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A Practitioner's Guide to a Low-Carbon Economy: Lessons from the UK

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Abstract

This paper identifies practical lessons for policy makers that seek to decarbonise their economies, drawing primarily on the UK experience. There are five main conclusions. First, decarbonisation needs a solid legal basis to give it credibility and overcome time inconsistency problems. Second, putting a price on carbon is essential, but low-carbon policies also have to address wider market, investment and behavioural failures. This in turn raises issues of policy complexity and coordination. Third, the low-carbon economy is likely to be highly electrified. Clean electricity could be a cost-effective way of decarbonising many parts of the economy, including transport, heating and parts of industry. Decarbonisation therefore starts in the power sector. Fourth, the low-carbon transition is primarily a revolution of production, not consumption. Both supply-side innovation and demand-side adjustments in lifestyle and behaviour are needed, but the former dominate. Fifth, the transition to a low-carbon economy is economically and technologically feasible. Achieving it is a question of policy competence and the political will to drive economic and social change.

Keywords: climate change policy, decarbonisation, green growth, mitigation, UK

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1 Introduction

More and more countries are taking action against climate change. Practically all major greenhouse gas emitters, including many emerging markets, now have climate change legislation on their statute books (Townshend et al. 2011). Under the Durban Platform for Enhanced Action, agreed in December 2012, these domestic initiatives will be the basis for a new global agreement that is to be reached by 2015 and will include a second commitment period under the Kyoto Protocol. Given what is at stake, and the complexity of the task at hand, it is important that policy makers learn from each other and establish a code of good low-carbon practice. This paper attempts to distil the main lessons from the UK.

The climate change debate in the UK is fairly advanced, with a strong legal basis for climate action, ambitious targets and sophisticated institutional arrangements (Fankhauser et al. 2009). Britain also has a constantly evolving regulatory landscape, with occasional policy failures and political u-turns. As such it is a good case from which to learn lessons.[1]

There is a rich analytical literature on many aspects of climate change policy. Much has been written for example about the relative merit of different policy options (Hepburn 2006; Pizer 2002), the design of emissions trading schemes (Fankhauser and Hepburn, 2010a, b; Grüll and Taschini 2011; 1998; Murray et al. 2009), policy performance (Ellerman and Buchner 2008; Ellerman et al. 2010, Martin et al 2009) and low-carbon innovation (Acemoglu et al. 2009; Aghion et al. 2011a, b; Dechezleprêtre et al. 2011; Popp 2002).

This paper differs from the existing literature in taking an explicitly practical approach. While drawing on the analytical literature, it looks at the concrete case of a country, like the UK, that wants to reduce its greenhouse gas (GHG) emissions. The policy ambition is much deeper than the marginal change in emissions, which concerns much of the literature. It is a comprehensive redesign of the modern economy. At the same time, the scope is narrower than that of the green growth literature, which includes wider notions of sustainable development besides low-carbon growth (Bowen and Fankhauser 2011). The focus here is on the latter.

The paper goes through four basic challenges that all decarbonisation efforts will face. The first challenge (discussed in section 2) is to put in place a strong legal and institutional basis for low-carbon policy. The second challenge (section 3) is to translate low-carbon objectives into a credible roadmap of sector, technology and reform targets that can guide policy and

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[1] For recent reviews of UK climate policy, see Bowen and Rydge (2011) and Mirrlees et al. (2011).

ascertains that the objectives are achievable. The third challenge (section 4) is to put in place the necessary policies to implement the roadmap, and the fourth challenge (section 5) is to manage the wider socio-economic consequences of decarbonisation.

2 Providing the legal and institutional basis

The starting point for economy-wide decarbonisation is a strong legislative basis. The fundamental reforms to energy, transport, industrial, agricultural and fiscal policy that will follow need statutory legitimacy. The adoption of a climate change law is also a way of forging the broad political consensus that will be needed during implementation. It is striking how many of the climate change laws in major economies have been bipartisan efforts (Townshend et al 2011). The UK Climate Change Act of 2008, for example, was passed near-unanimously.

Most climate change laws are unifying laws that bring together existing strands of regulation (e.g. on energy efficiency), express a long-term objective and create a platform for subsequent action. The UK Climate Change Act calls for a cut in GHG emissions of at least 80%, relative to 1990, by 2050. It also defines the mechanism through which the long-term target is to be met: A series of statutory, five-year carbon budgets that set a binding ceiling for GHG emissions over that period. The UK has been subject to this economy-wide carbon constraint since 2008.

A key purpose of the legislation is to make a statement of intent that can subsequently guide policy delivery and reduces uncertainty for decision makers. Building a low-carbon economy will take decades, much longer than policy makers can credibly commit. This creates problems for businesses, which will mistrust the long-term validity of the plan and hedge their behaviour. An important role of climate change legislation is to overcome such time inconsistency problems and instil long-term credibility into the policy effort.

