these were agreed in the Renewable Energy Directive in December. Each of the 27 EU countries is now legally required to increase its share of renewables by 5.5% from

2005 levels, plus an additional amount related to the country's GDP and other factors. The country targets were the subject of intense negotiations, with the UK taking a particularly cautious line on what could be achieved, and seeking loopholes such as the inclusion of investments in other low carbon (but non-renewable) technologies such as nuclear power (Seager and Milner 2007).

In the event the Directive was agreed without major loopholes (other than the absence of penalties for failing to reach any interim targets), and the UK signed up to achieving a 15% share for renewables by 2020. This is at the lower end of the range of commitments made – only seven EU countries have a lower commitment: the lowest is 11% (Luxembourg) and the highest Sweden (49%). Twelve EU countries signed up to achieving over 20% by 2020. This relatively low target reflects the UK's starting point towards the bottom of the EU league table when it comes to the use of renewable energy.

In June 2008 the Government, via the Department for Business, Enterprise and Regulatory Reform (BERR), launched a consultation on a new Renewable Energy Strategy (RES) (BERR 2008b). The tone of the consultation was pessimistic on the achievability of the target. It stated, "If all the options set out in this document were successfully implemented (and if no cost constraints were applied in deciding the measures we should take) our scenarios suggest that it will be possible to reach 15% renewable energy in the UK by 2020. This is at the very top end of the range of possible outcomes....' (BERR 2008b: 6).

The RES consultation was not only cautious on the extent to which the available policy options could meet the UK target. The document also emphasised the limitations within the prevailing 'free market' approach to energy policies. It argued: 'in a market economy policy alone cannot guarantee outcomes. How much these measures will deliver will depend on how energy companies, developers and investors in the market... respond to the signals we provide'

(BERR 2008b: 6). This emphasis on voluntary action by private firms can be contrasted with the Government's approach to other aspects of energy policy at the time. In relation to energy security objectives for example, there had been an emphasis for some time on the need for Government to intervene to ensure a desirable outcome. For example, in the Foreword to the nuclear power White Paper of January 2008 the former Prime Minister said that 'the Government will provide strong leadership...in addressing the imperative of ensuring secure energy supplies' (BERR 2008a).

In 2009 UK energy policy started to shift significantly, such that Government 'intervention' in areas such as energy markets and industrial policy were once again firmly on the agenda after two decades of market-oriented policy. This has been spurred by institutional change (the creation of the Department of Energy and Climate Change), new legislation (the Climate Change Act) and the response to the global recession (which has contributed to a renewed interest in industrial policy). These factors contributed to a change in government support for renewables, and a clear intention – including within the new Coalition – that the UK should meet the 2020 target.

This renewed commitment to a substantial role for renewables is a very positive development in moving the UK into a low carbon transition. Some major steps forward have been taken in policy terms. However the UK is starting from a difficult position. Not only does the UK have a very low starting percentage of renewables in its energy mix (3% of total energy and 7% of electricity in 2009), it also has to make up for decades in which successive governments had no effective industrial policy, and to address the barriers created by a highly centralised fossil-dominated energy system inherited from the earlier era of nationalised energy provision.

Unlike in some other countries, there is no established tradition in the UK of either energy

technology deployment or energy system governance and regulation at meso (regional or local) scales in the UK. Because of this heritage, the UK energy system is 'locked in' to centralised technologies, institutions, regulations and modes of decision making (Foresight 2008). This is likely to disadvantage the many renewable technologies that are not well suited to centralised deployment. Section 1.3 provides a brief overview of how the UK arrived at this starting point.

1.3 The UK's starting position, and how we got here

The UK Government first set a target for renewable energy in 1989, and has provided financial support for its use since 1990. However the UK remains near the bottom of European league tables for renewable energy deployment. This section begins to explain why this has been the case, in terms of the UK's historical development of a highly centralised, fossil-based energy system that effectively 'locks out' alternatives.

Using 'renewable energy' is as old as civilisation of course, but today's interest originated with the 1970s oil crises and consequent concern to find alternatives to fossil fuels. The UK provided R&D funds prior to 1990, with wave energy the most favoured technology in the late 1970s. However wave power was declared unlikely ever to become economic in the mid 1980s. Wind energy was now favoured, and early demonstration projects funded by Government were expected to 'prove' the technology, leading to private investment (Connor, 2003). Investment did not take off, however, until the Non-Fossil Fuel Obligation (NFFO) introduced subsidies in the 1990s. The NFFO came into existence as part of the 1989 Electricity Act and it mandated that suppliers source a given amount of electricity from renewable sources. The NFFO operated from 1990 to 1998 and many of the contracts let under that system are still operational. It was replaced by the Renewables Obligation in 2001.

The NFFO has been widely criticised. Mitchell and Connor (2004) explain its major drawbacks as follows. A major flaw arose because it was overwhelmingly a funding mechanism for the nuclear industry, and as such it was available for a short time period only under European Commission competition rules. This short time horizon raised the cost of capital for investors. Secondly the NFFO rewarded companies who bid into the process promising renewable energy at the lowest prices. This favoured large utilities that could self-finance investments, and encouraged rapid development of large installations at remote upland sites (with high wind speeds), provoking opposition on landscape grounds that has strong ramifications today. Thirdly there was no penalty for not actually investing – bidders could secure NFFO contracts in the hope of fulfilling them (or perhaps simply to exclude competitors), but then many decided not to go ahead. Many others projects foundered in the planning process.

The NFFO proceeded in a series of ‘tranches’, with the price cap for each technology progressively reduced in each. Mitchell and Connor conclude:

“The NFFO could have been a very good mechanism of support for renewables if there had been a penalty [for not investing once contracted] and if the cost-cap had been higher. However, there was a desire on the part of the Government department responsible – the Department of Trade and Industry (DTI) – to reduce the average price per kWh of each Order, thereby signifying that the policy was working. The DTI was effectively more interested in showing that their competitive renewables policy had ‘worked’ in principle than in achieving deployment on the ground.” (Mitchell and Connor 2004: 1938)

The NFFO was replaced by the Renewables Obligation in 2001, and Government’s commitment to market principles was taken further in that there were now no technology bands – all technologies would compete on price grounds, regardless of their stage of development or other considerations. The effect of the RO was to again

favour large utilities’ investing in wind power, which had become the technology closest to market. However installed capacity grew slowly, due to disputes over planning consent and the high costs and delays developers face in securing connections to the national grid.

Reforms of the RO have been implemented – including banding to account for the different economic and technological status of different renewables. A risk reduction mechanism was also proposed to provide more price certainty to investors. If implemented, these reforms would develop the RO so that it would become similar to the ‘feed-in tariffs’ that have been implemented in many other countries, notably Germany and Spain. These tariffs provide certainty by paying renewable generators a fixed price per kWh of electricity produced. However, serious questions remain about whether the RO reforms that are being implemented will make it as effective as a feed-in tariff. It is likely that the value of Renewables Obligation Certificates for renewable investors would continue to be subject to significant volatility. A Government response to the consultation on the Renewable Energy Strategy, published in 2009, concluded that the proposed risk reduction mechanism would not be implemented for the foreseeable future (DECC 2009a).

Research has shown that feed-in tariffs are more effective in achieving renewables deployment than tradable certificate schemes such as the RO (e.g. Mitchell, Bauknecht et al. 2006). In Germany and Spain, the feed-in tariff has had a significant role in the rapid growth in installed capacity, with wind energy becoming part of Spanish utilities’ core business (and political strategies), and new market entrants dominating the German market. In the UK by contrast existing vertically integrated energy utilities have been the main investors, but renewables remained a niche activity in their investment strategies (Stenzl and Frenzel 2008). In the UK there was also little emphasis on developing UK-based supply chains, and little

experience has been developed outside the major utilities. Meanwhile support dried up in the UK for many technologies such as wave power or biomass electricity.

Given this evidence, it would make sense for the UK to also move to a feed-in tariff system. It is therefore welcome that such a system is now being implemented for smaller scale renewables – and that the new government has announced that it will be made available to some larger renewables too. A bolder and more sensible move would be to abolish the RO altogether in favour of a feed-in tariff for all renewable projects.

This would not be a panacea, however. Barriers due to the UK’s predominantly reactive planning processes (particularly in England) and grid connection will still need to be dealt with, in part through more strategic or ‘positive’ planning for wind deployment (IEEP, 2009). However, a feed in tariff will offer investors much greater certainty than the volatile price signal offered through the RO. However, it will be important to ensure that the levels of incentive available are high enough – and that implementation is kept as simple as possible. Furthermore, to encourage efficiency and cost reductions, the level of feed in tariff offered to each technology should be declined over time.

Despite the UK having taken the wrong road with its main economic incentive scheme for renewables, the NFFO and RO did both result in some investment. Onshore wind investment has recently had its best year yet, and the UK is a global leader in deploying offshore wind projects. Other further-from-market technologies such as wave energy have advanced far less because they have been too immature to take advantage of the RO. Nevertheless tidal and marine technologies now appear to have a central position in UK policy, reflecting the UK’s large natural resources and experience in offshore engineering.

The 2009 Renewable Energy Strategy was developed as part of a concerted, ambitious plan for a low carbon transition in the UK,

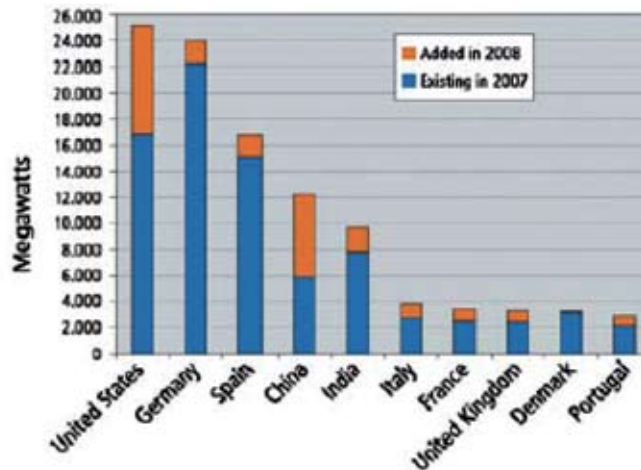


Figure 1. **Wind Power Capacity – Top Ten Countries (REN21 2009: 12)**

with renewable energy to make a significant contribution. The new Department for Energy and Climate Change has made a positive start in terms of steps taken to make the transition possible. Moreover, despite the overall picture painted above, in comparative terms the record to date on renewables is not all gloomy. The UK has the eighth largest installed wind power capacity in the world (Figure 1), and was the world leader in terms of offshore wind power as of 2008 according to the Renewable Energy Policy Network for the 21st Century (REN21 2009).

However, the UK continues to compare very unfavourably with other EU countries in the amount of renewable energy deployed. Two progress reports by the European Commission (European Commission 2009a; European Commission 2009b) examining preliminary efforts by Member States in realising their 2020 renewables targets demonstrate how policies prior to the RES were inadequate. For example progress towards renewable heat targets was stagnant in the UK, and in all but three other EU Member States. Figure 2 illustrates this and shows the share of renewable energy in the heating sector (columns and left axis) and early progress towards renewable heat targets (points, right axis) (European Commission 2009b: 10).

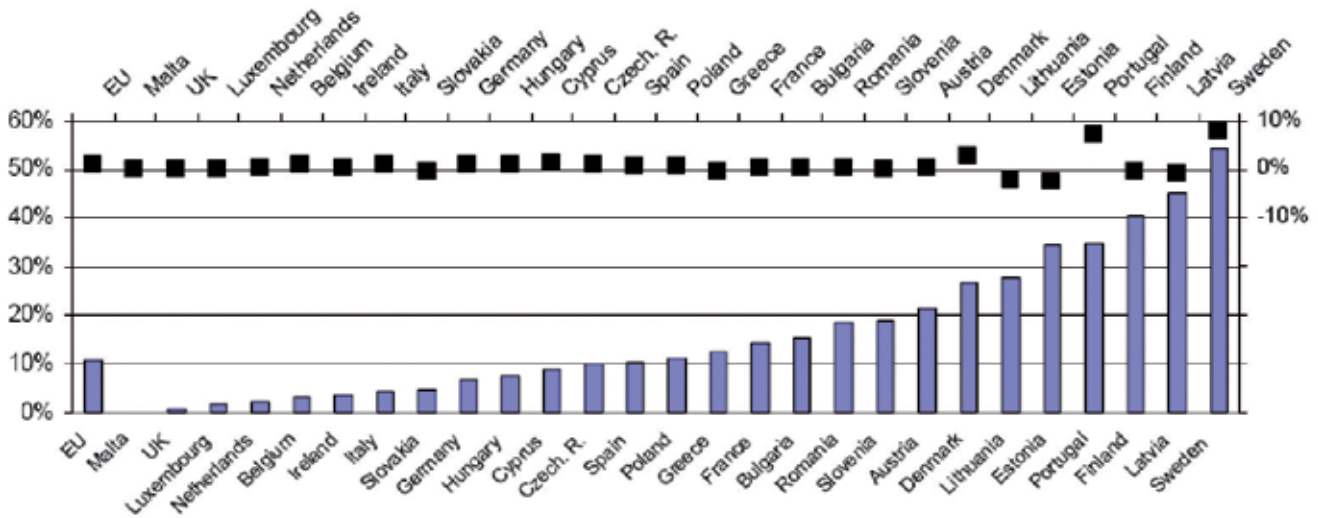


Figure 2. The share of renewable energy in the heat sector in the EU

2010 target (%)	Electricity			Biofuels		
	recent growth	progress made	2007 share (%)	2010 target (%)	recent growth	progress made
10	☹	☹	0.8	5.0	☹	☹

Key to "smiley" grades

progress made towards target	0-33%	34-66%	67-100%;
'04 - '06/'07 growth	≤ 0 percentage point change	> 0 – 1 percentage point change	> 1 percentage point change
	☹	☺	☺

Table 1. Early (lack of) progress towards the UK's 2020 target (European Commission 2009a: 11).

UK progress on biofuels and renewable electricity merited only grim expressions on the European Commission's smiley face scale (see Table 1). Whilst there are good reasons for slowing progress with some 'current generation' biofuels on sustainability grounds, the overall picture within the Commission's assessment was not positive. The Commission noted:

“between 2004 and 2006, electricity from renewable energy sources increased by 28.6% and electricity consumption increased by 1.1%. However the UK still has to make 68% of the efforts needed to reach its target. There are significant delays in connecting electricity from renewable energy sources to the transmission and

distribution network and the UK needs to increase the speed of deployment substantially in order to meet the 2010 target. In February 2008 there were 11GW of capacity in the planning system waiting for consent” (European Commission 2009b: 14).

The analysis in Section 2 suggests that the 2020 target is achievable despite this poor starting position. However there will be severe limitations on how much further the UK can go in deploying renewables if steps are not taken to change the UK energy system to one that better accommodates and exploits the diversity of scales available and technologies with current and future potential.

