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The Role of Energy Efficiency in Reducing Scottish and UK CO_2 Emissions

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ABSTRACT

In 2003 the UK government launched its long-anticipated White Paper on energy, the centrepieces of which were ambitious targets for the production of electricity from renewable technologies and the long-term aspiration of a 60% reduction in UK greenhouse gas emissions by 2050. In the White Paper it was recognised that such a dramatic reduction in emissions will require significant changes in the way in which energy is produced and used. However there has been a general failure to recognise the fact that in order to meet emissions targets, the UK will have to significantly reduce its energy consumption; this is not helped by the general misconception in the UK that reductions in CO_2 emissions will occur simply by increasing the production of electricity from renewable sources.

Specifically, this paper highlights the current trends in renewables deployment and energy demand, with a specific focus on Scotland, where the authorities have set more

ambitious renewables targets than the rest of the UK. As will be demonstrated in this paper without energy demand reduction, the deployment of renewables alone will not be sufficient to curtail growth in UK CO_2 emissions. This is illustrated using a case study of the Scottish housing sector; whilst this case study is necessarily local in scope, the results have global relevance. The paper will also address the magnitude of energy savings required to bring about a reduction in emissions and assesses the status of the policies and technologies that could help bring such reductions about.

Keywords: energy efficiency, CO_2, housing.

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Background

The UK government has been a strong supporter of the Kyoto protocol, which stipulates that the UK must reduce greenhouse gas emissions by 12.5% below 1990 levels in 2008-2012 (DEFRA, 2002). Further, with the publication of the Energy White Paper (DTI, 2003a) they set policy objectives beyond those set out in the Kyoto protocol by accepting the challenging targets set out by the Royal Commission on Environmental Pollution (RCEP, 2000) which stated that that the UK should reduce carbon dioxide (CO_2) emissions to 60% below 1997 levels by 2050. The White Paper set out potential mechanisms to achieve this challenging target and was essentially the UK's first real attempt at a coherent, strategic energy policy since the privatisation of the energy utilities in the 1980's. The implementation of the White Paper is being taken forward by a group of cross-departmental government units collectively titled the Sustainable Energy Policy Network (SEPN).

In the White Paper it was recognised that a significant reduction in greenhouse gas emissions is dependent upon a number of factors, including:

- increasing energy supply from renewable resources;
- widespread uptake of CHP and micro-CHP;
- the emergence of new technologies such as fuel cells;
- improving conventional generation e.g. retrofitting clean coal technologies; and
- increasing energy efficiency.

While the aims of the White Paper are laudable, its publication was set against a background increasing energy demand (DTI, 2003b) along with a rapidly changing energy supply picture. As will be illustrated later, this growth in demand could completely derail the UK's aspirations for long-term emissions reductions.

With regards to energy supplies, the most radical change has been in the production of electricity, where the composition of the generation plant has changed markedly over the last 15 years: since 1990 the proportion of electricity generated from gas has increased from around 1% to over 32% in 2003 (DTI, 2003c). The shift from coal to gas as the primary fuel source for electricity generation is commonly referred to as the "dash for gas". This has had two beneficial effects with respect to emissions. Firstly, the overall efficiency of a combined cycle gas turbine station can exceed 50%, while a coal station typically has an efficiency of less than 40%. Further, gas is a much less carbon intensive and cleaner fuel than coal; hence CO_2 and other emissions such as particulates and SO_X per unit of electricity produced have been reduced.

Renewable electricity supplies have also been increasing from a low base; driven primarily by the Renewables Obligation (RO), which requires all licensed electricity suppliers in England and Wales to supply an increasing proportion of their electricity from renewables and will remain in place until 2027. Currently the targets set under the

RO and the corresponding Scottish legislative mechanism RO (Scotland), require electricity suppliers to increase the share of renewable electricity to at least 15% by 2015 in England and Wales and 18% in Scotland by 2010 (Scottish Executive, 2000). It should be noted that Scotland already generates around 11% of its electricity from hydro power and so the aim to reach 18% by 2010 is not as radical as it might at first appear.

So far, the majority of renewable electricity in the UK has been produced by large-scale hydro schemes, biomass and waste combustion; however the total amount of electricity produced by onshore wind farms is increasing rapidly.

Energy consumption in the UK has been steadily increasing by around 1% per year, with consumption in 2003 around 10% higher than in 1990. Electricity consumption has been increasing by around 2% per year over the same period (DTI 2003b). This energy was used for many functions (the most important of which were space heating and transport) and was spread across the four main sectors of the economy: domestic, transport, services and industry.

Transport is the biggest energy end use in the UK as a whole. Fuel use for transport is a major source of CO_2 emissions and other emissions from vehicles are a contributory factor to poor urban air quality. The amount of energy consumed for transportation in the UK in 2001 was some 638.5 TWh per year (DTI 2003b), which is 95% more than the amount used in 1970. Since 1990 transport energy consumption has increased by 13%, resulting in transport-related CO_2 emissions rising by 7% (DEFRA 2004). During this period there have been significant improvements in vehicle fuel efficiency, however this has been more than offset by increasing vehicle numbers and increasing congestion. Specific figures for Scotland are as follows (Scottish Executive, 2003a).

- The volume of traffic on major Scottish roads has increased by 66% since 1984 and the total distance travelled is now some 41 billion vehicle km per year (around 8% of the UK total).
- Air travel is also increasing with the number of passengers carried in Scotland increasing by 9% per year on average since 1992.
- At the same time passenger numbers for more efficient forms of transport such as bus travel have decreased by 23%.

The domestic sector is the second largest energy end user, accounting for some 523 TWh per year in the UK (DTI 2003b), with consumption increasing year-on-year: overall, domestic energy consumption has increased by 19% since 1990, while domestic electricity consumption has increased by 50%. Scottish domestic energy consumption (heat and power) is estimated to be 47 TWh, 9% of the UK total; around 82% of this is used for space heating. Some 60% of space heating in Scotland is provided by natural gas, while 30% of dwellings are electrically heated (Utley et al. 2001).

The increases in energy consumption detailed above have been driven by a number of factors.