The issue is akin to the credibility of inflation targets (Kydland and Prescott 1977; Barro and Gordon 1983; Rogoff 1985) and the institutional remedies that have been proposed bear some resemblance. An independent institution, the Committee on Climate Change (CCC), was created to recommend and monitor the carbon budgets, in the belief that technocrats are more likely to take a long-term view than politicians. However, the carbon budgets are ultimately passed by Parliament to give them statutory credibility. A judicial review is likely if the government systematically ignored the Committee's advice or if key policy decisions were inconsistent with carbon objectives.

3 Defining a strategy for delivery

For the high-level objectives of the climate law to be credible they need to be backed up by a sound implementation strategy. The UK, the European Union and many other jurisdictions have developed concrete decarbonisation roadmaps for this purpose (CCC 2010; DECC 2011; European Commission 2011). These are not blueprints that need to be implemented to the letter. Markets and private initiative will determine most of the details. However, they are important strategies that determine the speed and direction of travel.

These roadmaps are underpinned by a fair amount of technical analysis, which ensures that the strategy is technologically and economically rational and consistent with the ultimate emissions objective. Numerical simulation models are well-suited to calculate the least-cost way of meeting a certain emissions target under given technology constraints. In the UK both the Committee on Climate Change and the Department of Energy and Climate Change (DECC) have employed such models to inform their low-carbon roadmaps. The model evidence used by the Committee on Climate Change in particular is quite detailed. Even so, model results are heavily complemented and qualified by professional judgement.

Least-cost optimisation models like MARKAL are used to determine the right choice of technologies as a function of their cost profiles (CCC 2010), which are themselves derived from detailed engineering studies (e.g., Mott McDonald 2011). Least-cost models also inform the allocation of scarce resources among competing uses; for example, whether to use the limited supply of sustainable biomass for electricity generation, heating or transport (CCC 2011a). Detailed models of the electricity market can simulate how the power sector may cope with a rising share of intermittent renewables and inflexible nuclear capacity (Pöyry 2011). Least-cost models provide estimates of the likely economic costs, although these bottom-up estimates should be complemented with general equilibrium or macroeconomic model runs (Barker et al. 2007).

A key question which the roadmap has to answer is about the speed of decarbonisation. What is the economically most rational pace of bringing emissions down? The anticipated fall in the cost of low-carbon technologies and the effect of discounting would suggest a slow start followed by steep emission reductions later.[2] The counter-argument is that progress in reducing technology costs is a function of cumulative investment, not just the passage of time. Postponing low-carbon investment may therefore delay the point at which these

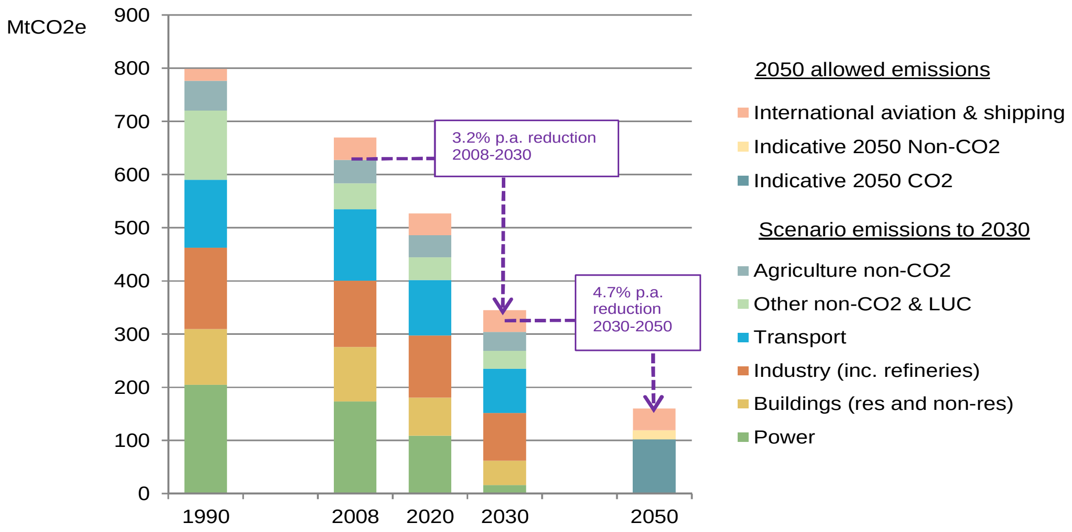
[2] Wigley et al (1996) were the first to propose this hump-shaped emissions path.

technologies become cost-effective. Scientists will also point to the climate benefits of acting early. Future climate change is determined by the sum total of emissions over time, and not their level in an arbitrary future year (Meinshausen et al. 2009), so each year of delay imposes a climate cost.

