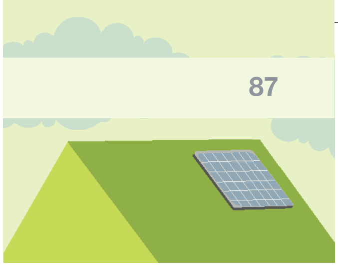


5. Environmental Sensitivities

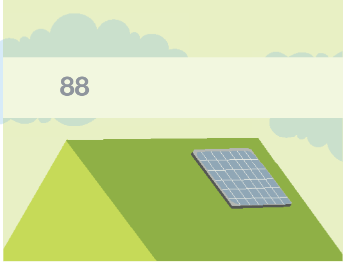
Key Messages

- Reducing CO_2 emissions leads, for the most part, to reductions in other emissions and pressures on the environment. The exceptions are radioactive releases, stress on water and land, and some aspects of air quality
- The development of bio-energy has a number of environmental implications, relating to air emissions, water availability and land use
- This is not a rationale for inaction on achieving a low-carbon economy, but signals areas in which further regulatory attention will be required
- Release of some pollutants, notably sulphur dioxide, will fall substantially
- A low-carbon strategy which emphasises energy efficiency and demand reduction will lead to considerably lower environmental impacts. Emissions of some pollutants could be halved in comparison to a supply-led strategy
- People's concerns about the environmental impacts of energy development can take several forms. They include concern about local impacts, fear of unfamiliar technological solutions, or concern about impacts on the natural environment and ecosystem services
- If people's concerns inhibit the development of certain technologies, then the costs of meeting CO_2 targets will increase. It will focus more attention on demand reduction policies
- The implications of a scenario where technologies are constrained if they are seen to harm ecosystem services could be particularly costly. A range of technologies and fuels (fossil, bio-energy, tidal barrages) would be affected. Globally, fossil fuel prices could rise as a result of certain extraction options being excluded

Environmental Impacts of Low-Carbon and Resilient Energy Scenarios

Energy systems, along with other human activities, interact with the environment in a number of well documented ways (Millennium Ecosystem Assessment, 2005). The interactions vary according to spatial and temporal scales and are dependent on both the magnitude of the driver and the ecosystem or organism being impacted. Within the first phase of UKERC a pragmatic approach was taken to make an initial examination of the environmental pressures generated by different energy scenarios.

The analysis summarised below aggregates the operational emissions of eight dominant pollutants (CO_2, CH_4, CO, N_2O, NO_x, SO_2, PM_{10} and radioactivity) from energy systems expected to be in operation between 2000 and 2050. Changes in pollutant emissions are described for each of the MARKAL Energy 2050 Core scenarios (Reference (REF), Low-Carbon (LC), Resilient (R) and Low-Carbon Resilient (LCR)). The total load for each pollutant was estimated by



aggregating the contributions from each of the energy generating technologies and uses for all sectors[1]. An important assumption is that emissions factors for each source and their associated abatement technologies perform as they do today, with a few exceptions relating to known emissions reduction policies such as the Large Combustion Plant Directive. As technology improvements are likely to lead to lower levels of emissions, the results may show a 'worst case' interpretation. Emissions from non-fuel sources and components not included in MARKAL were not considered here. In addition, a preliminary assessment of the altered water demand and land take and upstream carbon emissions for each scenario was conducted.

As the method adopted uses a comprehensive matching of specific technologies and activities to their emissions, the results can be used to compare changes in the environmental pressures associated with different energy generation and use strategies. This comparison reveals that there are some common trends across scenarios, but there are also divergences between values. With care, these can be interpreted as the implications of different energy decisions. Although changes in the magnitude of the pressures have been calculated, the impacts of the pollutants can only be described in general terms as the model has no spatial component and employs a coarse temporal representation (five-year time steps). Consequently, the analysis should be viewed as indicative rather than definitive.

Pollutant Emissions Under Different Energy Scenarios

Overall, emissions of the eight pollutants considered in this analysis decrease between 2000-2020 with little variation between the four Core scenarios. After 2020, the LCR scenario leads to significantly lower total pollution emissions, compared with the other Core scenarios. This demonstrates that the combination of a low-carbon pathway combined with a more resilient energy system has wider environmental and energy security benefits. The R scenario results in similar pollutant emissions to LCR for seven of the pollutants, but does not achieve the 80% CO_2 reduction target.

When the pollutants are considered individually it is also clear that there are key areas where LCR outperforms LC in reducing emissions. CO, N_2O, NO_x and PM_{10} emissions are significantly lower in the LCR scenario post 2020, mainly due to changes in the transport and residential sectors. The main differences between LC and LCR are that LCR has greater demand reduction particularly in the residential sector, and greater penetration of hybrid and electric cars. In contrast, LC has lower demand reduction in all sectors; greater biomass use for heating in the residential and service sectors (increasing PM_{10}, CH_4 and CO); and greater use of transport biofuels, as opposed to hybrid/electric cars in the LCR scenario. The analysis detailed below investigates these trends for each of the pollutants studied.

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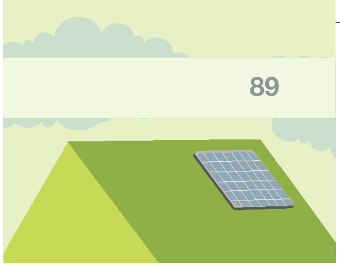
[1] Emission factors taken from NAEI (2006). Where unavailable, values were calculated from DUKES (BERR, 2008) and other scientific publications.



The combustion of coal releases sulphur dioxide (SO_2) and methane (CH_4). Consequently, SO_2 emissions are dominated by conventional coal-fired power stations; other sources include coal used in industry, and fuel oil and petroleum coke use in oil refineries. Coal power stations with carbon capture and storage (CCS) release very little SO_2 as it has to be removed to prevent it impeding the capture process. Consequently, emissions fall sharply in the LC and LCR scenarios (Figure 5.1) as coal CCS is introduced and becomes a dominant technology between 2020-2035. They fall, but to a lesser extent, in the REF and R scenarios, due to continued use of conventional coal-fired power stations. However, the requirement (from the EU Large Combustion Plant Directive) for flue gas desulphurisation (FGD) in conventional power stations after 2015, does reduce emissions by about 85%.

