zerocarbonbritain®

an alternative energy strategy

Foreword

The urgency of action on climate change is being recognised at an ever increasing rate, with new evidence constantly coming to light. Only last month, Jim Hansen, of the NASA Institute for Space Studies, warned of the possibility of more rapid melting of polar ice, with the implication that sea level rise this century may have been substantially underestimated by the IPCC Report published earlier this year.

We in the developed world have already benefited, over many generations, from abundant fossil fuel energy. Only recently have we realised the damage this is causing, damage that will fall disproportionately on poorer nations. The moral imperative is inescapable, in the first place – for us in the developed world to drastically reduce our greenhouse gas emissions over the next few decades, and also – to use our wealth and our skills to assist poorer countries to develop sustainably.

The report at the end of last year by Sir Nicholas Stern summarised both the scientific and economic cases for action, with a goal of stabilising greenhouse gas concentrations in the atmosphere between 450 and 550 ppm CO_2 equivalent (400–490 ppm for CO_2 only). The International Climate Change Convention, signed by all countries in 1992, decided that developed countries are responsible for taking the first action. Therefore, since CO_2 concentrations are already over 380 ppm, for us to arrive at the lower end of Stern's range implies large reductions by developed countries before 2030.

For such action to be taken demands the creation of an energy perspective that maps the way forward in both energy generation and use. In my lectures on climate change[1], I often compare the strategy to the preparation for a voyage. For the boat we are taking, technology can be thought of as the engine and market forces as the propeller. But where is the boat heading? Without a rudder and someone steering, the course will be arbitrary; it could even be disastrous. Every voyage needs a destination and a strategy to reach it.

Let me mention six components of the strategy that should direct any solutions.

1. As Gordon Brown has explained[2], the economy and environment must be addressed together and environmental considerations need to be paramount in establishing economic policy.

2. Technology and the market must be recognised as vital tools – but not as masters.

3. The long-term must be taken on board, as well as the short-term.

4. Adequate investment in research and development must be provided urgently, to bring promising potential technologies (e.g. wave, tidal stream and biofuel technologies) to the 'starting gate'.

5. Energy provision needs to be influenced by social values and 'quality of life', for instance, the community benefits of local energy provision should be recognised.

6. Energy security must also be addressed in the strategy debate.

zero**carbon**britain comprehensively takes on board all these components and demonstrates how they can be integrated together. It also recognises the inevitable implication of a target close to zero-carbon and develops, in detail, a possible energy strategy for Britain. For such a strategy to be realised in the time scale required, it is vital that government and industry work much more closely together, both nationally and internationally.

The authors of ***zero**carbon**britain*** present a time-scale for action that begins now. I commend their imagination (coupled with realism), their integrated view and their sense of urgency, as an inspiration to all who are grappling with the challenge that climate change is bringing to our world.

Sir John Houghton, June 2007

Former Co-Chair of the Intergovernmental Panel on Climate Change (IPCC)
Former Director General of the UK Meteorological Office

1 See for instance my Prince Philip Lecture (2005), Climate Change and Sustainable Energy, 2005 available under 'Talks' on the John Ray Initiative website, www.jri.org.uk [Live June 2007]

2 Address to the Energy and Environment Ministerial Roundtable, 15 March 2005 www.defra.gov.uk/corporate/international/energy-env/index.htm [Live June 2007]

Acknowledgements

zero**carbon**britain is the culmination of a year long collaboration at the Centre for Alternative Technology (CAT). The project was conceived and directed by CAT's Development Director, Paul Allen. The work has been conducted by and drawn on the knowledge and expertise of the Graduate Students of CAT's Graduate School for the Environment (GSE), CAT itself, the Public Interest Research Centre and consultations with many experts in the relevant fields. The process has been led by Tim Helweg-Larsen, a lecturer at the GSE and Director of the Public Interest Research Centre. The report has been diligently guided to conclusion by research co-ordinator Jamie Bull.

We would like to thank Mike Thompson and all the staff of the GSE for their support of the project.

The process has involved well over a hundred individuals and it is is not possible to accurately record here the detailed and varied contributions of all those involved. We hope on this page to give a sense of the contributions made.

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Reviewers:
While the final analysis and text of this report is entirely the responsibility of the authors, there are many who have commented helpfully on the evolving drafts. The final document does not necessarily reflect the opinions of those who reviewed it. These include many experts from a range of relevant fields: Richard Blanchard, Brenda Boardman, Colin Campbell, Rob Hopkins, Gavin Killip, Sarah Mander, Bob Todd, John Twidell and David Wasdell, as well as the considerable knowledge of CAT's own departments. We are especially indebted to Godfrey Boyle of the Open University whose encouragement, measured critique and extensive knowledge of renewable energy informed the concluding drafts of this report.

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At its heart, this report synthesises the insights of three great thinkers; Aubrey Meyer, David Fleming and David Wasdell. Their work on C&C, TEQs and climate feedbacks respectively stand as pillars of hope in effectively addressing the problems of global climate change.

Thank you to Sir John Houghton for his support and encouragement.

This page would be incomplete without our sincere thanks to the authors of the original 1977 Alternative Energy Strategy for the UK, the inspiration for ***zero**carbon**britain***: Bob Todd and Chris Alty.

Sponsored by:

UEL University of East London

Esmée Fairbairn Foundation

Centre for Alternative Technology 2007

Published by CAT Publications, a division of the
Centre for Alternative Technology Charity Limited; a company limited by guarantee.
Charity no. 265239; Company no. 1090006, registered in Wales.
Registered office: Llwyngwern, Machynlleth, Powys
www.cat.org.uk

In collaboration with the Public Interest Research Centre, Machynlleth
Registered no. 1112242 - Registered charity no. 266466
Registered office: 18 Victoria Park Square, London

First Published in the United Kingdom 2007

A CIP catalogue record is available from the British Library

ISBN 978-1-902175-48-5

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"The problems of the world cannot possibly be solved by sceptics or cynics whose horizons are limited by the obvious realities. We need men who can dream of things that never were."

John F. Kennedy

executive**summary**

Executive Summary

zero**carbon**britain is a radical vision of Britain's energy future, outlining bold policy drivers to reduce carbon emissions to zero within 20 years. What follows is a scenario demonstrating possible outcomes of these policies, using only existing and proven technologies.

This report is the Centre for Alternative Technology's considered response to the current understanding of the global climate.

Two things have changed in recent years.

- The international scientific consensus on the causes and gravity of climate change has moved from 'perhaps' to 'certainly'.
- A number of significant positive feedbacks have been identified in the climate system. Their effect is such that humanity's greenhouse gas emissions will act merely as a trigger for much greater and more rapid climatic changes.

Radiative Forcing – the Driver of Change

Large-scale planetary systems, if pushed beyond their limits of stability, will undergo spontaneous and accelerating change[1]. If triggered, will have unstoppable effects on the global climate. We may be decades or less away from such tipping points. To prevent such consequences, radiative forcing[2] must return to zero. This can be achieved in one of three ways:

1. Raised Outgoing Radiation – the planet is allowed to warm until it is hot enough for outgoing radiation to overcome the insulating blanket of the enhanced greenhouse effect. Outgoing radiation once again matches incoming radiation, but at the expense of a dangerously warmed planet.

2. Less Energy Retained – greenhouse gas concentrations are lowered to the point where radiation from the planet escapes at the same rate as solar radiation enters.

3. Reduced Incoming Radiation – through an increase in the albedo (reflectivity) of the planet, less solar radiation is absorbed, instead being reflected back into space.

Allowing the planet to warm to the point of renewed equilibrium – 1 above – poses risks to the global environment that do not bear contemplation. The emphasis of ***zero**carbon**britain*** is on pursuing approach 2 – reducing greenhouse gases to a level where the climate can gradually return to its former equilibrium.

It is recognised, however, that further interventions to increase the planet's albedo – approach 3 – may also need to be contemplated, depending on how strong the already triggered positive feedbacks have become.

Mapping the Unthinkable

These points lend the climate change problem a degree of urgency that is lacking in official policy. The UK Government's target of a 60% reduction of emissions by 2050 is well ahead of its peers, but still falls far short of what is now known to be needed. Even the IPCC, on whose authoritative data this work is based, is reticent in its advice for practical strategies, presumably because what the science shows must be done is not yet 'politically thinkable'.

zero**carbon**britain attempts to map the unthinkable, simply because the evidence compels us to do so. At the same time, it integrates solutions to the intimately connected issues of climate change, energy security and global equity.

The world now needs to move to net zero emissions as quickly as possible. It is the authors' belief that if society is motivated to do so, an emergency action plan could achieve this globally within 20 years. Britain must be a part of this process, and has the capacity to take a leading role. The strategy explores one possible scenario by which this could be achieved – 'Island Britain', where Britain becomes self-reliant in energy. It is a plausible outcome based on the likely

1 For example, reductions in the capacity of carbon sinks such as forests and oceans; the release of methane deposits and the loss of snow and ice cover causing accelerated warming

2 Under normal circumstances, the Earth system is in energy equilibrium, where incoming (solar) energy is exactly matched by outgoing (re-radiated) energy from the Earth. Any imbalance between incoming and outgoing energy causes a 'radiative forcing'. This can either be positive (warming the Earth) or negative (cooling the Earth). The currently raised levels of greenhouse gases are causing an ongoing positive radiative forcing. For a detailed account of this issue, see Chapter 3 of the report

ORIGINS OF THE PROJECT

zero**carbon**britain has its origins in *An Alternative Energy Strategy for the UK*, produced by the Centre for Alternative Technology in 1977. The conventional wisdom of the time was that economic growth and energy growth were inextricably linked. Policymakers predicted that by 2000, the UK's energy demand would be twice that of 1970. The 1977 document proposed the then-heretical view that energy growth should slow down, and then contract. It showed how reliance on nuclear and fossil fuels could be replaced by a carefully-designed combination of greater efficiency and renewable energy. In the event, its projections for the year 2000 proved far more accurate than those of the energy industry of the 1970s.

responses to Tradable Energy Quotas and feed-in tariffs.

The strategy does not however recommend isolation; rather it uses 'Island Britain' as a framework to demonstrate that Britain can achieve zero carbon emissions even under the strictest conditions, with no energy imports and without resorting to 'silver bullet' technologies such as carbon capture and storage (CCS).

It is hoped that this document will make a valuable contribution to the wider debate, demonstrating that an effective, pragmatic response is both thinkable and achievable.

Policy Recommendations

Although this is a strategy for Britain, it is necessarily also part of an international process. No single country can 'save itself' from climate change, because the atmosphere is a shared resource. The solution must therefore be a collective one. But collective solutions can only flow from binding international agreements. The only feasible basis for this is through equity in the allocation of emissions under a global cap. ***zero**carbon**britain*** advocates the international policy framework of Contraction & Convergence (C&C, see box), in which emissions rights are allocated on an equal per capita basis, proposed by the Global Commons Institute.

As the Stern Review demonstrates, the most economic option is to invest in tackling climate change

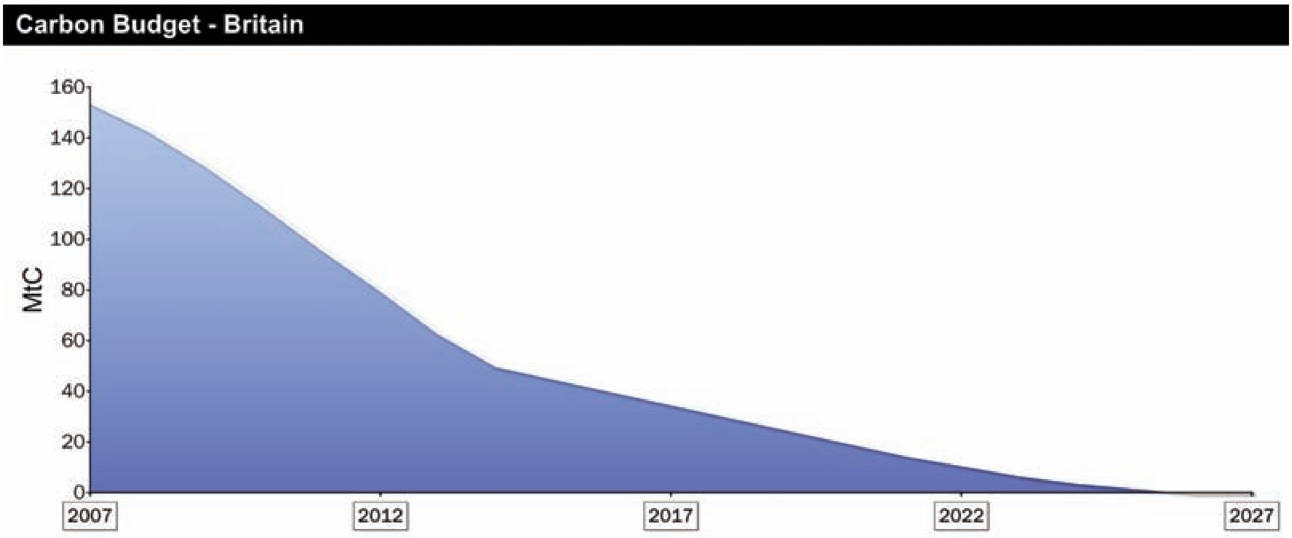
CONTRACTION & CONVERGENCE (C&C)

C&C is a global framework for an assured limit to future carbon emissions and their equitable allocation. Having agreed a global carbon budget to stabilise atmospheric CO_2 concentrations, a process of *contraction* of emissions is initiated, with progressively-reducing annual allocations that cumulatively fall within that overall budget.

At the outset, countries start with widely differing per capita emissions entitlement. However, a *convergence date* is agreed, by which time all countries' per capita emissions will have converged on equity. Thus, 'high carbon' nations (e.g. Britain, the USA) must reduce their emissions more dramatically than those starting from a lower level (e.g. Bangladesh, Niger).

To aid the process, countries whose emissions fall below their allocation in any given year can sell entitlement to countries that cannot reduce their emissions quickly enough. In this way, poorer countries are able to fund their development onto a low-carbon pathway, while richer nations can buy themselves time to achieve the necessary reductions.[3]

3 For details, see Chapter 6 of the report; also *Contraction and Convergence: the Global Solution to Climate Change* (Schumacher Briefings) by A. Meyer (Green Books, 2000)



immediately. This strategy does not propose that this investment be governed by command-and-control, but through market-based economic instruments. It is assumed that the economic framework can be adjusted in such a way that carbon reduction both motivates and funds itself.

To do this, the economic drivers must be transformed from those of today, where the primary constraints are financial, to an economy in which carbon becomes the overriding constraint. With such a shift, the most economically effective option is also that with the lowest embodied emissions. In this way the economy itself becomes an engine for rapid change and a race out of carbon.

It is assumed that convergence of national per-capita emissions is achieved by 2014, and that contraction to zero is completed by 2027. For Britain, the pattern of contracting emissions entitlements is shown in the graph above.

In addition to Britain's agreed carbon allocation, it is anticipated that for some years it would have to buy additional credits from within the global cap. Initially these purchases would grow as Britain's own allocation decreased, but would then start to decline as efficiencies were implemented and new renewables came on stream. This process would be complete by 2027. Most of Britain's purchases would come from less developed countries, and help finance their own sustainable energy strategies.

Internally, Britain's carbon allocation is translated into 'Tradable Energy Quotas' (TEQs). These are allocated free to households and sold through auction to businesses. Each year the cap on TEQs is reduced, so there are fewer to share, in line with the national budget.

Gradually, individuals and companies would have to learn to make low and zero-carbon choices, due to the cost or inconvenience of doing otherwise. TEQs are tradable, and represent a source of income for cash poor households. Essentially carbon credits become a kind of parallel currency.

This strategy explores a scenario that leads from the status quo to a zero-carbon Britain in a zero-carbon world. The pursuit of such a strategy will entail a challenging period in the country's history. The necessary rate of change will require rapid decision making and an urgent sense of common purpose, more akin to that which pertained during World War Two than in any period since.

Although most of the changes will flow naturally from the new economic drivers, the market may be too slow to provide all of the necessary resources in certain sectors. Some further government initiatives will be vital to catalyse the process. Particularly important are:

- A vastly expanded and dedicated Research & Development programme.
- Strong investment in new skills and training.
- A national public awareness programme to prepare people for what lies ahead.

The strategy envisages a dual process of 'powering down' energy demand, and 'powering up' renewable energy supplies. Only when demand has been reduced through new approaches and attitudes to energy use does it become possible to meet the nation's energy needs with indigenous renewables.

Powering Down

Britain is currently 'energy obese': far more is used than is actually required to deliver well-being. Years of cheap, abundant petrochemicals have led to highly wasteful practices and attitudes. Powering down does *not* mean deprivation, or a return to hardships of the past. It *does* however entail a thorough overhaul of attitudes to energy consumption. It also draws simultaneously on sophisticated energy management technologies, and on simple commonsense approaches to how energy is used.

This strategy recommends that by 2027, Britain will require half as much energy as at present.

This is a challenging goal[4]. A similar reduction was envisaged in one of the scenarios proposed in 2000 by the Royal Commission on Environmental Pollution, in its highly influential report on energy and climate change. However, that was to be achieved by the year 2050. The changes envisaged in ***zero**carbon**britain*** are much faster. The full document details the implications of this rate of powering down, sector by sector.

CONSUMERS

Consumers will find life gradually changing, as their quota declines and they learn to reduce their dependency on carbon intensive activities and processes. People will become much more aware of their energy consumption, and indeed could make money by living shrewdly and selling surplus quotas.

A great deal of Britain's emissions reduction will be in 'upstream' processes run by industry and government. However, this will result in a considerable shift in the range and prices of products available, in all sectors. At a domestic level, houses will use ICT[5] to maximise energy efficiency, and more visible metering to provide information on energy use. A range of tariffs will enable consumers to choose between high cost uninterruptible supplies and discounted rates where energy companies can control appliance use to balance demand[6].

The scenario also recommends a widespread change in transport patterns and an increase in localised activities.

INDUSTRY

Because they have to pay for TEQs, businesses will be highly motivated to make emissions cuts. Many technologies already exist to help achieve the necessary targets. A strong emphasis on combined heat and power (CHP) will shift the rationale for the location of power stations, and the associated markets for heat. Mechanical power will be delivered almost entirely from electricity.

BUILDINGS

The heat demand for buildings is expected to decline by 50% and electricity demand by around 10%. New buildings will be effectively zero-carbon from 2012. There will also be a vigorous programme to refurbish older buildings for lower energy consumption.

Some heating will come from biomass CHP, some from surplus renewable electricity. The benefits of electrical heating will be multiplied by the use of heat pumps. Some of the intermittent surpluses in renewable generation may also be stored as heat.

TRANSPORT

Power for transport will switch almost entirely to electricity. This is likely to be the most radical and demanding shift.

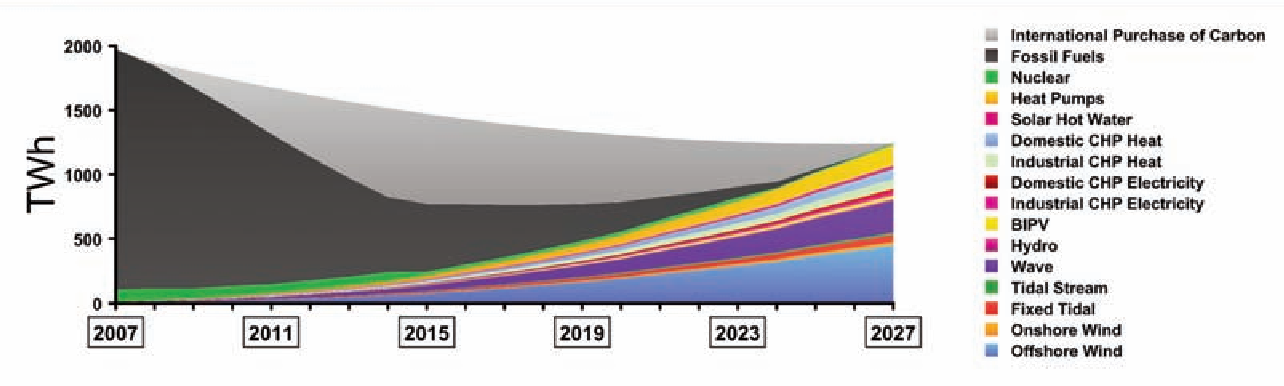
Private vehicles will become more expensive to run,

4 In relation to this, it must be recognized that energy generation from fossil fuels delivers only a fraction of the calorific value of the fuel as usable energy

5 Information and Communication Technology

6 For example, through remote-switching of non-critical appliances such as washing machines and freezers for just a few minutes at a time

Energy Profile (before losses): 2007-2027



but this will be offset by hugely improved rail and bus services. Virtually all vehicles will be electrically-powered, with the capacity to feed into the Grid as well as draw from it. This will be an important component for balancing a renewables based Grid.

With few alternatives to conventional aviation fuel, air travel is expected to decline dramatically. The incentives will be strong to pursue both efficiency and explore alternative energy sources and storage technologies. Domestic air travel may be limited to emergency use, while international flights will have to pay their full carbon costs through the system of carbon quotas, severely reducing demand.

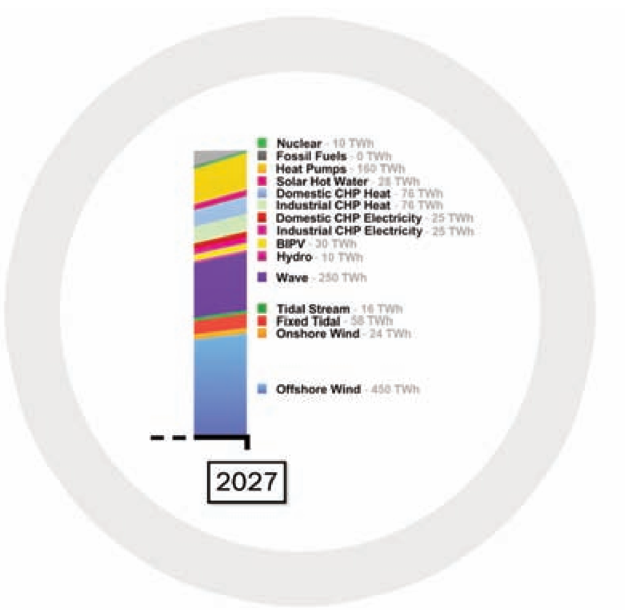
FOOD & LAND USE

The new 'carbon economics' will raise the cost of both petroleum based agrochemicals and the transport of produce. It will also favour the sequestration of carbon in organic matter. In consequence, the strategy envisages a largely organic agricultural system producing Britain's food.

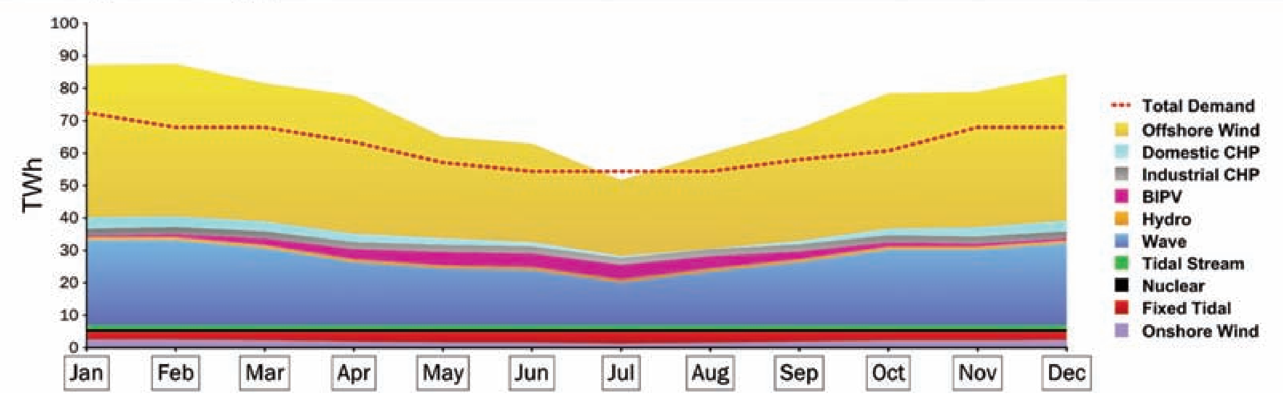
There is likely to be much more local supply for local markets, and less national bulk distribution. Carbon economics will also motivate a large reduction in livestock, probably by 60% or more. This will cause a major agricultural and landscape revolution, with several implications. One is a change in diet, with less meat and dairy produce (and also less fish) but an overall improvement in health. Another is the freeing up of large areas of land for forestry and biomass crops.

Power Up Renewable Generation

The 'Island Britain' scenario envisages demand for energy will reduce by 50% through the 'Power Down' process, giving an achievable target for indigenous renewable resources. Britain is a windy island, surrounded by powerful seas. The energy is there, and the economic drivers unleashed by TEQs will create a race to harvest it.



Electricity Demand/Supply Profile



With declining oil and gas, the electricity supply will be increased to compensate, requiring reinforcement of the National Grid. Compared to large-scale fossil fuelled generation, a grid with a high penetration of intermittent and variable renewables requires more sophisticated systems for integration and balancing of supply.

There will be times when renewables are generating more energy than is needed in a local area. In these situations, energy will be exported to other areas, or stored in vehicle-to-grid systems, flow batteries, pumped storage or geological hydrogen stores. In the opposite situation, when the available renewable resource is insufficient to meet local demand, grid distribution brings power from other parts of the country. This is followed by shedding demand on ‘economy’ tariffs and retrieving power from storage systems.

Beyond this, power is acquired from ‘firm’ renewables such as biomass fuelled CHP. If required, further energy reserves can be accessed from discharge of electric vehicle batteries and CHP from national strategic hydrogen reserves.

The ‘Island Britain’ scenario demonstrates that the country can not only provide all its energy from renewables, but that its storage requirements are also achievable.

The need for power balancing is minimised by intelligent load management, wide geographical distribution of renewable generators, plus ‘firm’ renewables such as tidal and biomass fuelled CHP.

Tidal energy, unlike wind and solar electric, is highly predictable and regular. The 11% of Britain’s electricity that this technology can supply is equivalent to the predictable and continuous baseload currently provided by nuclear generation.

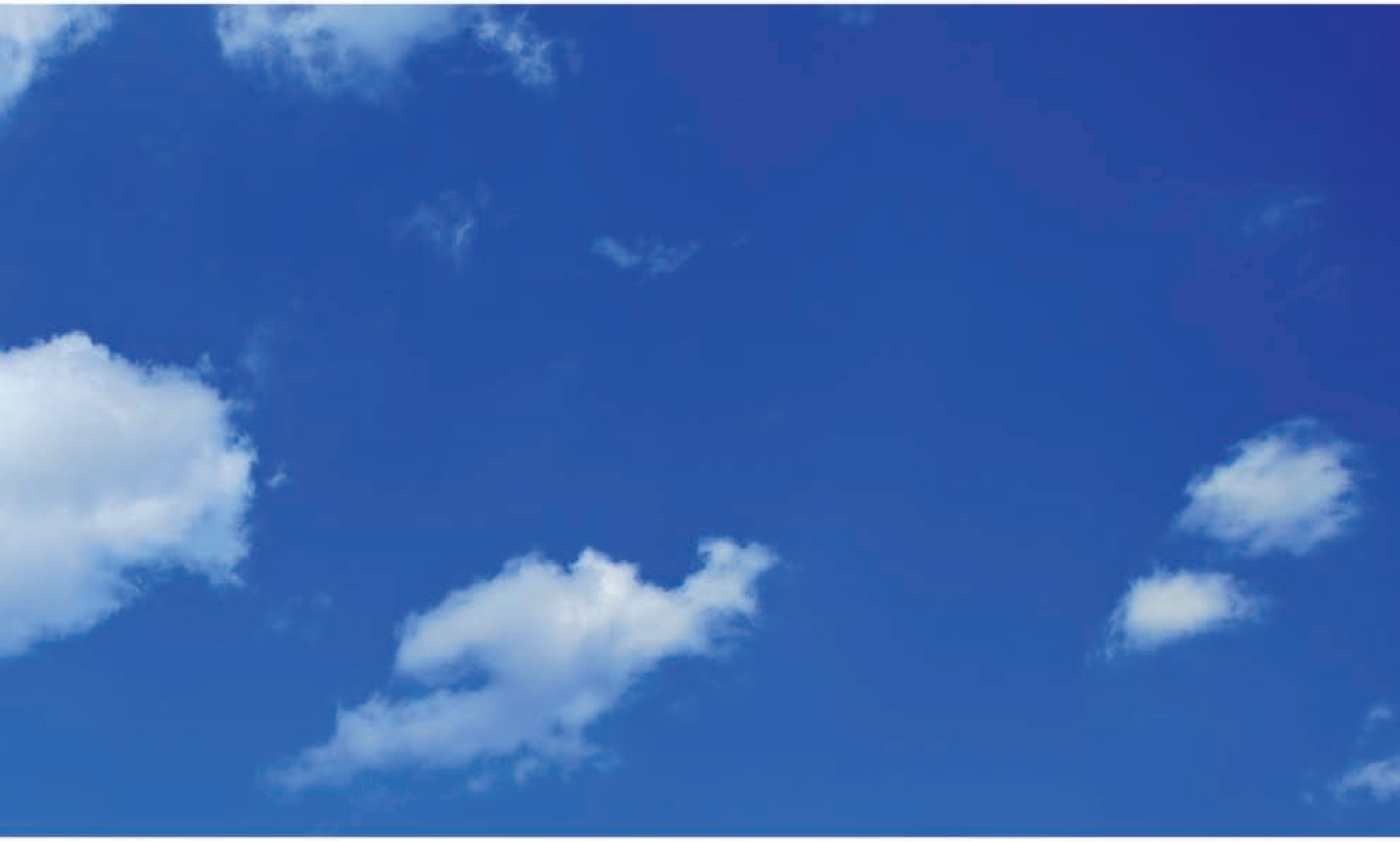
Generation sources include a strategic mix covering the different conditions throughout the year. Britain’s solar resource can deliver both electricity and heat in summer, complementing wind and marine renewables. With its good match to the demand profile across the year, wind will provide the greatest proportion of electricity in the scenario, at around 50% of total supply. Britain has a large resource, particularly offshore. It is estimated that 14% of the total potential offshore resource will be tapped by 2027.

Conclusion

This report concludes that ***zero**carbon**britain*** is both scientifically necessary and technically possible. With TEQs it can also be made socially acceptable. It may also deliver a higher quality of life, along with a sense of collective purpose that has not been felt in Britain for many decades.

What is needed now is to make a zero-carbon Britain politically thinkable. The authors are convinced that this can be achieved, but it will require strong leadership and a robust cross-party consensus.

zerocarbonbritain
an alternative energy strategy



"Climate change is for real. We have just a small window of opportunity and it is closing rather rapidly. There is not a moment to lose."

Dr. Rajendra Pachauri

Chairman, Intergovernmental Panel on Climate Change

introduction

Introduction

zero**carbon**britain takes as its starting point a penetrating analysis of the current state of the planet's climate system, to develop a radical blueprint for Britain's sustainable future.

The policies assembled in this document are the drivers for major advances in energy efficiency, allied to the rapid deployment of diverse and secure renewable energy supplies.

Supporting these policies is a detailed and plausible scenario, labelled 'Island Britain'. It deliberately adopts the worst-case scenario – one in which Britain must produce all of its own power – leading to the insight that this windswept nation could become a renewable energy exporter to Europe.

Zero Carbon

zero**carbon**britain is an intentionally bold title – one that reflects the necessary scale of response to the call of climate scientists for rapid and radical action to counter the threat of climate change.

The concentration of greenhouse gases (GHGs) in the Earth's atmosphere is cumulative. It reflects not only our emissions today, but those of years and decades past. Even a reduced level of output still adds to the overall atmospheric burden.

In view of the scale of climatic change that is already underway, the minimum necessary response is a move to zero net carbon emissions[1].

This entails a near-total switch from fossil fuels to renewable energy. Any residual emissions, whether from cement production, land use, or the natural feedbacks that have been triggered, must rapidly be compensated for.

"Climate change threatens the basic elements of life for people around the world - access to water, food production, health, and use of land and the environment."

Sir Nicholas Stern

1 In this instance, 'net' means that carbon emissions from fossil fuels must fall to zero or be balanced by sequestration

Chapter 1 History

The Original Strategy

Thirty years ago, in collaboration with the renewable energy experts of the day, The Centre for Alternative Technology (CAT) published an Alternative Energy Strategy for the UK.

The first of its kind, the report demonstrated with thermodynamic rigour that Britain's energy needs could be amply met from renewable sources. It was motivated by the realisation that conventional energy sources – both fossil fuel and nuclear – were ultimately finite, along with growing awareness of some of the environmental hazards posed by their continued and growing use:

> **"The Earth's fuel reserves are finite. Once consumed they cannot be re-used, and their use has the possibly undesirable long-term effect of raising the temperature of the Earth's surface."**
>
> Alternative Energy Strategy 1977[2]

The original strategy showed how an alternative approach could level off and ultimately reduce Britain's primary energy demand. At the same time it proposed increasing the generation of renewable energy, in order to reduce damaging emissions and slow the rate of resource depletion.

Its approach was poles apart from the mainstream thinking of the day, in which energy demand was predicted to continue the near-exponential growth it had undergone since the end of World War Two.

That historic growth had been fuelled by the discovery of North Sea oil reserves and the promise of cheap nuclear power. Conventional wisdom was to grid-link a small number of large-scale generation facilities. Renewable energy was seen as parochial and associated with the pre-National Grid wind or hydro schemes of remote and rural areas.

But CAT's vision shaped the thinking if not the action of Britain's policy-makers. Its approach influenced energy ministers from Tony Benn to John Battle, showing how energy efficiency measures and renewable energy sources could be integrated into a viable new policy for Britain.

A New Strategy

The original publication proposed a solution to a set of problems that were then only dimly and partially perceived. That stands in marked contrast to the present day, when the problems of energy security, global equity and climate change are unavoidable. These are the three key challenges that any viable energy strategy must now face:

1. CLIMATE CHANGE

Unchecked rises in CO_2 and other greenhouse gas emissions over the last 200 years have instigated a rapid warming of the planet. Increasing energy trapped within the atmosphere is creating a more variable and capricious climate. This effect is continuing and may reach a point where feedbacks[3] make it impossible to avoid further and unstoppable change.

> **"Climate change threatens the basic elements of life for people around the world - access to water, food production, health, and use of land and the environment."**
>
> Sir Nicholas Stern[4]

2. ENERGY SECURITY

In recent years, the security of global energy supplies has been significantly eroded. It is threatened not only by political instability in the

2 In this instance, net means that carbon emissions from fuels must be balanced by sequestration

3 CAT (1977) An Alternative Energy Strategy for the UK, CAT Publications 4 Stern, N. (2006) Stern Review on the Economics of Climate Change

4 Stern, N. (2006) Stern Review on the Economics of Climate Change

5 Energy return on energy investment for oil was 23 in the 1970s (1) and is falling as stocks are depleted. This has led to the increasing viability of unconventional oil such as tar sands with a lower EROEI than oil - less than two (2). (1 Roberts, S. (2006) *Energy as a driver of change*, The ARUP Journal) (2 Youngquist, W. (1997) *GeoDestinies: the inevitable control of earth resources over nations and individuals*, p. 436, National Book, Portland, OR

6 Carbon capture and storage in conjunction with enhanced oil extraction, as proposed by BP in the North Sea www.bp.com

Middle East, but also by growing dependency on single suppliers such as Russia. With geological constraints on supply, expanded demand from countries like China and India creates an inexorable upward pressure on prices. The erosion of surplus capacity has made the just-in-time supply chain increasingly vulnerable to external factors such as hurricanes in the Gulf of Mexico.

The geologically inescapable peak in global oil output lends particular urgency to the need to address these problems. As demand outstrips supply, oil prices will inevitably continue their rise as countries compete for the remaining sources.

3. GLOBAL EQUITY

Wealth and prosperity, measured in financial terms, are closely related to energy consumption. There are global inequities between those with easy access to energy resources and those whose access is limited. To the extent that inequity is a systemic outcome of current trading mechanisms and values, there are opportunities to ameliorate it through well-structured international policy.

In the context of global climate change, the energy-poor can be seen as living on the credit side of the environmental damage balance-sheet, while the energy-rich lie on the debit side. What is proposed in this report is a framework that acknowledges these respective positions, and establishes a mechanism through which their contributions and costs are properly accounted for and brought into balance.

Conclusion

The longer these challenges go unmet, the higher will be the cost. And that cost will have an increasingly human as well as financial dimension. There is therefore a pressing need for a well-founded strategy with which to respond. Based on detailed research into Britain's energy needs, CAT has created a radical yet pragmatic approach to meeting these challenges: ***zero**carbon**britain***.

The strategy balances supply and demand via two interlinked strands: demand reduction by minimising energy wastage (Power Down), and supply substitution by investment in renewables (Power Up). It looks critically at all possible options, relying only on proven and near-market technologies, while keeping a watching brief on the rest.

