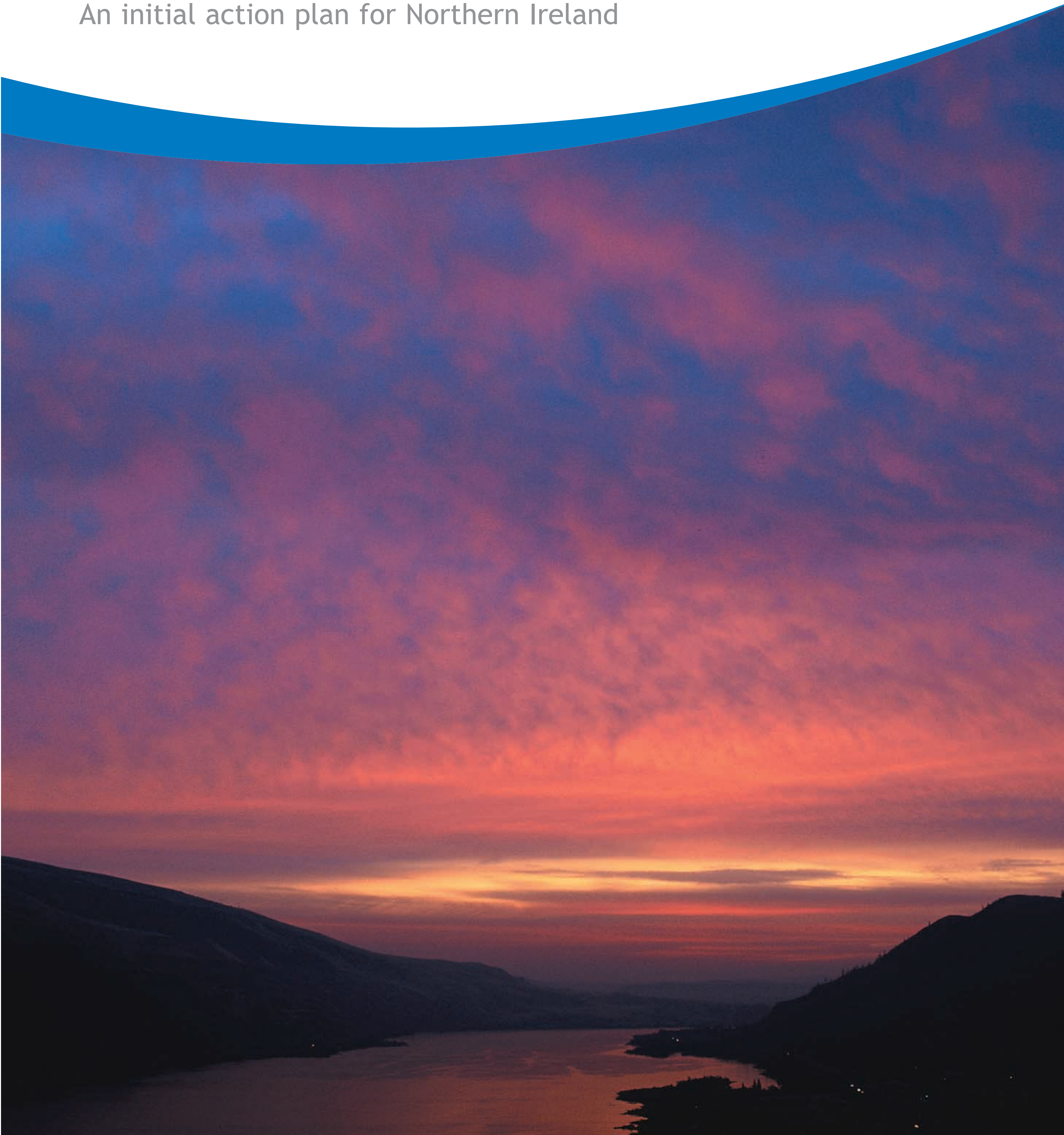
CARBON TRUST

Making business sense of climate change

Reducing our carbon footprint

An initial action plan for Northern Ireland



Preface

In June 2000, the Royal Commission on Environmental Pollution (RCEP) published its review of energy prospects for the 21st century and their environmental implications. This called for concerted action to halt the rise in the atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases, which are beginning to induce substantial climate change on a global scale.

The RCEP concluded that the only workable way of limiting CO_2 emissions (or 'carbon emissions') was to allocate national quotas that would converge to a standard allocation per person over 50 to 100 years.

For the UK, an international agreement along these lines implies a 60% reduction in carbon emissions from 1997 by 2050, and 80% by 2100.

In its Energy White Paper, the UK Government accepted the RCEP's recommendations and committed itself to the early development of a well-planned framework within which businesses and the economy generally, including the jobs and skills base, can adjust to the need for change, and take action to reduce carbon emissions within the course of normal capital replacement cycles.

The recent Department of Enterprise, Trade and Investment (DETI) strategic framework for energy in Northern Ireland acknowledges the need to reduce carbon emissions, and makes pursuing significant improvements in energy efficiency and enhancing the sustainability of the energy system a priority for the forthcoming Sustainable Development Strategy for Northern Ireland.

The Carbon Trust is a part of the UK Government's strategy for developing and implementing this national framework. The Carbon Trust helps business and the public sector cut carbon emissions, and supports the development of low carbon technologies.

In Northern Ireland, it is working with the Northern Ireland Government Departments to adapt this national framework into a programme of practical actions that can be implemented at local level.

As part of this process, the Carbon Trust and Invest NI sponsored a project to develop an action plan that would realise deep reductions in Northern Ireland's carbon emissions by 2050.

The objectives of the project were to:

- Explore how the RCEP recommendation of a 60% reduction could be met and the potential contributions of the different measures
- Define what a 'low carbon' Northern Ireland economy might look like in 2050 and to establish a vision to help stimulate future policy and programme development
- Identify issues that must be addressed to turn this vision into reality and specific actions that will reduce carbon emissions

This report summarises the work done and the action plan developed during the project.

Executive summary

In the Energy White Paper, *Our energy future - creating a low carbon economy*, the UK Government accepted the Royal Commission on Environmental Pollution's (RCEP) recommendations on how the UK should address the threat of climate change.

These recommendations included the early development of a concerted, co-ordinated and integrated strategy across all Government Departments that would put the UK economy on an early path to reducing carbon dioxide (CO_2) emissions by at least 60% by 2050.

Responding to this challenge, the Carbon Trust and Invest NI sponsored a project to develop an action plan that will set Northern Ireland on the path to realising the deep reductions in carbon emissions needed to reach this target.

The work on this 'NI vision study' started early in 2003 with the establishment of Steering Committee with representatives from a range of Northern Ireland Government Departments and Agencies, energy suppliers, academia, industry and environmental organisations.

During the project, the prospects for reducing CO_2 emissions (or carbon emissions) in five key sectors of the economy were examined. The main conclusion of this work was that it was possible to realise a 60% reduction in carbon emissions by 2050, provided early action is taken to set Northern Ireland on the path to a low carbon economy.

The project also prepared an initial action plan to help initiate change. This consists of:

- Immediate actions, including encouraging the uptake of energy efficiency measures, revising building regulations and changing public procurement procedures.

- Developing options for the future, by supporting the exploitation of renewable resources, modifying the regulatory scheme to support combined heat and power (CHP) and encouraging additional investment in low carbon technologies.

- Cross-cutting actions, including developing planning procedures that take account of sustainability, marketing campaigns to capture hearts and minds, developing a skills base in low carbon technologies and exploring more radical ways of cutting carbon emissions.

The other sections of this publication outline:

- The project background (page 2).

- Likely future energy demands under a range of market conditions (page 4).

- A vision of Northern Ireland in 2050 as a prosperous, low carbon economy (page 5).

- The steps needed to turn this vision into reality and areas for policy action (page 6).

- How to obtain advice on reducing your organisation's carbon footprint and how to obtain a copy of the full report (page 7).

Predicting our future energy needs

The Northern Ireland of 2050 is likely to be very different to that of today. The high economic growth rates realised in the last decade may be difficult to achieve in a 'carbon constrained' economy. Thus, to explore how Northern Ireland's carbon footprint might change under different political priorities and market conditions, the project used the UK Foresight programme scenarios to model likely changes in energy demand and supply to 2050.

Figure 1 illustrates the possibilities explored by the scenarios, ranging from a rapidly growing, lightly regulated economy (World Markets) to a tightly regulated, low growth economy (Local Stewardship). A 'Business As Usual' scenario was also used to build a baseline projection to 2050. This assumes current trends in society, the economy and energy markets continue.

Of these scenarios, 'Local Stewardship' with a 52% decrease in carbon emissions came closest to the 60% reduction target set by RCEP, but only at growth rates well below current trends. However, 'Global Sustainability' illustrated how carbon emissions could decrease by 46% while maintaining a very attractive level of growth.

The scenarios highlight the degree of fuel switching expected over the next 25 years as a result of the development of the natural gas network (see Figure 2). While this 'dash for gas' will substantially reduce carbon emissions, the resulting dependency on natural gas is a concern from a security of supply perspective.

Another issue that the scenarios highlighted was the possibility that Northern Ireland's carbon footprint could easily exceed current levels by 2050, unless major initiatives were taken to decouple economic activity and lifestyles from the consumption of fossil fuels.

In particular, energy demand is expected to increase as GDP per head catches up with the rest of the UK, and demand for electrical goods and international travel increases. Energy demand will also increase due to a growth in industry and commerce, as Northern Ireland becomes a more attractive place to live.

Figure 1 Northern Ireland' carbon footprint under the four Foresight scenarios

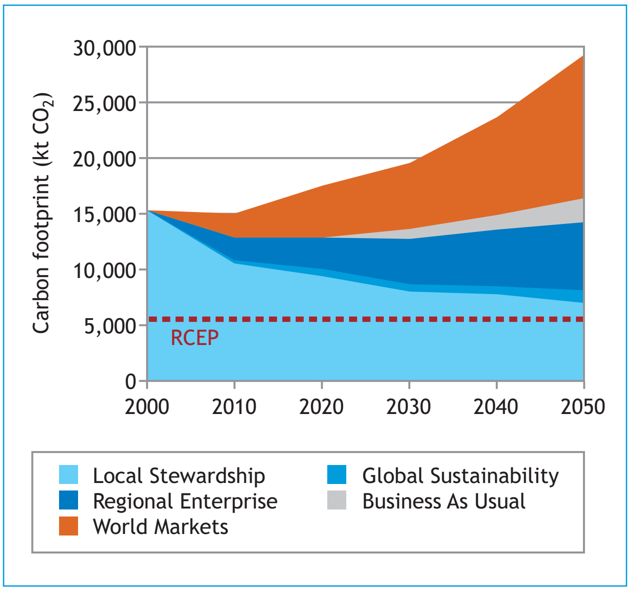
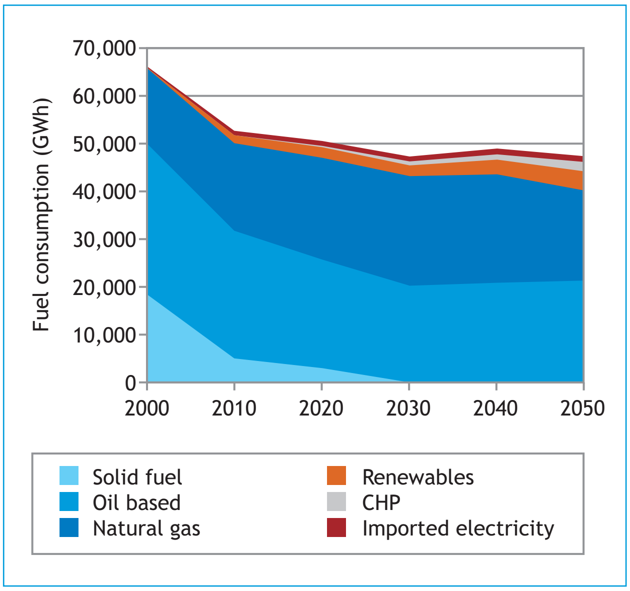


Figure 2 Energy consumption by fuel type under the 'Global Sustainability' scenario



Developing a low carbon economy

A low carbon economy in Northern Ireland is likely to be powered by a balanced mix of renewable energy, natural gas and oil. Some electricity will also be imported from the UK mainland. Cultural attitudes will have been transformed so that sustainability is at the heart of Government policy and high on the business agenda.

Other prominent features of this 'vision' that will ensure the RCEP reductions are met include:

- The development of zero-emission homes, offices, factories and vehicles
- Integrated retail and business parks that minimise energy use and travel
- An efficient and affordable integrated public-transport infrastructure
- Extensive exploitation of indigenous renewable energy resources.

Hydrogen and biomass fuels will probably play an important role in the development of low carbon vehicles. However, their widespread use is dependent on research programmes in the USA and Japan, and on whether the UK and EU set targets for the use of low-emission vehicles.

Nevertheless, the abundance of local renewable energy sources means that Northern Ireland is well placed to exploit these new, low carbon technologies when they become commercially viable.

A vibrant and prosperous economy

While implementing the necessary changes to realise this vision will be challenging, they should ensure the development of a prosperous low carbon economy in Northern Ireland by 2050, growing at 2.5% per annum, with average household incomes close to the UK average.

Unemployment should still be low with a growing service sector and a prosperous manufacturing sector producing high-value goods and environmental technology. While there will have been a shift towards higher technology manufacturing, the agriculture and food manufacturing sectors will still be substantial employers.

The costs of a low carbon economy

The cost of implementing a low carbon economy in Northern Ireland is difficult to predict given the long timescales involved, but the costs of inaction and delay are likely to be huge, so the sooner action is taken the better.

However, based on the carbon-abatement costs used in national studies, the estimated cost of reducing Northern Ireland carbon emissions by 60% by 2050 is £775 million or around 4% of Northern Ireland's GDP in 2004. This is £75 per tonne of CO_2, which is at the upper end of the cost range outlined in the Energy White Paper.

Some important caveats

These estimates do not take account of the structural differences between Northern Ireland and rest of the UK. They are also based on scenarios that assume oil and natural gas prices will rise, but that there will be no shortages in fossil fuel before 2050. They also assume substantial improvements in energy efficiency will be made in the next 50 years.

If a wider range of scenarios is considered, then the estimated cost of reducing Northern Ireland carbon emissions by 60% by 2050 increases to between £1.25 and £2.5 billion.

These last figures also illustrate the likely economic impact of delaying action by 10 to 20 years.