- There has been an increase in the number of households (particularly one-person households), for example in Scotland the number of households is expected to increase to 2.46 million by 2014, from 2.2 million presently (Scottish Executive, 2004).
- The average temperature at which dwellings are maintained has increased from 13^{o}C in 1970 to 18^{o}C in 2000 (Utley et al. 2001).
- The number of electrically powered appliances and the use of multi-source lighting in each household have increased.

It should also be noted that 60% of all transport energy demand is associated with the domestic sector (Scottish Executive, 2004).

Energy consumption is also increasing in the UK service sector (shops and offices) where electricity consumption has increased by 17% since 1990 (DTI 2003b).

Only in the industrial sector has there been a decrease in energy consumption, down 44% since 1970. A move away from energy intensive heavy industries towards light industry (e.g. electronics) and energy efficiency improvements have driven this trend in industrial energy usage. However this downward trend appears to have bottomed out with a slight rise of 3% in energy consumption since 1996.

Current and Future Supply and Energy Demand

Until recently, the environmental effects of increasing energy usage have in part been masked by the radical change in the makeup of UK electricity supplies mentioned previously. This has resulted in the UK achieving emissions reductions while doing little to address the future need for a reduction in energy consumption.

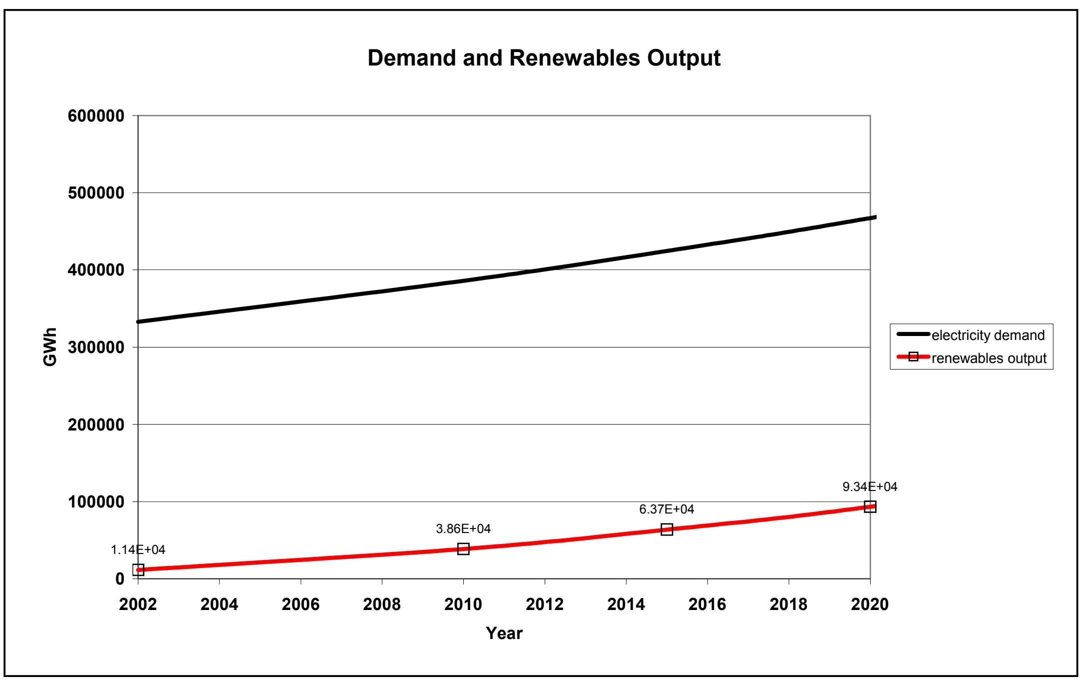

Figure 1 potential growth in UK electrical demand and renewables output.

Focusing on electricity, Figure 1 illustrates the potential growth in both electrical demand (if historical trends continue) and renewable electrical output up to 2020. Notice that the gap between the two (i.e. the energy that must be supplied by conventional means) increases slightly. If UK electricity demand continues to grow at around 2% per annum then by 2010 demand will have increased by around 30TWh. Renewables output could be expected to grow a similar amount over the same period. So the additional output from renewables could be completely absorbed by additional demand, so clearly if renewable resources are to have *any* impact on reducing CO_2 emissions then serious reductions in consumption will need to be achieved.

Figure 2, shows the UK governments own projection for CO_2 emissions, which unsurprisingly illustrates that these are forecast to rise after 2010 and indicates a growing gap between the UK's projected emissions and the Government's aspirational targets as set out in the White Paper. However, recent evidence suggests that UK CO_2 emissions are rising already, indicating that the beneficial effects of the "dash for gas" are being negated by continued growth in demand: in 2003 emissions rose by 2.2%, while emissions rose by 1.5% over 2004 (DEFRA, 2005). These increases in emissions indicate that not only is the UK likely to miss its own CO_2 reduction targets, but that it could also miss the target of a 12.5% cut in emissions agreed under the Kyoto protocol.

To compound the failure to curtail demand it is also unclear if targets for renewable electricity generation can be met. For example, in 2002 renewables accounted for around 3% of total UK electricity production; to meet the UK target of supplying 15% of electricity demand by 2015, renewables would need to supply some 60TWh of electricity per year, requiring an extra 17GW of renewable electrical capacity or 425 new 40MW wind farms. Between 2004 and 2015 approximately 1.5GW of renewable electrical generation will be required annually. However between 2002 and 2003 only

0.4GW of new renewable electricity generation capacity came on stream in the UK (DTI, 2003c).

Another point to make regarding UK CO_2 emissions is that they will be heavily influenced by the future of the nuclear industry, particularly in Scotland, where 55% of Scotland's electrical energy is currently generated from this source; intermittent renewables cannot directly replace nuclear power and so this leaves a potential energy gap in the future, as by around 2020 most existing Scottish nuclear plants are due to be decommissioned. If gas-fired stations replace any of this nuclear plant and electricity demands remain at current levels (or as is likely, increase) then there will be a net increase in CO_2 emissions (SEEF, 2003).