Implementation of energy efficiency and investment in renewables are now integral to Britain's energy policy, but their objectives have yet to be linked to the magnitude and timescale of the three challenges outlined above. Britain's climate change targets must integrate with the equally urgent need for energy security, as global demand for oil and gas begins to outstrip production. Likewise, the demand for global equity has never been higher, nor a more pressing moral concern.

Although all three challenges are widely acknowledged, policies to address them have tended to be piecemeal and isolated. There are solutions to dwindling oil reserves that accelerate climate change[5], and there are solutions to climate change that exacerbate peak oil[6]. What is needed is an integrated approach to all three challenges.

At each step, ***zero**carbon**britain**'s* approach is to seek the root cause of the problem and, in understanding the system's dynamics, explore systems-based solutions. It is from this standpoint that these policy recommendations are derived.

An adequate response to such a massive challenge requires using the available resources to their best effect. The longer the delay, the less time there will be in which to respond, and the more limited and costly will be the oil reserves with which to work.

There is now a unique chance to initiate a response and avert the immensely damaging consequences of a failure to address these challenges. Society is rapidly approaching its final opportunity to create a stable and equitable heritage for future generations.

Chapter 2 The Strategic Framework

zero**carbon**britain is first and foremost a recommendation for an effective national energy policy.

The transition to a zero-carbon Britain is a national response to increasing insecurity of fossil fuel supplies, and an essential part of the larger global response to climate change.

zero**carbon**britain therefore advocates effective international as well as national policies. The second half of this report explores one possible scenario, which represents a plausible outcome of the policies recommended in the first half. It does so under the additional constraint of treating Britain as an isolated island ('Island Britain').

It shows how such an energy policy might shape the future of Britain's energy production and consumption. What must be emphasised, however, is that this scenario is intended to be illustrative rather than prescriptive. It is a projection of the likely outcomes of a quota scheme, and the planned outcome of a bold public sector energy strategy.

zero**carbon**britain recommends the urgent adoption of Contraction & Convergence (C&C) as the guiding framework for international negotiations and planning on climate change (see Chapter 6).

The report combines the latest climate change science with the Contraction & Convergence model, to arrive at a global carbon budget that actively supports the larger project of avoiding catastrophic climate change. This global context provides the basis for establishing a CO_2 budget for Britain.

Within Britain, Tradable Energy Quotas[1] (TEQs – see Chapter 7) provide the mechanism by which the national carbon budget is distributed. TEQs (pronounced 'tex') provide the core policy driver, aligning the interests of citizens, industry and government towards a common purpose – a move away from carbon.

A quota scheme provides strong incentives to power-down wasteful energy demand and to power-up Britain's infrastructure of renewable energy supply. In order for it to take place, such changes have to be in the people's best interests.

TEQs would be supported by clear government strategy for changes in national infrastructure provisions such as transport, and by supplementary legislation on specific domestic and private sector issues.

It bears repeating that the scenario presented in this report is not the only possible outcome of the energy policies being recommended. It is an illustration of how such an energy policy might work in the light of climate change, energy security and global equity.

It demonstrates that Britain is capable of rapidly reducing its fossil fuel dependency while supporting high levels of well-being for the population. Furthermore, it demonstrates the practicality of this future under the worst case scenario of needing to derive all energy supplies from within Britain's borders.

A Strategic Economic Shift

In brief, the proposal is a shift from the traditional financial economy of today into an economy sensitive to carbon. The core dynamics and drivers are different. Maximising profit will always drive decisions. But in tomorrow's economy, decisions on every level – personal, business and governmental – will be driven by the imperative to conserve valuable carbon permits and to pursue cheaper, zero-carbon enterprises.

Return on investment will still be the key motivator of all business decisions – but whereas it used to be a financial return on a financial investment, it will increasingly be a financial return on a carbon investment. In the future it will become a financial return on a zero-carbon investment.

1 Fleming, D. (2005) Energy and the Common Purpose – Descending the energy staircase with Tradable Energy Quotas (TEQs) www.teqs.net/book/teqs.pdf [Live June 2007]

zerocarbonbritain
an alternative energy strategy

"This is not some slow, controlled change we're talking about. It's fast, it's unpredictable, and it's unprecedented during human civilisation."

WWF

globalcontext

Chapter 3 Climate Change

Introduction

Climate change continues to rise towards the top of political and social agendas. However, the potential level of threat that it poses is so far unmatched by commensurate action. This section discusses the extent to which human influence on the climate is hastening the onset of powerful processes to reinforce escalating climatic change.

It is argued that this escalation arises from positive feedback mechanisms within the Earth's climate system. An initial forcing, caused largely by anthropogenic greenhouse gas (GHG) emissions, may lead to climatic consequences of a greater magnitude. The limitations of our understanding, and the difficulties involved in quantifying the risk, strengthen the case for taking proactive steps to tackle climate change while doing so is still within our grasp.

Factors Governing the Climate System

GLOBAL WARMING & RADIATIVE FORCING

Global warming is the measurable rise in temperature of the atmosphere at the Earth's surface, and is the result of radiative forcing.

The term 'global warming' is now widely understood. 'Radiative forcing', however, has yet to fully enter the common vocabulary, but is essential for a sufficient understanding of climate change, if we are to respond appropriately.

Radiative forcing[1] is a measure of the net energy entering the Earth system. It is the difference (in watts per square metre) between the radiative energy received by the Earth, and the energy radiated from the Earth back into space[2].

As atmospheric GHG concentrations rise, virtually the same amount of energy continues to enter the system, but less is able to escape, due to an increasing proportion being trapped by the extra GHGs. Thus, a rise in GHG concentrations causes radiative forcing.

To stop global warming, radiative forcing must be returned to zero. This can be achieved through one or more generic approaches:

1 - More Energy Radiates Out

The planet warms until it is sufficiently hot for outgoing radiation to overcome the insulating blanket of the enhanced greenhouse effect. Outgoing radiation once again matches incoming radiation but at the expense of a warmer planet.

2 - Less Radiative Energy is Retained

Greenhouse gas concentrations are lowered to the point where radiation from the planet can escape at the same rate as solar radiation enters.

3 - Less Radiative Energy Enters

Through an increase in the albedo (or reflectivity) of the planet[3], less solar radiation is absorbed by the planet, instead being reflected back into space.

Reducing radiative forcing to zero prevents additional energy from being added to the stock of energy held in the Earth system as a whole. However, of the additional net energy that has been received over the last hundred years and more, only a small proportion is held in the atmosphere itself. Most is held in the mass of the Earth, and especially in its oceans.

This happens for two reasons. First, because the atmosphere is transparent, most of the sun's energy passes through it to be absorbed by the surface of the planet. Second, because the Earth and its oceans are some 1,000 times more dense than the atmosphere, they can – and do – store much more heat energy than the air. Their mass also means that there is a thermal delay of over fifty years[4] between radiative forcing and the measurable response in global temperature. A

1 Houghton, J. (2004) *Global Warming: The Complete Briefing* 3rd Rev Ed, Cambridge University Press

2 Some energy entering the earth system is also stored chemically and through phase changes

3 Tentative proposals exist for large-scale human intervention on the average albedo of the planet

4 Dr. R. K. Pachauri (Feb 2006)

THE ALBEDO EFFECT

Albedo refers to the reflectivity of a planet's surface. It represents the proportion of sunlight that is reflected back into space compared to the total amount that falls on the surface. The albedo of the Earth would range from about 0.03 (3%) if it were covered in water (highly absorbent), to 0.9 (90%) if it were covered in snow (highly reflective). Thus, a planet's albedo depends on the nature of its surface, along with the presence or absence of cloud cover or other reflective aerosols.

Albedo has a large effect on the climate system. It influences the balance of incoming and outgoing radiation, and while this remains constant the climate will remain in equilibrium (all else being equal). According to NASA, a drop of as little as 0.01 in the Earth's albedo would have a major warming influence on climate – roughly equal to the effect of doubling the amount of CO_2 in the atmosphere. Currently, the Earth's average albedo is around 0.3 (30%).

Technologies to combat the effects of global warming have been proposed that artificially manipulate the Earth's albedo. By reflecting more light and heat back into space the energy balance is altered, thus cooling the planet. Such ideas include:

- Cloudseeders – specially-constructed vessels that pump a fine mist of sea-water high into the air, forming and thickening the cloud cover over the oceans, to reflect more of the Sun's rays.

- Sulphur screens – by using rockets to inject sulphate particles high into the stratosphere, the 'global dimming' effect of volcanic eruptions could be artificially replicated. The sulphate particles reflect sunlight at high altitudes, effectively reducing the planet's albedo. One negative side-effect would be a substantial increase in acid rain.

The feasibility and side effects of these proposals remain both controversial and highly uncertain.[5]

second effect is that, since the start of the industrial revolution, considerable energy has been absorbed by the actions of melting ice and evaporating water. Both are highly energy-intensive processes, even though they do not cause a net increase in air temperature[6].

The average air temperature at sea level around the world has risen to some 0.7ºC above pre-industrial levels. As a result of the time lag noted above, this warming is equivalent to the equilibrium temperature consistent with atmospheric GHG concentrations as they were in the 1960s. Given that GHG emissions and resultant concentrations have risen dramatically since then, we have already set in motion a considerable and extended period of global warming and consequent climate change.

It is therefore clear that, even with no further anthropogenic (human induced) addition to atmospheric GHG concentrations, global temperatures will continue to rise. To prevent warming beyond that which is already locked into the Earth system requires an end to further radiative forcing. This means that there must be no further addition to the blanket of greenhouse gases in the atmosphere. Year-on-year emissions will have to drop to near zero. Beyond this, to mitigate against further warming will need a period of negative radiative forcing.

CONCLUSION 1

Regardless of future human actions, considerable warming is already locked into the Earth system.

5 Source: NASA Earth Observatory

6 Heating a bucket of ice (adding energy) will cause it to melt into water (a phase change), but its temperature will remain at zero degrees Centigrade

Forcings & Feedbacks

A radiative forcing can either be natural, such as a change in solar output, or anthropogenic, such as from the emission of CO_2 through burning fossil fuels.

A climate feedback is the response of the climate to either an external forcing or an internal variability. Such responses may serve to reinforce the effect of the original forcing (a positive feedback) or to dampen it (a negative feedback). It is the potentially overwhelming climatic effect of a number of interrelated positive feedbacks, *initiated* by external forcings (principally greenhouse gases), which is of fundamental concern. While continued emissions of greenhouse gases will themselves continue to warm the planet, this warming is likely to be small compared to the temperature increases due to positive feedbacks.

It now seems that positive feedbacks are dominating negative feedbacks. Some examples of positive feedbacks include:

- The Earth's oceans act as sinks for CO_2 and are responsible for around one third of the CO_2 sequestered from the atmosphere. As the temperature of the oceans increases their capacity to absorb CO_2 declines, resulting in higher temperatures (temperature-forcing-temperature feedback).

- A related effect is that dissolved CO_2 increases the acidity of the oceans. As the oceans grow more acidic they become less able to absorb additional CO_2, thereby further reducing their capacity to act as a carbon sink (carbon-forcing-carbon).

- Rising sea and air temperatures generate higher levels of atmospheric water vapour, the most plentiful single greenhouse gas in the Earth's atmosphere (temperature-forcing-temperature).

- A strong enough initial warming is forecast as sufficient to trigger the slow release of both undersea and land-based methane deposits, with significant further global warming potential[7] (temperature-forcing-methane-forcing-temperature).

- Snow and ice reflect far more of the Sun's radiation back into space than do soil, vegetation or ocean surfaces. The decline of sea ice and permafrost in the Arctic exposes more of the ocean and land surface to the sun. This allows those surfaces to absorb yet more solar radiation, which in turn causes regional and global warming, further accelerating ice losses (temperature-forcing-temperature).

Evidence now shows that, to varying extents, each of the feedbacks listed above is now in operation[8]. It is imperative that their progress is effectively countered before they become irrepressible.

CONCLUSION 2

A relatively small initial warming, caused by raised greenhouse gas concentrations, has the potential to trigger a much larger additional warming, due to positive feedbacks.

Implications of an Era of Positive Feedbacks

On the basis of the above two conclusions, it can be seen that it is not rising temperatures that are themselves the primary concern. Rather, it is the positive feedbacks to which they give rise. Without intervention, the growing anthropogenic influence seems set to lead to the crossing of critical thresholds within the Earth system. At this point it is likely that several of the positive feedbacks triggered will then become the overriding factors driving further temperature increases, irrespective of any belated attempt to curb anthropogenic greenhouse gas emissions.

One analogy is that of an old-fashioned Guy Fawkes-style bomb. While it may be dangerous in itself to light the fuse, the real damage happens when the bomb explodes. Humanity has lit a climatic fuse, and though it may still be possible to extinguish it, time is running out. If the bomb goes off, there will be little that can be done to contain its effects.

The implications of allowing such a 'runaway' process to begin may be devastating. Volatile, abrupt climatic

7 Mass for mass, methane has approximately 23 times the warming effect of CO_2: IPCC (2001) *Third Assesment Report*

8 IPCC (2007) *Fourth Assessment Report*

shifts could progress at a speed unmatchable by adaptation efforts; many millions of people will be vulnerable to sea-level rises, billions more to hunger and thirst, as agriculture becomes impracticable and droughts intensify; economic activity will be disrupted; large portions of ecosystems and biodiversity will be wiped out.

Migration of species towards the cooler latitudes of the poles is already being observed. The rate of this species migration, at around 6km per decade, is too slow for the poleward migration of isotherms (bands of equal average temperature) at 40km per decade[9]. In such a situation it is envisioned that geopolitical instability will be commonplace, as widespread struggles for land, food and water emerge. It is therefore essential that these critical thresholds are not crossed. The problem is exacerbated by the lack of certainty over where exactly the thresholds lie and how close the system is to reaching them.

HITTING A MOVING TARGET

Scientific understanding of the Earth's climate system continues to grow. This understanding is used in computer-based climate simulations, projecting future scenarios of climate change based on different emissions profiles. In turn, the validity or robustness of these models is tested against the historic records of climate change going back 400,000 years and more.

It must be emphasised that these models are only approximations of the real climate system. But the more impacting variables that are included in a model, the better its approximation. To date, most climate models have focused on the carbon cycle alone.

More recently, coupled climate-carbon models have been developed that factor-in some of the interactions and feedbacks between the carbon cycle and the climate system. These include degradation of the Earth's carbon sinks[10] as CO_2 levels and temperatures rise. There is growing evidence that the Earth's natural carbon sinks may be absorbing only a diminishing fraction of CO_2 emissions.

These models are still only approximations, but are already demonstrating the need for dramatically more stringent carbon budgets. For example, the model run by Damon Matthews[11], a contributing author to the Fourth Assessment report of the IPCC, suggests that in order to keep the rise in surface temperature below 2ºC, global emissions reductions in the order of 80% to 100% by 2030 are required. A dominant characteristic from Matthews' modelling is that the effect of CO_2 in the atmosphere is cumulative:

> **"The conclusion is that for the range of scenarios explored here, both stabilisation level and multi-century global warming were sensitive only to the total anthropogenic emission of CO_2, and not to the trajectory of emissions taken over the next century."** ***[Matthews, op. cit.]***

Furthermore, Matthews finds that in scenarios where emissions reductions come too late (and consequently the total emissions are too high), extended periods of *negative* emissions were required to achieve the stabilisation target.

The scenarios shown here represent some of the latest in climate modelling. But Matthews explicitly warns that the modelled relationship between CO_2 emissions and temperature stabilisation *only holds in the absence of substantial non-linear climate responses to increasing CO_2 forcing.* [Op. cit., p. 595].

Feedback mechanisms outside the climate-carbon system are also under active investigation. But there are no current models that integrate all of these mechanisms with the coupled climate-carbon models used by Matthews. Understanding of climate feedbacks, as well as expertise in modelling them, is racing to catch up with the observed pace of climate change.
In conclusion, a clear pattern is emerging from both the IPCC reports and ongoing climate research. The prognosis is ever more severe. In defining policy, it is only prudent to expect this trend to continue, as the science expands to create ever-closer approximations to the real-world Earth system.

9 Hansen, J. Sato, M. Ruedy, R. Lo, K. Lea, D.W. Medina-Elizade, M. (2006) *Global temperature change*, National Aeronautics and Space Administration Goddard Institute for Space Studies

10 Ocean- and land-based plants that absorb CO_2 from the atmosphere and act as carbon sinks

11 Matthews, H.D. (2006) *Emissions Targets for CO2 Stabilization as Modified by Carbon Cycle Feedbacks*, Tellus 58B, pp. 591–602

What is a 'Safe' Level of Emissions?

The constraints of current knowledge mean that it is not possible to determine our exact proximity to critical thresholds or 'tipping points'. This implies the need to be very conservative when attempting to define 'safe' levels of emissions. Though the magnitude and time frame of positive feedbacks is a contentious subject, the scale of their latent threat should prevent any complacency as to when, and to what extent, to act.

The upshot is that temperature change (and, accordingly, greenhouse gas stabilisation targets) must be kept to a minimum. In order to reduce the risk of the initial anthropogenic warming triggering massive chain reactions in the Earth's own subsystems, and further increasing temperatures, the atmospheric stabilisation level chosen must be set very low.

Furthermore, as climate science progresses, the boundaries of what is considered 'safe' in terms of atmospheric levels of greenhouse gases and climate change are continually being revised downwards.

Effective intervention will also need to outperform any positive feedback mechanisms that may be triggered during the long period of rising temperatures.

The required outcome for humanity must be the eventual return of the global temperature to a benign and stable equilibrium.

Implications for Global Energy Policy

Humanity's experiment with burning carbon over the last two centuries has propelled the planet into uncharted territory. We may even now have overshot the limits of the climate's self-stabilising capacity. This presents a disturbing predicament when defining future energy policy for the World, let alone Britain.

In relation to this scale of risk, the only rational response is to cut global carbon emissions to near zero. Indeed, it seems increasingly likely that urgent remedial action may also be required, to initiate a controlled programme of negative radiative forcing or 'global cooling'.

Countries that are first to realise the problem must act to mobilise their international neighbours to pursue a global solution to this unprecedented challenge. This energy strategy consequently represents a call to action on two levels:

International

- Cut fossil fuel emissions of CO_2 to near zero, through a managed programme of Contraction & Convergence.

- Support a full-scale push to clarify further our understanding of climate change and the Earth systems in which it operates.

- Develop and deploy further coordinated measures to return temperatures to a benign and stable equilibrium through the managed reduction of radiative forcing to zero, with contingencies for a managed period of negative radiative forcing.

National

- Implement policy measures to deliver well-being within the constraints of a globally acceptable carbon budget for Britain. The principal policy driver for this being Tradable Energy Quotas (TEQs).

Defining a Global Budget

In the above context, this strategy document explores an energy scenario for Britain that stands as a plausible outcome of the policy recommendations made.

The strategy takes a 20-year window to phase out carbon emissions globally. The need to entirely remove fossil fuel emissions is seen as an essential first step to mitigate against atmospheric climate change. Furthermore, it cannot be done too soon and the 20-year time frame is selected as an achievably short timescale to implement an emergency global action plan.

Emissions are currently estimated to be 8.5 billion tonnes per year[12]. A linear reduction over the 20-year time frame to zero emissions equates to a global budget of 85 billion tonnes of carbon or 311 billion tonnes of CO_2.[13] The global 20-year budget is smoothed allowing greater emissions in the early years and less in the later years.

Both the 20-year window and the 85Gt carbon budget do *not* on their own provide a clear route to a safe and stable climate. Rather, they represent a timescale and a budget that can achievably be worked within, given appropriate motivating conditions. They should likely be augmented by further measures, as near zero emissions alone do not guarantee against the following:

- Continued atmospheric warming from the already raised levels of greenhouse gas concentrations.

- The currently raised temperature of the planet, or the influence of the heat energy stored in the oceans, triggering ‘temperature-forcing-temperature’ feedbacks, which can operate independently of greenhouse gas concentrations.

- The continued and growing release of greenhouse gases from non-human processes – ‘carbon-forcing-carbon’ feedbacks.

CARBON CAPTURE AND STORAGE (CCS)

One approach to reducing greenhouse gas emissions is the capture and storage of carbon from large sources like power stations, by ‘scrubbing’ them from flue gases and storing the CO_2 in geological formations or in the deep ocean. The technology for CCS is economically available, burning fossil fuels in conjunction with CCS does not capture all emissions. Therefore, in pursuit of a truly zero-carbon Britain, CCS with fossil fuels is not envisaged in the ‘Island Britain’ scenario. However, when burning biomass with CCS the net result is carbon negative

Enhanced Carbon Sinks

While CCS prevents the release of additional CO_2 into the atmosphere, carbon sinks sequester that which is already there. There are many natural sinks, some of which store the carbon for a limited period (e.g. tree growth), while others permanently remove it from the environment (e.g. absorption by calcifying marine organisms, with subsequent burial in sea-floor sediments). The creation of new carbon sinks, or the enhancement of existing natural ones, may be of future value, but remain to be fully tested. Some examples are:

Black Soil or Terra Preta

These terms refer to the product of taking biomass such as wood, a natural carbon sink, and turning it into char via a process known as pyrolysis. The carbon rich char is then buried, locking it away from the atmosphere. These processes also provide many beneficial effects for the soil, including increased water retention, and mineral and micro-organism enrichment. This increases the soil’s fertility and its ability to moderate the effects of weather extremities, resulting in increased plant yields and nutritional content. The pyrolysis process releases by-products including methane and hydrogen that can be used for combustion or with fuel cells. The process appears to offer significant potential and warrants large-scale immediate research[14].

Phytoplankton Promotion

Phytoplankton (marine micro-organisms) absorb CO_2, and when their bodies sink to the ocean floor some of that carbon is sequestered. By adding nutrients to the oceans, their growth can be promoted. Two such methods are currently under investigation, one using urea (a component of urine), the other using iron particles. One advantage of such systems is that in the event of undesirable side effects, they could easily be stopped. [10]

12 Carbon Data Information Analysis Centre (CDIAC) www.cdiac.ornl.gov

13 1 tonne carbon = 3.644 tonnes CO_2 (CDIAC)

14 See for example www.technologyreview.com/Energy/18589/ and www.news.cornell.edu/stories/Feb06/AAAS.terra.preta.ssl.html [Live June 2007]

Chapter 4 Energy Security & Fossil Fuel Depletion

Introduction

Fossil fuels provide 88% of the World's commercially traded primary energy, see Fig 4.1:

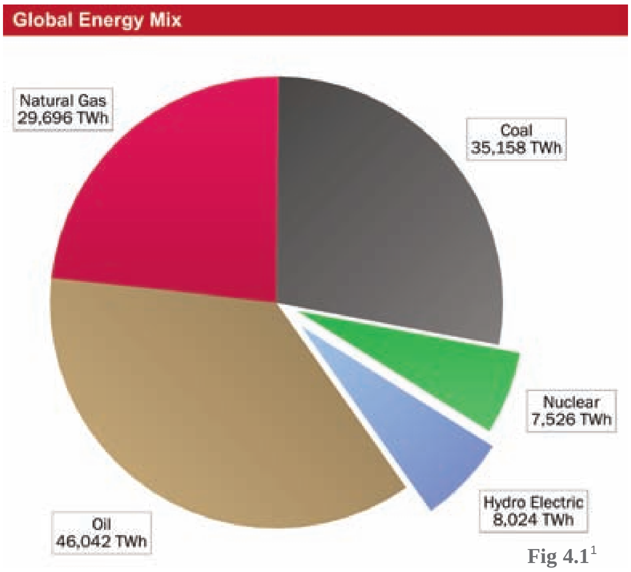


Fig 4.1[1]

Oil has a high energy density and its liquid nature makes it easily transported in relative safety. It is the fuel of choice for over 90% of the World's transport. It is also an important raw material for the chemical, plastics and pharmaceutical industries. Its energy density, versatility and ubiquity in the commodity supply chain lend oil its strategic importance to industrial economies like Britain's.

Significant non-conventional oil resources also exist. They comprise deep water oil, polar oil, heavy oil, tar sands and oil shale. The additional investment and energy inputs required to recover and/or process them is much higher than for conventional oil.

The additional measures required to contain and transport gas mean that it is primarily used for static applications: cooking, water heating, space heating and electricity generation. It is also widely used as a raw material for fertilizer production.

Coal is the least energy-dense (but most carbon-dense) of the fossil fuels, and its primary use in Britain is for electricity generation. Its worldwide use is growing more rapidly than any other fuel.

Global Fossil Fuel Stocks

Proven reserves of fossil fuels as at the end of 2005 were as follows in Fig 4.2:

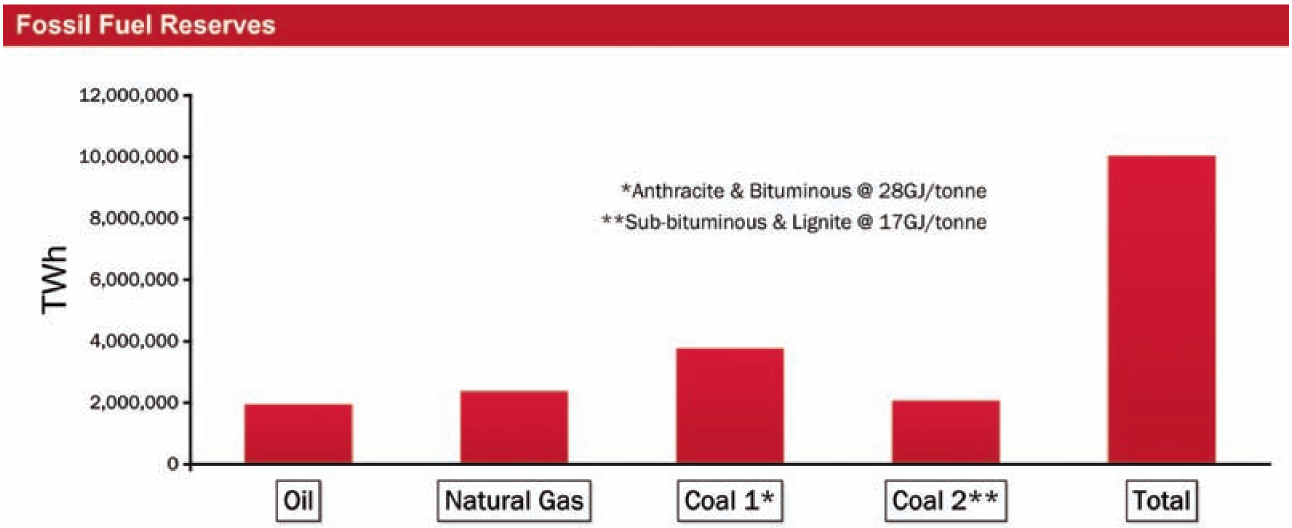


Fig 4.2[2]

1 Adapted from BP (2006) *Statistical Review of World Energy 2006* www.bp.com [live June 2007]

2 Adapted from BP (2006) *Statistical Review of World Energy 2006* www.bp.com (the 2007 report was released after *zerocarbonbritain* went to press)

Fuel Equivalence

Because fossil fuels are chemically similar, it is relatively straightforward to process abundant, low quality fuels into more useful ones. Natural gas can be processed into liquids; similarly coal can be converted into gas or liquefied directly. Such processes require energy inputs, so that less net energy is available for end use than if the fuel had been used in its original form.

Net Energy

As the fossil energy available to invest becomes more scarce, it will be increasingly important to measure energy investment against energy return. *Energy Returned on Energy Invested* (EROEI) is the ratio between the amount of energy a resource provides and the amount of energy input required to recover it. An EROEI of below 1 represents a net energy loss and the point of futility, barring other benefits such as providing a liquid fuel for transport.

EROEI typically starts high as oil and gas flows from a reservoir under natural pressure. Reservoir pressure drops during the course of extraction, necessitating the introduction of pumping to maintain production; more energy input is required and the EROEI ratio declines. Non-conventional oils have a relatively low EROEI due to more energy-intensive extraction methods and, in some cases, the need for subsequent processing into synthetic crude oil.

EROEI likewise declines for coal deposits as the richest seams are exhausted and less profitable ones are exploited.

The EROEI values for fossil fuels are falling as energy inputs for extraction and processing mount. Conversely, EROEIs for renewables continue to rise as technologies improve[3].

Projected Fossil Fuel Production

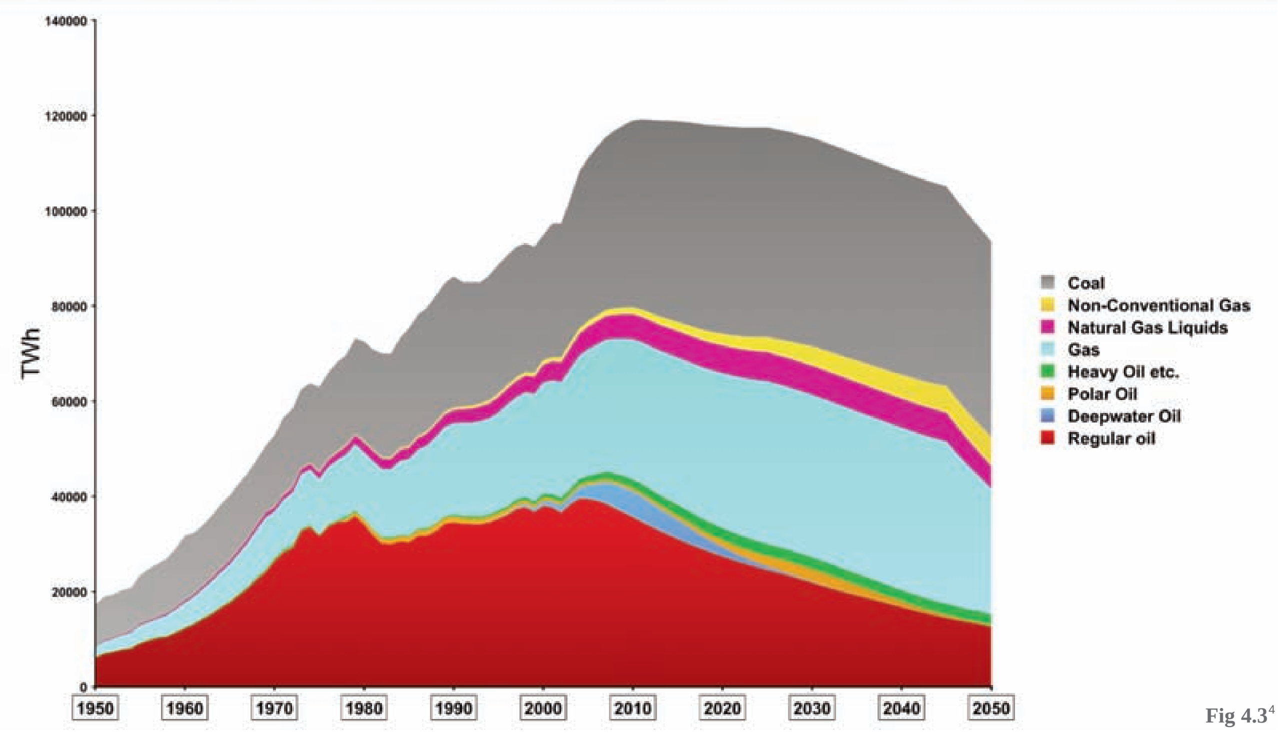


Fig 4.3[4]

3 Heinberg, R. (2005) *The Party's Over: Oil, War and the Fate of Industrial Societies (2nd edition)*, New Society Publishers

4 Source oil and gas figures: Campbell, C coal figures: Zittel, W and Schindler, J (2007) *Coal: Resources and Future production* - see footnote 6

Production Flows

The rate of oil production for a given oil province reaches a peak when around half of the recoverable reserves have been extracted. Beyond this peak geological factors dictate that the production rate enters irreversible decline, regardless of economic or technological factors.

Aggregating the production profiles of the world's oil provinces yields a similar overall profile: global production will peak and then decline when roughly half of the world's oil reserves have been consumed. This is irrespective of widely quoted, but overly simplistic, 'Reserves/Production ratios'[5].

Lack of reserve data transparency in most oil producing countries has led to considerable debate concerning the likely date of global peak oil, with projections ranging from 2006 to 2025 or beyond. However, there increasingly appears to be a grouping of forecasts around 2010-2011[6].

Coal production is set to follow a similar pattern, but reserve data is so poor that forecasting is even more difficult than for oil. However, recent downward reserve revisions in some countries could lead to a much earlier production peak than currently expected by many, possibly as early as 2025[7].

Peaking of natural gas production is generally believed to be some 20-30 years beyond peak oil, but when it comes it may be more abrupt due to gas production having a different profile[8].

Viewed together, it is clear that the combined peaks in oil, coal and gas production will begin to constrain growth in total fossil fuel consumption in the near future, see Fig 4.3.

For a number of reasons, the net energy derived from fossil fuel could diminish more rapidly than the overall production profile might suggest:

- The rate of overall production is falling.
- The energy return on investment of fossil fuels is falling.
- A migration away from oil, towards liquefied coal and gas, which themselves deliver lower net energy.

Risks

A decline in total energy available from fossil fuels and the attendant price rises present the world with a range of risks, some of which are already emerging.

Climate Change Mitigation

As noted, a decline in oil production is likely to prompt growth in energy-intensive synthesis of liquid fuels from coal, gas and non-conventional oils, resulting in higher CO_2 emissions per unit of delivered energy. Meanwhile, strip mining of tar sands in Canada is degrading the climate regulating capacity of significant tracts of boreal forest[9].

Expectations that a lifeboat may be on the horizon in the form of biofuels are overly optimistic. The diversion of crops such as maize and sugar cane from food to biofuel production is already pushing up food prices around the world[10].

High oil prices have already stimulated growth in the production of biofuels, which initially seem environmentally benign, but producing them requires energy inputs, which implies significant CO_2 emissions. Also, where peatlands are drained or primary forests are cleared to create plantations, large volumes of CO_2 are released from soils and biomass, and those regions' capacity to absorb CO_2 is impaired[11].

Overall, this implies a rise in greenhouse gas emissions associated with unchanged levels of industrial activity, coupled with a reduction in the capacity of the World's carbon sinks.

Economic Volatility

As domestic energy prices rise and rising electricity and crude oil prices work their way through the supply chain to finished goods in the consumer price index (CPI) basket, inflationary pressures are likely to mount.

5 Reserves/Production (R/P) ratio – if the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that level (BP 2006). R/P ratios fail to account for major factors such as demand growth or physical constraints to production rates. Source: Hirsch, R. et al (2005) *Peaking of World Oil Production: Impacts, Mitigation and Risk Management*, National Energy Technology Laboratory

6 Energy Watch Group, Zittel, W. & Schindler, J. (2007) *Coal: Resources and Future Production*, www.energywatchgroup.org/files/Coalreport.pdf [Live June 2007]

7 Energy Watch Group, Zittel, W. & Schindler, J. (2007) *Coal: Resources and Future Production*, www.energywatchgroup.org/files/Coalreport.pdf [Live June 2007]

8 Darley, J. (2004) *High Noon for Natural Gas: The New Energy Crisis*, Chelsea Green Publishing

With consumer and corporate debt at historic levels, monetary policy may become increasingly difficult to manage[12].

Raising base rates could harm borrowers – and potentially lenders, through increased levels of defaults – without effectively addressing the underlying cause of the problem. An increase in production costs, with few prospects for relocating production to cheaper overseas labour markets, now remains.

As prices rise and consumer spending power is eroded, periods of economic stagnation or decline seem highly likely until demand destruction due to high cost brings commodity prices under control, albeit temporarily.

Global Equity

Developing nations are likely to struggle with rising oil prices and find themselves priced out of the market. Such nations' dependence on imported grains exposes them to the rising food production and transport costs. Similarly, developing economies that have failed to diversify beyond key cash crops could find that their dependence on remote (and potentially contracting) foreign markets leaves them vulnerable to economic instability. Nations that are heavily dependent on tourism could be similarly affected by an aviation industry struggling with input costs.

Summary

Sufficient stocks exist to provide fossil fuels long into the future, however, production flows will become subject to physical constraints in the near future. This is to say that it is not the amount of oil left but the rate at which it can be delivered that will come under pressure after the peak.

Beyond peak oil, the sustained demand for liquid hydrocarbon products will increase demand for synthetic equivalents from other sources: net energy from fossil fuels will decline increasingly rapidly and CO_2 emissions associated with their production and processing will increase.

Timely adoption of Contraction & Convergence would allow management of the downslope of fossil fuel consumption. The global carbon budget of 85GTC advocated in this report represents 773 billion Boe (barrels of oil equivalent). This is notably less than the remaining 906 Boe[13] of accessible global oil supplies, meaning that climate change, if dealt with in this way, enforces a stricter constraint than peak oil. Strong incentives and bold regulatory measures to support renewable energy schemes would encourage a market-driven transition to a sustainable energy infrastructure.