Implementing the vision

Turning this vision into reality fundamentally involves just three steps:

1. Optimising energy use by implementing all possible energy efficiency measures.

2. Decarbonising energy/fuel supplies by investing in renewable energy resources.

3. Decoupling economic growth and social activity from the consumption of high-carbon fuels by developing low carbon technologies, products and services.

Optimising energy use

The introduction of natural gas has created an opportunity to reduce business energy costs and improve energy efficiency at the same time. The Carbon Trust is already helping business to realise savings by providing free energy surveys and technical advice. However, measures are needed to tackle the high cost of capital in Northern Ireland that is restricting investment in new plant and machinery.

The Building Regulations in Northern Ireland are currently being updated to align with England and Wales, and to meet the requirements of the EU Energy Performance of Buildings Directive. However, a further 'step change' in building energy-performance and carbon-performance standards is needed

Over the last 30 years, travel by bus and train has declined. The resultant growth in car journeys is increasing carbon emissions in Northern Ireland and action is needed to encourage the use of public transport, car sharing pools and more fuel-efficient vehicles.

Decarbonising energy/fuel supplies

Electricity generation is responsible for a substantial proportion of Northern Ireland carbon emissions and demand is increasing. Hence, it is vital to promote increased investment in low carbon technologies, including combined heat and power (CHP) and to commercialise renewable energy resources.

Action is also needed to fast track the development of lower carbon (and zero-emission) products, processes, buildings, vehicles and leisure activities, and to encourage the wider exploitation of renewable energy resources.

Decoupling activity from carbon use

Achieving deep cuts in carbon emissions depends on changing the established behaviour patterns of individuals and organisations. A media campaign aimed at winning hearts and minds, and encouraging changes in lifestyles, would kick start change.

The development of new products and services could also help to break the link between activity and carbon emissions. This will require measures to stimulate investment, as Northern Ireland businesses currently spend less on research and development than counterparts across the EU.

Essential supporting measures

The transformation of Northern Ireland to a prosperous, low carbon economy will require more skilled professionals. The development of vocational courses and centres of academic excellence in low carbon technology will be an important first step in this process.

To avoid duplication of effort, Northern Ireland businesses also should be encouraged to exchange best practice, solutions and ideas.

The public sector has a massive impact on the specification of new products and services. Thus public procurement procedures should be changed to encourage industry and business to develop lower carbon products and services.

Planning guidelines also need to be adjusted to improve the sustainability of new housing and to provide community transport, shops and public services within rural developments.

Action plan

Immediate actions

1. Encourage improvements in energy efficiency in all sectors of the economy by developing additional support mechanisms for smaller organisations and by setting up a capital fund to support major investment in new buildings and industrial plant.

2. Improve building energy efficiency via improved standards, efficiency labelling and compliance monitoring by, for example, requiring all buildings over 1,000 square metres to display a building energy performance certificate that complies with the EU Energy Performance of Buildings Directive. Also support moves towards zero emission buildings.

3. Change public procurement procedures to promote the highest energy efficiency standards and to demonstrate public sector leadership in reducing carbon emissions. This should include only procuring space in buildings within the top quartile of energy performance, a Government commitment announced in its Energy Efficiency Action Plan.

4. Improve the quality of data collected on energy use, and make it more readily available to consumers to facilitate better targeting of support for energy efficiency measures and to enable progress to be monitored and publicised.

Developing options for the future

5. Support the exploitation of local renewable resources such as wind and bio-energy by increasing renewable obligations on energy suppliers.

6. Modify the regulatory scheme to encourage the uptake of good quality CHP and discourage the use of inefficient local generators during peak periods.

7. Encourage investment in the fledgling low carbon technology sector and take the lead on developing new technologies where Northern Ireland could obtain commercial advantage.

Cross-cutting actions

8. Develop planning procedures that have the minimisation of energy demand and transport use as prime criteria and explore the options for a transport efficiency programme.

9. Plan and execute sustainability marketing campaigns to capture the hearts and minds of the population and seek to build up the skills base in application of low carbon technologies.

10. Keep a watching brief on international developments in low carbon technologies and position Northern Ireland to become an early adopter of emerging technologies, such as low/zero emission vehicles.

The next steps

Within its remit of working with business and the public sector to reduce carbon emissions, and to accelerate the development of low carbon technologies, the Carbon Trust and its partners have begun to implement aspects of this action plan. However, further work is needed to develop the detailed implementation strategies and investment plans needed before action can be taken in other areas. Work is also needed to encourage more sustainable approaches to economic development, transport and housing.

For information on how to take action to reduce carbon emissions, telephone the Carbon Trust Energy Helpline on 0800 57 58 74.

To learn more about the *NI vision study*, download a copy of the full project report from the Carbon Trust's website (www.thecarbontrust.co.uk).

The Carbon Trust welcomes discussion of the conclusions of this study. Readers with additional data or other knowledge that can be shared and used to develop this work are encouraged to email their information to the Carbon Trust (ctni@thecarbontrust.co.uk).

www.thecarbontrust.co.uk

Making business sense of climate change

The Carbon Trust works with business and the public sector to cut carbon emissions and capture the commercial potential of low carbon technologies.

An independent company set up by the Government to help the UK meet its climate change obligations through business-focused solutions to carbon emission reduction, the Carbon Trust is grant funded by the Department for Environment, Food and Rural Affairs, the Scottish Executive, the National Assembly for Wales and Invest Northern Ireland.

The Carbon Trust is a company limited by guarantee and registered in England and Wales under Company number 4190230 with its Registered Office at: 8th Floor, 3 Clement's Inn, London WC2A 2AZ.

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NORTHERN IRELAND VISION STUDY

Main Report

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CONTENTS

See overleaf for an index to additional briefing materials included in the report.

Annexes

Index to additional briefing materials

Executive summary

In its recent Energy White Paper, *Our energy future – creating a low carbon economy*, the UK Government accepted the Royal Commission on Environmental Pollution's (RCEP) recommendations on how the UK should address the threat of climate change. These recommendations included the development of a concerted, co-ordinated and integrated strategy across all Government departments that would put the UK economy on an early path to reducing carbon dioxide (CO_2) emissions (or 'carbon emissions') by at least 60% by 2050.

Responding to this challenge, the Carbon Trust and Invest NI decided to sponsor a project to develop an Action Plan that would set Northern Ireland on the path to realising the deep reductions in carbon emissions needed to reach this target. This project started early in 2003 with the establishment of a steering committee with representatives from a range of Northern Ireland Government departments and agencies, energy suppliers, academia, industry, commerce and environmental organisations.

During the project, the prospects for reducing carbon emissions in five key sectors were examined and a set of scenarios and a model of Northern Ireland's energy balance were developed. The main conclusion of this work was that it was possible to realise a 60% reduction in Northern Ireland carbon emissions by 2050. However, to do so, early action must be taken to:

- Ensure that all sectors of the economy adopt a sustainable approach to energy use
- Encourage the development of low carbon lifestyles
- Support the development of low carbon technologies, products and services
- Invest in energy efficiency and renewable energy programmes.

A programme of activities was mapped out to support the development of a low carbon economy and an initial Action Plan was prepared. This consists of three sections:

- **Immediate actions,** including encouraging the uptake of energy efficiency measures, revising building regulations and changing public procurement procedures.
- **Developing options for the future,** by supporting the exploitation of renewable resources, modifying the regulatory scheme to support combined heat and power (CHP), and encouraging additional investment in low carbon technologies.
- **Cross-cutting actions,** including developing planning procedures that take account of sustainability, initiating marketing campaigns to capture the 'hearts and minds' of the population, developing a skills base in low carbon technologies, and exploring more radical ways of cutting carbon emissions.

This report outlines the background to the work and the research carried out during the project. It then presents a 'vision' of a prosperous, low carbon economy in Northern Ireland by 2050, and the programme of activities needed to support its development. The report is accompanied by a series of seven technical annexes that review the potential for action in five key sectors of the economy, the prospects for bio-energy development, and the scenarios used in the project.

1 Introduction

In its recent Energy White Paper, *Our energy future – creating a low carbon economy* [1], the UK Government accepted the recommendations of the Royal Commission on Environmental Pollution (RCEP) on how the UK should address the threat of climate change (see Box A). These recommendations included the development of a concerted, co-ordinated and integrated strategy across all Government departments that would put the UK economy on an early path to reducing carbon dioxide (CO_2) emissions (or 'carbon emissions') by 2050 by at least 60% from current levels[1].

Responding to this challenge, the Carbon Trust and Invest NI decided to sponsor a project to develop an action plan for Northern Ireland (NI) that would realise the deep reductions in carbon dioxide emissions needed to achieve the RCEP's recommendation. This 'NI Vision Study' started early in 2003 with the establishment of a steering committee with representatives from a range of Northern Ireland Government departments and agencies, energy suppliers, academia, industry, commerce and environmental organisations (see Acknowledgements for list of participants).

The aims and objectives of the project were to:

- Explore how the RCEP's recommendation of a 60% reduction in carbon emissions can be met and to assess the potential contributions of different low carbon measures

- Define what a 'low carbon' Northern Ireland economy might look like in 2050 and to establish a vision to help stimulate future policy and programme development

- To identify issues that need to be addressed to turn this vision into reality and specific actions that could stimulate reductions in carbon dioxide emissions.

This report presents the main outcomes of the project and is accompanied by a series of detailed annexes that consider the potential for action in five key sectors of the Northern Ireland economy, look at specific technologies, and outline the scenarios used in the project to:

- Explore the trends in Northern Ireland carbon dioxide emissions over the next 50 years under a range of different political priorities and market conditions

- Assess the degree of change and public investment needed to transform Northern Ireland into a prosperous, low carbon economy by 2050 that meets the RCEP's recommendation.

An initial conclusion from this scenario work was that, if the Northern Ireland economy continues to grow in real-terms at the current average rate of 2.9% per year [2], carbon emissions in 2050 could easily exceed the level of those in the year 2000, unless major initiatives are undertaken to decouple economic activity and lifestyles from the consumption of high carbon fuels.

However, the steering committee also concluded that it would be possible to realise a 60% reduction in Northern Ireland's carbon emissions by 2050, and that it would be sensible to take early action to ensure all sectors of the economy adopt a sustainable approach to energy use and to encourage the development of low carbon lifestyles. Underpinning this conclusion were concerns over the future prosperity of Northern Ireland after 2020 when oil production would be declining and gas would increasingly be sourced from less stable regions of the world.

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[1] In this study, 2000 has been used as the base year for assessing current levels of Northern Ireland CO_2 emissions, because data were not readily available for the 1997 base year used by the Energy White Paper.

Box A: Background briefing on the Royal Commission's review

In August 1997, the Royal Commission on Environmental Pollution began a review of energy prospects for the 21st century and their environmental implications [3]. During the study, 300 organisations and individuals contributed information, visits were made to the USA, EU and Japan, and public meetings were held to present the results of its work. Its findings represent the most authoritative work on the implications of climate change to date and its conclusions have far-reaching implications for industrialised countries like the UK.

The Royal Commission concluded that concerted action was needed to halt the steady rise in the atmospheric concentrations of carbon dioxide and other greenhouse gases resulting from human activity that are beginning to induce substantial climate change on a global scale.

The Royal Commission also identified an upper limit for atmospheric CO_2 concentration of 550 parts per million by volume (ppmv), which should not be exceeded in order to minimise the risk of catastrophic alterations to the climate. This limit is double the atmospheric CO_2 concentration prior to the industrial age. The concentration in 2003 was around 375ppmv.

The Royal Commission also concluded that the only fair, acceptable and workable method of implementing this limit was to allocate carbon emission quotas to nations on a per capita basis upon which each would be expected to converge towards over 50 to 100 years. In this way, the developing nations could still achieve a similar prosperity to the industrialised nations, which could also continue to develop their economies by investing in low carbon technologies.

For the UK, an international agreement[2] along these lines would imply a reduction of 60% in carbon emissions between 1997[3] and 2050, and an 80% reduction by 2100. These represent massive changes, which the UK Government has agreed are necessary for the long-term stability of the climate and the safety and prosperity of future generations of UK citizens.

The Royal Commission concluded that it should be possible to realise substantial reductions in carbon emissions without damaging international competitiveness or causing hardship if a high priority is given to energy efficiency and the use of indigenous renewable energy sources.

In the Energy White Paper [1][4], the UK Government accepted the Royal Commission's recommendations and committed itself to the early development of a well-planned framework within which businesses and the economy generally, including the jobs and skills base, can adjust to the need for change, and act within the course of normal capital replacement cycles.

[2] Under the Kyoto Protocol, the UK has made a commitment to reducing emissions of a basket of six greenhouse gases by 12.5% by 2008-12. The Government is also committed to cutting CO_2 emissions by 20% by 2010.

[3] The Royal Commission uses 1997 as a base year for its research. The UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol are based on 1990 emissions levels.

[4] *Editorial note*:

In *Energy: a strategic framework for Northern Ireland,* published in June 2004, the Department of Enterprise, Trade and Investment (DETI) acknowledges the need to reduce carbon emissions. It makes pursuing significant improvements in energy efficiency and enhancing the sustainability of the energy system a priority for both the framework and the Department of Regional Development's forthcoming Sustainable Development Strategy for Northern Ireland. See http://www.detni.gov.uk/cgi-bin/downutildoc?id=547 for more details.

2 Exploring Northern Ireland's future energy needs

The Northern Ireland of 2050 is likely to be very different from that of today and high economic growth rates may be less realisable in a 'carbon constrained' economy. Thus to explore how Northern Ireland's carbon emissions (or 'carbon footprint') might change under different political priorities and market conditions, the project used the UK Foresight Programme scenarios [4], summarised in Box B, to model likely energy demand and supply to 2050.

Box B: The key driving forces under the Foresight scenarios

World Markets: A world defined by an emphasis on individual freedom, personal wealth and materialism, with highly developed, integrated world trading systems. This is a high growth economy, where energy efficiency is a low priority and use of renewable energy is limited.