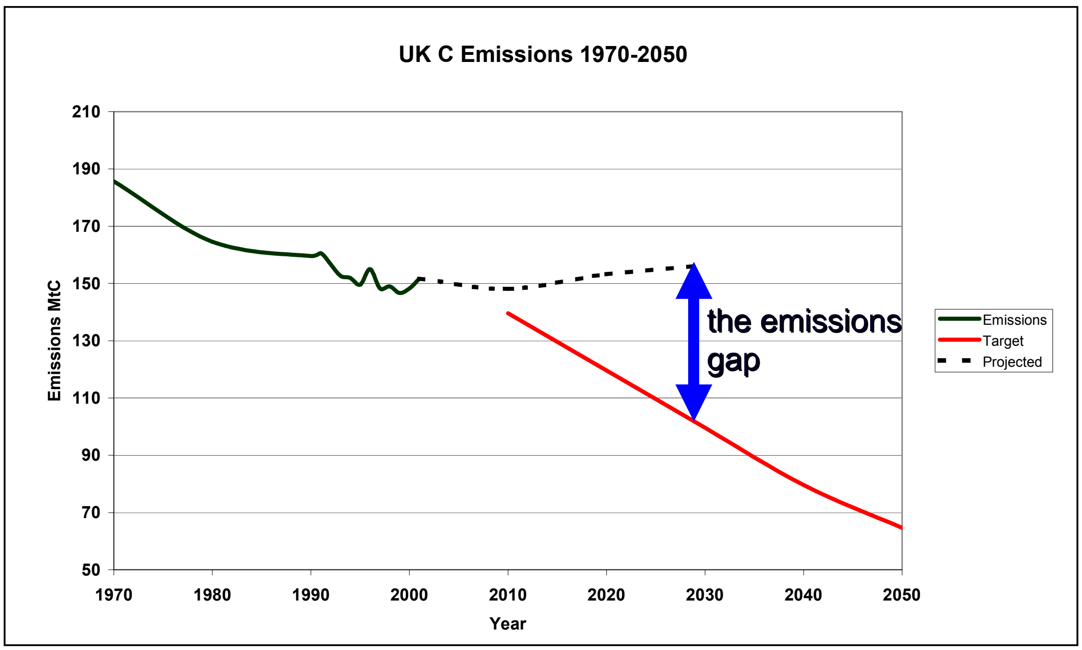

Figure 2 Historical, projected and aspirational UK emissions targets (DEFRA, 2004).

Finally, there are still serious engineering challenges to be addressed if renewables are to contribute a significant component of UK energy supplies. The most obvious of these is that renewables, with the exception of hydro and tidal power are intrinsically unpredictable. Hence, there will always be a requirement for base load and controllable response to temporal increases and decreases in demand; so existing thermal power stations must be maintained in the medium term until a viable solution (e.g. large-scale energy storage) to supply/demand mismatch is developed. Moreover those thermal power stations would be operating in a less efficient manner (i.e. more intermittently and at part load), increasing their CO_2 emissions per unit of electricity produced.

Case Study: Scottish Domestic Sector

It is clear that demand for energy will need to be curtailed if the UK (and Scotland in particular) is to have any hope of reducing greenhouse gas emissions and maximise the impact of adding renewables into the supply mix. A key question for policy makers is the magnitude of energy savings required to bring about CO_2 reduction targets. To do this for the whole of the UK economy would be beyond the scope of this paper, instead a limited illustrative limited case study is used: the Scottish domestic sector. The same analysis can be applied to other economic sectors.

According to the UK Energy White Paper, 45 million tonnes of carbon savings per annum are expected to come from energy efficiency by 2050. The bulk of these energy efficiency savings are likely to come from the built environment as it accounts for around 50% of delivered energy in the UK (DTI, 2003c) However, how can these savings targets in carbon emissions be translated to the actual savings needed in energy consumption? The answer to this question is not straightforward as energy savings do not directly correspond to emissions reductions: the prevailing electricity supply mix, fuel types for heating, the efficiency of energy conversion devices and the performance of other sectors of the economy (e.g. improvements in fuel efficiency in the transport sector) will all impact upon the required demand reductions.

The Energy White Paper sets out a UK target for savings of 10 million tonnes of carbon (MtC) per annum by 2020 from the domestic sector. Scaling this target proportionally based on the number of dwellings in Scotland compared to the rest of the UK, the

Scottish domestic sector could be expected to contribute savings of around 0.8 MtC savings per annum. If Scottish Executive targets are met it is anticipated that by this time around 40% of Scottish electricity will be produced by renewable sources (mainly from on-shore wind) with the remaining 60% being met by a combination of fossil fuelled power stations (mainly combined cycle gas turbine) and one remaining nuclear station, Torness. Domestic heating is assumed to be predominantly fuelled by gas or electricity: a similar situation to that seen today.

To estimate the required energy savings an integrated, scenario-based modelling approach is useful, where the integrated model comprises both a demand and supply component. Figure 3 illustrates the components of a domestic sector energy model, developed at the University of Strathclyde, which has been used to provide background data for energy policy analysis. The accuracy of the model has been verified by running the model with historical fuel mix and housing stock data comparing its output to the corresponding emissions and energy consumption data. However, no model can predict future events entirely accurately and so the output presented here should be regarded as qualitative as opposed to providing precise values.

The model comprises two main components:

- a supply side model; and
- a demand side model of the Scottish domestic housing stock.

The demand side model is used to calculate the overall energy consumption from the domestic sector based on such factors as projected improvements in energy efficiency, changes in appliance ownership and changes in energy conversion technology efficiency. The breakdown of energy consumption between the different fuel types is also calculated.

The supply model calculates of total CO_2 emissions by taking the calculated energy demands and mixtures of fuel required to supply those demands and mapping them back to the ultimate point of supply. To perform this calculation, the supply model uses existing data or a forecast of the prevailing mix of local and centralised energy conversion technologies and their ultimate efficiencies. Energy conversion technologies can range from a simple domestic boiler to a thermal power station.