9 Woynillowicz, Severson-Baker, D.C., Raynolds, M. (2005) Oil Sands Fever: *The Environmental Implications of Canada's Oil Sands Rush*, Report prepared by the Pembina Institute, Drayton Valley, Alberta, Canada

10 Ford Runge, C (2007) *How Biofuels Could Starve the Poor*, www.yaleglobal.yale.edu/display.article?id=9097 [Live June 2007]

11 UN - Energy (2007) Sustainable Bioenergy: *A Framework for Decision Makers*, www.fao.org/docrep/010/a1094e/a1094e00.htm [Live June 2007]

12 Leeb, S. & Leeb, D. (2004) *The Oil Factor: Protect Yourself - and Profit – from the Coming Energy Crisis*, Business Plus12 100 GtC (906 billion barrels) conventional oil and 159 GtC (1448 billion barrels) of all liquids - derived from Association for Study of Peak Oil (2007)

13 100 GtC (906 billion barrels) conventional oil and 159 GtC (1448 billion barrels) of all liquids derived from Association for Study of Peak Oil (2007)

Chapter 5 Equity

Global Inequality

Since the dawn of human civilization, inequalities have existed. But at no other time have the differences between the 'haves' and the 'have nots' been so pronounced, as evidenced by a range of recent figures and comparisons:

- Globally, the ratio between the average incomes of the top 5% to the bottom 5% increased from 78:1 in 1988 to 114:1 in 1993[1].
- In 2003 the average UK citizen emitted 9.4 metric tonnes of CO_2; the average Tanzanian emitted 0.1 tonnes[2].
- In 2006 Britain's estimated per-capita GDP (adjusted for purchasing power parity) was $31,400, compared with Tanzania's $800[3].

> "Today's net worth of the world's 358 richest people is equal to the combined income of the poorest 45% of the world's population (2.3 billion people)."
>
> Speth[4]

When considering the above inequalities in wealth and emissions, it is ironic that the impacts of climate change are predicted to hit the developing world hardest. Developing countries are generally warmer on average than developed nations, more dependent on agriculture, and have little disposable income to aid adaptation.

Significant disparities can also be seen within countries. In Britain for example, the Integrated Oxford Travel Study investigated the relationship between income and travel-related CO_2 emissions. It showed that, on average, respondents who earn at least 4 times as much as the lowest earners, produce 3.6 times the amount of annual emissions[5].

From Global Commons to Scarce Resource

As discussed in other areas of this document, the avoidance of possibly catastrophic effects of climate change will necessitate a strictly-enforced global cap on the amount of greenhouse gases that are emitted. This cap will necessarily change the nature of how the Earth's atmosphere is viewed. It must switch from being the common property of humanity to being treated as a valuable resource. As the atmosphere ceases to be a 'commons', it will become necessary to define property rights.

For a resource to possess economic value, it must be both scarce and useful. Essentially, if the atmosphere is given a value, a price will be established for the trade of atmospheric property rights, based upon the marginal utility to individuals of permission to emit greenhouse gases. Such a market-based approach would ensure that, as a global community, we would gain the maximum utility for the remaining capacity of the atmosphere. This leaves one important issue for the setting up of a national or international emissions trading scheme. In order to trade in a resource, one must own it.

Who Owns the Atmosphere?

Distributive justice concerns the just allocation of scarce goods in a society. As the atmosphere can be considered the common property of humanity[6], anyone who believes they are entitled to more than an equal per-capita share must prove that their differential treatment is based on merit, or some other morally justifiable criteria.

The usual justification for the appropriation of common property is that given by John Locke, in which, if a man mixes his labour with common property, he then increases its value. This is not the case with the atmosphere, which is diminished by prior use. This violates what has been termed the 'Lockean Proviso', which allows that:

1 B Milanovic (1999) *True World Income Distribution*, 1988 & 1993, World Bank

2 Source: United Nations Millennium - Development Goals Indicators. www.mdgs.un.org/unsd/mdg/Default.aspx [Live June 2007]

3 Central Intelligence Agency *The World Factbook*, www.cia.gov/library/publications/the-world-factbook/index.html [Live June 2007]

4 Speth (1996) taken from Ayres, R.U. (1998) *Turning Point -: An End to the Growth Paradigm*

5 Oxford University Transport Studies Unit (2006) *Counting your Carbon*, www.tsu.ox.ac.uk/research/oxontravel/reports/eoa_reports/eoa_rep_short_final_incl_AnnexA.pdf [Live June 2007]

6 After Cicero's *Res Publica*

"...enough and as good must be left in common, when common property is appropriated."

John Locke[7]

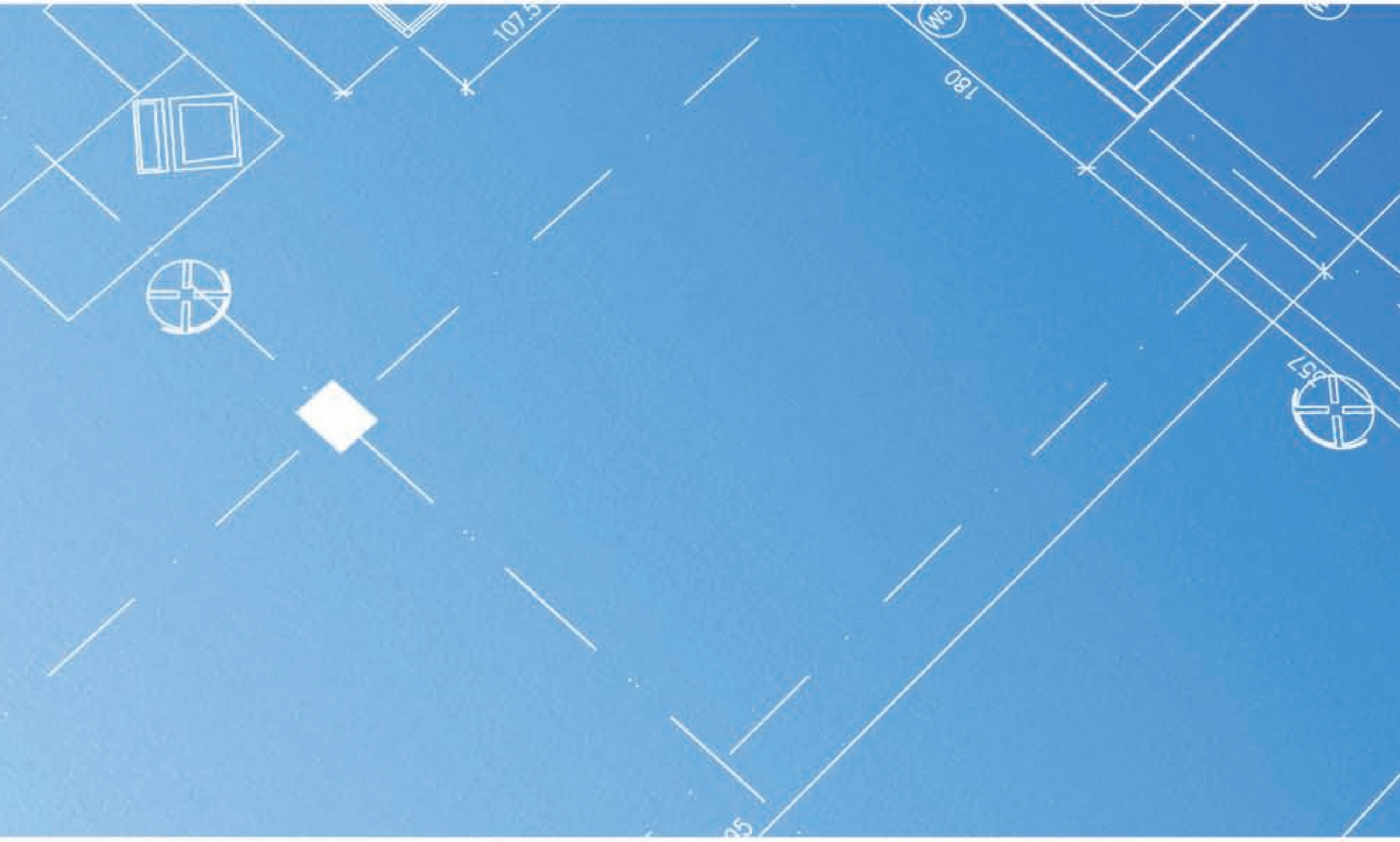
One possible ethical criterion for treating people differently in their allocation of atmospheric property rights would be to invoke the 'polluter pays' principle. On this principle, a greater proportion of atmospheric property rights would be allocated to developing nations, which historically have done least to cause the problem. This would equate well with other principles of distributive justice, in that countries that struggle to satisfy their citizens' basic needs could argue to have the greater requirement for emissions rights.

The above arguments sit well within a Rawlsian framework of justice. In Rawls' concept of 'justice as fairness'[8], he suggests that the allocation of society's burdens and benefits should be those chosen by rational, self-interested persons, from behind a 'veil of ignorance' of their positions in society. Thus, he argues, social and economic inequalities should be arranged to be of the greatest benefit to the least advantaged members of society.

The increase in population in developing countries can be argued to be the one negating factor for a greater share of emissions rights. This, and all the above arguments, is accounted for in the Contraction & Convergence proposal. From any view of distributive justice, it appears difficult to dispute the simple moral authority that the C&C scheme espouses. (Chapter 6 for more details on Contraction & Convergence).

7 Locke, J. (ed. Cox, R.) *Second Treatise of Government*, (1690) Harlan Davidson (1982)

8 Rawls, J, (1999) *A Theory of Justice*, Harvard University Press



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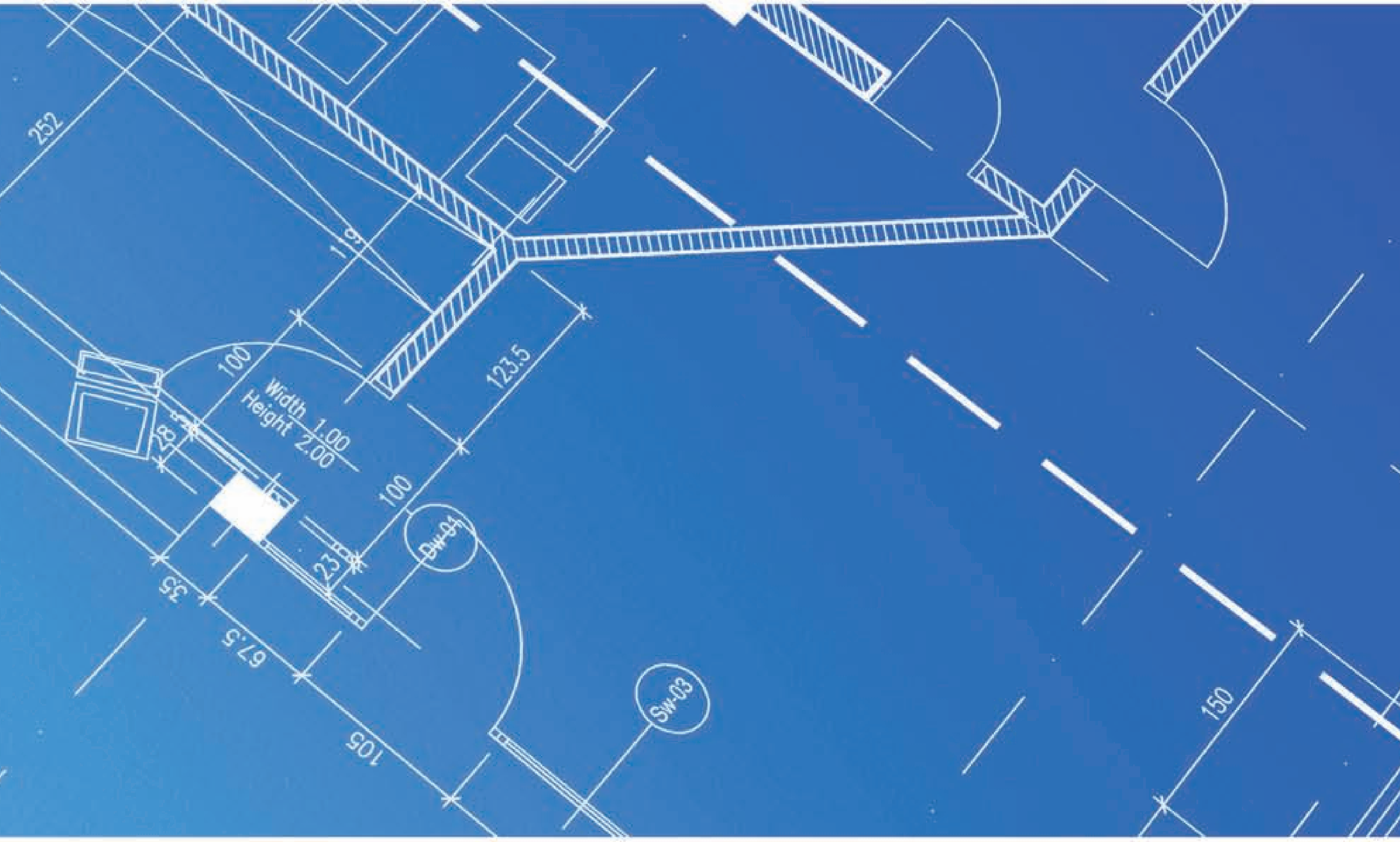
an alternative energy strategy



"The best hope is a system called Contraction & Convergence"

Lloyds of London

framework

Chapter 6 Contraction & Convergence

To reduce global anthropogenic CO_2 emissions to near zero requires rapid and coordinated action globally.

Emissions reductions from some nations are laudable but insufficient to the global task at hand. What is required first is to define a global cap or budget (informed by the science) and negotiate CO_2 allocations within that budget.

Contraction & Convergence (C&C) is a framework for the negotiation, planning and implementation of a global cap on CO_2 emissions. Developed by the Global Commons Institute, C&C has been recognised internationally as the irreducible response to climate change.

How it Works

C&C presents a coordinated plan to reduce CO_2 emissions worldwide in a deliberate and controlled fashion. C&C frames a simple two step solution[1].

STEP 1: CONTRACTION

As a global community: scientific advice must be taken on the state of the atmosphere and the decision taken on how much more carbon the planet can risk burning.

This represents the global carbon budget. Under this scenario this budget represents the remaining total amount of carbon that will be burnt between now and the year 2027 when emissions will drop to near zero.

The science shows that we cannot afford to burn all the oil, gas and coal that is left on the planet and that we have burnt too much already. The carbon budget must be much less than the available resource, and as small as can be managed.

The budget is split up into annual allocations. There is a year-on-year contraction (or reduction) in the size of the annual allocation.

C&C allows for this rate of contraction to be adjusted periodically as understanding of the climate science improves.

STEP 2: CONVERGENCE

Having defined the global budget of carbon and its contraction over time, it is then necessary to decide how it will be shared out amongst nations.

At present, rich countries emit many times more CO_2 per capita than poorer nations. The 'Convergence' objective of C&C is to move from this unequal situation to one where everyone on the planet has an equal share or entitlement to emit CO_2.

The current situation around the world might loosely be summed up as follows:

Rich countries have developed strong economies burning the majority of the carbon to date. These high levels of emissions cannot safely continue.

Poor countries have suffered most from climate change so far, and currently burn very little carbon. However, they now want rights to carbon to support

The resulting motivation will be massive and result in rapid investment for energy efficiency measures and renewable energy sources.

1 Meyer , A. (2000) *Contraction & Convergence*: The Global Solution to Climate Change, Green Books

their development, or at least to have an equal share per person of the total carbon the world plans to burn.

C&C allocates emission entitlements to every country. Starting with current emissions levels, it proposes a scheduled convergence to equal per-capita entitlements globally by an agreed date.

By doing this, convergence reduces the carbon shares of the rich, high-emitting countries until they converge with the (temporarily rising) shares of poorer, low-emitting countries.

The poor countries will be able to sell their surplus carbon shares to wealthier nations. This will generate income, which could be used to buy clean technologies.

The resulting motivation will be massive and result in rapid investment for energy efficiency measures and renewable energy sources.

Contraction & Convergence works because the contraction budget is science-based and because the convergence date provides a clear negotiating tool that countries with wide ranging national circumstances are able to engage with.

Britain's carbon allocation

Contraction & Convergence works not only as an administrative mechanism, but also as the framework for negotiating the size of the budget and the distribution between nations[2].

Carbon Budget - Global

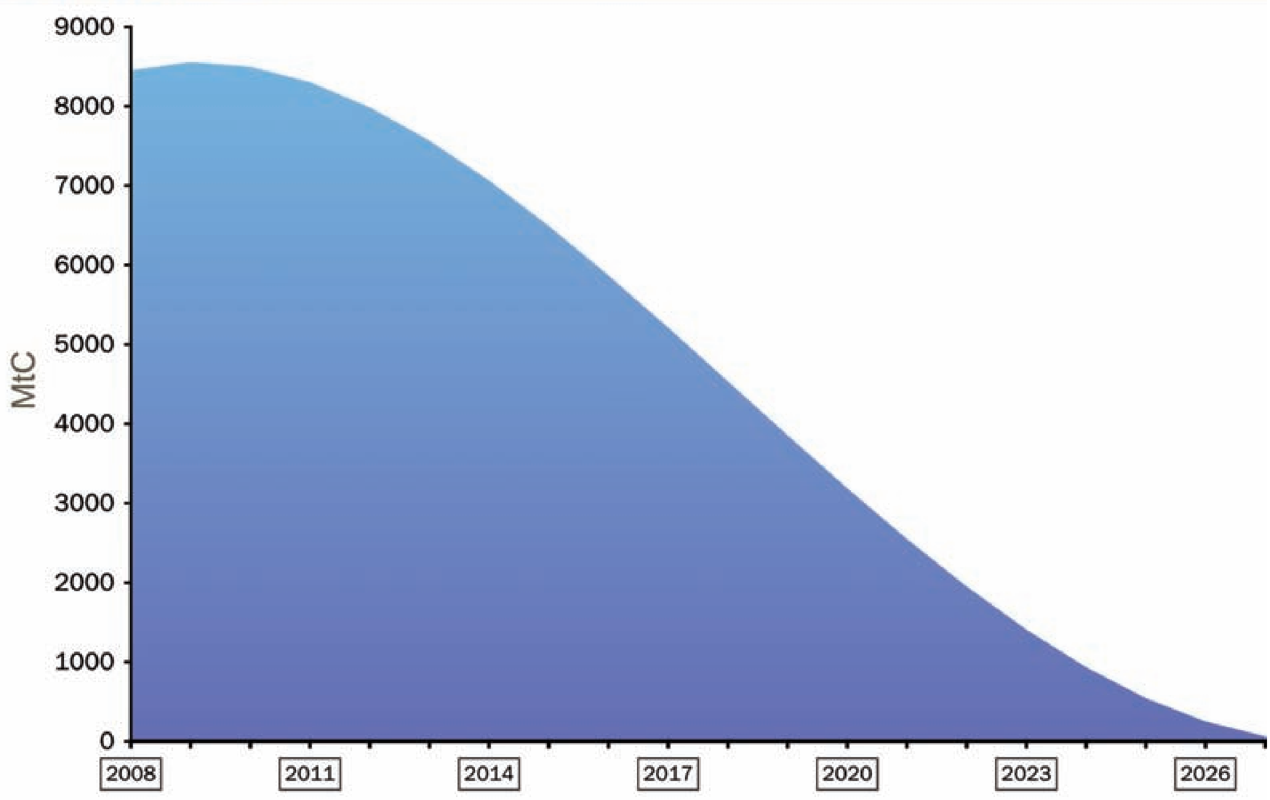


Fig 6.1

2 Meyer , A. (2000) Op. Cit.

We believe the framework of Contraction & Convergence represents best practice in defining a national carbon budget for the UK. It is consistent with the approach of the RCEP (Energy – The Changing Climate 2000). The climate science used by the RCEP is no longer current and therefore the budget they defined is in need of revision.

The UK Government has adopted as its own target, one of the RCEP scenarios, which was based on the Contraction & Convergence framework and defined a 60% CO_2 emissions reduction by 2050, with a convergence to equity in the same year. This report urgently calls on the Government to both recognise the framework of origin for their 60% target and to update their targets in light of current climate science.

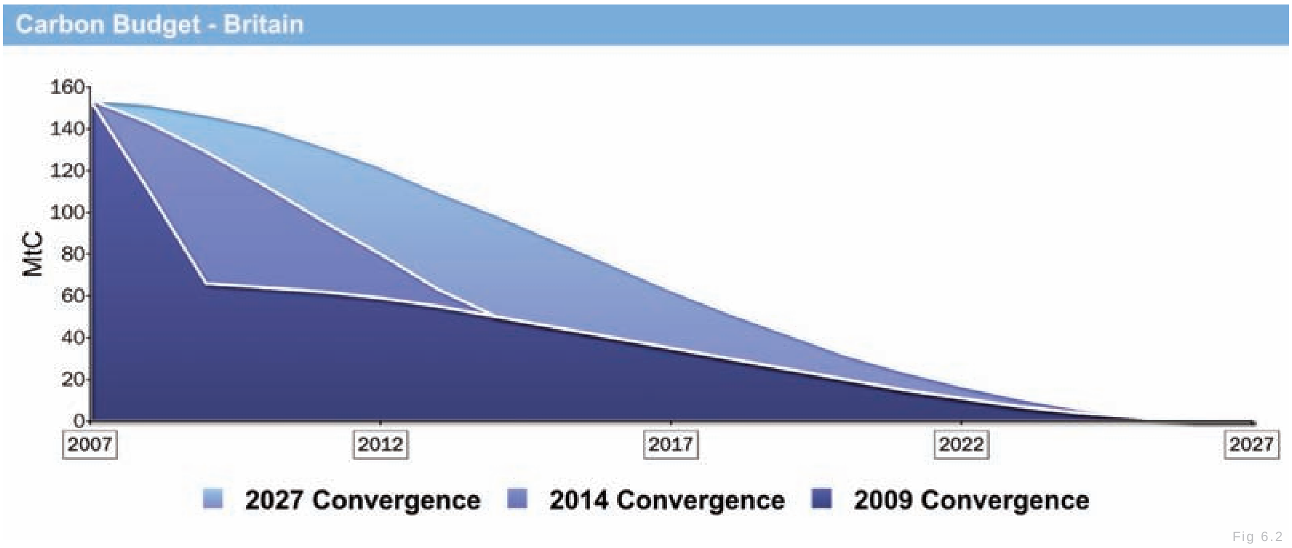


Fig 6.2

The global 20 year budget of 85 billion tonnes carbon defines the global contraction event.

Britain's allocation from that budget is arrived at through negotiating the 'Convergence Date', the year by which all countries will have converged on equal per capita allocations of carbon permits, which then drop equally towards zero.

While the global contraction budget is informed by the climate science, the convergence date is negotiated internationally.

This document provides a recommended global contraction budget of carbon, informed by an up-to-date reading of the climate science. It also provides a likely proxy for a negotiated convergence date. Both these figures are required to define Britain's carbon budget.

The year of convergence selected is 2014, this being one third of the way into the global carbon budget and considered by the authors to represent a plausible compromise between equity and realpolitik.This defines a carbon budget for Britain of 897 MtC.

Conclusion

With regards to climate change, the economy today does not provide sufficiently effective drivers and incentives for people, business or government to change.

It is therefore incumbent on those who are aware of the arguments, to support and instigate global and national policies that do provide effective drivers and incentives.

The international and national policies supported in this strategy are precisely that, the catalysts for change.

The scale of the climate change problem is daunting and the challenge of reversing the momentum of Britain's fossil fuelled society could be likened to turning around a tanker ship. A more useful analogy, however, might describe Britain not as a tanker but a flotilla of small boats. With leadership, these boats can turn neatly on a single command.

The global challenge of turning around the energy patterns of the World's nations is more daunting still. In this case Britain represents just one small boat. But if we begin to make the turn we have the potential to take the rest of the World around with us.

Chapter 7

Tradable Energy Quotas

Introduction

As is shown in the 'Island Britain' scenario, it would appear that we have the technological ability to operate without fossil carbon.

At present, however, the existing socio-economic framework works against the widespread adoption of less carbon-intensive technologies. While this may be partly due to existing infrastructure and the influence of vested interests, the main reason is that the external costs of burning fossils fuels have not yet been fully internalised.

What is needed is an explicit policy to propel the structural and societal changes that will need to be made in the next decade, transcending the historic legacy of wasteful attitudes to energy. The policy of 'Tradable Energy Quotas' (TEQs)[1] outlined below is an equitable, efficient and effective driver that can facilitate specific reduction of carbon within a specific time frame.

Just as Contraction & Convergence is a mechanism for dividing up carbon globally, TEQs (pronounced 'tex') are the national arrangement.

Essentially TEQs are a national cap-and-trade scheme for greenhouse gases, covering all sectors of society. The idea was developed by David Fleming from his earlier work on Domestic Tradable Quotas. This is a carbon-rationing scheme which allocates the 40% of carbon currently used domestically to adult citizens. This 40% of the national carbon budget is distributed to individuals on an equal per capita basis in the form of TEQs. The remaining 60% is sold to businesses and other organisations by auction, again as TEQs.

While our recommendation of TEQs is referred to as a personal carbon budget, a purely carbon based system would risk moving the economic externality of climate change from carbon to other greenhouse gases.

Under Fleming's TEQ system all greenhouse gases are covered and weighted using the global warming potential of different fuels as defined by the IPCC.

How it Would Work

1. SETTING THE CARBON BUDGET

The 897 million tonnes, 20 year carbon budget outlined in Chapter 6 of this strategy is Britain's total allowance from fossil fuels. This is all that will be allowed to be burnt over the 20 year time frame. Further fossil fuels can be purchased by Britain but only if extra internationally traded carbon permits are purchased beyond Britain's allocation.

A government-implemented carbon permit scheme then establishes the maximum quantity of greenhouse gases that the nation can emit from energy use during any given year.

This annual carbon budget is reduced year on year so as to meet emissions reduction targets. It is recommended that an independent, science-driven body (The Energy Policy Committee) be appointed to set and administer the carbon budget, and that this budget be set years in advance in order to deliver clear price signals to businesses and individuals.

The budget may be subject to further constraint by climate science and the growth in our understanding of the drivers and feedbacks for radiative forcing and climate change.

2. ALLOCATING CARBON PERMITS

Each annual carbon budget is divided into carbon permits, with 1 carbon permit representing 1 kg of CO_2 equivalent[2]. A proportion of these units are allocated, free and on an equal per-capita basis, as

1 Fleming, D. (2005) *Energy and the Common Purpose – Descending the energy staircase with Tradable Energy Quotas* (TEQs) www.teqs.net/book/teqs.pdf [Live June 2007]

2 Estimate of global warming potential of gases released by the production and combustion of fuels:

Fuel kg	CO_2/kWh
Natural Gas	0.19
Gas/Diesel Oil	0.25
Petrol	0.24
Heavy Fuel Oil	0.26
Coal	0.30

Source: Carbon Trust (2007) *Measuring* CO_2 *: Methodologies* www.carbontrust.co.uk/resource/measuring_co2/Measuring_CO2_Methodologies.htm [Live June 2007]

TEQs to all adult citizens.

The remaining carbon permits are sold to firms and other organizations through government auction. This revenue raised in the early part of the scheme should be ring-fenced for use in easing the transition to a zero-carbon economy.

3. SURRENDERING CARBON PERMITS

All fossil fuels are assigned a carbon rating according to their greenhouse gas or radiative forcing effect. Whenever an end user purchases fossil fuels they surrender to the vendor the corresponding number of carbon permits. This can be carried out electronically, adapting existing banking technology.

These permits are then returned up the supply line till they return to the primary producer or importer, who in turn returns them to the energy policy committee for accounting purposes. A national database of all participating citizens will need to be established.

Although dependant on efficient implementation of information technology, it should be no more difficult than managing credit cards or Oyster cards.

4. TRADING IN ENERGY QUOTAS

Central to the success of a carbon permit policy is the emergence of a carbon market where individuals who find they can live within their carbon budget can sell their excess permits on the open market.

Businesses, organisations and individuals who need more permits will have to pay the market price. The market in carbon permits will ensure that the necessary reductions will occur in the most efficient manner.

The success of the TEQs policy should be judged on three main criteria; that it is effective, efficient and equitable.

Effectiveness

One of the main advantages of the carbon permit scheme is the level of assurance it provides; the total number of permits issued determines the aggregate level of pollution. This cap on emissions eliminates problems such as the rebound effect, where a percentage of reductions are lost when the financial savings from increased efficiency are spent on other polluting activities.

The atmosphere's ability to absorb greenhouse gases will shift from being treated as common property to being considered as a scarce resource, under the strictures of a cap on greenhouse gas emissions.

Efficiency

By redirecting Adam Smith's invisible hand to take account of the threat of climate change, we can use the efficiencies of the market to our collective advantage.

Mainstream economics stresses that the efficient exchange and use of resources is only maintained through the price mechanism in a free market. A carbon permit scheme will involve millions of people making rational decisions, using their own personal knowledge and preferences, to establish the correct price for carbon to achieve the reductions required.

This contrasts with the implementation of a carbon tax, which would have to be an iterative exercise, as the price signal imposed would have to be readjusted continually to hit proposed targets.

Equity

This policy recognises that an individual gains a certain amount of utility when causing a unit of greenhouse gas to be emitted. Similarly, the rest of humanity suffers a cost, as there is one less unit of greenhouse gas that can be emitted by the rest of the population (once a cap is established).

By setting a national carbon cap and by distributing transferable property rights on an equal per capita basis, competing demands for the remaining greenhouse gas emissions can be satisfied in a just and equitable manner. This contrasts with the regressive nature of a carbon tax, since the less well-off spend proportionately more of their income on energy.

This report seeks to address the challenges of climate change, energy security and global equity. ***zero****carbon****britain*** advocates a small collection of policies that could make major inroads in these areas, but it is unrealistic to expect that, on their own, they will solve all the World's problems. There will, no doubt, be a need for secondary legislation to fill in some of the gaps. This report works on the basis that a well received policy is capable of inspiring widespread choices, from the population as a whole, that deliver a positive collective result.

We feel that TEQs (tradable energy quotas) give the best possible first approximation of equity in energy access in Britain. There are two key ways that equity can be supported further:

- It has been calculated that unassisted the system of TEQs could actually leave the poorest 20% of the UK population poorer[3]. This is in large part due to the capital costs individuals cannot meet to adjust to the new scheme, such as switching to energy efficient appliances and insulating their homes. Without these measures, their energy quotas will be used up much quicker, and these people will not be able to make the transition to needing less. As the cap on quotas tightens, the situation will further worsen for the poor. This could be mitigated if revenue from the 60% of TEQs auctioned to industry is hypothecated[4] to support the switch to a zero-carbon Britain, and a portion goes specifically to the poorest households.

- As well as capital investments the Government should finance a major programme of public education and training. Community champions should be supported as well as promising near-market technologies.

- The Government should support the transition of energy companies, which charge for fuel, to becoming energy services companies (ESCOs), which charge for the provision of lighting, warmth and hot water etc. In this way, consumers in low income households pay for the energy services they receive, leaving the ESCO to cover the capital costs of insulation and low energy appliances[5].

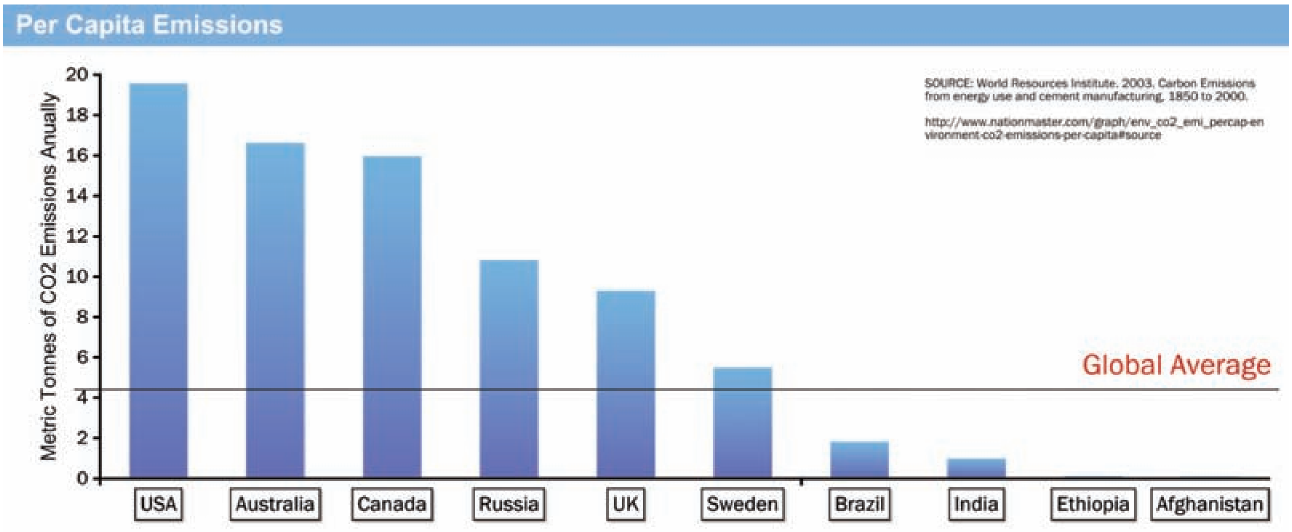


Fig 7.1[6]

3 Ekins, P., Dresner, S. (2004) *Reducing the Impact of Green Taxes and Charges on Low Income Householders*, Joseph Rowntree Foundation

4 Ring-fenced funds; something not traditionally done by governments, but will be essential

5 In promoting ESCOs care should be taken to ensure best value to customers and guard against high price monopolies

6 Source: World Resources Institute (2003) *Carbon emissions from energy use and cement manucaturing, 1850 to 2000*, www.nationmaster.com/graph/env_CO2_emipercaap-environment-CO2-emissions-per-capita#source [Live 2004]

TEQs as a Vote-Winner

At present, a minority of the global population burns the majority of the carbon.

There is no economic penalty attached to the environmental cost of burning this carbon. With TEQs distributed on an equal per capita basis, they will quickly become a valuable and appreciating commodity – with the majority of the population burning less than their initial TEQs allowances.

This means more money in the pockets of the majority of Britain's citizens, and an incentive for everyone to find ways of reducing their use of carbon. Thus, if people take up the incentive to reduce their emissions, then they stand to benefit financially, with government acting as the enabler.

The Government would be in the enviable position of having confidence that it could implement policies that would be popular and widely adopted. The same incentives are equally powerful for individuals, businesses and industry, both public- and private-sector. Britain's engagement with energy will have undergone a phase change.

Chapter 8 The Economics of Energy

Energy as the Fuel of Economy

In present day society, economics plays a pervasive and ubiquitous role. It lies at the heart of a vast range of society's relationships, transactions and dependencies. It forms a framework that guides and shapes almost every aspect of life, both nationally and internationally.

In consequence, finance – its availability, costs, terms and future prospects – is a primary driver of society's choices and activities.

From the perspective of that ubiquity and influence, perhaps the most radical of the proposals raised in this strategy is the assertion that, in the light of the constraints of climate change, energy security and global equity, energy is actually more fundamental – has a greater claim to primacy – than money.

Money-based systems of exchange possess many clear advantages over, for example, barter systems[1] – not least in their easy portability and in avoiding problems like the 'coincidence of wants'. Without money, it would not be impossible for society to find other ways to achieve its ends, but without energy modern society would be disrupted and, quite literally, disempowered.

Energy is a core necessity for life and for the complex ecologies that living organisms inhabit. For modern human society, energy – most commonly in the form of fossil fuels – is absolutely necessary to our industrial ecology or, more conventionally, our economy. Without that energy, there would be no industry, commerce or computing, no light, heat, transport or even food.

Society's Energy Inheritance

Both for individuals and societies, the availability of finance is often seen as a key limitation. But at present, it is the availability of energy that is rapidly becoming the most fundamental constraint.

Energy from fossil fuels has been abundant, and remains a potent and flexible source. The planet's fossil fuels represent a great energy inheritance, one that has been laid down over millions of years of photosynthetic activity and captured by the formation of oil, coal, and gas.

Having discovered this inheritance, humanity has been spending it as if it were a steady and growing income. But in reality, it is not income but a limited and diminishing stock of capital. The faster it is spent, the sooner it will be gone.

Humanity must learn to live within the Earth's income of solar energy. To make that transition will require wise use of our final endowment of fossil energy, an endowment which must be artificially limited by humanity to avoid catastrophic climate change.

Energy as the Fuel of Ecology

When studying an ecosystem, its carrying capacity for a species – the maximum population that it can sustain – can be calculated by surveying the sustainable energy resource of food to which it has access.

Human populations have been able to grow beyond these natural limits[2] as a result of enhanced food production using fertilisers derived from the stored energy in fossil fuels. But this is a dangerously fragile and temporary state of affairs. In the language of ecology, humanity is demonstrating a textbook example of 'overshoot'. If left unchecked, it will inevitably be followed by 'population die-back'.

1 Douthwaite, R (1999) *The Ecology of Money*, Green Books

2 Heinberg, R. (2003) *The Party's Over* New Society Publishers

Return on Investment: EROEI

Society's remaining fossil fuel endowment is limited, but avoiding catastrophic climate change demands even tighter constraints on its use, through a contracting annual carbon budget.