Moreover, there are limits to the speed at which emissions may be reduced cost-effectively later. As an illustration, if carbon-intensive capital has a lifetime of 25 years, the maximum annual emission cut that can be achieved through the regular investment cycle is 4%. To achieve this all new investment (in both replacement and expansionary capital) would have to be carbon-free. Going beyond 4% would require the premature scrapping of existing capital. This is expensive unless productivity improvements (e.g., through energy efficiency) are so high that an overall reduction in the capital stock is warranted. We will see below that this is not the case.

The UK debate about speed was heavily influenced by the particular time profile of investment needed in Britain's power sector. A large part of Britain's power plants are due for renewal in the 2020s. This creates both an opportunity and a necessity to decarbonise power generation early, as the investments made in the 2020s will determine electricity emissions for many decades to come.

Figure 1: Indicative UK Decarbonisation Roadmap



Source: CCC (2010).

For these reasons, the Committee on Climate Change has recommended a swift pace of emission reductions in the power sector and an overall abatement path that is only slightly back-loaded (Figure 1). This decarbonisation path has profound implications not just for electricity generation, but all emitting sectors, as we discuss next.

Energy

The decarbonisation of the electricity sector is at the core of the low-carbon transition not just in Britain and in all industrialised countries. This is for several reasons. First, power generation is a major source of GHG emissions (see Figure 1). Second, low-carbon power generation is well-understood and feasible. A number of low-carbon options are available, although not always cheap. They include renewable energy (wind, solar, biomass, hydro, in time perhaps marine), nuclear energy and (as yet unproven) carbon capture and storage (CCS). Third, decarbonised electricity has an important role to play in reducing emissions in other sectors, chief among them transport (through battery electric vehicles), residential heating (through ground source and air source heat pumps) and perhaps some parts of industry.

Any combination of renewables, nuclear and CCS will succeed in bringing down the carbon intensity of power production. The choice is determined by cost, environmental considerations and issues of system operation. Different countries make it differently. Germany, for example, is resisting nuclear energy, but has invested heavily in solar energy. The UK is emphasising wind power over solar PV and has so far accepted nuclear power. It is putting particular emphasis on off-shore wind, which is more expensive than on-shore wind, but raises fewer local environmental concerns. The carbon-intensity of electricity is required to fall by as much as 90% within 20 years, from over 500 gCO_2/kWh to 50 gCO_2/kWh, according to the timetable of the Committee on Climate Change (CCC 2010).

This tight target reduces the scope of intermediate technologies like gas, which might otherwise be attractive. Modern combined cycle gas turbines emit around 350 gCO_2/kWh – a considerable improvement on the current system average, but too much in a truly low-carbon power sector. Unless fitted with CCS, future gas-fired power plants will therefore only be used sparingly, primarily as back-up capacity. This is a limited but important role. The combination of intermittent wind and baseload nuclear power creates challenges for load management, since neither is particularly flexible to respond to short-term fluctuations in demand. Gas can provide that flexibility and balance supply and demand. However, electricity market arrangements in the UK do not currently reward a mode of operation where a plant is predominantly idle. They would have to change.

Current electricity market arrangements create another obstacle to low-carbon investment.

Power prices are currently determined competitively to reflect short-term operating costs. Low-carbon technologies, like nuclear and wind, typically have high capital cost and low operating cost. If they came to dominate the sector and set short-term marginal costs, the market prices may fall to a level that is too low to recoup the upfront costs. Further investment would stall.

Reform of the electricity market has therefore become an essential prerequisite for decarbonisation. After decades of liberalisation the reforms will bring about an increased role for the state. State intervention will be aimed at three market failures in particular, which would otherwise prevent low-carbon investment.

The first intervention is to put a price on carbon to internalise the climate change externality. Ideally this would happen through a carbon tax or a stringent emissions trading scheme. The reality in the UK is somewhat more complicated. The EU Emissions Trading Scheme (EU ETS) provides only a relatively weak price signal, so the UK has legislated a unilateral carbon price floor to strengthen that signal. While this will motivate UK emitters to abate further, it will not reduce EU-wide emissions, which continue to be set by the unchanged ETS cap (Fankhauser et al. 2010). The price instruments are complemented by a regulatory measure, an emissions performance standard set at (a high) 450 gCO2/kWh.

The second focus is on the promotion of low-carbon (in particular renewable) energy and addresses market failures related to technology development. The classic instruments are renewable energy obligations or feed-in tariffs (see section 4). The UK is moving from the former system to a variation of the latter, with the introduction of contracts for differences for low-carbon energy. Smaller-scale installations benefit from a straight feed-in tariff. These demand-pull measures are complemented by a moderate supply-push from a new green investment bank, which will offer renewable energy investors improved access to finance. An investment subsidy is available for CCS pilots, although that process has been very slow.