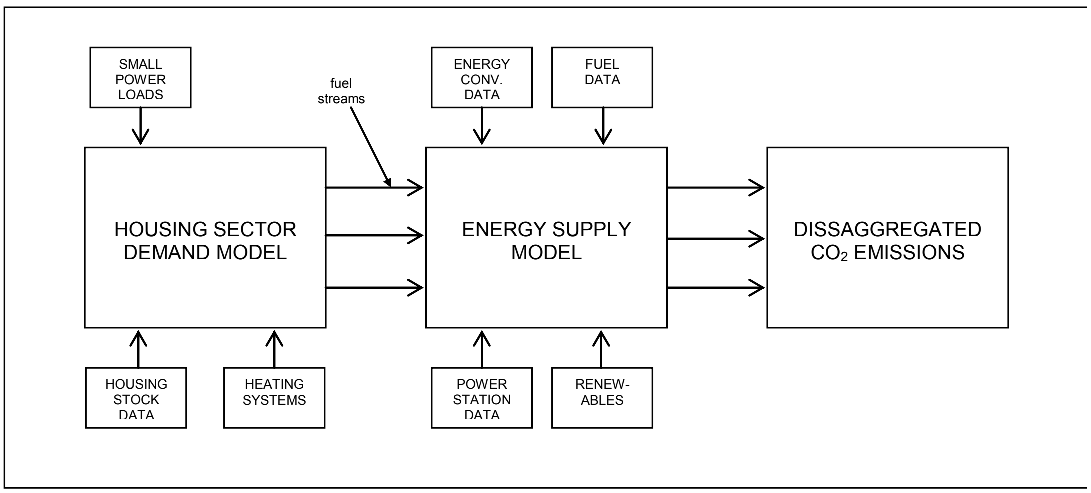

Figure 3 the structure of the supply and demand model.

The model was used to calculate projected CO_2 emissions for the following cases.

Case 1: "business as usual". The model is run with the assumptions that domestic sector energy consumption grows at around 1% per year, while the electricity consumed grows by 2%. By 2020 Nuclear power contributes 20% of the electricity used; renewables 40% and the remaining 40% comes from conventional fossil fuel sources (mainly gas). The graph of output shows that emissions associated solely with the domestic sector (e.g. space and hot water heating) and total emissions including those from power stations attributable to electricity supply for the domestic sector. Even with the addition of significant quantities of clean renewable power in the supply mix (40%), domestic sector carbon emissions could increase by around 0.15 MtC per annum by 2020.

Case 2: the “necessary reduction”. Figure 4b shows the output from another model run. This indicates that the required saving of 0.8MtC per annum can be achieved with a reduction of around 6% in heat and power demands in buildings combined with 40% renewable electricity production. The 6% figure was determined after some iteration of the model to find the appropriate savings and emissions levels.

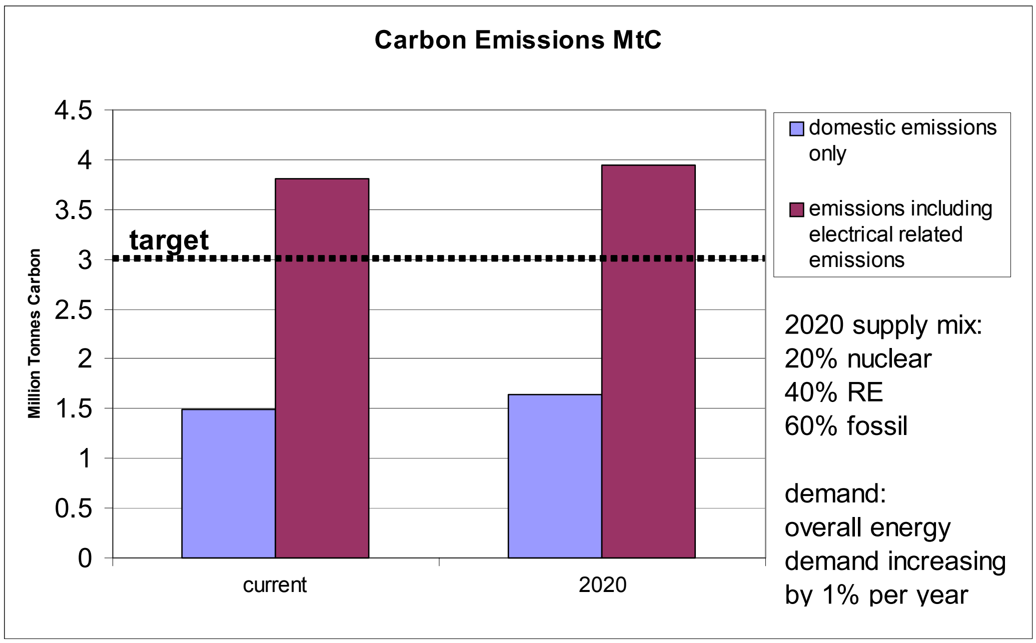

Figure 4a Scottish domestic sector carbon emissions now and in 2020 with increasing demand.

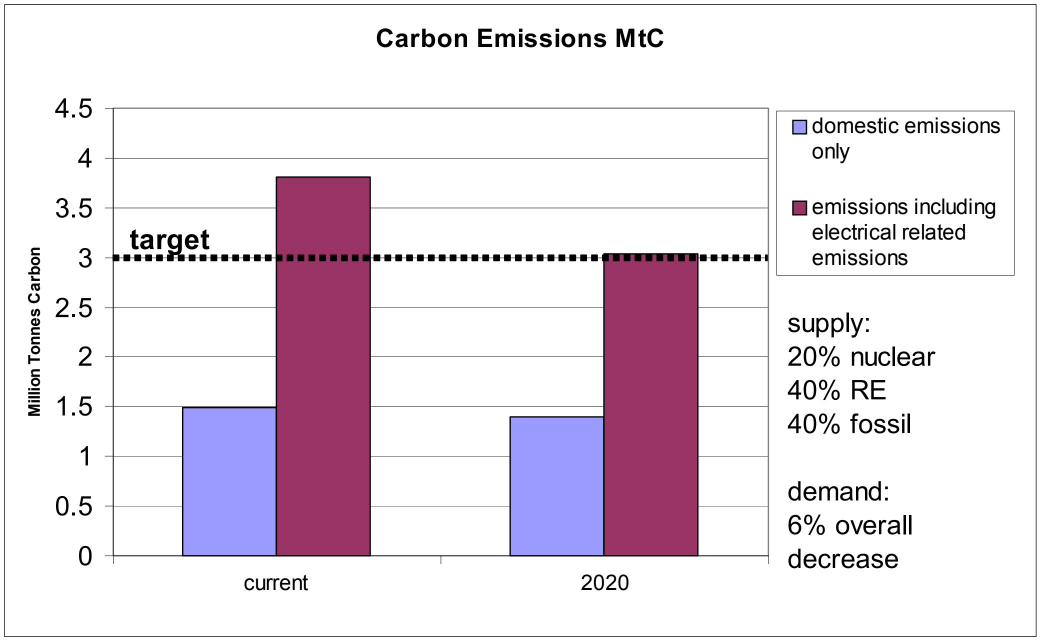

Figure 4b Scottish domestic sector carbon emissions now and in 2020 with a 6% demand reduction.