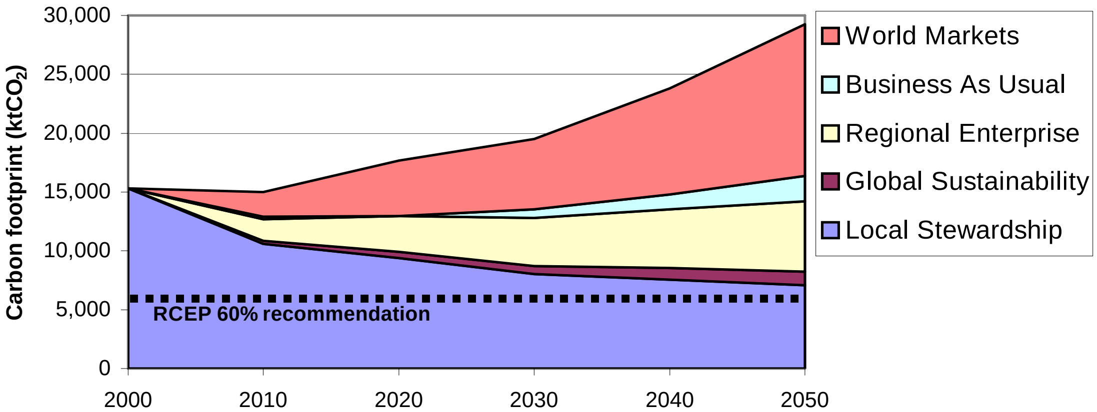
Regional Enterprise: A world dominated by consumerism and short-term values with a high degree of national independence and regional/local autonomy. This is a medium-low growth economy, with some investment in energy efficiency, but use of renewable energy is limited.

Global Sustainability: A world in which social and ecological values are considered in economic decisions and global action is taken to tackle environmental problems. This is a medium-high growth economy with high levels of energy efficiency and renewable energy.

Local Stewardship: A world where stronger national and regional regulation ensures that social and ecological values have a fundamental role in market development. This is a low growth economy, but energy efficiency and the use of renewable energy are a high priority.

Figure 1 illustrates the wide range of possibilities explored by the scenarios, ranging from a rapidly growing, lightly regulated economy (World Markets) to a tightly regulated, lower growth economy (Local Stewardship). A 'Business As Usual' scenario was also developed to illustrate how carbon emissions would change if current trends in the economy continue.

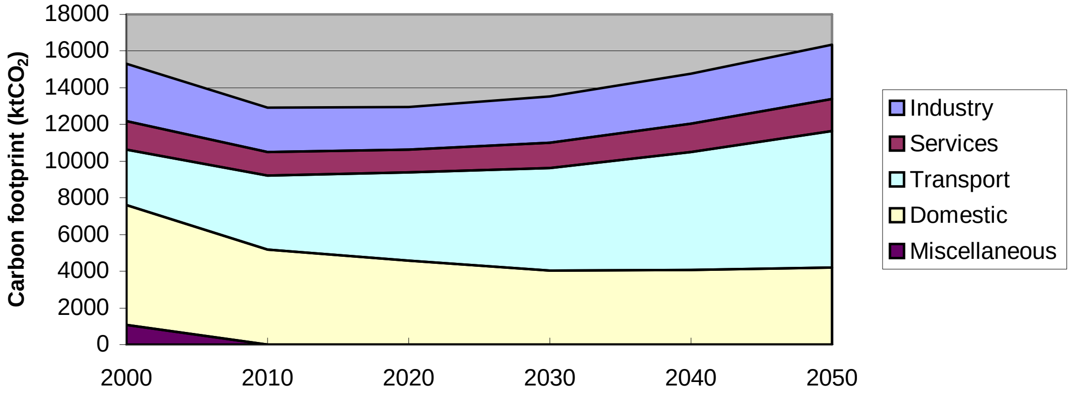
Figure 1 Northern Ireland's carbon footprint under the scenarios



Of these scenarios, Local Stewardship came closest to the 60% reduction recommended by RCEP with a 52% fall in carbon emissions by 2050, but only against a background of modest economic growth. However, Global Sustainability illustrated how carbon emissions could decrease by 46% while maintaining an attractive level of economic growth through the adoption of all technically possible energy efficiency measures and the extensive use of renewable energy.

None of the Foresight scenarios assumed a concerted effort to eliminate fossil fuels, or the use of carbon dioxide capture and storage technologies. However, the scenarios provided a good starting point for exploring the potential contributions of different low carbon measures. In particular, by examining the 'Business As Usual' model (Figure 2), it can be seen that the growth in transport is likely to be a major cause of rising carbon emission levels after 2010. Energy demand is also forecast to rise in virtually all sectors of the economy.

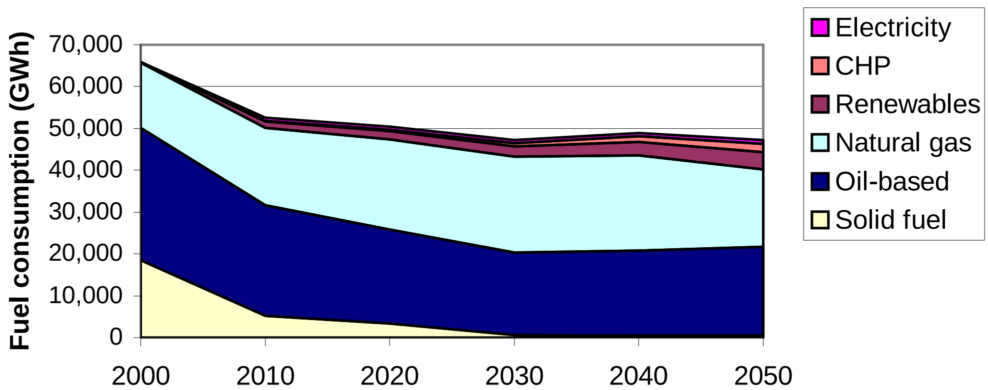
Figure 2 Carbon footprint by sector under Business As Usual



The increase in energy demand under Business As Usual is due to an expectation that Northern Ireland's gross domestic product (GDP) per head would catch up with the rest of the UK, thus increasing demands for electrical goods, international and social travel, and personal comfort in homes and offices. However, energy demand can also be expected to increase due to growth in the industrial and service sectors. This growth is likely to need an enlarged workforce that, in part, would be drawn from elsewhere, as Northern Ireland becomes a more attractive place in which to live.

The models also illustrate the degree of fuel switching that can be expected over the next 20-25 years as a result of the development of the natural gas pipeline network (see Figure 3). While this 'dash for gas' is a key factor behind the reduction in carbon emissions, the resulting dependency on natural gas is a major concern from a security of supply perspective and more radical action is needed to avoid future economic growth being stifled by higher energy prices.

Figure 3 Energy consumption by fuel type under Global Sustainability



3 Developing a low carbon economy by 2050

A low carbon economy in Northern Ireland is likely to be powered by a balanced mix of renewable energy, natural gas and oil. Some electricity will also be imported from the UK mainland. Cultural attitudes will have been transformed such that sustainability is at the heart of government policy and high on the business agenda. Other prominent features of this 'vision' of the future that will help to ensure the RCEP's recommendations are met include:

- The development of zero carbon-emission homes, offices, factories and vehicles
- Integrated retail and business parks that minimise energy use and optimise travel
- An efficient and affordable integrated public transport infrastructure
- Extensive exploitation of indigenous renewable energy resources.

Hydrogen (see Box C) and biomass fuels (see Box D) will play an important role in the development of low carbon transport. However, the exact timing of the mass production of alternative fuel vehicles will depend on the progress of fuel cell research programmes in the USA and Japan, and on whether the UK and other EU member states adopt targets for the use of low emission vehicles. Nevertheless, the abundance of local renewable energy sources means that Northern Ireland is well placed to exploit these new technologies as they become available.

Box C: Hydrogen: the key to clean, zero emission vehicles?

Hydrogen looks likely to play a key role in future low carbon energy systems, as an energy carrier or 'vector' through which renewable energy can replace fossil fuel in applications as fuel-cell powered vehicles and small-scale domestic combined heat and power (CHP) units.

Hydrogen-fuelled vehicles generate no carbon emissions at the point of use, and hence most experts believe they can provide a low carbon alternative to petrol and diesel-driven vehicles. As a result, multi-billion dollar research programmes are underway in the USA and Japan to develop fuels cells that are suitable for mass production and use in consumer vehicles, and to produce safe and cost-effective hydrogen production, storage and distribution systems.

Hydrogen can be produced from a range of sources including fossil fuels, biomass and waste products, or the electrolysis of water. This last option opens up the possibility of generating hydrogen from renewable energy and the widespread use of 'zero emission vehicles'.

The development costs of a hydrogen generation, storage and distribution infrastructure are high. Experts are still debating its relative merits compared with potential alternatives such as carbon dioxide capture and storage technology. However, because of its compact nature, Northern Ireland could be a suitable location to pilot the technology prior to its wider use.

A number of countries are building demonstration-scale hydrogen generation and storage plants that will allow the overall economics and technical feasibility of the technologies involved to be assessed. For example, Iceland has set itself the goal of developing a hydrogen economy within the next 30 years and similar efforts are underway in Hawaii and Norway.

These countries are able to use low-cost electricity from hydro and geothermal schemes to generate hydrogen, whereas Northern Ireland's renewable energy resources are much more expensive to develop (see Box G). Nevertheless, Northern Ireland could lead the UK by demonstrating the use of hydrogen in local transport fleets such as buses and taxis.

Underpinning this vision is the assumption that a more rational use will be made of energy resources, forced in part by rising energy prices due to declining oil and gas reserves, but also by the widespread adoption of energy efficiency measures and more sustainable lifestyles.

While implementing the necessary changes to realise our vision will be challenging, they should ensure the development of a prosperous low carbon economy in Northern Ireland by 2050, growing at rate of 2.5% per year, with average incomes close to the UK average.

Unemployment should still be low, with a strongly growing service sector and a prosperous manufacturing sector focused on producing high-value goods and environmental technology. Although there will have been a shift towards higher technology manufacturing, the agriculture and food manufacturing sectors will still be substantial employers.

Box D: Bio-energy for transport and heating applications

Alongside hydrogen produced from renewable energy, the use of bio-energy made from biomass is an alternative way of fuelling lower emission ‘carbon neutral’ vehicles. Northern Ireland is rich in sources of biomass such as farm wastes and forestry residues but, if necessary, it could also grow crops to support the production of bioethanol and biodiesel. These biofuels can also be blended with fossil fuels to produce lower carbon fuels that can be used by existing vehicles.

Biofuels could also be used for large-scale power generation, in CHP schemes in industry and buildings and, on a smaller scale, for domestic heating applications.

Northern Ireland has the potential to produce enough bio-energy to satisfy at least 5% of its energy demand by 2050 (see table below), and exploitation would secure many jobs in rural areas. Its development could also have a positive environmental impact where energy crops displace intensive agriculture, provided local biodiversity is maintained by growing native species.

Biomass source	GWh/year	Opportunities/barriers
Forestry residues	400	Currently expensive to recover/transport.
Sawmill conversion products	1,000	Could divert from current low value uses.
Mushroom compost and poultry litter	800	Solution to biological waste problem, but may not be optimal for the farmer economically.
Energy crops	5,500	Could be grown on marginal land.

The energy markets in Northern Ireland are also more favourable to the use of biomass than in many other areas of the UK due to the limited penetration of natural gas and Northern Ireland’s essentially rural character. There is also growing enthusiasm for the development of bio-energy resources for use in heating and CHP. Co-firing of wood and energy crops with coal at the Kilroot power station is also a short-term option that could provide an initial start-up market for the technology. In the longer term, however, the main markets for bio-energy are likely to be domestic and process heating rather than electricity generation.

The successful development of local bio-energy resources will require substantial Government support, particularly in the early stages of development when new infrastructure for collecting, processing and transporting biomass will be required. Support will also be needed to develop the local skills base, to raise public awareness of the environmental benefits of the technology, and to establish a competitive market for bio-energy (see Annex B for details).

4 Likely costs of moving to a low carbon economy

The costs of implementing a low carbon economy in Northern Ireland are difficult to predict with any accuracy given the long timescales involved, but the costs of inaction (see Box E) are likely to be huge and increase with time. Thus, the sooner action is taken, the better.

A simple ballpark estimate of likely costs can be obtained from the costs of carbon abatement published in national studies (see Annex A) completed by Future Energy Solutions for the DTI as part of the Interdepartmental Analysts Group study into long-term reductions in greenhouse gas emissions in the UK [5]. These studies concluded that it was possible to reduce UK carbon dioxide emissions by 60% by 2050 at an annual cost to the UK economy of between 0.01% and 0.02% of GDP. They also estimated that the total implementation cost by 2050 was likely to be between 0.5% and 2% of UK GDP.

Applying the marginal abatement costs reported in these studies for a Global Sustainability scenario produces an estimated cost of reducing Northern Ireland's carbon emissions by 60% by 2050 of £775 million. This corresponds to about £75 per tonne of CO_2, which is at the upper end of the abatement costs of £55–£82 per tonne of CO_2 quoted in the 2003 Energy White Paper.

These ballpark estimates take no account of structural differences between Northern Ireland and the UK, and the greater economies of scale available to the rest of the UK. They are also based on scenarios that assume that oil and natural gas prices will rise but there will be no shortages before 2050. They also assume that substantial improvements in energy efficiency will be realised over 50 years. If a wider range of scenarios is considered, then the estimated cost of reducing Northern Ireland's carbon emissions by 60% by 2050 is between £1.25 and £2.5 billion.

Box E: Why act now? A summary of the costs and benefits

The 2003 Energy White Paper [1] outlined a number of reasons why it is important for the UK to act now, rather than delay action until low carbon technology has been developed elsewhere.

- Early investment in energy efficiency measures will increase NI and UK competitiveness.
- Reducing fossil fuel use will reduce air pollution and improve the quality of life in cities.
- Exploiting renewable energy resources will reduce dependence on imported fossil fuels.
- By taking a lead in developing new low carbon technologies, many jobs could be created.

The consequences of delaying action not only involve losing potential business opportunities to develop and export the technology, but also the costs of developing a low carbon economy will increase substantially. Each year of delay means that key opportunities to implement cost-effective changes to the design of new industrial plant, machinery and buildings will be missed, and more expensive retrofit measures will need to be employed to reduce carbon emissions.

National studies [5] suggest that abatement costs will increase by 25% if implementation is delayed by 10 years and by 100% after 20 years. Such delays in implementation also increase the risk that the RCEP's recommendation might not be achieved without increasing energy prices to the point where some businesses become uncompetitive, thereby raising unemployment levels.

There are also risks that inaction will result in: decreased security of energy supply systems due to over-dependence on importing natural gas from remote regions; and/or the exploitation of fuels that increase air or land pollution, or that are located in environmentally sensitive areas.

5 Mapping out the route to a low carbon economy

Turning the vision into reality involves not only investing in energy efficiency and renewable energy, but crucially it also depends on changing attitudes towards energy use, and breaking the long-established link between economic growth and the consumption of high carbon fuels. Low carbon lifestyles will also take time to develop and to obtain widespread acceptance.

Themes 1 to 12 outline a series of activities that will be needed to support the development of a low carbon economy in Northern Ireland. Each theme contains a number of ideas developed by the project team that illustrate some potential actions that could be undertaken now, though feasibility studies will be needed to develop implementation strategies and investment plans.