The third focus is on the need to ensure investment into backup capacity, as discussed above. In the UK this will be achieved through the introduction of capacity payments. We will discuss the economic merit and practical challenges of this policy mix further in section 4.

Transport

Surface transport is the second most important source of GHG emissions in the UK after electricity (Figure 1 above). Transport emissions are dominated by cars, although lorries, vans and buses also matter. Railways account for no more than 2% of the transport total.

The strategy to reduce car emissions is two-pronged. In the short-term the emphasis is on reducing the carbon intensity of conventional cars, partly through technological improvements and partly by incentivising drivers to switch to more efficient cars. The UK has adopted a European Union target to reduce the carbon intensity of new cars from currently around 145 g/km to 95 g/km in 2020. A similar target exists for vans.

In the medium term further efficiency improvements will have to come from new technologies, such as battery electric cars, plug in electric vehicles and perhaps fuel-cell-based vehicles. Biofuels will also play a role, with the limited amount of sustainable biofuel probably best targeted at heavy-goods vehicles and aviation, where there are fewer alternatives. The Committee on Climate Change calculates that 60% of new cars sold in 2030 will need to be electric (CCC 2010), rising to 100% by 2035 for a fully electric car fleet in the late 2040s. These are very ambitious targets, which, if met, will have repercussions on electricity demand and the country's refuelling infrastructure.

In comparison to technology, the role of demand-side measures is relatively modest and insufficient to reverse the growth in driving-kilometres. It is nevertheless important. Changes in travel behaviour such as eco-driving, better journey planning, car sharing and modal shift can have a noticeable effect, as a UK pilot on "smarter choices" showed (CCC 2010).

As in the power sector a diverse set of policies are in place to encourage the transition. Arguably the most powerful one of them is primarily a fiscal measure: Fuel duty accounts for almost 5% of total government income and is the most important source of indirect tax revenue after VAT (Adam and Browne 2011). Fuel duty helps to corrects a multitude of transport-related externalities, but if the entire levy were treated as a carbon tax the implicit tax rate would be over GBP 200 per tCO2 (Bowen and Rydge 2011).

In addition, other vehicle-related taxes, such as the excise duty or company car tax, are differentiated by carbon efficiency. Electric cars are subsidised by up to GBP 5,000 per vehicle, while matched funding for recharging stations is provided under the Plug-In Places programme. The policies have been relatively effective. Since 2008 the carbon intensity of new cars in the UK has fallen by about 9%, although the uptake of electric cars is still very low.

Residential buildings and industry

The buildings and industrial sectors combined account for over two-thirds of UK GHG emissions. A large part of this is indirect emissions from electricity use, which are assigned to the power sector in the carbon accounts, but both direct and indirect emissions are important from a demand-management perspective.

The initial focus in reducing residential and industry emissions is on energy efficiency. There is much debate about the potential of energy efficiency measures that is available at low or zero economic cost. In the UK, the Committee on Climate Change expects a 23% reduction in non-electric energy use in buildings and industry by 2020, relative to 2007, and a 13% reduction in electricity use (CCC 2011b).

Over the medium term the focus may shift from energy efficiency to renewable heat. The Committee on Climate Change expects the share of renewable heat to rise from currently 1% of heat demand to 12% in 2020, much of it back-loaded, as renewable heat is still relatively expensive. From the late 2020s onwards further decarbonisation will require currently expensive options such as solid wall insulation and heat pumps. Additional measures in industry include industrial CCS, process innovation and product substitution. None of these options are as yet proven.

Energy efficiency gains are notoriously elusive. There is a multitude of policy, market and behavioural barriers, some well-understood, others less so. This intricacy of issues is mirrored in the policy framework. No other aspect of Britain's low-carbon agenda has seen more policy experimentation and nowhere else is the policy landscape more complex. Regulatory measures dominate, but there are price incentives in the form of a Climate Change Levy (a carbon-cum-energy tax) and the indirect effect of the EU Emissions Trading Scheme, whose cost are passed through to end-users. Businesses can avoid the Climate Change Levy by entering into a voluntary Climate Change Agreement, and most of them do.

Renewable heat is subsidised through a renewable heat incentive. The service sector has its own mechanism, the CRC Energy Efficiency scheme, which relies on a combination of reputation effects (through a performance league table) and price incentives (through a carbon tax, later to be converted into a trading scheme). Residential energy efficiency has been promoted primarily through a succession of supplier obligations (which commit energy utilities to certain efficiency targets in their client base) and the much-vaunted Green Deal, which promises easier access to energy efficiency finance. Despite this flurry of activity progress in increasing residential and industrial energy efficiency has been mixed (CCC 2011b).