Today's use of fossil fuels is split between that which is actually required to deliver the desired benefits, and that which is wasted, for lack of careful management.

The latter requires a strict policy of waste minimisation; the former, a programme of investment in equipment to deliver ongoing energy dividends, to obtain the best possible return on the fossil fuel capital that remains.

From an energy perspective, determining which energy technologies give the best return on investment, requires a detailed energy audit. This is clarified best in terms of EROEI: energy return (ER) on energy investment (EI), expressed as:

$$EROEI = ER / EI$$

By changing the economic drivers through implementing appropriate policies, pursuit of a good financial return on investment will naturally support the pursuit of technologies that deliver good energy returns.

From Incurring Costs to Investing in Assets

Today's approach to fossil-fuelled energy provision follows the pay-as-you-go principle. Like renting a house, each day's use is paid for, but with no lasting accrual from those payments. It represents an ongoing cost.

Pursuing the housing analogy, building new nuclear power stations is like paying to build a house, paying rent to live in it (the cost of fuel and maintenance), and finally being evicted after 30 years, with the obligation to pay for the dismantling of the house and then passing to future generations the obligation to continue paying indefinite further rent. It is an ongoing, open-ended liability.

Renewables present the opportunity to build and own a home outright. This home will require a significant initial investment and take time to complete. But once built, the benefit of the infrastructure is free excepting maintenance costs. Investment of this sort provides society with an enduring asset.

Policy

In today's society, energy is not highly valued. Fossil fuel production has grown to meet demand, and for the majority of consumers – both individual and corporate – its costs are a small fraction of total expenditure. Even today, official statements on the need to constrain consumption are muted.

If policy changes are deferred until peak oil constrains supply, society will have both lost the window of opportunity to invest in renewables, and exhausted the available carbon budget. That will leave no way to supply future energy needs short of pushing the planet further into the path of extreme climate change.

Economic drivers need to be turned around so that energy and carbon are the most highly valued commodities. Fossil fuel supply needs to be artificially constrained, both immediately and rapidly, but without causing social or economic disruption.

Britain needs a carbon budget that provides a strict limit to future CO_2 emissions, with fair access to this budget being assured for all people. This can be done most simply and cost-effectively through issuing a portion of the carbon budget as free quotas to all adults, as with TEQs.

The Importance of Discounting the Present

The incentive to take action on climate change now is weakened by the way costs and benefits are evaluated over time. Standard economic theory places great store in short term gain, with future costs generally considered more affordable than costs today. This arises from a combination of factors. Firstly, due to the inflationary nature of most economies, money becomes worth less and less as time goes on. Secondly, money invested today can multiply into the future[3].

In the case of climate change, this model is inverted. While money may become worth less in the future, climate change costs will grow. Any delay in tackling climate change results in progressively increasing the costs of:

- mitigating further climate change,
- damage limitation,
- repair,
- adaptation.

These costs rise with time, so that continued delay progressively[4] approaches an infinite cost. Future costs are greater than the costs of action today. It is *today's* costs that are discounted and it is *today* that society should invest everything it can in solving climate change.

Latent Motivation

The task represents a sizeable change of direction. But it is no larger than many of the projects Britain has undertaken in the past. Over the years, the energy industry has demonstrated huge determination and investment in its pursuit of fossil fuel energy from around the globe and in the most challenging physical and geological environments. This determination must now be directed firmly at what is ultimately an even larger resource: secure, long-term sources of renewable energy.

3 A further driver for money to be worth more today is that people cannot guarantee that they will be around in the future to spend it.

4 According to Munich Reinsurance statistics there has been a doubling in climate damages every decade since 1960

zerocarbonbritain
an alternative energy strategy

"One thing is clear:
the age of easy oil is over"

David J O'Reilly
Chairman & CEO, Chevron

powerdown

The 'Island Britain' Scenario

The 'Island Britain' scenario has been developed by the ***zero**carbon**britain*** team as one possible scenario based on likely responses to the policy of TEQs and feed in tariffs. It takes a look at the available energy efficiencies and accessible energy resources within Britain, in order to show that we can be self-sufficient in energy without the need for fossil fuels, energy imports, or nuclear power.

The 'Island Britain' approach allows for the simplest accounting. The borders of this island nation provide a convenient modelling boundary; and from a practical perspective it demonstrates energy security under the worst-case scenario.

Founding Britain's energy policy on self-sufficiency is a very strong starting position. The knowledge that we could provide all the energy and food we need ourselves allows us to look at trading energy, food and goods with other countries in Europe as a method of achieving our objective more simply and cheaply.

The two following sections, Power Down and Power Up, look at ways Britain can meet the challenge of a rapid and self-sufficient withdrawal from its addiction to fossil fuels.

Methodology

'ISLAND BRITAIN' SCENARIO

zero**carbon**britain provides a detailed energy analysis of Britain as an island nation. It must *not*, however, be taken as recommending Britain's isolation from Northern Ireland, Europe or the World. Britain is treated in relative isolation, for two pragmatic reasons:

- First, doing so provides a highly conservative assessment. The capacity to be self-sufficient in energy and food addresses the worst case position.
- Second, it provides a useful simplification of the energy model – one that eases the energy- and carbon-accountancy that is involved in managing a national carbon budget. By analysing Britain as a discrete entity, it becomes far easier to map the energy and carbon flows.

FOOD & ENERGY SECURITY

Having demonstrated Britain's *in-principle* capacity to meet its food and energy needs as an isolated system, international trade can only serve to make life easier:

- If Britain can independently meet its food requirements, then the security of our food supply is only enhanced through international trade.
- If we can independently supply our energy needs, then our energy security will only be more robust through links with an international supply network.
- In addition to enhancing the security of energy and food supplies, international trade in these commodities serves also to reduce their ultimate costs.

Over recent years, geopolitical and other factors have tended to make energy supply increasingly insecure. The race out of carbon and an expansion of locally produced renewable power serves to reverse this trend. Furthermore, many of the findings of this report for Britain could be scaled up to an international level, illustrating the potential of a global energy and food economy characterised by increased stability and security.

INTERNALISING ENERGY COSTS FOR BRITAIN

The report shows that all Britain's food and energy needs can be met, within 'Island Britain'. The one thing that has not been internalised is the trade in

manufactured goods and services.
Currently, Britain imports the vast majority of its manufactured goods, and relies upon a broad range of services originating in other countries. The energy embodied in the manufacture and transport of these goods and the provision of these services is significant.

Data on this 'offshore energy and carbon footprint' is scarce, but sufficient to arrive at a working approximation. For the present it is estimated as being of the order of 7% on top of Britain's direct domestic consumption[1].

NO RELIANCE ON SILVER BULLETS

zero**carbon**britain is a practical and achievable blueprint for Britain. It relies solely on proven technologies, or on robust emerging developments based on proven engineering, to deliver energy in a zero-carbon future. Other more speculative ideas, which are currently under research, may also come on stream and make the task easier, but the report's conclusions do not depend on their success.

Many of these 'silver bullet' technologies are identified, and the report recommends a watching brief be kept on their progress. It is hoped that some will emerge as viable future technologies, at which point their contribution will be enthusiastically received. Where relevant these 'silver bullets' are featured in text boxes.

However, this strategy principally recommends policies, not technologies. The technologies that are explored are the details of a single scenario that is believed to be an achievable outcome of the recommended policies.

The recommended adoption of C&C internationally and of TEQs at the national level has at its core the power to reduce demand and support generation of energy from carbon neutral sources. As a policy, it does not play favourites, but supports the best technology for the job.

It is therefore a driver, not only of the renewable energy technologies discussed in this report's 'Island Britain' scenario, but equally of emerging or possible technologies – the energy solutions or 'silver bullets' of the future. The aim is to provide incentives that encourage people and businesses to select the best solutions for themselves, rather than government attempting to push its own choice.

Power Down

From a thermodynamic perspective, Britain is an energy-wasteful country. A great number of power stations could be retired if we were to make the right decisions to minimise that waste; in the 'Island Britain' scenario, those decisions are made.

In part this is due to policy decisions such as TEQs, described in the first half of this document. But there will also need to be further legislation put in place to guide the way we use our energy.

Primarily, Power Down is about each of us learning to make the right choices in order to secure the services we derive from energy.

Choices that we make about where we live and work, how we keep ourselves warm, where we holiday, and how we choose to interact with technology, all impact on the quantity of energy we use, and therefore the amount of CO_2 emissions we are responsible for today[3].

For example, when we move house, whilst we might take some measures to better insulate our new home, its size, structure and the materials with which it is built will determine the cost of heating it throughout the time we live there. Similarly, when we buy a car, it largely commits us to a certain rate of fuel consumption until we buy a new one.

Power Down discusses the changes we expect to implement when we are making choices in the context of the policies proposed.

1 Derived from: CES (2005) *UK Carbon Attribution Model*, University of Surrey

2 Taking electricity as an example, primary energy is what is consumed at the power station, as opposed to the smaller amount of energy that is ultimately delivered to the end-user

3 DTI (2006) *Energy – its impact on the environment and society*, www.dti.gov.uk/files/file32546.pdf [Live June 2007]

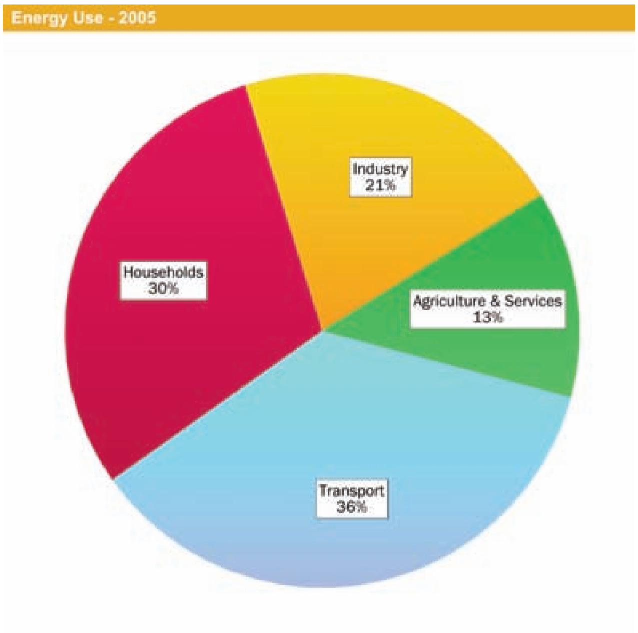
A snapshot of our current energy use, as seen in this chart, is as follows:

- Transport has been the biggest single user of primary energy in Britain for the past 18 years, and accounted for 36% of final energy use in 2005.

- Households are responsible for 30% of final energy use, whilst industrial consumption now accounts for 21%.

- The remaining 13% of final energy is used by the services and agriculture sectors[4].

Powering down in all these areas is the primary objective of the 'Island Britain' scenario. The energy demand that remains can be met by powering up zero-carbon technologies.



4 DTI (2006:2) *UK Energy Sector Indicators 2006*, www.dti.gov.uk/files/file29698.pdf [Live June 2007]

Chapter 9 Buildings

Introduction

Buildings account for nearly a half of Britain's energy use. Thus, improvements in this sector can have a large impact on overall consumption. The energy cuts to be proposed for buildings are ambitious. They require changes to the building stock that may initially be unpalatable to traditional thinkers and environmentalists alike, due to the scale of demolition, new build, and refurbishment required.

The proposals are 'broad brush' for several reasons: the stock itself is complex, and current knowledge of both domestic and non-domestic stock is limited, as is our understanding of building user behaviour.

First the current scale and distribution of energy use in buildings is examined, along with a projection of the likely position in twenty years time under a 'business as usual' scenario. Next, the available strategies for reducing demand are considered, followed by an assessment of strategies that have already been implemented and the opportunities that may have been missed.

The final recommendations are for a large increase in refurbishment, demolition and rebuilding. Underwriting all of this is the recognition that to be successful, all sectors of society – legislators, administrators, developers, builders, owners and users – must be engaged in the process. The dominant driver for the shift in consumption patterns will be from TEQs.

Prospective homebuyers will be keen to know how much of their weekly quota will be required to heat and service their new home; likewise, builders and quantity surveyors will be quick to adjust their purchasing and construction methods to remain competitive.

The Current Situation

ENERGY USE IN BUILDINGS

Building energy use currently accounts for 46% of total UK energy consumption. Most of this energy is used in the domestic sector.

Type	Percentage
Domestic	63%
Non-domestic	37%

Table 9.1: Building energy use by sector[1]

BUSINESS AS USUAL SCENARIO

Sector	TWh Now	Expected Increase	TWh 2027
Residential	545	21%[2]	664
Non-Domestic	199	26%[3]	251
Total	**744**		

Table 9.2: Business as usual scenario: trends in energy use, unabated

Table 9.2 illustrates the future situation if no action is taken to mitigate current trends in energy consumption.

DOMESTIC BUILDINGS

Numbers & Condition

There are some 25 million dwellings in Britain. Their condition varies, but there is widely thought to be a large backlog of outstanding repairs, with replacement of large sections of the stock being overdue. In the

1 Communities & Local Government (2004): *Age of Commercial & Industrial Stock: Local Authority Level 2004*, www.communities.gov.uk [Live June 2007]

2 Energy use per household increased by 5% between 1971 and 2001. This equates to 3.33% for 20 years. Government forecasts estimate that there will be 29.5m households by 2027. The average consumption per household is currently 21.8kWh p.a., therefore average annual use per household in 2027 will be 22.5 kWh.

3 Based on the BRE estimate of 26% over the 20 year period 2000 to 2020 referenced below.

absence of hard data on their energy use, the ages and types of dwellings in Britain provide a degree of guidance.

Dwelling Age	Number
Pre-1919	4,584,000
1919-1944	3,856,000
1945-1964	4,489,000
1965-1980	4,738,000
Post-1980	3,946,000

Table 9.3: Dwelling Age[4]

For example, modern, small, semi-detached and terraced houses tend to be more energy efficient than older, large, detached houses. Houses with cavity walls and roof spaces have an advantage over the nearly seven million[5] with solid walls.

Dwelling type	Number
Small terraced house	2,629,000
Medium/large terraced house	3,494,000
Semi-detached house	6,127,000
Detached house	3,631,000
Bungalow	2,072,000
Converted flat	654,000
Purpose-built flat(low rise)	2,677,000
Purpose-built flat (high rise)	328,000

Table 9.4: Dwelling Type[6]

Energy use in Housing

In the domestic sector, space and water heating account for most of the energy use.

End Use	2002 (TWh)	2002 (%)
Space heating	336	61
Hot water	129	23
Lighting & appliances	73	13
Cooking	15	3
Total	553	100

Table 9.5: Total domestic energy consumption by end use[7]

Construction Trends

Most existing buildings were constructed with little regard for energy conservation. There is consequently a large potential for improvement, but not at the current rate of replacement and renovation. At present, only 20,000 dwellings are being demolished and replaced per annum (0.08% of the stock), with a further 180,000 being built.

This does not even meet the Government's own predictions for housing numbers. Defra's *Market Transformation Programme* estimates growth at about 1 million every five years for Britain, driven by rising population and an increase in single person occupancy. This represents an increase of 4.5 million households to 29.5 million by 2027[8].

Consumption Trends

Energy use has risen consistently over the last thirty years, but not necessarily in the most obvious ways.

While energy use in cooking has fallen, space heating consumption has risen due to an increase in the proportion of houses having central heating, along with

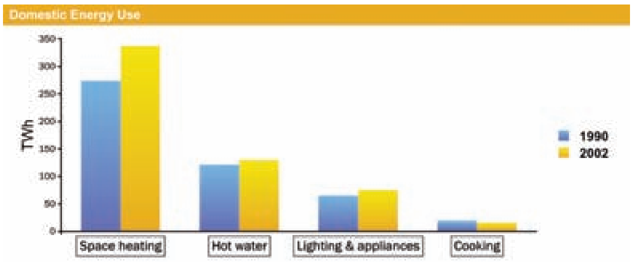


Fig 9.1: Growth in total domestic energy consumption by end use [9]

4 Department for Communities and Local Government (2004) *English House Condition Survey 2004*, www.communities.gov.uk [Live June 2007]

5 From: The Centre for Sustainable Development

6 Department for Communities and Local Government (2004) *English House Condition Survey 2004*, www.communities.gov.uk [Live June 2007]

7 Figures derived from DTI *Domestic Energy Consumption by End Use, 1970 to 2004* www.dti.gov.uk [Live June 2007]

8 *Defra Market Transformation Programme (2007): BNXS25 UK Household and Population figures 1970 – 2020*, www.mtprog.com/ApprovedBriefingNotes/PDF/MTP_BNXS25_2007January16.pdf [Live June 2007]

9 Figures derived from DTI *Domestic Energy Consumption by End Use, 1970 to 2004*, www.dti.gov.uk [Live June 2007]

higher comfort levels. The effect has been moderated by better insulation, a rise in average outside temperatures, and more efficient boilers and heating equipment[10].

Lighting and appliance consumption continues to rise at about 2% per annum. Energy use for domestic appliances is a particular issue, with households acquiring ever more energy-consuming electrical goods[11]. For example, the Guardian reported last year that each household now owns an average of 2.4 televisions, and that those with plasma screens use up to four times the energy of previous designs[12].

Standby power is also a significant consumer of energy. The *Market Transformation Programme* estimates that appliance standby power lies in the range of 5 to 30W, accounting for some 6 to 10% of annual household electricity demand[13].

NON-DOMESTIC BUILDINGS

Non-domestic buildings are much harder to assess, both because the buildings themselves vary widely, and because little data has been collected on them.

Once more, using age as an indicator of insulation standards, the picture is not encouraging. Over half the non-domestic stock dates from pre-1940, and only around 2% was built under any energy efficiency legislation[14].

Energy Use in Non-domestic Buildings

Non-domestic buildings account for 17% of Britain's total energy demand. Consumption by end use is show in Fig 9.2. As in the domestic sector, heating accounts for the greater part of the demand.

Trends

The Building Research Establishment (BRE) estimates a growth in non-domestic floor area of 25% between 2002 and 2020, and an energy consumption increase of 26% if measures are not taken to decrease them[15]. At present, energy use is not given a high priority in non-domestic buildings, as it makes up a very low percentage of a company's total expenditure.

This is particularly true in commercial buildings, where the financial bottom line is of primary concern. The demand for more appliances and better cooling means that energy use in the commercial sector is growing faster than in any other. Air conditioning has become the norm for offices, and it is increasingly difficult to let office space without it.

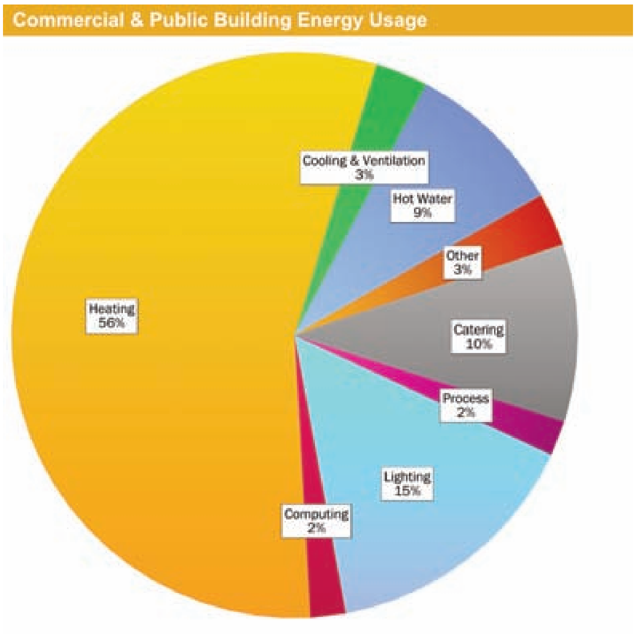


Fig 9.2: Commercial and public sector energy consumption by end use[16]

Similar factors apply in the retail sector. In supermarkets, the competing demands of keeping chilled and frozen goods cold yet accessible, while keeping customers comfortably warm, has led to high levels of energy consumption.

The Way Forward for Buildings

The business as usual scenario is clearly untenable. It is not simply a case of reducing existing consumption. A viable energy policy needs to address the increasing energy demand that comes from a larger population, in more households, and with higher expectations.

Before introducing a model for a reduction in buildings' energy use, it is first important to identify why the market has thus far failed to deliver the necessary

10 Sustainable Development Commission (2006) Stock Take – *Delivering Improvements in Existing Housing London*, Sustainable Development Commission

11 Lord Dixon-Smith (27th April 2006) Speaking in the House of Lords on Energy Efficiency *Hansard text for 27 Apr 2006 (60427-31)*, www.publications.parliament.uk [Live June 2007]

12 Maley, J. (2006) *Gadgets Drive up Household Energy Use*, Guardian, 03/07/06

13 Defra Market Transformation Programme (2007) BNXS15 – *Standby Power Consumption – Domestic Appliances,* www.mtprog.com/ApprovedBriefingNotes/PDF/MTP_BNXS15_2007May1.pdf [Live June 2007]

14 Communities & Local Government: *Age of Commercial & Industrial Stock: Local Authority Level 2004,* www.communities.gov.uk [Live June 2007]

15 Pout, C.H., Mackenzie, F. and Bettle, R. (2002) *Carbon Dioxide Emissions from Non-Domestic Buildings: 2000 & Beyond* BRE: Watford, England

improvements. Fundamental structural changes will be required to rectify this.

BUILDING NUMBERS

As already noted, government expectation is for household numbers to grow from 25 million today to nearly 29.5 million in 2027. This is a passive projection, in which the market is expected to accommodate demand by building new homes at a rate of nearly 250,000 per year.

In this strategy, a significant growth in building numbers is allowed for. However, it is expected that co-housing will become increasingly popular, leading to a reduction of the more than 250,000 second homes in Britain. The forecast therefore is for a figure of 27.5 million households by 2027.

The non-domestic sector also has prospects for reduced growth. Likely drivers include economic slowdown due to carbon pricing and fuel scarcity, the more efficient use of existing space, and the development of high-technology home-based solutions for work, shopping and entertainment.

STOCK KNOWLEDGE

In order to reduce CO_2 emissions, strategies must quickly be formulated and acted upon. But what is still lacking is a sufficiently detailed understanding of the construction and energy performance of the existing building stock. Broad analyses have been undertaken, but often without considering energy issues. Several rather disparate projects are currently ongoing to remedy this, but we are far from having a complete picture, particularly in relation to non-domestic buildings[17].

Energy Performance Certificates are seen as a tool for data collection as well as a means of influencing building owners in energy efficiency decisions. But their detail is limited, and while energy prices remain low they remain of limited effectiveness. Public sector buildings and offices are some way behind the residential sector in this respect, despite pressure from the EU *Energy Performance of Buildings Directive*.

SUPPORT, INFORMATION & DESIGN

Support

The *Energy Savings Trust* and the *Carbon Trust* provide support on demand for the domestic and non-domestic sectors respectively.

However, while simple, minor improvements such as cavity wall and loft insulation are supported, more challenging solutions for older buildings are not. There is an urgent need for more research, support and information into the best approaches for hard-to-treat homes and buildings.

At the same time, there is a need to address the understandable concerns of building owners and occupiers. Key issues are the possible need to replace buildings (because they are not cost- or energy-effective to insulate), and the effects of loss of space, amenity and aesthetics that energy improvement works often involve.

For example, the majority of dwellings with solid walls will require either demolition or disruptive and expensive insulation. This is likely to involve internal insulation (leading to a loss of floor space), or external insulation (leading in most cases to change in the building's appearance).

Information

There is increasing sophistication and understanding of *Building Energy Management Systems* (BEMS) in commercial buildings. These, combined with remote metering, have proved very effective in managing energy demand, in a sector where waste is almost endemic and where even the ownership and location of meters are sometimes unknown to occupants.

Such systems have also recently been introduced for domestic use. Knowledge and transparency of energy use are vital in all sectors, in order to engage occupants in the process of demand reduction. As knowledge grows, action can be targeted with increasing accuracy towards the most inefficient buildings and those using high-carbon fuels.

16 Taken from CH Pout, F Mackenzie and R Bettle (2002) *Carbon Dioxide Emissions from Non-Domestic Buildings: 2000 & Beyond* BRE: Watford, England

17 'Knowledge of the non-domestic building stock is 'probably 20 years behind' that of the domestic stock. Researchers are confined to making "reasonably good guesses" Professor Oreszczyn, in evidence to the House of Lords Select Committee on Science and Technology – Second Report (2005), www.publications.parliament.uk [Live June 2007]

Britain is good at producing advice and strategy, but poor on delivery. The EU *Energy Performance in Buildings Directive* (EPBD) is arguably now the key driver for legislative change since coming into force in January 2003

Solutions to the energy performance of buildings can be complex. More research is needed, and access to information and training needs to be both free and encouraged, in order to engage people in the task.

Design

Design too is of central importance. The challenge is to create effective, durable and adaptable buildings that meet or exceed energy performance demands. The recent move towards low cost *Modern Methods of Construction* (MMC) is not encouraging in this respect.

While the build quality of MMC can be good, the buildings' longevity and appropriateness to future climate remain in doubt.

LEGISLATION

Britain is good at producing advice and strategy, but poor on delivery. The EU *Energy Performance in Buildings Directive* (EPBD) is arguably now the key driver for legislative change since coming into force in January 2003[18].

Recent changes in the UK Building Regulations Part L, which have set a significant but insufficient improvement in energy standards for new buildings, have been driven by the EPBD. The subsequent *Code for Sustainable Homes* is intended to pave the way for improved measures, leading to zero-carbon building by 2016[19].

One anomaly in the Building Regulations means that energy performance requirements are relative to size, not to use. This allows greater energy use and emissions from larger buildings. Instead, these requirements should be absolute.

While building regulations are impacting slowly on new build standards, there is still very limited application of regulations to existing stock. There is little requirement or incentive for owners of existing buildings to improve their energy efficiency. This is vital, and could be achieved in part by using the recommendations of *Building Market Transformation*. These suggest mandatory energy efficiency improvement at exchange of contract on sale, and when letting[20].

More building inspectors must be trained in order to ensure that these regulations can be effectively enforced.

Although regulating building standards is crucial to this process, it is equally important (and often ignored) to ensure that design standards are matched by standards in use. This should not only occur on completion, but on an ongoing basis, so that lessons are learned about designing for energy efficient usage. Thermography, air pressure testing, building log books and energy management systems are tools that should be used as a matter of routine. They would help ensure that buildings continue to meet or exceed their design standards, and that the occupants fully understand what contribution they can make to energy saving.

A large part of the responsibility for energy saving in buildings lies in the hands of the private sector. For example the *Energy Efficiency Commitment* (EEC) requires energy suppliers to achieve targets, in proportion to their customer base, for installing energy efficiency measures in households. While this may be a positive use of the market, the energy companies' obligation to their shareholders also requires them to maximise sales and profits.

18 See DCLG (Department of Communities and Local Government) (2007) The Energy Performance of Buildings www.communities.gov.uk for details of implementation in the UK [Live June 2007]

19 BROWN, G. Rt Hon MP, Chancellor of the Exchequer (2006) Chancellor of the Exchequer's Budget Statement 22nd March 2006, www.hm-treasury.gov.uk [Live June 2007]

20 Oxford University Environmental Change Institute (2007) Building Market Transformation study, www.eci.ox.ac.uk [Live June 2007]

Warm Front and the *Decent Homes Programme* are also seen as tools for encouraging improvements in energy efficiency. *Warm Front* has been particularly effective.

TAX

For the domestic sector, rebates have been proposed on property related taxes such as Council Tax and Stamp Duty in exchange for the installation of efficiency measures. Such tax incentives can play an important role in reducing energy demand.

There are also strong grounds for the abolition of VAT on refurbishment. This would level the playing field with new build, and reduce the cost of retrofit insulation and improvement.

"by far the most promising in terms of long-term lighting energy efficiency is the light emitting diode or LED. This technology is expected to achieve efficiencies at least ten times better than tungsten filament lamps and up to twice as good as fluorescent lamps"

Defra[21]

Finally, there is an urgent need for a review of the use of lighting in streets, buildings and advertising hoardings.

LIGHTING

There is considerable scope for improvements both in the design and use of lighting. With the widespread availability of low energy alternatives, there is little need for the continued sale of incandescent light bulbs, running at around 5 times the energy consumption of compact fluorescents. Australia has announced their phasing out by 2010. Further research and development to support other lighting technologies is also needed.

There is also great potential for automatic and person-sensitive lighting. While earlier systems have had limited success due to poor interface design, considerable savings can result from such technology, particularly in offices.

APPLIANCES & OFFICE EQUIPMENT

Considerable potential exists for energy saving in appliances. This is of particular relevance due to growth in the number and range of appliances in use.

Here, legislation has a key role. Standby power consumption should be labelled in the same way as white goods' energy efficiency. It is widely thought that standby power (if needed at all) could be reduced to 0.1W.

Energy ratings should be extended to cover all electric appliances and equipment, and all new equipment being sold should be A-rated. The rating should be permanent and clearly visible on the front of the appliance.

One reason why performance in use falls short of design performance is due to skills shortages in the construction industry. This is a matter of particular concern at a time of rising energy standards.

21 Defra: Market Transformation Programme (2007) *BNDL101: New lighting technologies Version 2*, www.mtprog.com [Live June 2007]

AIR CONDITIONING

Air conditioning is a further significant growth area. Good building design incorporating natural and 'mixed mode' ventilation systems should be mandatory. Together with changes in behaviour and increasing energy costs, such systems have the potential to reverse this trend.

ENFORCEMENT AND TESTING

Post-occupancy evaluation in the form of air pressure testing has now been introduced for new developments, but too little and too late. The *Usable Buildings Trust* has repeatedly demonstrated (often in the face of considerable opposition) that buildings rarely meet their design performance.

Such shortcomings are due to poor building practice, lack of enforcement, and limited knowledge of how buildings and people interact. Post-occupancy evaluations need to be mandatory, ongoing and openly published for these lessons to be clearly learned[22] by the industry.

SKILLS

One reason why performance in use falls short of design performance is due to skills shortages in the construction industry. This is a matter of particular concern at a time of rising energy standards.

These in turn demand greater understanding and attention to detail on the part of builders. It assumes yet greater importance in the context of the call for a large increase in new-build and refurbishment.

Modern Methods of Construction is only part of the answer. First, the cost saving potential of MMC seems to have been emphasised more than its quality improvement potential. Second, quality is no longer guaranteed once the prefabricated units reach site. Thus, there is significant risk of widespread building component failure unless adequate investment in skills and supervision is made within the industry.

PLANNING

Various recommendations have been made for relaxed planning constraints. While it will be necessary to release land and speed up planning decisions, it must not become a free-for-all.

Planning is not ultimately the best tool for ensuring energy efficiency, and there are important environmental and cultural reasons for exercising caution. There are for example 66,000[23] listed buildings in Britain, for which insulation measures are largely impractical.

Buildings: What Will We Do With Them?

REPLACEMENT & REFURBISHMENT

Key strategic decisions concern the rate at which existing stock is replaced, and which buildings should be targeted for demolition and replacement. A number of complex social, economic and environmental factors are involved.

Discussions of energy use often focus on embodied energy. Despite considerable debate, no clear conclusions have emerged. According to *Constructing Excellence*, refurbishment to high-efficiency standards has around one tenth of the carbon impact of new build[24].

It is generally agreed however that the impact of embodied energy in demolition and replacement is greatly outweighed by the energy saved in use for efficient buildings. Whatever the conclusion, both refurbishment and new build must achieve a significantly higher standard than at present. There are substantial challenges for both.

In any event, it is unrealistic to assume that most buildings can be refurbished to the same energy standards as can be achieved with new build. In many

22 www.usablebuildings.co.uk, [Live June 2007]

23 English Heritage (2007) *Listed building figures*, www.english-heritage.org.uk/server/show/nav.1430 [Live June 2007]

24 Sustainable Development Commission (2006): *Stock Take: Delivering Improvements in Existing Housing*, www.sd-commission.org.uk [Live June 2007]

cases, demolition and rebuilding will be the better option.

Refurbishment to the required standard is hugely disruptive and unpredictable. But while there are strong social and structural reasons not to demolish and rebuild, developers, planners, clients and lenders all tend towards new buildings rather than refurbishments, because of greater certainty in the result.

The *Building Market Transformation Programme*[25] suggests that refurbishment should be encouraged when people move. This takes advantage of the

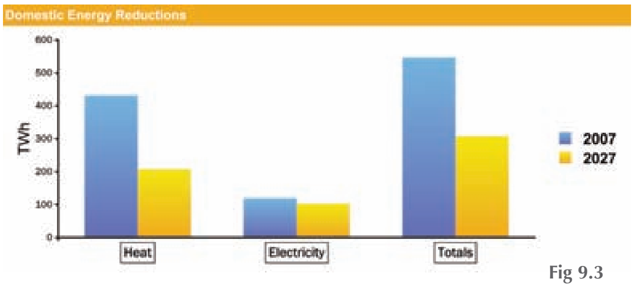


Fig 9.3

potential release of capital from private sales, and helps reduce disruption. It will however have the effect of inhibiting mobility and house sales, and may result in a piecemeal approach to improvement.

The level of refurbishment needed to achieve the necessary energy gains requires a more planned approach. Occupants will generally have to move out of the buildings to facilitate the work. In some circumstances it will be more sensible (if in other ways unpalatable) to build new houses and demolish as people move.

There is also a strong case for investing in energy efficient building stock while there are still the carbon resources to facilitate it. However, Britain's recent record in mass construction of good quality, durable houses requires considerable improvement. Decisions may thus be better based on social and practical grounds rather than energy ones.

These conclusions are inevitably oversimplified, and the best strategy may, ultimately, only be found by seeking a balance between social, economic and environmental factors at a local level, and applying energy targets to buildings by region or area.

"...in a rational policy of housing renewal, the impact of embodied energy needs to be taken into account, but the gains from improving the efficiency of the built fabric far outweigh the losses embodied in the necessary building work..."

The Environmental Change Institute [26]

ENERGY MODEL FOR BUILDINGS 2007/2027

Having considered the nature of the present stock and the options for improving its energy efficiency, what follows is an outline quantifying the build, refurbishment and efficiency targets.

For the domestic sector, this involves an ambitious building and refurbishment programme. After 3 years' bedding in, it entails an annual target of 262,500 new builds/replacements and 500,000 refurbishments.

It also includes a 10% saving in heating every 4 years, plus 5% in hot water and electricity. These result from progressive modification in user behaviour, and from small-scale technologies such as heat recovery.

Only brief reference has been made to onsite renewables, as these are covered under Power Up.

The above savings are thus through insulation and useage patterns, except in the case of domestic hot water where an anticipated 50% saving in energy use is through solar hot water, better insulation and improved appliance efficiency.

These proposals recognise the need to preserve Britain's heritage by omitting a significant proportion of energy inefficient houses from the refurbishment programme, but assume that savings will still be made in these properties through behaviour changes.

A higher density of housing in replacement of inefficient

25 Building Market Transformation Programme
Environmental Change Institute,
www.eci.ox.ac/research/energy/bmt.php

26 B. Boardman (2007) *Reducing the Environmental Impact of Housing, Final Report, Appendix E* Environmental Change Institute, University of Oxford, www.rcep.org.uk [Live June 2007]

Building Energy Use - Predicted Change

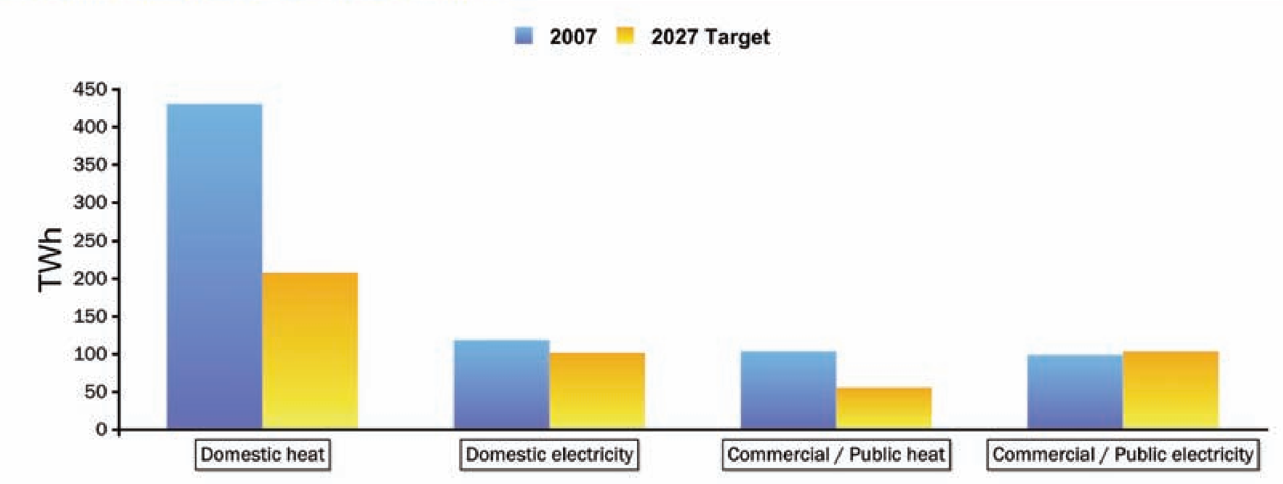


Fig 9.4

Action	2007	2008-2011	2012-2015	2016-2019	2020-2023
Build new		300,000	550,000	550,000	550,000
Demolish & replace		300,000	500,000	500,000	500,000
Refurbish		1,000,000	2,000,000	2,000,000	2,000,000
Stock number	25,000,000	25,300,000	25,850,000	26,400,000	26,950,000

Table 9.6: Domestic sector – dwelling numbers

	2007		2027		
	No. of households	Annual MWh per household	No. of households	Annual MWh per household	Energy decrease %
Domestic heat	25m	17.16	27.5m	7.5	43%
Domestic electric	25m	4.68	27.5m	3.64	22%
Domestic totals	25m	21.8	27.5m	10.25	57%

Table 9.7: Average energy decrease per household

old stock is assumed, thereby allowing new build to progress ahead of demolition, and housing numbers to grow.