Initially in MARKAL, CH_4 emissions are dominated by the residential sector's use of coal and solid smokeless fuel for heating. In all four scenarios this use is phased out by 2025-30, resulting in a steady decline in emissions. However, it is important to recognise that only 2% of Britain's methane emissions are represented in MARKAL (NAEI, 2006), with 80% of existing emissions from waste decomposition and livestock. There are also other energy related methane sources not represented in this assessment, including gas leakage and methane from coal mining.

Most particulate (PM_{10}) emissions are from the transport and residential sectors; within transport, diesel vehicles are the main source of emissions. In LC, R and LCR scenarios, total PM_{10} emissions halve by 2050, in part through reduced diesel consumption (Figure 5.2). However, in all scenarios future technology developments may decrease particulate emissions further.

In the residential sector PM_{10} emissions fall in all scenarios, by approximately 95% between 2000-2030, due to the phasing out of coal, oil and wood for heating. However, in the LC scenario increased use of biomass fuel in the residential sector causes total emissions to rise by around 15% between 2030 and 2035 (Figure 5.2).

Figure 5.1: Total emissions of sulphur dioxide (SO_2) over time in the Core scenarios

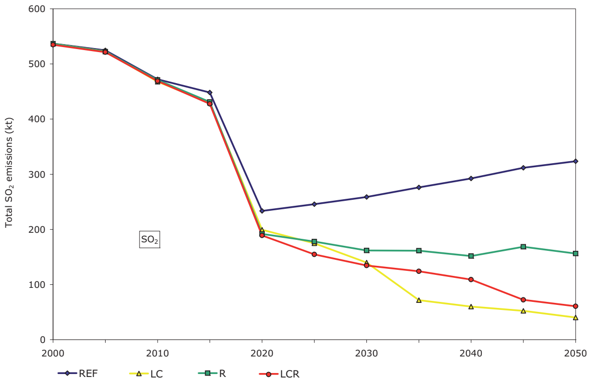
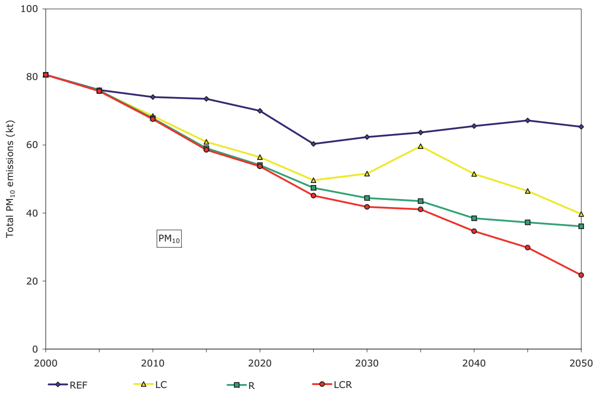
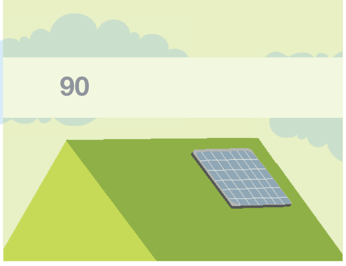


Figure 5.2: Total emissions of particulates (PM_{10}) in the Core scenarios





The extent of this rise will depend on the specific technologies used to reduce health impacts in modern biomass boilers or stoves.

Energy use in transport generates a number of different pollutant emissions and is the dominant anthropogenic source of carbon monoxide (CO) and the oxides of nitrogen (nitrous oxide (N_2O) and NO_x). However, each transport mode and fuel type has its own distinct footprint, so for example CO is mostly from petrol cars whilst NO_x splits more evenly between all liquid fuel cars and HGVs. The increasing use of catalytic converters in petrol cars caused an initial decrease in CO emissions in 2000-05 in all scenarios. The trend continues through the addition of bioethanol to the petrol fuel mix (Figure 5.3).

The residential sector provides another source of CO emissions (approx 20% in 2000). Phasing out coal and solid smokeless fuel use between 2000 and 2025-30 reduces CO emissions in all the Core scenarios (Figure 5.3). Only the LC scenario shows any reversal in the trend due to the use of wood in the residential and service sectors in 2035-2050. The lowest CO emissions are found in the two resilient scenarios (R, LCR), due to the introduction of hybrid and plug-in cars, and transport sector demand reductions.

Nitrous oxide (N_2O) emissions increase initially by the uptake of catalytic converters in cars, the inverse of the effect seen with CO (Figures 5.3, 5.4). Demand reduction and the use of hybrid and plug-in cars reduces emissions in the R and LCR scenarios by 2025. The same factors produce a later and smaller fall in emissions in the LC scenario through the increased use of hybrid and plug-in cars; the REF scenario shows a continuing rise. However, energy (as represented in MARKAL) is only responsible for 20% of the UK's N_2O emissions (NAEI, 2006), with over half of UK emissions derived from agricultural fertilisers.

Emissions of the other oxides of nitrogen (NO_x) are also dominated by the transport sector (~50% of emissions), particularly cars and HGVs. In all cases the emissions show a decline, down to approximately 65% of 2000 emissions in LCR scenario by