Agriculture

Agriculture accounts for perhaps 10% of UK greenhouse gas emissions, most of them in the form of methane and nitrous oxide. There are accounting issues, though. Agricultural and land-use emissions are known with much less certainty than energy-related emissions. Similarly, low-GHG options for agriculture are less well understood than decarbonisation in other sectors.

The evidence that is available suggests there is scope to reduce emissions further, for example through increased feed efficiency and dietary changes in livestock, the deployment of anaerobic digestion systems and better nutrient management for crops. However, beyond these low-cost measures deep decarbonisation may be difficult. On the supply-side further action could raise ethical and environmental issues (e.g. related to animal welfare and the role of genetically-modified food). On the demand-side it could require behavioural change with respect to diets, which is likely to be controversial (although it would have substantial health benefits, Ganten et al. 2010). This makes it likely that agricultural emissions (together with sectors like aviation) will account for an increasing fraction of the increasingly tighter carbon budgets over the longer term.

Although agriculture is one of the most highly regulated sectors in the UK economy, the policy approach to agricultural decarbonisation has chiefly relied on voluntary action. Opportunities to reduce emissions through adjustments in existing policies, such as the EU Nitrates Directive or the Common Agricultural Policy, have not been taken up. Consequently, emissions have primarily come down as a result of unrelated policies and developments. Fertilizer-related emissions, for example, have fallen significantly as a consequence of higher prices and regulation. (A similar story holds for waste management, where methane emissions have fallen sharply as a by-product of an aggressive landfill tax).

4 Designing policies

Policy measures to create a low-carbon economy are needed on three fronts (Stern 2006). First, policies are needed to put a price on carbon, that is, to internalise the climate change externality. Second, there is a need to promote low-carbon technology, that is, to address externalities and market failures related to innovation. A third set of policies concerns barriers to carbon-efficient behaviour and investment, in particular to unlock the existing energy efficiency potential.

The three sets of policies are equally important, although the emphasis is often on the carbon price. As the previous section showed,[3] the UK has an elaborate low-carbon policy landscape, with measures to put a price on carbon (EU Emissions Trading Scheme, climate change levy, carbon price support), support new technologies (renewable energy obligation, renewable heat incentive, feed-in tariff), provide investor confidence (electricity market reform), change energy efficiency behaviour (CRC Energy Efficiency Scheme, supplier obligations) and facilitate access to finance (Green Deal, Green Investment Bank). Despite this complexity, which itself poses challenges, independent observers doubt that the UK policy environment is sufficient to meet the targets the country has set itself (CCC 2010).

Putting a price on carbon

There are two generic ways of putting a price on carbon, taxation or an emissions trading scheme.[4] There is a long literature on the relative merits of the two options, going back to Weitzman (1974); see Hoel and Karp (2001) and Newell and Pizer (2003). On balance it probably favours a carbon tax, although in a situation with mandatory carbon constraints, as in the UK, the traditional Weitzman argument would advocate quantity-based policies.[5]

In practice, policy makers have been swayed less by theoretical niceties than political realities, and in most cases an emissions trading scheme is easier to implement than a carbon tax. It creates a valuable asset, emissions permits, which can be used to pacify industry. In the case of the EU ETS the stock of permits is worth around €30 billion a year, and handing these assets out for free has indeed been sufficient to secure industry buy-in. However, there has also been a backlash against the windfall profits enjoyed by "carbon fat cats" (Sandbag 2011),

[3] See also Bowen and Rydge (2011).
[4] Implicitly, regulation also puts a price on carbon, which is reflected in the cost of compliance.
[5] According to Weitzman (1974) quantity-based policies are preferred if the marginal benefit schedule is steep relative to marginal costs of abatement. A national emissions target that would be (politically) costly to miss turns the marginal benefit curve for policy makers vertical.

and the European Commission has found it hard to reverse the practice of free allocation. This suggests that the use of free permits should be curtailed as much as possible from the outset, although some will be necessary to create consensus. The EU ETS has yielded a wealth of other practical lessons, including on the need to manage price fluctuations (e.g. through an auction reserve price) and the importance of competent regulation. They are reviewed in Ellerman et al. (2010) and Fankhauser and Hepburn (2010a, b).

Even in the presence of an emissions trading scheme, most countries have complementary taxes that cover emissions outside the scheme, strengthen the price signal within it, address other externalities or simply raise revenue. Levying taxes on top of a trading scheme will have a detrimental effect on the carbon price and reduce the gains from trade (Fankhauser et al. 2010), but there is merit in using the two instruments in parallel in different parts of the economy.

The most effective way of sending a carbon price signal through taxation is a pure carbon (or carbon-equivalent) tax, probably levied upstream as this is administratively easier. In practice, policy makers often opt for a combination of carbon and energy taxes, hoping to meet different objectives with one instrument or responding to industry pressure. The result can be widely different carbon prices across sectors and therefore a potentially inefficient allocation of the abatement burden. According to Mirrlees et al. (2011) the implicit carbon tax on UK transport and energy emissions ranges from zero to almost GBP 250 per tCO_2.[6] The potential for green taxes and green tax reform is discussed by the Green Fiscal Commission (2009).