1.4 Why deliberately transform the energy system?

We need a major expansion in the use of renewable energy in the UK, but not as an end in itself. Rather this expansion should take place in a context of aggressive energy saving, so as to displace unabated fossil fuel use (i.e. where carbon is not captured and stored). Today, as in the 1970s, the essential aim in promoting renewable energy is to power and heat modern homes, industries, vehicles and so on without an ever-increasing dependence on oil, gas and coal. Energy security concerns remain an argument in favour of maximising the use of domestic energy resources, particularly those that are non-exhaustible. However since the 1970s additional reasons to wish to reduce dependence on fossil fuels, whether domestic or imported, have begun to shape policy. The most significant of these is the mitigation of greenhouse gas emissions. However there are also wider environmental benefits in terms of human health and ecology (and, arguably, landscape) if extracting, transporting and burning fossil fuels can be avoided.

The benefits of renewable energy, then, are largely those that arise from *not using fossil fuels* – less risk of fuel price shocks and energy shortfalls, fewer greenhouse gas emissions, fewer toxins in the atmosphere and less coal and oil production and transport (and all the associated environmental and landscape impacts). These are benefits to society as a whole. Moreover the same benefits can, up to a point, be gained by saving energy – doing without fossil fuels rather than substituting for them. In practice energy saving and use of renewables are two sides of the same coin (given that the UK commitments are expressed as a percentage of overall use). Progress in both areas has so far been very limited in the UK, with negligible impact on fossil fuel use.

Businesses, individuals and potentially the whole economy are in positions to gain from a major expansion of renewables, but the benefits are

primarily social. Society is currently denied those benefits because mechanisms have not been in place to socialise the costs involved in moving to a non-fossil energy based system. The centralised, fossil-based energy system in place in the UK was largely created on behalf of society, using public funds, prior to the privatisations of 1989. The national electricity grid and road and gas pipeline networks have served UK society well in many respects. However, while society's priorities and Government's policies have moved on, the infrastructures upon which the energy system is built have changed little. Since privatisation, energy industries have concentrated on sweating existing assets (Helm 2007), with resultant under-investment in shared infrastructures and even in generating capacity. This has contributed to a 'lock-out' of technologies that better suit today's goals.

In principle, renewable energy technologies can fit into the existing centralised system, in the form of large wind farms, biomass and energy from waste (EfW) plants (though the extent to which the latter are renewable is disputed). Equally, very small renewable energy devices can be installed in households, and local biomass resources can be used to generate heat and power, displacing some fossil energy use at the level of the user. However making fuller use of renewable energy means capitalising on the diversity of scales, technologies and business models for deployment, so socially beneficial solutions suited to local and regional circumstances can be found. UK policy has proven far from successful in overcoming the system-wide barriers to renewables at this meso-scale (between that of the end user and centralised provision). Section 2 suggests good reasons to be optimistic regarding the future share of renewables in the UK energy system. However this will demand much greater emphasis on overcoming these systemic barriers, through infrastructure investment and industrial policy, and by enabling local authorities to raise finance and invest (see Section 4).

2. How achievable is the 2020 commitment, and what comes after that?

This Section provides a quantitative analysis of the UK Government’s plans with respect to the 2020 target. Section 2.1 shows the target is ambitious but achievable, and emphasises the central role energy saving must play. Section 2.2 then examines UK ambitions in three sectors: heat, electricity and transport. Section 2.3 then looks to the longer term, and cautions against any temptation to make less effort in the short term due to the financial crisis.

2.1 How achievable is 15% by 2020?

Article 3 of the Renewable Energy Directive (2009/28/EC) states “[e]ach Member State shall ensure that the share of energy from renewable sources, calculated in accordance with Articles 5 to 11, in gross final consumption of energy in

2020 is *at least* its national overall target” (European Parliament and the Council 2009, emphasis added). In June 2009 BERR began consultations on a proposed renewable energy strategy, in which thirteen classes of renewable energy use, divided between heat, electricity and transport uses, were used to illustrate how the UK could meet the 15% commitment (Figure 3).

However, at the time, Government made it clear it felt the target was at the very upper limit of what was achievable, and instructed its consultants to proceed on this basis in their modelling calculations of what was possible. Policy statements at the time often read like invitations to conclude that the target was too high and unachievable (Mackerron, Lehtonen et al. 2008) and therefore should be modified or open to loopholes. For example the consultation

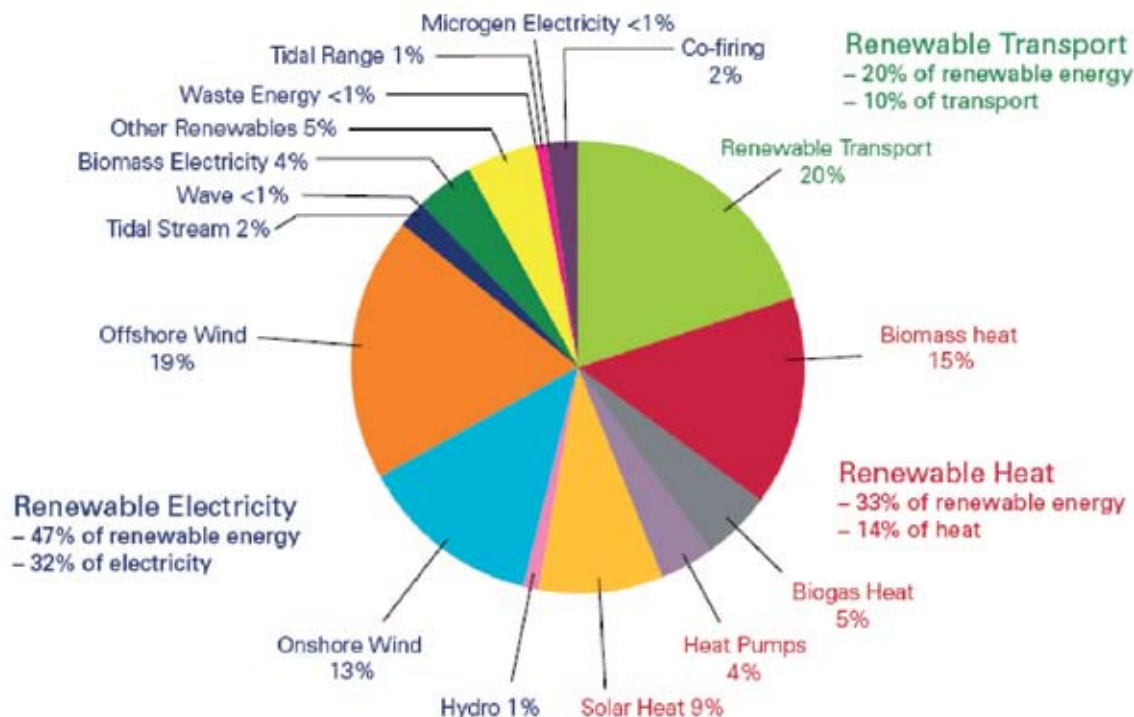


Figure 3. Illustrative renewable technology shares to reach 15% renewables in the UK by 2020 (BERR 2008b: 8)

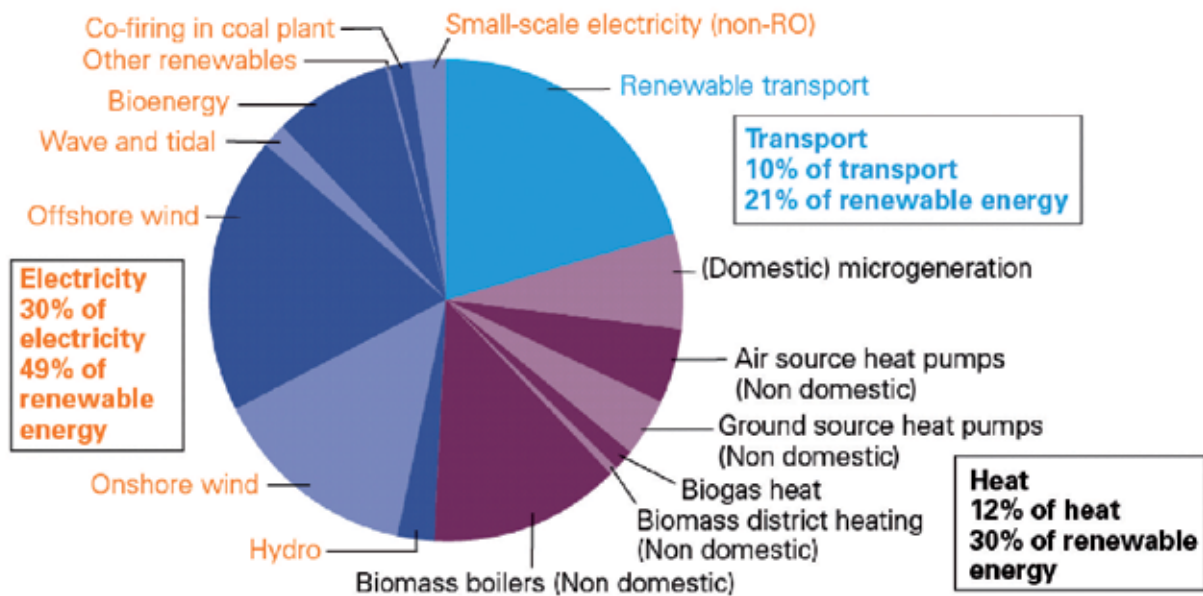


Figure 4. Illustrative renewable technology shares to reach 15% renewables in the UK by 2020 (DECC 2009f: 11).

document suggested there was no slack should any technology deliver less than expected: “[i]f sustainability concerns meant that [biofuels in] the transport sector could not contribute 10%, and the same overall renewables target were retained, then the contribution from the other sectors would have to be higher. In this circumstance it is unclear how we could meet the target domestically without making use of other options such as trading with other countries” (BERR 2008b: 7).

While it was not clear these targets were at the upper limit of what was possible – for example the British Wind Energy Association (British Wind Energy Association 2009) considered the 14 GW target for offshore wind “distinctly unambitious” – the tone of policy debate at the time was mainly one of pessimism and regret that the UK had agreed to an impossibly ambitious 15% target for overall energy use by 2020.

However this attitude changed when BERR’s energy functions were moved into the new Department of Energy and Climate Change in

October 2008. Its first Secretary of State, Ed Miliband, surprised critics - first with the ambition set out in DECC’s Heat and Energy Saving Strategy consultation in February 2009 (DECC 2009b), and then in the Renewable Energy Strategy (RES) of July 2009. In the RES it became less clear exactly how much Government thought each technology might contribute by 2020 (see Figure 4 and its lack of indicative percentages for individual technologies), but not achieving the overall target was no longer in question. Indeed the RES stated “[t]here is nothing to stop industry groups expanding further than this illustrative mix, if supply chains and build rates can deliver faster than the assumptions underlying the analysis” (DECC 2009f: 41).

In 2008 general pessimism about the achievability of the 15% target was worsened by Government’s low estimates of what would be achieved given policies already in place. The RES consultation stated that “under current policies we expect [the share of renewables] to rise to 5% by 2020”

(BERR, 2008a, p.5). Consultants to Government (Pöyry 2008a) and to the EU's Directorate-General for Energy (Capros, Mantzos et al. 2008: 5) were less doubtful than Government about its existing policies than BERR itself, which suggested the additional task was somewhat smaller. However the question 15% of what remains.

Capros et al. estimated UK total final energy consumption in 2020 under existing policies could rise to as high as 1900 TWh. This compares with actual consumption in 2008 of 1695 TWh (DECC 2009f). However the RES consultation depended on fairly ambitious energy savings targets, to enable the envisaged contributions from renewables adding up to 15%. The RES predicted yet more impressive energy savings by 2020 based on policies in the Heat and Energy Saving Strategy. It envisaged energy demand in the UK in 2020 totalling 1590 TWh – down slightly on current

consumption. This is ambitious, but not necessarily at the limit of what is achievable. For example in a report to the World Wildlife Fund and Greenpeace, Pöyry (2008b) note that energy demand could fall to as low as 1414 TWh by 2020¹. In view of the steep fall in energy demand in 2009 due to the recession, such further progress in demand reduction looks more achievable. Figure 5 illustrates the effect these assumptions have on the total renewables capacity the UK will need in 2020 in order to meet its 15% target.

These are significant differences in the absolute magnitude of renewables required to meet 15% of total energy needs – in the tens of TWh per annum – purely based on assumptions about energy saving. For comparison, total renewable energy in final energy consumption in the UK was 39 TWh in 2008. This underscores the need for a successful drive to cut UK total energy consumption alongside

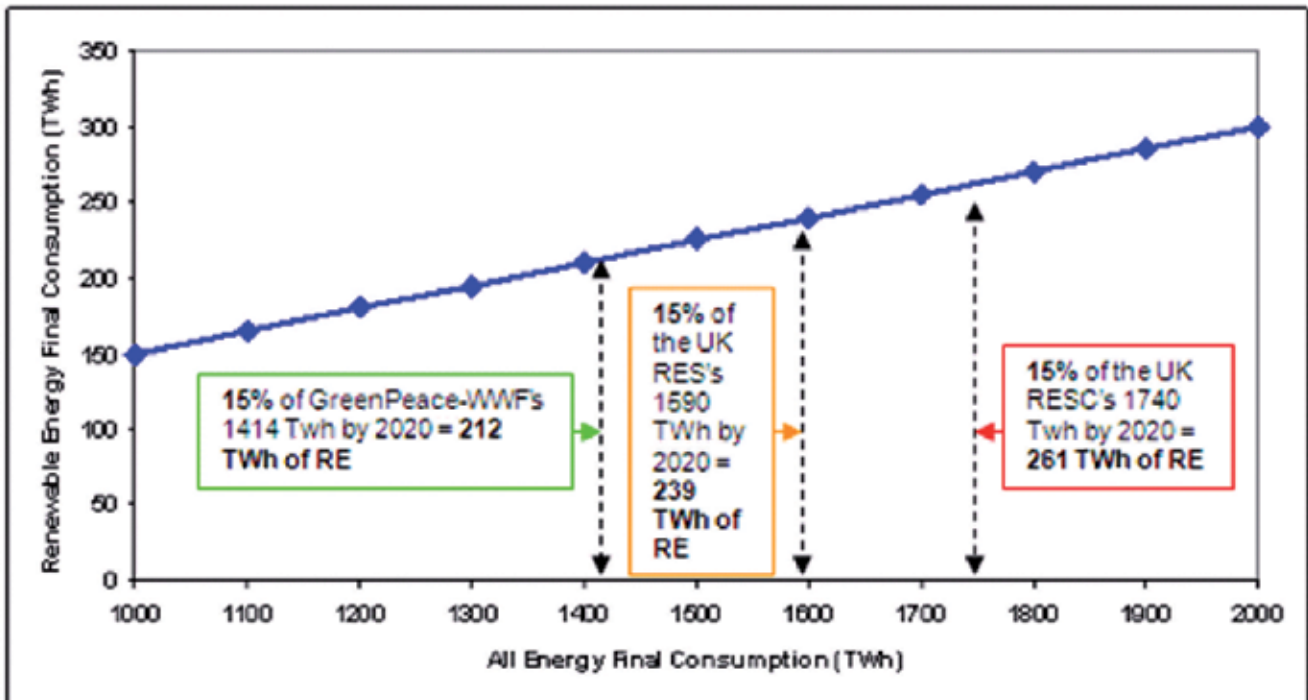


Figure 5. Amount of renewables required to reach 15% of energy needs as a function of predicted total energy consumption in 2020 according to the UK renewable energy strategy consultation (UK RESC), the UK renewable energy strategy (UK RES) and work by Pöyry for Greenpeace and WWF.