Figure 5.3: Total emissions of carbon monoxide (CO) in the Core scenarios

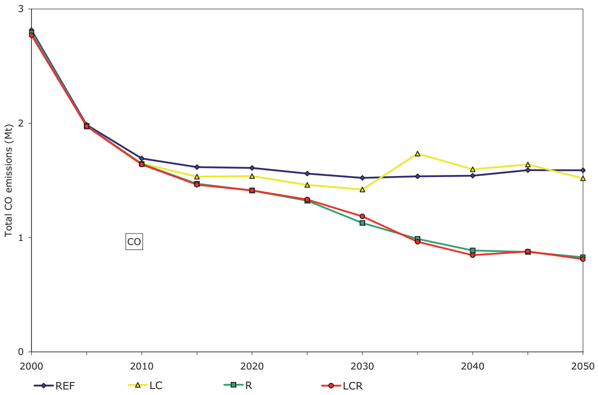
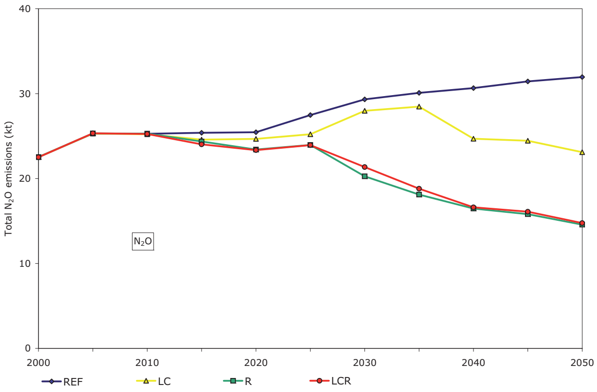


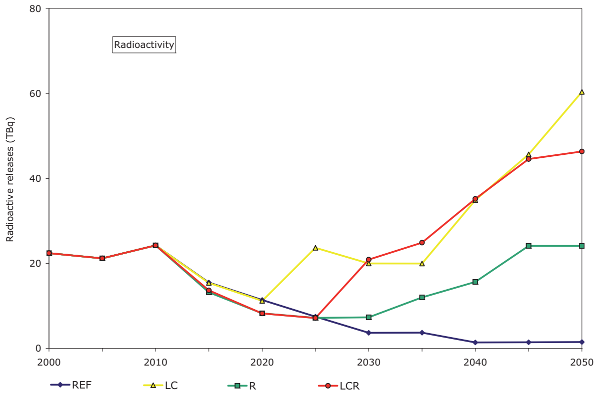
Figure 5.4: Total emissions of nitrous oxide (N_2O) in the Core scenarios



2050 and a smaller reduction of 20% in the REF scenario. Energy technologies and uses (in MARKAL) are responsible for 80% of our current NO_x emissions. Emissions not included in MARKAL are predominantly from international aviation and shipping.

Radioactive releases considered are from nuclear power stations, coal-fired power stations and other sources such as oil and gas platforms. Radioactive releases decline in the REF scenario, as nuclear power stations coming to the end of their life are not replaced (Figure 5.5). In the other scenarios, nuclear power stations are built so emissions rise to varying extents after a time lag due to the long planning and construction time required. The highest estimated discharge occurs in the LC scenario resulting in a nearly three-fold increase in discharges by 2050, matching its tripling of power generation. All new discharges would need to be assessed for exposure to both humans and the environment. Such increases may require quite detailed assessments, where appropriate, on the potential risk to wildlife, with a focus on reducing current uncertainties in the habitat assessments.

Figure 5.5: Total radioactive releases in the Core scenarios



The need for such assessments will depend upon where these increased discharges are occurring and the extent to which protected Natura 2000 sites are potentially impacted.

Relationship Between Pollutant Emissions and Energy Demand

If there is a strong and robust relationship between individual pollutant emissions and total energy demand, then a simple rule of thumb could be applied to describe changes in environmental pressures from different energy strategies. Although there are strong positive correlations between all of the pollutants and energy use, i.e. greater demand creates more pollution; the precise form of the relationship varies between pollutants and scenarios.

To investigate this relationship, total annual energy demand was plotted against estimated pollutant emissions, with each year represented as a point on the graph. Values for CH_4 (Figure 5.6) show a generally tight curvilinear fit across all scenarios, indicating that CH_4 emissions are strongly related to energy demand, regardless of the scenario. In contrast, for CO_2 (Figure 5.7), there is a strong correlation between energy demand and emissions within individual scenarios, but the trends of scenarios are significantly different from each other. In the LC scenario, technologies are selected with the aim of minimising CO_2 emissions, so on the graph this scenario has the steepest slope, due to large reductions in CO_2 emissions over time, despite little change in energy demand. In the R and LCR scenarios there is a greater reduction in energy demand over time, which means that less

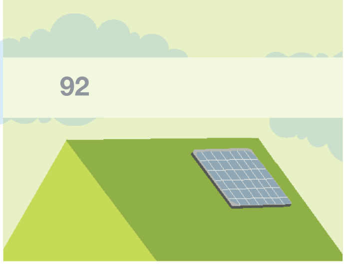


Figure 5.6: Relationship between emissions and energy demand between 2000 and 2050 for methane (CH_4) in the Core scenarios