Recognising the difficulties in reducing electricity demand, annual use per household reduces by only 21% from 4600kWh to 3640kWh. This is achieved through a combination of more efficient appliances and occupant behaviour.

In the non-domestic sector the position is less clear. It is anticipated that savings of around 50% can be made on heating, while there will be a small increase in electricity use. Growth in the non-domestic sector is expected to be less than that anticipated by the BRE due to the market constraint of carbon permits.

Cuts in energy use will be achieved through replacement of buildings and improved insulation, but it is expected that the most significant reductions will be a result of changes in building management and consequent occupant behaviour. This is driven by pressure from carbon prices, other legislation, improved corporate social responsibility, energy targets and occupant awareness. Although there is great potential for renewable technology to be incorporated into non-domestic buildings, allowances for this are included in the Power Up section rather than here.

This leads us to these overall figures for the buildings sector:

	2007 TWh	2027 target TWh	Change (%)
Domestic heat	429	206	-52%
Commercial/ public heat	102	54	-47%
Domestic electricity	117	100	-15%
Commercial/ public electricity	97	102	+5%
Domestic totals	545	306	-44%
Commercial/ public totals	199	156	-22%
Overall totals	**744**	**462**	**-38%**

Table 9.8: Predicted change in buildings' energy use 2007–2027

Conclusion

It is recognised that current knowledge of Britain's building stock is limited, rendering the above proposals somewhat crude. They provide a broad frame of reference for the decisions and action required.

Appropriate design and technology, along with occupant engagement, are the tools that will enable the targets to be reached. What is also needed is ongoing research, to learn from existing and new buildings, to ensure that they meet their design performance in use, and to assist occupants in using them with greatest efficiency.

Central to the scenario's implementation is the need to ensure that it does not worsen fuel poverty, build quality or user engagement. But of equal importance is the need for prompt action at a scale that matches the magnitude of the climate change challenge.

Chapter 10 Transport

CURRENT SITUATION

Transport currently represents around a third of Britain's primary energy consumption, it is also one of the areas in which we recover the greatest savings in this scenario.

The savings arise in large part from the wholesale switch from oil powered road vehicles to electric vehicles (EVs).

The internal combustion engine used in oil powered road vehicles is only some 20% efficient in converting the chemical energy stored in oil into useful energy to move the vehicle.

On balance, the recommendation is to convert to electric vehicles, encourage walking and cycling for short local journeys, and support a modal shift for freight and short haul aviation, thus reducing the annual 680TWh transport energy requirement to 151TWh.

ROAD

In 2005, 504 billion kilometres were travelled by road vehicles[1], of which 80% were cars, with bus/coach travel accounting for 5.4 billion. On the commercial front, light van traffic covered 63 billion kilometres, and HGVs 29 billion.

Motorcycle use has been increasing in recent years, as has cycling, which accounted for 4.4 billion kilometres. Car travel fell in 2005 by 0.9 billion kilometres, the first decrease since 1991. The energy consumed by the road traffic sector in 2005 was 490TWh.

RAIL

In 2005/06, passengers travelled 43 billion kilometres, an increase of 43% since 1980[2]. Freight transport declined during this period, owing to the shift from coal to gas for power stations, but has been increasing again, reaching 22 billion net tonne kilometres in 2005 – the highest level since 1974[3].

The energy consumed by the rail sector in 2005[4] was 12.7TWh (10TWh oil and 2.7TWh electricity).

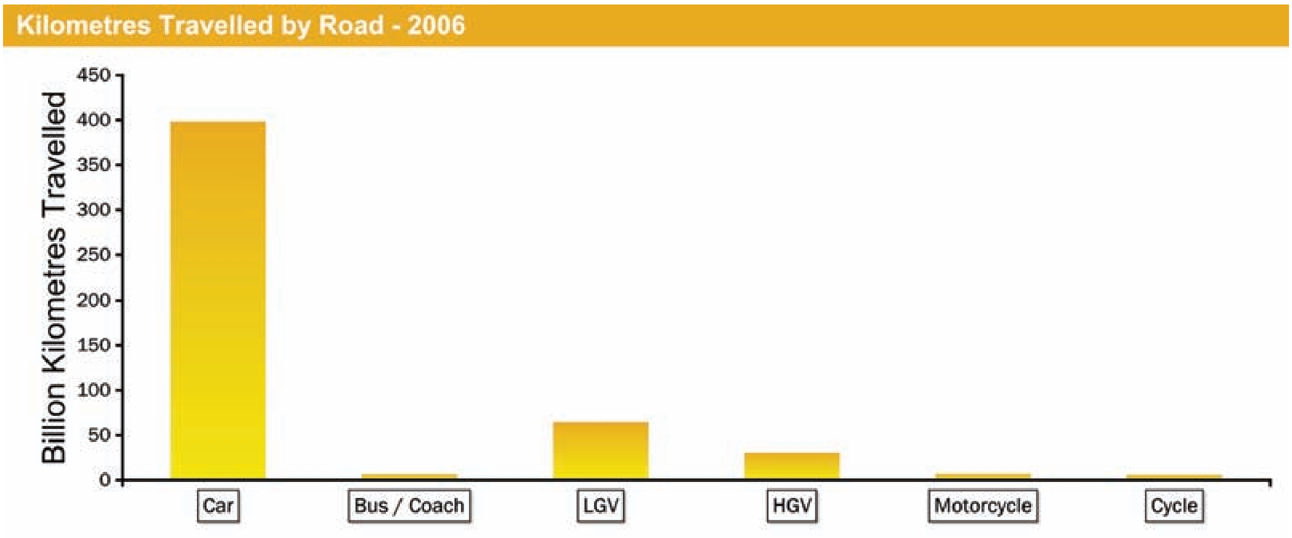


Fig 10.1[5]

1 DFT (2006) *Transport Statistics for Great Britain: 2006 edition*, www.dft.gov.uk [Live June 2007]

2 DFT (2007) Online transport statistics, www.dft.gov.uk [Live June 2007]

3 DFT (2006) Online transport statistics, www.dft.gov.uk [Live June 2007]

4 DTI (2006) Digest of United Kingdom Energy Statistics 2006 www.dtistats.net/energystats/dukes06.pdf, [Live June 2007]

5 Source: DFT www.dft.gov.uk

AVIATION AND SHIPPING

Air passenger numbers have nearly quadrupled since 1980, reaching 191 million in 2004. 24 million people travelled on domestic flights, with international traffic growing at a slightly faster rate than domestic[6].The implications of continued growth of the aviation sector have been modelled by the Tyndall Centre[7], who noted that the IPCC (1999) – supported by RCEP (2002) – has estimated the mean radiative forcing of aviation emissions as 2.7 times higher than the radiative forcing of CO_2 alone at ground level.

Tonnages handled through Britain's ports rose by nearly 7% between 1995 and 2005[8]. Crude petroleum and petroleum products dominated total waterborne freight traffic, amounting to 47 billion tonne-kilometres of goods moved in 2005 (78% of all waterborne freight)[9].

THE FUTURE

ELECTRIC VEHICLES

The carbon budget of this strategy demands that, within the next 20 years, our entire transport system must be replaced with one that is powered almost completely by renewable energy. We envisage that battery electric vehicles will be the technology that enables this, rather than hydrogen fuel cells.

Electric vehicles have been feasible for nearly 20 years; the infrastructure costs of their widespread adoption would be much lower than for hydrogen vehicles and, perhaps more importantly, their full cycle efficiency is better[10].

Electric motors are more efficient than internal combustion engines,[11] thus there is an immediate energy saving; lighter motors and other components lead to lighter vehicles supporting a virtuous cycle of efficiency improvements.

V2G (VEHICLE-TO-GRID POWER)

As a form of transport, electric vehicles combine a high level of energy efficiency with the ability to use renewably generated electricity. In addition, their batteries can double as energy stores for the Grid. Technologies have been developed to allow energy to flow in either direction between vehicle batteries and the Grid, while at the same time preventing discharge below a minimum level (set according to the owner's anticipated requirement).

Known as vehicle-to-grid power (V2G), the concept involves harnessing the energy storage of electric vehicle batteries for load balancing. When the Grid's supply exceeds its demand, the surplus is used to top up the batteries of all connected vehicles. When demand exceeds supply, those batteries are used to make up the shortfall. This effectively turns connected vehicles into additional grid storage.

The National Travel Survey (2005) found the average car in Britain travels around 25 miles per day. Thus, cars remain parked for about 23 out of every 24 hours. If they are connected to the grid, their storage capacity can be used to smooth the fluctuations of electricity supply and demand, thus reducing the necessary peak generating capacity.

The amount of energy that could be stored in this way is substantial. There are currently 27 million vehicles in Britain. The average capacity of an electric vehicle is approximately 50kWh, giving an aggregate storage of 1.65TWh – around 1.6 days of Britain's total electricity consumption. Likewise, a single vehicle holds the equivalent of over 2 days' supply for the average household.

6 DFT (2007) Aviation statistics, www.dft.gov.uk [Live June 2007]

7 Anderson, Dr. K., Bows, Dr. A., and Upham, Dr. P. (2006) *Growth scenarios for EU & UK aviation: contradictions with climate policy*, Tyndall Centre Working Paper No 84 www.tyndall.ac.uk [Live June 2007]

8 & 9 DFT (2007) Online transport statistics, www.dft.gov.uk [Live June 2007]

10 DFT (2005) *Waterborne Freight In The United Kingdom 2005*, www.dft.gov.uk [Live June 2007]

11 Youngquist, W. (1997) *GeoDestinies: The Inevitable Control of Earth Resources Over Nations and Individuals*, p. 436, National Book, Portland, OR

12 Source: DFT www.dft.gov.uk

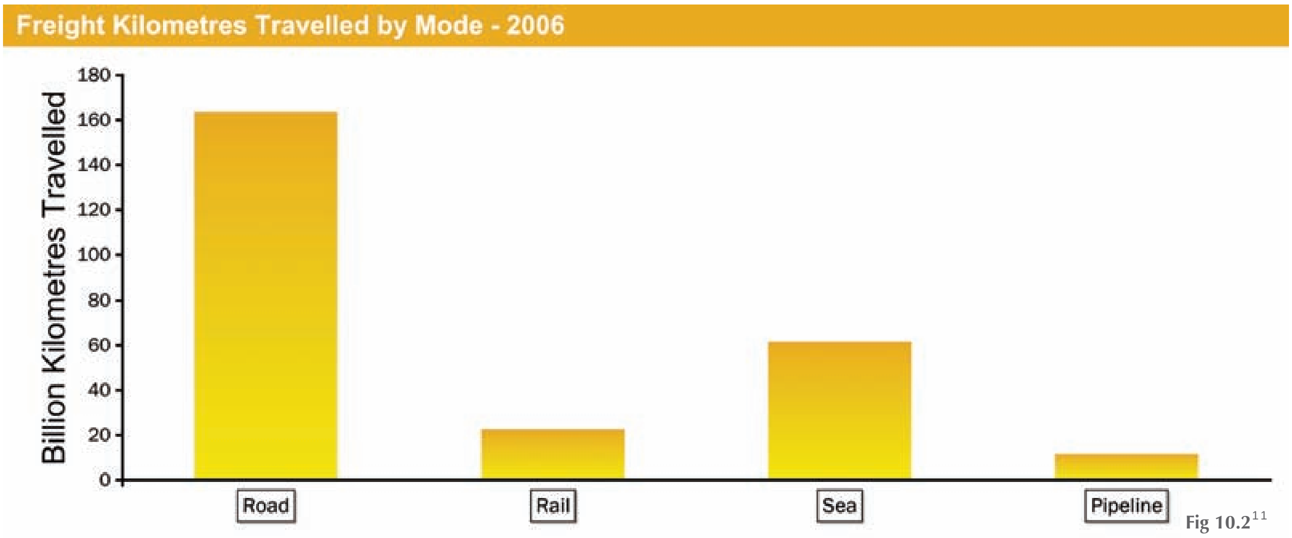


Fig 10.2[11]

A major incentive for people to adopt electric vehicles would be a Vehicle to Grid system (V2G), which would allow people to sell the use of their onboard power and battery storage back to utility companies while they are not being used[12] (see Chapters 16 Demand Management and 17 Integration and Balancing).

If the nation's 27 million cars[13] were entirely replaced by electric vehicles, and their batteries had an average rating of 15kW, they would have a total power of 405GW – more than ten times the average power requirement of the National Grid. Even with optimistic reductions in vehicle ownership, and with only a fraction being plugged in at any given time, it is clear that they could provide much of the extra storage necessary to the Grid for security of supply in a renewable future.

TRANSPORT MIX

CARS & PERSONAL TRANSPORT

During the transition to renewable electric-powered cars, electric-ethanol co-powered hybrids would be required for long-range journeys. Given that nearly 25% of all car journeys are 2 miles or less[14], improvements to cycle lanes and pedestrian facilities would help to reduce vehicle usage and encourage alternative modes of transport.

As the replacement rate for cars is approx 8% per annum[15], a 30% changeover by 2017, and 100% replacement by 2025, is achievable. This changeover to electric cars will return an energy saving of 87%[16], thus energy used by cars will reduce to 51TWh per annum by 2025 (based on kilometres travelled in 2005); this ignores further savings that may be achieved through a modal shift to coach, rail, and foot/cycle.

COMMERCIAL

We envisage a modal shift in the heaviest freight transport from Heavy Goods Vehicles (HGVs) to rail. Ultimately, HGVs would need to be entirely replaced by trains and lighter goods vehicles, which would be electric. In the interim, there may be scope for the use of compressed natural gas to power the largest HGVs.

A move to local food distribution would create some reduction in freight, although the greater reduction would be in car travel for shopping. HGVs currently consume 117 TWh, and Light Goods Vehicles 69 TWh, per annum[17]. An assumed reduction in freight of 40%, owing to re-localisation of production of food and other goods, would deliver a saving of 75TWh.

13 "Electric motors convert 75% of the chemical energy from the batteries to power the wheels—internal combustion engines (ICEs) only convert 20% of the energy stored in gasoline." US Department of Energy and US Environmental Protection Agency (2007)***Fuel Economy Guide: Electric Vehicles (EVs)*** **www.fueleconomy.gov/feg/evtech.shtml** [Live June 2007]

14 Kempton, W. et al: University of Delaware research programme (2007) *Vehicle to Grid*, www.udel.edu/V2G [Live June 2007]

15 RAC (2007) *RAC Business: Useful Information: Fleet Statistics*, www.rac.co.uk [Live June 2007]

16 DFT (2005), *National Travel Survey 2005*, www.dft.gov.uk [Live June 2007]

17 RAC 92007) *RAC Business: Useful Information: Fleet Statistics*, www.rac.co.uk [Live June 2007]

18 Eberhard, M. and Tarpenning, M. (2006) *The 21st Century Electric Car*, www.stanford.edu [Live June 2007]

HYDROGEN FOR TRANSPORT

Types

Hydrogen fuelled vehicles fall into two categories – combustion and fuel cell.

- Combustion: hydrogen is used instead of fossil fuels in a modified internal combustion engine. This produces a very clean exhaust, consisting largely of water vapour. Some pollutants also remain, although in a greatly reduced form.

- Fuel Cell: hydrogen is mixed with oxygen within a fuel cell, directly generating electricity. This is used to drive highly efficient electric drive motors. Such systems can also incorporate regenerative braking, reclaiming up to 85% of the energy from the car's momentum.

Generation

Hydrogen can be generated from renewable electricity sources via electrolysis. Electrolysis uses electricity to break water down into hydrogen and oxygen, effectively providing a storage medium for electrical power which can help to overcome issues of variability. Hydrogen can also be generated from biomass. However this is an inefficient use of such resources.

Hydrogen can also be extracted from fossil fuels via a number of different methods. This approach could be combined with future carbon capture technology. However such technologies will always be subject to large inefficiencies.

Storage

Hydrogen has a high energy density per unit of mass. But, due to its low physical density, it requires a large storage volume compared to fossil fuels. It can be stored as a compressed gas, a liquid or in solid metal compounds known as metal hydrides.

- Compressed Gas: this requires high-grade cylindrical storage canisters, to provide sufficient strength to withstand the large pressures involved. Such systems are too large for use in conventional cars, although they are suitable for larger vehicles such as buses, where they may be located in the roof space.

- Liquid: to store liquid hydrogen, it must be cryogenically cooled to around -250°C. This requires a significant amount of energy, and if left to warm up, the liquid hydrogen will evaporate, a problem known as 'boil-off'. This would result in a full fuel tank of liquid hydrogen boiling off if it were left for a few weeks. This may not be a problem for the proposed liquid hydrogen-fuelled planes (e.g. Airbus), as the hydrogen could be generated on-site by electrolysis to meet demand.

- Metal Hydrides: here, hydrogen is stored in a solid crystal lattice structure. The very small hydrogen atoms are held within the molecular 'spaces' in various metal compounds. This is an area of active development, but the current consensus is that there are significant issues of both weight and recharge/discharge timescales when considered for transport storage purposes.

Efficiencies

There are several stages in the hydrogen cycle, including initial extraction/generation, storage and eventual use in electrical applications. As each stage has conversion losses, the overall 'power plant-to-wheel' efficiency is much lower than using modern batteries for road transport.

COACHES

Coaches use less energy per passenger mile than trains[18], we also already have an extensive road and motorway network. Coach journeys at present are slow, and an improved system must be rapidly developed in order to overcome this.

Through carrying more people, coaches can replace more than thirteen times the traffic of cars on motorways[19]. It is thus imperative that a lane in each direction of the UK's busiest motorways is converted to be a dedicated coach lane. Some 200 coaches would continuously circle the M25, while other services would travel up and down the M1 and the M6. There would be orbital coaches for Birmingham and Manchester.

Public transport would be extended or improved to develop existing motorway service stations as coach stations. Waiting times would be reduced to a few minutes and it would become quicker to travel by coach than car for most journeys.

Coaches would also be battery electric vehicles, of perhaps 100 kW each. It may be sensible to install overhead cables on some sections of the dedicated coach lanes.

RAIL

Figures from 2003 indicate that nearly 12,000 of the UK's 17,000 kilometres of track are electrified, using 12.7TWh of energy per annum in 2006[20], of which electricity comprises 2.7TWh. Further electrification to complete the network would increase annual electricity demand by 5.7TWh, but result in reduced primary energy requirements.

Significant improvements to infrastructure, and expansion of services to permit longer, faster, more frequent trains and passage of standard transport containers below bridges, will be required to encourage the continuing modal shift from road and air to rail.

AVIATION AND SHIPPING

Displacement of 90% of domestic and short haul flights will be encouraged by the large number of TEQs the industry is required to buy. The expansion of high-speed, frequent rail and sea services will be required to support this change in behaviour.

As Britain's economy moves to renewable sources of energy, a reduction in imports of oil and gas will result. Coupled with fewer fossil fuel derived goods being manufactured overseas, a consequent decline in tonnages passing through Britain's ports and airports will be experienced.

Aviation is currently a large and growing sector for GHG emissions. Curtailing this in the future requires fundamental shifts beyond reduction in overall air travel. Alternative fuel sources will need to be explored. Hydrogen is considered by Boeing to be a contender, however, it raises a secondary concern that jet flights at high altitude introduce GHGs in the form of water vapour. We may see a renaissance of low flying propeller driven aircraft, but electrically driven.

OVERALL REDUCTION

In conjunction with the changeover to electric cars, a modal shift was modelled from car to coach of 30%, from car to rail of 30%, and from car to foot or cycle of 5%, with the aim of reducing congestion.

It was noted that a fourfold increase[21] in capacity, and consequently energy used, within the coach and rail sectors would be required to achieve this shift. A transfer of 20% of road freight to rail is also envisaged. To achieve such significant modal changes, the nationalisation of bus and rail systems may be required.

However, some sources[22] indicate that less energy may be required when cars and commercial vehicles are preferred to train and bus services in certain circumstances. This might partly be a consequence of increased journey lengths being required when using public rather than personal transport. For example, a return trip from Leominster to central Birmingham is 90 miles by road, whereas it is nearly 160 miles by rail on the current network lines.

19 DTI (2006) Digest of United Kingdom Energy Statistics 2006, www.dtistats.net/energystats/dukes06.pdf [Live June 2007]

20 Victoria Transport Policy Institute, Canada (2007) Energy Conservation and Emission Reduction Strategies, www.vtpi.org/tdm/tdm59.htm [Live June 2007]

21 Storkey, A. (2005) A Motorway-based National Coach System, www.bepj.org.uk/wordpress/wp-content/2007/03/motorway-based-coach-system.pdf [Live June 2007]

22 DTI (2006) Digest of United Kingdom Energy Statistics 2006, www.dtistats.net/energystats/dukes06.pdf, [Live June 2007]

Chapter 11 Industry

Introduction

This section deals with Britain's industrial energy use. It looks at how the energy impact of our imports should be taken into account and calls for further research on this issue. Furthermore it points out that the sort of growth favoured in much of government policy is unsustainable without far greater use of renewable energy.

By way of example, two of the most energy hungry industry sectors are looked at in terms of how they have performed recently and some of the measures they could continue to implement are laid out.

Finally a set of conditions is proposed in order to meet the targets laid out in other sections of this strategy.

IMPORTED EMBODIED ENERGY

It should be stated that assessing Britain's industry as just that which takes place on its shores, presents only a partial picture. Britain's balance of carbon is about 7% above that which it exports[1]. There are many British based companies that site their manufacturing operations elsewhere in the world. In this way Britain's business is deriving financial benefits and Britain's consumers are using goods that have not been added to their energy balance. It is estimated that Britain's businesses (not just industry) are responsible for as much as 12–14% of global CO_2 emissions[2] [3].

The global policy of Contraction & Convergence, with a market for carbon, is a way of both limiting and internalising those costs associated with manufacture abroad. Further work is required to explore how this international market will integrate with Britain's carbon trading market of TEQs.

In accounting for Britain's global energy footprint in this scenario (both domestic and offshore), the approach taken has been to count the energy associated with all goods imported to Britain for Britain's benefit, and to subtract the energy associated with any goods exported from Britain, and therefore not directly for Britain's benefit. This is an energy analysis and not a financial analysis.

Regarding the operation of transnational corporations with UK registered offices, our analysis has explicitly not included the energy associated with their business and/or manufacturing activities. This report therefore is very much a snapshot of what is happening on British soil, which is not to pass judgment on international business, but rather to provide a simplification for accounting purposes.

Such an approach allows us to view Britain as a microcosm of the world. The national policies recommended here sit within a global framework of carbon permits, and we would hope to see similarly changed conditions in our neighbouring countries, near and far.

This is a legitimate approach when seen in the context of widespread global adoption of similar national policies of carbon permits. Companies operating internationally will have to take account of local carbon costs wherever they operate.

1 CES (2005) *UK Carbon Attribution Model*, University of Surrey

2 Trucost and Henderson Global (2005) *The Carbon 100: Quantifying the carbon emissions, intensities and exposures of the FTSE 100*, www.trucost.com/Trucost_The_Carbon_100.pdf [Live June 2007]

3 Christian Aid (2007) *Coming Clean: Revealing the UK's true carbon footprint*, www.christian-aid.org.uk [Live June 2007]

Overview of Industry Energy Use

GROWTH

Continual growth is not sustainable[4]. No matter what level of efficiencies are brought in, if growth in demand for goods and services continues as a compound percentage, it will eventually outstrip whatever gains can be made on efficiencies. For this reason improvement in carbon intensity is not a good enough measure when looking at the economy as a whole. A cap on CO_2 emissions is needed, and will serve to slow growth, recognised as long ago as in the Marshall Report of 1998[5].

However, it is an almost impossible task to project the precise effect a cap on CO_2 emissions will have on industry. All that can be done here is to look at current progress (which has generally only been in carbon intensity) and make projections as to what level of improvement needs to be made to reach the goals demanded by the climate change science covered earlier in this report.

RECENT USE

The graph below, Fig 11.1, tells a sad story. It suggests that most of any gains made by an increase in efficiency have been wiped out by growth. This has left us with an industrial sector which used only 1% less energy in 2004 than in 1998.

Renewables and waste-generated power contributed approximately 1% per year, although this has actually reduced slightly over time from 5 TWh in 1998 to 3 TWh in 2004. This situation must change; efficiency can only go so far and then low- and zero-carbon technology must take up the rest of the burden.

Case Study: The Chemical Industry

The chemical industry is one of the largest single components of the DUKES (Digest of UK Energy Statistics) split of industry sectors. In 2004 it used around 74 TWh, equivalent to almost 20% of the total amount used by industry, which makes it a prime target for efficiency measures. In fact, it does have some of the most challenging targets.

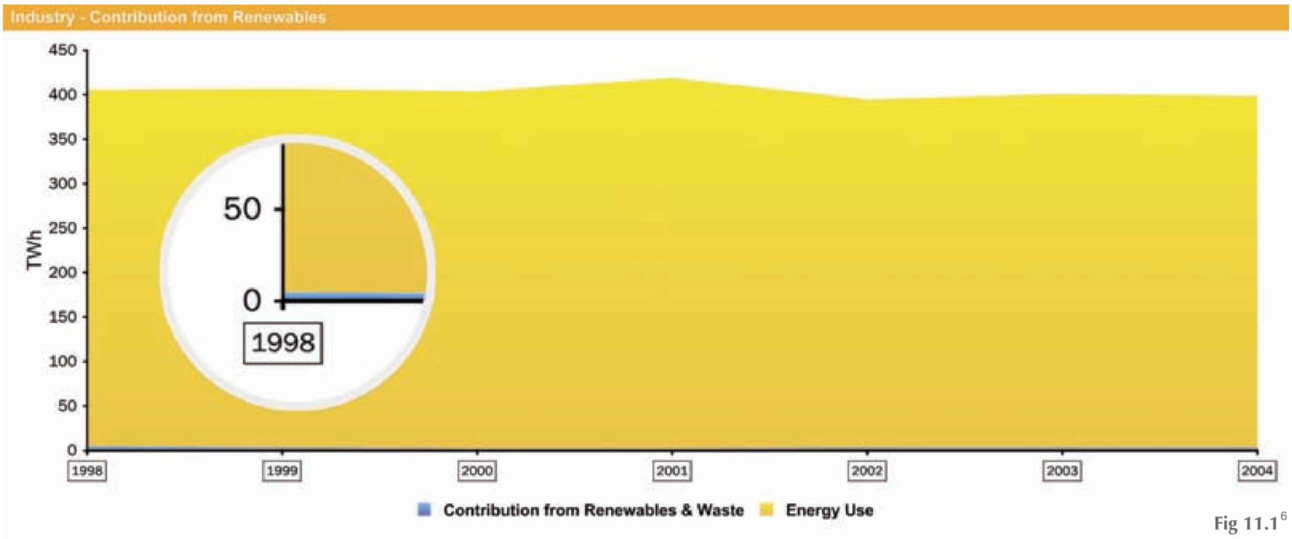


Fig 11.1[6]

4 Meadows, D.H., Randers, J. and Meadows, D.L. (2004) *Limits to Growth: The 30-Year Update*, Chelsea Green Publishing, Vermont

5 Lord Marshall (1998) *Economic Instruments and the Business Use of Energy*, www.hm-treasury.gov.uk

6 DTI (2006) *Digest of UK Energy Statistics*, www.dti.gov.uk

One Defra target is an 18.3% reduction in energy use at an assumed level of throughput between 1998 and 2010, based on all cost-effective (ACE) measures[7] .

One of the major problems with such targets is that they only demand increases in efficiency rather than a real term reduction in energy use or even in emissions. This is done by using an 'assumed level of throughput', which ignores the impact of growth. Unfortunately the sector is predicted to grow by 30% between 2000 and 2010[8], which would easily wipe out all of the gains made by ACE efficiency measures. Therefore, this scenario assumes that carbon trading will constrain growth to an environmentally sustainable level by the setting of a challenging cap on emissions. Again drawing from the sector's Climate Change Agreement, the following areas are seen as possible sources of energy efficiencies[9]:

- Gains from better energy management, improved and correctly sized motors and drive systems.
- Optimising for efficiency – using large diameter pipes, reducing losses and requiring smaller pumps and fans.
- Good housekeeping measures.
- Improved process control and process design.
- Additional waste heat recovery.
- Improved steam systems.
- Improved distillation processes, reactor technology and refrigeration systems.

Energy use in the chemical industry may be modified by the REACH directive[10], although the effects cannot yet be predicted. The directive requires registration of some 30,000 chemical substances over a period of 11 years, from 2007. Manufacturers and importers are required to generate data for all chemical substances produced or imported into the EU above one tonne per year, and identify appropriate risk management measures. The authorisation system will require a progressive switch to safer alternatives where they exist[11].

Case Study: The Iron and Steel Industry

The iron and steel industry has more than halved its energy consumption in real terms since 1998, despite Lord Marshall's report in that year which projected a maximum all technically possible (ATP) measures reduction of 16% by 2010[12]. This perhaps says more about the reliability of forecasting than anything else. It serves to illustrate that there can often be far more measures available in the very near future than expected.

There is a suggestion that carbon capture and storage (CCS) may be employed in furnaces, which would not provide direct energy savings but would be a positive step in terms of reducing emissions. In fact, by 2027 all fossil fuelled furnaces should be replaced either by electric furnaces or by biomass/biogas fuelled furnaces that can continue to use CCS, making them carbon negative.

The iron and steel industry used 21 TWh of energy in 2004, down from 46 TWh in 1998. This includes an 18% drop in Britain's steel production, which accounts for a part of the savings[13]; however the remaining industry made an energy saving per unit of production of 44%, suggesting that many energy saving measures were taken up. This makes sense in such an energy-intense industry.

As with other industry sectors, ETSU made suggestions as to where the iron and steel industry could make savings[14]. These are laid out below.

- Improvements in metal melting and holding.
- Improvements in ladle preheating insulation etc.
- Improved use of high efficiency motors and variable speed drives.
- Improvements in lighting and space heating.
- Improvements in yield.
- Improvements in molten metal distribution.

7 ETSU (2001) *Climate Change Agreements – sectoral energy efficiency targets, Version 2* AEA Technology

8 Oxford Economic Forecasting (2006) *Research on Output Growth Rates and Carbon Dioxide Emissions of the Industrial Sectors of EU-ETS*

9 ETSU (2001) *Climate Change Agreements – sectoral energy efficiency targets, Version 2* AEA Technology

10 A new European law on chemicals, REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals), entered into force on 1 June 2007

11 European Commission (2006) Regulation (EC) no 1907/2006 of the European Parliament and of the Council, Concerning the registration, evaluation, authorisation and restriction of chemicals (REACH), www.eur-lex.europa.eu [Live June 2007]

Industrial Energy Use

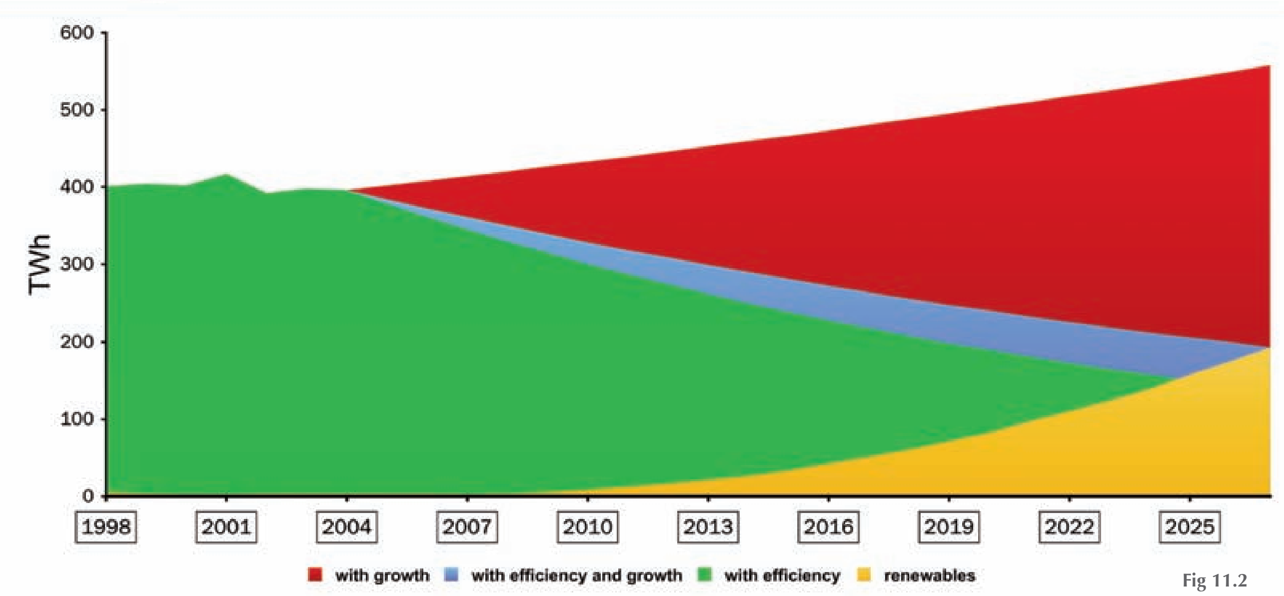


Fig 11.2

- Improvements in core making and sand reclamation.

- Improved maintenance and control of compressed air use.

- Implementation of improved energy management and monitoring systems.

What the Strategy Demands of our Scenario

In the graph above, the red wedge shows the growth in energy use at 1.5% per year should efficiency measures not be applied (an unrealistic expectation as many efficiency measures are already cost-effective, shown here for comparison). The green fossil fuel wedge demonstrates an improvement in efficiency of 4.5% per year. The blue wedge then allows for the 1.5% growth per year envisaged by the strategy. The yellow wedge shows the renewables coming in to meet the remaining demand by 2027. This scenario demands:

- Greater than 'Factor Four'[15] efficiencies, (i.e. more than doubling efficiency/halving energy use) instead of doubling use over 20 years.

- 4.5% increase in efficiency per year, halving in 15 years (before allowing for growth).

- Growth limited to 1.5% per year.

- Rapid increase in renewables over 20 years.

The latest IPCC report on climate change mitigation[16] suggests that future improvements in industry emissions could be made by:

> "More efficient end-use electrical equipment, heat and power recovery, material recycling and substitution, control of non-CO_2 gas emissions, and a wide array of process-specific technologies."

12 Intergovernmental Panel on Climate Change (2007) Climate Change 2007 - Mitigation of Climate Change: Working Group III contribution to the Fourth Assessment Report of the IPCC, Cambridge University Press

13 Iron and Steel Statistics Bureau (2006) UK crude steel production 1985-2005 www.issb.co.uk/issb/files/image/jpeg/key_ukcrude.jpg [Live, June, 2007]

14 ETSU (2001) Climate Change Agreements – sectoral energy efficiency targets, Version 2, AEA Technologie

15 Weizsäcker, Lovins & Lovins (1998) Factor Four, Earthscan

16 IPCC (Intergovernmental Panel on Climate Change) (2007) Climate Change 2007 - Mitigation of Climate Change: Working Group III contribution to the Fourth Assessment Report of the IPCC, Cambridge University Press

Some of the specific measures mentioned are:

> **"Advanced energy efficiency, CCS for cement, ammonia, fertiliser and steel manufacture [and] inert electrodes for aluminium manufacture."**

The individual industry sectors should make updated projections of their potential for efficiencies, taking account of current progress. Adoption of lean manufacturing methods, such as Kaizen[17], and Six Sigma[18], can provide substantial savings in energy and resource use, whilst also improving reliability and quality. Furthermore, ISO14000 series application and approval by companies can, through Life Cycle Assessment, assist in identifying and mitigating their environmental impacts.

Even companies with a reputation for efficiency can continue to make improvements. For example, Toyota Australia reported each vehicle manufactured in 2005/06 took 8.54GJ, against 8.77GJ in 2004/05, a 2.6% reduction. This builds on their record from 2000/01, when it was 9.13GJ. Their current energy target is 8.34GJ[19].

Conclusion

A challenging target has been set here for Britain's industry. It is a target based on the level of savings that other sections of this scenario have shown we must make.

