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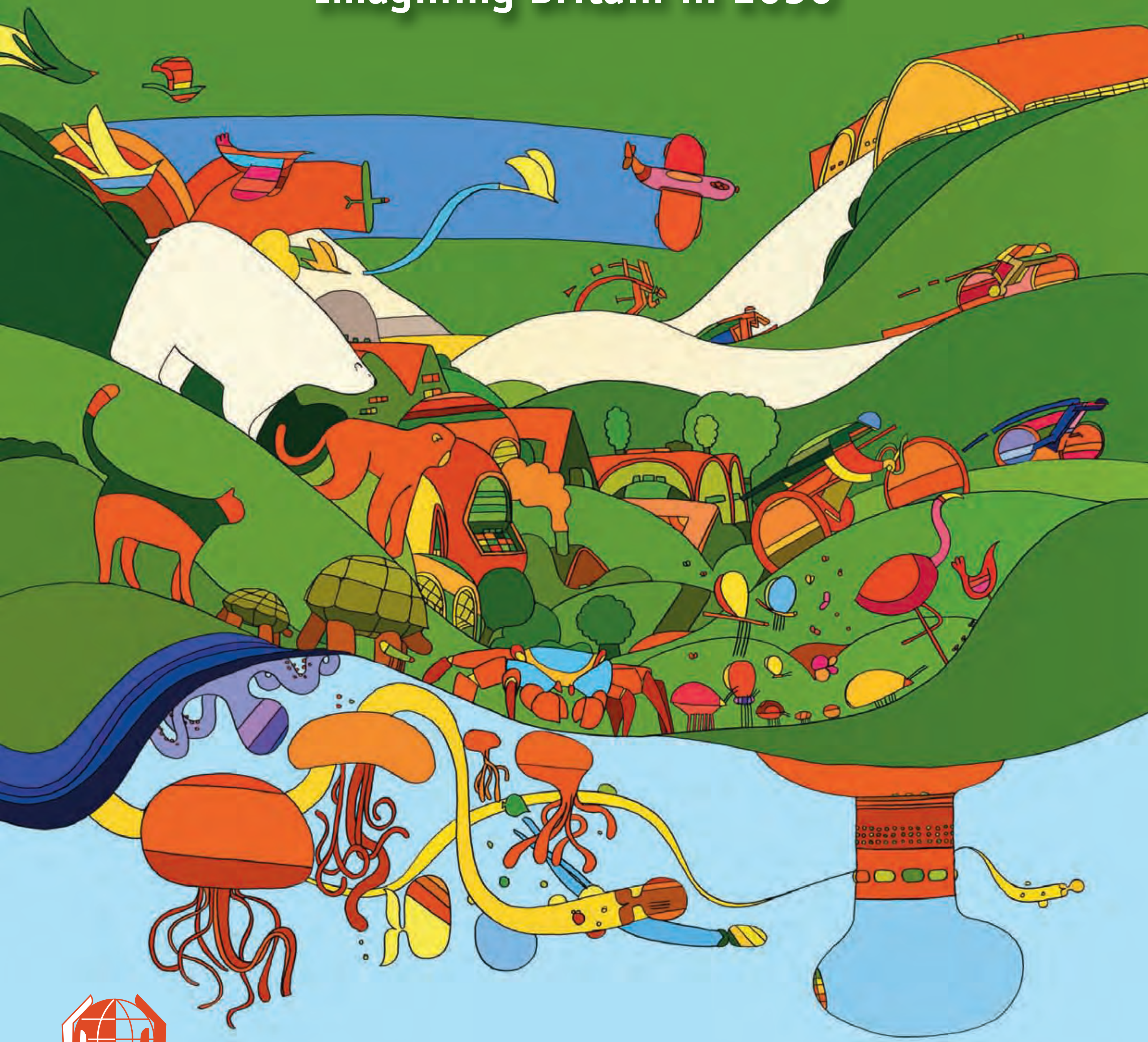
Imagining Britain in 2050



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EDITORIAL

DR MARK EVERARD and ADAM DONNAN

In the *Foundation Series* by Isaac Asimov the field of mathematics has developed to such a degree that it can predict the future. Using these techniques, a particularly bright mathematician, Hari Seldon, foresees the imminent fall of the governing authority and a dark age lasting thirty thousand years.

Our mathematics and science has developed to the extent that we can say, with reasonable assuredness, that certain things are going to happen in 2050: for example, a total lunar eclipse will take place on 30th October; and, if the authors are still alive we will be 92 and 68 years old respectively. But future societal evolution and adaptation, driven by technological advances, cultural values and behavioural change is beyond the ability of our scientific tools to map. Just take a look at any visions of the future from popular culture such as The Omega Man, 1984, Blade Runner or 2001: A Space Odyssey, to see the pitfalls of imagining the future.

So is there any point in trying to imagine a Britain in 2050, which has fulfilled its carbon reduction obligations, when we are so likely to get most things wrong? We believe so. We all aspire towards a sustainable future, but to begin on a journey, you need to know where you are heading. The clear light of science, even at our rudimentary level of development, is absolutely essential to clarify what does or does not constitute more or less helpful choices on the long path ahead to sustainability.

When we talk about a date, like 2050, that seems relatively distant, the danger is people divorce that time from actions today. But societal development is path dependent, so fractional changes in the path today can lead to changes of much larger magnitude in forty years time.

The light at the end of the tunnel

So here we are in 2050. What is it like?

Let us not fall into the common trap of overemphasising the speed of change; the sights which confront us in 2050 are unlikely to be appreciably different to today. We will still travel, farm, live in houses, work and play. There will certainly be more wind turbines, photovoltaic systems and less television aerials and telegraph wires as technologies converge into unified iEverythings. Notwithstanding more distributed and embedded energy generation, the energy mix necessary to ensure reliable and secure power supplies 24/7 means that we will still have big power plants, a grid of some sort, and people fixing it.

And what do we smell? Concerns about VOCs already put into effect will surely see less fugitive emissions and odours from industry, sofas and other domestic products. If we see lots more biofuels - which would not be a great idea given their extensive land/habitat 'take' and the energy, chemical and above all water inputs required to produce fuels of very low energy intensity - then we will have the stronger aromas of more oilseed rape and other crop aromas in the countryside and the dubious bouquet of biodiesel emissions in the city. But with fewer emissions to air, land and water, we should see improving environmental quality which will hopefully allow the recovery of wildlife in both urban and rural contexts. Conversely, the need to recycle not just more but virtually all spent products and resources may mean that we have more composting centres and spreading to land of treated sewage sludge, so there are possible odorous trade-offs on the route to 2050.

In terms of sounds, let us hope that today's hubbub has abated somewhat by 2050. After all, noise is friction is inefficiency is wasted energy, and all modes of transport will have had to address noise as a by-product of this inefficiency. Background rumble asides, our bold and sustainable future may not in fact sound a lot different, except for a lot more bees humming and birds calling in cleaner air around recovering populations of wild flowers, accompanied by cockerels and other farm noises from more embedded food production systems.

In a sustainable 2050, much of our food will be produced not by the quickest and cheapest production methods but equitably and in ways that retain the quality of soil and landscapes, and the diverse ecosystems and ecosystem services that they provide for the benefit of all in society. That will mean greater value for regionally- and seasonally-appropriate produce, with far less 'food mile' implications to meet our current unsustainable demands for out-of-season goods (see the April 2010 Environmental Scientist for further details).

In much of India and Africa, the personal space that people expect is far, far smaller than for those of us in richer parts of the world. But we had better get used to smaller personal spaces, not merely because 2050 will be substantially more crowded. Sustainability has people and the environments that support them at its heart. If we have attained sustainability - or more correctly have seriously embarked on the unending journey towards that goal in an ever-changing world - then we will be continuously learning from and about each other, our different perspectives and value systems, engaging in participatory and adaptive decision-making and governance processes that respect rather than marginalise diversity, and in so many other ways finding space for more and different people.

The pace of 2050

In a 1930 essay, *Economic Possibilities for our Grandchildren*, economist John Maynard Keynes envisaged that "for the first time since his creation, man will be faced with his real, his permanent problem – how to use his freedom from pressing economic cares, how to occupy the leisure, which science and compound interest will have won for him, to live wisely and agreeably and well." This development simply has not happened. Productivity and efficiency gains have largely been used to increase wealth rather than leisure time.

This cannot continue. If we aspire to the journey to sustainability, we will have to have more reflective time to make space for the learning that this implies. What was the outcome of what we just did, affecting people directly but also through impacts on the environment which inevitably influence their wellbeing? What were the economic implications, when these diverse 'goods' and 'bads' are accounted for alongside the money implications? What has this taught us about how we should do things differently tomorrow?

Quality rather than quantity of work will be a hallmark of the sustainable journey, recognising reflective time and dialogue with others as investments rather than indulgences. 'Fast' will be the indulgence of the future, synonymous with the adjectives 'slapdash' or 'exploitative' today, in that fast things are likely to omit important considerations about how decisions and actions impact those around us and the world we share.

So of course the economy will be somewhat different, increasingly internalising ecosystem services in much the same way as it is beginning to do today through 'paying for ecosystem service' (PES) markets, levies on climate change gas emissions, and so forth. With disposal increasingly costly, long-life durable products that consume little energy and have few maintenance requirements will gain market advantages over the 'cheap and cheerful' tat so commonplace in today's 'throwaway' marketplace. Perhaps the lifetime costs of products, including refurbishment and disposal/recovery, could be included as some form of bond held against current market externalities? That would change the manufacturing economy profoundly.

Conclusions

We hope that you find this future scope a useful exercise. Perhaps we have gone about it the wrong way; many of the authors have worked from the assumption that Britain had fulfilled its carbon reduction obligations (currently 80% reduction on 1990 levels). This is a big 'if'. Their motivation is to offer a positive and desirable view of the future from which we could 'backcast'. Backcasting approaches the challenge of discussing the future from the opposite direction (for more on backcasting see the 2050 Bristol article). Other authors have looked to current trends and questioned what society will look like if these trends have continued. The final approach has been to offer a number of different scenarios, depending on the societal choices we make. All these approaches have their merits and disadvantages.

In the *Foundation Series* scientists manipulate the development of society in secret; we have the luxury of being more open. In a report last year, Futerra, a sustainability communications agency, argued that climate change is no longer a science problem, but a salesman's problem. They called upon scientists, campaigners and business to stop selling visions of hell but sell a new vision of a' low carbon heaven'. This journal is the Institution's contribution to that vision. As Rose Bailey and Professor Jim Longhurst say in their article it is time to "stop trying to 'predict' the future and think about 'creating it' instead."

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TRANSPORT IN A LOW CARBON BRITAIN

Changes in energy sources and transport modes will dominate a low carbon Britain in 2050, according to ROGER KEMP

Society in 2050

Within British culture, transport is a subject that raises strong emotions – many still think of Lord Beeching's report of March 1963, *The Reshaping of British Railways*, with antagonism and the railways attract a greater following of enthusiasts, magazines and commentators than any other sector of the national infrastructure. The growth of 20th century society went hand in hand with the development of the automobile. Cars and motorcycles are iconic and aspirational in a way that most other energy-consuming goods are not and are central to much contemporary culture. Transport cannot be treated simply as a technical issue to be dealt with in terms of engineering practicalities and accounting. Politicians have long recognised that to be seen as "anti car" is the surest route to being out of office.

Transport in a 2050 low carbon Britain will be determined by the state of British society at the time. Some official studies assume a continuation of what went before; this thinking was exemplified in the Stern Review which discussed how climate change mitigation might make the difference between 2.49% and 2.50% per annum growth over the whole of the 21st Century (Stern, 2007).

By contrast, Professor John Beddington, the government's Chief Scientific Advisor, has warned that "a perfect storm of food shortages, scarce water and insufficient energy resources, due to come to a head in 2030, threatens to unleash public unrest, cross-border conflicts and mass migration as people flee from the worst-affected regions" (Sample, 2009). Set against Beddington's perfect storm, Stern's hypothesis of steady growth for the next 90 years seems more than a little complacent.

It is possible that the year-on-year growth of the first years of the 21st century will be resumed and will continue for decades. Alternatively we might see a stagflation, high levels of structural unemployment, increased economic migration, energy shortages and a deterioration of infrastructure. A vision of transport in 2050 has to include either end of this wide spectrum of outcomes but, in a short article, there is insufficient space to consider more than a small part of this spectrum.

Where will energy come from in 2050?

A recent study by the Royal Academy of Engineering looked at how energy might be provided in 2050, while meeting the target of an 80% cut in emissions (Royal Academy of Engineering, 2010a). The present energy system is shown in Figure 1:

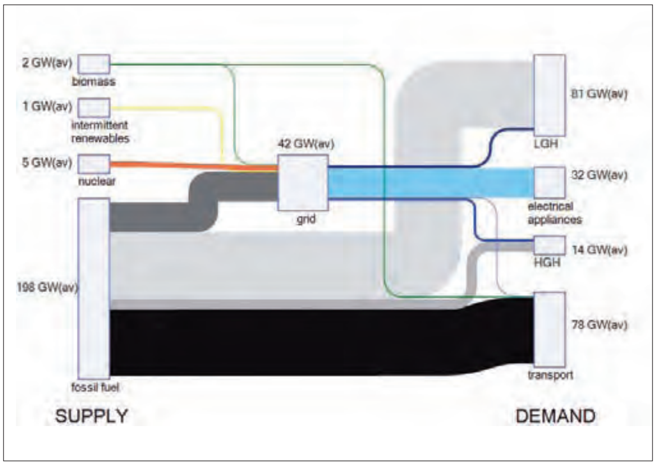

Figure 1: UK energy flows 2008 (GW average) *(Source: Royal Academy of Engineering, 2010a)*

On the left of the diagram are energy sources: fossil fuels, nuclear power, intermittent renewables (mainly wind) and biomass. On the right are the users: transport, high-grade heat (HGH) (mainly for industrial use), electrical equipment and lighting and low grade heat (LGH) (including domestic heating and cooking). It can be seen that the two largest flows of energy are from fossil fuels to transport and LGH. This means that, during peak periods in the winter, the LGH flows will be much greater and, at off-peak times in the summer, much less.