Figures 4a and b illustrate that only a combination of increased renewables in the supply mix and reduced energy consumption will bring about the necessary reduction in carbon emissions.

Case 3: "accounting for nuclear". A peculiarity of Scotland's CO_2 emissions is their sensitivity to the availability of nuclear power. The closure date for Torness power station (Scotland's most modern station) is currently 2023 (Hansard, 2003) and with the closure of that station the nuclear input into the Scottish electricity supply will drop from 20% to 0%. Notice that if this 20% of capacity is replaced by fossil fuel alternatives then far deeper cuts in energy consumption will be required to meet emissions targets. Figure 4c shows that with 0% nuclear input a cut of around 27% in heat and power demands will be required from the domestic sector (as opposed to 6% in Case 2) if the 0.8MtC per annum emissions reduction targets is to be achieved.

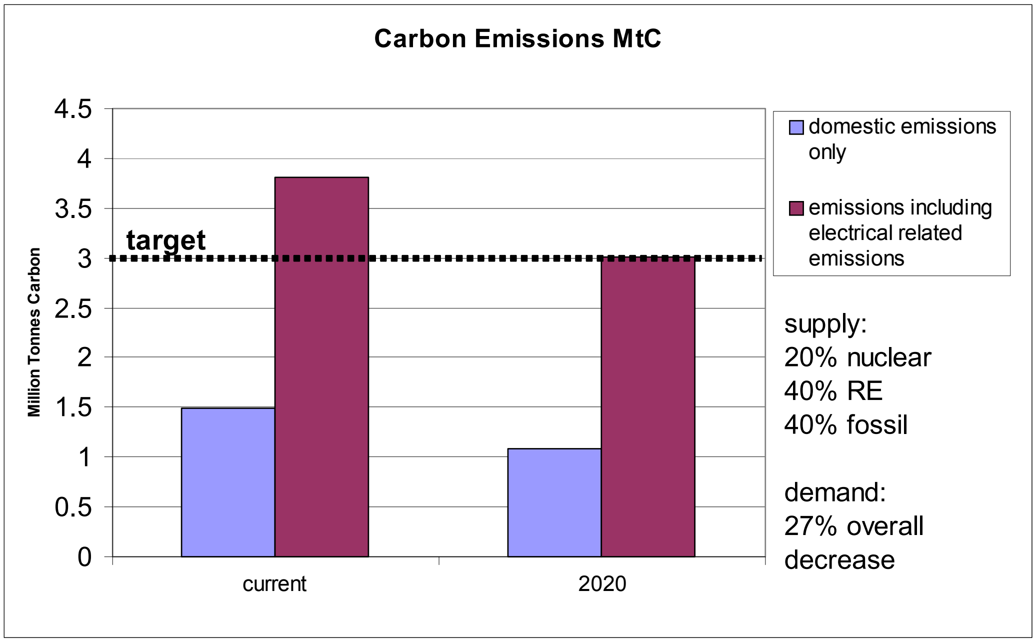

Figure 4c Scottish domestic sector carbon emissions now and in 2020 with a 27% demand reduction and no nuclear electrical production.

The output from the model indicates that, for the Scottish domestic sector, only reversing the current trend of increasing heat and power demands will result in any tangible emissions savings. The mechanisms that could achieve this along with current policies targeted at reducing energy consumption are now examined.

Mechanisms for Demand Reduction

There are a variety of mechanisms by which the energy consumption from the built environment can be reduced by 6% and 27% as indicated by the modelling exercise. These are:

- improving the quality of and new and existing buildings to reduce heat and power demand;
- installing more energy efficient equipment; and
- installing local, clean or energy efficient heat and power supplies.

Improving the Energy Efficiency of the building stock is the most effective method of reducing the associated CO_2 emissions. Very often no-cost and low-cost actions can result in very significant financial and environmental savings. It also results in a reduction of the total energy consumption: reducing both heat and power demands. The action plan for energy efficiency (DEFRA 2004) announced that improvements in the UK's building regulations would be used as one of the main tools to improve the energy efficiency of the housing stock. In England and Wales the building regulations are the responsibility of another government department – the Office of the Deputy Prime Minister (ODPM). Scottish building regulations are devolved to the Scottish Executive. The scope for energy efficiency improvements (and increasing the penetration of renewables) in the building stock is large. This is particularly true for older, less energy efficient buildings, which make up the majority of the stock. For example, 86% of Scottish buildings are over 20 years old and 40% were built before 1945 (Utley et al. 2001). It is also estimated that around 40% of energy used in buildings over 10 years old is wasted due to the poor quality of the fabric and systems (Johnston, 1993). To avoid this, the simplest measure to implement is to ensure that the fabric and systems of buildings are properly maintained. However in the UK building maintenance is often given a low priority and is often cutback or not done at all when budgetary savings must be made.

Proper insulation of buildings offers the greatest potential for energy savings given the poor history of energy conservation in UK building design, particularly in the domestic sector. Pre 2005 UK insulation standards were equivalent to those set in Scandinavian countries in the 1930's. Estimates of savings in heat demand from better insulated buildings range from 20% to 80% (Olivier, 2001). In addition to energy and emissions savings, better-insulated domestic dwellings would also mitigate some of Scotland's other chronic building-related problems:

- fuel poverty: there are around 369,000 households in Scotland classified as 'fuel poor' (Communities Scotland, 2002)
- dampness, mould growth: 131,000 dwellings in Scotland are affected by damp and 233,000 are affected by mould growth (Communities Scotland, 2002)
- related health effects: mould infestation, condensation and cold indoor temperatures present a significant risk to health in the very young and the elderly, particularly with respect to exacerbating cardiovascular and respiratory problems (Clarke et al., 1999).