The two energy-hungry industries looked at here have made great savings – greater than predicted in the case of the steel industry. This gives confidence that, with the right financial drivers and perhaps additional legally binding sectoral targets, industry energy use could be halved in absolute terms over the next 20 years.

These gains must not be achieved by the export of polluting industry overseas (without internalising the cost of carbon through the purchase of permits within a coalition of capped countries). It is imperative that we in Britain learn to live within our means, which may result in a slower rate of growth until the renewable energy industry is able to catch up with our energy demands.

17 Huntzinger , J. (2002) *The Roots of Lean: Training within Industry - the origin of Kaizen AME, Target, Volume 18 No 1, First Quarter*

18 Motorola (2007) *What is Six Sigma?*, www.motorola.com/content.jsp?globalObjectId=3088 [Live June 2007]

19 Toyota Corporation Limited Australia, (2006) *Environment and Community Report 2006*, www.toyota.com.au/TWP/Upload/Media/368.pdf [Live June 2007]

Chapter 12

ICT and Energy Intensity

Introduction

Information and Communications Technology (ICT) has a vital role to play in Britain's energy future. It has changed beyond recognition over the last decade, and continues to do so at a remarkable pace. Communications are no longer restricted to telephone services, but include the internet and mobile phones, with broadband and wireless access.

These have fundamentally changed how people work and play, how they interact with each other, and the energy used in doing so. This chapter highlights the benefits and drawbacks of the growth in ICT, commenting also on the connection between GDP and energy consumption.

Bringing the World to Homes & Workplaces

PCs and mobile phones are no longer the preserve of business, but are now an essential part of modern life. All of these devices impose a small additional load which, taken together, is significant, typically adding 100 – 200W to the average household peak power demand.

However, working from home also significantly reduces travel. A report from the sustainable transport consultancy Transport for Quality of Life estimated that teleworking could cut overall car travel by 1.6% by 2010, and by 5.4% during peak hours. In a more ambitious scenario, the figures increase to 2.8% and 9.7% respectively[1]. The resultant easing of congestion would also allow remaining traffic to move more freely and efficiently.

Set against this, more energy is consumed on lighting and heating when working from home, compared to working in an office, particularly in the winter months. A recent report concluded: "If an employee works at home all year... he or she pumps out 2.38 tons of carbon dioxide, whereas a typical office worker produces only 1.68 tons of carbon per year."[2]

However, this assumes that the whole house is lit and heated. The same report states that upgrading home heating controls, so home workers heat only their office and not the whole house, would produce just 0.9 tonnes of CO_2 per annum.

There is also the manufacture, distribution and subsequent disposal of the control equipment to consider. While this is offset by transport savings, along with reduced office energy use, additional energy demand is created from new leisure activities such as video-on-demand.

The internet also has an energy downside. It brings together people with shared interests, but once a connection is made, there is a prospect that people will wish to meet face-to-face, resulting in more travel, often over considerable distances.

Ordering goods over the internet reduces the need to travel locally to shops, but the delivery of goods from further away, perhaps even the other side of the world, has a negative energy impact. But some services, such as the growth in downloaded music, may reduce overall energy demand[3].

Other Benefits

Teleconsulting, both between doctors as well as between doctors and patients, has benefits in immediacy, time and travel savings. This translates into more effective use of the doctor's time, prompt detection of patient problems and reduced energy consumption.[4]

The appropriate application of ICT in intelligent buildings (Energy Management Systems) is crucial in

1 Forum for the Future (2004), *Sustainable Development in Broadband Britain*, www.btpc.com/Societyand environment/Reports/Reports.htm [Live December 2006]

2 WSP UK (2007), *Cut your carbon – work from home during the Summer!* www.wspgroup.co.uk/en/WSP-UK/Press/News-Archive/Cut-your-carbon-work-from-home-during-the-Summer/ [Live June 2007]

3 Türk, V. et al. (2003) *The Environmental and Social Impacts of Digital Music*, www.forumforthefuture.org.uk/publications/digieeuropemusic_page298.aspx [Live June 2007]

4 Forum for the Future (2004) *Sustainable Development in Broadband Britain*, www.btplc.com/Societyand environment/Reports/Reports.htm [Live June 2007]

order to minimise energy consumption in those buildings[5]; heating controls for home working, as mentioned above, are a typical example. The technology is available to monitor and adjust the internal environment automatically, instead of requiring individuals to switch off and turn down services and appliances that aren't required.

Social Implications

Over the next 20 years, many people living in Britain could face social exclusion, if action is not taken to close the gap between those with access to technology and those without[6].

New technologies and services need to be genuinely inclusive, and consumer interfaces with them must be intuitive or even invisible. For people with disabilities, or those living in extreme poverty, social and community programmes are essential to ensure access.

But on the whole, the widespread adoption of broadband internet provides the potential for significant improvements in work/life balance and gives communities, both rural and urban, access to wider resources[7].

GDP and Energy Intensity

Energy intensity (or the energy ratio) is a measure of the energy efficiency of a nation's economy. It is the ratio of overall primary energy consumption to GDP at constant prices. Carbon intensity is the ratio of CO_2 emissions to primary energy.

As the economy has grown, demand for energy has continued to rise despite the increased efficiency with which it is consumed. Between 1990 and 2005, energy demand increased by 9.5% compared with a GDP increase of 43%.

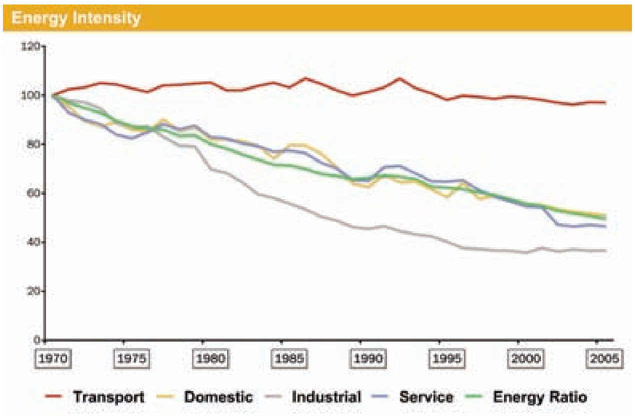


Fig 12.1[8]

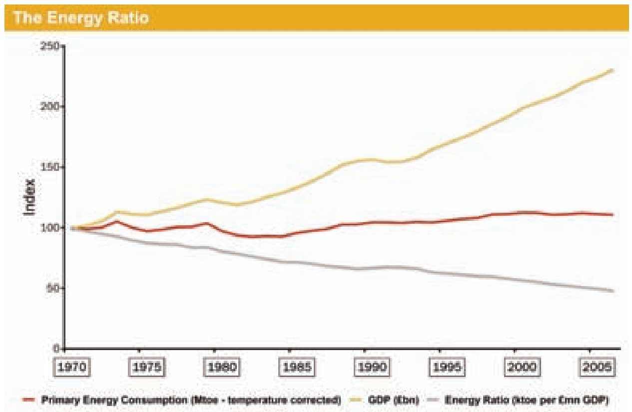


Fig 12.2[9]

Net CO_2 emissions fell by 5.5% over the same period, leading to a decline of 35% in carbon intensity. This decline in carbon intensity may be broken down into two elements: a decline in the overall carbon emissions factor (carbon emissions per unit of energy consumed) of 14% and a reduction of 25% in energy intensity[10].

However, reductions in carbon intensity do not necessarily equate to a reduction in actual CO_2 emissions. Between 1990 and 2000 the carbon intensity of the US economy declined by 17% yet total emissions increased by 14%[11].

The trend indicates that energy efficiencies alone are not sufficient. More radical measures are required to curtail the continuing rise in demand as presented in the accompanying chapters of this section.

5 See Chapter 9 Buildings

6 BT (2004) *The Digital Divide in 2025*, www.btplc.com/Societyandenvironment/Reports/Reports.htm [Live June 2007]

7 James, P. & Hopkinson, P. (2006) *E-working at BT - The Economic, Environmental and Social Impacts*, www.btplc.com/Societyandenvironment/Reports/Reports.htm [Live June 2007]

8. See footnote 10

9. See footnote 11

10 DTI (2006) *UK Energy Sector Indicators 2006*, www.dti.gov.uk/files/file29698.pdf, [Live June 2007]

11 Fischlowitz-Roberts, B. (2002) *Carbon Emissions Climbing*, www.earth-policy.org/Indicators/indicator5.htm [Live June 2007]

Khazzoom-Brookes & the Rebound Effect

Any energy strategy would be remiss if it did not take account of two important effects relating to energy efficiency: the Khazzoom-Brookes postulate[12] and the Rebound Effect.

The Khazzoom-Brookes postulate states that when money is saved through energy efficiency, that saving is often subsequently spent on other, more energy intensive processes. The net result is that overall energy consumption is reduced less than might be expected, and may even increase.

An example is the explosion in the number of computers in both office and home. Old mainframe computers had very limited processing power and were very energy intensive and expensive. Modern PCs are small and getting ever cheaper and more powerful. But everyone wants one (or more), so overall energy consumption for computers continues to rise. But with the adoption of carbon quotas, Khazzoom-Brookes should not be an issue, due to the upper limit placed on emissions[13].

While the Khazzoom-Brookes postulate applies to the macroeconomic level, the Rebound Effect works on individuals, at a microeconomic level. A better-insulated house needs less fuel to maintain a given temperature but, as fuel costs decline, people tend to turn up the thermostat. In fact, average domestic temperatures are estimated to have increased from 16ºC in 1990 to 19ºC in 2002[14]. But while the Rebound Effect may result in lower energy reductions than expected, it is unlikely to result in an overall *increase*[15] in consumption.

Conclusion & Recommendations

ICT and the move to work from home provide an opportunity for significant energy savings. However, the level of these savings is hard to quantify. The required infrastructure and the behaviour of the individuals involved may themselves increase consumption.

Emerging technologies such as intelligent buildings (Energy Management Systems) have the potential to provide additional savings, but also other emerging technologies may increase consumption in areas like entertainment.

In an 'Island Britain' scenario, the Khazzoom-Brookes postulate should not be an issue in terms of emissions, because these are capped under the system of TEQs. Energy use, however, may still be subject to both Khazzoom-Brookes and the Rebound Effect. GDP growth must therefore be further decoupled from energy consumption and CO_2 emissions, including through investment in renewables.

12 Herring, H. (1998) *Does Energy Efficiency Save Energy: The Implications of Accepting the Khazzoom-Brookes Postulate*, www.technology.open.ac.uk/eeru/staff/horace/kbpotl.htm [Live June 2007]

13 See Chapter 7 on Tradable Energy Quotas (TEQs)

14 DTI (2006) *Energy – its Impact on the Environment & Society* www.dti.gov.uk/energy/environment/energy-impact/page29982.html [Live June 2007]

15 Monbiot, G (2006) *Heat: How to Stop the Planet Burning*, Penguin Books

Chapter 13 Agriculture

Current Overview

Considering the importance of agriculture as an industry, its direct use of fossil energy is small, at less than 1% of the UK total. Its global warming potential (GWP) however is of much greater significance – about 10% of the total[1].

Most of this is due not to CO_2 emissions but to methane and nitrous oxide, largely from the livestock sector and its associated grassland. If the entire food sector, including imports, is considered, it accounts for between 20% and 30% of emissions attributable to the UK, depending on where the boundaries are drawn between different sectors[2].

These simple facts have profound implications for agriculture, and indeed for the food sector as a whole, in a zero-carbon Britain.

Future Prospects

Higher carbon costs would create pressure on farmers to make different choices. Among the changes that would be expected are the following:

- A higher level of national self-sufficiency in food.
- Relative re-localisation of production within Britain.
- Greatly reduced numbers of livestock and land dedicated to feeding them.
- Substantial shifts in the composition of diets.
- A move towards low-input farming methods.
- On-farm fuel production for farm use.
- Expansion of forests for fuel wood, industrial products, biodiversity and carbon sequestration.
- More land used for dedicated biofuel crops and co-products.
- Carbon sequestration credits for various agricultural practices, both traditional and innovative.

Present Energy Demands & GWP in Britain's Agriculture

The current energy consumption of British agriculture is about 33 TWh per annum[3], 54% of which is attributable to nitrogen fertiliser. The provision of phosphate and potash in fertiliser only accounts for 10% as much energy as nitrogen[4], although in the long term the mineral resources on which they are based, particularly for phosphates, are finite[5].

The Haber-Bosch process, by which nitrogen fertiliser is produced, is responsible for 1.3% of World fossil energy consumption, and many would consider this as energy well spent. Indeed some GWP analyses of food production suggest that under certain circumstances, chemical nitrogen inputs can reduce net emissions per kg of yield, simply by increasing the output per hectare[6].

Nevertheless, industrial nitrogen fixation has a large influence on the natural nitrogen cycle. Although the direct energy involved may be considered modest, the 'diffuse' global warming potential may be much more significant. Adding substantial extra quantities of nitrogen to soils causes greater emissions of nitrous oxide, which as a greenhouse gas is considered to be 320 times more powerful than carbon dioxide[7].

The emissions caps assumed in this study will cause farmers to consider alternative ways of achieving high yields. There are of course other reasons than climate change for reducing chemical inputs to farming, reasons that form the ideological core of the organic movement. But this strategy is concerned only with the industry's impacts on climate.

1 DEFRA Digest of Statistics, www.statistics.defra.gov.uk/esg/indicators/h4b_data.htm, [Live June 2007]

2 *Environmental Impact of Products (EIPRO): Analysis of the Life Cycle Environmental Impacts Related to the Total Final Consumption of the EU25*, European Commission Technical Report, EUR 22284 EN, May 2006.

3 G.Boyle, B. Everett and J. Ramage, *Energy Systems & Sustainability* Oxford 2003

4 Vaclav Smil, *Enriching the Earth: Fritz Haber, Carl Bosch and the Transformation of World Food Production* MIT 2001

5 Natural History Museum, www.nhm.ac.uk/research-curation/projects/phosphate-recovery/p&k217/steen.htm [Live June 2007]

6 Cranfield University Institute of Water and Environment: *EnvironmentalBurdens of Agricultural and Horticultural Commodity Production*, Defra-funded Projects IS0205 and IS0222

7 Smil, op.cit.

In conformity with the conservative assumptions of this study, it is assumed that by 2027, all Britain's agriculture will be broadly, if not literally, 'organic'.

Proposed Changes in Land Use

There are 20m hectares of land devoted to agriculture in Britain, used roughly as follows:

6m ha arable (including set-aside and rotational grass)
6m ha permanent grass
6m ha rough grazing
2m ha woodland
2m ha roads and buildings

The strategy envisages substantial changes, as follows:

10m ha arable rotation (incl. rotational grass; no set-aside)
1m ha permanent grass
1m ha short rotation willow coppice (SRC)
3m ha short rotation forest (SRF), e.g. ash coppice, conifers
2m ha rough grazing
3m ha woodland
2m ha roads and buildings

National Self-Sufficiency in Food

In accordance with the boundaries of 'Island Britain' the strategy sets out a plan for a much higher level of food self-sufficiency. Currently Britain imports 40% of its food by value, but this is more a reflection of market forces than an indication of Britain's inability to provide for itself[8].

With cheap energy and transport, rich countries often prefer to import food than to grow it. Most of the imports are non-seasonal and tropical goods. As transport costs increase, these become more expensive relative to indigenous and seasonal foods.

Greater or even complete self-sufficiency is possible, given the agricultural and dietary changes discussed below. In reality, the international trading of foodstuffs is bound to continue, but this study adopts worst case assumptions.

Relocalisation

The same forces that promote nationally produced food will encourage local production for local use. Food processing and transport will become relatively expensive, enhancing the appeal of fresh, local produce. Food retailers will tend to source more locally, and direct relations between farmers and customers will be an advantage for both parties. This will contribute to the social and economic glue that binds local communities together[9].

Fruit and vegetable production, which requires relatively small areas of highly fertile land, will be concentrated near to centres of population in order to eliminate the energy currently used to transport these bulky commodities.

Where space permits, there will be production in and around towns and cities, on allotments and in private gardens[10]. In the longer term, waste disposal systems need to be redesigned to return human wastes, suitably composted, onto the land[11].

Livestock Reduction

Ruminant animals (mostly cattle and sheep) are responsible for between 4% and 7% of Britain's GWP, according to different estimates and assumptions. This is principally due to their methane and nitrous oxide emissions[12]. This may seem relatively minor, but in the context of strict GHG limitations it presents difficulties, particularly as there are no obvious technical solutions.

Despite historical preferences, Britain's citizens are unlikely to spend their entire carbon allowances on beef, mutton and cheese. It is inevitable that the number of ruminants will be greatly reduced. This implies a significant move away from permanent pasture, and a freeing of large land areas for other purposes. It will also send an important international signal[13].

8 For example Defra's *Food Security & the UK: An Evidence & Analysis Paper*, www.statistics.defra.gov.uk/esg/reports/foodsecurity/foodsecurity.doc [Live June 2007]

9 The Soil Association's, *Cultivating Communities*, www.cuco.org.uk [Live June 2007]

10 Howe,J., Viljoen, A. (2005) *Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities*, Architectural Press

11 Christie et al (2007) *The Nutrient Cycle: Closing the Loop*, Green Alliance www.green-alliance.org.uk/uploadedFiles/Publications/reports/TheNutrientCycle.pdf, [Live June 2007]

12 Food Climate Research Network, www.fcrn.org.uk [Live June 2007]

13 The worldwide impact of increasing livestock numbers is set out in FAO (2006) *Livestock's Long Shadow*

Other food animals such as poultry and pigs generate lower emissions per unit of produce, but still have impacts through manure emissions and the inputs and transport needed to provide feedstuffs. It will be a matter of choice how much land to dedicate to feeding animals, and how much for other purposes. Under the assumed organic shift, there will be a rapid decline of industrial pig and poultry farming in favour of extensive local systems.

Dietary Changes

With tightening emissions caps, the relative costs of animal products will increase substantially, prompting a considerable reorientation of the typical British diet.

The quantities of grains and flours, legumes, nuts, fruit and vegetables, dried goods and plant-based oils will rise relative to meat, fish and dairy products. While any imaginable diet will still be available at a price, the changing costs will be marked enough to shift average eating habits if not actual preferences.

This can be expected to improve health on average, in line with the dietary recommendations generated in a long-term study by the Harvard School of Public Health[14]. It is reminiscent of the unexpected improvements in general health in Britain's population, attributed to the severe but balanced World War 2 diet[15].

It should be noted there is no requirement for vegetarianism: meat, fish and dairy products will still be available. It is just that their high cost will probably lead to a different type of cuisine in which, rather than being the centrepiece of a dish, their strong flavours are used as highlights for meals consisting mainly of non-animal products. Alternatively, animal-based ingredients can be 'saved up' for special occasions. This is normal in many national cuisines around the world[16].

This shift away from animal-based foods would affect not only the British population. In terms of the development and modernisation of societies all over the world, it would mark the reversal of a well-established historical correlation between increasing affluence and the consumption of animal products. A similar observation applies to the consumption of alcohol, which also uses large quantities of grain. Another aspect of the food system that would be affected by high carbon prices is processing, which accounts for a large proportion of the total. This would make processed foods more expensive relative to raw ingredients. Again this goes against historical trends, but would provide a more nutritious and healthier diet[17].

Low-Input Farming Methods

The environment in general would benefit from a change to organic methods. These resemble traditional British farming, with longer, more complex rotations than are currently practised.

Under the assumptions of this study, many inputs to farming would become expensive or less freely available on account of their high carbon intensities. This would include fuels and agrochemicals. There is clearly a limit to the amount by which agricultural energy demand can be reduced. Agricultural fuels may have to be protected, or farmers will have to produce their own fuels (see below).

Chemical inputs however can be reduced to virtually zero. This is largely what is meant by 'low input agriculture', typical known as 'organic farming'. In this report, *organic* is taken to mean agrochemical-free agriculture. That is, one that maximises nutrient recycling and on-farm fertility building, rather than strict adherence to the published standards of the Soil Association or other certifying organisations.

Currently in Britain 3.9% of farm land is under organic management. Secretary of State, Margaret Beckett, has proposed that the sector could undergo a three-fold increase to around 10%. Others propose a more ambitious target, with 30% of production and 20% of the retail food market being organic by 2010. At this rate of expansion, organic systems would easily dominate Britain's agriculture by 2027. Thus, the present study is essentially based on a 'business as usual' premise[18].

Organic-style agriculture will be favoured by the high input costs of industrial systems, and is therefore

14 www.hsph.harvard.edu/nutritionsource/pyramids.html [Live June 2007]

15 British Library www.bl.uk/learning/langlit/booksforcooks/1900s/diethome/principles.html [Live June 2007]

16 Matalas, A.L., Zampelas,A., Stavrinos, V. and Wolinsky, I., (2001) *The Mediterranean Diet: Constituents and Health Promotion CRC Press*. See also www.clearspring.co.uk/ for information on the traditional Japanese diet. [Live June 2007]

17 See www.hsph.harvard.edu/nutritionsource/pyramids.html [Live June 2007]

18 See Defra: www.defra.gov.uk/farm/organic/policy/actionplan/prospects.htm [Live June 2007]

Crop	Yield/ha	Food energy/kg	Food energy/ha	Protein/ha
Winter wheat	8t	14.5MJ	116GJ	880kg
Winter wheat (organic)	4.5t	14.5MJ	65.25GJ	495kg
Spring oats	5t	15MJ	75GJ	530kg
Spring oats (organic)	3t	15MJ	45GJ	318kg
Beans (organic similar to conventional)	4t	10.9MJ	43.6GJ	800kg
Rape	3.5t = 1.4t oil	37MJ	51.8GJ	Nil (all the protein is in the 'waste' expeller cake)
Rape (organic)	2.7t = 1.08t oil	37MJ	39.96GJ	Nil, as above
Potatoes	40t	3.2MJ	128GJ	560kg
Potatoes (organic)	24t	3.2MJ	76.8GJ	336kg
Carrots	37.5t	1MJ	37.5GJ	262kg
Onions	27.5t	1MJ	37.5GJ	275kg
Green beans	5t	4MJ	20GJ	350kg
Milk	6000l/cow @ 1.9 cows/ha =11400litres	2.9MJ/litre	33.06GJ	365kg
Milk (organic)	5000l/cow @ 1.5 cows/ha =7500litres	2.9MJ/litre	21.75GJ	240kg
Beef (single suckled)	0.262t	11.76MJ	3.08GJ	76kg
Beef (single suckled, organic)	0.178t	11.76MJ	2.09GJ	52kg
Lamb	0.324t	13MJ	4.21GJ	81kg
Lamb (organic)	0.216t	13MJ	2.81GJ	54kg

Table 13.1: Britain's lowland yields, compiled using data from Nix, Measures & Lambkin and food labels

expected to expand under the assumptions of this study. But it has other benefits too, including biodiversity, animal welfare, health and employment[19].

One important matter should be noted: that in moving from unsustainable to sustainable production methods, yields per hectare are lower, often by a substantial factor (see Table 13.1). This has a bearing on whether 'Island Britain' could really feed itself. This potential problem is solved by the assumed reduction in livestock numbers.

It is not usually appreciated just how much land is required for animal rearing. In the case of Britain, between 60% and 70% of agricultural land is used either for grazing or growing fodder, not to mention the 'ghost hectares' overseas that produce soy-meal and other high-protein feeds.

Table 13.1 shows the dramatic differences between the yields per acre of crops and livestock, even for protein. Livestock reduction will release large quantities of land for crops that can be consumed directly by people. It will also release enough to grow energy crops without compromising food security. This redistribution is summarised in Table 13.2.

On-Farm Fuel Production

Although the direct energy needs of farming are small, they are essential. But part of the land released by livestock reduction can be devoted to energy crops, providing on-farm fuel. All forms of energy are likely to be expensive. While it would not apply to all farms, many farmers might find it advantageous to grow their own fuels, probably in the form of biodiesel, since the processing can be carried out economically at quite a small scale[20].

In practice, groups of farmers might pool their outputs in one local processing plant. Surpluses could of course be sold on the open market, or to local customers. 'Community-supported agriculture' is usually thought of in terms of food, such as vegetable box schemes, but could equally apply to certain kinds of biofuels.

Britain can readily produce sufficient biodiesel from rape oil to fuel its farm machinery – 13 TWh. A much larger biomass output will come from forestry and *Miscanthus*. This will eventually provide around 335 TWh of energy to be used in CHP plant. In addition to this, 17 TWh will also be available from straw. By 2027, the annual output will be 250 TWh.

Expansion of Forests & Woodlands

The strategy envisages a much greater area of forest, about half of which is specifically designed for energy supply. The new forests could be designed with highly diverse local variations to serve a great variety of functions, including biodiversity, flood control, timber products, fuel wood, and carbon sequestration.

The potential of carbon sequestration is modest but important, representing about 5% of Britain's current emissions[21]. But it must be remembered that most of the technologies envisaged in this report are low or zero-carbon, not net-negative. Forests are the only net-negative technology currently available, and if they can be made to work both economically and in other ways, and if they do not compete unduly for other land uses, they should be expanded.

One industrial material that will be strongly favoured by higher carbon costs is wood for permanent applications such as buildings. Wood is not only a low-embodied-energy material in itself, but of course is a form of sequestered CO_2. Sustainable harvesting and replanting of wood is likely to be an increasingly important mitigating strategy[22].

Land for Biofuel Crops

There is much justified anxiety about biofuels. Sometimes presented as a means of maintaining post peak oil mobility, a few simple calculations show that biofuels come nowhere near to providing enough for the World's (or even Britain's) current transport demands.

A key reason why they are not a panacea is that under typical field or forest conditions, photosynthesis is

19 For a systematic comparison of conventional and organic environmental impacts, see www.defra.gov.uk/farm/organic/policy/actionplan/annex3.htm [Live June 2007]. On wildlife effects, see Hole, D.G., Perkins, A.J. Wilson, J.D., Alexander, I.H., Grice, P.V. and Evans, A.D. (2005) Does Organic Farming Benefit Biodiversity? Biological Conservation, volume 122, pages 113-130

20 See for example www.biodieselwarehouse.co.uk/index.php?cat=Oilseed_press&ActinicSID=c1e2d243e216fd0e1000f8594dd398b7 [Live June 2007]

21 www.forestry.gov.uk/forestry/infd-6vlkkm, [Live June 2007]. See also Carbon Stock Growth in a Forest Stand: the Power of Age, Alexandrov G. A. 2007, www.cbmjournal.com/content/2/1/4#IDA52JI [Live June 2007]

22 See for example Stern Review on Economics of Climate Change – Response from the Forestry Commission www.hm-treasury.gov.uk/media/FC3/89/climate_change__forestry.pdf, and The Carbon Balance of Forest Biomes, www.plantsci.cam.ac.uk/forestbiomes/ [Live June2007]

simply not very efficient turning sunlight into biomass. For a given area, windmills produce 20 times more energy, photovoltaic panels 100 times more. To make a serious contribution, biomass crops need large land areas, with obvious implications for food production, biodiversity, landscape aesthetics etc[23].

In the globalised World, developed countries' demand for biofuels has resulted in deforestation elsewhere to make room for biofuel crops – probably a backward step in terms of climate change[24]. Furthermore, conventional production of biofuels often requires so much fertiliser and processing that there is little net reduction in carbon emissions[25].

Despite these drawbacks, this strategy recognises that bio-energy can play a useful role in a sustainable energy strategy, and tries to mitigate some of the worst problems. Part of the energy is seen as coming from traditional forest, part from 2m ha of new short-rotation forest, part from short-rotation coppice, and the rest as part of an organic rotation on arable land.

Although organic bio-energy production is a novel idea, there is no reason why it should not work, since the energy crops act as 'break crops' to maintain the health of the soil in an organic rotation. Most of the fuel crop is *Miscanthus*, a perennial grass that can be undersown with clover to improve nitrogen fixation. For various reasons, successive harvests of *Miscanthus* deplete soil nutrients very little, but improve soil structure[26]. In some areas hemp might be used instead.

A typical arable rotation would be as seen in Fig 13.1 (although in practice, cropping would vary to suit location, prevailing weather and soil type).

Carbon Sequestration

The carbon sequestration benefits of forestry have already been mentioned. But other aspects of farming – particularly organic farming – can also act as carbon sinks. Part of the reason is that adding organic matter to the soil is an essential principle of organic systems.

Much of this is mineralised and returns to the atmosphere as CO_2, but a proportion remains in the soil as stable accumulations of humus[27]. The rate at

CROP ROTATION

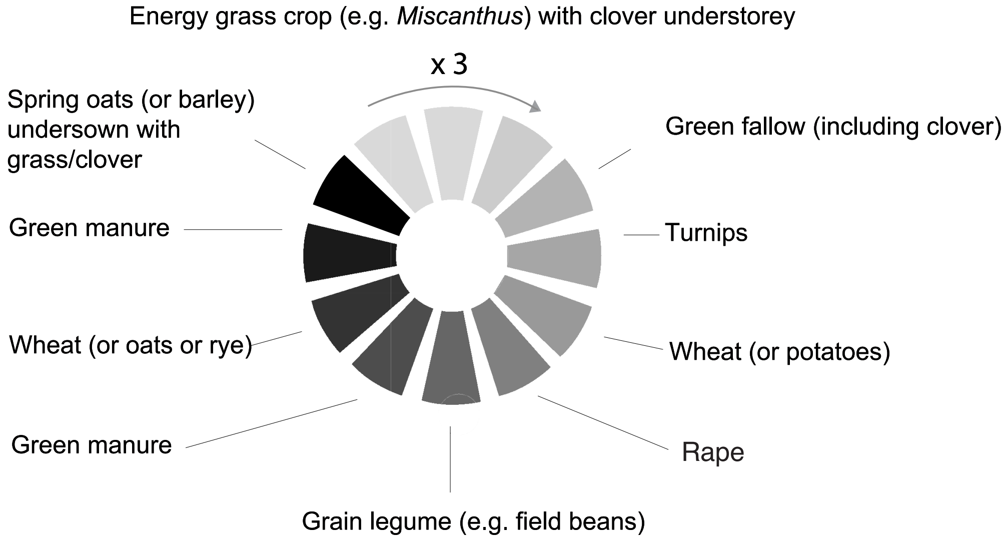


Fig 13.1

23 Brown L. How Food & Fuel Compete for Land, The Globalist, Feb 01 2006, www.theglobalist.com/StoryId.aspx?StoryId=5077 [Live June 2007]

24 See for example www.monbiot.com/archives/2005/12/06/worse-than-fossil-fuel [Live June 2007]

25 For example Towards a UK Strategy for Biofuels - Soil Association response to Department for Transport consultation, July 2004

26 For example www.defra.gov.uk/erdp/pdfs/ecs/miscanthus-guide.pdf, and www.rothamsted.bbsrc.ac.uk/aen/CarbonCycling/Biofuels.htm [Live June 2007]

which this happens varies from place to place, but it is an undoubted benefit of organic systems as whole, and could possibly earn carbon credits for farmers.

An unverified but promising further method of soil-based sequestration is the use of 'black carbon' (essentially charcoal), produced in some biofuel production processes. It appears that this form of carbon endures in the soil for very long periods, and has the benefit of greatly increasing soil fertility.

Thus wood from a forest could be processed into a liquid or gaseous biofuel that displaces fossil fuels, leaving a char residue that can be returned to the soil, where it improves yields. This process sequesters carbon at a much greater rate than the traditional slow build-up of humus[28]. Overall estimates of the carbon sequestration potential for the proposed new land uses are given in Table 13.3.

Crop	Food energy: MJ/person/day (year)	Fuel energy: TWh/year
All cereals	8.25 (3011)	Straw: 16.7
Beans	2.07 (755)	
Rape	Nil (but high protein meal by-product available for animal feed)	Oil: 13.28 OSR Straw 20
Energy crop (*Miscanthus*)	Nil	83.5
	0.45 (163)	
Milk		Nil Some manure anaerobic digestion (AD) + local food and sewage wastes + suitable farm products
Beef	0.097(35.28)	Ditto
Lamb	0.012 (4.55)	Ditto
Wood (SRC)	Nil	Not available immediately see Table 13.3
Wood (SRF:coppice) 2mha	Nil	83.3, not available immediately see Table 13.3
Wood (conifers) 1mha	Nil	55.5, not available immediately see Table 13.3
Wood (trad. forestry)	Nil	25.00, not all available immediately see Table 13.3
Totals	**10.88** (3971)	**335.48 final yield** (100 years) initial yield: 123.33 after 3 yrs: 171.68 after 30 yrs: 254.98 after 50 yrs: 310.48

Table 13.2: National energy yields from farming sector

27 See www.rothamsted.bbsrc.ac.uk/aen/CarbonCycling/LongTermC.htm [Live June 2007]

28 See www.rothamsted.bbsrc.ac.uk/aen/CarbonCycling/BlackCarbon.htm [Live June 2007]

Crop type & area	Carbon sequestered per year (until stable productive state is reached)	Years of growth to first harvest	Carbon in established productive forest
Existing woodland 2m ha	Negligible	Happened in the past	400Mt
New trad. woodland 1m ha	2Mt	100	200Mt
New trad. coppice 2m ha	6Mt	30	80Mt
New coniferous woodland 1m ha	4Mt	50	100Mt
Short rotation coppice 1m ha	5Mt	3	8Mt

Table 13.3: Forestry outputs & sequestration

Conclusion

The radical assumptions adopted in this report have correspondingly radical implications, both for Britain's agriculture and for the entire food system. This section shows that, in principle, Britain has the capacity to feed itself, albeit on a very different diet to that of today.

Furthermore, the country can also supply a useful component of its energy needs through biomass. In many parts of Britain there would be substantial changes in the appearance of the landscape, but not necessarily for the worse.

A gradual change to organic style farming would result in a more agreeable, diverse and nature-friendly countryside.

zerocarbonbritain
an alternative energy strategy

"Someday we will harness the rise and fall of the tides and imprison the rays of the sun."

Thomas Edison

powerup

Chapter 14

Nuclear

In the 1950s and 60s, nuclear energy was seen as the natural and inevitable successor to coal and oil.

However, in the following decades support gradually waned, both in government and business sectors and among the general public. But as part of the industrialised nations' collective concerns about energy security and climate change, nuclear fission technology is back on Britain's policy agenda[1].

It is accepted that nuclear electricity is a low carbon energy source. It is also a relatively well-understood class of technologies. In this scenario, existing plants will continue to generate until the end of their designed operational lives. It has nevertheless been decided to exclude new nuclear capacity from the model, for reasons of its unique political and technological 'brittleness' in the face of potential instabilities in the 21st century. Nuclear power poses many uncertainties, but in this scenario, it is rejected on the perhaps less obvious basis of energy security.

The conventional case against nuclear power is well-known.

- There is a finite, if low, risk of very serious accidents:

> **"There have been 57 incidents at nuclear power stations since 1997, which met the ministerial reporting criteria."**
>
> **Malcolm Wicks[2]**

- The problems of long-lived high-level waste remain unresolved:

> **"We are concerned that plans for a long period of storage, which is envisaged as part of the Phased Geological Repository Concept, are not sufficiently underpinned technically."**
>
> **Environment Agency[3]**

- Costs of permanent disposal are unknown and might be very high.

- There are doubts about the continued availability of uranium, especially given a worldwide nuclear renaissance[4].

- There has been a long history of massive subsidies and cost-overruns[5].

- Lead-times for planning, construction and commissioning can be very long.

- Water consumption is high per unit of output, a potentially serious matter in a world of uncertain weather[6].

These are serious drawbacks. Nevertheless they could potentially be overcome given the political will, or reluctantly tolerated in a world desperate for energy. There are, however, important further reasons why new nuclear has been excluded from this scenario.

The twin threats of sophisticated ideological terrorism and 'recreational malice' can no longer be ignored, given the terrorist atrocities of 2001 and 2005 and the widespread targeting by hackers of all categories of systems. There are dozens, perhaps even hundreds or thousands of people who are prepared to spend years plotting a major 'accident' in one way or another, often through inside knowledge.

Such risks will become even greater if there is a continued failure to address the issue of global equity, or if international order is not maintained in the transition from high carbon technologies. A specific danger is that, following a serious incident, it may be necessary to shut down a large proportion of the network's nuclear capacity, leaving a critical gap in supply.

1 Malcolm Wicks, 11 July 2006, among others.

2 Malcolm Wicks in Hansard Written Answers, 12 June 2006. Other major incidents include: Three Mile Island, USA 1979; Chernobyl, Ukraine (formerly USSR) 1986; Thorp Reprocessing Plant (Sellafield) 2005. Less well-known cases include: Koeberg, South Africa, 2006 & 2007; Brown's Ferry, USA 'Data storm' 2006; Forsmark, Sweden 2006; Leningradskaya, St Petersburg, Russia, 2007; Yongbyon, North Korea 2007.

3 Environment Agency (2005). Their report is available from http://tinyurl.com/3kdrb6 [Live June 2007] See also Jan Willem Storm van Leeuwen & Philip Smith, Nuclear Power - the Energy Balance 4 August 2005; www.opendemocracy.net/globalization-institutions_government/nuclear_waste_3559.jsp [Live June 2007].
The official view is that it is less of a problem, as in Ernst & Young's *The Management and Financing of Nuclear Waste*, www.dti.gov.uk/files/file36328.pdf, [Live June 2007]

Thus the solid base-load supply of nuclear electricity, usually thought of as one of its great strengths, could paradoxically become its Achilles heel. Its large-scale, centralised nature, coupled with the need for high levels of safety and security in its operation, render it subject to compromise in ways that could not happen to a distributed mix of renewable sources, however variable.