¹ And further to 1274 TWh by 2030, according to a scenario “based on the aspirational targets contained in the UK National Energy Action Plan” (Pöyry 2008b); p21.

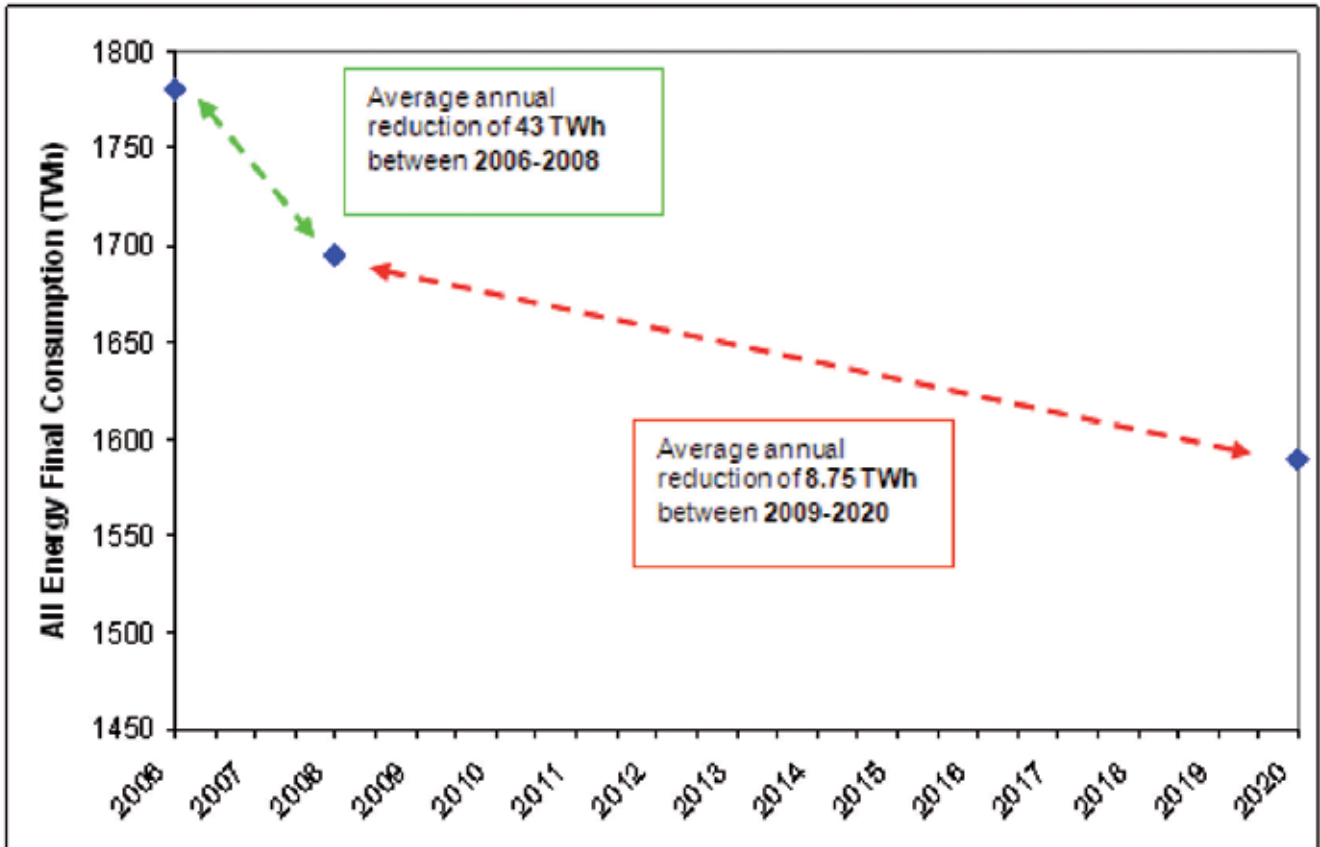


Figure 6. **Recent (2006-2008) and required (2009-2020) average annual reductions in energy consumption in order to converge upon 1590 TWh by 2020**

expanding renewables use. So, how realistic is the proposed trajectory for energy savings?

This is difficult to gauge, as many of the policies now on the table have not yet been put into practice in the UK, such as a rolling programme of whole house energy efficiency improvements. Despite the overall underlying trend towards growth in energy demand in the UK economy, falls in total consumption have occurred over the last few years to the extent that the rate of reduction in energy demand required to reach 1590 TWh in 2020 (from a baseline of 1690 TWh in 2008) is much lower, for example, than the actual rate of reduction in energy demand seen between 2006 and 2008. Clearly this is reflective of the economic downturn, rather than a response to specific measures put in place to reduce energy

use, but the comparison of these rates in Figure 6 is instructive nonetheless.

Overall the discussion above suggests that the previous Government is right to have reversed its pessimistic outlook on the achievability of the 2020 renewables target, and in its assessment that the target could even be exceeded. Indeed, it would be logically unjustifiable to maintain the pessimism which permeated through the consultation given that the absolute magnitude of renewables required to meet the 15% target is now predicted to be lower than at the time of the consultation by virtue of the increased role being seen to be played by reductions in overall energy demand. Nevertheless, the question still remains as to whether the RES goes far enough to overcome the inertia to change discussed in

Section 1 above. Before going on to consider where more change is needed and specific policy proposals in Sections 3 and 4, we now turn to how exactly the outgoing Government proposed to meet the 2020 target (in terms of sectors and technologies), and the implications for what happens after 2020.

2.2 How did the previous Government propose we will get there?

Table 2 summarises UK ambitions for renewables as a share of total energy use in three sectors in 2020, compared to actual figures for 2008. These are not sub-targets, but previous Government indications of how the 2020 target could be met.

Heat

At 72 TWh, or 12% of total UK heat use, less heat is to be sourced from renewables in 2020 than was envisaged in the 2008 consultation (90 TWh). After consulting, the Government “considered it prudent to slightly reduce the contribution of renewable heat in our lead scenario”, but noted “it is of course possible that renewable heat makes a greater contribution than we have envisaged: this would be extremely welcome” (DECC 2009f: 45). The latter more

optimistic view is reinforced in the impact assessment for the Renewable Heat Incentive – the proposed policy instrument for the deployment of renewable heat technologies. This was due to be introduced in 2011 but is now under review. This shows that renewable heat could account for up to 14% of UK heat by 2020 (80TWh) under some scenarios (DECC 2010).

In the 2008 consultation the main technologies envisaged to increase the amount of heat from renewables were biomass-based and solar thermal. However sustainability concerns about biomass, particularly imports, place constraints on biomass heat in Government’s view and that of many respondents to the consultation (DECC 2009d). In the RES the contribution of biomass-based technologies was reduced somewhat from the (already constrained) 2008 figure. Contributions from microgenerated solar heat were also reduced, due to lower predictions on average output from that technology. These downward revisions are partially compensated for by an increased role for air and ground source heat pumps (from 10.4 to 23.9 TWh). Heat pumps are relatively cost-effective (NERA 2008) and, according to central scenario cost assumptions

In TWh	Renewable energy in final energy consumption, 2008	Renewable energy in final energy consumption, 2020 (as % of total renewable energy)	All energy final energy consumption, 2008	All energy final energy consumption, 2020 (% from renewable source)
Heat	7	72 (30)	711	599 (12)
Electricity	22	117 (49)	387	386 (30)
Transport	9	49 (21)	598	605 (10)
All sectors	39	239 (100)	1695	1590 (15)

Table 2. UK final energy consumption² in 2008 and projections for 2020 based on an illustrative mix of renewable energy needed to meet the 2020 renewable energy target (data from (DECC 2009f)).

² The EU/EUROSTAT definition

made by Enviros (2008), the maximum output possible from ground source heat pumps by 2020 is 28.2 TWh.

Electricity

Government envisaged renewable electricity making up the lion's share (49%) of total UK renewables in 2020, with 30% of electricity coming from renewables by that date. Again the 2009 figures are slightly lower than those presented in the 2008 consultation, reflecting the room for downward revision made possible by more optimistic estimates for energy saving.

Redpoint Energy, which conducted both sets of modelling exercises, described the RES target for electricity as a "step change compared with expected renewable penetration arising from existing policy measures" (Redpoint Energy and Trilemma 2009: 10). Nevertheless the electricity targets are achievable: "as long as the financial incentives provided by any support scheme are both attractive and credible, the supply chain will respond to the expected market need and gear up production capacity of the necessary plant and equipment" (Redpoint Energy and Trilemma 2009: 14-15). Questions remain, however, about the speed at which this response will occur – and the extent to which this will lead to new job creation in the UK.

In the RES it is not clear precisely how much renewable electricity Government envisaged coming from various technologies (onshore or offshore wind, tidal, wave, hydro, biomass and so on). However the relative shares appear to match those suggested in 2008, where percentage figures were estimated for each (see Figures 3 and 4 above). On this basis 19% of total renewables would be from offshore wind in 2020, which translates to 45.4 TWh in the strategy compared to a larger 50.4 TWh in the consultation by virtue of the differences in final energy demand predicted across the two documents. Sinclair, Knight and Merz (Sinclair Knight Merz 2008b; Sinclair Knight Merz 2008a) suggest a somewhat higher capability by 2020 than this at 53.2 TWh

(assuming a load factor of 40%). The Renewables Advisory Board suggest 63 - 84 TWh of offshore wind-generated electricity could be achievable by 2020 (Renewables Advisory Board 2008)³. The British Wind Energy Association (British Wind Energy Association 2009) considers the offshore wind objective "distinctly unambitious", and based on exaggerated supply chain constraints. It is welcome to note how these high-end possibilities are acknowledged and given credence in the UK RES – something that was lacking in the earlier consultation.

The envisaged contributions from wave and tidal power are small in the RES, at less than 2% (approx 5 TWh). Twice this amount was envisaged in the consultation, and some respondents at the time saw this as too low (DECC 2009d). Earlier work by the Carbon Trust (2006) was also more optimistic in tone, and found that the technical potential for tidal stream electricity in the UK is 18 TWh per year, whilst the equivalent figure for wave energy is 8 TWh per year.

Microgeneration (e.g. building scale installations of solar photovoltaics, solar thermal and wind turbines) is also envisaged contributing approximately 2% of renewable electricity in 2020, up from less than 1% in the UK RESC. The background to this is important in understanding this relatively low share: the 2006 Microgeneration Strategy (Department of Trade and Industry 2006) did little more than emphasise commitments to further research so that by 2008 the number of microgeneration installations in the UK was found to have only increased to around 100,000 (from 82,000 in 2004). Most of these are solar thermal installations.

A report by Pöry for the Government (Pöry 2009: 24) estimated there is a very large technical potential for sub-5MW renewable electricity in the UK (131TWh/yr) – including substantial potential for micro-generation at the smallest scales. Of course, the economic potential is much smaller. For example, Pöry estimated

that 8TWh of this potential would be realised if a uniform feed in tariff of 15.5p/kWh were implemented. Nevertheless, greater commitment to microgeneration in the RES in part reflected Government's rhetorical recognition of the benefits of involving householders in contributing to (and benefiting from) meeting the renewables target. This support has been substantiated by the introduction of feed-in tariffs. This has been controversial⁴, for example due to the costs – particularly of supporting solar photovoltaic technology in this way – and the poor performance of micro-wind technology in some urban locations (Watson, Sauter et al. 2006).

There is also significant potential for schemes at a scale larger than 5 MW but smaller than a typical larger-scale wind farm. As section 4 of this report will argue, such 'meso-scale' renewables are often neglected in policy debates and do not have enough support. At present, they fall between small scale installations of less than 5MW which enjoy feed in tariffs and planning derogations and large-scale installations of above 50MW which are the subject of much of the policy activity and focus.

In summary, there is evidently scope for further ambition in terms of tidal stream, wave, meso- and micro-scale generation and offshore wind, and potentially in other areas of renewable electricity generation such as bioenergy and onshore wind.

Transport

The UK RES committed to 10% renewables⁵ in transport fuels, which is the minimum required by the Energy Directive (European Parliament and Council, 2009). The UK RES states that, because of sustainability concerns associated with biofuels⁶, it is not appropriate to assume that renewables in transport will exceed 10% by 2020 (DECC 2009f: 47). The envisaged trajectory is for renewable fuel to comprise 3.25% of total transport fuel supplied in 2009-10, rising to 5%

by volume in 2013-14 (DECC 2009f: 49). This is consistent with the recommendations made by the Gallagher Review (Gallagher 2008) which indicated anything beyond 5% biofuels after 2013-14 should only be agreed if the fuels were demonstrated to be sustainable, with reductions in biofuels after this date if sustainability criteria are not met.

It should be noted that these specific concerns relate to 'first generation' (i.e. current technology) liquid biofuels used to replace petrol and diesel, rather than to all biomass energy (e.g. solid fuels for heat or electricity, or, potentially, liquid biofuels derived from woody crops). However, sustainability concerns have also been raised about some of these other forms of biomass. As argued above, other renewables could plausibly make up any resulting shortfall in contributions towards the 2020 target resulting from a reduced role for transport biofuels. Better public transport and a shift to electricity powered road vehicles and trains may prove preferable longer-term means to increase the share of renewables in UK transport than substituting for petrol and diesel. The electrification of transport would, according to MacKay "deliver transport at an energy cost of roughly 15 kWh per 100 km. That's five times better than our baseline fossil-car, and significantly better than any hybrid cars" (McKay 2009: 127). Mass production and roll out of electric vehicles across Europe starting in 2018 has recently been suggested by the European Technology Platform on Smart Systems Integration (ERTRAC EPoSS and Smartgrids Taskforce 2009).

2.3 Looking beyond 2020

The analysis above suggests that the 2020 target can be met and possibly exceeded. However this should not be seen as an end in itself, but a milestone on a steeply rising path towards an even greater share for renewables. So, what proportion of UK energy might potentially derive from

⁴ See the online debates between George Monbiot, Guardian columnist and Jeremy Leggett, Chief Executive of Solar Century; www.guardian.co.uk/environment/georgemonbiot/2010/mar/05/solar-feed-in-tariff

⁵ The figures for renewables in transport by 2020 as given in Table 2 appear to be less than 10% of all energy consumed in 2020, this is because the share of renewables in transport is calculated on the basis of total surface transport only. However, renewables used in shipping and aviation can count towards the target.