It is worth noting at this point that as only 3% of the building stock is replaced each year (Utley et al. 2001), building regulations alone will not have an immediate impact on overall energy efficiency. The installation of energy efficient equipment into buildings is likely to have more effect in the near-term and many options exist. These range from the improved uptake of existing low-carbon technologies such as replacement of old boilers and installation of efficient lighting, to the deployment of new technology such as domestic micro-power. These technologies and their prospects are discussed below.

In the domestic sector in Scotland 56% of dwellings have gas central heating systems installed (Utley et al., 2001), however very few of these dwellings have condensing gas boilers as the main heat source. Condensing boilers have efficiencies between 10-20% higher than conventional boilers, with efficiencies of over 90% being reported (Willoughby, 2001 SEDBUK, 2005); this presents a significant opportunity for energy savings.

One of the most effective means to reducing energy consumption and emissions from the commercial and services sector is to reduce the energy required for artificial lighting. Typically, lighting systems in buildings in the UK are becoming more energy efficient with the installation of high frequency fluorescent tubes and the replacement of incandescent lighting with fluorescent alternatives. However the control of lighting systems is still generally rudimentary, with most still manually switched. Controllers linked to occupancy and/or daylight sensors offer the potential to significantly reduce lighting electricity consumption by between 40 and 90% (Holtz 1990, Knight 1999). Energy efficient lighting is being promoted in the UK under the Government's Enhanced Capital Allowance (ECA) scheme, under which 100% of the capital cost of the installation can be deducted from taxable profits for the first year of the investment.

In addition to reducing energy demands, there are also a range of technologies, which if implemented widely within the built environment could reduce emissions associated with the supply of energy. Moreover, some of these technologies (e.g. micro combined heat and power [CHP]) have the potential to significantly alter the demand characteristics to the built environment, through adding a degree of controllability to electricity demand as seen by the supply grid; this could be a mechanism for control of grid stability in a future electricity system incorporating a high percentage of renewables and where the supply will be more difficult to predict and manage (Kelly, 2003).

The government is actively promoting micro, small and large scale CHP, which offers the potential of reducing carbon dioxide emissions by 10-50% depending upon the electricity and heat sources the CHP displaces. The target set in the Energy White Paper is for 10 GW of installed CHP capacity by 2010. 2004 also saw the release of the Government's strategy for combined heat and power, which added detail to the targets set out in the White Paper. However, despite government efforts the 10 GW target currently looks unobtainable as since the advent of the New Electricity Trading Arrangements (NETA) and imposition of the Renewables Obligation (RO)[1] on CHP

[1] NETA resulted in lower costs for CHP produced electricity exported to the grid; this coupled with the RO, which is effectively an additional charge levied in fossil fuel generation (including CHP) have made CHP less economically attractive in the UK.

produced power, CHP installation rates have reduced dramatically with a 95% downturn in CHP capacity coming on-line. There has also been an overall *reduction* in CHP installed capacity and reduced exports of CHP produced electricity to the grid (Green, 2003). The major problem for CHP is that of reducing prices for exported/displaced electricity and increasing fuel prices (usually natural gas), which make it an unattractive investment prospect. Unfortunately this situation appears unlikely to change in the near future and factors such as exemption from the climate change levy (CCL) for CHP produced power and the inclusion of CHP in an enhanced capital allowance (ECA) scheme appear to be having little effect in re-energising the market.

Conversely, the reducing gas-electricity price differential could be beneficial for heat pump technologies. Heat pumps operate using a refrigeration cycle and effectively transport heat from one point (the environment), upgrade its quality (temperature) and dump it to another (the heated space) with the help of work input from a compressor. There are two basic types of heat pump technology suitable for installation into buildings: ground source heat pumps (GSHP), which use the ground as a low temperature heat reservoir and air source heat pumps (ASHP) which use outside air for the same purpose. GSHPs have historically been the more common system, as the more stable thermodynamic conditions under which they operate results in better performance. Typically heat pumps will transport 3-6 times more heat than the input electrical energy required to run the compressor. Heat pumps have been widely deployed in Scandinavia and the US but there are very few installations in the UK due to lower capital cost alternatives such as all-electric and gas central heating. However, advances in ASHP technology could allow it to compete directly with electric heating systems and possibly gas central heating if the gas and electricity price trends highlighted above continue. Recent studies have indicated that emissions savings of up to 50% compared to gas central heating are possible however running costs are around 20% higher (Kelly et al., 2004).

Two advanced technologies, which offer the potential for carbon-free power for buildings are fuel cells and photovoltaics (PV). Fuel cells use hydrogen (or a hydrogen rich fuel), which combines with oxygen in an electrochemical reaction to release heat and an electrical current. The two main types of fuel cells being developed for buildings are proton (or polymer) exchange membrane (PEM) and solid oxide fuel cells (SOFC). SOFC are more suited to combined heat and power applications due to their higher operating temperature (800-1000^{o}C). Fuel cells running on hydrogen generate no CO_2, however fuel cells running on hydrogen-rich fuels such as methane do generate some CO_2, but in lesser quantities than alternative technologies such as internal combustion engines running on petrol or diesel.

Much attention has been lavished on photovoltaics (PV) in recent years, however the actual energy yield from PV in a UK climate is poor, with typical output at around 90-120 kWh/m^2 per year (Clarke et al. 1996). Costs of PV are also high at approximately £3500 per m^2.

Solar thermal collectors, while a somewhat more mundane technology than PV and fuel cells, offer significant potential for emission reductions, with 4m^2 of collector being able to supply 40% of a typical family of 4’s yearly hot water needs: a saving of around 1200kWh per year; this equates to an emissions saving of 200kg of carbon when the water is heated by gas or 500kg when electric water heating is used. The most up to date survey indicates around 42,000 solar thermal installations in the UK (STA, 2004), though this figure is small compared to other European countries such as Spain and Greece.