Having established the current position, we then projected this forward to 2050. Of the various scenarios considered, two are particularly relevant to transport; both these scenarios assumed a 40% reduction in the use of LGH by better insulation and the widespread adoption of heat pumps, and a 20% reduction in all other energy use, including transport. These are challenging targets, bearing in mind the likely increase in population by 2050.

In both scenarios the maximum feasible contribution from renewable energy is assumed: 10,000 onshore wind turbines, offshore wind equivalent to 38 London Array wind farms, 25 million houses fitted with solar panels, 1000 miles of Pelamis "sea snake" wave energy converters, the largest option for the Severn Barrage, etc. The amount of fossil fuel used was determined by the allowable emissions and the balance was made up by nuclear power or fossil-fuel plants fitted with 100% efficient carbon capture and storage (CCS).

Figure 2 shows a scenario in which fossil fuels prioritised for transport.

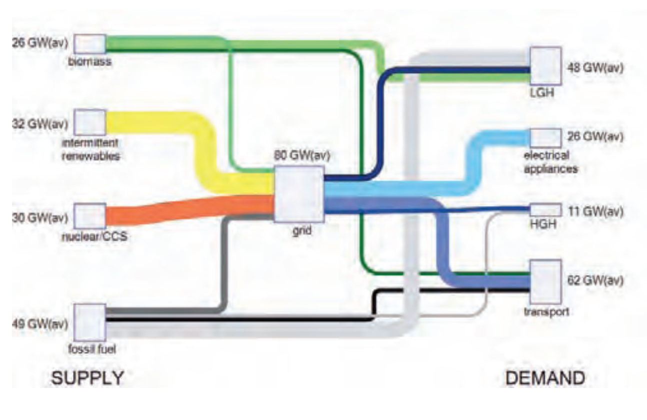

Figure 2: Fossil fuel prioritised for transport *(Source: Royal Academy of Engineering, 2010a)*

What is striking about this scenario is the extent to which transport will be electrified; even if fossil fuel is prioritised for transport, a third of the energy delivered will be in the form of electricity. As the efficiency of an electric vehicle is higher than vehicles with an internal combustion engine, the mix of vehicle types will be weighted towards electric propulsion. The scenario would require a revolution in the home – gas boilers would be phased out and heating would be through heat pumps and direct electric heating. This would require nuclear power or CCS providing an average of 39 GW which, bearing in mind seasonal and diurnal variations, implies perhaps 60 GW installed capacity (For comparison, Sizewell B nuclear power station is 1.2 GW).

In the alternative scenario in which fossil fuels are prioritised for heating, the hydrocarbon fuel left for transport is barely sufficient for aviation and all surface transport would need to be electrically-powered.

One way of reducing emissions is modal shift from high-energy modes, usually thought of as road and air, to low-energy modes, such as rail. How realistic is this as an option though?

Modal shift

One way of reducing emissions is modal shift from high-energy modes, usually thought of as road and air, to low-energy modes, such as rail. How realistic is this as an option though?

The proportion of people and goods travelling by different transport modes is analysed in the Government's annual report *Transport Statistics, Great Britain* (DfT Transport Statistics, 2008). For this study, data from the November 2008 report have been used. The overall split for passenger transport is shown in Figure 3.

This graph shows the challenge involved in achieving emissions reduction by modal shift; since the 1950s travel by car (including vans and taxis) has increased until it now represents 85% of the total. A similar situation can be seen in freight transport; road transport is dominant and represents 66% of the total.

Increasing rail's share

Figure 3 shows that rail accounts for about 10% of all passenger journeys. It is the dominant mode in those areas where it is most suitable, such as commuting into London and intercity journeys to or from Central London.

Commuting covers a wide range of different situations. It includes someone living ten minutes walk from Carshalton Beeches station and commuting to an office in Victoria Street as well as someone living rurally in Betws-y-Coed and commuting to an industrial estate on the outskirts of Wrexham. The former could easily commute the 20 km by rail (and probably chose to live at that address to make it possible). The latter has no real option but to commute the 75 km by road. Looking at the statistics we see that less than a third of the population lives near a rail network and, of these, only a third commute regularly by train. Thus to achieve 10% modal shift would require doubling the number of people using rail in areas where it is available.

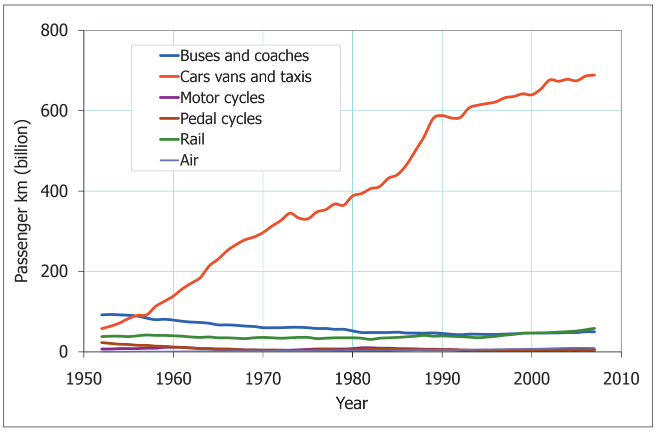

Figure 3: Modal split, passenger transport *(Source: data from DfT 2008)*

As commuter services into major cities are already frequently overcrowded, doubling the number of rail commuters would require building new lines as well as new trains and would still make only a small dent in CO_2 emissions. Similar arguments apply to intercity travel – doubling the capacity of the present network to encourage modal shift, not traffic growth, would require new lines serving routes like Cambridge – Chester; not just the traditional intercity corridors targeted by the proposed High Speed Two rail line.

Apart from the cost, re-establishing the dense network of lines that existed in the early 20th Century is not environmentally desirable. Trains are efficient means of moving large numbers of people on defined corridors; a good example is the Tokyo – Osaka Shinkansen that can carry 30,000 passengers per hour per direction. In contrast, the Edwardian rural train services, seen by some as totemic of the *Golden Age of Railways*, were environmentally disastrous, burning tonnes of coal for very few passenger-km.

Freight poses a different problem – most road freight travels only short distances. Figure 4 shows the changes in average trip lengths over 30 years.

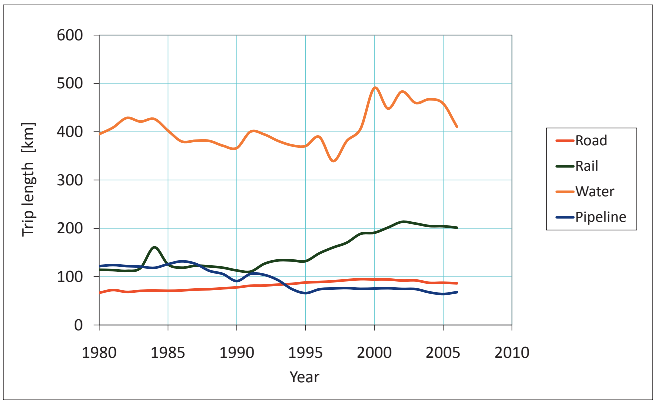

Figure 4: Average trip lengths *(Source: data from DfT 2007)*

The average trip distance for road freight is less than 100 km; as this includes a proportion of long-distance hauliers, a large number of trips will be less than 50 km and will involve small payloads in urban areas – a market that cannot be addressed by rail freight.

While there is a strong environmental case for further railway electrification and encouraging suitable traffic to use the network, modal shift will not result in a reduction of CO_2 approaching the 80% target. For a century, society has developed around the flexibility of the car and the delivery van; restructuring society to fit round an inflexible rail network is a challenge that politicians are unlikely even to consider.

Electric cars

Transport policy makers are in a quandary; there is no realistic possibility of modal shift from road to electrified rail and, even if fossil fuels are prioritised for transport, a large fraction of the energy in a low carbon society will have to come from electricity. At present, electric vehicles (EVs) are limited to small cars suitable for urban use; can they ever supplant hydrocarbon fuels for business use and the family car?

In May 2010, the Royal Academy of Engineering published a report into the implications of a widespread switch to electric vehicles (Royal Academy of Engineering, 2010). This analysed the options for extending the range of EVs from the present 100 – 150 km to the maximum owners might want to drive in a day – typically 600 km (equivalent to a trip from London to Edinburgh).

A medium-size electric car uses around 0.2 kWh/km. Thus a car with a range of 100 km needs a battery capable of storing 20 kWh. Until the last decade, most EV batteries used lead-acid chemistry with a maximum energy density of 35 kWh/tonne. Now Lithium ion batteries can be made with an energy density of 150 kWh/tonne and it is expected that Lithium-Sulphide or Zinc-air batteries with an energy density of 500 kWh/tonne will be available within a decade. With these emerging technologies, an EV with a 200 kg battery pack would be able to store 100 kWh giving it a range of 500 km. Problem solved – apart from the cost of the battery.

Unfortunately there is another problem: how to charge such a battery? A domestic 13 A socket is capable of supplying three kW; EV drivers could charge a 20 kWh battery in six hours, during the night time when there is likely to be a surplus of low carbon electricity. Recharging a 100 kWh battery would need a 60 A socket. If there are only one or two EV owners in a street, this would not be a problem but, if many people bought such cars, the electrical distribution system would need major reinforcement.

Researchers at Imperial College (Offer *et al.*, 2010) have used data from the National Travel survey to assess the proportion of trips that can be made by an EV with different battery capacities (Figure 5). This shows that, for the mythical "average motorist" a 20 kWh battery will provide sufficient energy on nine days out of ten and would allow 80% of mileage to be electrically powered.

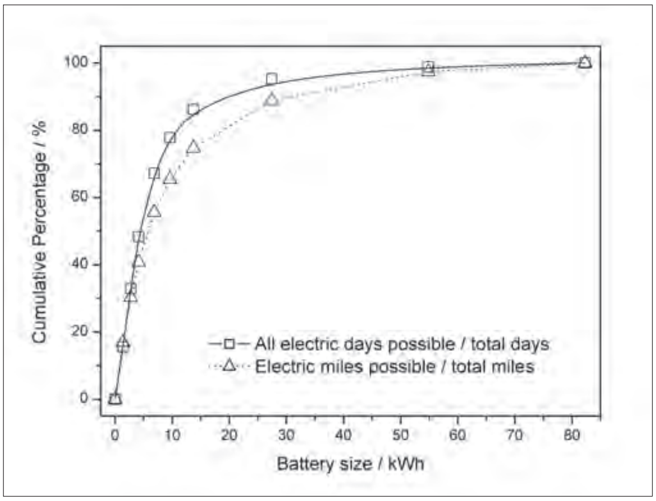

Figure 5: Proportion of trips possible from batteries of different capacities *(Source: Offer et al., 2010)*

The question then becomes how to come with that one day in ten when the battery does not hold sufficient energy. Various options have been proposed:

- Owning two cars? This cuts out most of the population;
- Leasing a petrol car once every 10 days? Problematic if everyone wants to go on holiday at the same time;

- Battery exchange stations? Fine for urban areas, less likely in the Mull of Kintyre and relies on perfect international standardisation;
- Fast recharging? This requires heavy connectors, comparable to an aircraft ground supply, and a high-capacity grid connection to the charging station;
- Topping-up at cafés, car parks, shopping centres, sports grounds? This is likely to use electricity at peak periods when it is supplied by fossil fuel, hugely expensive infrastructure.

None of these options looks a winner.

The alternative might be the plug-in hybrid electric vehicle (PHEV). This is an electric vehicle with a small petrol or diesel engine, connected to a generator that switches-on when the battery reaches a particular level of discharge and provides the average power needed for the rest of the journey. Since it does not need to operate over a wide speed range, provide peak power for overtaking or high torque at low speeds for initial acceleration, the engine could be much smaller, lighter and more efficient than conventional car engines. If a PHV can achieve 60 mpg when running on liquid fuel and the battery is sized so 80% of the distance travelled is electrically-powered, that is equivalent to 300 mpg, which meets the objective of an 80% cut in CO_2 emissions – always assuming the battery can be charged at night when low carbon electricity is available.

How "green" is a PHEV compared with a train?

It is a principle of faith in some environmentally conscious groups that trains are always more environmentally desirable than cars. A study for the White Paper on Sustainable Railways (Royal Safety & Standards Board, 2007) showed that the energy consumption of high-performance diesel trains was not appreciably less than a modern car. Best practice for a suburban electric train is energy use of 0.03 kWh per seat-km. If an electric car achieves 0.2 kWh per km and has four seats, this is equivalent to 0.05 kWh seat-km. There is, however, a crucial difference between these numbers: the train has no energy storage so the energy has to be supplied by the grid when it is used, whereas an electric car can be charged when low carbon generation is available.

By 2050 it is likely that almost all of the night-time electricity supply will be effectively zero-carbon. However there will always be a need for peak-lopping or standby capacity that is likely to be provided by gas turbines, if for no other reason than that the embedded energy in most renewable generation makes it environmentally undesirable to build capacity that is used only at peak times. Looked at solely from the point of view of CO_2 emissions, 0.05 kW taken at night will be "greener" than 0.03 kWh taken during the peak commuting period.

Transport in a low carbon Britain

What will transport in a low carbon Britain be like? We can ignore science fiction dreams of jet packs, personal heliports, 500 km/h magnetic levitation or personal rapid transport systems; instead we are likely to see concepts based on those with which we are already familiar – cars, vans, trains and buses.