Promoting low-carbon innovation

The central role of new technologies in decarbonisation make innovation policy a critical part of the low-carbon strategy. There are well-known externalities in research and innovation, most of them generic and not related to climate change. Countries have research and development (R&D) policies to address them, such as research grants, innovation prizes, patents and tax credits. These are available to low-carbon innovators.

The question then is whether there are additional market failures in low-carbon innovation that require further intervention, or whether the combination of a carbon price (to correct the climate externality) and R&D support (to address innovation externalities) would be

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[6] Such calculations are difficult to make. For example, it is not clear to what extent (implicit or explicit) taxes on other externalities were taken into account. See e.g. Newbery (2005).

sufficient. Aghion et al (2011a) suggest there is a need for further intervention. They find evidence of path dependence in, for example, the automotive industry (Aghion et al. 2011b), which makes traditional high-carbon research more likely than low-carbon innovation. High-tech firms may also find it harder to access finance because they create few tangible assets at the outset. The focus on new processes (e.g., different ways of generating power) rather than new products makes it difficult to segment the market and attract early adopters. There is a well-documented “valley of death” between demonstration and pre-commercial deployment, when new technologies receive little help (Grubb 2004). Most support is for basic research and commercial deployment, with a particular focus on renewable energy technologies.

Lipp (2007) identified 40 jurisdictions (countries or sub-national entities) with a feed-in tariff for renewables and a further 38 with tradable renewables certificate systems (sometimes called renewable obligations). Both systems have advantages and disadvantages. Countries with feed-in tariffs, such as Germany, have generally been more successful in building up a renewable energy sector than those with renewable obligations, such as the UK (Butler and Neuhoff 2007; Mentanteau et al. 2003). However, this may have been achieved at higher costs to consumers. Feed-in tariffs put less emphasis on competition to keep down rents than certificate systems. Moreover, other factors like differences in planning regime, which is notoriously difficult in the UK, may play an equally important role in explaining past performance.

Overcoming behavioural and managerial barriers

Much has been written about the difference between actual and theoretical levels of energy efficiency. The reasons for the gap are well-rehearsed and include knowledge gaps, asymmetric information (e.g. between landlords and tenants, shareholders and managers), hidden transaction costs, management issues, bounded rationality and many others (Martin et al. 2011; de Canio 1998; de Canio et al 1998; Sanstad and Howarth 1994).

The policy measures to close the energy efficiency gap are equally diverse, and often predate concern about a low-carbon economy. They include price incentives, regulation (e.g. efficiency standards for buildings and appliances), access to information (e.g. energy performance certificates for buildings), access to services and know-how (e.g. subsidised energy audits) and supplier obligations on energy companies.

Regulation is often the most effective way forward. But there are good examples of market-based instruments, such as trade in energy savings (or “white”) certificates (Vine and Hamrin 2008) and in the UK the CRC Energy Efficiency Scheme. The latter is a complex piece of regulation aimed at bringing energy efficiency to the attention of senior management. An intriguing feature is the use of reputational incentives: Participating firms are ranked in a publicly-available league table. The idea is not new – the World Bank (1999) highlighted the role of public opinion as an "informal regulator" over a decade ago – but it remains powerful today. Particularly consumer-facing businesses are as concerned about their reputation as they are about costs.

The need for lifestyle and behaviour changes is not confined to energy use. Policy intervention may also be required to encourage the uptake of new technologies like electric cars or renewable heat. Typically this has taken the form of financial incentives (e.g., the UK's renewable heat incentive or lower road taxes and subsidies for electric cars). Less well proven is the effect of public information and advertising campaigns, although for more difficult adjustments (for example in eating and driving habits) they may be an important complement to price signals and increase their political acceptability.

Policy coordination

The full package of policies to price carbon, promote innovation and overcome efficiency barriers needs to be assessed as a whole. Policies do not act in isolation. They interact, sometimes reinforcing and sometimes offsetting each other.

In principle, a combination of policies is the best way of tackling multiple market failures (Bennear and Stavins 2007). However, there are exceptions. In the case of renewables the measures to promote low-carbon investment (a renewable energy obligation or a feed-in tariff) tend to reduce the price in, and thus the effectiveness of, emissions trading schemes (e.g., Morris et al. 2010; Unger and Ahlgren 2005). Forcing renewable energy into the abatement mix alters the marginal emission reduction activity and this affects the carbon price. Fankhauser et al (2010) find a similar effect for the interaction of carbon taxes and trading schemes. As Bowen and Rydge (2011) observe, the weakened carbon price signal could have a detrimental effect on energy efficiency, R&D and low-carbon investment decisions.