It is worth repeating at this point that the majority of the energy requirements in the UK and Scotland are for space and water heating. Given this fact, the efficient provision of heat using combined heat and power CHP and/or solar thermal technologies is actually more effective at reducing emissions than renewable electricity production. Demand side reduction and local production of heat and power are very compatible strategies in that there is a direct linkage between the means of supply, energy demand and the end user. Further distributed energy systems are likely to engage the communities and businesses that they supply as their close proximity to the consumer will increase awareness of energy supply and demand; there is also a tangible incentive for energy efficiency in that the less energy which is required the less the initial capital cost of the local distributed energy systems (e.g. reduced demands reduce the required size and initial cost of CHP units).

From the preceding paragraphs it is clear that the methods and technologies exist to drive down demand, reduce the carbon content of energy supplies and significantly reduce the carbon emissions from buildings. However in the short-term it is those actions and technologies which reduce demand that have the greatest potential to deliver savings given the problems experienced by CHP and the fact that advanced technologies such as PV have a high capital cost (Figure 5), which despite generous grants limits their current application to niche markets.

Recall that the modelling exercise described earlier in the paper showed that energy savings of only 6-27% were required to meet 2020 emissions targets. Achieving these targets requires that effective policies and structures are in place both to drive down demand and also to encourage the uptake of new energy efficient technologies.

Delivering on Demand Reduction

In the UK responsibility for general energy policy formulation rests with the Department of Trade and Industry (DTI). The DTI's primary objective is to develop a favourable business environment in the UK and so it is charged with ensuring that the

UK has sustainable energy supplies at competitive prices. Responsibility for energy efficiency in England is the responsibility of the Department for Food, Environment and Rural Affairs (DEFRA). While this Department is not tasked to administer policies directly related to energy, it is responsible for those that result in enhanced social benefit and reduced environmental pollution. These include the Energy Efficiency Commitment, the Home Energy Conservation Act, and various fuel poverty schemes.

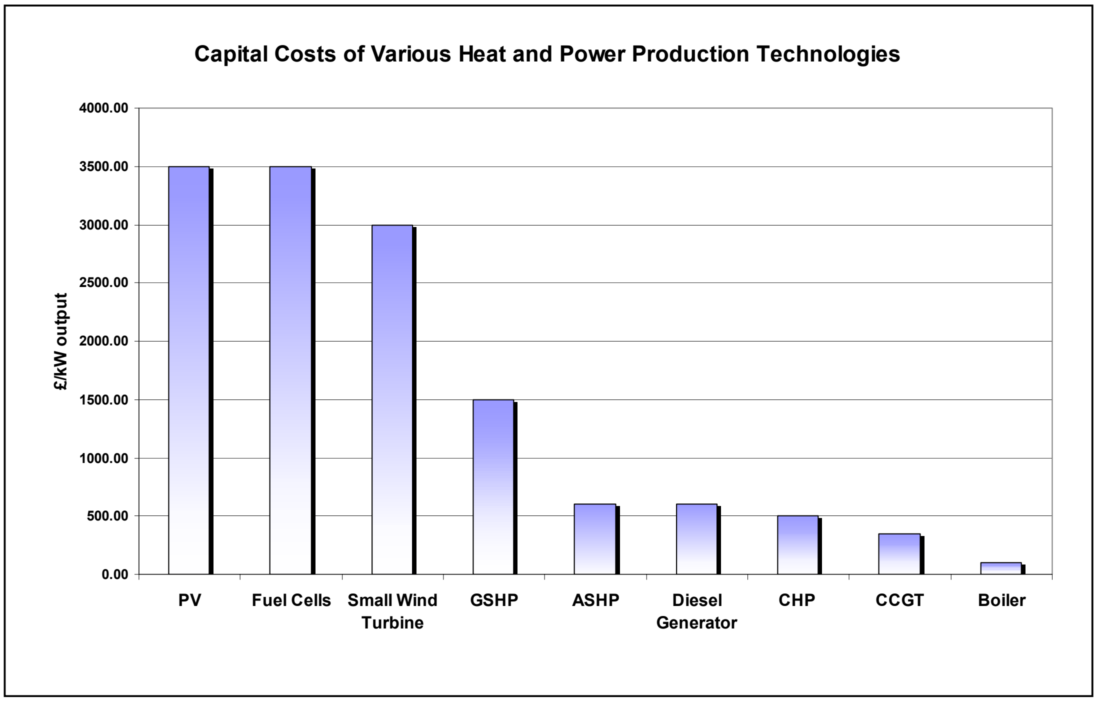

Figure 5 Relative costs of energy supply technologies (Kelly, 2003).

The UK government published its strategy for energy efficiency a full year after the Energy White Paper. The document, entitled "Energy Efficiency: The Governments Plan for Action" (DEFRA, 2004) expands upon the targets for improved energy efficiency set out in the Energy White Paper and details the mechanisms by these could be achieved. The Plan also updates targets for a reduction in emissions from improved energy efficiency to 12 MtC by 2010 (the target set out in the White Paper was 10 MtC). The main mechanisms to be used to achieve this are the introduction of new domestic building regulations (which came into force in 2005) to improve energy efficiency in new housing and the implementation of an emissions trading scheme for industry. Outside of these two new measures, the strategy is very much a continuation of current policy and delivery mechanisms for energy efficiency, which are primarily incentive based.

Energy Efficiency implementation and some energy strategy development is also undertaken at a regional level. For example in Scotland, energy efficiency is fully devolved to the Scottish Executive, which is committed to a policy of sustainable development. Energy efficiency is one of the components in the Executive's contribution to the UK climate change programme and this area is co-ordinated by Scottish Energy Efficiency Office (SEEO), which promotes the efficient use of energy and waste minimisation. In London the Greater London Authority has produced its own energy strategy (GLA, 2004).

The delivery of demand reductions is being undertaken through various bodies that oversee a variety of energy efficiency and fuel poverty initiatives. In 2003/04 the total budget set aside for the delivery of these initiatives was nearly £270 million (see table 1).

Table 1. 2003/04 Funding for Energy Efficiency and Fuel Poverty Initiatives (Kelly et al., 2003).