The one thing in common with all these will be the use of electricity. Plug-in hybrids will be the usual drive system for smaller vehicles, with trolley or battery hybrid buses and all-electric trains. There will still be good land-use reasons to discourage cars in city centres but the environmental benefits of PHEVs for rural and inter-urban journeys could encourage a different view of what counts as "green".

Energy (and thus transport) will however be expensive. Installation and maintenance of the fleet of renewable energy equipment will require tens of thousands of skilled technicians and support staff, often working in difficult conditions. Nuclear and CCS fossil-fuel generation will also be expensive. People will travel less than now; long-distance commuting to work from a rural idyll will be seen as an aberration, not an aspiration. Britain may become a more urban society and one where it is, once again, usual to live near your work.

All this is, however, conjecture – Beddington's perfect storm may have other outcomes that are far less enviable.

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CITIES AND THE VISION OF A GREEN, PLEASANT AND LOW CARBON UK

DOTUN OLOWOPOROKU and JIM LONGHURST

discuss the future implications of current low carbon initiatives in a number of major cities in the UK

Although carbon emissions cuts across geographical boundaries, its management on a global scale poses significant governance challenges, given the differing local circumstances, priorities, capabilities and political situations. The scale of these challenges is further increased by the existing dichotomy between the global impact of carbon emissions and its local sources. Large proportions of sources occur at the local scale, such as car exhausts, household heating and cooking, and energy use in schools and offices which are often within the administrative jurisdictions of city and large urban local governments.

Approximately half the world's population now lives in urban areas and about 70% will be city dwellers by 2050. Accordingly, cities and large urban areas in the UK account for a large proportion of energy consumption and subsequently a good share of its carbon emissions. Cities have specific influence on renewable energy and greater energy efficiency through their role in local planning, transport, housing and education, and their ability to reach out to wider communities and encourage other local service providers to take action.

The overriding theme in this article is to explore the role and importance of the city-region contribution to low carbon 2050 vision based on existing direction and pace of policies and strategies. Given the potential influence of local government on issues such as transport, housing, spatial planning and evolution of public attitudes, what are the existing or will be the substantial contributions of the major cities towards meeting the carbon emissions target? What are the identified priorities and the importance given to them in relation to other local or regional policy? Does carbon management sit in isolation from other policies or is it effectively integrated? Are the identified plans and framework sufficient to deliver the expected goals? Are the cities resourced sufficiently and appropriately for implementing the carbon management plans? Most importantly, what is there in the current and potential city/council-led low carbon strategies and policies that provide sufficient confidence that we may realise the green and pleasant 2050 vision?

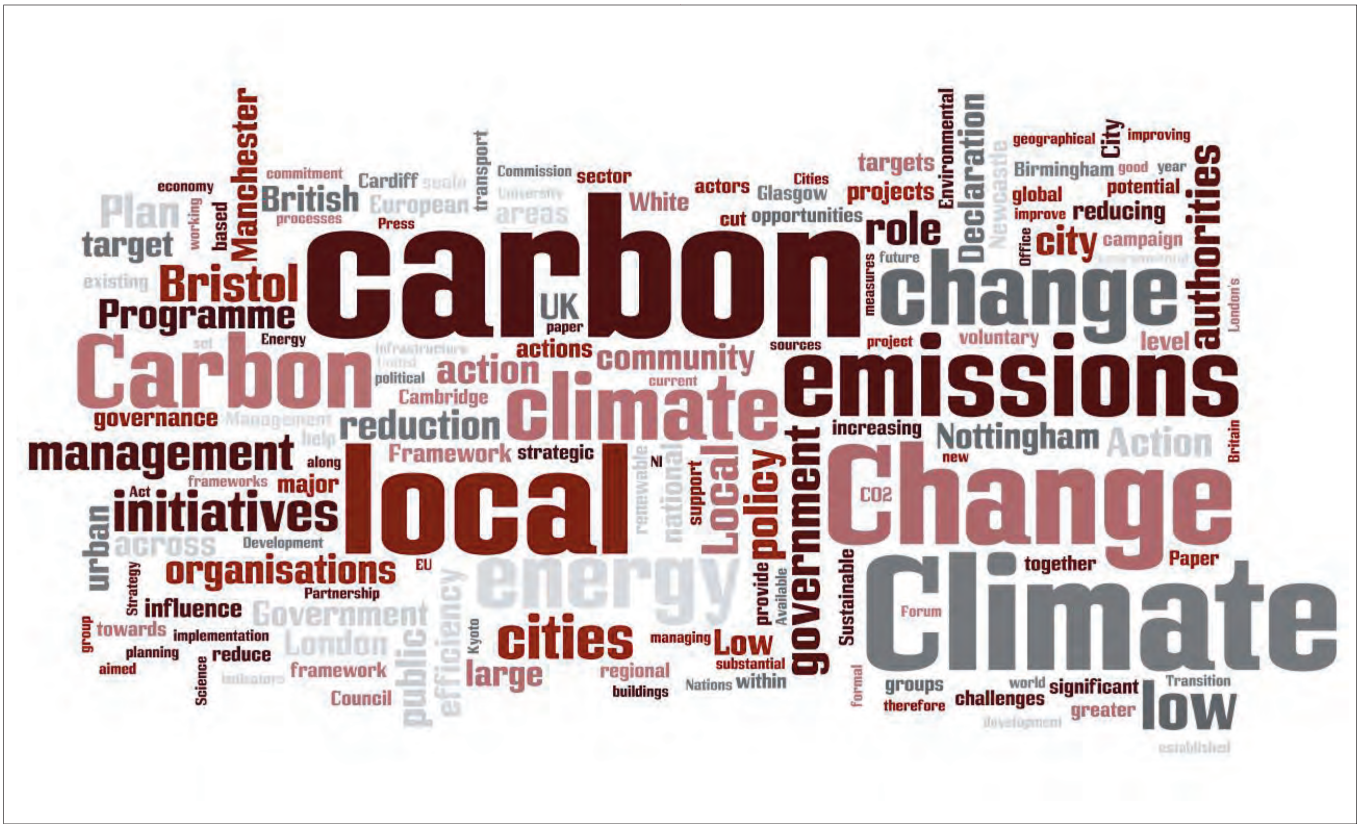
To conceptualise the impact of city-region on this, it is necessary to situate the city-regional led initiatives in the current climate change policy development and the expectations which are articulated in the Climate Change Act.

Current low carbon initiatives in major UK cities

The ability of local government, especially the major cities and large urban areas in Britain, to influence and shape the 2050 low carbon expectations is principally derived from their regulatory role and direct links with community groups and individual households. The actual implementation of the policy intentions is, however, conditional to the availability of necessary institutional capacity - at the local government levels - in consolidating and streamlining action. Within the existing policy framework, city councils can provide institutional opportunities for aligning energy, pollution management, transport and spatial planning policy with low carbon initiatives. Estimates by the Local Government Association (LGA, 2007) suggest the local authorities can help cut carbon emissions by 150 million tonnes of carbon dioxide a year, contributing to the national target of a 26–32% reduction by 2020. Considering the policy direction outlined in the 2009 White Paper UK *Low Carbon Transition Plan* (DECC, 2009) the years ahead will see greater emphasis on increasing the local-level action and community based initiatives that will influence carbon emissions reduction locally.

The implementation of such initiatives will, however, not just occur at distinct levels of formal governance by state actors based on defined geographical scales in isolation to others – the local, national and international – but also by non-state actors that cross geographical and traditional governance boundaries and scales. This is particularly true in the increasing number of projects and initiatives involving joint commitment between government and non-governmental environmental organisations, companies, charities, and campaign groups with direct influence on formal governance. As noted by Bulkeley and Moser (2007) there is a current shift from traditional "mainstream global environmental politics" with a primary focus on the role of state-based actors and formal political processes to the emerging grassroots movements, campaign groups and companies which cut across state and non-state actors. While the actions of informal groups and processes will play significant role in shaping the low carbon future, the lack of information and regulation surrounding such processes implies that it is the actions of local governments that will become more apparent. The pivotal role for local government has been frequently articulated through a range of recent legislative and policy instruments, including:

- **Local Government Act 2000** which strengthened the importance of developing community strategies.



◆ **Nottingham Declaration on Climate Change** which was launched in October 2000 as a voluntary declaration. Over 300 local authorities now pledge to systematically address the causes of climate change and to prepare their community for its impacts.

◆ **Climate Change Declaration (Scotland)** which commits signatories to contribute to the delivery of Scotland's and the UK's Climate Change Programme, including efforts to reduce greenhouse gas emissions and to adapt to future climate change scenarios

◆ **Climate Change Programme 2006**, in which the action of local authority on climate change is prioritised.

◆ **'A Climate of Change'** report published in 2007 by the Local Government Association (LGA) Climate Change Commission which concluded that a significant and measurable improvement in the local government response to climate change was essential given its "proximity to citizens, and a strategic role leading other public, private and voluntary sector partners."

◆ **Performance Framework**, introduced in 2007, includes three sets of national indicators relating to climate change abatement and adaptation.

◆ 2009 White Paper UK **Low Carbon Transition Plan** which expressed Government's desire to 'unlock greater action by local authorities in identifying the best potential for low carbon community-scale solutions in their areas'

◆ **Carbon Trust Local Authority Carbon Management Programme** which provides councils with technical and change management support and guidance tools to help them realise savings in carbon emissions.

◆ **Carbon Reduction Commitment** outlining strategy for improving energy efficiency and reducing carbon emissions through awareness campaigns and behavioural changes in large organisations such as large local authorities.

◆ **Low Carbon Cities Programme** (LCCP) which supports three major UK cities - Bristol, Leeds and Manchester - in developing city-wide carbon reduction target led by the public sector, supported by the private sector and owned by the entire community.

◆ **Core Cities Group** which is a network of major regional cities responsible for around 30% of England's carbon emissions. It provides help in increasing local renewable energy supplies, improving public transport, addressing the energy efficiency of buildings, and enhancing waste and water management services.

Although there are apparent failings in post-Kyoto international agreements towards reducing carbon emissions, as demonstrated by the Copenhagen meeting, emerging trends suggests that there are significant efforts at the city-region level towards carbon management. While these efforts, for the most part, are fragmented and piecemeal, local

1 Belfast

- Sustainable Development Action Plan embodying priority actions identified in Northern Ireland
- Range of measure to reduce carbon emissions in line with (but not tied to) a cut of 25% carbon emissions by 2025 and 80% by 2050
- Focus on reducing emissions from council buildings and operations and reported through primary performance indicator

2 Birmingham

- Climate change strategic framework: *Cutting CO_2 for a Smarter Birmingham Strategic Framework*
- Birmingham's Local Strategic Partnership (LSP) that brings together various partners to develop a partnership-based approach to both reducing emissions and helping the city prepare for a changed climate
- Climate Change Carbon Reduction Partnership which is responsible for delivering part of Outcome 5 and NI 186

3 Bristol

- Green Capital Initiative aimed at accelerating the pace of change in the economy and communities towards the low carbon future
- Climate Change Action Plan and Low Carbon Cities Programme
- Innovative low carbon building and renewable energy policies in Local Development Framework
- Bristol Environmental Technologies Sector (BETS)
- Forum for the Future's ***'Sustainable Bristol City-region'***: a 10-year project aimed at making "the Bristol city-region a model for the UK and for the world".
- Ongoing sustainable development based projects such as rapid transit; greater Bristol bus network and the development of a further 6MW of wind turbines

4 Cardiff

- Signatory to low carbon initiatives such as the 2006 Welsh Declaration on Climate Change and Energy Efficiency and the 10:10 Campaign
- Changing Climate, Changing Places focussing mainly on adaptation measures along with some mitigation
- A staff awareness campaign is being piloted within Cardiff Council, focusing on climate change mitigation issues, with the aim of replicating the campaign in partner organisations across Cardiff
- In 2009 a Vision Forum Carbon Lite group was established with representatives from key organisations along with major energy users working together to share best practice and identify projects where joint working will be beneficial

5 Glasgow

- Carbon Management Plan setting carbon baseline and reduction target over a five- year period
- Signatory of Scotland's Climate Change Declaration in 2007
- Review progress on Scottish Climate Change Declaration targets
- Glasgow Climate Change (GCC) Partnership which brings together public, private and voluntary sector organisations to adapt to the challenges of climate change through education and by sharing good practice
- Sustainable Glasgow Project providing evidence to support investment in projects that will contribute to its sustainability objectives

6 London

- Investment in decentralised energy infrastructure, waste and recycling infrastructure
- Greening London's public spaces
- Opening up opportunities for a low carbon economy
- Launch of ten pilot Low Carbon Zones awarding grants, public support and programme management to each winning zone
- Conversion of London's bus fleet to less carbon-intensive hybrid buses

7 Manchester

- City Council objective of becoming a "Green City" by 2015
- Manchester's Climate Change Action Plan setting out a strategic framework for addressing the challenges and opportunities of climate change
- Low carbon energy infrastructure
- Establishing a Manchester Prize, attracting cutting edge designers and architects from across the world to turn the City into a living laboratory for climate change solutions
- ***i-Trees*** project to create a green corridor along Oxford Road by planting more trees and installing green roofs and façades.
- Climate Change Agency established in 2009
- Environmental Business Pledge
- 100 Months Club established in early 2008 to enable businesses in Greater Manchester to share strategies for carbon reduction
- Manchester's "Mini-Stern" identified high economic costs of failing to take effective action (up to £21 bn in Greater Manchester by 2020)

8 Newcastle

- Newcastle City Council Climate Change Strategy and Action Plan
- North East Regional Climate Change Declaration as a regional extension of the Nottingham Declaration
- CarbonNeutral Newcastle offering the potential to engage with businesses in delivering the City's climate change strategy
- Raising the profile of climate change across all audiences
- Signing up businesses, organisations and events to carbon management programmes
- Influencing regional policy and strategic development to adopt low-carbon principles
- Newcastle Warm Zone (NWZ) a not-for-profit partnership aimed at reducing fuel poverty and improve energy efficiency across all of the city's households by offering free or discounted insulation and heating measures together with an integrated package of benefits assistance and energy efficiency advice

9 Nottingham	
	● ZERO 2100 Climate Protection Strategy ● Commencement of a new climate change plan for the city; ● Nottingham Carbon Club ● Nottingham City Council is participating in the Carbon Trust Local Authority Carbon Management Programme ● Eco-Management & Audit Scheme (EMAS)

Table 1: Summary of current low carbon initiatives and activities in selected UK cities

governments in major cities and large urban areas in the UK are demonstrating continuity in high-level targets and measures informed by climate science (see Table 1). The cities highlighted in the table are not representative of the UK local authorities. Rather they are selected as examples of major cities in the UK with council-led low carbon initiatives.