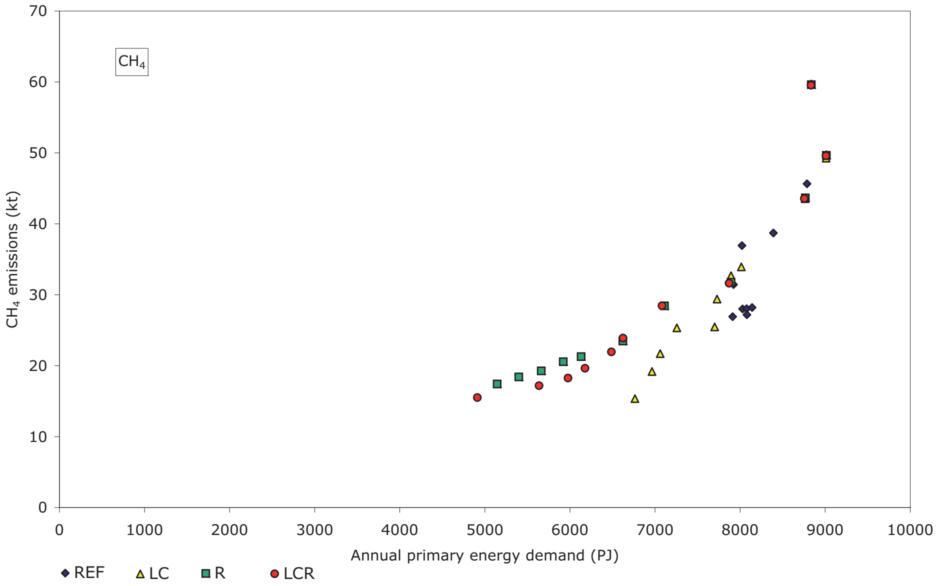
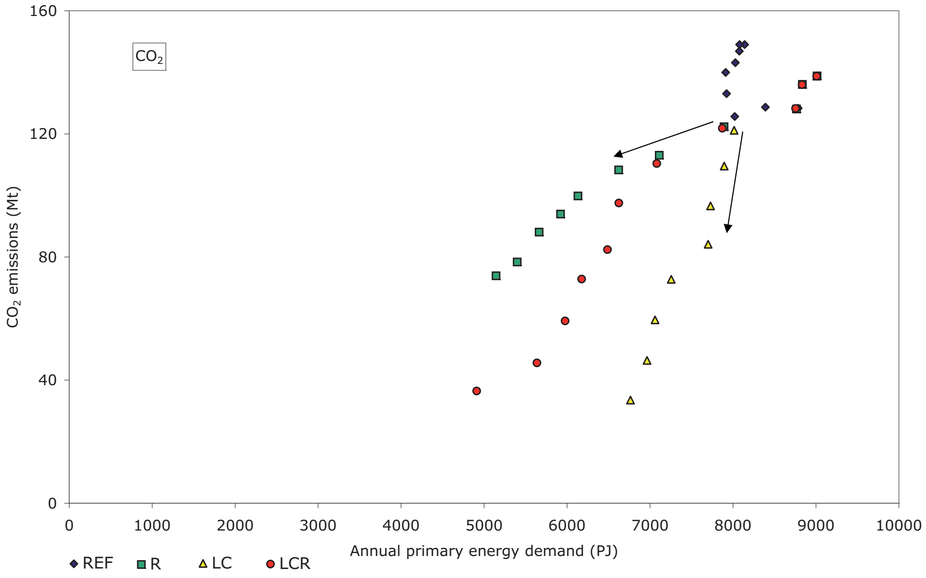


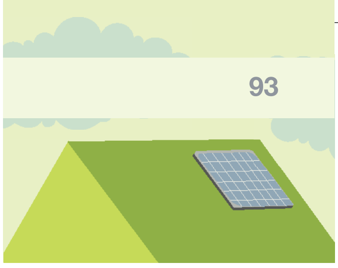
Figure 5.7: Relationship between emissions and energy demand between 2000 and 2050 for carbon dioxide (CO_2) in the Core scenarios. Arrows indicate the direction of change in demand over time.



investment is required in low-carbon technologies. Therefore, in these scenarios, each PJ of energy used will produce higher CO_2 emissions than a PJ of energy used in the LC scenario.

Wider Environmental Pressures

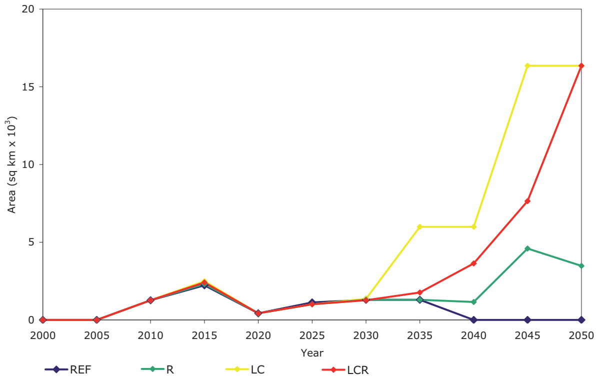
Further environmental pressures relate to changing demand for water and land where resource depletion and change in condition are issues. Water is a power source (hydro



and pumped storage), and is used for cooling in power stations and for agricultural and forestry production of energy crops and biofuels. A preliminary analysis suggests that the LC scenario will result in the largest increase in water demand, driven by increased electricity generation from coal CCS and nuclear power, as well as the extensive production of biofuels and energy crops. Water demand for the agricultural production of energy crops also increases in the LCR scenario, while the REF and R scenarios show the smallest increases in water demand.

The current perception of energy generation systems is of a limited number of power stations, refineries and mines which only cause local environmental impacts. New technologies can be far more demanding in terms of area in which to operate. Some technologies, such as wind power, are capable of operating with other land uses in a multi-functional way, whilst others, such as bioenergy, can become monocultures. The land take for bioenergy in the Core scenarios is shown in Figure 5.8. The scenarios show similar trends through to 2030 where bioenergy starts to be significantly deployed in the LC and LCR scenarios, both rise to eventually use about 8% of the British land area – around a third of our current arable land or more than 10% of our total agricultural area (including semi-natural extensive grazing area). The impact of this change will be dependent upon the location, condition and habitat history of the land replaced.

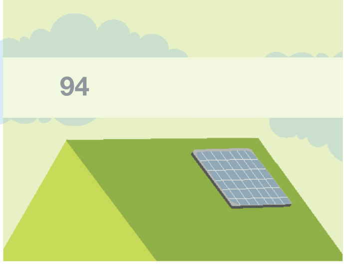
Figure 5.8: Land take for bioenergy in the Core scenarios



Energy Scenarios with Socio-Environmental Constraints

The environment is central to all future energy scenarios; it supplies the resources and receives the impacts of energy capture and use. However, the environment has another more subtle but equally powerful influence over future energy systems; public and stakeholder perceptions and evaluation of the socio-environmental risks and benefits of activities provide powerful constraints and drivers of change. The UKERC Energy 2050 Core scenarios demonstrate how low-carbon and or resilient energy systems can develop in the UK to meet specific targets, but these scenarios will require public buy-in and acceptance if they are to become established. In this study, three variant scenarios were developed, in which some aspect of this public buy-in is missing, imposing an extra constraint on the evolution of the energy system. The variant scenarios (DREAD, ECO and NIMBY) use the 80% Low-Carbon Core scenario (LC) as a baseline. Thus, like LC all the socio-environmental scenarios are constrained to deliver an 80% reduction in carbon emissions by 2050.