At the end of each theme, there is an indication of the additional potential reduction in carbon emissions relative to 'Business As Usual' that could be realised by addressing the issues highlighted, together with a ballpark estimate of the anticipated costs of implementation. These figures should be treated only as a 'rough guide' to potential costs and benefits.

Theme 1: Investing in industrial energy efficiency

The introduction of natural gas has created a unique opportunity for NI industry to reduce its energy costs and improve energy efficiency at the same time. However, intense competition, skill shortages and the high cost of capital mean that many businesses are unable to invest in new plant and machinery. This needs to be addressed by taking action to:

- Improve the skills of local energy efficiency consultants and plant engineers
- Initiate a marketing campaign to tackle the 'like for like' replacement culture
- Organise supply chain initiatives to reduce the cost of energy efficient products
- Establish a capital loan fund to facilitate the purchase of major plant items
- Encourage the increased use of CHP systems
- Provide energy efficiency design audits for new plant and machinery.

Additional potential reduction by 2050	800ktCO_2/yr	Total investment needed	£60m

Theme 2: Transforming building design and construction

Building regulations in Northern Ireland are currently being updated to align with those in England and Wales, but they will still lag behind those in Scotland, Scandinavia and Switzerland in terms of minimum design specifications for energy efficiency and carbon footprint. As most buildings are designed to last at least 50 years, further action is needed to:

- Develop a route map for future improvements to the building regulations
- Review current building regulations and make a step change in performance
- Provide incentives for developers to go beyond the minimum specification
- Ensure major energy efficiency measures are implemented during refurbishment
- Train builders, architects and engineering consultants in energy efficient practices.

Additional potential reduction by 2050	1,000ktCO_2/yr	Total investment needed	£75m

Theme 3: Decarbonising the electricity supply industry

The centralised production of electricity is responsible for a substantial proportion of Northern Ireland's carbon dioxide emissions. With electricity demand increasing, it is vital that its industry is encouraged to invest in low carbon technology and renewable energy sources. This should be addressed by taking action to:

- Steadily increase incentives to generate electricity from local renewable sources
- Overcome barriers to increased use of intermittent renewable energy sources
- Create an economically viable market for CHP
- Develop a market for electricity from local biomass and waste organic by-products
- Use the All-Island electricity market to help reduce carbon emissions
- Introduce net metering[5] to encourage more decentralised electricity production.

Additional potential reduction by 2050	1,000ktCO_2/yr	Total investment needed	£75m

Theme 4: Demonstrating the way ahead by example

Public procurement procedures have a massive impact on the way that manufacturers and contractors develop new products and services for the wider market. Capital cost often dominates decision-making, even when there is a sound financial case for spending more to reduce the carbon footprint of public services. This should be addressed by taking action to:

- Change public procurement rules to factor in short-term and long-term environmental impact/costs and to develop opportunities for suppliers of low carbon technology
- Introduce flexibility to offset increased capital spending against future savings
- Create a ring-fenced investment/loan fund to facilitate low carbon purchasing
- Offer incentive payments to contractors realising carbon footprint improvements
- Commission independent audits of the carbon footprint of public projects.

Additional potential reduction by 2050	350ktCO_2/yr	Total investment needed	£25m

Theme 5: Planning for sustainable housing development

Currently there are relatively few barriers to housing developments, and increasing prosperity means that new homes are being built in record numbers. Since this trend is expected to continue as the economy develops, action is needed to adjust planning guidelines to maximise the sustainability of new housing developments, particularly in rural areas. Examples include:

- Checking that there is adequate local provision of education facilities
- Ensuring the provision of low carbon/zero emission community bus services
- Including provision for local services (e.g. corner shops, community centres, etc.)
- Encouraging new developments close to business parks, shops and leisure centres
- Using 'planning gain' from rural sites to subsidise the redevelopment of urban sites.

Additional potential reduction by 2050	1,500ktCO_2/yr	Total investment needed	£115m

[5] Net metering allows end-users to sell locally generated electricity to their electricity supplier when it is not required and to buy it back at the same price when they are not generating enough locally (e.g. at night).

Theme 6: Developing the skills base

The successful transformation of Northern Ireland into a prosperous, low carbon economy is ultimately dependent on the availability of trained engineers, technicians, architects, builders, planners and consultants with expertise in low carbon technology. The local skills base is quite weak and action is needed to develop it in the following areas:

- Teachers and lecturers are needed to deliver training in low carbon technologies
- Centres of excellence need to be encouraged to extend the local knowledge base
- Educational demonstration centres are needed to transform social attitudes
- Tradesmen and technicians need high-quality vocational training courses
- More specialist consultants are needed to provide advice and enable change.

Additional potential reduction by 2050 200ktCO_2/yr	Total investment needed £15m

Theme 7: Winning 'hearts and minds'

Achieving deep cuts in carbon dioxide emissions will depend on changing many long-established behaviour patterns of individuals and of public and private organisations. This transformation will take decades to complete, so action is needed to increase the rate of change through a carefully co-ordinated public information campaign aimed at:

- Clearly signposting the carbon footprint of consumer products and activities
- Promoting a 'less is more' lifestyle in schools, universities and communities
- Developing metrics to enable relative carbon cost-effectiveness to be assessed
- Highlighting examples of high, low and unnecessary carbon footprint activities
- Encouraging organisations to monitor, report and justify their carbon footprint.

Additional potential reduction by 2050 300ktCO_2/yr	Total investment needed £20m

Theme 8: Enabling changes in lifestyles

For those who live outside Belfast and its environs, the concentration of professional and business services in Belfast city necessitates frequent travel by car. This, in turn, causes congestion that makes travel by bus and cycle unattractive to those living in Belfast. Hence, action is needed to develop viable and attractive alternatives to car use including:

- Broadband digital highways to reduce the need for business travel
- Teleworking service centres – to reduce commuting and business travel
- Cycle and bus priority lanes, traffic-free zones and congestion charging
- Public transport – integrated low carbon/zero emission rail, tram, bus and air services
- Local leisure and shopping facilities – to cut non-business travel.

Additional potential reduction by 2050 1,500ktCO_2/yr	Total investment needed £115m

Theme 9: Driving home the message

Increased personal mobility is a consequence of increasing wealth and education, while business also benefits from the increased flexibility delivered by employees with their own cars whose mobility is not dependent on public transport. This has resulted in a decline in travel by bus and train that will require extensive action to reverse (prior to the widespread availability of low cost, zero emission cars) including:

- Making pool cars more financially attractive than use of own transport
- Reducing on-street parking and increasing off-street parking charges
- Encouraging and supporting the purchase of more fuel-efficient vehicles
- Additional tax breaks on car-sharing and community car pool schemes
- Hard-hitting advertising campaigns to drive home the message.

Additional potential reduction by 2050 500ktCO_2/yr	Total investment needed £40m

Theme 10: Exchanging best practice, solutions and ideas

Often organisations waste valuable resources addressing seemingly difficult problems that have been solved by other organisations or in other countries. Wasteful practices and inefficient products also continue to exist, because not enough time is available to research more energy-efficient alternatives. This problem needs to be addressed by taking action to:

- Encourage organisations to share best practice
- Facilitate international exchange visits, study tours and research projects
- Establish local sustainable development forums for business managers
- Sponsor technology clinics, seminars and conferences for industry
- Carry out independent reviews of current business energy use and practices.

Additional potential reduction by 2050 400ktCO_2/yr	Total investment needed £30m

Theme 11: Stimulating innovation and product development

Despite a good track record for innovation, NI businesses spend less on research and development than their counterparts across the EU. Often good ideas are not developed due to restrictions on private venture capital, and action is needed to stimulate the local development of low carbon products and services, including:

- A stronger emphasis on low carbon technology in product development grants
- The establishment of a challenge fund to stimulate community low carbon projects
- The creation of a low carbon design service to support manufacturing companies
- Public scholarships and industrial fellowships to develop low carbon ideas
- Local awards and prizes to recognise success in low carbon innovation.

Additional potential reduction by 2050 500ktCO_2/yr	Total investment needed £40m

Theme 12: Exploring new technology options

The development of new technology, products and services could lower the costs of reducing carbon emissions. Various ideas have already been identified, but some of these may be too expensive to develop. Hence, action is needed to explore a range of new technology options, including the development of a hydrogen-based economy. This should be addressed by:

- Monitoring developments overseas for alternative approaches
- Supporting additional research work to explore new ideas/options
- Establishing a small academic 'think tank' to explore radical options
- Funding 'toe in the water' projects to firm-up likely technology costs
- Developing the infrastructure necessary to deliver a hydrogen economy.

Additional potential reduction by 2050	2,200ktCO_2/yr	Total investment needed	£165m

Table 1 summarises the overall programme of activities in terms of target impact in ktCO_2/year and investment costs. For simplicity, investment costs have been rounded to the nearest £5 million. The programme costs are based on the lowest estimated cost of abatement (i.e. £775 million, which is around £75 per tonne of CO_2 per year not emitted into the atmosphere).

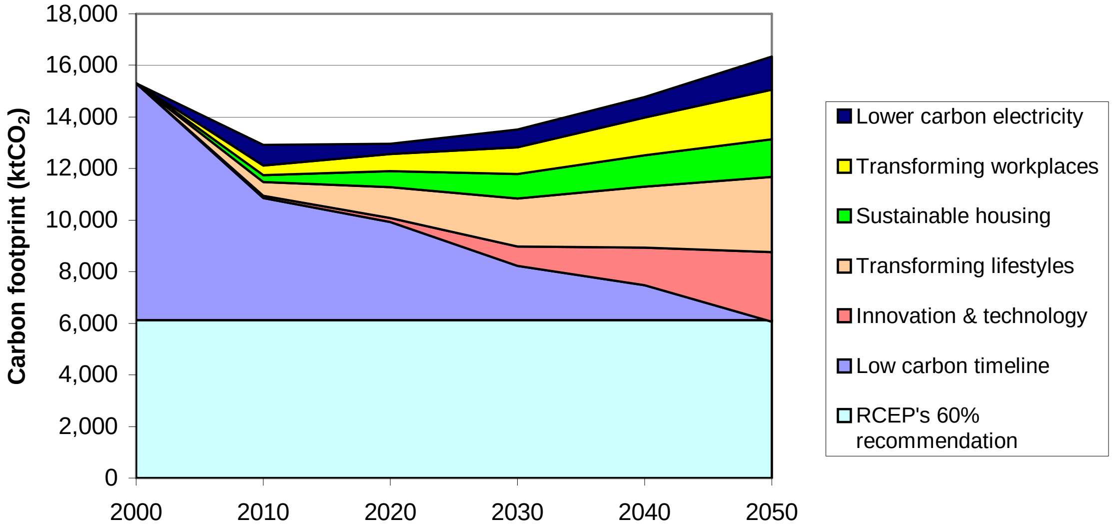
Table 1 Programme for realising a 60% reduction in carbon emissions by 2050

Theme	Programme theme	Target reduction by 2050 (ktCO_2/yr)	Total investment £m (2004 prices)
1	Investing in industrial energy efficiency	800	60
2	Transforming building design and construction	1,000	75
3	Decarbonising the electricity supply industry	1,000	75
4	Demonstrating the way ahead by example	350	25
5	Planning for sustainable housing development	1,500	115
6	Developing the skills base	200	15
7	Winning 'hearts and minds'	300	20
8	Enabling changes in lifestyles	1,500	115
9	Driving home the message	500	40
10	Exchanging best practice, solutions and ideas	400	30
11	Stimulating innovation and product development	500	40
12	Exploring new technology options	2,200	165
	Total	**10,250**	**775**

Figure 4 illustrates the estimated timeline of activities needed to establish a low carbon economy in Northern Ireland by 2050 that meets the RCEP's recommendation of reducing carbon emissions by 60%. For simplicity, we have grouped some themes outlined in Table 1 as follows:

- Transforming workplaces covers themes 1 to 3
- Low carbon lifestyles covers themes 6 to 9
- Innovation and technology covers themes 10-12.

Figure 4 Timeline for the development of a low carbon economy



Box F: Energy efficiency: some facts and figures [6]

In the home

In 2002, the electricity and heating fuel used in Northern Ireland homes caused over 6,500ktCO_2 to be emitted into the atmosphere. That's an average of 10 tonnes of CO_2 per home, which is enough to fill ten hot air balloons (of 10 metres diameter) or about 56 double-decker buses!

However, carbon emissions from Northern Ireland's homes could be reduced by 25-30% by: upgrading loft and wall insulation; better draught-proofing; through double-glazing; and by replacing old coal-fired and oil-fired heating systems with high efficiency condensing boilers.

A further 10-15% reduction in carbon emissions could be realised by replacing older household appliances (i.e. fridges, freezers, washing machines, etc.) with modern, higher efficiency 'A rated' ones and by switching off televisions, DVD players and computers rather than leaving them on stand-by.

At work

Surveys of industrial sites and commercial buildings identify, on average, potential energy savings of 20–30% [7]. About half of these savings could be realised by implementing no-cost and low-cost energy efficiency measures that have an average payback period of less than a year.

If every business were to adopt similar no-cost and low-cost energy efficiency measures, this would save £45 million/year and reduce Northern Ireland carbon emissions by 580ktCO_2/year. It would also add £115 per employee to the bottom line (after the payback period).

On the road

By buying a smaller, more fuel-efficient car operating at 45mpg rather than 30mpg, a typical car owner driving 10,000 miles/year can reduce carbon emissions by one tonne a year. This car owner would also save £400/year at the petrol station and pay £100 less in tax and insurance.

Box G: Tapping into Northern Ireland's renewable resources

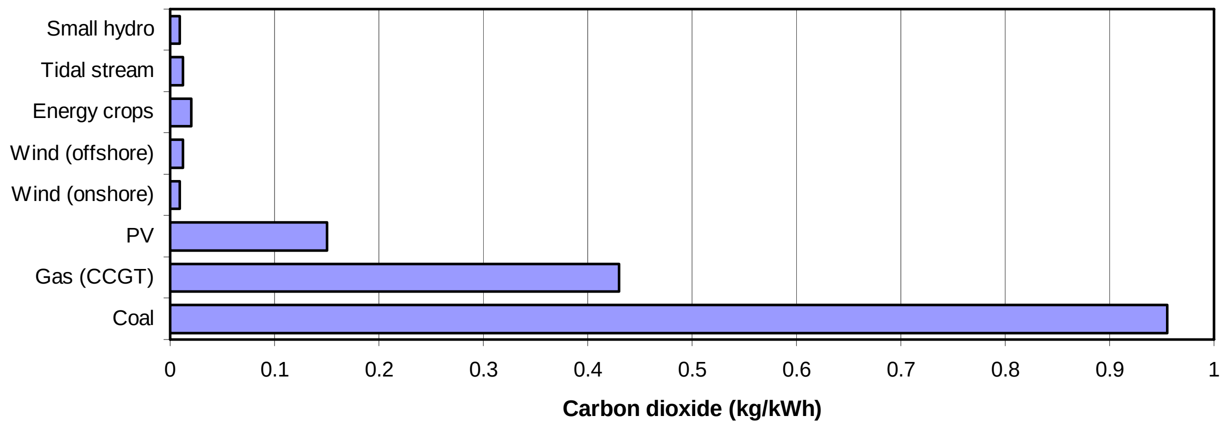
Northern Ireland has some of the most plentiful renewable energy resources in Europe, including wind (both onshore and offshore), bio-energy and tidal stream (see Annex E). Under our vision for a low carbon economy, these technologies could potentially supply at least 50% of Northern Ireland's electricity demand by 2050 (see table below).