Cautious optimism

Considering the current trend, by 2050 UK cities will have better informed public attitude towards carbon management at the local level, in addition to the potential of promoting innovation, locally-specific solutions and business opportunities for emerging low carbon economy. Despite the snippets of climate change scepticisms, public opinions and, to a great extent, public policies in the UK will be largely influenced by the realities of climate change and its impact. This is demonstrated by some of the optimisms expressed in the article in this journal on 2050 low carbon Bristol scenarios which are grounded in existing initiatives and opinions of local stakeholders and decision-makers within a UK city-region. According to the article, it is expected that by 2050 spatial planning development, housing, energy and transport policies may give more consideration to innovative ways of reducing per capita and regional carbon footprints. Rhetorical commitments to newer frameworks in line with the national policy intentions will increase, but with a limited number of carefully calibrated interventions to minimise future carbon emissions. Herein lay the uncertainties around the ambitious green and low carbon future.

Any real and substantial reductions at the city-regional level are conditional to the direction and pace at which council-led low carbon initiatives are implemented along with associated target indicators and monitoring programmes. By and large, it is difficult to determine with confidence that the resources being deployed, at the moment, match the articulated ambition for such reductions. It is also not certain that the current rate of implementing measures will be sufficient to deliver the 2050 vision. Despite the various political and popular posturing, evidence does not yet suggest that carbon management is at the heart of the decision-making processes of the city councils. For example, the popularity of the Nottingham Declaration among most of the authorities is seen by many as 'good publicity' for minimal effort. Its non-obligatory nature implies that it lacked checks or monitoring regimes, which potentially allows councils to become signatories without necessarily taking difficult actions. In the face of an array of frameworks and activities, consistent and coherent integration into city-regional decision making processes does not yet appear to be present.

Less talk, more action

Given the current media spotlight on climate change, it is inevitable that most local politicians will continue to discuss ambitious adaptation and mitigation programmes. There are, however, concerns that strong rhetoric and high ambitions will be constantly weakened by a deficit in measurable implementation strategy. It will take more than rhetoric, ambitions and political posturing to achieve the 80% carbon emission reduction by 2050. Better coordinated, consistent and measurable actions are therefore needed at the local level. There is a better chance for a better future if city governments start paying due regard to climate change mitigation and adaptation in all their decision- making roles. Real progress will be made when carbon management is used as the primary reason for overturning an otherwise attractive economic development proposal. Until this occurs the hope of green, pleasant and low carbon future is still in doubt.

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WILL WE BE BREATHING EASY IN 2050?

Will air quality still be a problem in 2050? **DAVID MUIR and BERNARD FISHER** consider the possibilities under a "business as usual" and other alternative scenarios

How does one try to imagine what life, let alone air quality, will be like in 2050? Science fiction writers have made many 'predictions' about life on earth in the near and not so near future. Themes range from an ever increasing population to speculation on a radioactive world. One interesting scenario is presented by Frederik Pohl in *The Years of the City* which describes a world becoming increasingly polluted as a result of power demand and getting hotter and hotter... within a time span of the 21st Century!

The remit of this edition of the *Environmental Scientist* is to look at what we might expect the environment to be like in 2050 in a low carbon world. In order to do this for air quality it is also necessary to consider, albeit briefly, what 2050 might be like in a 'business as usual' world.

Looking back to inform the future

First of all we have to ask the question "Is air quality still likely to be an issue in 2050?" Sadly, the answer is probably "Yes". History has shown us that whenever we think we have sorted out the problems caused by air pollution a new issue arises. By 1970 the air quality profession thought we had finally solved the centuries old problem of smoke from (mainly) domestic coal burning only for industrial air pollution to emerge as an issue. When this appeared to be coming under control the issue of lead from petrol engine road traffic emerged. This was then tackled and, as we were starting to congratulate ourselves on this success, nitrogen dioxide and fine non-exhaust particles, again mainly from road traffic, sprang up in the 1990s and are still very much on the agenda.

What then can we expect in the next 40 years? At present seven pollutants are proscribed for the purposes of Local Air Quality Management (LAQM) in the United Kingdom (UK). Five of these, carbon monoxide, lead, sulphur dioxide, benzene and 1,3 butadiene, do not present significant challenges although there may be some specific locations where work is still needed to meet the statutory concentrations and - barring any new evidence for adverse health or ecological effects at lower concentrations of these - we can be reasonably confident that we have no major concerns about them. The other two, nitrogen dioxide and particles (as PM_{10}), have proved to be more difficult to address and will continue to be an issue for the foreseeable future; at least under a 'business as usual' scenario.

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland and the European Air Quality Directive also address a number of other pollutants but not specifically for the purposes of LAQM. Some of these, such as polycyclic aromatic hydrocarbons and some more 'exotic' metals such as nickel, arsenic and mercury, are only likely to present problems in specific locations; for example mercury near crematoria. There are, however, two pollutants that are widespread: particles as $PM_{2.5}$ and ozone. Ozone has long been recognised as a problem, both from the point of human health and for its effects on ecosystems. Worryingly, in recent years background concentrations have been steadily creeping upwards, especially in urban areas, even though peak concentrations have been falling.

It is only relatively lately that $PM_{2.5}$ has been recognised as being important in its own right, instead of a subset of $PM_{10.}$ Targets have been set for exposure reduction over areas, rather than concentrating on hotspots as previously had been the case for pollutants other than ozone, which is an area wide problem. There is also concern over these two as there is strong evidence (COMEAP 2009) that there is no threshold for health effects of $PM_{2.5}$ and a strong feeling that this is also the case for ozone.

Business as usual, a central scenario

So, having established a baseline, what might we expect to see over the next 40 years with 'business as usual'? It is not unreasonable to assume that for those pollutants where there are clear and controllable sources we will see reductions in concentrations, quite probably to well below the specified Limit Values. There are more problems with those pollutants where atmospheric chemistry is important as a 'source' and the precursors have many sources, some anthropogenic, some natural. Unfortunately these pollutants include nitrogen dioxide, ozone and particles. The only possible silver lining is the serious questions being asked as to whether nitrogen dioxide itself is the problem from a human health perspective, or whether it is a marker for some other pollutant, possibly particles, but maybe some other substance that has not yet been identified.

One big imponderable is the identification of other 'new' pollutants with adverse health or ecosystem effects. Another is the identification of influence of recognised pollutants but at concentrations below those currently recognised as having adverse effects. Apart from these possibilities it is almost certain that particles will still be a cause for some concern. It is highly unlikely that we will continue to leg-

islate on particles of a particular size fraction measured as mass per unit volume but on one metric, or possibly more, based on numbers of particles per unit volume or on the total surface area of particles in a unit volume of air. It is also possible that more attention might be paid to the chemical composition of those particles in addition to whatever metrics are specified in legislation. There is in 2010 some concern that concentrations of precious metals such as rhodium and platinum in air are increasing as a result of their use in catalytic converters. There are currently no environmental standards for these substances and no certain evidence as to their health effects but, as will be seen, they present an interesting, if small, case study.

Where then does a low carbon future impinge on this? The answer seems to be "in many ways but not necessarily obvious ways". The most obvious impacts would be in the potential for reductions in the products of combustion. Many of the current air quality problems are associated with combustion of one form or another with emissions from road traffic being the most obvious. A major shift away from fossil fuel combustion in road traffic has the potential for delivering some improvement in urban air quality but it must be remembered that tailpipe emissions are not the sum of road traffic pollution issues. Particles are 'emitted' by road traffic as a result of friction between tyres and road, brake pad wear and clutch wear in addition to re-entrainment of road dust.

The case of the precious metals is interesting as, prior to the widespread introduction of catalytic converters, lead from vehicle exhausts was considered a problem. It does seem highly likely though that, apart from their persistence in dusts, emissions of these metals will fall away if there is a major shift away from vehicles using fuels that require a catalytic converter to remove toxic gases from the exhaust. This scenario is, however, dependent on alternative technologies such as hydrogen-fuelled vehicles becoming generally available.

Perhaps the main consideration of all in relation to air quality in a low carbon future is the development of policies to bring about benefits for both air quality and climate change. Department of Environment, Food and Rural Affairs has recently produced a short report examining some of the issues in this and it is clear that there are some policy options that are considered to be beneficial to both air quality and climate change, whereas some of the measures designed to deliver climate change improvements have seriously adverse effects on air quality. There are some measures to improve air quality that are identified as having adverse climate change effects. Examples include three way catalytic converters on petrol engine vehicles, diesel particulate filters and flue gas desulphurisation. It is not clear whether these disadvantages impact air quality to the degree of some of the proposed climate change measures.

Is it possible then to look forward to a low carbon future with improved air quality? Unfortunately early signs are not hopeful. In the last two decades the road traffic field has seen a significant switch towards diesel engine private cars with the benefits of lower carbon dioxide emissions compared to petrol engine vehicles. The consequences of this were higher emissions of particles and primary nitrogen dioxide making the fulfilment of air quality obligations more difficult.

Biomass is another area that has been identified as having serious air quality implications; particularly if a biomass plant is located in an urban area. On the other hand there may be considerable benefits from the use of biomass in rural areas. The main considerations relate to the emissions from the actual combustion of the biomass. There are, however, other air quality considerations for the use of biomass, most notably the potential for emissions of biologically active particles from the feedstock.

In road traffic the potential of a switch to hydrogen or electric powered vehicles - possibly via a much greater use of hybrid vehicles as an intermediate - offers a clear opportunity for air quality benefits. Nevertheless, real climate change benefits from these will only accrue if the hydrogen/electricity is generated from low carbon sources. Biofuels potentially offer climate change benefits but there are question marks over their air quality impacts. Certainly biodiesel is unlikely to offer overall emissions improvements over conventional diesel fuels, but biomethane or bioethanol might give both air quality and climate change benefits. The major issue is the sourcing of the biofuel. Current methods of production using oil seed rape and similar crops are wholly inadequate, so if there is to be more use of biofuels it is essential that they derive from second or third generation sources such as coppiced crops or - in the longer term - hydroponics.

In conclusion it seems highly unlikely that there will be no air quality issues in 2050, low carbon economy or not. What we do have is the opportunity to develop a low carbon future which has the potential to produce more air quality benefits than 'business as usual'. Equally we will need to take care to avoid a low carbon future without those benefits.

Alternative scenarios

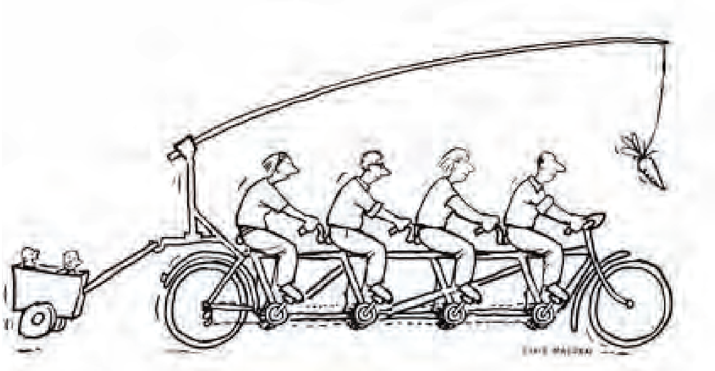
Our central 'business as usual scenario' visualises 80 million people in the UK living mainly in urban areas. It supposes this population lives comfortable lifestyles that are more energy efficient than is current.

This central scenario is only one of many possibilities; there are a range of alternative scenarios. We list some below if only to act as a warning to expect the unexpected.

Policy-makers and economists are generally optimistic. They expect policy and economic forces to behave in a way that allows, and often expects, innovation to have solved environmental problems. More cynical observers may speculate whether by 2050 society will have solved the other long-term, intractable social and economic problems such as inequity, social exclusion, resource management and pension provision. One nightmare scenario is that by 2050 a large majority of the urban poor have to work until they are 80, extracting materials from former waste disposal sites to keep essential industry going. The reduction in quality of life has either been brought about by shortages in materials, deliberate decisions to live a more sustaining life, economic hardship or by military intervention to secure global supplies in which the UK may have been less successful than in the former days of the British Empire. We could propose a set of scenarios describing the state of the country and for each one could speculate about the consequences for air quality. A selection of scenarios is listed below.

A Totalitarian state, possibly brought about by military defeat, in which a small minority live in luxury but responsibly and the majority have limited consumer opportunities. The outcome is good air quality.

B Totalitarian state in which a small minority live in luxury and the majority have limited consumer opportunities. Industry, however, runs inefficiently with high emissions. The likely outcome is possibly good urban air quality but poor air quality elsewhere.



C Sustainable communities in which voluntary choices have been made to limit consumption. Working together has reduced inequality. The outcome is good air quality.

D Successful innovation, clever renewable options and effective implementation of nuclear power or similar technologies, has allowed for continued growth in life style choices. Most people have no need to work. The outcome is good air quality. The 'business as usual' scenario discussed in the first part of the paper falls close to this scenario.