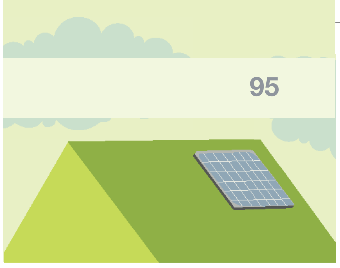
In the most extreme scenario, DREAD, the deployment of certain technologies is



halted by public fears about how those technologies could pose unknown but potentially catastrophic dangers which could threaten human life. In part reinforced by the prospect of catastrophic climate change, there is a general mistrust of Government, regulatory bodies, the scientific community and big business, rooted in the assumption that all of these have some cynical or self-interested motive. Within this scenario novel and 'threatening' technologies are not deployed, so there is no new nuclear build, no CCS and no use of hydrogen for power or transport.

The second scenario variant, called ECO, represents considerable public concern for the conservation of ecosystem goods and services with a consequence that there is a financial cost for a sustainable lifestyle. Peoples' acceptance of energy systems is built around a wider perception of environmental costs of operation, including imported feedstocks. In the ECO scenario, fossil fuel prices are increased due to concerns about the ecological impact of certain types of fossil fuel extraction. For instance, in this scenario, oil is not taken from oil sands or other ecologically sensitive areas. This leads to increased global prices. Domestically, open-cast coal mining is deemed to be too environmentally damaging and is thus not allowed after 2010. Bioenergy is only seen as an option where the ecological impacts can be minimised. Therefore, liquid bio-fuel for transport is not allowed in the UK, as it is considered to be inefficient and requires intensive agricultural management to deliver. Imported biomass and biofuel are also banned because the public is unconvinced about the sustainability merits of overseas production and thus rejects it in an attempt to protect rainforest and threatened habitats. Further, in response to ecological concerns about land use change, the growth of crops is heavily constrained to only 11% of the total capacity considered to be available in the LC scenario. There is also a 25% constraint on wind power (onshore and offshore) and wave and tidal power due to concerns about the environmental impact of those technologies in certain areas. In addition, a tidal barrage is not allowed at all in this scenario due to concerns about potential damage to the environment.

NIMBY, or Not In My Back Yard, is the third variant scenario. In this scenario the public objective is to preserve the local environment, lifestyle and systems. The public rejects new developments when they have a high visual impact, while existing facilities are allowed to continue at their current levels because they are already accepted aspects of the landscape. Consequently, nuclear power is allowed, but no new nuclear sites are permitted, there can only be redevelopment at existing commercial reactor sites. Coal CCS is a less familiar technology with no existing plants. However, a limited number of CCS plants are allowed in certain locations where existing power plants and infrastructure can be modified without major aesthetic impacts. Onshore wind is only permitted where windfarms are already established or planning consent has been awarded. Offshore wind is only permitted where it has minimal visual impact. Therefore, in the NIMBY scenario,



offshore wind farms are only allowed to be built beyond a 12 nautical mile coastal buffer zone. Bioenergy production is accepted so long as it maintains the appearance of the existing landscape. Consequently, energy crops such as Miscanthus and short rotation coppice are not allowed because they are unfamiliar and would alter the character of the landscape. The production of traditional crops such as wheat and oil seed rape for biofuel is constrained to 37% of the potential production available in the LC scenario due to the public's resistance to changing non-agricultural land to produce more crops. Tidal barrages are not allowed because of the way that they would change the character and visual aesthetics of an area.

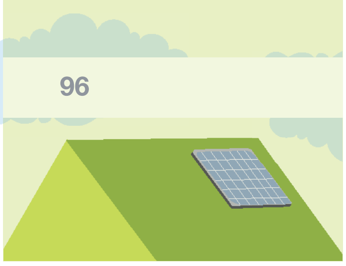
These environmental constraints are summarised in Table 5.1.

Implications of the Socio-Environmental Constraints

The energy systems developed within the three socio-environmental scenarios offer different strategies to meet the 80% decarbonisation target and address their additional wider concerns. While all scenarios initially decarbonise the power system they employ different supply side technologies which carry wider implications across the entire energy system. As a consequence of the additional socio-environmental constraints, each scenario then takes its own approach to decarbonisation of different sectors. The strategies employed are predominantly reducing demand and making alternative technology selections. The difference in demand reduction strategies can be seen in their electricity generation (Figure 5.9).

Table 5.1: Summary of the additional constraints over those set in the LC scenario on the energy sources for the socio-environmental scenarios. Empty cells indicate no additional constraint

	DREAD	ECO	NIMBY
Nuclear	None allowed		Only existing sites allowed
Fossil fuel price		Increased cost	
Coal CCS	None allowed		Limited sites
Hydrogen	None allowed		
Renewables			
Wind		Limited onshore & offshore	Only far offshore allowed; No new onshore planning consent given
Bioenergy		No imported biomass allowed; No biofuels allowed; Limited crop production	No energy crops allowed; Limited crop production
Marine		No tidal barrage allowed; Limited tidal stream and wave	No tidal barrage allowed