Agency/Programme	000's £
Carbon Trust	33,500
Energy Saving Trust	22,487
Action Energy Programme	22,050
Community Energy Programme (capital	34,000

grants)	
Fuel Poverty	156,000
Total	268,037

The Energy Saving Trust (EST) is responsible for the operation of fifteen programmes (Kelly et al 2003); of these the majority are directed towards homeowners and Local Authorities. The EST supports Energy Efficiency Advice Centres located throughout Scotland that help the domestic and small commercial consumers. In addition to the EST, The Carbon Trust focuses on aiding large industry consumers in adopting energy efficiency practices and technologies so they may realise increased carbon and energy savings in their day-to-day activities. Two Government Departments, DEFRA and the Department for Work and Pensions (DWP) also have programmes geared towards finding novel ways of meeting energy needs through adoption of new technologies and materials. Finally power utilities are obliged under the energy efficiency commitment (EEC) scheme to provide help and assistance (usually in the form of grants) to consumers to assist them in reducing their energy bills.

The SEEO directly funds and manages the delivery of UK programmes operated in Scotland by both the Carbon Trust and the Energy Saving Trust.

Focusing on Scotland, in 2003 there were no fewer than 28 different support programmes offered to assist the uptake of energy efficient technologies, materials and activities, reduce total energy demand, and help alleviate fuel poverty. Eight different organisations administered these programmes, which ranged from the provision of advisory services through to providing grants for the development of energy efficient products (Kelly et al., 2003). In Scotland the majority of funding for The Carbon Trust and EST comes via the Executive, which also directly funds two other energy efficiency-related programmes "Warm Deal" and the Central Heating programme.

Delivery of both is contracted to another body - the EAGA Partnership. The involvement of the Executive in financing many of the delivery bodies means that the funding of energy efficiency projects is more centralised and co-ordinated in Scotland than in the rest of the UK, however from an end user's point of view the sheer number of financial support mechanisms and different delivery bodies (whether funded by the Executive or otherwise) is a source of confusion and a potential barrier to the uptake of the available programmes. There is an obvious need for a simplification of the delivery mechanism for all the different energy efficiency programmes, one means by which this could be achieved would be the formation of a body to oversee and co-ordinate the delivery mechanisms for all of the different energy efficiency schemes, with that same body acting as a single point of contact for those seeking funding.

The current fragmentation and seeming lack of co-ordination in delivering incentives for energy efficiency is a clear indication that Government in not yet taking efficiency as seriously as it should be. A simple and effective mechanism to deliver energy efficiency targets is required if the UK's poor performance on demand reduction is to be improved. Such a mechanism already exists for renewable power generation in the form of the Renewables Obligation (RO). If the targets and mechanisms are not put in place to drive down demand then the entire UK CO_2 reduction programme will continue to perform poorly.

Outlook for Energy Efficiency

Despite the publication of the energy efficiency strategy, the general thrust of UK energy policy is still very much orientated towards renewable electricity supplies. There is also a general misconception amongst the general public and some policy makers that renewable energy deployment is the solution to carbon emissions. The main reason for this is that renewable energy has a far higher profile than demand reduction both in government and in the media mainly due to the fact that renewable deployment, especially wind power is a highly contentious issue. Additionally renewables are regarded as a potential source of future employment and economic growth (DTI 2003a), the perceived economic benefits on the energy supply side acts to the detriment of energy efficiency, where the perceived benefits, in terms of employment and growth are not as strongly defined. Also, unlike renewable electricity supplies, the mechanisms used and proposed by the government to increase energy efficiency are incentive-led such as enhanced capital allowances for low-energy equipment. With the increasing energy consumption trends highlighted previously it is evident that this approach is not having the desired effect.

Another barrier to the implementation of energy saving measures and energy efficient technologies has been the historical low cost of both electricity and gas in the UK, which increases the payback time for capital expenditure on energy efficiency projects, reducing their attractiveness. This situation looks set to change as UK electricity and particularly gas prices have seen sharp increases over 2004-5. Unfortunately gas prices have risen more quickly than electricity over this period, with gas wholesale prices rising 51% (BBC, 2005). As was highlighted previously, this has resulted in a reducing price differential between gas and electricity, reducing the attractiveness of combined heat and power (CHP) in the UK.

Conclusions

This paper has indicated how demand reduction will be essential if the UK government's ambitious emissions targets are to be met.

Renewables alone will not reduce CO_2 emissions; in fact as has been shown in the modelling undertaken for this paper emissions will increase if current trends in demand continue. Only with a balance between reducing energy use and renewable supplies can the UK hope to meet its emissions reduction targets.

Additionally, only demand-side energy efficiency measures such as improved insulation and better quality buildings offer the prospect of attacking other important problems such as fuel poverty and ill health.

The technologies are available or are emerging, to radically reduce the emissions associated with supplying heat and power to buildings. However, a combination of adverse economics high capital costs and confusing support mechanisms mean that the take up of technologies such as CHP, solar thermal collectors and heat pumps is low.

The prospect of energy supplies from fuel cells and PV is a more distant prospect as both of these technologies have extremely high capital costs.

However, significant emissions savings can be obtained from the built environment with relatively modest reductions in energy consumption (6-27%) and these savings do not necessarily require high-tech solutions: simple measures such as maintenance can have a dramatic effect on improving energy efficiency.

Current support mechanisms to promote energy efficiency in the UK and Scotland are fragmented, with multiple bodies delivering large numbers of similar programmes; this provides a confusing and perhaps off-putting picture to those interested in reducing their energy consumption.

If it is to attain its emissions targets, the UK government must concentrate on ensuring that sufficient, coherent legislative and fiscal incentives are in place to both improve the uptake of energy efficient supply technologies and encourage improvements in the energy efficiency.

Finally it is worth reiterating that despite increasing awareness of the need for energy efficiency and sustainable resource use, the historical absence of a coherent energy policy; a migration from the use of fiscal measures and legislation towards promotion and incentive-lead approaches to energy conservation; and demographic/lifestyle changes have resulted in the increasing energy consumption observed in UK since 1990. With the reality of increasing energy demand in most sectors of the economy and the prospect of those increases in demand derailing Government targets on CO_2 reduction, there is an urgent requirement for the UK Government and devolved administrations to re-examine their policies and activities in energy efficiency.

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