Cartoons by Chris Madden, www.chrismadden.co.uk

E Competitive society in which taxes, rationing or similar have pushed up the cost of energy intensive or material intensive products. Society relies on expensive basic products (renewable energy sources have not become significantly cheaper or efficient and nuclear waste and disposal remain serious issues.) Inequalities are unlikely to narrow. Inefficient products are likely to remain in use. The outcome is poor air quality.

This list of scenarios is not exhaustive and there are many potential micro-variations, one example being that either of the totalitarian scenarios could be a theocracy or could be secular. Could this influence the air quality outcome?

Conclusions

One sees that the prospects for good air quality are high for most of the scenarios but the reasons are different. A depends on a small number of heavy consumers who can afford to control their emissions. B represents a throwback to some of the worse economic practices of the Soviet bloc. C depends on a large number of light consumers, who have voluntarily chosen to control their emissions. D depends on technology ensuring all consumption is very efficient limiting possible emissions. Only scenarios B and E lead to poor air quality, one under an uncaring regime and the other under a market driven economy, in which the market or environmental regulation, for some reason, does not work effectively.

Although one might not accept any of these scenarios it is plainly overoptimistic to extrapolate forward on the basis of a single projection. One should anticipate some worst case situations and assess the risks. We cannot claim that this is due to ignorance. Ways of tackling air pollution are well known, but for socioeconomic and technical reasons they are not perfect. It would appear that the main question is the development of society and how it is organised.

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◆ *David Muir has worked in the air quality field for over 30 years, mostly with Bristol City Council. He completed a PhD at the University of the West of England in 2003 looking at means of identifying the possible sources of PM10 during pollution episodes. Since May last year when he left BCC he has done some consultancy work but has also resumed his research work. He serves on the committee of the Institute for Air Quality Management and the Council of the Institution of Environmental Sciences in addition to involvement with Environmental Protection UK.*

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HOUSING, SUSTAINABILITY AND BEHAVIOUR CHANGE

Realising a low carbon world will require not just technical innovation but behavioural change and mechanisms for achieving this, says **ALINA CONGREVE**

The energy we use in our homes makes a significant contribution to our total greenhouse gas emissions. The most recent data shows domestic energy contributing 27.5 per cent of UK total greenhouse gas emissions (DECC, 2009a). If we are to successfully reduce our overall emissions we cannot afford to ignore the one quarter that comes from our homes. If we are to reduce this level of emissions we will therefore need to change the way we build and refurbish homes, but also how we live in them. Part of the reason our houses make such a significant contribution is the age of our housing stock: we have more houses built before 1919 and (therefore without cavity walls) than most other European countries (Allen and Hicks, 1998). Even houses built more recently, such as in the 1980s and 1990s, have levels of environmental performance that are behind most other northern European countries.

What about building new houses?

Our aging and energy inefficient housing stock has led some environmental commentators to lobby for more of these houses to be demolished and replaced with new energy efficient homes. Boardman *et al.* from the Environmental Change Institute recommend demolishing 14% of our current housing stock and replacing it with new and environmentally efficient dwellings (Boardman *et al.*, 2005). This would involve demolishing four times the number of houses flattened in recent years – from 20,000 per year to 80,000 per year. If this happened new-build would make up one third of the housing stock by 2050.

Critics of 'demolish and rebuild' point to the large amount of carbon dioxide released in the production of construction materials for new houses. The 35 tonnes of carbon dioxide released in materials and construction for each new house means that over a 50-year period there is no advantage in demolishing older housing and replacing them with new (Empty Homes Agency, 2006). Unless there is a marked change in policy to promote demolish and rebuild, between 80 to 85 per cent of the houses that are built today will still be in use in 2050 (Sustainable Development Commission, 2010; Federation of Master Builders, 2008).

In the current economic climate there is even less enthusiasm for large scale demolition and rebuilding. Setting high standards for new dwellings is important. With our low rate of replacing housing, however, a policy that focuses mainly on new houses will not deliver the energy savings that are needed from the domestic sector. Even under the plans of Boardman *et al.*, renovation is still the preferred option to demolition for most of our housing stock.

Making the most of our current housing stock

Whether built in the 1930s or the 1980s we need to do the best we can with our current housing stock. Some of the measures needed require significant financial investment, either on the part of the landlord or the householder. These measures include upgrading the heating system by fitting a new condensing boiler or adding insulation to the walls. Grants can be available to help cover some or all of the costs of these measures, particularly for low income and vulnerable households. Progress has been slow, however, particularly in the owner occupied and private rented sectors.

A number of reports published recently outline the physical changes we can make to our houses to improve their energy efficiency (Federation of Master Builders, 2008; Housing Corporation, 2008; Energy Saving Trust, 2007; Sustainable Development Commission, 2006; Empty Homes Agency, 2006). These reports have also discussed the funding and policy mechanisms required to ensure that green refurbishment programmes are implemented. Research has also shown that rather than being a liability, the jobs and skills created through eco-refurbishment could turn our aging housing stock into an asset.

Physical changes to the fabric of houses are, however, only part of the story. Adopting low carbon lifestyles and use of homes is also important. There are also many free of charge energy savings measures that simply require behavioural changes, which can have considerable impact on energy usage. Some of the most significant of these no-cost actions are shown in figure one (adapted from White, 2008). This gives a total saving of 2,417 kg of carbon dioxide if all these measures were implemented.

Note that these figures are based on a three bedroom semi-detached house with gas central heating, which has a standard heating pattern, occupancy, and stock condition. *(For more details on the assumptions see White, 2008).*

Of course not all these measures may be possible for all households. Turning the thermostat down by three to four degrees Celsius creates the biggest saving but may be more than is comfortable. Households with very elderly members or those with health problems may not be comfortable with lower temperatures. For some small flats it may not be possible to locate the fridge away from the heat of the cooker

Action	Annual Financial Saving (£)	Annual CO_2 saving (kg)
Reduce the temperature in the home by 30-40C	108	903
Switch off five 60W lights	55	290
Dry clothes naturally instead of using a tumble drier	53	280
Programme the thermostat of your home to a cooler temperature at nigh and when you are out	53	440
Turn off standby for multiple appliances	33	173
Place the fridge in a cool environment	28	150
Washing your clothes at 400C not 600C	10	52
Use your washing machine only when full	8	45
Unplug chargers when not in use	6	33
Just boil enough water for your hot drink	5	25
Fix dripping taps	2	20
Let food cool to room temperature before putting in the fridge	1	6

Figure One: No Cost Actions

to optimise efficiency. The list is not exhaustive and other measures such as putting lids on saucepans when cooking and fitting lined curtains to windows and closing them on cool nights can also save energy. Implementing the measures listed in figure one will however make a significant contribution to reducing household energy consumption.

The Carbon Trust estimates that the average British resident is responsible for around 11 tonnes of carbon dioxide (CO_2) per year, of which 6,442 kg are used in the home for heating, hot water, cooking and electrical appliances. This gives a potential saving of 37.5% of CO_2 emissions from the home from behaviour change steps with no cost implications. These savings would only be achieved if the behaviour was carried out consistently and not on an ad-hoc basis. If we can save money and benefit the environment at the same time why are households not carrying out these steps?

Persuading people to use less energy: information campaigns

The Government and environmental pressure groups have run information campaigns trying to persuade people to use less energy in the home since the 1970s. Environmental campaigns have also tried to promote other activities including: recycling domestic waste; walking, cycling or using public transport rather than driving; buying local food; and wasting less water in the home. It has been assumed that the reason most people did not fully participate in these activities was because of their lack of knowledge.

These information campaigns used mass media, including television and radio, magazine advertisements, advertising posters and printed leaflets available in public places such as council buildings and libraries. Owens (2000) points to the similarities in approach taken by the UK Government's 'Save it' campaign of the mid 1970s and the '*Are you doing your bit campaign*' launched in 1998. Both were based on information provision. The material tended to take a '*one size fits all*' approach and was not usually targeted at people from different backgrounds.

Despite the production of this campaign material, domestic energy use has increased by 36% over a 30-year period from 1971-2001. This increase has been caused in part by a rise in the number of households; more of us are living alone and in smaller family units. The average energy use per household only shows an increase of five per cent over this period. The wider use of electrical appliances and central heating has offset any gains made in energy efficiency (Office of National Statistics, 2004).

Perhaps now that most households have central heating and a range of electrical appliances more attention can be focused on reducing waste. Evidence however suggests otherwise, with the increased use of new energy intensive appliances such as plasma screen TVs, which consume much more energy than traditional televisions.

Communicating climate change

One of the key messages put forward by the Government and environmentalists is the serious consequences of climate change. Environmental communications specialist Futerra is critical of the way in which climate change is communicated to the public.

"The most common message on climate change is that we're all going to hell. That's what climate change looks like when you get right down to it; rising seas, scorched earth, failing food supplies, billions of starving refugees tormented by wild weather. But contrary to every expectation, hell doesn't sell. Although these Armageddon climate scenarios might be accurate and eye-catching, they haven't changed attitudes or behaviours nearly enough. Threats of climate hell haven't seemed to hold us back from running headlong towards it." (Futerra, 2009 p2).

Whilst some environmental behaviour, such as recycling domestic waste has become mainstream, most pro-environmental behaviour has not. Messages about living in more sustainable communities have too often been based on technical arguments or encouraging self-sacrifice. Whilst such arguments may win over a small number of committed environmentalists they do not engage in any realistic way with the wider public.

Behaviour Change

Giving people more information about an issue does not make it certain, or even more likely they will change their behaviour. There is a gap between people's knowledge and awareness of environmental issues and their willingness to undertake pro-environmental behaviour. This gap has been identified in dozens of separate studies and reviews of studies (van Raaij, 2004; Kollmuss and Agyeman, 2002, Burgess *et al.*, 1998). So how can this gap between knowledge and behaviour be understood, and how can it be overcome?

Behaviour is determined by three factors: motivation, ability and opportunity. Until recently people could have been motivated to recycle domestic waste but lacked the opportunity of doorstep recycling to carry it out. There is a relationship between those three factors. Someone with a high level of motivation may spend a long time on the Internet looking for places to recycle unwanted items. Motivation and the ability to search the Internet may produce an opportunity for recycling or reuse that a less motivated person missed. Whilst some knowledge is necessary – for example the rules when separating household waste – most pro-environmental behaviour is easy to understand.

Recently there has been a shift in some of the activities of environmental non-governmental organisations and government departments from providing information to favouring methods that can bring about behaviour change. The term 'social marketing' has become increasingly used to describe a range of activities in the fields of the environment, social policy and public health. Social marketing can be defined as "the development and distribution of products or services to influence behaviour on a large scale for the purpose of societal benefit rather than commercial profit" (Maibach *et al.*, 2008 p489). Social marketing has been widely used on public health issues, including anti-smoking and AIDS awareness. Advocates of social marketing claim that it has advantages over traditional approaches by starting with an individual's behaviour and then trying to find a tactic suited to address that this (McKenzie-Mohr and Smith, 1999).

In trying to influence climate change behaviour some of these initiatives use primarily web-based material and are national or international (e.g. dothegreenthing.com) while others focus on specific local areas (e.g. Transition Towns, Low Carbon Communities Network). These networks enable groups to share resources and ideas but as voluntary groups with limited resources, funding is not available for rigorous evaluation. Knowing of events and that people enjoyed participating is useful, but it is important to qualify whether they resulted in behaviour change. We urgently need more information about which approaches to behaviour change are most effective.

There are also opportunities to combine behaviour change projects with programmes that improve the energy performance of homes and generate green energy. The Hockerton Housing Project provides a practical example of how living in a green home can support pro-environmental behaviour. Unlike many other green demonstration projects the homes are similar in price to regular market housing. Their book 'Saving energy in the home' provides one of the most accessible introductions to the subject. The Hockerton Housing project has recently started working

Hockerton Housing Project

Hockerton Housing Project

with a local social housing provider to retrofit energy improvements to existing homes alongside detailed home energy advice.

Some recent opinion polls suggest that public concern about climate change is reducing. In January this year 31% thought that climate change was a definite reality, while the same number thought over-exaggerated (MORI, 2010). This is a fall in support from January 2009 when 44% thought that climate change was a definite reality and 21% thought it was exaggerated (MORI, 2009) The cold weather and the failure of the climate negotiations in Copenhagen may have contributed to these results. It is important to act quickly and effectively on climate change and behaviour change programmes while most people remain reasonably sympathetic to the issue.

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SCIENCE, TECHNOLOGY AND SUSTAINABLE FASHION AND TEXTILES

With consumers becoming increasingly demanding, considering the environmental impact of the clothing industry is all the more important. SANDY BLACK describes current research into meeting both environmental and consumer needs

The Fashion Paradox

The concept of sustainable fashion appears to be a contradiction in terms given that fashion is an endemically wasteful system. The paradox surrounding the fashion and clothing industry is that this inherent wastefulness translates into an economic driver for employment and global trade – it represents the fifth largest economic sector by activity. Approximately 40 million people are employed in the textiles and clothing industries worldwide of which up to 19 million are employed in China, 2.7 million in the EU and 400,000 in the UK, – around the same as the aerospace and automotive sectors combined (OECD, 2004). These figures exclude those employed in the retail industry, which in Britain is responsible for importing around £13 billion net worth of clothing (BATC, 2006). The turnover for UK woven and knitted apparel manufacturing declined by nearly 50% in the period from 1997 to 2006, but nevertheless, 80% of companies export their products. However, despite 90% of clothing sold in the UK being manufactured overseas, the high street retailers control a significant proportion of volume production through their design, specification and sourcing roles from UK headquarters. Retailers therefore play a highly significant intermediate role in connecting fashion design, manufacturing and the consumer, and have increasingly been called to account by the media on their environmental credentials and social responsibility policies.