⁶ The EU Energy Directive states that "the binding character of the biofuel target is appropriate subject to production being sustainable, [and] second-generation biofuels becoming commercially available..." European Parliament and Council 2009, (p. 6).

renewable sources in 2030? Any discussion of this question is necessarily speculative, especially on the specific shares that can be expected from any particular technology, but it is worthwhile to consider the overall picture as it helps frame debate over priorities in the coming decade – when the conditions for further growth beyond 2020 are being established.

Barrett’s (Barrett 2006b; Barrett 2006a) modelling suggests that the UK could have a 90-100% renewables-based electricity sector within several decades. MacKay (2009), however, considers all UK energy consumption (not just electricity) and concluded that to match today’s energy use using only renewables would be a mammoth task and is only possible to demonstrate analytically by “throwing all economic, social and environmental constraints to the wind” (McKay 2009: 103).

With large energy savings, however, it is plausible for renewables to make a significantly greater contribution than 15% by around 2030. Figure 7

illustrates the amount of renewables needed to achieve various percentage shares, depending on overall energy consumption in 2030. Achieving a 50% or greater share by 2030 would require extremely aggressive energy saving policies, but 30% appears within reach if energy demand falls to around 1400 TWh as modelled by Pöyry (Pöyry 2008b). Meeting the UK’s 2020 and interim targets could put the UK firmly on a trajectory towards this sort of substantial contribution.

In appreciation of the difficulties and likely short shelf-life of attributing specific magnitudes to specific technologies by 2030, some interesting, albeit crude, observations can be made about the potential overall proportion of energy sourced from renewables by 2030 by virtue of the fact that the envisaged trajectory of this variable to 2020 follows a near-perfect quadratic-in-time function when parameterised using data on the share of renewables between 2005 and 2008, the interim

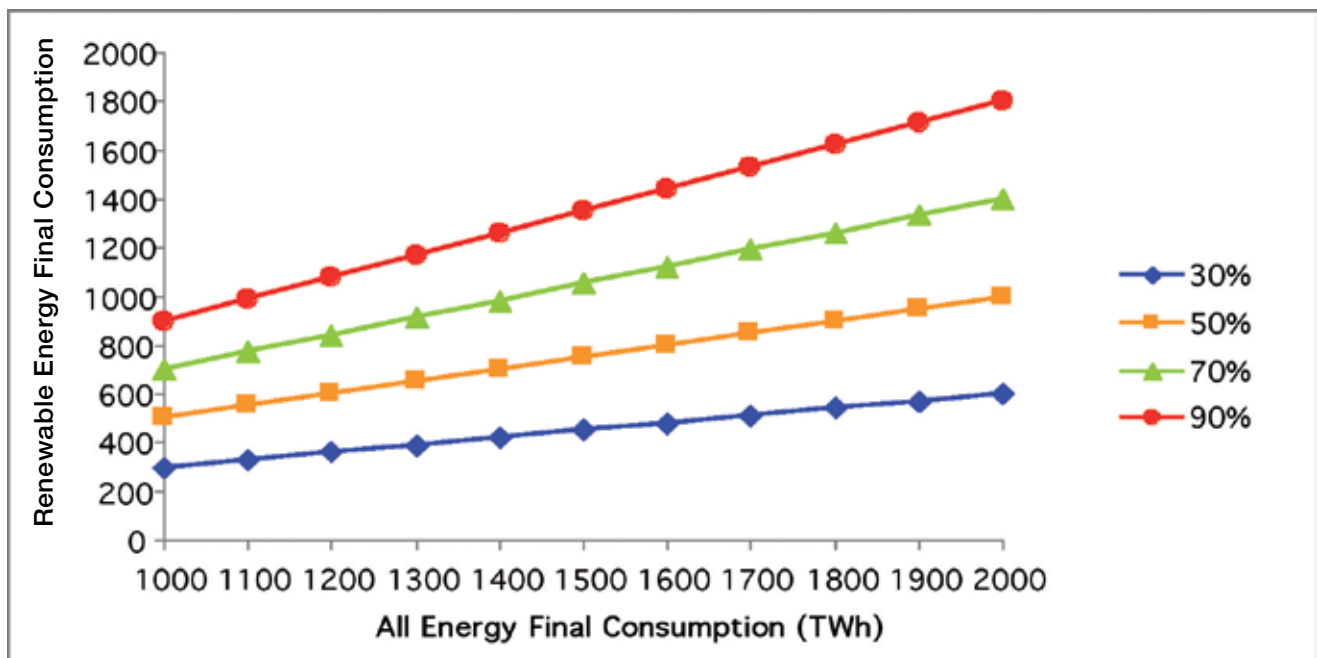


Figure 7. Amount of renewables required to reach 30-90% of energy needs as a function of total energy consumption.

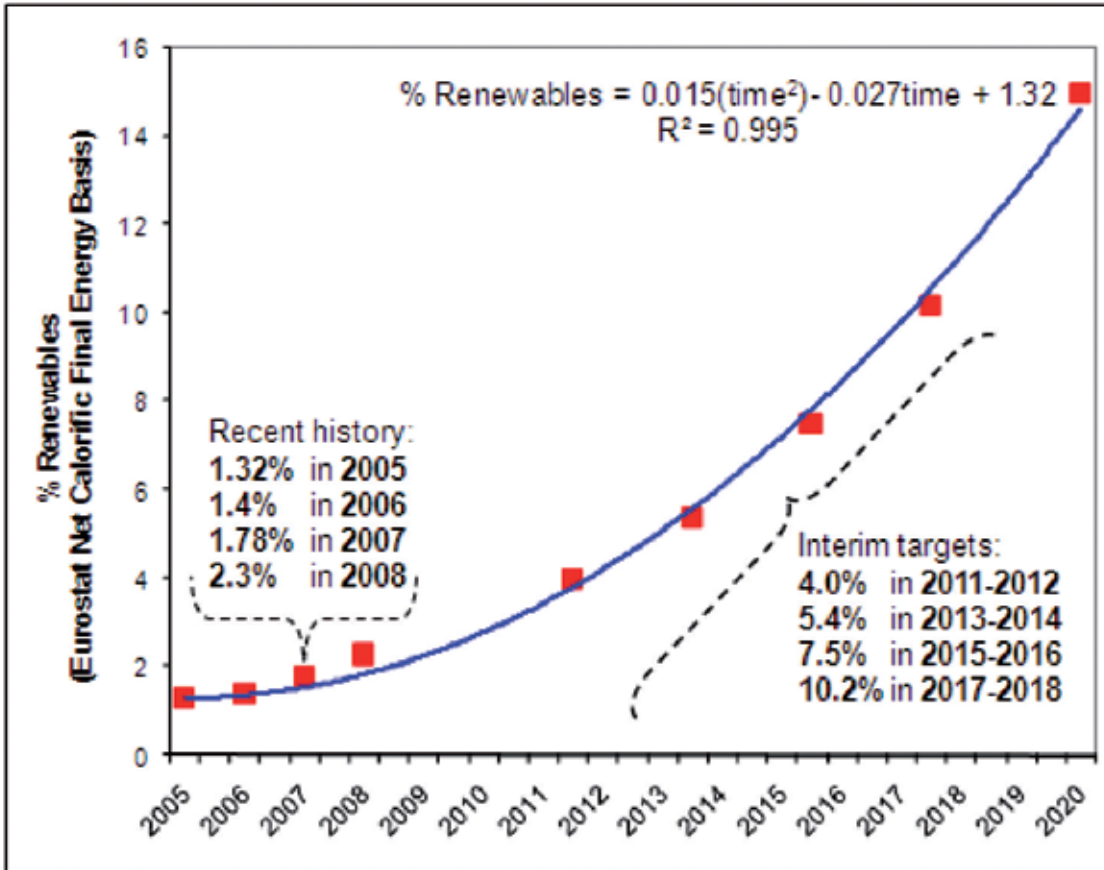


Figure 8. **Idealised share-of-renewables trajectory (line) according to recent actual shares of renewables, interim and 2020 targets (points).**

targets set for the UK by the EU⁷ and the final 15% by 2020 target (Figure 8).

Extrapolating this function to 2030 shows that the UK could approach 40% renewables by 2030 (Figure 9). Such a simple quadratic function clearly lacks mechanistic detail⁸ and does not give any information about how such a high percentage could be realised. However, it is consistent with the idealised 'hockey stick' trajectory to 2020 envisaged by the interim and final renewables targets, and assumes that the rate of renewables penetration increases over time. Although this may be consistent with assumptions about the changing importance of demand and supply side barriers over time, it also reduces the magnitude

of benefits (such as forgone carbon dioxide emissions) reaped from renewables between now and 2020 or 2030. An alternative trajectory in which more progress is made in the short term would increase these benefits – and may also be desirable to counteract the natural political tendency to push more rapid progress into the future rather than dealing with how to achieve it in the short term.

The new Government needs to keep up momentum to enable a major take off in renewables, at small scale including households (below 5MW) and meso-scale (between 5 and 50MW). The medium-term policy implications of this expansion in decentralised energy, in addition

⁷ 4.0% in 2011-2012, 5.4% in 2013-2014, 7.5% 2015-2016 and 10.2% in 2017-18.

⁸ Factors affecting an increase in the proportion of renewables are all subsumed within a time variant $[0.015*(time^2)]$ rate of increase and time invariant $(0.027*time)$ rate of decrease; the intercept (1.32%) is calibrated to match the share of renewables in 2005.

to greater use of large centralised renewable electricity generation, are addressed in Sections 3 and 4 below. In the shorter term there is a need to ensure that the current economic downturn provides a platform for progress instead of decline. Recent years have seen an unprecedented decline in electricity consumption - in the last quarter of 2008 and the first quarter of 2009 the UK experienced 3% and 6.8% reductions in electricity demand respectively. Carbon dioxide emissions in the UK are estimated to have declined by almost 10% in 2009. However, there is a real danger that lower fossil fuel prices and reduced investment in renewables will increase emissions in the medium to longer terms, according to the International Energy Agency (International Energy Agency 2009). This global picture differs by region and although there are signs that the European

Union has managed to maintain investment in renewables, globally investment in renewables is down by 38% in 2009 (based on data from the first quarter) compared to the previous year (International Energy Agency 2009).

The analysis so far has presented a mixed picture: there are good reasons to believe renewables can provide a substantial share of UK energy, rising well beyond 15% in 2020. However the history of UK policy suggests there are significant obstacles to overcome, not all of which are addressed in the RES. How the RES is implemented, and how additional barriers identified in Sections 3 and 4 below are addressed, will determine whether the UK succeeds, or continues to fail, in making renewables central to its plans for a low carbon transition.

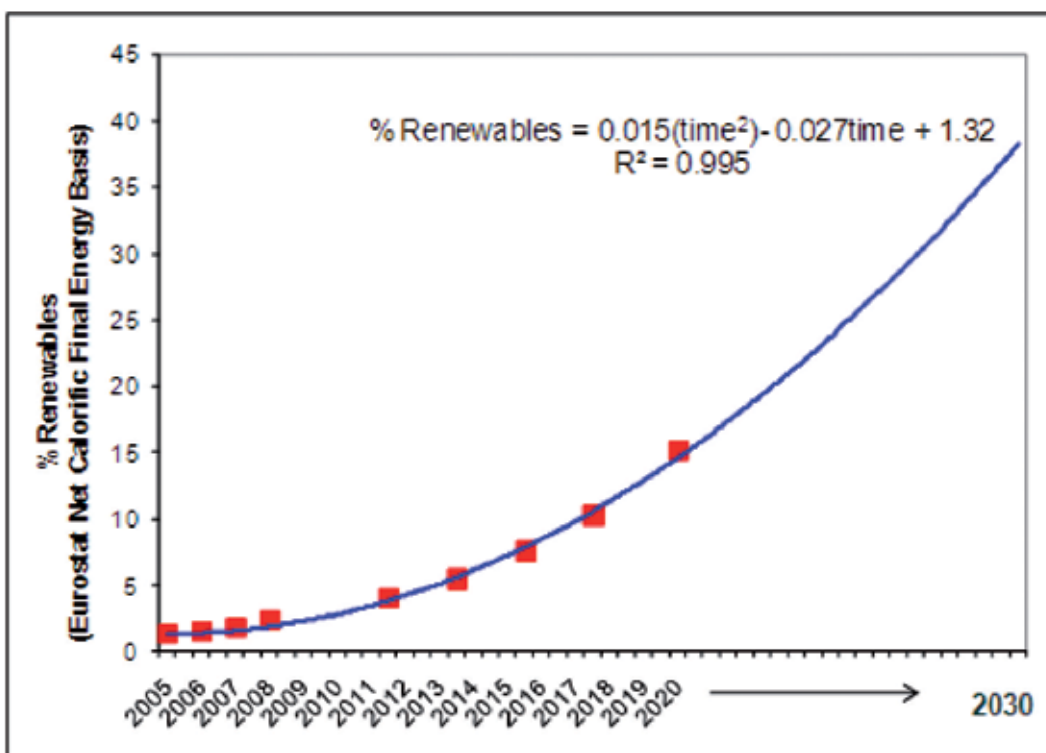


Figure 9. **Idealised share-of-renewables trajectory (line) according to recent actual shares of renewables, interim and 2020 targets (points) and extrapolated to 2030.**

3. Are we still locked in to a centralised, high carbon energy system?

This Section first explains the idea of 'lock-in' and identifies its main technical and social dimensions, some of which remain significant concerns despite recent policy changes. Sub-section 3.2 then discusses three key dimensions in turn: infrastructure, scale and industrial policy.

3.1 Lock-in: explaining inertia

Technological 'lock-in' is no great mystery, yet it usually attracts one of two equally mistaken interpretations. The first is that it is a kind of conspiracy theory dreamt up by advocates for uncompetitive technologies in order to place the blame for low uptake on 'the system'. The second is that lock-in is a 'bad thing' and should be done away with. In fact the mechanisms for technological lock-in are well understood, and are very strong (Unruh 2000). The challenge, we argue, is not to eliminate lock-in, but to appreciate and fully address its technical and social dimensions so that we become 'locked-in' to low carbon development paths. This will demand deliberate transformation of UK heat, electricity and transport systems.

For example in the electricity sector what will need to change is not just the layout of cables, but rather the overall system infrastructure that connects generation and supply, including for example new control systems infrastructure that can integrate demand into system operation. This transformation will not just be a technical challenge. The Government's vision also needs to have economic, institutional and regulatory components. History shows that technologies, institutions and policies change in inter-related ways. In the UK, these changes have built an increasingly centralised electricity system, which is built around fossil and nuclear generation. The 'lock-in' of this system to a centralised model presents a challenge when Government policies now require the system to change (Foresight 2008).