Resource	**GWh/year**	**Constraints on development**
Wind onshore	1,500	Grid stability, public acceptability and planning issues
Wind offshore	1,000	Grid stability and environmental impact issues
Tidal stream	800	Environmental impacts, uncertainty over future costs
Bio-energy	1,000	Fuel cycle issues and long-term finance availability
Others	125	More expensive options including solar and small hydro

Under the support regime of Renewables Obligation Certificates (ROCs), onshore wind energy is already being produced competitively in the rest of the UK at a generation cost of 4-7p/kWh. Offshore wind is also currently being developed around the UK coastline with support from ROCs and capital grants. Tidal stream electricity could be produced at a cost of about 9p/kWh, while bio-energy costs are presently in the range 6-8p/kWh. These prices are based on what a developer would need over a 10 to 15-year period (in real money terms) to make a return on developing a project using the technology. These figures can be compared to the current cost of electricity generation from combined cycle gas turbines of around 2p/kWh.

Figure 5 illustrates the very substantial reduction in carbon emissions that these renewable technologies can deliver over their life-cycle compared with coal and gas fired power stations.

Figure 5 Life-cycle carbon emissions from different power generation technologies



The key priorities for renewable energy technologies in Northern Ireland are:

- Increasing the obligation on electricity suppliers to purchase renewable power
- Developing land use planning guidance that positively supports their development
- Addressing the grid constraints that presently limit the development of wind energy.

The public also need to be informed how renewable energy can deliver environmental and economic benefits in the medium to longer term and why investment is required now.

6 An initial Action Plan

At the end of the project, the following initial Action Plan for Northern Ireland was developed.

Immediate actions

1. Encourage improvements in energy efficiency in all sectors of the economy by developing additional support mechanisms for smaller organisations and by setting up a capital fund to support major investment in new buildings and industrial plant.

2. Improve building energy efficiency via improved standards, efficiency labelling and compliance monitoring by, for example, requiring all buildings over 1,000 square metres to display a building energy performance certificate that complies with the EU Energy Performance of Buildings Directive. Also support moves towards zero emission buildings.

3. Change public procurement procedures to promote the highest energy efficiency standards and to demonstrate public sector leadership in reducing carbon emissions. This should include only procuring space in buildings within the top quartile of energy performance, a Government commitment announced in its Energy Efficiency Action Plan.

4. Improve the quality of data collected on energy use, and make it more readily available to consumers to facilitate better targeting of support for energy efficiency measures and to enable progress to be monitored and publicised.

Developing options for the future

5. Support the exploitation of local renewable resources such as wind and bio-energy by increasing renewable obligations on energy suppliers.

6. Modify the regulatory scheme to encourage the uptake of good quality CHP and discourage the use of inefficient local generators during peak periods.

7. Encourage investment in the fledgling low carbon technology sector and take the lead on developing new technologies where Northern Ireland could obtain commercial advantage.

Cross-cutting actions

8. Develop planning procedures that have the minimisation of energy demand and transport use as prime criteria and explore the options for a transport efficiency programme.

9. Plan and execute sustainability marketing campaigns to capture the 'hearts and minds' of the population and seek to build up the skills base in application of low carbon technologies.

10. Keep a watching brief on international developments in low carbon technologies and position Northern Ireland to become an early adopter of emerging technologies, such as low/zero emission vehicles.

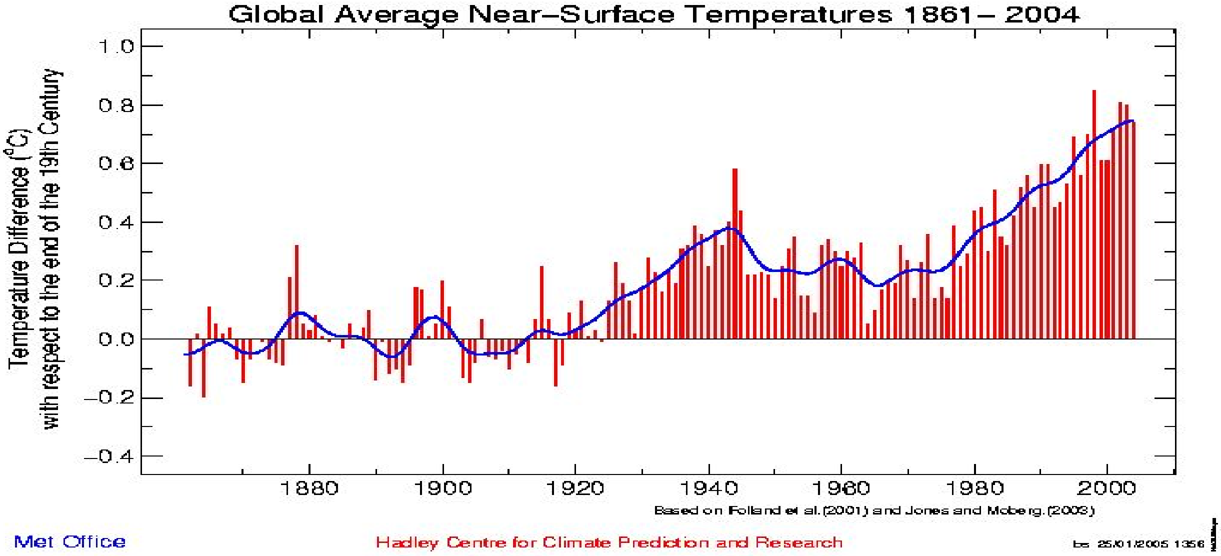
Box H: Did you know? Simple measures can have a big impact!

If every household permanently replaced three standard 60-watt light bulbs with energy-saving compact fluorescent ones, it would reduce Northern Ireland's carbon emissions by 100ktCO_2/year. This would reduce electricity bills by £20 million/year and save each household £30/year [8]. The energy saved would power all the street lighting in Northern Ireland!

Box I: The link between carbon emissions and climate change

There is strong scientific evidence that major climate change is happening and that it is being accelerated by human activity. As shown in Figure 6, the global average temperature rose by 0.6°C during the last century and nine of the last 10 years were the warmest since records began.

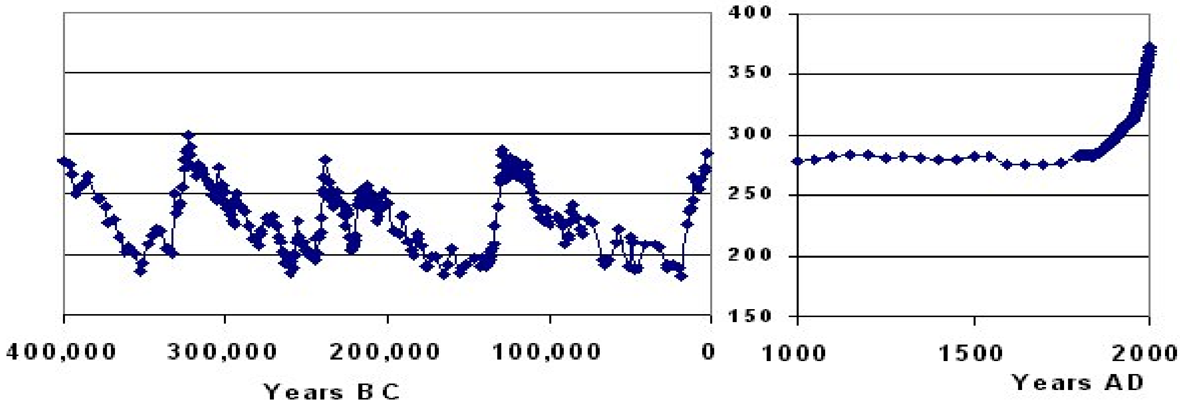
Figure 6 Global average near-surface temperatures (1861 to February 2004) [9]



This rise in temperature can be correlated with rising atmospheric CO_2 concentrations caused by the burning of vast quantities of fossil fuels (i.e. coal, oil and gas) during the industrial age.

While there are natural variations in CO_2 levels, studies of ice cores from the Antarctic and Greenland show that CO_2 concentrations are now 50% above the average over 400,000 years.

Figure 7 CO_2 concentrations (in ppmv) over the last 400,000 years [10]



For Northern Ireland, the most likely outcome of 'global warming' is less predictable weather patterns with an increase in the number and intensity of storms, higher incidents of flooding and more frequent summer droughts (see Box J for more details of possible impacts). Hence, concerted action is now essential to limit further increases in worldwide carbon emissions and to minimise the risk that our children will have to face more catastrophic climatic changes.

Box J: The likely impacts of climate change on Northern Ireland

In 2002, the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) published the results of a study into the implications of climate change on Northern Ireland [11]. This report identified a wide range of potential impacts on the economy and environment.

Agriculture, horticulture and forestry

- Farming in the west may become more marginal due to increased rainfall
- Increase in pests and disease associated with warmer countries
- Decreased biodiversity and disappearance of unique habitats.

Coastal and flood defences

- A rise in sea level of between 13cm and 74cm by 2050
- Loss of inter-tidal areas and marshland biodiversity
- Increased erosion of beaches and dune coasts.

Economic development

- Outdoor construction projects interrupted by wetter weather
- Low-lying land may become unsuitable for development
- More weather disruption increases insurance premiums.

Fisheries

- Decline in fish stocks due to disruption of breeding cycles
- The displacement of native species by shellfish colonisation
- Increased disruption of angling and associated tourist industries.

Health and welfare

- New diseases may arrive from warmer countries
- Increased humidity promotes transmission of infectious diseases
- Increased road accidents due to more frequent storms and wet weather.

Personal property

- Higher insurance costs due to more chaotic weather patterns
- Problems insuring and protecting low-lying and coastal properties
- Increased risks of accident, rodent infestations and storm damage.

Transportation and services

- Increased disruption of air and sea trade by severe weather
- Road and rail infrastructure become more prone to flooding
- Water treatment plants need to be resited on higher ground.

The Energy White Paper [1] also identifies some extreme climatic events that might occur at the upper end of possible temperature rises, such as a reduction in or even cessation of the Gulf Stream which warms Northern Ireland by an average of 8^{o}C. This could have a catastrophic impact on the quality of life in Northern Ireland as much colder winters could be expected. Similar climatic catastrophes in other parts of the world could also have a massive impact on the Northern Ireland economy. For example, mass migration due to increased levels of famine and rising sea levels could disrupt key international trade routes.

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Acronyms and abbreviations

CHP	combined heat and power
CO_2	carbon dioxide
Defra	Department for Environment, Food and Rural Affairs (London)
DTI	Department of Trade and Industry (London)
GDP	gross domestic product
kt	kilotonnes
NI	Northern Ireland
ppmv	parts per million by volume
RCEP	Royal Commission on Environmental Pollution
ROC	Renewable Obligation Certificate
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research

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Helpline 0800 085 2005
www.thecarbontrust.co.uk

NORTHERN IRELAND VISION STUDY

Annex A: Scenarios for a low carbon economy

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IMPORTANT NOTICES

CONTENTS

See overleaf for an index to additional briefing materials included in the report.

Appendices

Index to additional briefing materials

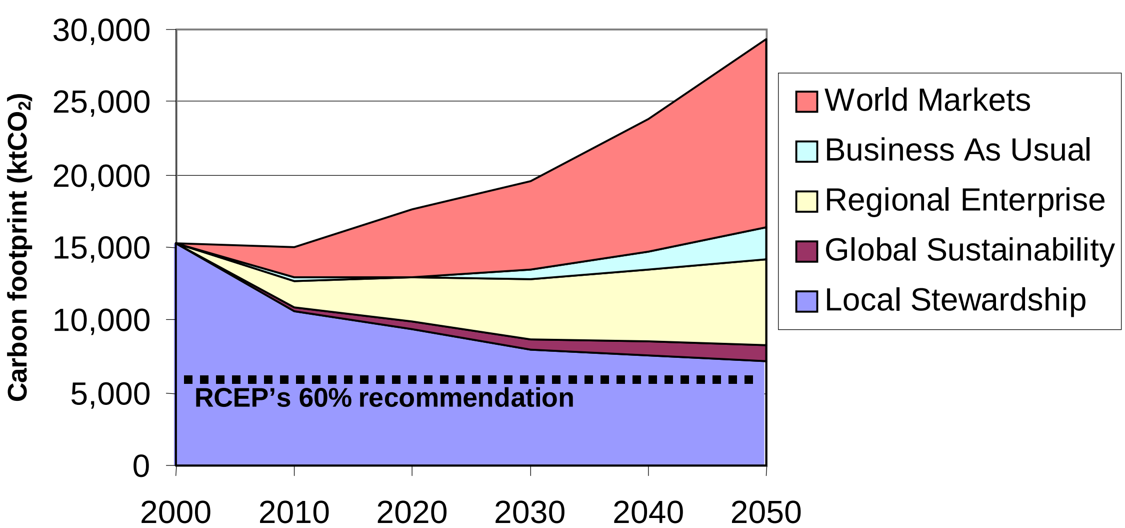
Executive summary

This annex outlines five scenarios for how energy supply and demand could change between now and 2050, and the consequential effect on carbon dioxide emissions. These scenarios are the four scenarios developed by the UK Foresight Programme, which have been widely used in national studies, plus a 'Business As Usual' scenario. These scenarios were adapted to reflect the Northern Ireland economy, social trends and political arrangements (including the possibility of an All-Island energy supply market). The UK Climate Impacts Programme's regional adaptation methodology was used to ensure consistency with the results of a project by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), which had previously modelled the impact of climate change on Northern Ireland to 2100.