The Fashion Industry Context

Fashion is a highly complex business with long supply chains stretching around the world – clothes today are well travelled commodities with brief lives. The fashion industry is characterised by fluctuations in demand, speculative manufacturing, short runs, fast turnover and a diverse range of products channelled through a fragmented and frequently changing supply chain distributed over many global locations. Risk factors such as changing trends and unseasonal weather result in stock remaining unsold and eventually disposed of by incineration or landfill.

Since the mid 1990s and changes in international trade agreements (including relaxation of export quotas), increasing globalisation of manufacturing has taken place, with new countries, such as Bangladesh and Vietnam, entering the industry. Cheaper off-shore labour costs have made it difficult for UK and European companies to stay competitive at a time when clothing consumption has increased and prices have declined. Greater competition has led to faster fashion cycles, pushing the price of fashion products down, whilst simultaneously increasing production volumes, with the consequent environmental impact. Fashion consumption in the UK has grown significantly in recent years: there was a 37% increase in the amount of clothes purchased per capita between 2001 and 2005 (Allwood et al., 2006) and this trend has continued. A recent study for the Department for Environment, Food and Rural Affairs found that "Even amongst the most pro-environmental [consumers], clothing choices most often derive from considerations of identity and economy rather than of sustainability impact" (Fisher *et al*. 2008). Many purchases are made on impulse, with much clothing never worn before being thrown away. In addition to the impacts from manufacturing and transportation, for much of the everyday wardrobe the most significant environmental impact arises from the use phase of the garment life cycle: clothes cleaning, drying and ironing.

Fashion has become a powerful construct in society, for example as a communication medium and social catalyst to express belonging or difference. A further paradox is that despite (or because of) its fast cycles, the industry has been slow to change and adopt new technologies. How can changes be made to the fashion system in order to reduce its environmental impact whilst sustaining trade and employment? How can environmental issues be reconciled with the importance of fashion in meeting our personal and symbolic needs, over and above clothing's functional role?

Science, technology and Fashion

Collaborative and cross-disciplinary research can provide solutions to some of these entrenched problems, through radical thinking. Research within the London College of Fashion (LCF) Centre for Fashion Science takes a design–led approach to catalyse connections between new and old technologies, craft and industry, science, design, art and technology, thus attempting to reconcile the paradoxical – sustainability and wellbeing with desirability and fashion. One example of this phenomenon in action is given by the work of designer and artist Prof Helen Storey (Co-Director of the Centre for Fashion Science at LCF) and polymer chemist Prof Tony Ryan of Sheffield University, in their recent collaboration entitled 'Wonderland'. This project sought to communicate the 'problem of plastics' in the environment in a positive and engaging way and, through dialogue between fashion and science, and developed a soluble

One step knitting process of seamless sweater *(Photo: Sandy Black)*

> *Future fashion products must address the complex issues of sustainability and still satisfy our personal, economic and social needs.*

plastic which would decompose benignly. These were worn by fashion models poised above tanks of water, to carry the visual message around the world.

The fashion industry is one of the few remaining craft-based industries; the manually operated sewing machine is still the principal means by which garments are made. Retail clothing stores cater for a range of product variables numbering tens of thousands of products per season per retailer, but these ranges still do not satisfy the needs of a large proportion of the population due to narrow scope of sizes and poor fit. To address a wider spectrum of individual requirements it is essential to create greater responsiveness and agility through development of new production processes. So-called 'mass customisation' in fashion (in which mass production processes are reconciled with personalised choices in apparel or footwear) is becoming technologically feasible: online retail systems have emerged (for example Nike ID trainers) with the ability to respond to individual consumer choice whilst maintaining the benefits of mass production. In addition, body scanning technology is starting to impact made-to-measure clothing in the US and the UK. By better satisfying customer needs it may be possible to reduce the rate at which fashion products are consumed and replaced.

Current Research

Research projects within the Centre for Fashion Science investigate emerging materials and technologies for new fashion applications. The aim is to create innovative products and processes for fashion within the context of sustainability. Convergence of digital technologies and diverse disciplines has opened up unprecedented possibilities for new design and manufacturing processes, helping to create the paradigm shifts required. Two current projects, Considerate Design (led by the author) and Catalytic Clothing (led by Prof. Helen Storey), are outlined below.

Considerate Design is a concept and toolkit being developed to support designers to tackle life cycle impacts of fashion product design and manufacturing, to aid trading-off in design and manufacturing decision making. Few fashion designers realise the environmental impact of their design decisions, so this project helps embed sustainability in their design process and is developing tools to assist in evaluating the viability of personalised fashion. The toolkit will be appropriate to different scale companies, from individual designer-makers to design teams within large clothing retailers. In a fast–moving industry such as fashion, sustainability is a concept which paralyses, rather than motivates, designers. Considerate Design aims to break down design for sustainability into elements relevant to fashion through considering:

- the environmental impact of the clothing production supply chain;
- the end user; and
- the lifecycle of the product.

This will be applicable within the constraints of bespoke, small batch production or mass manufacturing.

The Considerate Design for Personalised Fashion project has developed pilot products (which integrate body scan data with processes including rapid prototyping technologies in new ways to create personalised fit. The proposition is that personal engagement in product choices increases satisfaction so that the product will be used for longer. Eliminating processing steps along the way is a key component of the research, such as through developing seamfree constructions. A collaboration with partners from engineering design at Cambridge University and the Open University has applied process modelling software to these fashion case studies to assess the design cost and risks associated with personalised products, which are being developed to the next stage.

Seamless personalised sweater *(Photo: Sandy Black)*

Catalytic Clothing is an exploratory project in development which aims to harness for the first time the massive surface area represented by our clothes, when taken together in urban environments. Given the air pollution created in cities, especially NOx, the Catalytic Clothing concept proposes to use a mass of humans working together to purify the air by wearing clothes to effectively remove noxious pollutants from the atmosphere through treated or specifically developed fabrics with nano scale functionality (such as embedded titanium dioxide). These clothes will later release the pollutants, which will be treated as part of the laundering process, using specially developed cleansers, before entering the waste water system. It has been estimated that 40 people walking across one metre of pavement could purify two metres of air space in one minute. A campaign of engagement with industry partners and funding bodies is underway, together with feasibility studies at Sheffield

Silver Hook Bag by Steven Harkin and Frances Geesin
(Photo: Steven Harkin)

University to test a range of possibilities for fabric treatments and compositions, funded by the Engineering and Physical Sciences Research Council. Unusually for science based projects, it is proposed to engage the public through communication of the potential of the project at the same time as the scientific research is being conducted.

Future scenarios

Increasing convergence of diverse technologies will have an impact on the future of textiles and clothing. Over the last ten years new multi-disciplinary approaches to textile research have emerged; as micro-, nano- , bio- and information technologies and biomaterials have continued to evolve, there is an array of new possibilities for enhanced functionalities within textiles – from new fibre structures, composite materials and coatings at the nano and micro scale to the visible integration of electronic assemblies into clothing.

The UK has led innovation with several different patented technologies for embedding responsive functionality in textiles, including electronic functionality via integration of conductive fibres into fabric structures, particularly in the medical monitoring and sportswear arenas using textiles for sensing and switching functionalities. Wearable electronics

Evolving textiles soft glove prototype by Philip Delamore *(Photo: David Sweeney/LCF Digital Studio)*

will not however become mainstream until the technology meets genuine needs, becomes invisible and intuitive, and the aesthetics merge with the technology itself.

As consumers expect and demand more from their clothes, – nanotechnologies and microtechnologies may provide new developments in textiles. Environmental impact analyses need to be conducted in tandem with these innovations to avoid simply adding to the environmental burden. Targets to aim for would include fabrics which last longer, stay cleaner, and use less energy and resources to make; decompose benignly; can renew themselves and recharge their functionalities. Some of these are currently in stages of development around the world.

Fashion can be a powerful catalyst for engagement and social change. It is not proposed to eliminate fashion for the economic and symbolic reasons outlined above. Future fashion products must however address the complex issues of sustainability and still satisfy our personal, economic and social needs. It is therefore essential to rethink systems, products and processes, utilising both existing and emerging science and technology, to increase satisfaction but ultimately reduce production and consumption and thereby contribute to reduction in resource depletion, carbon emissions and environmental damage.

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BLUE AND GREEN BRITAIN: A LOW CARBON FUTURE

SUE CHARLESWORTH describes the potential role of Sustainable Drainage Systems in mitigating climate change to achieve a low carbon world

To comply with the Climate Change Bill committing Britain an 80% reduction in carbon emissions by 2050, current emissions will need to be reduced by four per cent annually. Whilst reducing current outputs are important, there is also a need to mitigate the legacy of historical carbon emissions. Technological fixes have been hailed as the way to reduce Greenhouse Gas (GHG) emissions and sequester and store excess carbon. This paper, however, suggests that vegetated devices originally designed for their flood mitigation benefits can also provide a means of mitigating some of the changes brought about by Global Climate Change (GCC) and also adapt to the changes which have already happened.

Imagining a low carbon Britain in 2050

Travelling forward in time to 2050, a low carbon Britain would also be a Blue and Green Britain. Most buildings would have green roofs and some would have green walls; some buildings might even have ponds on their roofs. At ground level, urban ponds and streams would be "skylighted": set free of their concrete constraints to flow through towns and cities and be valued for their amenity and biodiversity benefits as well as their carbon storage and sequestration (CSS) abilities. Householders' front gardens would be *gardens* rather than extensions to the roadway on which to park their cars, and the streets outside of their houses would be cool, green havens planted with large, native street trees. The urban periphery would have networks of ponds and swales, possibly an urban forest, and further away from urban centres, trains of devices including wetlands would be designed into out of town shopping areas, industrial estates and Motorway Service Areas. A flexible and multiple benefit approach to providing all this would be by utilising the vegetative devices in a Sustainable Drainage System (SUDS), and the following sections explore the relationship between SUDS and low carbon living.

Sustainable Drainage Systems

The SUDS approach has been introduced by Charlesworth *et al.*, (2003) and Sharma and Maltby (2008) in the traditional sense of providing flood resilience. Whilst Sharma and Maltby (2008) are quite correct in stating that: "the need for a more sustainable approach to urban surface water management has never been so great" (p.8), SUDS can however offer far more, in particular mitigation and adaptation to climate change. This is illustrated by Figure 1 which compares conventional drainage with the SUDS triangle: the equal balance between water quality enhancement, water quantity reduction as well as amenity and biodiversity, which can be modified into a 'rocket' by its application to climate change (Figure 1c). This article will focus on the built environment since by 2070 70% of human beings will live in cities.

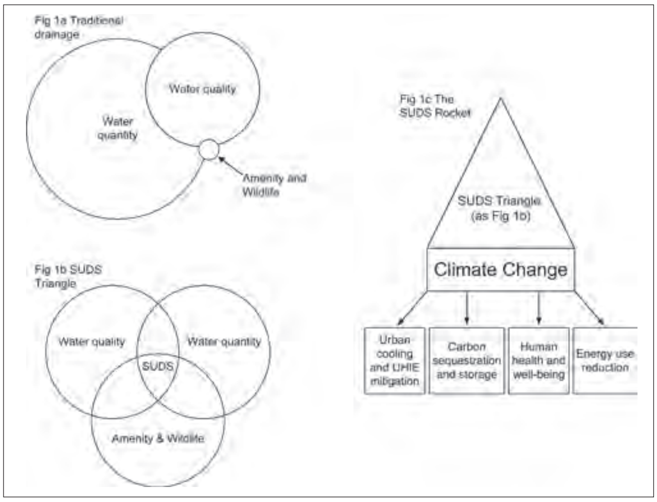

Figure 1a) Conventional drainage focuses mainly on water quantity
Figure 1b) SUDS balances water quantity, water quality, biodiversity and amenity
Figure 1c) Adaptation of the SUDS triangle to take account of climate change: the SUDS Rocket.

Carbon and the built environment

Contrary to popular belief that transportation is responsible for the greatest percentage of GHG emissions, it is in fact buildings which globally emit 48% of GHGs. London alone produces 8% of the UK's carbon dioxide (CO_2) emissions, which amounts to 44 million tonnes CO_2 pa. This is projected to rise to 51 million tonnes by 2025 if preventative measures are not taken (GLA, 2007). These impacts are generally due to:

- industrialisation and urbanisation leading to increased fossil fuel use for both heating and cooling homes;
- increased impermeable surfaces including those with heat absorbing properties;
- decreasing numbers of natural water bodies such as canalisation, channelization and straightening of urban water courses;

Figure 2 Green roofs on houses in the Upton Development, Northampton, UK.

- infilling of small ponds; and
- loss of vegetation as a whole but specifically the replacement of some street trees with small non-native specimens.

Urban Heat Island Mitigation: SUDS and urban cooling

There has been much research investigating the Urban Heat Island Effect (UHIE), which was first noted in 1819 in London; it is peculiar to cities where, even in winter, urban areas can be several degrees warmer than the surrounding countryside. Not caused by GCC, it is nonetheless exacerbated by it, to such an extent that in cities such as Tokyo "summers are ... fast becoming unliveable" (Trautlein, nd). Temperatures in Tokyo are predicted to peak at 43°C by 2030 with the central UHIE area spreading to encompass more of the City. Energy is therefore used to cool building interiors so that people can live and work in them in comfort, but excess heat is released from the building into the environment and more CO_2 is produced due to use of air-conditioning. The focus of much research is therefore on urban cooling, particularly using green roofs (see Figure 2).

Remote sensing of urban areas has revealed a patchwork of discrete heat islands related to the distribution and structure of buildings and streets, as well as areas with much lower temperatures associated with parks and greenspace (Yu and Hien, 2006). The incorporation of vegetation can create an "oasis effect" whereby temperatures are reduced at the local level near planted areas. SUDS devices, which have been used extensively for this purpose are green roofs, have the added advantage that they can be retrofitted to suitable buildings utilising unused roof space. This can represent up to 50% of the impermeable surfaces of a city. The difference between a standard hard roof in summertime and a cooler green roof can be up to 22°C, and in the substrate under the green roof it can be as much as 32°C cooler.