Lock-in is everywhere, even in fast moving and highly competitive sectors. It has had

especially strong and enduring influences on the development of energy systems, because these are based on capital-intensive, long-lived and inflexible assets. There are also social, institutional and political dimensions to lock-in that are particularly strongly felt in the energy system. These dimensions stem from the institutions (such as Ofgem), markets (such as British Electricity Transmission and Trading Arrangements or BETTA), and regulations (such as the EU emissions trading scheme) that have co-evolved with the UK's technical energy infrastructures.

So, how does lock-in work, and what have been its central manifestations in UK energy markets? Beginning with technical innovations themselves one can identify mechanisms that result in inertia or 'momentum', pushing system developments along particular paths. Brian Arthur (1989) identified four mechanisms of 'increasing returns' that begin to explain the processes of 'path dependency': scale economies, learning economies, adaptive expectations and network economies. In short, as production volumes increase costs fall, investors grow more confident and networks of complementary technologies, infrastructures and users emerge. In the words of Freeman and Perez, 'Under favourable conditions... business confidence improves, leading to an atmosphere of "boom" in which, although there are still risks and uncertainties attached to all investment decisions, animal spirits rise. Such favourable conditions include complementarities between innovations and the emergence of an appropriate infrastructure as well as some degree of political stability and institutions which do not hinder too much the diffusion of new technologies' (Freeman and Perez 1988: 43).

Of course as well as potentially hindering such diffusion, both private and public institutions also play key roles in making it happen. Discussing the role of private institutions in creating lock-in, Unruh (2000) describes how private and often non-commercial organisations emerged to facilitate, and to lobby for, expansion

of private automobile use. Organisations were formed to train auto engineers, and academic disciplines and departments created to provide higher-level technical know-how. Unions, users' clubs and journalists all joined a 'large, self-sustaining network of like minded professionals and institutions that are invaluable to the growth of the system' (Unruh 2000: 823). This creates a political constituency for further growth of road transport. Meanwhile societies co-evolve with technologies, and social norms, behaviour and even settlement patterns adapt such that people depend on (and therefore naturally have a preference for) car ownership and private transport.

Thus private actors and associations can create momentum behind a technology. Governments can respond by intensifying this momentum, for example by setting the 'rules of the game' in technology markets, and reducing investment risks and uncertainty about the future of a technology. Government bureaucracies typically change only slowly once established, creating another source of technological inertia. Roads and fossil fuel lobbies are well organised and politically powerful, whereas those who suffer the effects of climate change are dispersed all over the world. Unruh explains the problem of collective action to break out of carbon lock-in as follows: 'the fossil fuel industries... are in the advantageous position of being smaller in number and able to coordinate their substantial resources to resist any change that threatens their interests, such as limits on the combustion of fossil fuels. On the other hand, the diverse beneficiaries of climate protection policies have much greater difficulty in coordinating their responses' (Unruh 2000: 828).

There is little reason to think that these mechanisms of lock-in would apply any less forcefully under a low-carbon development path. Breaking out of *carbon* lock-in and creating momentum behind energy efficient and low-carbon technologies is possible for governments, but it is politically challenging. Correcting a few market

failures, supporting a little R,D&D here and there and developing aspirational 'visions' is not going to be sufficient. Lock-in' means new technologies face pervasive barriers to adoption because the relevant system is not set up to accommodate them: it is a short hand for a set of systemic barriers to innovation. So breaking carbon lock-in is not simply a matter of more low carbon innovation (though that is needed), it is also a matter of deliberately countering the mechanisms by which high-carbon technologies dominate the market. By extension, creating a low carbon economy is only partly about innovating: it must also be about creating the processes of lock-in that give technologies momentum so they displace and exclude competing technologies.

A recent report by our SPRU colleagues identifies seven dimensions of socio-technical lock-in: 'market and consumer cultures', 'institutions', 'economics', 'capabilities', 'vested interests', 'politics and power', and 'infrastructure' (Scrase, Stirling et al. 2009). These are systemic features that reinforce one another, lending momentum to certain development paths and closing off others. These dimensions are considered in turn below, in the light of the UK's *Low Carbon Transition Plan*.

Market and consumer cultures. Understandably, people and businesses resist change and risk taking unless they can foresee a good chance of significant gain. This remains a problem in the energy sector where the damaging consequences of climate change have yet to be felt, and the existing energy system has generated profits and served most people well (in terms of providing electricity, transport and warmth). However the need to act to avert the worst consequences of climate change is increasingly widely recognised, and evidence suggests that people and businesses are keen to act provided there is an expectation that this is the direction others will take. Moreover since the financial crisis faith in competition and free markets has weakened, making more cultural space for concerted efforts to bring about change.

Institutions. Government departments, regulatory bodies, policies and incentive structures that make up the 'rules of the game' have co-evolved with today's energy system, and tend to create a second source of inertia. As with the cultural dimensions of lock-in, these institutions are beginning to change. The previous Government's recent commitment to revising the remit of the energy regulator Ofgem to better reflect climate concerns is an example of the weakening of this source of inertia.

Economics. Due to long periods of dynamic increasing returns, existing technologies are typically cheaper to use in the prevailing energy system than newer technologies. This is recognised by Government, and emphasis has moved from 'levelling the playing field' to providing the necessary incentives to secure investment (for example in offshore wind). Change in policy is likely to be reinforced by market effects: there is still scope for renewables costs to fall through increasing returns, while the economics of nuclear power and fossil fuels with CCS are uncertain.

Capabilities. Assuming there is a demand for change in the energy system, and appropriate institutions and incentives in place, investors still need relevant capabilities if they are to invest in renewables. Provided incentives are credible and sufficiently long-term, businesses will invest in developing these capabilities. This has been seen in Spain, where utilities saw the value in developing capacities in manufacturing and installing turbines as well as operating wind farms. As Section 1.3 showed, the structure of UK incentives for renewables has resulted in the development of little UK capacity. While large investors may gain such capacities through international investments, an uphill task remains in developing capacities in smaller firms and organisations such as local authorities that are better placed to exploit renewables resources at the meso-scale.

Vested interests. Energy assets tend to be long-lived, so incumbents will tend to resist radical change in order to defend sunk investments. This can of course also work in favour of new technologies once investments have been made. However in the UK renewable energy has been treated largely as a niche activity undertaken by large energy utilities, and as such interests remain strongly vested in the existing centralised, fossil-based energy system. This observation underscores the importance of incentive structures that result in significant investment, and that encourage new market entrants. This then plays into the politics around energy market development.

Politics and power. Large companies have significant political power, and tend to use this to defend their vested interests. Conversely, they may also use it to encourage policy changes that open up new opportunities, provided they have a realistic expectation that a good return can be made. Moreover encouraging new entrants (without such vested interests) builds a political constituency for further change. In the UK the RO has stimulated little investment and few new entrants. Lessons from Spanish and German experience (e.g. Stenzl and Frenzel 2008) reveal how companies' corporate and political strategies are shaped by ownership structures within the energy system and the design of incentives. In the UK the political constituency for change could be considerably strengthened by creating investment opportunities at the meso-scale of renewable energy technologies.

Infrastructure. Lastly, energy systems have an in-built inertia because existing infrastructures are most able to accommodate the technologies for which they were built. The UK's electricity system, for example, is highly centralised, which makes accommodating distributed generation exceptionally challenging. This in part explains the attraction of simply replacing ageing nuclear and

coal fired power stations with modern equivalents at the same sites. Some large scale renewables can be accommodated by extending the centralised electricity network. However integrating a large share of renewables into the energy system will require significant experimentation and investment to make the grid smarter.

In summary, while there is an evident cultural shift towards concerted action to tackle climate change, and the economic and institutional contexts for change are improving, overcoming lock-in to the existing system remains a major challenge in terms of developing the capacities, political constituencies and infrastructures that will give renewables investment real momentum.

3.2 Addressing lock-in: scale, infrastructure and industrial policy.

Having set out the problem of lock-in, and why it is so important, the remainder of this section develops a rationale for the policy proposals that follow in section 4. It focuses on the three areas of the deployment of renewables at a range of scales, financing network infrastructures, and industrial policy. Government action in these three areas – as well as ensuring that sufficient economic incentives are in place for investors in renewables – will be vital to overcome the different dimensions of lock-in.

Strong economic incentives are required to overcome *economic and market* dimensions of lock-in. They are needed to persuade firms and other actors to invest in renewables rather than other options – particularly at a time when many renewable technologies have yet to reap economies of scale which has the potential to significantly reduce their costs.

A focus on the scale at which renewables are deployed is required to overcome the power and *vested interests* dimensions of lock-in. Opening up opportunities for renewable projects beyond the large scale and the household scale will contribute to the attainment of the 2020 target – but is

likely to mean that new actors need be engaged in renewables deployment including community groups, non-incumbent firms and Local Authorities.

A focus on how to finance new network infrastructures (e.g. heat grids) and transformations of existing infrastructures (e.g. electricity grids) is required to overcome the *infrastructure* dimension of lock-in. Without this, renewable energy sources that do not fit with current monopoly infrastructures (e.g. offshore wind farms) will not be commercialised as quickly as is required.

Finally, a focus on industrial policy will also be needed to overcome the aspects of lock-in that relate to a lack of *capabilities* and skills – whether it is in developing next generation renewable energy technologies (e.g. marine renewables) or installing and integrating the current generation (e.g. via smarter network technologies),

Scales of Renewables Deployment

It is important that renewable energy deployment at all scales is not only made possible, but is provided with clear incentives. Because the UK energy system has historically been built around large-scale supply options (particularly in electricity), policy has neglected the role of energy systems at scales below this. This is particularly true of ‘meso scale’ options that operate at scales between large-scale (e.g. power plants of several hundred MW) and the building scale (i.e. micro-generation in households). Table 3 illustrates the range of potential scales together with examples of technologies, institutions and policies.

The mix of renewable technologies to meet the UK commitment that is provided in the UK RES illustrates this point very clearly. This shows that significant contributions are possible from large-scale options that connect to high voltage transmission grids – particularly offshore and some onshore wind. There are also some contributions from microgenerated electricity and heat (particularly solar heat), some of which would be deployed in households. But in between, there is

	Geography	Technologies	Institutions	Regulations and Incentives
Centralised	International	Large solar PV plants in Africa exporting power to Europe	International Energy Agency; European Union	EU Emissions Trading Scheme
	National	Centralised electricity and gas grids	Central government; national energy regulators	Energy market rules; national incentives (e.g. for renewables)
Decentralised	Regional/City	City scale heat and power systems (e.g. 'Berlin Mitte', Germany)	Municipal utilities in other EU countries	Regional energy strategies;
	Town/Neighbourhood	Area heat power schemes	Local Authorities	Local planning rules; local grants
	Building	Building insulation; Efficient appliances; Building micro-generation	Community organisations; Building managers	Grants and incentives for householders

Table 3: **The spectrum of energy system scales** Note: Grey shading highlights neglected 'meso scales' Source: Adapted from (Foresight 2008)

an array of options, including smaller onshore wind farms and biogas / biomass heating systems that are likely to be deployed in between these two ends of the scale spectrum. With this in mind, the characterization of options as either centralised or decentralised within the consultation (and other Government documents) can be too simplistic. There is an array of scales at which energy systems – and hence, renewables – can be deployed (see Table 3).

As noted in Table 3, these different potential levels of technical deployment can be accompanied by different kinds of regulations, incentives and governance. Instead of the main agents of policy being national government – and the main

implementers of renewables being larger energy companies and households – this opens up greater potential for small and medium sized businesses and for other levels of government, particularly those that are local or regional.

The RES consultation document of 2008 rightly acknowledged the role that Local Authorities and Regional Development Agencies could play – something that has been constantly mentioned as important since the 2003 White Paper on energy but that seems resistant to real change so far.

In principle, there is nothing to stop investment in renewables at this full range of scales. However, the absence of energy investments in the UK at 'meso' scales (between national scale and

building scale) speaks volumes about the difficulty of making this happen in practice. Whilst there are good examples of renewables deployment at these meso scales (Walker, Hunter et al. 2007) and some local authorities such as Woking have pioneered decentralised energy system, they are notable because they are rare. Unlike some other countries, there is no established tradition in the UK of either energy technology deployment or energy system governance and regulation at meso scales in the UK. The importance of the renewable energy partnerships and networks operating at local and regional levels has been recognised by central government since the 2003 White Paper on energy. Sussex Energy Group research into renewable energy promotional activities in the English regions identified considerable appetite and innovative initiative (Smith 2007). However, our research also found central government was failing to capitalise on the experience and enthusiasm in these lower levels.

So what is needed to 'open up' the UK energy system so that the full range of energy options (including renewables) are more likely to be deployed? The new economic incentives being implemented – i.e. the feed in tariff and the renewable heat incentive – will help. However, they only provide partial coverage of meso scale renewables. For electricity, the feed in tariff cut-off at 5MW is arguably too low – and this has been acknowledged by the new government which plans to widen eligibility for feed in tariffs. Within this, detailed implementation will matter. For example, at present wind developers with plants that are larger than 1.5MW are eligible for a much smaller tariff than smaller schemes. Biomass schemes using solid and liquid fuel remain within the Renewables Obligation (RO).

The current structure of this and other policies leave many potential 'meso level' renewables schemes exposed to too much risk in areas such as planning and financial incentives. In many cases, they will be too large to be affected by local planning derogations and too small to be impacted

by the Infrastructure Planning Commission. They are also exposed to the RO, but may in some cases be run by small investors who would benefit significantly from the certainty of a feed-in tariff. The planned abolition of the IPC and the extension of feed in tariffs represent opportunities to reduce such risks.

To explore further how meso-scale renewables could be encouraged more strongly, reforms in both planning and economic incentives are therefore required (see section 4). In addition, a series of local energy system experiments as recommended by recent Foresight study (Foresight 2008) would contribute to a process of learning how deployment at meso scale could work – and what problems will need to be solved. There are signs that this approach is being taken seriously. Several programmes were launched by the previous government which targeted communities rather than just individual households. These included the Community Energy Saving Programme (CESP). Under the Renewables Strategy, the Government is funding up to 15 community 'test hubs' for local action to improve sustainability. In each case, the emphasis is on a holistic approach which does not only provide incentives for the deployment of new technologies, but does so as part of a comprehensive investment in more sustainable energy infrastructures. In the case of CESP, there is a focus on targeting the poorest households with multiple measures instead of the least cost approach to energy efficiency that has been followed until now.