The initial conclusion of the scenario development was that, if the economy continues to grow at current rates, Northern Ireland carbon dioxide emissions are set to return to year 2000 levels by 2050 unless major initiatives are undertaken to decouple economic activity and lifestyles from the consumption of high carbon fuels.

The roadmap below illustrates the range of possibilities explored by the scenarios, ranging from a rapidly growing, lightly regulated economy (World Markets) to a tightly regulated, lower growth economy (Local Stewardship). This scenario projected a 54% reduction in carbon dioxide emissions and came closest to realising the 60% reduction recommended by the Royal Commission on Environmental Pollution (RCEP).

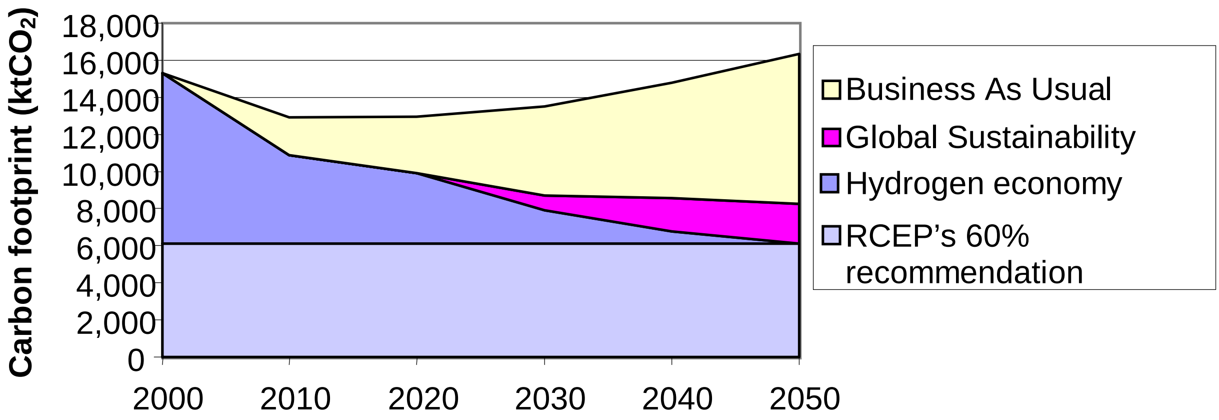
Northern Ireland's carbon footprint under the different scenarios



Another scenario, Global Sustainability, illustrated how carbon dioxide emissions could decrease by 46% while maintaining an attractive level of economic growth. However, this scenario assumed a step change in Northern Ireland's building regulations and the adoption of all technically possible energy efficiency measures in all sectors of the economy by 2050.

These scenarios highlighted the fact that the RCEP's 60% recommendation could only be met if the link between mobility and oil-based fuels could be broken. Options considered to achieve this break centred around the development of a hydrogen economy in which hydrogen derived from renewable energy was used by cars, and hydrogen is mixed into the natural gas system to reduce fossil fuel consumption by all sectors. Both of these ideas, while technically feasible, would require a substantial investment in infrastructure and raise questions over the quantity of hydrogen that would be needed. The roadmap below shows the envisaged timeline for the development of a hydrogen economy, which needs to be phased over 25 years to meet the RCEP's 60% recommendation.

Northern Ireland and the hydrogen economy



Other options are available for investigation, but there is clearly scope within the chosen options to reach the RCEP's 60% recommendation – although further work is needed to assess the technical feasibility, economic viability and political acceptability of these and other options.

During scenario development, the implications for the development of an All-Island energy market of reducing carbon dioxide emissions by 60% were also explored. It was concluded that the development of a low carbon economy could release generating capacity in Northern Ireland that could be used to provide electricity to the Republic of Ireland, and that an All-Island energy market might create a larger electricity network more able to exploit intermittent renewable energy sources from more remote parts of the island.

This annex presents the results of the modelling work in a graphical format. It also provides an outline of the methodology and framework used to develop the scenarios, along with details of the main assumptions used in the models (see Appendix 2). It ends with a short section that explains how to interpret the scenarios before drawing some conclusions about the transition to a prosperous low carbon economy in Northern Ireland, including a ballpark estimate of the costs to the economy of the transition of between £800 million and £2.5 billion by 2050.

1 Introduction

This annex presents the results of modelling work to develop a set of consistent scenarios for energy demand that illustrate how Northern Ireland's carbon footprint might change between 2000 and 2050 under a range of market conditions and patterns of economic development.

The specific objectives of scenario development were to:

- Explore how the 60% reduction in carbon dioxide emissions recommended by the Royal Commission on Environmental Pollution (RCEP) could be achieved and to assess the potential contributions of different low carbon measures

- Help to define what a 'low carbon' Northern Ireland might look like in 2050

- Examine the sensitivity of future emissions to the development of an All-Island energy supply market and the greater integration of social and economic activities.

The annex outlines five scenarios for how energy supply and demand could change between now and 2050, and the consequential effect on carbon dioxide (CO_2) emissions. These scenarios are the four scenarios developed by the UK Foresight Programme[1], which have been widely used in national studies, plus a 'Business As Usual' scenario. The annex also explores the likely impact of different market conditions on the different energy-using sectors in Northern Ireland (NI) and discusses how the scenarios could be adapted to reflect sector-specific views on the scope of reducing CO_2 emissions by 2050.

The structure of this annex broadly reflects the methodology used (see Figure A1). This involved the following tasks:

1 Select the most appropriate scenarios (from a range of possibilities)

2 Adapt the scenarios to NI's geography, economy and culture

3 Develop a Business As Usual projection from current trends

4 Establish the baseline for carbon emissions in each economic sector

5 Construct a model to predict carbon use for each economic sector[2]

6 Estimate overall NI carbon emissions between 2000 and 2050.

The annex presents the results of the modelling work and then explains how to use and interpret the Global Sustainability scenario, which the main report uses to illustrate what Northern Ireland's carbon footprint might be like in 2050 if society were to adopt more sustainable development patterns and lower carbon lifestyles. This is followed by a discussion of some of the more radical ideas examined in the search for ways of bridging the gap between the predictions of carbon emissions in 2050 under the Global Sustainability scenario and the RCEP's 60% recommendation. The annex ends by considering the likely costs to the economy and public purse of the transition to a low carbon economy in Northern Ireland.

To improve the flow and readability of the annex, details of the assumptions used in the scenarios and models of energy demands have been condensed and presented in Appendix 2.

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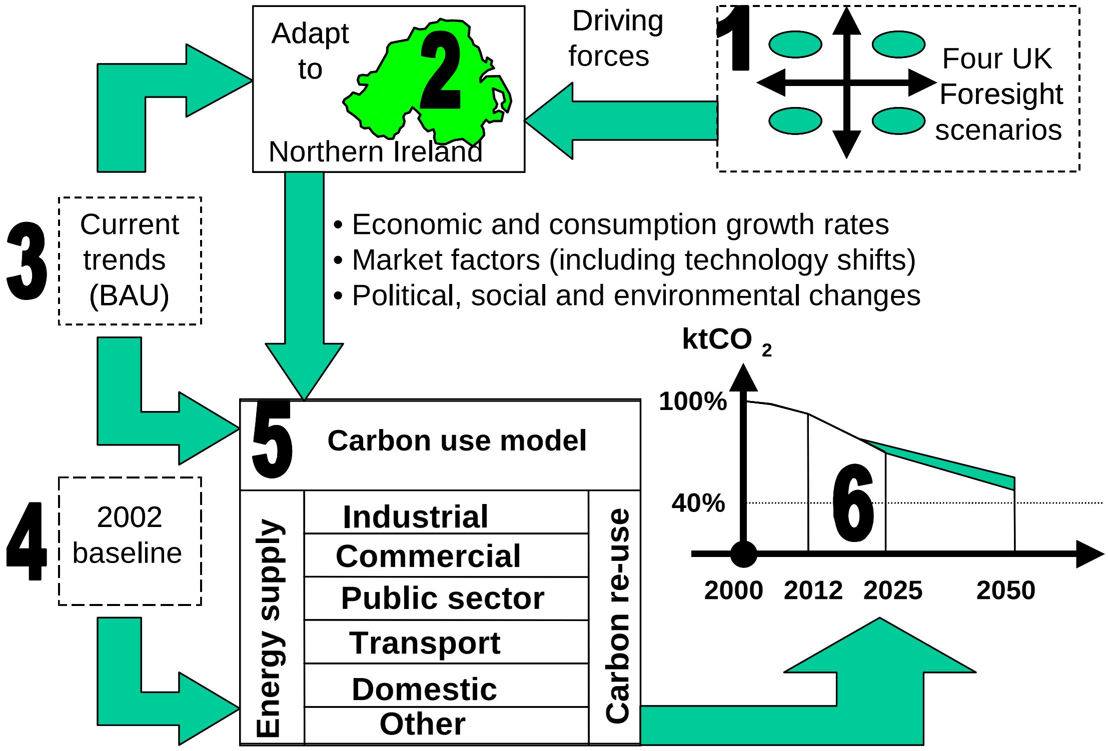
[1] Managed by the Office of Science and Technology (www.foresight.gov.uk)

[2] The use of scenarios is a well-established technique for developing long-term plans and strategies that cover both optimistic and problematic futures. In using scenarios to predict future emissions, it is important to remember these predictions are not robust forecasts, since the scenarios are looking 'over the horizon' beyond the reach of simple extrapolations and complex deterministic models. However, a wide range of future possibilities can be explored by examining contrasting scenarios.

Details of the fuel mix used to estimate the carbon footprint of the electricity supply industry under each of the scenarios has also been omitted, as these figures are presented in Annex E.

Figure A1 Overview of the scenario development methodology



2 Scenario selection

The four scenarios developed by the UK Foresight Programme [1] formed the initial basis of this work. These scenarios identify key social and economic trends (see Appendix 1) and then explore how these might change under different political priorities, markets conditions, social attitudes, etc. Their names and themes are:

- **World Markets.** People aspire to greater personal independence, material wealth and mobility to the exclusion of wider social goals. Greater market integration and minimal government are viewed as the way to deliver this, and an international framework is developed to ensure the efficient functioning of world markets.

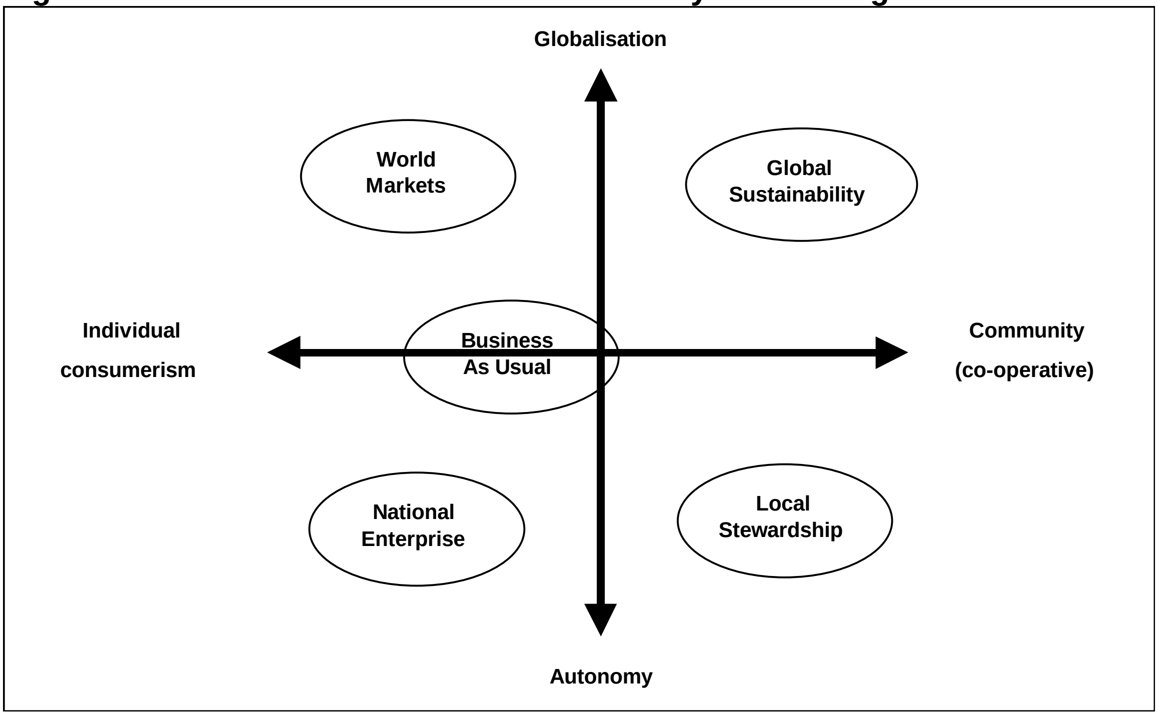
- **National Enterprise**. People aspire to personal independence and material wealth within a national cultural identity. Liberalised markets, strong national institutions and a commitment to develop the capabilities needed to secure a high degree of national self-reliance and security are seen as the best way to deliver these goals.

- **Global Sustainability**. People aspire to high welfare levels within communities with shared values, better-distributed opportunities and a sounder environment. A more active public policy is seen as the best way to deliver these goals, and there is an emphasis on increased international co-operation at the EU and global levels.

- **Local Stewardship.** People aspire to sustainable levels of welfare in networked communities. Markets are subject to social regulation to ensure a more equal distribution of opportunities and a high quality local environment. Public policy encourages small-scale regional economic activities, rather than large-scale ones.

The relationships between the four scenarios and 'Business As Usual' are shown in Figure A2.

Figure A2 Socio-economic framework used by the Foresight scenarios



Factoring in the effects of climate change

One of the problems of applying the Foresight scenarios is that they do not consider the interaction between the level of investment in low carbon technology and the rate of global warming, and the consequential social pressure for reducing emissions. In addition, they were initially developed with the objective of looking 20 years ahead, rather than the 50 or 100 years needed to fully understand the impacts of climate change.

To address these shortcomings, the UK Climate Impacts Programme (UKCIP) has adapted the Foresight scenarios for use up to 2100 [2]. UKCIP has also published four scenarios that explore the interaction between socio-economic trends and different sensitivities of the environment to global warming. These scenarios are named after the degree of sensitivity assumed, i.e. High, Medium–High, Medium–Low and Low[3].

The UKCIP also reworked the Foresight National Enterprise into 'Regional Enterprise' to reflect trends towards devolution. This scenario was used by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) in a project to assess the implications of climate change for Northern Ireland [3]; the SNIFFER final project report provided a useful starting point for scenario development within this project.

The scenarios developed by UKCIP are broadly similar to the UK Foresight scenarios, but they have a regional focus and use different growth rates to reflect the longer timescales being investigated. This means that their predictions for earlier periods (2010 and 2020) are not directly comparable with those based on the four UK Foresight scenarios alone.