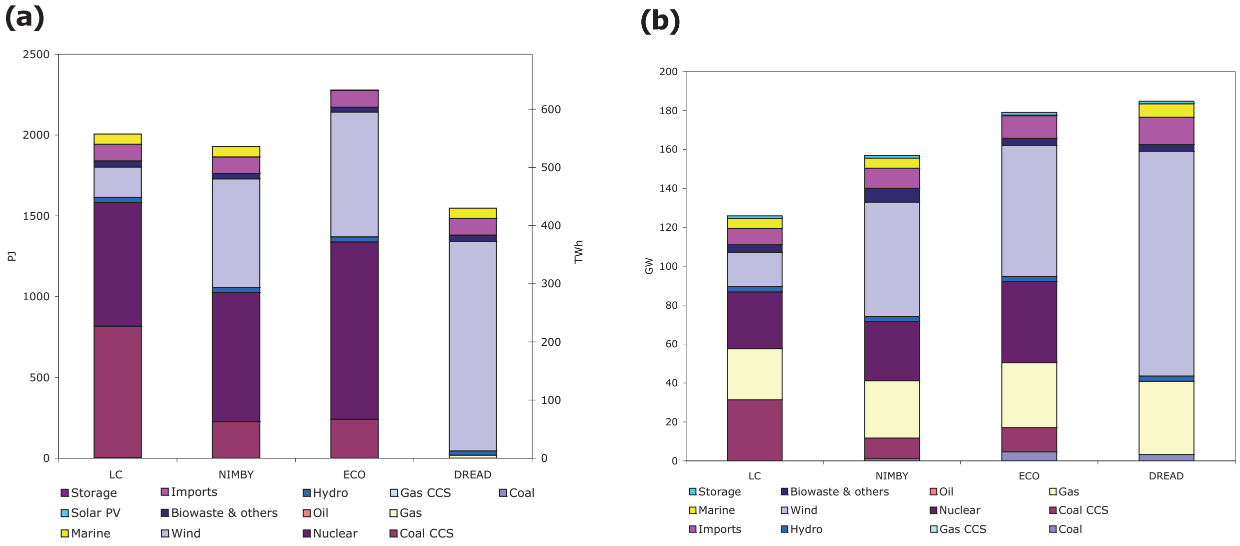


Figure 5.9: The electricity generation in 2050 for the 80% low-carbon Core scenario (LC), NIMBY, ECO and DREAD variants broken down by (a) electricity generating type and (b) the installed capacity delivering the power in 2050

As a result of the different pathways to decarbonisation, the sectoral emissions of CO_2 show dramatic differences by 2050 with the ECO and DREAD scenarios showing greatest divergence from both one another and LC (Figure 5.10). For instance, within ECO, the limits on transport set by increased costs of fossil fuel and lack of biofuel availability, counter-intuitively forces the continuation of use of diesel and petrol which produces higher transport sector emissions and pushes other sectors to reduce their emissions more than in the other scenarios.

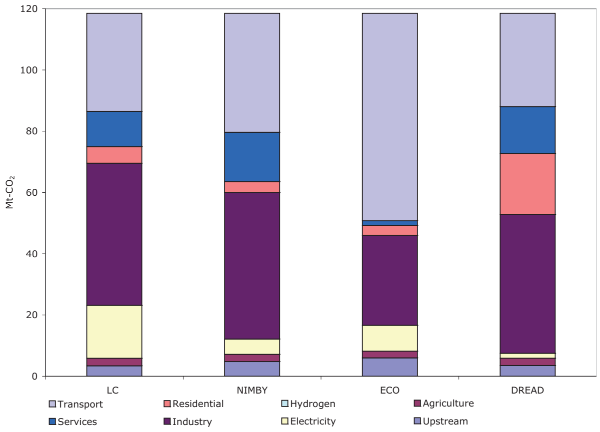
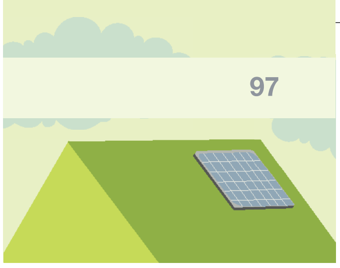


Figure 5.10: Total emissions of CO_2 in 2050 for the 80% low-carbon Core scenario (LC), NIMBY, ECO and DREAD variants broken down by sector. Emissions in millions of tonnes of CO_2

DREAD Scenario

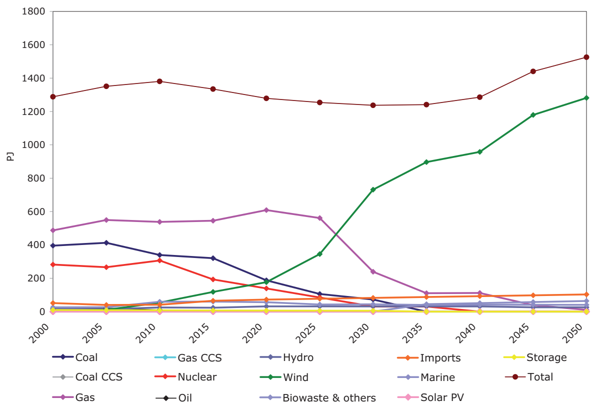
To achieve the 80% reduction in carbon emissions, each of the variants shows the same general strategy employed in the LC scenario of decarbonising the electricity sector and then targeting transport and the residential sector. The additional constraints produce novel mixtures of power generating sources, but also bring about reductions in demand. The most stringent constraints were applied in the DREAD variant and that shows the greatest demand reduction. Primary energy demand is reduced by 19% of the LC scenario,



nearly to the level in the low-carbon resilient (LCR) Core scenario.

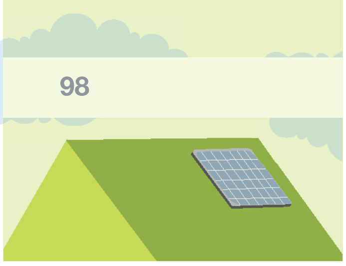
Not surprisingly, power generation under the constraints imposed by DREAD is very different than the LC Core scenario. The power sector is not very diverse in the DREAD scenario and is dominated by wind power (offshore, onshore and microgeneration); 84% of electricity is generated by wind in 2050 with the bulk of it offshore (Figure 5.11). As a consequence, the system has a very low base load (less than 10%) which is balanced with back-up gas capacity. By 2050 over 60% of the installed capacity is wind. This installed capacity of wind is three times the size of gas capacity which is installed as back-up. Achieving this type of power sector would pose a substantial challenge to society and would necessitate advances in storage technology and smart grids. This scenario therefore illustrates that if a number of energy supply technologies were constrained it could become much more difficult to achieve the UK's 80% decarbonisation target.

Figure 5.11: Changes in the electricity generating mix 2000-2050 in the DREAD scenario variant



A power supply system that is dominated by a single generating source such as is the case in DREAD is less likely to be resilient. In this case the system is built around high levels of wind power. Although the operation is predominantly under UK control, it risks both periods of still air and threats of altered resource due to changes in climate. Storage sounds to be an attractive solution, but within this variant less storage is employed than in the low-carbon Core scenario (LC). Initially both DREAD and the Core scenario use the same quantity and type (storage heaters and a little pumped hydro) but then after 2035, the level of plug-in hybrid vehicles in DREAD is only about 60% of the total used in the LC scenario. Here we have to question the capability of the model adequately to capture the opportunities of supporting intermittent power sources; the decrease in plug-in hybrid storage is probably because electricity becomes so expensive that there are better options for transport.