New low-carbon measures also interact with existing policies. Two of the most powerful GHG taxes in Britain, for example, were introduced without climate change in mind. The fuel duty on petrol is primarily a revenue raising measure, although it also corrects for local externalities (Newbery 2005). The landfill tax is in place primarily to modernise waste management. The powerful impact it has had on UK methane emissions was coincidental. The interaction effect is not always positive. The distributional decision to charge a lower rate of VAT on energy means energy consumption in the UK is essentially subsidised, compared with other goods (Bowen and Rydge 2011; Mirrlees et al. 2011).

5 Addressing wider socio-economic effects

Like all change, the transition to a low-carbon economy will create both winners and losers. Policy makers are understandably nervous about any negative socio-economic effects, but they also try to maximise positive spill-overs.

Competitiveness and jobs

One of the main concerns of policy makers is the effect of decarbonisation measures on economic competitiveness, particularly if they are more progressive than those of the main trading partners. Loss of competitiveness has an environmental corollary in carbon leakage: If economic activity relocates, emissions will move abroad too (see e.g., Babiker 2005).[7]

Two factors have to come together for competitiveness to be an issue. First, the decarbonisation costs in an industry have to be high, relative to its output, and, second, affected sectors have to be subject to international competition. If only one factor is present competitiveness is not an issue. The financial sector, for example, is fiercely competitive but carbon compliance is not a big cost factor. In power generation, decarbonisation costs are high, but there is not much international trade. In neither sector are competitiveness effects an issue.

The number of sectors where the two factors come together is small and at least in the UK they do not account for a large share of employment and GDP (although they can be important locally). This means solutions can be targeted and tailor-made. Among the most vulnerable sectors are steel, basic metals, refined products and other chemicals. Aluminium production is affected indirectly as it is a large consumer of electricity (Carbon Trust 2008).

The currently preferred solution to help these sectors is to offer them free emission allowances if they are subject to a carbon trading scheme. The economic logic of such a lump-sum transfer is unclear, as it only affects long-term location decisions, and not how intensively a plant is run in the short-term. In a similar vein, the UK offers firms a discount from the climate change levy if they agree voluntary standards. These climate change agreements have been found to be relatively weak (Martin et al. 2009). If they were not competitiveness would still be an issue.

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[7] The correlation between loss of competitiveness and leakage is not perfect though. There are other channels of leakage (for example, through price effects), and differences in the carbon efficiency of countries can reduce or (more often) enhance leakage rates.

Unfortunately, superior alternatives to free permits are often difficult to implement. The best solution would be a set of international standards for the sectors concerned, but this may be as hard to agree as an overarching climate treaty. Border adjustments such as a carbon tax on imports can be justified economically. They are Pigouvian taxes levied at consumer or intermediary level (Ismer and Neuhoff 2007). However, in practice they would be open to a costly legal challenge under WTO rules.

Another corollary to the competitiveness debate is the discussion on low-carbon jobs. Policy makers make much of the potential for green jobs. Low-carbon electricity generation, for example, tends to use more labour than traditional electric power. However, this is the wrong perspective (Fankhauser et al. 2008). The high labour input into renewable energy is a reflection of their still high cost and translates into a low level of labour productivity (and hence wages). This will change as renewables become more cost-competitive. In the meantime the right question for policy makers to ask is not the number of jobs created, but their attractiveness and the ease with which skills can be transferred into these sectors. Rigidities are likely and may require policy intervention.

Fiscal balance

In economically difficult times policy makers wonder about the fiscal effects of climate policy. It is right to embed low-carbon policy into the broader macroeconomic debate, although the transition to a low-carbon economy is about long-term structural change and cuts across the business cycle.

Low-carbon policies can be adjusted to fiscal realities without compromising the carbon targets. During the economic crisis of 2009 the case was made for low-carbon investment to provide a Keynesian “green fiscal stimulus” to the economy (Bowen and Stern 2010; more recently Zenghelis 2011). The UK was one of many countries that responded, devoting 15% of its then-stimulus package to green causes (HSBC 2009).

Subsequently, when concern over Britain’s budget deficit initiated a phase of fiscal austerity, previously revenue-neutral carbon policies became revenue-raising. The move towards permit auctioning in the EU ETS was serendipitous, but the government’s decision not to recycle the revenue from the CRC Energy Efficiency Scheme was deliberate. EU ETS auctioning could net the UK exchequer over £2 billion a year between 2013 and 2020 (Cooper and Grubb 2011), while the CRC is expected to raise £1 billion a year. Internationally, Nordhaus (2010) has long called for a carbon tax as a means to address fiscal imbalances in the US.

Fuel poverty

In the UK most of the cost of power sector decarbonisation, including the cost of renewable obligations, supplier obligations and the EU ETS, are passed on to consumers through higher electricity prices. This is economically correct as electricity prices should reflect the full cost of electricity, including any externalities.