When Business As Usual is included, the UKCIP work creates over 20 combinations of the two different scenario sets. However, guidance[4] from UKCIP on how to select a smaller sub-set of scenarios, which covers a wide range of possibilities, cuts the number of scenarios needed to eight (see Table A1). The working group then reduced the number of scenarios that needed to be developed to five by assuming that the Business As Usual scenario would be insensitive to the rate of climate change[5].

[3] The Low and Medium–Low scenarios assume an increase in future greenhouse gas concentrations of around 0.5% per year, while the Medium–High and High scenarios assume 1% per year.

[4] The rationale behind the UKCIP guidance is that other combinations of Foresight and climate change scenarios are inconsistent or incompatible with each other, and hence are unlikely to occur.

[5] For sensitivity analysis, this annex used three scenarios: Business As Usual, Global Sustainability and Local Stewardship. The Business As Usual scenario creates the greatest socio-economic pressure on natural resources, while the Global Sustainability scenario is closest to completing the transformation into a low carbon economy. The Local Stewardship scenario illustrates the effects of assuming lower growth.

Table A1 Northern Ireland economic development targets for 2010

Foresight scenarios	UKCIP climate change scenarios			
	Low	Medium-Low	Medium-High	High
Business As Usual	X	X	X	X
Regional Enterprise				X
World Markets			X	
Local Stewardship		X		
Global Sustainability	X			

3 Adapting the scenarios for Northern Ireland

The following methodology was used to adapt the Foresight/UKCIP scenarios to Northern Ireland.

1 Assume that for each scenario, Northern Ireland is operating within the wider UK context set by the corresponding Foresight scenario. Hence similar sectors will be growing and declining in all regions of the UK (allowing for local exceptions).

2 Identify equivalent economic, transport and social **indicators** (see Appendix 1) that are characteristic of the energy use and carbon emissions in Northern Ireland.

3 Develop outline **storylines** for each scenario outlining the general thrust of the scenario and including a short exposition of economic, social and environmental trends, and a brief analysis of likely progress towards a low carbon economy.

4 Estimate likely values for the indicators identified in step 2 for each scenario, taking account of baseline values and trends. Apply sanity checks where available, including checking that indicators are consistent and do not 'saturate' by 2050.

The outline storylines developed for each scenario are shown in Boxes A1–A5.

Box A1: Regional Enterprise

The Regional Enterprise scenario is the most bullish of the four scenarios developed for the Northern Ireland Vision Study. It suggests a vibrant, autonomous region, keen to promote and maintain its distinctive qualities and values in a highly competitive world.

The key to success is the imaginative development and exploitation of its human and natural resources, and a high level of innovation in the development of new enterprises. Social expectations are more cohesive with a focus on 'building the future together'.

Economy: Northern Ireland is encouraged to become less dependent on support from central government and to develop investment strategies for particular growth sectors. Medium–low growth is the norm as the Northern Ireland economy is more isolated, and unemployment is medium–high as a result.

Society: A high degree of devolution encourages considerably more involvement in political life, with 'citizens' able to directly see the connection between their decisions and economic, social and regulatory changes. Unemployment is seen as a key indicator of progress, and there is a major focus on job creation and internal investment. Reducing poverty and improving health and education are tackled by 'working together' initiatives.

Environment: There is greater awareness of environmental issues and the importance of the environment to the quality of life, but it is seen as a valuable asset to be exploited.

Progress towards a low carbon economy: Investment means that energy efficiency is increasing in the growth industries, but other sectors are becoming less energy efficient. The need to reduce energy costs to compete is driving the switch from oil to gas, but the growth in renewable energy has slowed because of limitations on public funding.

Box A2: World Markets

The World Markets scenario is one based on the pursuit of high and sustained growth within a global context, where trade barriers continue to be lowered, and there is a continuing focus on increasing international competition and supply chain optimisation.

Under this scenario, Northern Ireland needs to adopt a ruthless focus on the development of high-value products and services to protect its economy from being undercut by regions with lower labour costs. Greater deregulation is undertaken to reduce its cost base.

Economy: Support from central government is cut and less competitive sectors decline more rapidly, resulting in high unemployment. Investment in high technology sectors is increased, resulting in high levels of economic growth and creating some local 'hot spots'.

Society: Intense competition for employment in a highly deregulated economy increases migration and disrupts social cohesion. The gap between the rich and poor increases further.

Environment: Strategic economic priorities increase the pressure for development in high technology areas and investment in environmental improvement projects decreases.

Progress towards a low carbon economy: Energy efficiency is a low priority in growth industries (potentially locking-in high carbon use), but the rapid decline of some sectors eliminates older, less efficient plant. Competitive pressures drive the switch from oil to gas, but the growth in renewable energy stalls as public funding is reduced.

Box A3: Local Stewardship

The Local Stewardship scenario assumes there is a major shift in emphasis towards recognising and conserving regional assets, and that society accepts significantly lower levels of economic growth and the contraction in less 'environmentally friendly' sectors.

Under this scenario, regional decision-makers have responsibility for developing a more balanced economic strategy, resulting in a greater emphasis on sustainable development.

Economy: The focus on sustainability encourages the development of niche markets, particularly in environmental products/services. The natural beauty of Northern Ireland helps to increase tourism. Economic growth is low and unemployment is medium–low.

Society: Policy-making involves extensive public consultation and citizen involvement, as attention focuses on protecting the local environment and supporting community projects.

Environment: Environmental issues are a priority and fundamental to the quality of life, but lower growth restricts the funds available for major environmental improvements.

Progress towards a low carbon economy: Commitment to energy efficiency is high but investment levels are low, particularly in the industrial, domestic and transport sectors. The switch from oil to gas is accelerated by environmental concerns, and there is substantial growth in renewable energy as local opposition to its introduction decreases.

Box A4: Global Sustainability

The Global Sustainability scenario envisages a world in which sustainable development takes precedence over local economic needs. It suggests a more regulated economy, which is focused on a rapid transformation of the world to a low carbon economy.

Under this scenario, investment is diverted from the development of high technology into environmental improvement projects, and older inefficient industries are closed. There is a marked change in social expectations and greater international co-operation generates a sense of urgency and focus on combating climate change and sustainable development.

Economy: Increased investment in environmental improvement projects creates growth in the service sector, but increased regulation reduces the scope for economic development in other sectors. As a result, growth is medium–low and unemployment is medium–low.

Society: Greater concern for the environment and over the effects of climate change result in more individual and community initiatives on adopting sustainable 'lifestyles'. There is a loss of personal freedom, particularly in the mode of travel and leisure activities.

Environment: Environmental protection is paramount and issues such as biodiversity, water conservation and energy efficiency are factored into all local planning decisions.

Progress towards a low carbon economy: Energy efficiency increases rapidly as a result of investment, but fuel poverty increases as employment increases. Renewable energy resources are exploited to the full, but depend on high levels of public subsidy.

Box A5: Business As Usual

The Business As Usual (BAU) scenario assumes current trends in the economy, society and environment largely continue. However, account is taken of on-going strategic initiatives and targets including those set by the Northern Ireland Economic Development Forum [4,5].

Economy: Under BAU, the Northern Ireland economy grows at a faster rate than the UK as a whole, partly reflecting recent improvements in the political and security climate. This growth is underpinned by increased business investment in R&D and high technology. As a result, economic growth is medium–high and unemployment is low.

Society: Increasing social cohesion and involvement of disadvantaged groups result in a better educated workforce, with high levels of competence in ICT and foreign languages.

Environment: Environmental issues and the quality of life are increasingly important, but the major strategic priorities are on economic growth, social cohesion and devolution.

Progress towards a low carbon economy: Energy efficiency increases slowly as the Northern Ireland economy expands, but growth in transport energy use is rapid. The switch from oil to gas progresses rapidly, but the transformation is driven by economics and does not expand to its full potential. There is a slow but steady growth in renewable energy.

4 The development of a Business As Usual scenario

The main assumption behind a Business As Usual (BAU) scenario is that the economy will continue on its current path with no major shift in Government policy. Hence, the scenario would normally involve the extrapolation of trends in the Northern Ireland economy from 1990–2000, including any underlying trends in efficiency.

However, due to a lack of historical data on energy use and trends, and levels of energy efficiency within Northern Ireland, the BAU scenario had to be derived in four steps from UK-wide energy statistics, survey reports and strategy reviews.

1 A 'trends continued' baseline projection was developed based on work carried out by the Interdepartmental Analysts Group (IAG) [6] and the Energy Review published by the Performance and Innovation Unit (PIU) [7].

2 This baseline projection was adjusted to compensate for the effects of the climate change programme. The resulting BAU scenario assumes that a 15–20% improvement in energy efficiency is realised by 2010/2012.

3 The resulting BAU scenario was compared with the bottom-up estimates from the sector annexes and adjusted for consistency.

4 Finally, a year 2000 baseline for Northern Ireland carbon dioxide emissions was developed from the results of the Northern Ireland Energy Study (see Section 5).

The BAU scenario assumes that the Northern Ireland economy will grow at 2.9% per year over the next 50 years and that the productivity gap (in terms of gross domestic product (GDP) per capita) between Northern Ireland and the UK is closed. This assumption is in line with the current economic strategy, which is targeting a 25%+ growth in industrial output by 2010 and the development of a prosperous knowledge-based economy within Northern Ireland allied to a gradual shift in industrial production from low-tech to high-tech products.

The economic development strategy [4] includes targets (see Table A2) for increasing expenditure on the transport infrastructure by 50% and states that economic growth is dependent on increasing exports and improved roads.

Combined with increasing disposable incomes and expanding air networks within the EU, Business As Usual will result in increasing CO_2 emissions across the industrial, commercial and transport sectors in Northern Ireland unless economic growth is progressively decoupled from the consumption of (high) carbon-based fuels or increased mobility.

Table A2 Northern Ireland economic development targets for 2010

Target	1999	2010
GDP per head as percentage of the UK average	80%	90%
Average weekly earnings as percentage of UK	86%	91%
Employment growth (per year)	0.5%	1.5%
Percentage of workforce in long-term unemployment	4%	2%
Registrations of new business per 10,000 population	31	40
Exports as percentage of Northern Ireland GDP	21%	30%
Percentage of employment in high-tech industries	2.9%	6%
Percentage of workforce qualified to Level 4 or above	23%	35%
Business R&D as percentage of GDP	0.6%	1.5%
Investment in roads as percentage of GDP	1%	1.5%

5 Establishing a base year for RCEP comparisons

The RCEP used 1997 as the base year for its recommendation of a 60% reduction. The baseline year for the Northern Ireland Energy Study [8] was 2002 because this was the only year for which adequate data on energy supply and demand could be assembled.

Due to the rapid uptake of natural gas, which was first introduced to Northern Ireland in 1996, carbon dioxide emissions declined substantially between 1997 and 2002. As it was not within the scope of this project to compile a baseline dataset for 1997, it was agreed to develop a year 2000 base year by assuming energy demand remained constant and backtracking the uptake of gas using sales figures from electricity, gas and coal suppliers. This method gave a 3.2% reduction in Northern Ireland carbon dioxide emissions since 2000, which has been factored into the RCEP comparisons presented in this annex[6].

Table A3 outlines the estimated energy demand in GWh delivered (d), fuel mix as a percentage and carbon footprint in kilotonnes of CO_2 ($ktCO_2$) for each sector in 2000. The most noticeable changes are:

- A scaling back on gas use in all sectors (excluding electricity supply) to balance natural gas use and sales data
- A reduction in transport fuel use and an increase in oil and coal consumption.

A row called 'Unallocated' has been added to accommodate the fuel difference between energy demands in 2002 and the energy supply figures for 2000. Most of this row relates to increased use of electricity and heating fuel.

It was not possible within the scope of this project to validate these fuel splits at a sector level and the figures for natural gas seem low compared with those reported in the Northern Ireland Energy Study [8]. However, these fuel splits generate an overall total that is consistent with known natural gas sales in 2000, and any discrepancy in the year 2000 figure is relatively unimportant to the long-term projections in this annex.

[6] The estimated total reduction in NI carbon dioxide emissions between 1997 and 2002 is around 5%. This figure was derived from fuel imports data published by the Department of Enterprise, Trade and Investment (DETI) and other available data. However, further work is needed to validate the assumptions made in this estimation about fuel mix in electricity generation, gas sales, aircraft movements and invisible imports of petrol/derv from the Republic of Ireland (RoI).

Table A3 Northern Ireland energy use and carbon emissions in 2000

Sector	Energy use GWh(d)	Solid fuel %	Oil products %	Natural gas %	Electricity %	Carbon footprint $ktCO_2$
Electricity supply	10,949	47	4	46	3*	†
Agriculture	690	19	42	7	32	281
Industry	6,440	4	52	8	36	2,699
Construction	296	15	43	7	35	125
Commercial	1,810	17	50	8	25	677
Public sector	2,134	3	41	20	36	890
Domestic	17,520	29	48	1	22	6,511
Transport	12,427	–	100	–	–	3,020
Unallocated	2,783	–	70	–	30	1,093
Total#	**55,049**	**20**	**52**	**12**	**16**	**15,296**

*Includes output to grid from renewable energy sources (1.5%) and combined heat and power (CHP) systems (0.1%).

† Carbon dioxide emissions from the electricity supply industry (6,542$ktCO_2$ in 2002) have been allocated pro-rata to the users of electricity to obtain a carbon footprint for each sector.

Fuel split excludes fuel used in electricity production (see first row of table for these data).

6 Modelling energy demand and carbon use

The four Foresight scenarios depict the pattern of energy use for a range of possible futures. None include a concerted effort to reduce carbon dioxide emissions. However, fuel switching and energy efficiency measures are factored into the energy demand and supply projections for each of the scenarios as and when they meet the prevailing investment and selection criteria.

The energy demand and carbon dioxide projections presented in this annex are based on a set of interconnected economic models of consumption in the electricity supply industry and seven other sectors (see Table A3).

Assumptions about key influences behind energy use and carbon dioxide emissions are factored into the models (see Appendix 2). These include:

- Economic growth and structural changes
- Energy productivity, energy efficiency and fuel mix
- Transport demands, modal shifts and fuel efficiency levels
- Housing stock and quality, family structure and personal lifestyles
- Electricity generation plant/mix, including renewable and CHP obligations.

Changes in energy prices consistent with each of the scenarios are also modelled implicitly through the assumptions made, as are issues such as anticipated improvements in the energy efficiency of energy supply and energy demand technology.