The costs of nuclear power also pose uncertainties and risks. Nuclear power plants are relatively cheap to run, but have high 'front-end' capital costs and possibly even greater 'back-end' costs[7]. The full life-cycle costs, relative to the actual price of electricity paid for by customers, are vigorously disputed. Given a chain of optimistic assumptions, 'statistically reasonable' levels of safety and security, and risks underwritten by government, it can be made to look affordable.

But with pessimistic assumptions, lack of government backup, 'precautionary' standards of safety, an insistence on total decommissioning and the establishment of final depositories for high-level waste, it can appear expensive relative to other options.

Should society be adventurous or cautious? The view of this strategy is that the uncertainties of the coming decades are challenging enough, and should not be compounded.

> **"...any public subsidies for nuclear must be weighed against the substantial progress towards reducing carbon emissions and ensuring a greater degree of security of supply which these alternatives could achieve with similar subsidies."**

Environmental Audit Committee 6th Report

The high capital costs of nuclear energy compete with investment in other energy technologies, and particularly renewables, that tend to be 'front-end loaded'. It could reasonably be argued that nuclear has had more than its fair share of investment, subsidy and research input, and must now sink or swim as a mature technology.

> **"A new nuclear power programme could divert public funding away from more sustainable technologies that will be needed regardless, hampering other long term efforts to move to a low carbon economy with diverse energy sources... there is no justification for bringing forward plans for a new nuclear power programme, at this time... any such proposal would be incompatible with the Government's own Sustainable Development Strategy."**

Sustainable Development Commission

Investment capital is now needed for the development of other low carbon sources, particularly the marine renewables of tidal, wave and offshore wind. In addition to the financial costs, there will be competition for 'carbon investment' as the carbon budget is reduced under climate control mechanisms. Opportunity costs should not be dominated by high risk options.

Since climate change is a global problem that can only be solved by coordinated action, the international dimensions of Britain's energy policy must also be considered. Even if Britain stays within the tight carbon budget defined in this report, humanity can only avoid crossing climate change 'tipping points' if other countries have equally constrained caps. If, as its advocates suggest, Britain and other developed nations make new nuclear power a core component of their response to climate change, many other rapidly developing economies will seek to follow suit.

It will be very hard for resurgent 'nuclear nations' to make a foreign policy case as to why less wealthy countries should not be granted access to the same technology, yet must also meet their climate change targets. *The Role of Nuclear Power in a Low Carbon*

4 OECD (1999) Towards a Sustainable Energy Future, Dieter M. Imboden (Swiss Federal Institute of Technology) & Carlo C. Jaeger (Swiss Federal institute of Environmental Science & Technology) Energy: The Next 50 Years, OECD, 1999. Mobbs 2004 Turning the World Upside Down, Paul Mobbs, The World Today vol.60 no.12, Royal Institute of International Affairs, December 2004. These views are disputed by the nuclear industry, which argues that we have hardly scratched the surface of uranium prospecting. For example www.iaea.org/NewsCenter/News/2006/uranium_resources.html. Much of the disagreement comes from assessments of how much generating capacity is envisaged, and whether Fast Breeder technology will be used to extend the supply.

5 www.greenpeace.org.uk/files/pdfs/nuclear/nuclear_economics_report.pdf, [Live June 2007]

6 EPRI (2002) *Water & Sustainability (Volume 3): U.S. Water Consumption for Power Production—The Next Half Century, Topical Report*, www.epriweb.com/public/000000000001006786.pdf, [Live June 2007]

Economy report, reaches this conclusion:

> **"If the UK cannot meet its climate change commitments without nuclear power, then under the terms of the Framework Convention on Climate Change, we cannot deny others the same technology."**

UK Sustainable Development Commission

This poses considerable political risks – ones that could destroy the delicately structured international order required to steer humanity through the climate change crisis. In addition to the possibility of accidents and sabotage, there is a continuing prospect of diversion of radioactive materials for a variety of malign purposes, ranging from actual nuclear weapons, to 'dirty bombs' and radioactive contamination of water supplies.

These risks are more or less proportional to the scale of nuclear activity. In many countries controls are already inadequate, with a correspondingly greater likelihood of diversion of fissile material. Further risks of this kind would be incurred if plutonium generating breeder reactors were built in response to a shortage of high grade uranium ores.

The principal objection to nuclear energy, then, is its 'brittle' quality. It contains hard to assess but potentially serious risks that should only be taken if there is absolutely no alternative. It is believed that there *are* viable alternatives. Renewables are, by and large, the opposite of 'brittle': they are robust and adaptable, decentralised, and easily reversed if required.

Britain would make a more positive contribution to World energy security – and thereby, to its own – by taking a lead in the development and export of local-scale renewables and expertise, rather than of nuclear engineering.

7 NDA chairman Sir Anthony Cleaver has stated that the cost for the nuclear clean-up itself – including decommissioning, cleaning up existing waste and running existing operations until their planned closure dates – was estimated to be £62.7bn. Additional costs linked to contaminated land would drive up the total to about £72bn. (BBC News, Thursday, 30 March 2006)

Chapter 15

Renewables

Electricity

WIND

Britain has a large resource of both on- and offshore wind – the figures quoted for the latter are for up to 3,212 TWh/year[1]. The intention for the 'Island Britain' scenario we are modelling is that 14% of this resource will be tapped by 2027.

Wind will provide the greatest proportion of electrical energy in the scenario, at around 50% of total supply (before transmission losses). It has a good match to the demand profile, in that wind energy is greater in winter than summer, when demand is 30% higher. Use of the existing National Grid will smooth out variability from wind power sources if they are geographically widespread – increasing its potential for energy market penetration[2].

Wind power is also well suited to distributed generation, since turbines can be sited on- and offshore all around the country. As wind speeds are greater offshore, this is where the majority of turbines will be sited. This also ameliorates some of the objections to on-shore turbine siting. The 'Island Britain' scenario projects that onshore wind energy in 2027 will provide 24 TWh and offshore 450 TWh.

> "The Danish Wind Industry Association works for a target of 35% wind power in 2015... The goal is that wind power will cover 50% of the Danish electricity consumption in 2025."
>
> www.windpower.org

Wind turbines are now a mature technology, and power outputs are steadily increasing. Denmark in particular relies on a large proportion of its energy coming from wind. The Danish aim is for 50% of their electricity to come from offshore wind by 2030[3]. They also have a thriving industry in building turbines, both for their own needs and for export.

Due to the current worldwide growth in demand for wind power, there is a global shortage of turbines. For a country with such a huge wind resource as Britain, this presents a major opportunity for investment in manufacturing, both for domestic use and for export.

> "Wind energy is officially the fastest growing energy source worldwide, with an average annual growth rate of 23% over the last 15 years."
>
> www.britishwindenergy.co.uk[4]

As regards sustainability, little research has been published yet on the variation of global wind profiles due to climate change. However, Scotland is likely to retain a strong margin[5 6], owing to its buffeted location in the North Atlantic. In addition, climate change may make some parts of the south-east of Britain less habitable, and some centres of population may well migrate northwards. It would therefore be prudent to lay down flexible, expandable energy infrastructure in Scotland[7]. Wind power could then be managed independently of England, if the national electricity infrastructure were to fail in some parts of the south.

SOLAR ELECTRICITY

Photovoltaics (PVs) have a different profile to wind. They are more efficient in summer when more sunlight is available. This matches the demand profile well, due to the reduced wind and wave resource in summer. The PV technology employed in this scenario is building-integrated PV (BIPV).

The other main solar technology – large-scale solar concentrators – is not well suited to Britain, due to the low average level of direct solar radiation.

1 DTI (Nov 2002) *Future Offshore: A strategic framework for the offshore wind industry*, HMSO www.dti.gov.uk/files/file22791.pdf. [Live June 2007]

2 Sinden, G. (2007) *Renewable Energy and the Grid*, *Earthscan*. See also www.eeru.open.ac.uk/natta/docs/3.G.Sinden2.PDF [Live June 2007]

3 DTI (June 2001) *Offshore Wind Energy: Wind Energy Fact Sheet 1*, HMSO www.dti.gov.uk/files/file17774.pdf. [Live June 2007]

4 Source: BWEA (2006) www.britishwindenergy.co.uk

5 www.risoe.dk/vea/projects/nimo/WAsPHelp/EuropeanWindResource.htm [Live June 2007]

6 www.scotland.gov.uk/Publications/2006/04/24110728/21 [Live June 2007]

7 www.viewsofscotland.org/map [Live June 2007]

BUILDING-INTEGRATED PHOTOVOLTAIC (BIPV)

The figures for Britain's potential for BIPV are taken from a 1999 ETSU study prepared for the DTI. The study[8] identifies three figures relating to annual electricity generation from photovoltaic systems.

The maximum practicable resource

This represents the power that could in principle be generated if every available surface (excluding doors, windows, overhangs, etc.) of all buildings in Britain, of every orientation, were fitted with PV panels. Clearly a substantial proportion will achieve limited output due to low levels of received sunlight, e.g. north-facing surfaces. However, based on the above assumptions, the maximum practicable resource in 2025 will be 266 TWh/year.

The technical potential

This assumes the incorporation of BIPV into all newly constructed buildings. The figures are obtained from estimates given in a second ETSU study[9], which assumes the build rates in the different building sectors to be 49% new build offices, 36% new build domestic estates, 10% superstores/hypermarkets, 3% office refurbishments and 2% prestige public buildings. According to this second study, the technical potential by 2010 is 7.2 TWh/yr; by 2025 it is 37 TWh/yr.

The market potential

The market potential makes a qualitative assessment of the rate at which the technical potential might be realised, assuming that uptake is limited by cost until BIPV systems approach cost effectiveness. This is taken to be when the marginal cost of PV electricity generation is less than 5p/kWh above standard tariffs, except for those sectors (e.g. supermarket chains and prestigious office developments) where the cost premium may be offset by indirect benefits such as green marketing. The figure given in the former ETSU study is 32.5 GWh/yr by 2010 and 170 GWh/yr by 2025.

The ETSU report concludes that this is indicative of the market; it is conservative in that it does not take into account the full range of possibilities in integrating PV in buildings.

In addition, ETSU does not consider a possible carbon limited moratorium on new construction and building

FEED-IN TARIFFS

Feed-in tariffs are the amounts paid by power utilities for electricity that is generated by small producers. Power retailers contract with major generators for the bulk of their supply, but a growing number of small-scale electricity producers also have surpluses from time to time. Power companies should have an obligation to purchase these surpluses at a tariff that encourages small-scale generation of renewable electricity.

There is currently no obligation on power companies in Britain to buy such electricity. The tariffs offered by those who do are very low. For example, Good Energy (a 100% renewable supplier) currently pays 4.5p/kWh, compared with its lowest supply tariffs of 11.3p/kWh (day) and 8.0p/kWh (night)[10].

In contrast, Germany encourages small-scale renewable generation through a guaranteed preferential tariff for up to 30 years. The actual amount paid depends on various factors including the technology employed and the scale of the plant. Other EU countries offer schemes based on similar principles[11].

The Stern Review considers feed-in tariffs to be an effective way of encouraging the deployment of renewable power generation[12].

8 DTI (1999) *New and Renewable Energy: Prospects in the UK for the 21st Century* HMSO www.dti.gov.uk/files/file21102.pdf [Live June 2007]

9 ETSU (1998) *The Value of Electricity Generated from Photovoltaic Power Systems in Buildings* HMSO. Online www.dti.gov.uk/files/file17278.pdf [Live June 2007]

10 Source: Good Energy www.good-energy.co.uk/gyo_home_gen [Live June 2007]

11 Klein, A et at (2007) *Evaluation of different feed-in tariff design options best practice paper for the International Feed In cooperation*, Frounhofer Institute Systems and Innovation Research www.feed-in-cooperation.org/images/files/best_practice_paper_final.pdf [Live June 2007]

12 Stern, N. (2006) *Stern Review – The Economic of Climate Change Part IV 'Policy Responses for Mitigation', chapter 16*, HM Treasury, available on www.hm-treasury.gov.uk/media/9A3/57/Ch_16_accelerating_technological_innovation.pdf [Live June 2007]

development, owing to strict carbon control measures, which would mean that uptake of PV would need to be through retrofitting existing housing stock, offices and public buildings, which would demand discussion of the higher concomitant cost.

In the present scenario, it is the technical rather than the market potential that would seem preferential to consider, due to the fact that the economic driver of carbon quotas will substantially alter the dynamics of the energy markets[13].

Furthermore, this scenario assumes that roof space and other areas best suited for BIPV should be shared with solar thermal (hot water). For this reason the total provided from BIPV is less than the technical potential of 30 TWh annually.

MARINE

Fixed Tidal

Tidal energy, unlike wind and PV, is very predictable and regular. The 11% of Britain's electricity that this technology can supply is equivalent to the predictable and continuous base load currently provided by nuclear power stations. When sites are spread around the coast, the intermittency of generation can be considerably smoothed out[14].

One technology in particular, tidal barrages, poses considerable impact on the local environment. Friends of the Earth Cymru calculates that by building tidal lagoons instead of a barrage in the Severn Estuary, 5–7 TWh more energy could be generated each year[15] than with the proposed barrage, a total of 58 TWh/yr[16].

Wave

It is considered that wave power has been somewhat neglected up to now. This is perhaps surprising, as the greater density of water when compared with air should lead to higher energy density. Although there are signs that interest is growing, there are still significant challenges facing wave power. It can be difficult to convert a slow, oscillating, choppy wave motion into electricity. There are also issues with there being too much energy available during stormy conditions. This and the corrosiveness of salt water make the sea a challenging environment for engineers.

However, there is now an experimental 'Wave Hub' planned off Cornwall[17] and a commercial wave farm using Archimedes Wave Swing technology planned for Scotland, following testing at the European Marine Energy Centre (EMEC)[18]. The seas west of Scotland and Cornwall are the best locations in terms of available power[19] and in order to meet the target this scenario sets for 2027 the as-yet substantially untapped resource will need to be developed rapidly. For the purposes of this report, we have assumed an ambitious provision of 250 TWh out of a technical potential of 600-750 TWh annually[20].

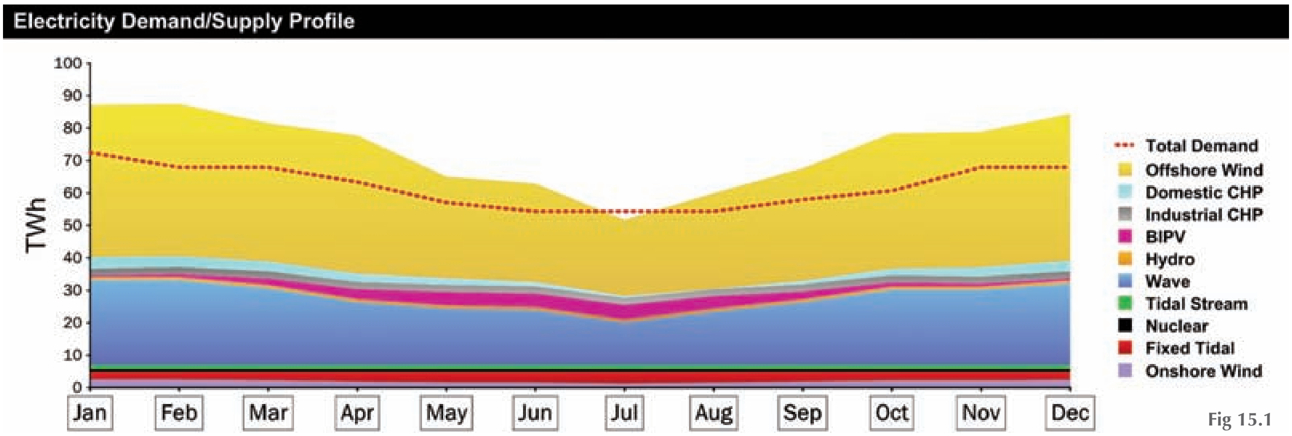


Fig 15.1

13 Those who would have been employed in the construction of new buildings would be diverted into the installation of small-scale solar renewable energy technologies, which would become increasingly popular owing to the increased economic burden of carbon energy.

14 Sinden, G (2007) *Renewable Energy and the Grid*, Earthscan

15 Friends of the Earth Cymru. (Jan 2004) *A Severn Barrage or Tidal Lagoons?*, FoE www.foe.co.uk/resources/briefings/severn_barrage_lagoons.pdf [Live June 2007]

16 www.royalsoc.ac.uk/downloaddoc.asp?id=1198 [Live June 2007] "It has been estimated that in Britain if all possible opportunities were exploited it might ultimately prove possible to win 200 TWh per annum - corresponding to a continuously operating 23 GWe station."

17 South West England RDA. (April 2007) South West England Wave Hub Project, www.wavehub.co.uk [Live June 2007]

Tidal Stream

Tidal stream technology takes advantage of the reliable source of energy in fast-moving, near-shore water in various locations around Britain. Favourable locations include the Pentland region on the tip of mainland Scotland, and the Channel Islands[21]. There is estimated to be around 16 TWh available if the full resource is exploited[22].

Fig 15.1 shows, in solid stacked colour bands, the potential contribution of the various renewable technologies that are currently available. Superimposed on this is a plot of the projected electrical demand for 2027, shown by a dotted red line.

This demand profile (the changing level of demand throughout the year) has been assumed to stay similar to that of 2007 as it is impossible to predict just how electricity demand will change in shape across the year by 2027. A useful assessment could be made of just how much increased air conditioning in summer will be matched by increased electrical heating in winter (replacing the use of gas-fired central heating owing to increased expense).

As can be seen, the supply profile of the projected renewables mix provides a close match to this demand profile, with a small reserve margin throughout most of the year.

Heat

SOLAR THERMAL

Solar thermal competes for space on buildings with BIPV. A hybrid system could potentially reduce this to improve overall efficiency. However, this scenario assumes an efficiency of 5 times that of the BIPV (which is estimated to have a system efficiency of around 12% by 2020[23] compared with a solar thermal efficiency of around 60%).

This means that it's more productive to heat water with dedicated solar thermal equipment than it is to use PVs for electrical heating (enhanced with heat pumps). In 2027 solar thermal is projected to provide Britain with 28 TWh of heat.

VARIABILITY OF RENEWABLES

An estimate has been made of the capacity credit assignable to each of the renewable technologies to be used in 2027. Capacity credit is a complex figure, derived from an assessment of how much optional plant (fossil or hydro) could be retired when a given level of renewable energy is brought onto the Grid.

There is much debate over assignment of capacity credit to the various renewables. Hydro and biomass CHP are argued to have the same capacity credit as fossil fuels (i.e. 100%[a]). On the other hand, some argue that the variability of renewables such as wind and solar PV means that optional generation needs to be maintained for those times when there is no available resource.

In this scenario, we assign a conservative capacity credit to the electrical renewables, particularly to wind (11% for offshore wind). This gives an idea of how much of the total supply can be relied upon. The supply variability figure helps to assess how much storage will be required in order to provide reliable supply.

Of note: as policies for decentralisation of energy supply are pursued, less renewable energy will enter the Grid, but less power will be demanded of the Grid – reducing the overall capacity credit issue.

[a] (Capacity credit for wind is approximately the square root of the installed capacity, i.e. for 81.5 GW of wind, capacity credit = 9 GW = 11%.) (Derived from Laughton, *Renewable Energy and the Grid*, Earthscan, 2007.)

18 AWS Ocean Energy (Feb 2007) Scottish Executive funding announced, www.awsocean.com/news.html [Live June 2007]

19 ABP Marine Environmental Research, (Jan 2006) Path to Power, BWEA www.bwea.com/pdf/pathtopower/Stage2.pdf [Live June 2007]

20 BWEA. (2007) Marine Renewable Energy. British Wind Energy Association, www.bwea.com/marine/resource.html [Live June 2007]

21 Carbon Trust (July 2005) *Variability of UK Marine Resources*, www.carbontrust.co.uk [Live June 2007]

22 Black and Veatch Ltd (2005) *UK Tidal Stream Energy Resource Assessment*, The Carbon Trust www.lunarenergy.co.uk/Userimages/PhaseIITidalStreamResourceReport.pdf [Live June 2007]

23 DTI (1999) *New and Renewable Energy: Prospects in the UK for the 21st Century HMSO*, www.dti.gov.uk/files/file21102.pdf [Live June 2007]

GROUND SOURCE HEAT PUMPS

Heat pumps work on the same principle as a refrigerator, only in reverse. An evaporation-condensation cycle transfers heat energy from one location to another. In a fridge, energy is extracted from within the cabinet, to be dissipated as waste heat to the surroundings. In a heat pump, energy is extracted from ground, air or water (which acts in effect as a solar collector where the solar heating has been diffuse and widespread) and is released as usable heat within buildings[24].

The process consumes energy (usually electrical) to run the compressor and pump, but far less than is delivered as usable heat. The coefficient of performance (CoP) describes the efficiency of the process. The working figure used for this evaluation is 3.1. That is, for every kW of electricity consumed, 3.1 kWh of useful heat is delivered. This technology is assessed as having a potential of 160 TWh annually[25].

The energy for heat pumps will largely come from wind. There is an abundance of wind energy during the winter months, giving a good match between energy supply and demand.

Domestic heat pumps on three quarters of buildings rated in excess of Standard Assessment Procedure (SAP) 70 provide all their heating energy[26]. That equates to 30 TWh of heat annually. In other domestic buildings at a lower CoP, they provide a further 50 TWh annually. Non-domestic heat pumps provide 80 TWh annually.

However achieved, installation of ground source heat pumps would need to be 10 times that projected by the DTI for this kind of contribution.

ELECTRIC STORAGE HEATERS

Electricity is a very valuable form of energy and ideally would not be used directly for heating. On the other hand, once the technical potential of heat pumps and other heating technologies has been reached, there is likely to remain a need for a significant heat load.

The envisaged storage makes use of phase change materials (PCMs), which allow a greater amount of heat to be stored in a smaller volume than with conventional water or thermal mass systems. This can ideally be used as a form of storage or interruptible supply, to assist with levelling out fluctuation of Grid power.

Because of this usefulness, direct electrical heating will provide around 25% of heating during the winter months, when the possibility of over-supply from wind is quite high. In 2027 direct electrical heating will provide 91 TWh of heat.

COMBINED HEAT & POWER (CHP)

The future UK energy regime envisaged in this scenario will no longer generate electricity thermally without also taking the opportunity to use the waste heat that is produced. In CHP, heat and power generation efficiencies can reach up to 80%[27].

The fuels used will be a mixture of biomass – for example, woodchip and wood-pellet boilers, along with municipal waste and hydrogen. Where possible (particularly in new developments) this will be installed in district-heating systems due to the greater efficiency of larger plant. In addition, such installations are more appropriate for gasification and pyrolysis if these are seen as preferable.

In CHP heat mains, despite making transmission pipes as well insulated as possible, some heat losses will occur. This and other heat losses including storage efficiencies are assumed to account for 10% of the total heat provision.

Biomass fuel will provide 103 TWh of heat and 34 TWh of electricity after accounting for losses. Chapter 13, on agriculture, provides more information on the figures for the potential of biomass.

Britain's residual waste has an energy equivalent of 5 million tonnes of coal. This figure is what is available after separating recoverable materials such as paper from the waste stream[28]. This equates to approximately 22 TWh of heat and 7 TWh of electricity after

24 One example www.cibse.org/pdfs/4dspitler.pdf [Live June 2007]

25 CAT (1977) *An Alternative Energy Strategy for the UK*, CAT Publications

26 SAP (2005) *Standard Assessment Procedure*, BRE Publications

27 Beggs, C. (2002) *Energy: Management, Supply and Conservation*, Butterworth-Heinemann

28 Chartered Institution of Wastes Management (2006) *Position Statement: Energy Recovery from Waste* www.ciwm.co.uk/mediastore/FILES/12321.pdf [Live June 2007]

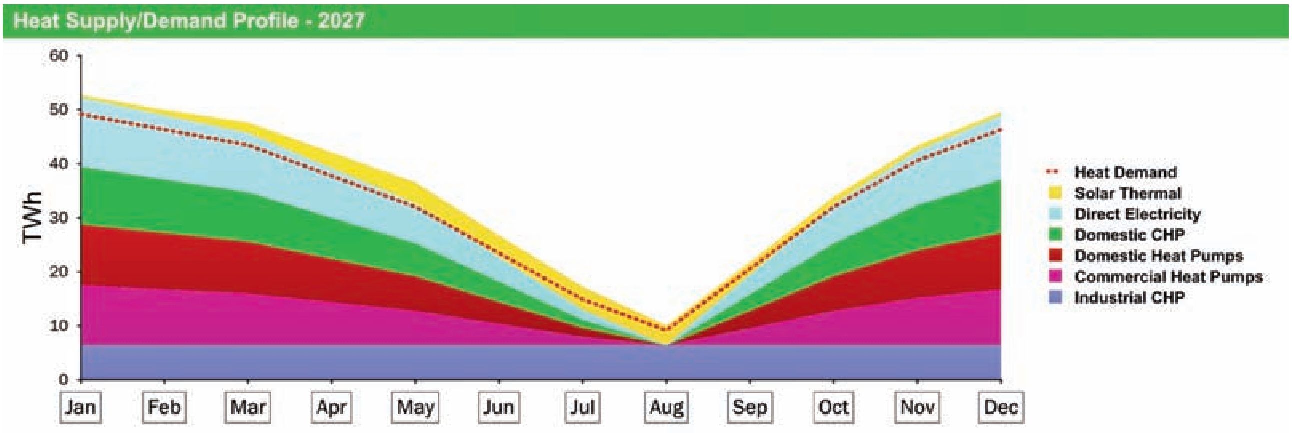


Fig 15.2

accounting for losses.

A further 2.4 TWh can be generated through pyrolysis of worn-out tyres:

Tyres: 400,000 tonnes[29]
GJ/tonne[30] **= 7.5MWh**
Efficiency of CHP = 80%
400,000 x 7.5 x 0.8 = 2,400,000 MWh = 2.4 TWh

Some of this energy from waste would be a short-term measure as it is likely that society will become less wasteful given a carbon price for manufacturing and transporting materials. Also, less traffic will mean there are fewer tyres available for pyrolysis.

However, shortly after 2027, large amounts of additional biomass will become available as the 25 year rotation forestry matures, and will start to be used to replace energy from waste.

CHP is the only area where carbon capture and storage (CCS) is considered, both in the interim before the zero fossil fuels target is achieved, and afterwards in order to capture the emissions of CO_2 from biomass combustion. This would actually make the process carbon negative, meaning that it would remove CO_2 from the atmosphere to be sequestered. However, CCS has not yet been carried out on a commercial scale in Britain, and as such more research is needed.

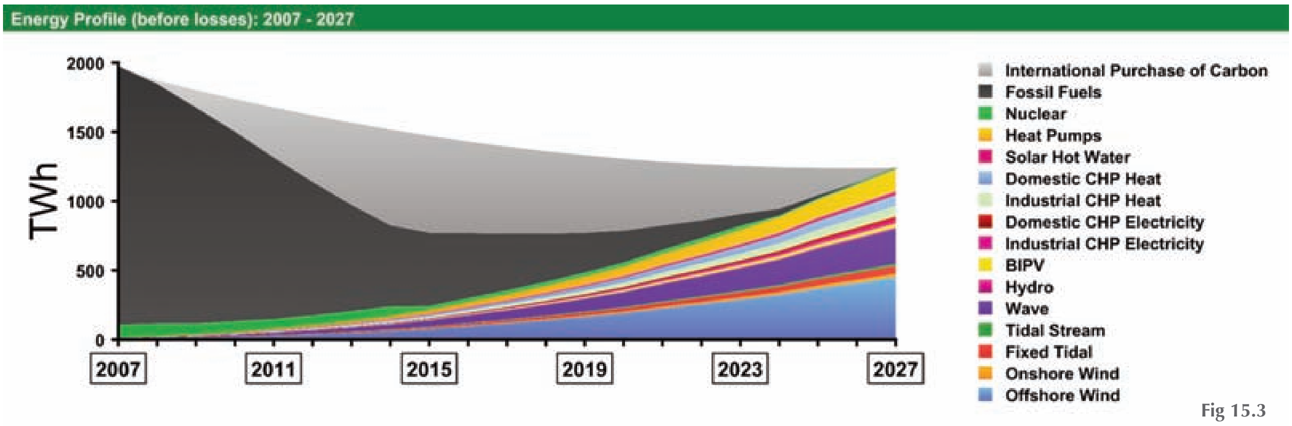


Fig 15.3

29 AEA Technology (1999), *Developing Markets for Recycled Materials*, DTI

30 Australian Government Department of the Environment and Water Resources (2001) *A National Approach to Waste Tyres. Commonwealth Department of Environment*, www.environment.gov.au/settlements/publications/waste/tyres/national-approach/tyres6.html [Live June 2007]

Chapter 16

Demand-Side Management

The National Grid Company has a legal requirement to supply 'quality' electricity around the clock[1] - voltage fluctuations must stay within + or - 1 volts of 230 volts and frequency must stay within + or - 0.5 Hertz of 50 Hertz.

Fossil fuel generated energy generally provides a predictable output, but renewably generated energy is more variable, so needs closer management.

voltage = current (supply) x resistance (demand).

Therefore, a fluctuating supply (current) must be balanced, either by managing the level of demand (resistance), or by charging and discharging energy from storage. And the same is true when managing a fluctuating demand.

This chapter deals with demand management, minimising both overall demand and fluctuations in demand so that the job of supplying this smaller and steadier demand becomes significantly easier.

Total Regulation of Demand

There are three timescales over which demand fluctuates.

High resolution (seconds/minutes)

The moment-by-moment changes in electricity demand. In practice, much of this variation is smoothed out by diversity of demand. In other words while the energy demand for a single person over a day may look quite erratic, the energy demands of 60 million people show much smoother trends of consumption.

Medium resolution (hours)

The diurnal pattern in which demand peaks at around 6pm and troughs at around 6am.

Low resolution (months)

Variations over the year, which results in a difference of around 30% between summer and winter demand.

All of these issues can be addressed to some extent by good demand-side management. The current norm is to expect a demand fluctuation of 30%, where voltage and frequency are generally maintained through measures on the supply-side (e.g. turning on more fossil fuelled power stations).

Current Methods of Demand Matching

At present, there are several ways in which supply and demand are matched. The techniques used are primarily on the supply side. This is done by keeping a large amount of generating capacity offline or running below its maximum load, ready to be brought onstream to soak up a peak. These include:

- Hydro, including pumped storage.
- Single cycle gas turbines.
- 'Spinning' reserve[2].
- Flywheels[3].

These topics are expanded further in the section on integration and balancing.

On the demand side, a few methods are already in use. One that is familiar to many householders is the Economy 7 tariff – a cheaper electricity supply that can be used only at night, for example to top up storage heaters. This is needed for two reasons:

1. Base-load generators such as coal-fired or nuclear power stations cannot easily be 'throttled down' when demand is low, and are therefore kept running at their full output both day and night.

1 Boyle, G., Everett, B., Ramage, J. (2003) *Energy Systems and Sustainability* p.340 Open University, Oxford University Press, Oxford

2 Fossil or biomass fuelled generators that are kept running, synchronised with grid frequency, but unconnected until their capacity is needed.

3 Such systems are currently used only in smaller-scale, local generation facilities rather than at a Grid level, but might be scaled up for Grid level application.

2. Due to the difficulty of storing electricity, it makes economic sense to sell it at a lower price when demand is low, to encourage take-up at those times rather than peak.

A related idea is that of interruptible tariffs for industrial electricity consumers. This is where an industrial consumer with a high demand can be cut off during unexpected peaks in overall network demand, in return for a lower priced tariff.

The Future of Demand-Side Management

INTELLIGENT APPLIANCES/PLUGS

The standard mains frequency of 50 Hz is affected by demand. As demand rises, there is a corresponding small drop in frequency. Intelligent appliances, for example fridges and freezers that can 'listen' to this frequency, decrease the amount of power they are drawing when grid frequency drops at times of high demand. Such devices help to maintain Grid voltage and frequency, and represent a method of desynchronising demand and reducing peak loads[4] .

A related idea is already used in Germany. There, appliances have different ratings depending on how critical it is that they be continuously powered. At times of peak loading, signals can be sent down the Grid lines to temporarily switch off appliances with a lower rating, enabling the power demand to be 'time-shifted' and evened out.

HEAT STORAGE

There is a great potential for excess generation of both heat and electricity to be absorbed as heat into thermal storage systems such as storage heaters and hot water storage.

Such systems can use water, the thermal mass of buildings, and phase change materials[5] (PCMs). This energy can then be released slowly over time in the case of thermal mass, or when desired in the form of hot water or controllable space heating.

It has been calculated that 300 GWh can be stored in this way. This would improve the stability of a highly renewables reliant grid[6].

PEAK DEMAND MANAGEMENT

This is equivalent to customers being paid to reduce their demand at peak times and to spread it more evenly across the day. This could be immensely popular if, as envisaged, drivers of electric vehicles can actually be paid for charging their vehicles[7].

INTELLIGENT PRICING

A further method to encourage consumers to use power at times when there is a surplus and discourage use at times of short supply is variable pricing schemes. This already happens in the field of mobile telecommunications, albeit for financial rather than supply reasons.

The principle is of an electricity market where the price responds to demand[8]. This is already the case for electricity generators, when they sell their power into a centralised 'pool'. Intelligent pricing could pass those costs on to consumers rather than absorbing them into an averaged price per kilowatt hour over the year.

This would further encourage the desynchronisation of demand, as electricity supplied at peak times would be more expensive than that at other times – during the night for example. It would also be more expensive at times of low supply, such as when there has been a period of calm, cloudy weather over large parts of the country. One can envisage the weather forecaster not only making predictions for the outlook and temperatures for the week ahead, but also for expected electricity prices.

Electric vehicle owners will be able to set their vehicle batteries to discharge at a preset electricity price down to a certain level of charge, and to recharge when the price falls below a certain level. This would automatically tend to concentrate recharging during the

4 Gross, R. (2004) *Technologies & Innovation for System Change in the UK: Status, Prospects & System Requirements of Some Leading Renewable Energy Options Energy Policy*, vol. 32, pp.1905-19, Elsevier.

5 These materials absorb large amounts of heat energy as they go from solid to liquid (high latent heat of fusion). They are capable of storing up to 14 times more energy per unit volume than conventional materials such as water or concrete.

6 Barrett, M. (2006) *Bartlett School of Graduate Studies Response to 2006 Energy Review, Complex Built Environment Systems Group*, Bartlett School of Graduate Studies, University College London, www.cbes.ucl.ac.uk/projects/EnergyReview.htm [Live June 2007]

7 Letendre, S., Kempton, W. (2002) *The V2G Concept: A new Model for Power?* Public Utilities Fortnightly

8 Tickell, O. (Feb 2006) *Response to Ofgem Domestic Metering Consultation* 20/26, www.ofgem.gov.uk/Markets/RetMkts/Metrng/Smart/Documents1/13371-Oliver_Tickell_response.pdf [Live June 2007]

night when other loads are lower. It would also encourage charging when more electricity is being supplied than is needed, acting to regulate the grid voltage[9].

In some industries, there is far more scope for interruption of supply. Interruptible (or variable) tariffs can be written into the contract to supply at a given maximum number of hours interruption per year. The greater the risk of interruption, or the shorter the notice period to be given, the lower the price paid by the company for the rest of the year. These would be prearranged tariffs, and entirely a matter of the consumers' choice as to how much they are prepared to pay for a given security of supply.

These policies and pricing structures give an economic rationale for storage, both on the domestic scale in electric vehicles and also on the generators' scale. It may make sense for some wind farm operators to store their generated energy in large 'flow' batteries – perhaps where the cable reaches land, in the case of large offshore wind farms – or in centralised storage similar to gasometers. By doing so, they will then be able to store it until peak demand when they will achieve a higher selling price.

However, this is not desirable for all generators, as there is an inherent loss in conversion into and out of storage. A deep and flexible market will need to be built up to ensure maximum efficiency. This is explored further in the section on storage.

9 Letendre, S., Kempton, W. (2002) *The V2G Concept: A new Model for Power?* Public Utilities Fortnightly

Chapter 17 Integration and Balancing

Variability

Compared to large-scale fossil fuelled generation, an electricity grid with a high penetration of intermittent and variable renewable sources requires sophisticated systems for integration and balancing of supply. This includes balancing through optional generation, and through various means of storage. Balancing is particularly important in dealing with fluctuations in demand in a future with no fast-responding fossil fuelled power stations on standby.

Many of the zero fossil fuel technologies that will be relied on in 2027 cannot be expected to provide energy around the clock, 365 days a year. The sun does not shine at night or as strongly through clouds. The wind is a chaotic system, and is hard to predict with any degree of accuracy more than a few hours or days in advance, although this is improving[1]. On a micro-scale, turbulence can make it impossible to predict the output of a single turbine from moment to moment. However, this is mitigated by the spread across many turbines in a wind farm.