However, higher energy bills raise concern about the distributional consequences of climate policy. The Committee on Climate Change (CCC 2011c) estimates that low-carbon policies and investments will add perhaps 10% to the typical UK fuel (gas and electricity) bill between 2010 and 2020. This is on top of an anticipated rise in international fuel prices, which could have a similar effect on bills.

The rise in energy costs has been seized upon by the (climate-sceptic) popular press, but in reality the instruments to deal with fuel poverty are both known and available. In particular, the successful uptake of basic energy efficiency options would offset not just the cost effect of green policies but also that of higher fuel prices (CCC 2011c). Other measures to address fuel poverty include direct income support (e.g. through the existing winter fuel allowance) and block tariffs, an option the UK has not adopted. Neither is perfectly targeted at the fuel poor. Winter fuel allowance in the UK is available to all pensioners, whether or not they are fuel poor, while a block tariff would not reach the many poor families in houses with above average energy needs (e.g. large families or the elderly).

The UK defines fuel poverty as spending in excess of 10% of income on energy. This is a relatively crude way of assessing the distributional incidence of low-carbon policies. A more complete assessment would not just capture energy use, but also the indirect effect of higher energy prices on the entire consumption basket (Gough et al. 2011). It would also factor in any adjustments in consumption patterns that households might make. Many people insulate their home to enjoy more comfort, for example, rather than to reduce bills. Bowen and Rydge (2011) report that this 'rebound effect' is particularly pronounced in low-income households.

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6 Conclusions

There is much interest in low-carbon and more generally green growth, with a substantial academic literature and an emerging cottage industry in low-carbon growth plans. But as yet there is little guidance on how a low-carbon growth strategy might look in concrete policy terms.

This paper asks how the transformation to a low-carbon economy might be achieved in practice. Drawing lessons primarily from the UK, the paper explores the legal prerequisites and policy challenges for low-carbon growth. High-level lessons of this kind are not a substitute for detailed policy analysis, but they can nevertheless provide useful insights for low-carbon policies in Europe and elsewhere.

A first lesson that emerges is that the low-carbon transition needs a solid legal basis. Given its long-term nature, decarbonisation policy is prone to time inconsistency problems. Governments will be tempted to postpone difficult measures to the future, particularly in economically hard times. The UK structure, with a clear long-term commitment (enshrined in law) and statutory short-term targets that are recommended and monitored by an independent body, holds some promise in this respect. It passed its first test in 2011, when a stringent carbon budget for 2023-27 was adopted despite opposition in business and finance circles.

Second, decarbonisation requires more than just putting a price on carbon. To achieve low-carbon growth policy makers have to address a complex web of market, investment and behavioural barriers. This can only be done through a mix of policies. Some of them are generic and probably already in place (e.g. on local pollution), but many will have to be adjusted or strengthened (e.g. on energy efficiency or low-carbon innovation). This raises issues of coordination between the different policy measures. The UK experience shows that the policy landscape can easily become very complex.

Third, the low-carbon economy is likely to be a highly electrified economy. Practically all decarbonisation strategies have a low-carbon power sector at the core of their plans. Electric power is central because it accounts for a large fraction of total GHG emissions and because clean electricity may be a cost-effective way of decarbonising other parts of the economy. It is risky to pick technology winners, and other solutions (e.g. based on bioenergy) are clearly possible, but the current indication is that the decarbonisation of road transport, residential heating and perhaps parts of industry will be based on low-carbon electricity.

Fourth, the low-carbon transition is primarily a revolution of production, not consumption. Decarbonisation requires a combination of technological (supply-side) innovation and behavioural (demand-side) adjustments. Both will have to be stimulated by policy. Their relative importance varies by sector, but the low-carbon strategies discussed in this paper suggest that technology will be the dominant factor. Behavioural change plays an important but complementary role, including in ensuring the uptake and acceptance of new technologies like electric cars.

The fifth and perhaps the most important lesson is that the transition to a low-carbon economy is feasible. It is a matter of policy competence and political will, rather than economic affordability or technological feasibility. This paper has outlined a credible roadmap for decarbonisation, based on known technological solutions, complemented with realistic behavioural adjustments in high-emitting sector such as in electric power, transport and residential buildings. There are some sectors where emissions will be hard to reduce and where more research is still needed. Aviation, agriculture and parts of industry fall into this category, and they will take up an increasing share of the remaining emissions headroom.

This is not to say that moving to a low-carbon economy will be easy. Neither policy competence nor political will can be taken for granted. Nor will decarbonisation be costless. The literature on mitigation costs and its findings (e.g Edenhofer et al. 2010) remain valid. It suggests that even well-implemented reforms have a cost. But it is small relative to the expected trend improvements in income and productivity.

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