Germany has been utilising green roofs for approximately 30 years with at least 20% of the country's roofs greened. An exemplar of the use of urban greening is Stuttgart in which planning has been climate-based since 1938 resulting in the city being 60% covered in greenery, with particular focus on street trees. Tokyo and New York have both concentrated particularly on green roofs and should 50% of both cities.' flat roofs be greened, the UHIE effect could be reduced by up to 0.8ºC (Rosenzweig *et al.*, 2006). The internal temperature of any building under a green roof is therefore likely to be cooler, reducing the need for air conditioning use, thus cutting energy usage and carbon release.

Green walls have been used less than green roofs, but they have the same benefits. In a study of a "vertical deciduous climbing plant canopy" in the UK, Ip *et al.* (2010) found benefits due to shading in the summer leading to a reduction in internal building temperature by four to six degrees Celsius. When the leaves fell in autumn, any incident solar radiation was allowed through the windows, heating the room inside, hence reducing fossil fuel use. Augmentation of vegetative cover in cities at the *local* level (i.e. mitigation of the UHIE) can have *regional* benefits (i.e. mitigation of climate change), and hence reduced GHG emissions.

Carbon sequestration and storage

Obviously, vegetated SUDS will be growing in some form of substrate, however, the carbon cycle of soils is the least well known of all the carbon sinks. The focus for this section will therefore be on CSS studies of the vegetation only. The study of CSS in SUDS devices began in the last decade with most studies concentrating on urban trees (see Figure 3). Table 1 shows the results of a number of CSS studies from around the world of street trees, ponds and green roofs. It is difficult to contextualise these data since the release of carbon from a building depends on use, construction etc. A standard family car can however release one

	C storage total	C sequestration total	Number of trees	C sequestration per tree	C storage per tree
Trees					
Coterminus USA[1]	700 mT	22.8 Mt yr^{-1}			
7 cities in USA[2]			17,000 – 200,000	33-126 kg yr^{-1}	80-250 kg
Merseyside, UK[3]	16 tonnes ha^{-1}	0.13 tonnes ha^{-1} yr^{-1}	160 ha		100 kg
Chicago: Urban Forest Climate Project[4]	855,000 tonnes		4.1 million		
Canberra Urban Forest[5]		30.2 x 10^3 tonnes (2008-2012)	452,000		
Green roof[6]					
Above-ground biomass	167.9 gC cm^{-2}				
Below-ground biomass	106.7 gC cm^{-2}				
Substrate	912.8 gC cm^{-2}				
Whole roof	375 gC cm^{-2}				
Detroit rooftops (15 000 ha)	55,252 tonnes				
Ponds					
Global farm ponds[7]		148-17,000 gC m^{-2} yr^{-1}			
Single pond[8]		5,000 gC yr^{-1}			

Table 1 The carbon sequestration and storage capabilities of a selection of SUDS devices.

References: 1. Nowak and Crane, 2002; 2. Pataki et al., 2006; 3. Whitford et al., 2001; 4. McPerson et al., 1994; 5. Brack, 2002; 6. Getter and Rowe, 2009; 7. Downing et al., 2008; 8. Pondconservation.org (nd)

Figure 3 Trees on the campus at Coventry University, Coventry, UK.

tonne of carbon per year, and using the figures calculated by Whitford *et al.* (2001) shown in Table 1, one hectare of urban tree cover, or approximately 160 trees at 100 kg C stored per tree, could account for the emissions of 16 family cars per year.

Some cities have implemented tree planting schemes amounting to urban forests such as the Chicago Urban Forest Climate Project. As well as the CSS benefits shown in Table 1, the urban forest reduced air conditioning use due to the trees interception of up to 90% of incident solar radiation, thus providing multiple cost-effective environmental functions. They also found that the larger the trees the greater the benefits, and areas with few trees, such as the city centre, suffered the most during heatwaves. As a result, approximately 3 000 trees were planted in 60 parks in Chicago during 2007. The outcomes of the Canberra Urban Forest (Table 1) could translate into a financial value of the whole forest of over $US 20 million due to reduction in energy consumption and atmospheric pollution amelioration.

There are very few studies of green roofs which estimate their CSS capabilities, however Getter and Rowe (2009) report a study in which they assessed the carbon sequestration ability of extensive green roofs over two years of monitoring. They detail the "terrestrial carbon sequestration" pathway via vegetation from photosynthesis taking up CO_2 to transfer of the carbon eventually into the substrate due to incorporation of plant litter. Table 1 shows the results of their study and also extrapolation to the whole city of Detroit should all its rooftops be greened.

It is not only vegetated devices which can be instrumental in CSS, and Table 1 shows results of investigations of farm ponds in which it was found that globally, ponds capture and store more organic carbon in a year than the sea. According to Pondconservation.org a 15 m^2 pond could trap 5 000 gC yr^{-1}, whereas an area of 100 m^2 of trees would be needed to trap the same amount of carbon. Retention and detention ponds, and to a certain extent swales and constructed wetlands could therefore provide a means to store a portion the excess anthropogenic carbon.

Evaporative cooling using ponds and vegetation

"Arguably one of the most efficient ways of passive cooling for buildings and urban spaces in hot regions" is evaporative cooling (Robitu *et al.*, 2006, p436) which can be carried out biologically in plants or physically by ponds.

According to Pondconservation.org (nd), ponds are heat sinks, but there are few studies of the evaporative benefits of

SUDS ponds and wetlands. Robitu *et al.* (2004) found that a pond can cool an urban environment in summer, quoting the difference in temperature between the pond and a road surface in full sun at 3 pm as 29 K. Givoni (1998) suggests that roof ponds can cool individual buildings, finding temperature differences of two and three degrees Celsius between the cooler ceilings beneath a roof pond and the temperature of the air indoors.

The evaporative cooling benefits from vegetation are due to the process of evapotranspiration from the leaf surface into the overlying air. Green roofs, therefore, can reduce building surface temperatures as well the surrounding atmosphere and hence reduce the need for air conditioning. This has been demonstrated not only by field trials, but also by computer modeling (e.g. Onmura *et al.*, 2001) and is a technique which has been used globally as has been discussed earlier with particular reference to mitigating the UHIE.

Conclusions

It was suggested at the beginning of this article that a future, low carbon Britain would be both blue and green. It has been shown that vegetated SUDS devices offer multiple benefits. They have the ability to sequester and store carbon, and also to reduce the use of fossil fuels by cooling individual buildings, but also the wider urban area. Whilst mostly used to mitigate the UHIE, nonetheless by acting at the smaller scale, of an individual building or city, such benefits feed into the larger global scale necessary to cut carbon emissions. The process of evaporative cooling can occur from leaf surfaces, but also from ponds, wetlands and streams, and the combination of urban greening and integration of water bodies can reduce a city's energy use, thus providing climatic, economic and aesthetic benefits.

Whilst it has been shown that these SUDS devices are capable of tackling GHG emissions, more research is needed to investigate the CSS abilities of vegetative devices, in particular green roofs, but also swales and vegetative pavements. The evaporative cooling abilities of open water such as urban ponds and wetlands is known, but not quantified. More research is therefore needed to gain a better understanding of the role SUDS can play in mitigating and adapting to a changing climate in the built environment. It is clear however that SUDS are already proving valuable in giving cities the means to meet the challenges of climate change.

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CASE STUDY: 2050 BRISTOL – A WORLD LEADER IN GREEN BUSINESS AND SUSTAINABLE LIVING

ROSE BAILEY and JIM LONGHURST imagine what energy, transport and the economy will be like in a low carbon Bristol in 2050, and the unpleasant alternative if such a transition does not take place

Carbon dioxide and other greenhouse gases (GHG) are emitted from almost everything we do; from powering our homes, travelling to work, feeding ourselves to producing the goods and services we both want and need. Cities represent a concentration of these activities, and consequently of GHG emissions (Stern, 2007). It is clear, therefore, that cities as consumers and systems have a major environmental responsibility, and will play a vital role in the transition to a low carbon world. Significant potential for mitigation activity exists in the density of the population and the demand for services creating economies of a scale that can be utilised to make low carbon lifestyles a reality; public transport, district heating networks, car sharing, community gardens and other low carbon solutions become feasible. As the article 'cities and the vision of a green, pleasant and low carbon UK' also notes, with local governments becoming more influential, the road to 2050 low carbon Britain will increasingly depend on current and future implementation of city/region-led carbon management schemes. This article discusses one such carbon management approach, in the Bristol city region.

The decarbonisation policy challenge

The low carbon potential of urban areas is widely recognised (Dhakal and Betsill, 2007; McEvoy, *et al.*, 1998), and across the country and the world, cities are making commitments and progress towards achieving these ambitions. The article on cities and the vision of a low carbon UK details some of the aspirations and actions being taken by cities. There is, however, a significant question mark over whether the current low carbon rhetoric can and will be translated into reality. Overcoming the "implementation gap" (Bulkeley, 2006) between policy and action is critical. It is unquestionable that achieving the necessary emission reduction will require a transformation of unprecedented scale in the way our society operates. Investment, political will, and public buy-in will be needed, and at present there is significant scepticism, certainly at an international level, as to whether we can achieve the necessary reductions in emissions to limit the worst effects of climate change.

At the city level, the scale of the decarbonisation challenge – a minimum 80% reduction in GHG emissions over the next 40 years in the developed world – will require "a

A quintessential view of Bristol

broader spectrum of measures extending well beyond the traditional horizon of government policies or business investment decisions" (Hasselmann *et al.*, 2003). We have no idea what this 'low carbon 2050' might look like. Looking ahead 40 years from now is largely speculation. This poses a dilemma for policy-makers in a city: how can they really make robust plans to achieve something that is unknown and undefined? How do we know we are actually on the right pathway to achieve the necessary reduction in our climate impact? We can measure and report year-on-year progress, and forecast and predict the effects of current plans and decision-making, but there is no way of knowing for sure whether we are on the right pathway to achieve a truly low carbon future. We can, however, stop trying to 'predict' the future and think about 'creating' it instead. By generating a vision of how we would like our future cities to look, we can then establish a pathway to achieve it. This requires us to step out of our usual 'reactive' approach of predicting and responding to current trends and resources, and instead become proactive in creating a low carbon future.

'Envisioning the future'

Bristol has serious ambitions to become a low carbon city. As the only UK city to be shortlisted for the European Green Capital award, the UK's first 'cycling city', and with a concentration of green businesses and an ambitious target of a 40% reduction in emissions by 2020 (from a 2005 baseline), the city is taking on the low carbon challenge, and the

Self-built eco-house community in St Werburghts, complete with solar photovoltaics

opportunities presented by it. The city council, in conjunction with the Centre for Sustainable Energy, is supporting research at the University of the West of England (UWE), imagining the low carbon futures for the greater Bristol region (made up of the former counties of Avon).

This research is trying to turn the usual 'plan and predict' approach on its head, by instead defining the future, and then planning backwards or 'backcasting' (Robinson, 1988, 1990; Dreborg, 1996) to the present. Fore- and backcasts will be compared and options to close the gaps identified, to 'future proof' a pathway to a desired low carbon scenario. Key stakeholders and decision-makers (the 'experts') in the region are being invited to contribute their opinions on what this preferred vision for the future looks like, in a Delphi-like process (Linstone and Turoff, 2002). The intention is that through several rounds of anonymous online questionnaire, accompanied by a summary of the results from the previous questionnaire, an agreement for one or several broadly consensual visions for the future will be reached.

The following description of the region is drawn from the responses received to the Delphi study so far. One round of questionnaire has been completed, and the initial questions and responses have been quite general, with the intention of gathering broad opinions, ideas and themes. As such, the vision described below has been created from the largest clusters of common themes and opinions, and answers with the highest scores or most support. It will be refined in subsequent rounds of questionnaire, with additional quantitative description.

2050 low carbon Bristol

Bristol is a great place to live in 2050. The region saw the potential benefits from moving towards a low carbon, sustainable way of life, and took steps to make sure it was achieved. The emphasis is very much on 'local': local jobs, skills, food and resources. The city is largely self-sufficient and is one of the leading 'green' cities in the country – not that we use the phrase 'green' much these days, as green is just normality now. The region is very prosperous, progressive, innovative, and a popular place to live and run a business. This is particularly the case for environmental technologies; the region leads the world in this field. The transport and energy systems are super-efficient, clean and truly 'low carbon'. The city is very well connected to the wider region and the world, whilst retaining a focus on local supply, self-sufficiency and sustainability. The social inequality and deprivation in parts of Bristol 40 years ago have been largely overcome. Communities are diverse, integrated, and all residents experience a high quality of life.

Energy

The Bristol region is known as a centre of sustainable energy. Electricity generation is largely decentralised, and nearly all homes generate some of their own power to cover their needs, mostly through solar photovoltaic cells on the rooftops. There is a mix of energy generation from a wide range of renewable sources to account for peaks and troughs in both generation and use. The tidal ranges of the Avon and the Severn generate power through a number of different technologies, including tidal stream turbines and a mini-barrage on the Avon. There are several large off-shore wind farms in the Bristol Channel and many on-shore wind farms, including large sites at Avonmouth and on the Mendip hills south of the city. In fact, there are wind turbines in almost all directions, as many communities have set up their own wind farms to supply themselves with power. A biomass power station at Avonmouth provides much of the electricity needs for the industries based there, and heat is piped to the city along the Avon gorge.