The key question for the renewables target is whether these initiatives will be enough to enable deployment at the full range of scales. Further issues include the extent to which the initiatives need to be co-ordinated and what roles local actors (particularly Local Authorities) and national bodies (e.g. Infrastructure UK or DECC) might play in financing and implementation. A recent report by Consumer Focus suggests more co-ordination is required – with Local Authorities leading a

new series of franchises for the delivery of local energy services (Vaze and Mayo 2009). Section 4 develops some specific proposals that focus in particular on these important local actors.

Network Infrastructures for Renewables

New investments are needed in a range of energy and other networks to support the attainment of the 2020 renewables target. These include heat networks, new investments in the high voltage electricity grid, and smarter local electricity networks (including associated IT and communications networks).

In the case of heat networks, their unfamiliarity means that there is a particular need for policy development to ensure that finance is available for investments. The UK has little district heating infrastructure in existence - and heat markets are not well developed. There is an opportunity to design incentives so rectify this where appropriate. *The Low Carbon Transition Plan* includes welcome incentives for renewable heat: the proposed renewable heat incentive, that may still be implemented from April 2011, and the £25m of new funding for at least 10 'exemplar' district heating projects – some of which could use renewable resources. But as the previous Government acknowledged in the consultation on the Heat and Energy Saving Strategy, more action beyond these measures is required (DECC 2009b).

With respect to electricity grids, an important piece of context is the EU Renewables Directive. Article 14.2. of the Renewables Directive states, "*Without prejudice to the maintenance of the reliability and safety of the grid, Member States shall ensure that transmission system operators and distribution system operators in their territory guarantee the transmission and distribution of electricity produced from renewable energy sources. They shall also provide for priority access to the grid system of electricity produced from renewable energy sources. When dispatching electricity generating installations, transmission system operators shall give priority to generating installations using renewable energy sources*

insofar as the security of the national electricity system permits." (European Parliament and the Council 2009; emphasis added).

This comes close to requiring Member states to provide guaranteed, preferential grid access to renewables operators - something strongly resisted at the time in EU negotiations by the UK Government (Adam 2008). This applies to both the high voltage transmission system and into the more local distribution system controlled by District Network Operators (DNOs). Government is now committed to bringing forward investment in renewables, and enabling such preferential access will be vital.

The planned expansion of offshore wind power will increase the amount of intermittent power generation in the electricity system and will also require a new offshore network infrastructure to be built. There is a particularly large queue of wind power plants waiting for connection in Scotland. So far, the regulatory regime has given transmission companies little incentive to invest strategically in offshore infrastructure. Such strategic investment may be required before there are firm plans to build specific offshore wind farms that will fully use the resulting transmission capacity. The Coalition Agreement recognises this as a priority and, under the previous government, Ofgem initiated tendering for £15bn of such investment (Ofgem and Department of Energy and Climate Change 2009).

Whilst it brings with it risks of over-investment and stranded assets, this more strategic approach is long overdue. The work of the Electricity Networks Strategy Group shows some network investments are fairly robust to different scenarios of renewables deployment in the UK. The ENSG is chaired by DECC and Ofgem, and has been charged with identifying transmission investments to meet the 2020 renewables target. In its recent report on these transmission investments (Electricity Networks Strategy Group 2009), the ENSG proposed a series of investments that have been tested against a range of electricity

generation and demand scenarios to 2020. A key message is that many of these investments are robust to a range of scenarios, and could be implemented over the coming few years to ensure that there are no transmission barriers to the deployment of individual renewable energy projects.

At the more local scale of the electricity distribution network, the growing deployment of other renewable technologies and combined heat and power (CHP) will entail a need to integrate generation at a range of scales into electricity grids. Distributed generation can include household technologies such as micro-CHP or solar PV panels, small-scale wind farm in a village or a city-wide CHP system. Implementation of these options could include a variety of different investors from householders and energy companies to local authorities.

Significant policy changes are required to enable this full range of actors and options to play a significant role. For example, some of the economic and technical barriers to renewables have stemmed from the inability of the incumbent regulatory regime to provide appropriate incentives for distributed electricity generation. A key issue has been the costs of connection and integration which have, in the past, been passed through to prospective renewables projects. By contrast, in other countries (e.g. Denmark), the costs of integrating distributed generation plants have been shared or 'socialised'. Distributed generation is not seen in relation to the individual part of distribution network it is connected to, but rather as contributing to the electricity system as a whole, driven by national policy targets. Socialisation of network costs goes a long way to explain why – unlike in the UK – the network costs of DG have not been a major issue in Denmark. In the UK, the position has shifted to some extent – but there is still an ongoing debate about the extent to which the costs of network integration should be 'socialised' and passed through to consumers.

Given the relative novelty of distributed generation in the UK and recent advances in information, communication and control technologies, there is a need to demonstrate new electricity grid concepts. These should not only show how multiple distributed generators can be connected to the network, but should also include new network technologies and technologies for demand management. These so-called 'smart grids' have been increasingly discussed in the UK policy debate. In order to develop a strategy for their demonstration and implementation, it is important to clarify what these 'smart grids' are, and what they might do to help accelerate renewables deployment and integration.

Definitions of smart grids tend to differ in several important ways. They differ with respect to their geographical coverage. Some visions for smart grids are applied to whole countries. For example, President Obama recently said that the United states should 'build a new smart grid that will save us money, protect our power sources from blackout or attack, and deliver clean, alternative forms of energy ...'⁹. In the UK, smart grids are often conceived as more local in nature – since the requirements of smart grids will differ between locations. In his speech to launch the Low Carbon Transition Plan, Ed Miliband linked funding for several smart grids with the roll out of smart meters in the UK¹⁰.

There are two further definitional points that are important here. First, many definitions go beyond the grid, and also include the integration of the grid with electricity supply and demand and even transport (via electric vehicles). Second, many definitions go beyond technical issues to include organisations and markets. For example, the German E-Energy programme includes three elements designed to integrate technical and market aspects of smart grids: i) the creation of an electronic marketplace; ii) the use of information technology to connect, regulate and control system components, and iii) online links between the

30 ⁹ Speech by President-elect Barak Obama on the economy, 8th January 2009.

¹⁰ Speech by Ed Miliband MP, UK Secretary of State for Climate Change and Energy, 15th July 2009.

electronic marketplace and the technical system (Federal Ministry of Economics and Technology 2008). This latter German conception is the broadest and most useful since it makes explicit the link between technological change on one hand and changes in markets and policies on the other.

In principle, the UK's mechanisms of price-based regulation can be modified to promote smart grids by including incentives for network operators to invest in research, development and demonstration (R,D&D) for smart grids. Mechanisms such as the Innovation Funding Incentive (IFI) and Registered Power Zones (RPZs) were introduced in the fourth Distribution Price Control in 2005. However, they did not lead to smart grid concepts, research or trials being implemented. Ofgem has now recognised this, and has proposed a new £500m package of incentives (the Low Carbon Network Fund) that would be implemented as part of the fifth Distribution Price Control from 2010-2015 (Ofgem 2009).

Industrial Policy and Innovation

The 2009 *Low Carbon Industrial Strategy* signalled three major emphases in the previous UK Government's renewed interest in industrial policy.

- Innovation support across stages/ the innovation journey – additional investment in early stages and access to finance for growing businesses.
- Regional policy – ‘additional action to position particular regions in ways that play to their strengths’ (HM Government 2009: 4).
- Strategy – ‘a strategic view of Britain's low carbon strengths and opportunities’ (HM Government 2009: 4).

These are vital steps in the right direction, but the framing of the overall Low Carbon Industrial Strategy could be criticised as being too passive. The message is that the low carbon transition is coming and the UK should be better prepared: “the core objective of this strategy is to ensure that British businesses and workers are equipped

to maximise the economic opportunities and minimise the costs” (HM Government 2009: 5). This subsection suggests ways in which a more truly activist industrial policy could proceed in terms of supporting innovation and decentralising resources towards deliberate transformative change.

For decades the orthodoxy in UK energy policy has been that Government should always avoid trying to pick technological winners, reflecting some high profile white elephant industries supported in the 1970s, and the idea that competition should be maximised. However lessons can be learned from the past so that the failings of 1970s industrial policy are not repeated, for example by building in safeguards so that support for unsuccessful technologies is withdrawn quickly when evidence of failure is very strong. The context is now very different, as is the intent. There is extensive foreign ownership of relevant companies operating in the UK and it is very clear that UK leadership in the area of sustainable energy is unlikely to extend across all technologies and sectors.

What is needed is a more robust and transparent process through which support can be targeted, adjusted and withdrawn over time (Watson 2008). In addition to enabling better decisions, such a process could enable a more stable policy framework to prevail, lending more credibility to policy in the eyes of investors than renewables policies to date. Some suggested principles, and proposals for suitable headline criteria have recently been developed by the Carbon Trust (Carbon Trust 2009). This emphasises a case for tailored support for ‘families’ of low carbon technology (e.g. solid state lighting or offshore wind power) rather than ‘picking winners’ in terms of specific variants of a given family or particular firms. It also advocates the use of transparent measures of potential and performance.

The Carbon Trust approach uses two basic questions to analyse candidate technology families: First, to what extent is a technology

family required to meet carbon emissions reduction and renewable energy targets? Second, what economic benefit for the UK can be gained from supporting this technology family? It also makes a distinction between technologies that are ready for deployment support and those that at an earlier stage of the development process (and therefore have the potential to make a contribution over the medium to long term). This way, the approach covers both the environmental and industrial development goals of Government policies. Those technology families that are seen as essential for meeting UK targets – and will not be available quickly enough without UK policy intervention – should be prioritised. The Carbon Trust concludes that offshore wind and wave technologies fall into this category, with offshore wind in particular having the potential to generate net economic benefits to the UK.

Future energy technology programmes will also need to have robust evaluation and review procedures. Evaluations are currently carried out within the UK Government, though it is not clear how systematic the process is. As other authors have noted, conducting evaluations is far from simple. It is difficult to measure either the outputs (for example in terms of economic returns) or outcomes (in terms of successful innovations) of technology support programmes (Gallagher, Holdren et al. 2006). If ‘success’ is measured in terms of current cost-effectiveness in cutting emissions, this surely misses the point about long term innovation support.

A combination of qualitative and quantitative criteria will need to be used to assess the broader impacts of these programmes. Qualitative performance targets are often written in to US technology programmes at the start. Adjustments to portfolios to account for the relative success or failure of different options should then be made regularly. There will need to be a careful trade-off between withdrawing support when technologies show the first signs of failing to deliver, and providing more patient support that acknowledges the long-term nature of many developments (Foxon 2003).

The emphasis here has been on supporting others to innovate. However Government also needs to engage more meaningfully in wider networks, for example with local authorities, civil society groups and the public. This is necessary for instrumental, substantive and ethical reasons: to improve buy-in and deliverability (instrumental); so diverse knowledge helps shape better policies, and a diverse range of actors’ initiatives are valued and used in policy learning (substantive); and for democratic reasons – valuing openness, engagement and accountability, and building legitimacy for change (ethical). Scrase et al (2009) explains why a new approach to engagement is necessary if Government is to foster deliberate transformative innovation.

Section 4. Policies to meet ambitious renewables targets

This report has analysed the UK's 15% renewables target for 2020. It has also shown that, in principle, the share of renewables could be further increased well beyond 15% after 2020. It has highlighted some of the critical factors that will affect the successful deployment of renewables to meet the 2020 target – and the extent to which these factors have been built into current policies.

Many commentators have noted that reaching the 2020 target, let alone expanding renewables beyond 15% of UK energy, will be very difficult. One of the reasons why is the poor starting position that the UK finds itself in. At the end of 2009, only 3% of UK energy came from renewables – though this represents significant progress over the level in 2007 (1.8%). The UK is towards the bottom of the European league in this respect. This poor starting position reflects a meagre inheritance in which the UK energy system is locked in to a high carbon pathway with renewables failing to make significant headway despite two decades of policy incentives.

The recent shift in renewables policy in favour of a more positive approach is welcome. The EU target is clearly taken more seriously by government than it was a year ago. Under Labour, several policy shifts – e.g. on financing of renewables, Ofgem's duties, and on infrastructure for offshore wind – have been made. The Coalition Government has signalled an intention to go further, for example through the wider implementation of feed in tariffs. However policy needs to do more to overcome the UK's historic lock-in to a high carbon, centralised energy system – and to realise the full potential of renewables.

It is tempting to believe that the UK's progress with renewables to date is so slow, and the urgency of climate change is so pressing, that a radical programme of top down Government intervention is the only strategy that will deliver the 2020 target (and the broader 2020 emissions reduction target). A number of bodies and commentators have called for this. Most recently, the Institution

of Mechanical Engineers (IMechE) have called for a 'war against climate change' with 'centralised control for climate change policy' by government (Institution of Mechanical Engineers 2009).

But such analyses do not explain how government should go about putting such a shift into practice. Should it be the government's job to over-rule all local objections to renewables projects, micro-manage the development of electricity grids, and buy up strategic parts of the supply chain (e.g. ships for installing offshore wind farms)?

If so, is government better placed to do this than the firms who have the appropriate expertise? How will decisions and trade-offs be made? How will legitimacy and support from communities be gained for a shift to an energy system where most sources of energy are no longer remote from demand? Whilst the IMechE acknowledges a continuing role for markets, the language of 'centralised control' and wartime analogies implies that choice will be restricted and decision making closed.

If followed through, this shift would bring with it serious risks to the attainment of the UK's renewables target. It is important to remember the pros and cons of State control of this kind. Whilst the State-owned companies that used to run the UK's energy system (e.g. British Gas, British Coal and the Central Electricity Generating Board) ensured energy was supplied to consumers, they were not particularly good at innovation and commercialising new technologies. Renewables languished under the State-owned Central Electricity Generating Board (CEGB) which ran the electricity system from 1947 to 1989 – despite high oil and gas prices in the 1970s and the early 1980s. The UK's nuclear power programme was a good example of how not to proceed – with bespoke plants, delays and rising costs. Despite large investments in R&D, the CEGB failed to spot the potential of more efficient gas-fired technology (though ex-CEGB staff were quick to adopt it once they moved to the CEGB's successor private utilities). They also failed to commercialise options to clean up the use of coal. So a return to some

form of centralised planning would need to learn from this experience and say how these pitfalls would be avoided.

Nevertheless there are also risks that recent policy shifts by government – however welcome – are not enough to deliver the 2020 target. This report has identified a range of areas in which lock-in still needs to be tackled. In the sections that follow, specific proposals are put forward to strengthen the push for renewables. These do not advocate a top down centralised approach by government, but identify areas in which strategic, targeted intervention is required to deal with issues that the market alone will not.

As has been the case since specific renewables policies began in 1990, a crucial issue is the incentives available to renewable investors (large and small) and the extent to which they will be sufficient to meet the EU target in a timely fashion. With respect to renewable electricity – which will contribute most to achieving the 2020 target - the previous government made it clear that the Renewables Obligation in its original form is not fit for purpose. For smaller renewable electricity projects, a feed-in tariff has been introduced. In the case of larger renewable electricity projects, we welcome the incoming government's decision to broaden the feed-in tariff to larger renewables. However, for simplicity and to minimise financial risk **a feed in tariff would be a better form of incentive for all renewable electricity projects, irrespective of their size.** Any further feed-in tariffs that are introduced should be high enough to provide a sufficient incentive to investors – and they should also decline over time to encourage efficiency and capital cost reductions.