To deliver the power needed, the model employs two approaches: using power more effectively (by getting better returns for the energy used) and using less (by reducing demand). The DREAD scenario has a rapid increase in electricity generation after 2040 yet this increase is of a much lower magnitude than the increase in the LC scenario after 2035. Agriculture and industry maintain similar levels of electricity demand in both scenarios, but demand from the residential, service and transport sectors all fall. By 2050 in the DREAD scenario, a quarter less electricity is used than in the LC scenario.



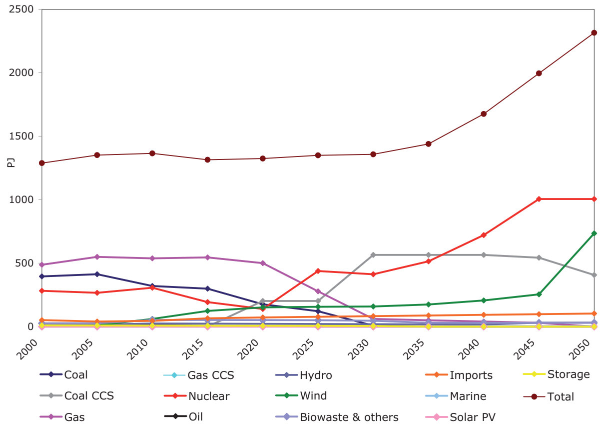
Transport fuel demand is similar between DREAD and the LC scenario until 2035, after which both show a decline as diesel and petrol use drop. The total transport fuel demand decrease is greater in LC as DREAD uses bio-diesel to deliver more of its transport needs. The greater uptake of biofuels is divided between the heavy and light goods vehicles and the introduction of bio-kerosene into the aviation sector after 2040. The strategy is, in part, targeted at reducing electricity demand while maintaining a low-carbon performance. The additional increase in biofuels is predominantly sourced within the UK and diverges from the LC scenario after 2035.

ECO Scenario

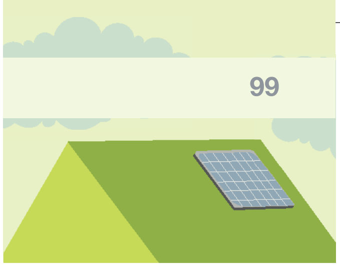
The ECO scenario illustrates a very different energy system to the LC or DREAD scenario. Primary energy demand in the ECO scenario is lower than the LC scenario; it is only around 80% of the LC primary energy demand in 2050. The ECO scenario has a very high level of electricity generation compared to the LC scenario and the other socio-environmental scenarios. Electricity production in the ECO scenario is primarily from nuclear power, which is the dominant source of electricity, coal with CCS and wind power, the latter rapidly increasing in the 2040s (Figure 5.12).

The removal of domestic open-cast coal and the increased global costs of fossil fuels have a noticeable impact on the development of the electricity mix over the 50 year period. Existing coal generation continues at a moderate level for slightly longer in the ECO scenario than in the LC scenario. However, in the ECO scenario, the uptake of coal CCS is significantly lower than in the LC scenario; in 2050 there is less than a third of the coal CCS seen in the LC scenario. This reduction in the use of coal CCS for decarbonisation in the ECO scenario reflects the reduced availability of domestic coal resources and the increased global price for imported coal which make coal CCS less cost effective than it was in the LC scenario. This is just one example of how public attitudes towards energy technologies could have a significant impact on the deployment of certain technologies and the overall energy system mix.

Figure 5.12: Changes in the electricity generating mix 2000-2050 in the ECO scenario variant



In the ECO variant, there is a rapid rise in electricity demand following 2040, with industry and hydrogen production taking the lion's share of the increase. Up until that point the industrial sector had shown a decline similar to that in the Core scenario. Both the residential and transport sectors in both ECO and LC also have increasing electricity demand, yet the increases start earlier in the ECO variant and are relatively more gradual in these sectors.



The installed capacity of the power sector in the ECO scenario rises to almost 180 GW by 2050 compared with 120 GW in the LC scenario. The increased installed capacity in the ECO scenario is largely due to the installation of wind capacity in the last 5-year time step; high levels of wind must be installed to meet the demand for electricity and further, when more wind capacity is built it has to be balanced by additional gas generating capacity.

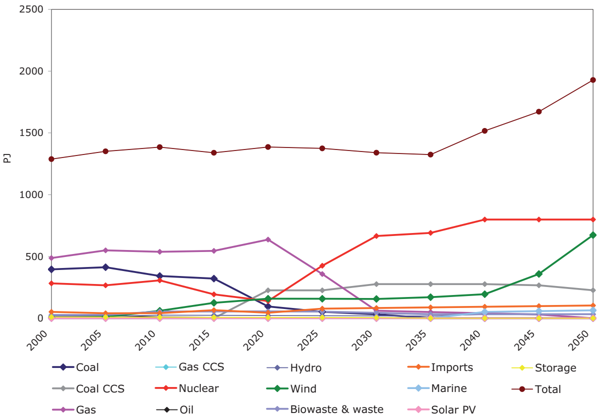
The total constraint on all transport biofuels in the ECO scenario leads to increased difficulties in decarbonising the transport sector. Whereas the Core scenario partly decarbonises the transport sector by utilising bioethanol, biodiesel, hydrogen and electricity as transport fuels, the ECO scenario cannot use either of the biofuels. The scenario continues to use some electricity for transport but it does not dramatically increase from the LC scenario, most likely because there are other more cost-effective measures to decarbonise the energy system. Hydrogen fuels are introduced 5 years earlier in the ECO scenario than in the LC scenario. As a result of the changes to transport fuel availability and costs, the ECO scenario retains higher levels of fossil fuels (petrol and diesel) than the LC scenario. This causes emissions from the transport sector to be significantly higher than the LC scenario. To balance out these transport emissions, there are significant emission reductions in the service, industry and electricity sectors in the ECO scenario.