The country's 'flexi-grid' connects up to both local grids and energy supply systems, and to electricity generation in other parts of Europe, including the Norwegian wind farms, Icelandic hydro and geothermal power plants, and the large solar farms in the Sahara. This allows local energy supply networks to be 'topped up' with additional electricity when needed. New nuclear power stations including one at Oldbury, just north of Bristol, provide a stable and not insignificant base load of generation, and the country has a couple of small residual fossil fuel power stations for backup generation when there are times of high demand; when Bristol's Banksy Memorial Stadium hosted the final of the 2046 World Cup, electricity demand in the region reached highs not seen for 40 years, and the clean coal power station at Longannet in Scotland had to be switched on to compensate.

Demonstration eco-house at the CREATE Centre

Homes and buildings have high levels of thermal efficiency, with minimum heating requirements. District heating networks in the cities and towns keep many of our houses and buildings warm with heat from industrial and commercial sources – including the Biomass power station at Avonmouth – waste incineration, and smaller biomass or waste-fuelled combined heat and power (CHP) plants. In rural parts of the region, solar thermal, air source and ground source heat pumps provide for much of the heating needs, although the newest housing is built along the 'passivhaus' principles of energy efficiency, thus requiring no space-heating at all. This is a relatively small proportion of the housing stock, however; most people are still living in the traditional Georgian or Victorian houses. These have had extensive retrofitting of solid-wall insulation and micro-generation to bring them up to the local zero-carbon housing standards. In the rural parts of the region, many have wood-chip boilers for heating.

Appliances and products in homes and workplaces are very efficient, and most have inbuilt 'smart' technology, interacting with the electricity supply network to respond to peaks and troughs in demand and supply. As a result, we use vastly less energy than we did 40 years ago, despite the increase in information technology and other appliances and gadgets in our homes. Many of these electricity savings are, however, counteracted by our increasing population (Bristol is a popular place to live!), and our use of electricity for transport.

Transport

The transport system in the Bristol region is highly efficient and integrated, and much of the demand has been reduced by re-localisation. Personal travel is a lot less than it used to be, particularly for work, education and shopping. Many people now work from home or from central work 'hubs', and more and more employers have been relocating within communities rather than the dated out-of-town business parks of the 'noughties'. Children walk to their local school. The internet and other high-tech solutions are increasingly used instead of travel – for instance, video conferencing and virtual meetings, online shopping, virtual-education and communication. Shopping is largely conducted in local shops or online, with consolidated deliveries of goods to areas at specified times.

Bristol was awarded "Cycling City" status and is investing in cycle routes across the city

Maritime Bristol is still thriving

Because work, school and shops are now located so close, most people can access everything they need on foot or bicycle. This is preferred by most because it is so quick, safe, and convenient: a network of dedicated cycle and footpaths criss-crosses the city. Recently, cycle lifts have been fitted on some of Bristol's most notoriously steep hills which have been very popular! The city's buses and trams are fitted with cycle carriers, and secure storage at stations, to allow good integration between different modes. Smart payment cards that work on both local and national public transport mean that getting about is easy and cheap.

Bristol has an extensive electric tram and bus, and urban rail network, connecting up all parts of the city, and to the surrounding rural areas. This is particularly important for bringing in food and fuel grown in the surrounding areas, and transporting people out of the city for recreation. Bristol is on the 'High Speed 3' rail route from London to Swansea, and as a result the journey time to London is now under one hour, and Paris is less than three hours away, which has really boosted the region's international competitiveness. The city is also well connected by fast rail to other UK cities, which has been important in the development of the low carbon industries in the region, and the Port.

Road transport, especially personal road transport, is banned from within many communities, but some of the wealthiest do still have a private car. They are heavily penalised for using them within the city, however. Most people, when they do need private transport, use the car share schemes. The majority of communities have several shared cars, run on electricity from local generation, which can be used by residents for a small charge. There is a network of charging stations across the country where batteries can be topped up or swapped out – these also act as an electricity store for when surplus electricity is produced on very windy or sunny days! Because there are no longer so many vehicles, many of the old roads within communities have been turned into vegetable gardens, community green space or have become cycle routes.

Although essential travel has reduced, recreational travel is still quite high. The public transport network across the country and to Europe is so fast and cheap that very few people choose to drive – using the shared cars for more than short trips is very expensive, especially with the high road prices in some places.

Goods and services are not locally produced are brought in to the region by rail, sea or inland waterways; Bristol's port is a major point of entry for many commodities. Bristol airport does not see much activity now because the price of fuel is so high. A few flights go a week to important business destinations only, such as Beijing, New York and Mumbai.

Economy and society

Environmental technologies, information technology and the creative industries are the dominant businesses in the Bristol region. The region saw the potential some 40 years ago and worked hard to make sure it attracted investment in these areas to put the city at the forefront of developing the technological solutions necessary to become a more sustainable world. It has put Bristol on the global 'green map'.

The public sector, education, and the local energy, transport and food systems are the biggest areas of employment in the city, with many jobs created by the local production of food and energy. Local shops and services also provide many jobs within communities. Most people therefore work close to where they live, but those employed in the major industries generally travel by train or tram to the industrial centres of Avonmouth, South Bristol's green-tech park, and North Bristol's Information and Communication Technology hub. Public sector jobs are generally in the city centres although many people work from home.

Housing, fuel and power are the biggest areas of expenditure for people, followed by food, transport and recreation. Food is mostly grown locally and less intensively, which keeps the cost down, and is largely organic and seasonal. Out-of-season and 'luxury' foods are very expensive, including meat, so people have largely vegetarian diets. Water is recycled and waste is minimised – what little residual waste there is goes to fuel local CHP plants.

St Werburghs city farm and allotments with new and old houses behind

Communities in Bristol are diverse and cohesive, with shared facilities, and an emphasis on the neighbourhood and all things 'local'. People take responsibility for their community and each other, and quality of life is high. There is a good work-life balance, and social time is valued, especially as working from home can often be isolating. There is a lot of space for leisure, local facilities and shops, trees for natural cooling, and numerous allotments and gardens, which both make communities pleasant places to live and meet some of the food demands of residents.

In sum, in the year 2050 Bristol is a vibrant, happy, integrated, sustainable and prosperous place to live.

Moving forwards

This vision of 2050 Bristol has been drawn from responses to a Delphi study with local stakeholders and decision-makers. It represents a very real desire, and for the most part very achievable, vision for the future. The important thing is to make sure it happens. Countries such as China are making big advances in low carbon technologies, and there is a real danger that the UK will 'miss out' on the opportunities that the low carbon agenda is presenting. If we do not move swiftly, and start making real changes to the way we live and work, we risk being left behind.

This vision of the future of Bristol is an optimistic one, based on the assumption that we will meet the emission reduction targets set locally and nationally under the Climate Change Act (HM Government, 2008). As discussed, its intention is to provide the end point that current policy making can head towards, and as such a pessimistic, 'failed' vision is not being considered. This alternative vision is not a pleasant one.

The unpleasant alternative

In an unpleasant future, Bristol, and the UK, is an uncompetitive economic backwater. It failed to capitalise on the opportunities presented by the low carbon transition, and has lost out to the new Asian super-powers. Energy insecurity and unavailability are major issues. The world's ability to extract oil has declined, pushing up prices to impossibly high levels, which in turn has increased the price of food and fuel across the world. Many people can no longer afford to heat their homes, especially as Russia and some eastern European countries have capitalised on their gas-supply monopoly. The anticipated wind farms never got built because of objections on scenic grounds, so instead to keep the lights on we have had to build coal-fired power stations, fuelled by indigenous supplies. Carbon capture and storage technology never materialised at a large scale, and as a result our emissions have rocketed, and our air is considerably more polluted. Road transport still dominates, fuelled largely by imported biofuels from former nature reserves in south-east Asia, as fossil fuels are so expensive. Food prices have gone up hugely because of the price of agricultural inputs and the transport of imported produce. Locally-grown food is all many people can afford, and as a result diets are a lot less varied, and there is increasing conflict over land for food or fuel.

Population has increased rapidly, especially with the influx of environmental refugees from other parts of the world affected badly by the temperature rises. Communities are disparate, polarised, over-crowded and are experiencing conflict over space and access to services, as increasing demands are diminishing the quality of public services. There are high rates of poverty. All but the wealthiest, who fiercely guard their privileges, experience a poor standard of living and quality of life.

We failed to limit temperature rises to the 'safe' level of two degrees Celsius, and as a result the world is now seeing

The city of Bristol, with both old and new-build.

catastrophic climate change. Bristol has experienced flooding and droughts, heat waves and severe storms, all causing damage and loss of life. This is nothing in comparison to the effects seen in the poorest regions of the world though, and people across the world are angry and disappointed with previous generations for not making the simple changes to their lifestyles that would have avoided some of the problems of today.

Which will it be?

The UK, Bristol, and many other cities have the ambition, and there exists legally binding commitments to reduce emissions, but we are by no means guaranteed the 'clean and green' future in this article. As 'cities and the vision of a green, pleasant and low carbon UK' notes, whether any real and substantial reductions will materialise through measurable implementation is still debatable. As one survey respondent said: *"We need courage, conviction and leadership. This is a fantastic opportunity for the West of England to become one of the best places to live and work in the whole of Europe. Act now not later."*

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ENVIRONMENTAL SCIENCE IN 2050 (AN EXERCISE IN WISHFUL THINKING)

At a recent meeting, the IES Council discussed how the environmental science professions might look in 2050. **ADAM DONNAN** reports on their conclusions

By 2050, the Institution of Environmental Science (IES) will no long be representing a new discipline. The environmental science profession will arguably be over 100 years old and the Institution itself nearly 80. So how will the profession have changed?

The 2050 environmental professional works across vocational boundaries. In particular, this professional acts as a sociologist - understanding how people operate and think - and uses this knowledge to influence people to lead sustainable lifestyles. There is a greater recognition of the inter-relatedness of environmental and social problems (so called wicked questions). Environmental 'solutions' are targeted at this level and aim to solve multiple problems, not just single local environmental issues. This change in focus has inevitably lead to greater collaboration between different professions and disciplines, organisations, the public, private and voluntary sectors, and even between countries. Environmental scientists have aided professionals in other fields to become, to a degree, environmental professionals. No segment or activity of society is immune from environmental impacts, nor any longer naive about this fact.

Environmental science (and the IES) enjoys a much higher profile within society. The consistent messages of the unsung heroes of the environmental movement are finally given due credence. The responsible behaviour of environmental scientists and their willingness to engage with public engagement and open debate means that public scepticism over issues such as climate change - and as certainly to a wide range of additional problems yet to be discovered - is an attitude belonging to the early century. Environmental professionals encourage sustainable choices through transformational education and have successful rebuffed those calling for more authoritarian approaches.

Through the past four decades, environmental professionals have painted a clear vision of an alternative future benefiting from living within environmental limits and with greater social justice. They have based this vision on a rigorous understanding of science and evidence. Enthused by this soundly-argued vision, all in society, including governments and enterprises of all types, have pulled together to see that it becomes a reality.

So what will the world actually look like in 2050? Innovation is an unpredictable animal, so the precise shape will be hard or impossible to predict albeit that the principles of sustainable living are already clear. Suffice to say that the inclusion, in the 2050 edition of the *Environment Scientist*, of extracts from the July 2010 edition provided much mirth for IES members.

IES: NEW MEMBERS AND RE-GRADES

Name	Occupation	Grade
Ali Allafi	Student	Af
James Appleby	Senior Environmental Scientist	M
Ian Ayres	Student	Af
Alan Beckham	Retired	Af
Alastair Blain	Environmental Scientist	M
Jonathan Bound	Environmental Consultant	M
Mathew Bulmer	Senior Geo-Environmental Engineer	M
Swapnika Challa	Research Student	Af
Alan Clark	Environmental Consultant	M
James Clayton	Environmental Consultant	A
Keith Clement	Consultant	Af
Jennifer Colam	Environmental Consultant	A
Amy Collard	Graduate	A
Lucia Collinwood	Principal Environmental Consultant	M
Laurence Cullen	Junior Consultant	A
Barry Cumming	Principal Consultant	M
Helen Cummins	Senior Environmental Consultant	M
Marco Da Silva Catarino	Graduate	Af
Daniel Dalton	Senior Environmental Surveyor	M
Lisa Durrant	Assistant Consultant	A
Jon Finnigan	Graduate Geotechnical Consultant	A
Rachel Greenway	Graduate Environmental Scientist	A
Gareth Grindle	Senior Environmental Consultant	M
Justin Haves	Environmental Consultant	M
Lucy Hay	Senior Environmental Scientist	M
Simon Ho	Assistant Consultant	M
Robert Hope	Development Control Team Leader	M
Nina Hughes	PhD Research Student	A
Roseline Ikem	Graduate	A
Ying Jiang	PhD Student	A
Mark Jones	Graduate	A
Ana Juricic	Domestic Energy Assesor	A
Eric Lawson	Scientific Officer	M
Sarah Legge	Director	M
Daniel Matthews	Principal Environmental Consultant	M
Maeve McLoughlin	Envionmental Specialist	M
Philippa Meares	Associate	M
Umma Mistry	Graduate	A
Nuno Neves da Costa	Environmental Specialist	A
David Ogilvie	Senior Environmental Protection Officer	M
Susan Parr	Principal Environmental Scientist	M
Barry Phillips	International Business Sector	A
Michelle Pickford	Senior Geoenvironmental Scientist	M
James Rawlinson	Senior Environmental Scientist	M
Kate Rowen	Assistant Environmental Manager	A
Clive Shrubsole	Student	A
Christopher Sowerby	Principle Environmental Scientist	M
Neil Titley	Principal Air Quality & EIA Consultant	M
Steven Turnock	Graduate	M
Elaine Tyldesley	Principal Environmental Scientist	M
Andrew Waterfall	Assistant Air Quality Consultant	A
Anastasia Wood	Research Assistant	A
Ella Yerushalmi	Senior Environmental Scientist	M

KEY: F = Fellow, M = Member, A = Associate, Af = Affiliate