Getting incentives right through a feed-in tariff is only part of the story. An important impediment to renewables deployment in the UK has been the lack of action to address barriers within the energy system. It is likely that these barriers would have hindered deployment even if a less risky incentive regime (such as a feed-in tariff) had been in place. In the following sections, three areas for bolder

policy development to deliver the 2020 target – and to go much further after 2020 – are identified to address more systemic barriers to deployment. In each case, some specific policy proposals are put forward. These areas are:

- The need to open up the energy system so that renewables can be readily deployed at the full range of scales – from households, through community projects to large offshore wind farms.
- The need for a new approach to investment in energy network infrastructures such as smarter grids, heat grids and information technology networks.
- The need to build on the previous government's renewed emphasis on 'industrial policy' so that the benefits of renewables expansion are both reduced emissions and new jobs.

4.1 Promoting renewable energy at many scales

Meeting the renewables target is not just about deploying large wind farms and micro-renewables in households. It will require investments at a range of scales including community scale wind farms and local biomass heat and power plants. Opening up opportunities at this 'meso' scale in between will not be easy – partly because there has been little policy attention to it so far (apart from some limited funding through the Community Renewables Initiative). In view of the historic lack of attention **the Government should place special emphasis on how 'meso scale' renewable schemes can be deployed in much greater numbers.**

For example, planning policy has been largely concerned with large scale infrastructure (e.g. above 50MW in capacity for power projects) and very small installations (which are designated as 'permitted developments'). A large number of potential projects will fall in between. A range of policies will be required to provide incentives for community scale actors to deploy renewables

– and, in particular, ways to empower local government (i.e. Local Authorities) so that it can play a more active role in future energy strategies and decision making.

As noted above, economic incentives will be an important part of this picture so that renewable projects at this unfamiliar ‘meso’ scale become more attractive. A recent Conservative green paper highlighted the potential for community ownership to promote involvement in renewable energy at the local level. Under the Coalition Government’s plans for an expanded feed in tariff, many communities will have an additional source of income for renewable electricity projects for the first time. This could – if administered and distributed appropriately – provide a direct financial benefit, and help to gain support. It is important that the new feed-in tariff and renewable heat incentive schemes are strong enough. Indeed, efforts to improve the engagement of local actors including Local Authorities in renewable energy developments will be considerably hampered if the feed-in tariff and renewable heat incentive prove to be insufficiently attractive.

Powers and guidance for Local Authorities

Given the local nature of community renewables projects, there is a key role for local government to co-ordinate and complement ‘top down’ policies and incentives from central government. However, Local Authorities have historically had a minor role to play in energy system development. Whilst the efforts of some local authorities such as Kirklees and Woking have attracted widespread attention, they are so well known because they are so rare. Many Local Authorities do not have the resources – either in terms of finance or other powers – to follow suit (Local Government Association 2007). Therefore, there is a need for new duties on local authorities to help deliver the renewables target, for example through the planning guidance given to them. But there is also a need for new resources to match. Politicians of all persuasions often advocate decentralising power (in the political sense). This is one way in which such proposals can be put into practice.

The existing guidance for Local Authorities on climate change in the supplement to Planning Policy Statement 1 (PPS1) is seen by many as a useful step forward – but as being not strong enough to encourage action. In the light of this, the previous Government began work on new planning guidance on climate change, including updated guidance on renewable energy to reflect the 2020 target. Such action has the potential to fulfil a key conclusion of the Local Government Association’s Climate Change Commission: i.e. that a new duty on Authorities to deliver on climate change mitigation and adaptation should be considered (Local Government Association 2007).

Whilst planning processes should continue to be a forum in which different local, national and international needs are considered – and the views of local communities taken into account – we agree with this need for **stronger guidance to Local Authorities to ensure that their planning decisions are compatible with the Climate Change Act and meeting the 2020 renewables target**. The Coalition Government’s abolition of the regional tier of planning and regional renewable energy targets could undermine delivery at the local level, unless some other way is found to encourage collaboration and forward planning across local authority boundaries. A more strategic approach to planning for onshore renewables has been adopted in Wales and Scotland with some success, and experience in Germany and Denmark suggests ‘positive planning’ has been central to successful deployment of onshore wind in those countries (IEEP, 2009) It is also important that the implementation of National Policy Statements on energy infrastructure leaves room for local deliberation and ‘buy in’ for investments that are given consent to go ahead.

Finance for local action

Finance is also important for Local Authorities to be able to play a significant role in developing local renewable energy resources. Due to the planned squeeze on public spending over the next few years, new ways to provide this finance

need to be urgently explored. Some Local Authorities have already demonstrated novel approaches to financing. For example Woking Borough Council founded a new energy service company, Thameswey Energy, to develop a private electricity network that incorporates a number of decentralised energy generation plants.

The Community Infrastructure Levy (CIL) implemented by the previous government is one route that can be used to help finance new local energy infrastructure, including district heating (Department of Communities and Local Government 2010). **It should be possible for Local Authorities to apply the Community Infrastructure Levy to both existing and new developments – and to extent the scope beyond district heating.** Local Authorities wishing to follow the example of Woking Borough Council could use it to invest in private wire networks for example since they would not be eligible for Ofgem’s new Low Carbon Network Fund. Further detailed recommendations on Local Authority financing of network infrastructure are discussed in section 4.2.

But the CIL may not be enough. Additional sources of finance are likely to be required. There are general constraints on Local Authority investment in new low carbon energy projects and infrastructures because any borrowing to finance it has an impact on their budgets. **Feed-in tariffs and the Renewable Heat Incentive could help to overcome constraints on Local Authority financing, and it is important that they can borrow against the expected revenue.** However, interest payments on borrowing have historically been counted against revenue by central government when making decisions about caps on Council Tax rates. One part of the solution is therefore to change the rules to relax these constraints as advocated by Tony Travers recently (Travers and Arup 2009). We support his proposal that **interest payments by Local Authorities that have borrowed to finance low carbon investments should not be counted in any decisions about capping rates of Council Tax.**

4.2 New energy network infrastructures

It is widely accepted that the sustainable energy transition requires a UK energy system that is radically different to the one we have now. Whilst the composition of this future system is inherently uncertain and open to debate, shared network infrastructures will have a key role to play in facilitating change. The role of infrastructures has recently risen up the agenda. A number of recent reports have identified energy infrastructures as critical for the UK’s future well being (Council on Science and Technology 2009; Helm, Wardlaw et al. 2009).

Network infrastructures play a crucial role in linking energy supplies to energy consumers and include gas pipelines and electricity networks. They are shared because they can be used by multiple actors, and have a key role to play in facilitating access to markets. They also tend to be natural monopolies – i.e. assets that firms would not invest in fully for private commercial reasons (Helm, Wardlaw et al. 2009). Some form of government regulation or incentive is required to reflect the fact that these assets deliver wider social benefits.

Some of the network infrastructures required to facilitate the energy transition will be completely new. Examples include CO₂ pipeline networks connecting carbon capture and storage projects, and local district heating grids. Others will build on those that already exist. These include, for example, offshore extensions to electricity grids and enhanced information technology systems for ‘smarter’ electricity grids.

Section 3 has already highlighted three network infrastructures that are particularly important for the rapid expansion of renewables in the UK:

- Extensions to high voltage electricity transmission networks. These are already proving to be crucial for offshore wind power expansion.
- New district heating networks which may be powered by renewable fuels (e.g. biomass).

- Additional investment in electricity networks to enable 'smart grids', and to better integrate the supply and demand sides of electricity systems. This investment will focus in particular on information, communication and control technologies.

In most cases, there is a need for government to intervene to ensure that these network infrastructures are developed quickly and in a way that serves broader policy goals for emissions reduction and renewables. A good example that illustrates how such infrastructures could be identified is the recent work of the Electricity Networks Strategy Group (ENSG). This example points to the need for a new policy approach for network infrastructures such as electricity networks. This new approach has two main elements:

1. Identification of strategic infrastructure investments which require regulatory intervention. Such investments will be implemented 'ahead of need' (i.e. before their full capacity is required by the users of these infrastructures), and should be robust to different possible scenarios.
2. The implementation of mechanisms to pay for these investments. These incentives should be designed so that companies with the skills to make the investments in networks can do so – and can recover the costs from the energy producers and consumers that will use those networks.

A new body, Infrastructure UK, has been established to take a strategic view of UK infrastructure needs over the next 5-50 years, and help to attract private-sector investment into low carbon infrastructure (HM Treasury 2009). In a joint report with HM Treasury launched with the 2010 Budget, Infrastructure UK proposed a new Green Investment Bank to provide equity capital for low carbon infrastructure (Infrastructure UK and HM Treasury 2010). The new Coalition Government has affirmed its commitment to the Green Investment Bank, but few details

about its role are available at present. Questions remain about how far Infrastructure UK and the Green Investment Bank will be able to fill the financing gap for these network infrastructures. The previous government's ambition that the Green Investment Bank will have £2bn to spend is welcome. But this sum is small when compared to what is required (Helm, Wardlaw et al. 2009). There is also a risk that the priorities of the Green Investment Bank will focus disproportionately on renewable generation assets, and will not pay enough attention to investments in the network infrastructure which is required to connect these assets. **It is therefore essential that the Green Investment Bank is properly financed and that it invests in infrastructures to mitigate and adapt to climate change. A priority focus should be network infrastructures to support renewables expansion.**

High voltage transmission networks

The Electricity Network Strategy Group proposals for funding the reinforcement and upgrade work to meet the 2020 renewables target are a good basis for investment over medium term. Ofgem has already allowed some modest spending by network companies to start this process. But there is clearly a need to go beyond this preparatory work as soon as possible. Ofgem and the Government should therefore ensure that the transmission network companies implement the ENSG investments in full. Given the urgency of accelerating the deployment of renewables (particularly offshore wind), **ENSG investments that will enable renewables integration should be prioritised.**

Whilst investment in this new offshore infrastructure is essential, there is also a need for a clear charging regime for generators that connect to this network. DECC recently used its new powers in the Energy Act 2008 to take control of reforming this regime from Ofgem (DECC 2009c). Three main options were proposed in 2009, which vary in the extent to which costs of network upgrades to absorb new generation can be socialised.

Our view is that the costs of network upgrades to accommodate new renewable generators should be entirely socialised – i.e. they should be shared by all network users. There are two key rationales for this. First, the connection of new low carbon generation such as renewables is helping to meet social and policy goals. Second, loading reinforcement costs onto new generators will help to strengthen the lock-in of the current network architecture. It makes little sense to penalise generators that require expensive upgrades to the current network because this network was never designed with climate and renewable energy targets in mind.

There are two key rationales for this. First, the connection of new low carbon generation such as renewables is helping to meet social and policy goals. Second, loading reinforcement costs onto new generators will help to strengthen the lock-in of the current network architecture. It makes little sense to penalise generators that require expensive upgrades to the current network because this network was never designed with climate and renewable energy targets in mind.

District heating networks for renewable heat

The two-step approach to network infrastructure policy outlined above can also be applied to district heating. In this case, the identification of priority investments and mechanisms to help finance them are local rather than national. Our specific proposals are as follows:

1. Identifying opportunities for district heating, including renewable heat. **Local Authorities should be required to maintain accurate, up to date heat maps of their area.** These can underpin their own involvement in developing district heating schemes and schemes developed entirely by third parties. These maps should not only identify the distribution and size of heat loads, but should also pay attention to the scope for using renewable energy sources to meet these loads.
2. Compulsory connection and charging for district heating networks. The previous Government proposed two ways in which Local Authorities could help to overcome financial barriers to new district heating schemes. These will supplement incentives from the Renewable Heat Incentive, which may not be sufficient to finance new networks from scratch. First, the Planning Policy Statement on Planning and Climate Change allows Local Authorities to require new developments to connect to an existing district

heating network. Second, the Community Infrastructure Levy can be used to help recover the up-front costs of district heating schemes from new developments. These are welcome shifts in policy – but do not go far enough. **The power to require connection to district heating networks, and the power to raise money through the Community Infrastructure Levy for these networks, should also apply to existing developments.** The application of these powers to existing developments will need to be exercised carefully, and can be most cost effectively (and sustainably) employed when existing developments are replacing or substantially upgrading their heat generating facilities.

Smarter distribution networks

Smart electricity distribution grids could also have a key role to play in delivering the 2020 renewables target – and also in enabling progress beyond 2020 to a completely decarbonised electricity system. Implementing smart grids will be challenging. They do not yet exist, except in a few notable demonstrations in cities such as Boulder, Colorado. It is therefore welcome that the Electricity Networks Strategy Group was asked to shift its attention from the integration of large scale renewables to developing a vision for smart grids. Ofgem’s proposed £500m Low Carbon Network Fund (Ofgem 2009) and the support given to smart grids in the Coalition Agreement are also positive.

Whilst these initiatives are important, it is not yet clear whether they go far enough. Policy needs to move quickly to the stage where a range of different smart grids are being demonstrated in locations around the UK as part of the push to meet the 2020 target. **The Government and Ofgem should be more specific about their smart grid plans, and ensure that at least 10 smart grid demonstrations result from the Low Carbon Network Fund.**

The Low Carbon Network Fund could be a good way to realise smart grid demonstrations as long

as funded projects are genuinely innovative. As the Smarter Grids publication from DECC acknowledges, these projects would bring together local renewable and other low carbon generation technologies, control systems and the integration of smart technologies for demand management (DECC 2009e). The selection of appropriate sites should be informed by the ENSG's Route Map – and each demonstration should be subject to rigorous evaluation to see what works. This learning process would also help to design a national programme of information, communication and control technology investment to enable smarter grids across the UK. **Infrastructure UK could be asked to ensure that synergies between energy and telecommunications infrastructures are maximised within smart grids.**

Unlike heat grids, local electricity grids are already in place across the UK, and are therefore part of an established regulated industry. It therefore makes sense for policy incentives to focus on the role of the owners and operators of local distribution networks – the distribution network operators (DNOs) – rather than Local Authorities. However, there will be a need to better co-ordinate between Local Authorities and electricity distribution companies – and to recognise that innovation in smart grids may require a diversity of actors and institutions to be involved such as retailers, generators, consumers and ICT firms. Infrastructure UK should be well placed to lead this co-ordination, and support the formation of local partnerships for planning and investment.