This unpredictability can lead to problems of power quality, such as flicker, harmonics, brownouts etc. Most importantly, fluctuations in voltage and frequency must be kept to a minimum. This can be done by using optional generating capacity such as CHP plant with heat storage, pumped hydro and other storage technologies.

Other Integration Issues

SYNCHRONISATION

On the British Grid, AC current is synchronised at 50 Hertz (± 0.5 Hz). Syncronisation can be more difficult to achieve with a high penetration of wind and other variable renewables. Turbine and grid systems can however be adapted to account for this.

GRID STRENGTHENING

A further challenge is that many areas that have ample power available from renewable sources do not currently have sufficiently strong grid connections. This includes areas such as the north of Scotland and other windy fringes of the country. It is strategically important that connections are upgraded between the available resource and the market. If the distances involved are great enough, then these connections could be high-voltage DC cables (HVDC), which serve to minimise losses[3], like the existing interconnector with France.

This will enable the benefits of distributed generation[4] – one of the most efficient forms of balancing – to be realised.

INTERCONNECTORS

For the purpose of the 'Island Britain' scenario, all balance management is provided for within Britain and ignores the current existance and extended possibilities for electrical interconnectors. It should be recognised that the various storage technologies discussed may not be the most economical way of balancing supply and demand. A more efficient route may be to spread the distribution of generation still further, by increasing the integration of European Grid networks – a 'SuperGrid' as in the Airtricity proposal[2].

This is an international network of high-voltage direct current (HVDC) cables. High voltage minimises losses, while direct current allows for the SuperGrid to operate independently of the carefully balanced frequencies of the various national grids, all of which operate with alternating current.

1 Lange et al (2007) Renewable Energy and the Grid, Earthscan

2 www.airtricity.com/ireland/media_center/documents_forms/corporate_documents/Supergrid%20V1.4%20(printed).pdf [Live June 2007]

3 Patterson, W (1999) Transforming Electricity

4 See box, 'Distributed generation'

DISTRIBUTED GENERATION

Graham Sinden, of Oxford University's Environmental Change Institute (ECI), has shown that during the last 35 years there has never been a time when all of Britain was becalmed. As Laughton points out (see *Renewable Electricity & the Grid*, Earthscan 2007), there have, however, been times when wind speeds were very low, sometimes below turbine cut-in speeds.

Sinden's data, recorded over the past 35 years from 66 stations around Britain, is used to create a model to allow calculation of the generative capacity of any area at any time during that period. This enables him to calculate the probability percentiles for generative capacity falling below demand level. He also finds that the further apart or more distributed the generating turbines, the less correlation in their outputs.

Wind Output & Energy Demand

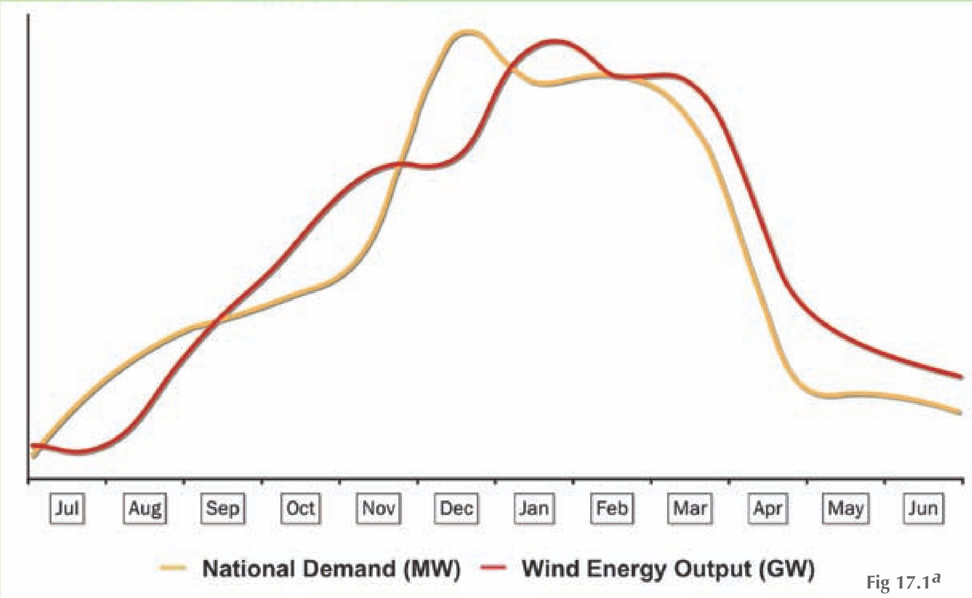


Fig 17.1[a]

In addition, rather than behaving randomly, Britain's wind resource is concentrated at certain times of day and year, thus increasing its predictability. This allows it to be relied upon, both practically and financially, given appropriate levels of distributed generation and storage.

Sinden shows that the wind has been blowing strongly enough (>4m/s) to generate some electricity all of the time for the last 35 years in some part of Britain. He also demonstrates that the wind blows more strongly in daytime and in winter, which correlates with times of peak demand.

These conclusions are based on data for onshore wind. Offshore wind, which is preferred in this scenario, is even better distributed geographically, giving a yet lower risk of losing all generation. In general, the more widely distributed and diversified the generating mix, the lower the probability of power shortages.

a Source: *BWEA* www.bwea.com

Strategic Hierarchy

OVERSUPPLY

There will be situations when renewable energy is providing more energy than is needed in the local area. In isolated, sparsely populated areas this may be true for much of the time. In these situations, the scenario has a hierarchy of where the excess power should go:

- Grid distribution to other areas of the country[5].
- Use by non-time-specific applications – e.g. refrigeration, heating.
- Storage through charging of electric vehicle batteries.
- Storage in other batteries (vanadium flow batteries, etc.) and systems, including pumped storage, in order of efficiency.
- Conversion to heat in storage heaters, etc.
- Electrolytic generation of hydrogen as a strategic store.
- 'Spill'[6] kept to a minimum.

UNDERSUPPLY

In the opposite situation, when the available renewable resource is not producing sufficient power to maintain Grid frequency, a similar hierarchy has been developed.

- Grid distribution from other areas of the country where more power may be available.
- Power from pumped storage.
- Power from other batteries such as flow batteries and from 'firm' renewables, e.g. biofuelled CHP, in order of efficiency.
- Energy from discharge of electric vehicle batteries.
- CHP from strategic hydrogen stores.

Balancing Technologies

PUMPED STORAGE

This is a mature technology, and is currently used in Britain to provide peak-time electricity. There are already 2,833MW of pumped storage installations in Scotland and Wales (capable of storing 20 GWh). It has been calculated that by converting existing hydro power stations in Scotland alone, an additional 500 GWh of storage capacity could be created[7].

This is equivalent to around 7 hours of Britain's 2027 electricity demand (599 TWh/yr = 1.64 TWh/day average). The efficiency is estimated to be around 75-85%[8] .

FLOW BATTERIES

A flow battery, is a large-scale rechargeable battery that can be connected to the Grid. The battery stores energy by ionising a solution of vanadium (a chemical element), and the energy is recovered by stripping the ions from the vanadium. Vanadium and other flow batteries can be sited near population centres, to smooth moment-to-moment fluctuation and provide longer-term storage for load balancing[9].

These are large installations, and will provide a service equivalent to that currently provided by gasometers for mains gas supplies. There will also be localised flow battery storage on a community and possibly even a domestic level, if the technology advances, to provide supply security and efficient load-spreading of embedded microgeneration.

The efficiency is in the region of 85%[10]. Flow batteries of the scale and number of current gasometers are estimated to have a capacity of 0.45 TWh, around another 6 hours of Britain's projected demand.

5 Or to other areas of Europe given the availability of a 'SuperGrid'.

6 Energy which is generated and cannot be used immediately or stored

7 ESRU: http://tinyurl.com/6bqfh5 [Live June 2007]

8 Electricity Storage Association, www.electricitystorage.org/tech/technologies_technologies_pumpedhydro.htm [Live June 2007]

9 VRB-ESS - Energy Storage & the Development of Dispatchable Wind Turbine Output, Sustainable Energy Ireland, Sorne Wind, www.sei.ie/index.asp?locID=1030&docID=-1, [Live June 2007]

10 ESA: www.electricitystorage.org/tech/technologies_technologies_vrb.htm [Live June 2007]

11 California Energy Commission, (2005) An Assessment Of Battery And Hydrogen Energy Storage Systems Integrated With Wind Energy Resources In California, www.energy.ca.gov/2005publications/cec-500-2005-136/cec-500-2005-136.pdf [Live June 2007]

HYDROGEN

Hydrogen can be used as another form of storage, generated renewably either from electricity or biomass. However, hydrogen from biomass is an inefficient use of this resource. As an electricity store, its 'round trip' efficiency of as little as 30-40%[11] is much less than either flow batteries or lithium-ion batteries.

However, it does provide large levels of scalable storage in underground chambers such as at Teeside[12], where 600 tonnes are currently stored as compressed gas with further room for expansion. It is thus ideal for soaking up 'spill' – storage requirements over and above that provided by the combination of pumped storage, car batteries and vanadium storage systems.

The production and large scale storage of hydrogen could provide a substantial interseasonal reserve that can be used for large scale and district CHP. Dependant on energy trading climates, additional storage of several TWh may be required as a longer term security buffer.

Hydrogen is also one of the few forecast non-fossil fuels for jet aircraft[13] which, according to the Airbus consortium[14], has no technical show-stopper barriers and could be developed within 10 to 15 years. Due to 'boil off' issues connected with storing liquid hydrogen, it could be produced and stored on demand at airports.

CAR BATTERIES

The network of electric vehicles provides a significant amount of distributed storage. A protocol known as V2G[15] or vehicle-to-grid power has been proposed and is undergoing testing in the USA. The current preferred technology is Li-ion batteries with close to 100% efficiency[16]. The latest Tesla electric car has a storage capacity of over 30 kWh per vehicle[17]. The batteries used in these cars have two purposes, to provide storage for the vehicle itself and secondly as storage for the National Grid. The costs can consequently be shared between these two uses. The storage available from cars will be 0.2 TWh, equivalent to 12 hrs of Britain's total transport (151 TWh/yr = 0.4 TWh/day).

COMPRESSED AIR & FLYWHEELS

Compressed air can be used for large-scale storage, and the first prototypes are in development. These require and are restricted to availability of large and suitable geological formations. Efficiencies for such systems are not yet available, but may in time offer significant storage options that complement flow cells and hydrogen.

A flywheel is a mature technology for energy storage. A mass is spun at very high speed generally on magnetic barings and in a vacuum to minimise frictional losses.

This spinning mass can store and discharge a large amount of kinetic energy. Flywheels are undergoing continued development, and show promise due to their very high efficiencies of 90%[18]. However they are currently only suitable for smaller-scale storage, although this may in time make them suitable for localised domestic or community-scale storage.

Losses

Every time energy is stored, some of it is lost due to the fact that no storage technology is 100% efficient. For this reason the scenario assumes a loss of 16% of the total electricity supplied. This assumes an 8% loss in transmission and a further 8% loss associated with electricity going in and out of storage. This figure is an estimate as no research has been found that can provide a reliable figure on what levels of storage would need to be used to back up a 100% renewable energy supply system.

If the true figure is much higher than 8%, then the 'Island Britain' scenario would need either a greater contribution of energy from wind and wave or for the restriction on interconnectors to be eased.

12 DTI – Evaluation of Hydrogen Demonstration Systems, www.dti.gov.uk [Live June 2007]

13 Svensson et al (2004) *Reduced environmental impact by lowered cruise altitude for liquid hydrogen-fuelled aircraft, Aerospace Science and Technology 8* (4) 307-320

14 Airbus Deutschland GmbH, Liquid Hydrogen Fuelled Aircraft – System Analysis www.cordis.europa.eu/data/PROJ_FP5/ACTIONeqDndSESSIONeq112242005919ndDOCeq1266ndTBLeqEN_PROJ.htm [Live June 2007]

15 Proposed by Letendre and Kempton (2002). Many links available from www.udel.edu/V2G/

16 Electricity Storage Association www.electricitystorage.org/tech/technologies_technologies_liion.htm [Live June 2007]

17 Incorporating a NanoSafe battery pack with a capacity of 35 kWh

18 Electricity Storage Association, www.electricitystorage.org/tech/technologies_technologies_flywheels.htm [Live June 2007]

Chapter 18 Conclusion

The 'Island Britain' scenario produced in support of the ***zero**carbon**britain*** strategy has suggested that one of the most important ways in which Britain can adjust to a fossil fuel free future is to improve the efficiency of its energy use. This includes measures to radically improve the thermal performance of its building stock, converting to electric vehicles, and improving industrial processes.

Perhaps the biggest inefficiency in Britain's current energy mix comes from the losses associated with thermally generated electricity. In the proposed switch to 100% renewably generated energy, we avoid the loss of the 50% of fossil fuel energy that is currently wasted as heat lost from power stations.

This scenario finds that a reasonable target is to work on the premise that we can power down by over 50% assuming that policies such as TEQs are able to both constrain growth and to support consumer and business decisions to cut energy waste and improve efficiencies. It is important to note that if growth is not constrained then efficiency measures alone will not be able to cut our overall energy use.

We have more than enough renewable sources of energy to power up. The technical wind and wave resource off the coast of Britain is massive – estimated figures vary but amount to several times current use.

However, the biggest challenge in this scenario is integration of the various sources – primarily the close balancing of supply and demand. The high penetration of variable renewables presents a sizeable engineering challenge for maintaining Grid frequency. Some methods of dealing with this problem have been proposed including demand regulation and a suite of storage technologies.

It must be noted that although costs have not been fully assessed, they are likely to be high in this scenario. As has been pointed out earlier in the strategy, however, it should not be cost but survival that is our greatest concern.

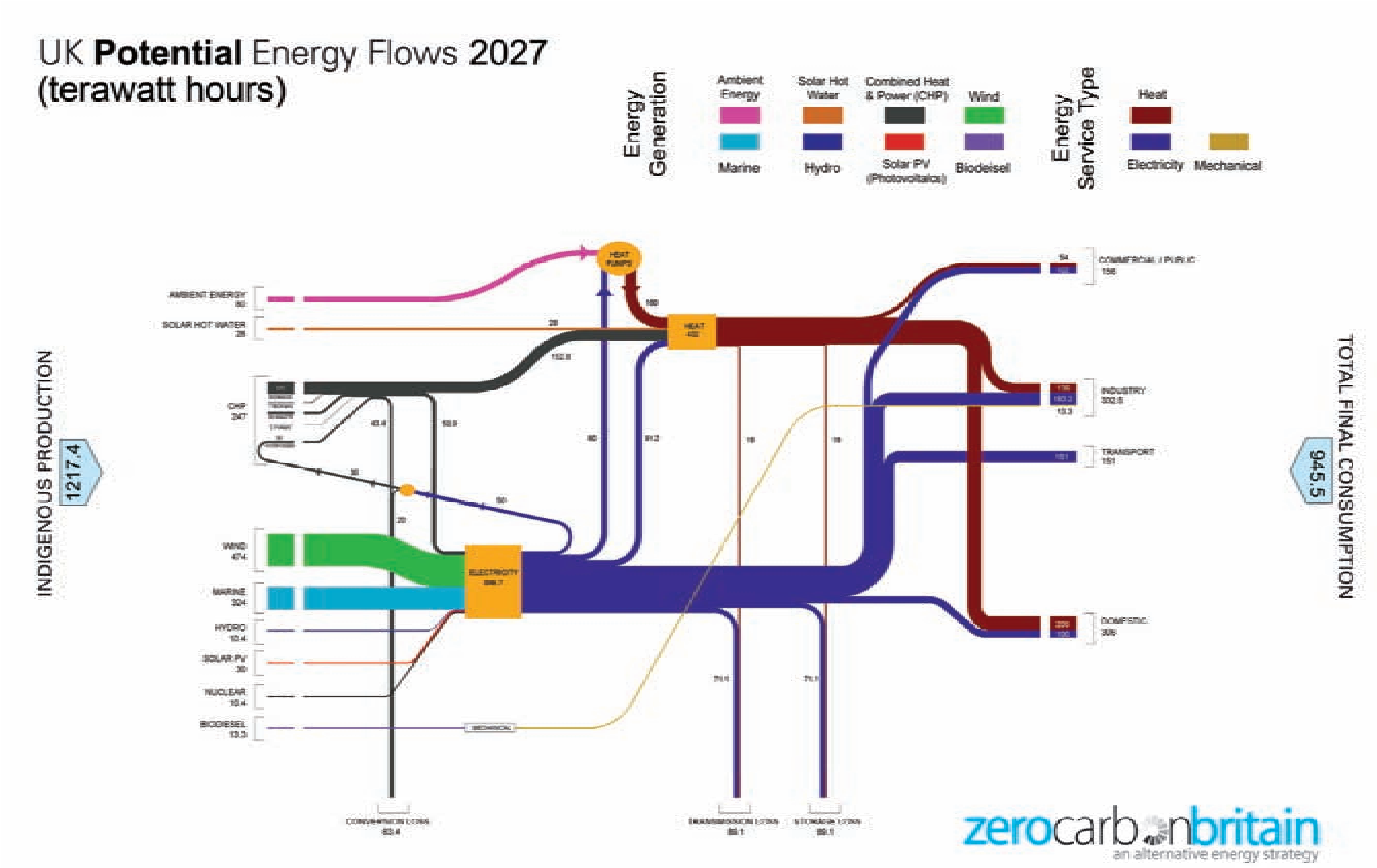
The scenario is deliberately Britain focused and shows how Britain can secure its own energy needs at the expense of no other nation. It provides a blueprint with which Britain can demonstrate leadership both from its actions at home and through its support of effective policies on the international stage.

Within Europe, we have the opportunity to join and support our neighbours in adopting equally pragmatic national strategies. This means looking beyond our own borders and taking the initiative to find reciprocal arrangements with other countries. Poland, for example, has a large resource of grain but little opportunity for renewable energy generation. We might trade wind and wave power, via the proposed European 'SuperGrid', in return for grain. Scandinavia has forestry biomass and Spain has sun. All could be traded, reducing costs and increasing the security of supply for all through furthering the distribution of generating plant.

The policies put in place in the first half of this strategy make these exchanges a possibility and in fact will encourage such trade as they promote the cheapest, most efficient solution to the problem.

Finally, the 'Island Britain' scenario gives us every reason for optimism. Even in what initially seems a tightly constrained scenario, Britain is still able to deliver a healthy and exciting future for our society.

We have more than enough renewable sources of energy to power up. The technical wind and wave resource off the coast of Britain is massive...


UK Potential Energy Flows 2027
(terawatt hours)
Energy Generation
Ambient Energy
Solar Hot Water
Combined Heat & Power (CHP)
Wind
Marine
Hydro
Solar PV (Photovoltaics)
Biodeisel
Energy Service Type
Heat
Electricity
Mechanical
INDIGENOUS PRODUCTION
1217.4
TOTAL FINAL CONSUMPTION
945.5
AMBIENT ENERGY 80
SOLAR HOT WATER 28
CHP 247
WIND 474
MARINE 324
HYDRO 10.4
SOLAR PV 30
NUCLEAR 10.4
BIODIESEL 13.3
HEAT PUMPS
HEAT 402
ELECTRICITY
MECHANICAL
CONVERSION LOSS 63.4
TRANSMISSION LOSS 89.1
STORAGE LOSS 89.1
COMMERCIAL / PUBLIC 156
INDUSTRY 302.5
TRANSPORT 151
DOMESTIC 306
zerocarbonbritain
an alternative energy strategy

Glossary

Adaptation: policies or actions that enable society to adapt to the effects of climate change – for example, by moving people or industries to more favourable locations, or designing building that are better equipped to cope with changed weather conditions.

Agrochemicals: chemicals that are used in farming – for example, fertilisers, herbicides, insecticides.

Albedo: the reflectivity of a surface. Snow and ice reflect a higher proportion of the sun's radiation than vegetation, especially forest canopies. Thus, as warming causes snow to melt and be replaced by vegetation, further warming occurs due to the landscape's increased absorption of solar energy.

All-cost-effective (ACE): energy savings that would be possible if each industry sector implemented all available cost-effective management and technical energy efficiency measures. Like all such bottom-up approaches, the scenario places no limit on the overall management time or capital needed for implementing such measures, and so is inherently optimistic.

Anthracite: a hard, dense, high-quality coal, often used as a smokeless fuel.

Anthropogenic: literally, 'caused by humans'. It refers to the actions and effects humans have on the natural world, such as 'anthropogenic CO_2 emissions' – those emissions that are attributable to human activities.

Atmosphere: the layer of gases surrounding the planet, containing about 78% nitrogen, 21% oxygen, and small amounts of argon, carbon dioxide and water vapour. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation and moderating temperature extremes.

Barter system: one in which goods and services are exchanged for other goods and services rather than for money.

Biodiesel: a processed fuel derived from biological sources such as vegetable oils, which can be used in unmodified diesel-engines.

Biodiversity: the variety and number of plant and animal species living in a given area.

Bio-energy: energy derived from organic materials.

Biofuel: liquid or gaseous fuel derived from plant matter.

Biomass: organic material. In this report it refers to the use of biological material as fuel for energy production – e.g. wood, straw, plant wastes etc.

Bituminous coal: A dense, high-quality coal used primarily in power stations and for the production of coke.

Broadband: a range of communication technologies that provide a high-speed internet connection; contrasted with older methods of connection with lower data transmission speeds, known as narrowband.

Brownout: the reduction of grid voltage when electricity demand exceeds the supply, resulting in the dimming of lights. As opposed to blackouts (caused by complete power failure), brownouts can prevent the proper starting of motors, leading to faulty operation and overheating of equipment.

Capacity credit: the amount of conventional generating capacity that could be retired by the installation of (variable) renewable generating capacity.

Carbon budget: in this report, the term is used to describe an allocation of carbon (fossil fuel) burning rights. In broader terms, it is the balance between the gains and losses of carbon within a system or on a global basis. It is used as a measure of whether the atmosphere or biosphere is functioning as a sink or source for CO_2.

Carbon capture and storage (CCS): capturing and storing the CO_2 produced by fossil fuel burning – usually in sealed underground rock formations – instead of releasing it into the atmosphere.

Carbon economy: an economy whose foundations and future growth rely upon controlling the emission of carbon (and other greenhouse gases) into the atmosphere through burning fossil fuels.

Carbon footprint: a measure of the amount of CO_2 emitted by an individual, organisation or process, through the combustion of fossil fuels in a defined process or timescale. It is generally expressed in tons of CO_2.

Carbon intensity: the ratio of CO_2 emissions to primary energy, or the amount of energy produced per unit of carbon emitted. It provides an indication of the efficiency of the economy with respect to carbon emissions.

Carbon Permits: issued by governments, carbon permits are licenses to pollute and can be traded. The aim is to increase the cost of polluting, while rewarding those companies that reduce emissions (see Emission Trading Schemes).

Carbon Sink: 'reservoirs' such as the oceans and plants, which remove carbon from the atmosphere. In plants, the carbon is incorporated into biomass, while oxygen is released.

Carbon Tax: a tax on fossil-fuel burning, which emits CO_2 into the atmosphere. Its purpose is to provide an incentive for energy efficiencies and the development of renewable energy sources.

Cash Crops: crops grown for sale rather than for subsistence. The increasing trend towards cash crops has tended to result in an over-dependence on, and vulnerability to, markets.

Climate Change: variation in the Earth's global (and regional) climate over time.

Combined Heat and Power (CHP): technologies that combine power generating equipment and a heat engine to simultaneously generate electricity and useful heat.

Contraction & Convergence (C&C): a framework for the negotiation, planning and implementation of a global cap on CO_2 emissions. It was developed by the Global Commons Institute in the early 1990s.

Critical Threshold: the temperature point beyond which scientists predict that runaway climate change will occur. This is widely believed to be 2°C above the current average global temperature.

Crop Rotation: the practice of planting dissimilar crops on the same field in successive growing seasons to avoid excessive depletion of soil nutrients, and to reduce the buildup of pests and diseases that can occur when the same crop is repeatedly grown.

Deep Water Oil: offshore oil deposits located in deep water.

Defra: the Department for Environment, Food and Rural Affairs.

Ecosystem: the totality of organisms living in a particular area or habitat, and their relationships and interdependencies.

Embodied Energy: the amount of energy required to manufacture and supply a product, material or service. Methods for calculating embodied energy vary considerably, as the scope of the calculation varies, but all seek to account for the true cost of a product or service in terms of the energy consumed.

Emission Trading Schemes: economic instruments used in the reduction of greenhouse gases (see Carbon Permits). Participants are given individual emission quotas or permits, and can trade units of emissions, enabling emission targets to be met in the most cost-effective way.

Energy Footprint: a measure of the amount of energy used by an individual, organisation or operation, within a defined process or time scale. It is generally expressed in terms of the amount of primary energy used, in kilowatt hours.

Energy Intensity: a measure of the energy efficiency of a nation's economy. It is the ratio of overall primary energy consumption to GDP at constant prices. Also known as the energy ratio.

Externality: a cost or benefit to a party not involved in the original transaction. In an environmental context, industrial air pollution is the most obvious negative externality, as its costs are borne by those living nearby rather than by the polluter.

Flicker: short lived voltage variations in the electrical grid which may cause light bulbs to flicker. It may occur if a wind turbine is connected to a weak grid, since short-lived wind variations will cause changes in power output.

Fossil fuel: hydrocarbons, mainly coal, oil or natural gas, formed by heat and pressure on organic materials over hundreds of millions of years. The burning of fossil fuels is the largest source of CO_2 emissions.

Global warming: the comparatively recent increase in the Earth's average near-surface air and ocean temperature, and its expected continual rise. Global warming has largely been attributed to human activities, namely the burning of fossil fuels.

Global warming potential: a measure of how much a given mass of greenhouse gas is estimated to contribute towards global warming.

Greenhouse effect: the process by which short-wave infrared solar radiation penetrates the Earth's atmosphere and warms the land and oceans, while a proportion of the long-wave infrared radiation that is re-emitted from the land and ocean surfaces is trapped by greenhouse gases. This results in an increase of average global temperature.

Greenhouse gases: gases in the Earth's atmosphere that contribute to the greenhouse effect. Some of these gases occur naturally, while others are released into the atmosphere as a result of human activities such as the burning of fossil fuels. Examples of such gases include water vapour, carbon dioxide, methane, nitrous oxide and ozone.

Gross domestic product (GDP): a measure of the size of a country's or region's economy. It is normally expressed as (consumption) + (investment) + (government spending) + (exports - imports).

Ground source heat pump: technologies that use the Earth as a heat source. They consist of an external loop containing water or a water/antifreeze mixture, and an internal loop containing a refrigerant, both of which pass through a heat exchanger.

Haber-Bosch Process: the industrial reaction of nitrogen and hydrogen to produce ammonia.

Harmonics: grid-based power generators produce an alternating voltage and current of 50Hz (50 cycles per second). Ideally these are both sinusoidal, but often the waveform is distorted by the generator or load adding extra frequencies to the fundamental frequency of 50Hz. These harmonics are always whole-number multiples of the fundamental frequency – 100Hz, 150Hz, 200Hz etc. The energy contained in these harmonics often cannot be used by electrical equipment, leading to reduced efficiency, overheating and potential damage to power transmission equipment and loads.

Heavy Oil: crude oil with a high viscosity and specific gravity.

Humus: the top layer of soil containing freshly broken-down organic matter such as decayed leaves.

Hydrocarbon: organic compounds consisting mainly of hydrogen and carbon, such as oil and natural gas.

Information and communications technology (ICT): an umbrella term referring to all forms of electronic communication. IT (Information Technology) refers to a narrower subset concerned only with computer and data systems.

Intelligent Buildings: buildings that incorporate computer-based systems to provide integrated energy management.

Intermittency: A measure of how much of the time an energy source is available. High intermittency implies that the generator is less likely to be producing power at any given time.

Just-in-time: a manufacturing technique where items only move through the production system as and when they are needed. It originated at the Toyota motor company in Japan.

Kaizen: a workplace 'quality' strategy often associated with the Toyota Production System. It aims to eliminate all forms of waste, in turn defined as 'activities that add cost but do not add value'.

Khazzoom-Brookes Postulate: this states that when money is saved through energy efficiency, that saving is often subsequently spent on other energy-intensive processes. The net result is that overall energy consumption is reduced less than might be expected, and may even increase.

Life cycle assessment: 'cradle to grave' analysis of a product or service, used to assess the impact (often in carbon terms) of its manufacture, use and disposal.

Lignite: the lowest quality coal, used almost exclusively in power stations.

Mineralisation: the conversion of an organic material into an inorganic material through biological activity.

Mitigation: often used in the context of climate change, referring to the direct reduction of greenhouse gas emissions or other methods to limit global warming.

National Grid: the high-voltage electrical power transmission network in Britain. It connects power stations in a national network, and allows distribution to consumers throughout Britain.

Natural gas: a gaseous fossil fuel consisting primarily of methane.

Oil province: a geological region containing oil-bearing structures, such as the North Sea.

Oil shale: fine-grained sedimentary rock containing sufficient organic material to yield oil and gas. Attempts to develop these reserves have so far met with limited success.

Optional generation: backup electricity generation, fuelled by firm energy sources, that can be called upon to meet additional demand or to fill supply shortages.

Organic farming: a system of farming that avoids the use of synthetic fertilisers and pesticides, plant growth regulators, and livestock feed additives.

Peak oil: the theory developed by Marion King Hubbert (1903 – 1989), a Shell geophysicist, who proposed that the output of an oilfield follows a bell-shaped curve. After rising to a maximum, it then goes into irrevocable decline. The model also applies to the global oil reserve. Projections for global peak oil range from 2006 to 2025 or beyond. However, current forecasts are grouped around 2010 to 2011.

Per-capita: literally, 'for each person'.

Permafrost: ground that is below freezing point for two or more successive years.

Photosynthesis: the process by which a plant uses energy from sunlight to produce its own food.

Photovoltaics (PV): the direct conversion of light to electricity via solar cells or panels.

Polar oil: oil deposits within the Arctic Circle, such as the Arctic National Wildlife Refuge in northern Alaska.

Positive Feedback: in the context of climate change, this refers to the additional warming that can occur beyond that which is directly caused by human activities. For example as temperatures rise, additional carbon dioxide is released from warming soils and oceans, leading to yet more warming. (See Runaway Climate Change).

Post-occupancy evaluation: an assessment of the performance of a building after it is occupied. It often seeks to compare the building's actual performance with that which it was designed to achieve. Assessments may be done in any terms, but most commonly assess occupant satisfaction, materials and energy in use.

Primary energy: the energy contained in an original fuel such as coal, gas and oil. It also includes biofuels, nuclear energy, hydroelectricity, geothermal heat and other renewable sources of energy. It is often contrasted with delivered energy (e.g. electricity), which is derived from the combustion of primary energy sources. The conversion efficiency and transmission losses determine what proportion of the primary energy is available as delivered energy.

Proven reserves: mineral reserves that are reasonably certain to be economically recoverable at current prices, using existing technology.

Radiative forcing: a measure of the net energy entering the Earth system. It is the difference (in Watts per square meter) between the radiative energy received by the Earth, and the energy radiated from the Earth back in to space.

REACH: the Registration, Evaluation and Authorisation of Chemicals – an EU directive for regulating the use of chemicals. It came into force on 1st June 2007.

Renewables: energy resources that do not rely on the consumption of finite reserves of fossil fuels – for example, wind and wave power, photovoltaics.

Runaway climate change: a theory predicting that a relatively small rise in average global temperature can lead to an exponential rise as a result of the disturbance of the global climate equilibrium (see Positive Feedback).

Sea ice: frozen seawater, as distinct from icebergs, consisting of glacially-transformed snow.

Sequestration: carbon sequestration refers to any means of removing CO_2 from the atmosphere and locking it up over very long periods, in order to mitigate the effects of anthropogenic climate change. For example, CO_2 can be pumped into depleted oil wells for indefinite storage.

Six Sigma: a system of practices originally developed by Motorola to systematically improve processes by eliminating defects. Since it was originally developed, Six Sigma has become an element of many Total Quality Management (TQM) initiatives.

Socio-economic framework: the combination of social and economic systems that govern certain patterns of behaviour in society.

Solar thermal: technologies that directly harness the sun's rays as a source of heat – for example, roof-mounted panels for domestic water heating.

Strip mining: removal of upper layers of soil and rock (the 'overburden') to extract underlying minerals. Also known as open-cast mining, in contrast to underground mining where access shafts and tunnels are constructed to gain access to the minerals without disrupting the land surface.

Sub-bituminous coal: coal whose properties range from those of lignite to those of bituminous coal. Used primarily in power stations.

Sustainability: the ability to continue a behaviour, activity or process indefinitely. The term has been subject to varying interpretation since its introduction into global affairs in the Brundtland report Our Common Future in 1987.

Synthetic crude: crude oil produced by chemical processing from gas or non-conventional oils such as tar sands.

Tar sands: a combination of clay, sand, water and bitumen, extracted by strip-mining or through in-situ recovery techniques involving pumping steam underground. Massive reserves exist, but recovery is slow and energy-intensive.

Teleconsulting: also called telemedicine, it is the remote communication between patient and doctor or GP and specialist, using ICT.

Teleworking: working from home, also known as telecommuting. It gives employees flexibility in their working location and hours, using ICT to connect to a central place of work. It can help to cut carbon emissions by reducing the need for travel.

Thermodynamics: the science of energy transformations and interactions. It studies the effects of changes in temperature, volume and pressure on physical systems, at the macroscopic level.

Thermography: the science of thermal imaging to measure heat losses from buildings.

Tradable Energy Quota (TEQ): a national cap-and-trade scheme for greenhouse gases, covering all sectors of society. The idea was developed by David Fleming from his earlier work on Domestic Tradable Quotas.

Variability: a measure of the extent to which the output of an energy source may change over time. A high variability implies less confidence that the power from a particular energy source will be available when required.

Vegetable-box scheme: deliveries of fresh, locally-grown, seasonal organic produce, the contents of which are largely determined by availability.

Vehicle to Grid (V2G): an electricity storage technology using the distributed storage provided by electric vehicles. The battery power of plug-in or hybrid electric vehicles is used to feed the grid during periods of peak demand.

Video-on-demand (VOD): systems that allow users to select and watch video and television programmes over a network at a time of their choosing, rather than according to a set schedule.

zero**carbon**britain: The Island of Great Britain in which fossil fuels are not burned or in which all emissions arising from such are prevented from entering the atmosphere. National GHG emissions are managed and international policy supports the timely restoration of radiative forcing to zero while avoiding catastrophic climate change.

Zero-carbon economy: an economy in which fossil fuels are not burned, or in which the emissions arising from such use are prevented from entering the atmosphere.

Zero-carbon technology: a technology in which fossil fuels are not burned or in which the emissions arising from such use are being prevented from entering the atmosphere.

Acronyms

AC	Alternating current
ACE	All Cost Effective
ATP	All Technically Possible
BIPV	Building Integrated Photovoltaic
BRE	Building Research Establishment
CAT	Centre for Alternative Technology
CCS	Carbon Capture and Storage
C&C	Contraction and Convergence
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CoP	Coefficient of Performance
CPI	Consumer Price Index
DC	Direct Current
DEFRA	Department for Environment, Food and Rural Affairs
DTI	Department for Trade and Industry
DUKES	Digest of United Kingdom Energy Statistics
ECI	Environmental Change Institute
EEC	Energy Efficiency Commitment
EMEC	European Marine Energy Centre
EROEI	Energy Return on Energy Investment
ESCO	Energy Service Company
ETSU	Energy Technology Support Unit
EU	European Union
EV	Electric Vehicle
GCI	Global Commons Institute
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
GWP	Global Warming Potential
HGV	Heavy Goods Vehicle
HVDC	High Voltage Direct Current
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
ISO 14000/1	International standards code for environmental management
LGV	Light Goods Vehicle
MMC	Modern Method of Construction
PC	Personal Computer
PCM	Phase Change Material
PV	Photovoltaic
SAP	Standard Assessment Procedure
TEQ	Tradable Energy Quota
V2G	Vehicle to Grid

Units of Energy

J		Joule: Unit of Energy (defined as the energy supplied by the force of one Newton in causing movement through a distance of one metre)
W		Watt: Unit of power equivalent to one joule per second (J/s)
kWh		kilo Watt/ hour : Unit of power used over a period of one hour. (1 KWh = 3.6 mega joules)
tC		tonnes of Carbon
Boe		Barrels of Oil equivalent
Mtoe		Million tonnes of Oil equivalent
Btu		British Thermal Unit
ppmv		Parts per million by volume
k	**Kilo:**	one thousand 1000
M	**Mega:**	one million 1.000.000
G	**Giga:**	one billion 1.000.000.000
T	**Tera:**	one trillion 1.000.000.000.000
P	**Peta :**	one quadrillion 1.000.000.000.000.000