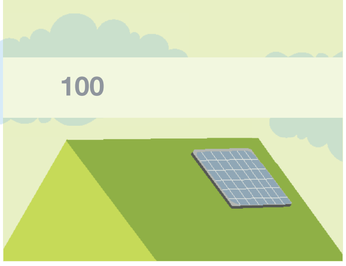
NIMBY Scenario

In the final scenario variant, NIMBY, while the primary energy demand drops by about 18% of that in the LC scenario, the primary demand breakdown by fuel type and sector remain close to the LC baseline. NIMBY remains the most similar to the LC scenario, with the only major divergence being in the selection of dominant electricity sources in the electricity mix. In primary energy, the major difference is a reduced use of coal, by 2050 being less than a third of LC scenario. Although biomass and waste also show a lower demand, other energy sources, namely nuclear and renewables show earlier uptake; nuclear levels off at its capacity limit by 2030.

The electricity demand in NIMBY matches that of the LC, but the generation mix has nuclear growing rapidly through the 2020s, to replace the role that coal with CCS has in the LC (Figure 5.13). The selection of power sources, with the exceptions of nuclear and coal CCS, show similar trends in both NIMBY and LC, through to the 2040s, when NIMBY shows a dash for wind; surprisingly, there is only marginally more gas installed to balance the

Figure 5.13: Changes in the electricity generating mix 2000-2050 in the ECO scenario variant





intermittency. As a consequence of expanding wind power, the final total installed capacity in NIMBY is greater than in the LC (~160 GW as opposed to 120 GW).

Transport fuel use in the NIMBY variant shows very similar trends to the LC, with both dominant fossil fuels (petrol and diesel) showing declines at equivalent rates. In LC, diesel declines slightly more in the last decade (2040 to 2050) and is balanced by an increase in bioethanol and biomethanol. In NIMBY, there is less biofuel available than in the LC because crops are restricted to landscapes where they are already established. Interestingly, despite crop limitations, aviation does take up bio-kerosene in the NIMBY variant.

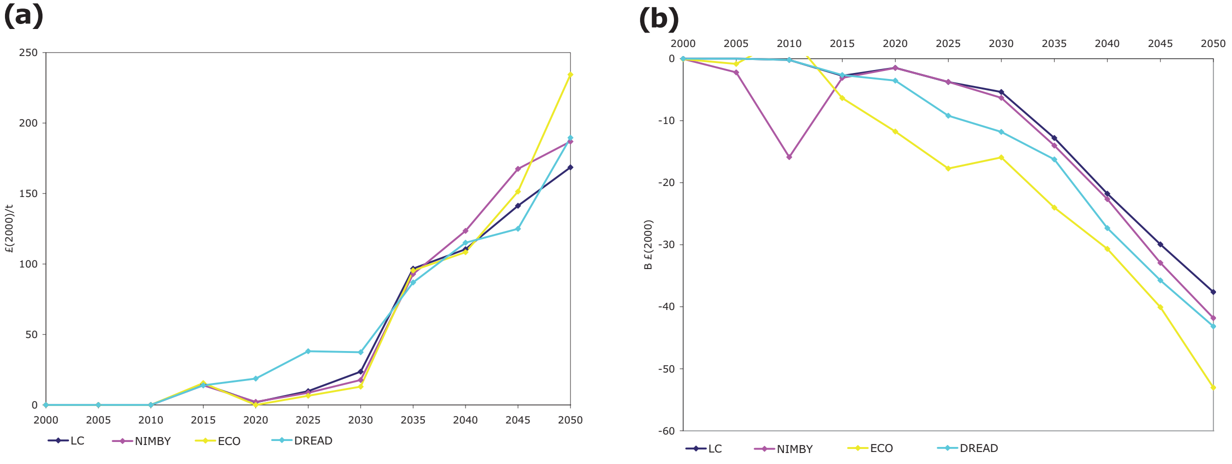
Overall Impact of Public Acceptance of Energy Technologies

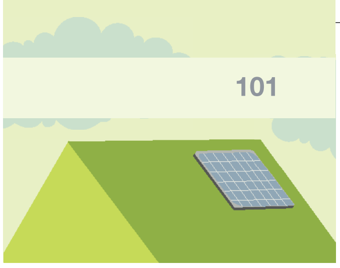
The ECO scenario has the highest cost implications for society. By 2050 the marginal cost of CO_2 is the highest in ECO as seen in Figure 5.14a. Further, using consumer and producer surplus as a measure of societal welfare, the ECO scenario shows a significantly greater decline in welfare from 2015 onwards than in the LC, DREAD or NIMBY scenarios (see Figure 5.14b).

Although the marginal cost of CO_2 in 2050 is highest in the ECO scenario, the marginal cost of CO_2 in the DREAD scenario is the highest in the middle period (2015-2030). In all three of the scenarios costs are higher than in the LC scenario. This illustrates that public acceptance of energy technologies can have a substantial impact not only on the make-up of the energy system but on the cost of decarbonisation. When the public rejects certain technologies for any of the various reasons explored in this report, decarbonisation becomes more costly and more challenging.

Yet this consideration seems to be widely neglected in discussions of decarbonisation; there is even less public discussion about how the carbon reduction

Figure 5.14 (a) The marginal costs of CO_2 (in £$_{2000}$ /tCO_2) and (b) Societal welfare expressed as consumer and producer surplus (in £$_{2000}$). Shown for 80% Low-Carbon (LC) Core, NIMBY, ECO and DREAD scenarios





targets should be met than there is of the targets themselves. If public attitudes towards UK decarbonisation strategies continue to be neglected then there may be some unexpected and unpleasant surprises in the quest to reach 80% decarbonisation, including failure to achieve the target. This is not to suggest that public attitudes should be overridden in order to reach 80% decarbonisation; rather, these socio-environmental attitudes must be understood and considered when planning the transition to a decarbonised economy.

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