This broader conception of network innovation – that includes customers and generators – highlights another important policy issue: the need to join up different Government initiatives so that smart grids facilitate smarter energy systems. These systems could include vehicle charging points (with intelligent controls so that vehicles charge when prices are low) and smart meters in homes and businesses. So far smart

grids, smart meters and electric vehicle trials are dealt with separately by UK policy. However, these are all facets of smarter energy systems in which an integrated approach is needed to fully realise potential benefits (DECC 2009e). Smart meters have a particularly important function since they link consumers to generators and network companies. Depending on what else is associated with smart meters (e.g. real-time information on energy use via an electronic wall display) they could also be important from an energy demand reduction perspective. **Given the potentially crucial role of smart meters, the previous government's planned time schedule for smart meter roll out is far too slow. A full roll out by 2015 – not 2020 – should be the policy ambition.** This roll-out should take account of new evidence as it becomes available over the next few years from large scale trials of smart meters that are currently underway in the UK and abroad.

4.3 Implementing an Activist Low Carbon Industrial Policy

The 2009 Low Carbon Industrial Strategy has made the case for a more activist industrial policy. In essence, this policy represents a significant break with mainstream government thinking of the past thirty years. Rather than continuing with a 'hands off' approach to industrial policy, this Strategy signalled a wish to intervene to support low carbon innovation, businesses and jobs within the UK. The new coalition Government supports this general aim of low carbon job creation though it is not yet clear whether they share the approach set out in the Strategy.

There are many welcome elements to the 2009 Strategy. These include an explicit prioritisation of a subset of low carbon technologies for focused support. Within the renewable energy family, the Strategy emphasises offshore wind and marine energy technologies. In addition, it is recognised that information and communication technologies could have a key role to play in facilitating energy system decarbonisation – and a particularly

important role in integrating variable renewable technologies. The Strategy also has a welcome geographical element. An initial low carbon economic area was announced in the South West, with a focus on marine renewables.

Implementation of this more interventionist approach has started to deliver some welcome results. For example, the announcements by Mitsubishi and General Electric on the siting of new wind manufacturing and research facilities in the UK have been facilitated by the provision of public co-funding. As implementation progresses, we believe that the Coalition Government needs to go further. Whilst the previous government moved away from the 'hands off' approach of the past, it did not fully recognise important elements of a more interventionist policy. Three of these are emphasised here. First, there needs to be a clear strategic rationale for setting priorities for government support. Second, there needs to be sufficient emphasis on next generation technologies to deliver renewables beyond the 2020 target. Third, a need for evaluation and review of support programmes that is more rigorous and systematic than previous practice.

Getting the technology portfolio right

Whilst the *Low Carbon Industrial Strategy* came up with a set of priority technology areas for the UK, it failed to justify these with respect to clear criteria. There are many reasons why the design, development and manufacture of particular renewable energy technologies might be supported within the UK. These include significant natural resources (e.g. the availability of many good wind power sites), the relatedness of new technologies to existing UK industries (e.g. in offshore engineering skills that could be applied to wave and tidal technologies), and the potential for job creation. As discussed in section 3, the Carbon Trust has outlined a framework for assessing candidate technologies (Carbon Trust 2009). This includes both the potential economic benefits of developing a particular technology and

the extent to which it is needed to realise the UK's low carbon transition. A critical distinction is also made between technologies that require development/demonstration support and those that need support for deployment.

Whilst there are good reasons for the Government's current renewable energy priorities (i.e. offshore wind and marine renewables), a key weakness of the Low Carbon Industrial Strategy is the lack of a clear framework to justify these priorities. **Our view is that a framework such as that put forward by the Carbon Trust should be explicitly used to set the UK's low carbon technology priorities.** This framework should include clear criteria to justify both the level and type of support offered to each technology family. Within this, it is important that a number of renewable technology families are included along with key enabling technologies such as smart meters and smart grids.

Thinking ahead beyond 2020: the next generation

As noted above, the Carbon Trust framework to set low carbon technology priorities makes an important distinction between technologies that is based on their stage of development. Some are considered for development and demonstration support, whilst others are closer to being ready for commercial deployment. The Renewable Energy Strategy last year set out a clear view of which technologies are expected to deliver the 2020 target. But it is also important to plan now for the next generation of renewable energy technologies that will be required to go further beyond 2020. Examples include next generation solar technologies, and some wave and tidal options. History shows that the lead times of developing such technologies – particularly in getting them through the early experimental phase – are very long (Jacobsson and Bergek 2004). **Therefore, the UK's support for new low carbon technologies should include a balanced portfolio of near-market renewable**

technologies, and technologies that are still at the early stage of development. Within the latter, further from market category, some priority areas for the UK are clear, and should include renewable technologies themselves (particularly wave and tidal technologies) and further advances in developing smarter grid infrastructures to support their integration into electricity systems.

**Getting value for money:
the role of evaluation and review**

A final essential issue that is often overlooked by government innovation policy is evaluation and learning. A more active industrial policy has significant risks – particularly in the current climate of very tight public budgets. For example, the Government may end up propping up poorly performing or uneconomic technologies. The communities developing such technologies can become dependent on Government support and can develop powerful lobbies to stop funding from being withdrawn.

One way to guard against this is to avoid backing specific companies or technological variants – and instead to focus on generic technology families such as wind or wave. Another is to build a robust process of review and evaluation into the implementation of new support programmes. Whilst evaluations of past technology support programmes are carried out within government, these are not systematic or formalised – and rarely have any impact on current priority setting. The *Low Carbon Industrial Strategy* made no mention of evaluation. To rectify this, **the implementation of the Low Carbon Industrial Strategy should be subject to regular evaluation by a separate team within DECC or an independent body such as the National Audit Office.** This function should have clear terms of reference, and be asked to advise on periodic reviews of the Government's portfolio of support for low carbon technology portfolio. It should be made clear under what conditions support for a particular technology area should be continued – and when it should be withdrawn.

References

- Adam, D. (2008). Britain tries to block green energy laws. *The Guardian*. 24th July 2008
- Arthur, B. (1989). Competing Technologies, Increasing Returns and Lock-in by Historical Events. *Economic Journal* **99**: 116-131.
- Barrett, M. (2006a). Green Light: A UK electricity scenario. London, Complex Built Environment Systems Group, UCL.
- Barrett, M. (2006b). A renewable electricity system for the UK: a response to the 2006 Energy Review. London, Complex Built Environment Systems Group, UCL.
- BERR (2008a). Meeting the Energy Challenge: A White Paper on Nuclear Power. London, The Stationary Office.
- BERR (2008b). UK Renewable Energy Strategy: Consultation. http://www.decc.gov.uk/en/content/cms/consultations/cons_res/cons_res.aspx.
- British Wind Energy Association (2009). Powering a green economy: wind, wave and tidal's contribution to Britain's industrial future. London, BWEA.
- Capros, P., L. Mantzos, et al. (2008). Model-based analysis of the 2008 EU policy package on climate change and renewables. Athens, Greece, NTUA.
- Carbon Trust (2006). Future Marine Energy. London, Carbon Trust.
- Carbon Trust (2009). Focus for success: A new approach to commercialising low carbon technologies. London, Carbon Trust.
- Council on Science and Technology (2009). A national infrastructure for the 21st century. London, Council on Science and Technology.
- DECC (2009a). Government Response to the 2009 Consultation on the Renewables Obligation. London, The Stationery Office.
- DECC (2009b). The Heat and Energy Saving Strategy Consultation Document. London, The Stationery Office.
- DECC (2009c). Improving Grid Access: Consultation Document. London, The Stationery Office.
- DECC (2009d). Renewable Energy Strategy Consultation: Analysis of Consultation Responses. London, The Stationery Office.
- DECC (2009e). Smarter Grids: the opportunity. London, The Stationery Office.
- DECC (2009f). The UK Renewable Energy Strategy. London, DECC.
- DECC (2010). Impact Assessment of the Renewable Heat Incentive scheme for consultation in January 2010. URN 10D/547. London, The Stationery Office.
- Department of Communities and Local Government (2010). Community Infrastructure Levy. An overview. London, DCLG.
- Department of Trade and Industry (2006). Our Energy Challenge, Power from the people: A Microgeneration Strategy. London, DTI.
- Electricity Networks Strategy Group (2009). Our Electricity Transmission Network: A Vision for 2020. London, ENSG.
- Enviros (2008). Barriers to Renewable Heat Part 1: Supply Side. Report to Department of Business, Enterprise and Regulatory Reform. London, Enviros.
- ERTRAC EPoSS and Smartgrids Taskforce (2009). European Industry Roadmap: electrification of road transport. European Technology Platforms: ERTRAC, EPoSS and Smartgrids.
- European Commission (2009a). The renewable energy progress report. COM (2009) 192 final. Brussels, European Commission.
- European Commission (2009b). The Renewable Energy Progress Report: Accompanying document to the Communication from the Commission to the Council and the European Parliament. SEC (2009) 503 final. Brussels, European Commission.

European Parliament and the Council (2009). Directive on the promotion of the use of energy from renewable sources. Official Journal of the European Union L 140/16. Brussels, European Commission.

Federal Ministry of Economics and Technology (2008). E-Energy: ICT-based Energy System of the Future. Berlin, Germany, BMWi.

Foresight (2008). Powering Our Lives: Sustainable Energy Management and the Built Environment. London, Government Office for Science.

Foxon, T. (2003). Inducing innovation for a low-carbon future: drivers, barriers and policies. Report for the Carbon Trust. London, Carbon Trust.

Freeman, C. and C. Perez (1988). Structural crisis of adjustment, business cycles and investment behaviour. in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete, Eds. Technical Change and Economic Theory. London, Pinter: 38-66.

Friends of the Earth (2009) Cutting carbon locally - and how to pay for it. Research by Tony Travers and Arup. London, FOE.

Gallagher, E. (2008). The Gallagher Review: of the indirect effects of biofuel production. London, Renewable Fuels Agency.

Gallagher, K. S., J. P. Holdren, et al. (2006). Energy-Technology Innovation. *Annual Review of Environmental Resources* **31**: 193-237.

Helm, D. (2007). The New Energy Paradigm. Oxford, Oxford University Press.

Helm, D., J. Wardlaw, et al. (2009). Delivering a 21st Century Infrastructure for Britain. London, Policy Exchange.

HM Government (2009). The Low Carbon Industrial Strategy. URN 09/1058. London, Department of Business, Innovation and Skills and Department of Energy and Climate Change.

HM Government (2010). The Coalition: Our Programme for Government. London, Cabinet Office.

HM Treasury (2009). Securing the recovery: growth and opportunity. Pre-Budget Report. London, HM Treasury.

IEEP (Institute for European Environmental Policy) (2009) Positive planning for onshore wind. <http://www.ieep.eu/whatsnew/newsitem.php?item=189>

Infrastructure UK and HM Treasury (2010). Strategy for national infrastructure. London, The Stationary Office.

Institution of Mechanical Engineers (2009). Climate Change: Have we lost the battle? London, IMechE.

International Energy Agency (2009). The Impact of the Financial and Economic Crisis on Global Energy Investment. Paris, IEA.

Jacobsson, S. and A. Bergek (2004). Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change* **13**(5): 815-849.

Local Government Association (2007). A Climate of Change. Final report of the LGA climate change commission. London, LGA.

MacKerron, G., M. Lehtonen, et al. (2008). Government consultation - UK Renewable Energy Strategy: Response from Sussex Energy Group. Brighton, SPRU, University of Sussex.

McKay, D. (2009). Sustainable Energy – without the hot air, Available from <http://www.inference.phy.cam.ac.uk/sustainable/book/tex/cft.pdf>.

Mitchell, C., D. Bauknecht, et al. (2006). Effectiveness through risk reduction: a comparison of the renewable obligation in England and Wales and the feed-in system in Germany. *Energy Policy* **34**: 297-305.

Mitchell, C. and P. Connor (2004). Renewable Energy Policy in the UK 1990-2003. *Energy Policy* **32**: 1935-1947.

- NERA (2008). Quantitative Evaluation of Financial Instruments for Renewable Heat. Report for Department for Business, Enterprise and Regulatory Reform. London, NERA.
- Ofgem (2009). Electricity Distribution Price Control Review: Initial Proposals. London, Ofgem.
- Ofgem and Department of Energy and Climate Change (2009). Overview of Great Britain's Offshore Electricity Transmission Regulatory Regime. Joint DECC/Ofgem statement. London, DECC and Ofgem.
- Pöyry (2008a). Compliance costs for meeting the 20% renewable energy target in 2020. A report for the Department for Business, Enterprise and Regulatory Reform. Oxford, Poyry Energy Consulting.
- Pöyry (2008b). Implications of the UK meeting its 2020 renewables target. Report to WWF-UK and Greenpeace-UK. Oxford, Poyry Energy Consulting.
- Pöyry (2009). Design of Feed-in Tariffs for Sub-5MW Electricity in Great Britain. Oxford, Poyry Energy Consulting.
- Redpoint Energy and Trilemma (2009). Implementation of EU 2020 Renewable Target in the UK Electricity Sector: RO reform. London, Redpoint Energy.
- REN21 (2009). Renewables Global Status Report: 2009 Update. Paris, Renewable Energy Policy Network for the 21st Century.
- Renewables Advisory Board (2008). 2020 VISION – How the UK can meet its target of 15% renewable energy. London, Renewables Advisory Board.
- Scrase, I., A. Stirling, et al. (2009). Transformative Innovation. Report for Defra. Brighton, University of Sussex.
- Seager, A. and M. Milner (2007). Revealed: Cover up plan on energy target. *The Guardian*. 13th August.
- Sinclair Knight Merz (2008a). Growth Scenarios for UK Renewables Generation and Implications for Future Developments and Operation of Electricity Networks. Newcastle upon Tyne, SKM.
- Sinclair Knight Merz (2008b). Quantification of Constraints on the Growth of UK Renewable Generating Capacity. Newcastle upon Tyne, SKM.
- Smith, A. (2007). Emerging in-between: the multi-level governance of renewable energy in the English regions. *Energy Policy* **35**: 6266-6280.
- Stenzl, T. and A. Frenzel (2008). Regulating technological change – The strategic reactions of utility companies towards subsidy policies in the German, Spanish and UK electricity markets. *Energy Policy* **36**(7): 2645-2657.
- Travers, T. and Arup (2009). Cutting carbon locally – and how to pay for it. Report Commissioned by Friends of the Earth. London, FoE.
- Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy* **28**: 817-830.
- Vaze, P. and E. Mayo (2009). A New Energy Infrastructure. Consumer Focus Discussion Paper. London, Consumer Focus.
- Walker, G., S. Hunter, et al. (2007). Harnessing Community Energies: explaining and evaluating community-based localism in renewable energy policy in the UK. *Global Environmental Politics* **7**(2): 64-82.
- Watson, J. (2008). Setting Priorities in Energy Innovation Policy: Lessons for the UK. ETIP Discussion Paper. Cambridge, MA, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University.
- Watson, J., R. Sauter, et al. (2006). Unlocking the Power House: Policy and system change for domestic microgeneration in the UK. Brighton, University of Sussex.