The level of disaggregation of the energy demand sectors within the models is less than that used in UK studies by the IAG and PIU [6,7] and in national energy demand forecasts [9]. This was partly due to time constraints, but a more fundamental reason was the lack of historical data on energy use in Northern Ireland at a more disaggregrated level.

To assist future decision-making, it is recommended that action is taken to ensure that detailed energy data are collected and collated for each major Northern Ireland sector.

Within the model, energy demand in each of the eight sectors consists of a number of relationships that link trends in energy demand to related variables such as economic output and population. These equations implicitly incorporate historical trends in energy efficiency at a national level which, given the lower energy intensity of Northern Ireland industry, may over-estimate the natural rate of uptake in energy efficiency measures. It could also be argued that the take-up of energy efficiency measures should be higher due to the higher costs of energy in Northern Ireland, but there is little evidence from historical trends and site surveys to support this claim.

To assist future decision-making, action should be taken to measure levels of capital investment in energy efficiency measures and to assess the true scope for savings.

The choice of whether or not to invest in energy saving technology depends on:

- The availability and cost of the technology
- The perceived payback to the investor in terms of cost base, personal comfort, social responsibility and functional utility.

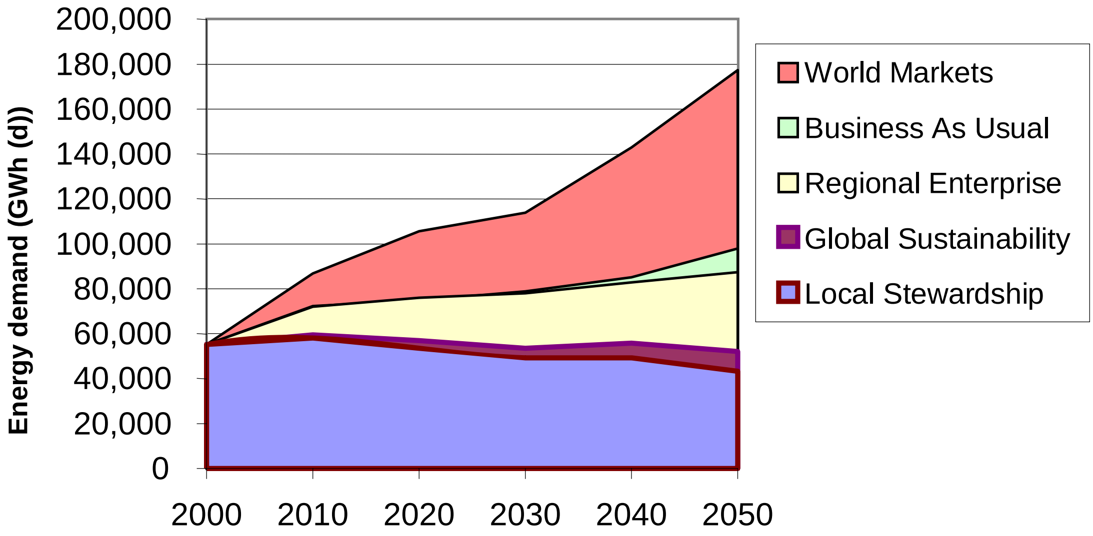
Various estimation techniques have been used in UK studies to appraise the likely impact of these factors on the uptake of different energy saving technologies, but their application was beyond the scope of this study. Instead, the scenario development work relied on expert judgement of the likely take-up of energy efficiency measures under different scenarios. The assumptions used were reviewed by those involved in preparing the other annexes, and adjusted to reflect discussions.

7 Energy use and carbon emissions under the scenarios

The predicted energy use and carbon dioxide emissions under the five scenarios are shown in Figures A3 and A4, respectively. The effects of the adoption of energy efficiency measures can clearly be seen in the two lower growth scenarios (Regional Enterprise and Local Stewardship) and, under Global Sustainability, where higher levels of growth are counterbalanced by a major step change in Northern Ireland's building regulations and the adoption of all technically possible energy efficiency measures in all sectors.

Another major feature highlighted by all the scenarios is the effects of the uptake of natural gas within Northern Ireland on its carbon footprint between 2000 and 2025.

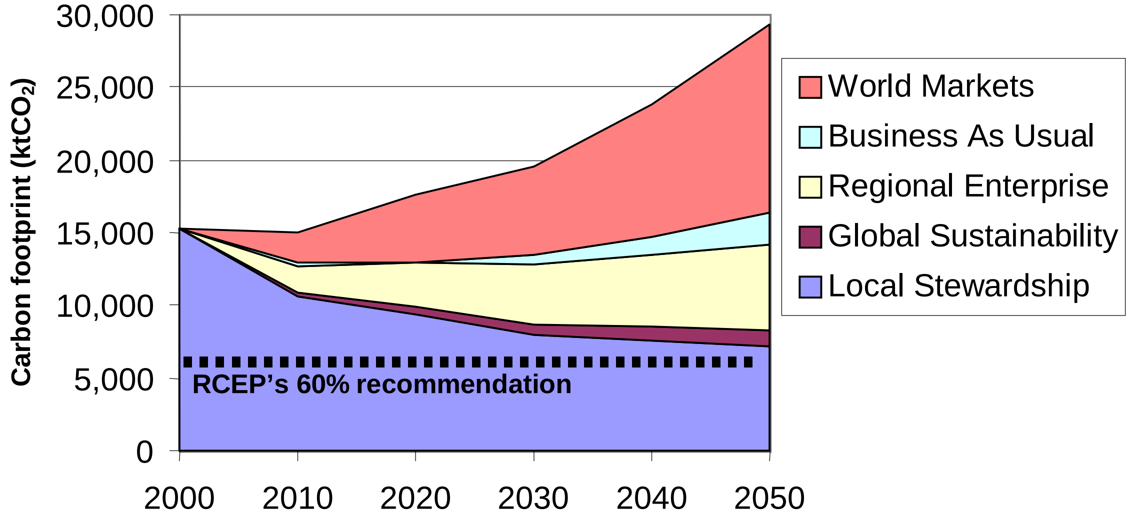
Figure A3 Northern Ireland energy demand under the scenarios



The RCEP's 60% recommendation is not realised under any of the scenarios, but carbon dioxide emissions are projected to decrease by 54% over 50 years under the Local Stewardship scenario, which assumes lower growth and a tightly regulated economy. Another scenario, Global Sustainability, illustrates how carbon dioxide emissions could decrease by 46% while maintaining a more attractive level of economic growth. However, this scenario assumes the implementation of all technically possible energy efficiency measures and the extensive use of renewable energy and CHP systems.

Under the two remaining scenarios, World Markets and Regional Enterprise, carbon dioxide emissions initially decline as a result of fuel switching but then begin to rise as a result of economic and population growth. These scenarios are not discussed further in this annex, but illustrate the range of carbon dioxide emissions that might result if sustainable development policies are not adopted by government and society does not adopt lower carbon lifestyles.

Figure A4 Northern Ireland's carbon footprint under the different scenarios

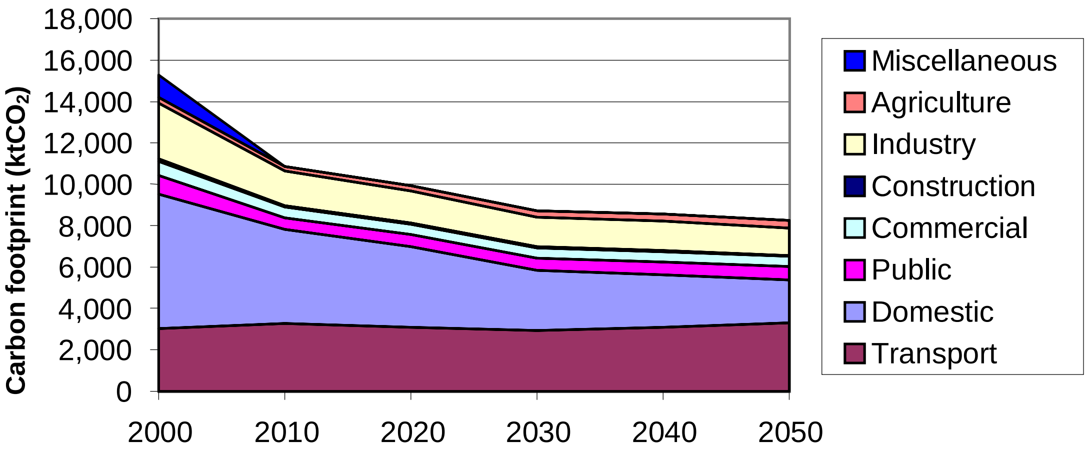


8 Understanding the Global Sustainability scenario

Figure A5 illustrates how the carbon footprint of each sector changes over time under Global Sustainability. The key features are the early realisation of energy efficiency savings in industry and the services sectors, followed by a period when the carbon footprint of these sectors is prevented from rising by gains in energy productivity.

In the domestic sector, carbon intensity is reduced by Scandinavian (or Swiss) style building regulations and the progressive development of low/zero emission houses. Transport emissions are also kept in check by encouraging sustainable lifestyles, but over time become the major source of carbon dioxide emissions in Northern Ireland.

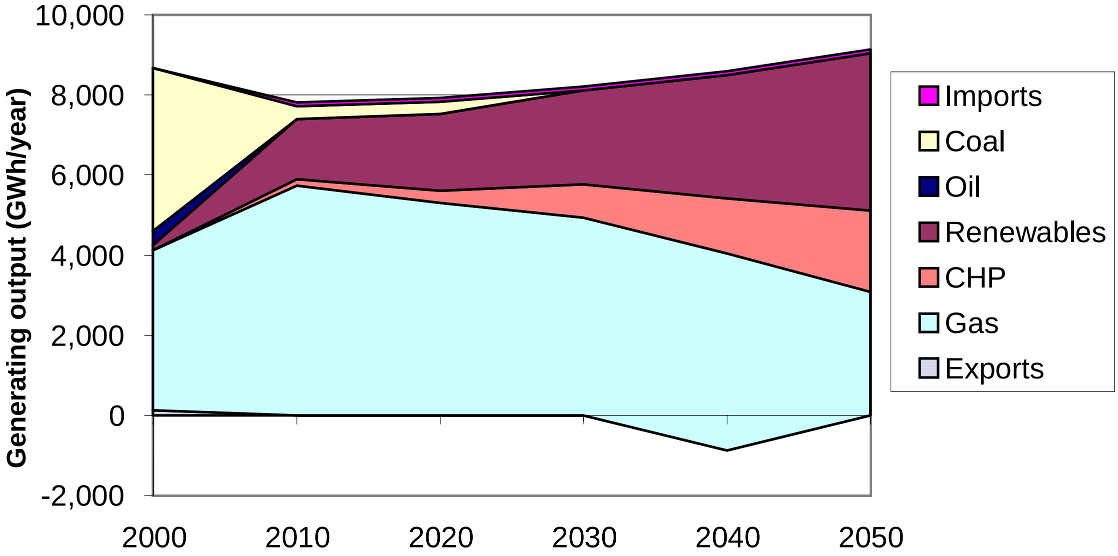
Figure A5 Sector impacts under Global Sustainability



Another major measure undertaken under Global Sustainability is the decarbonisation of the electricity supply industry. This involves ramping up the use of renewable energy sources and CHP (see Figure A6), phasing out the use of coal by 2025, and reductions in gas use as these schemes come on line. There are some key exports of electricity to the RoI or UK markets to maintain the economics of gas generating plant[7].

[7] Exports of electricity are represented by the negative portion of Figure A6.

Figure A6 Electricity generation by fuel under Global Sustainability



The plans in Annex E suggest there would be excess generating capacity by 2050 (see Figure A7), which may well be used to export electricity to the UK market and the RoI. Here it may be that a third combined cycle gas turbine (CCGT) plant may not be built, but this depends on whether it is cheaper to import 'green' electricity from Scotland.

Strategically it may also be necessary to maintain the extra generating capacity to cope with peaks in demand and the intermittent nature of renewable energy sources. This excess capacity could also be a key part of an All-Island electricity market.

One issue of concern is the security of supply and the potential depletion of affordable oil and gas reserves by 2025. Under this scenario, the Northern Ireland economy would still be dependent on petroleum-based fuels (see Figure A8) and there is a risk that economic growth will be stunted by increasing energy prices – although it could force radical changes in transport demands/modes.

One way of overcoming this problem would be to use coal to oil/gas conversion technology to exploit the UK's extensive coal reserves. To minimise carbon dioxide emissions, this would require expensive carbon capture and storage systems to be installed so that carbon dioxide could be injected into depleted oil and gas wells.

Figure A7 Generating capacity by fuel under Global Sustainability

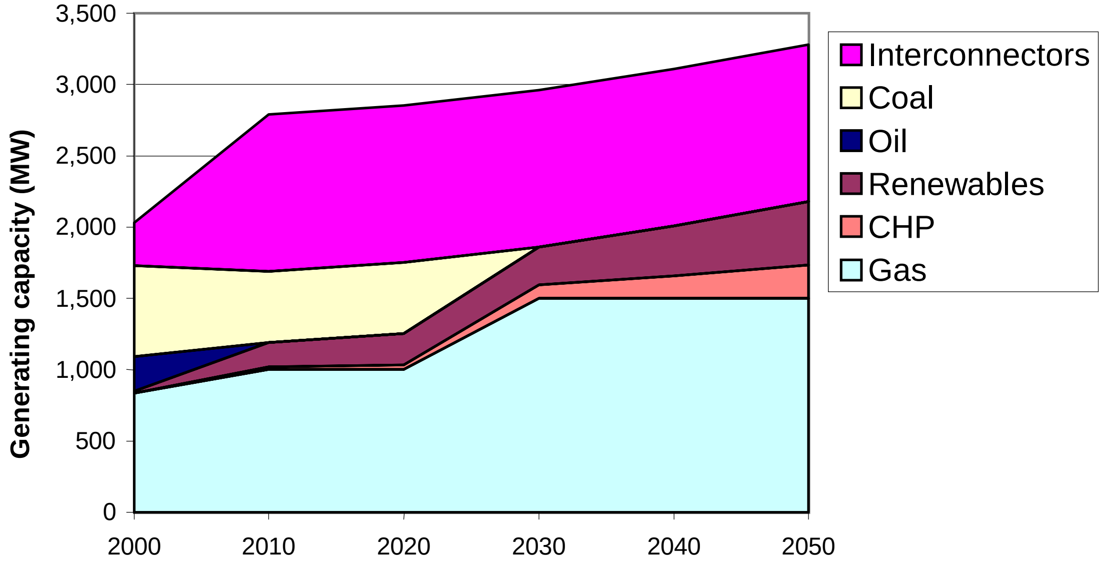
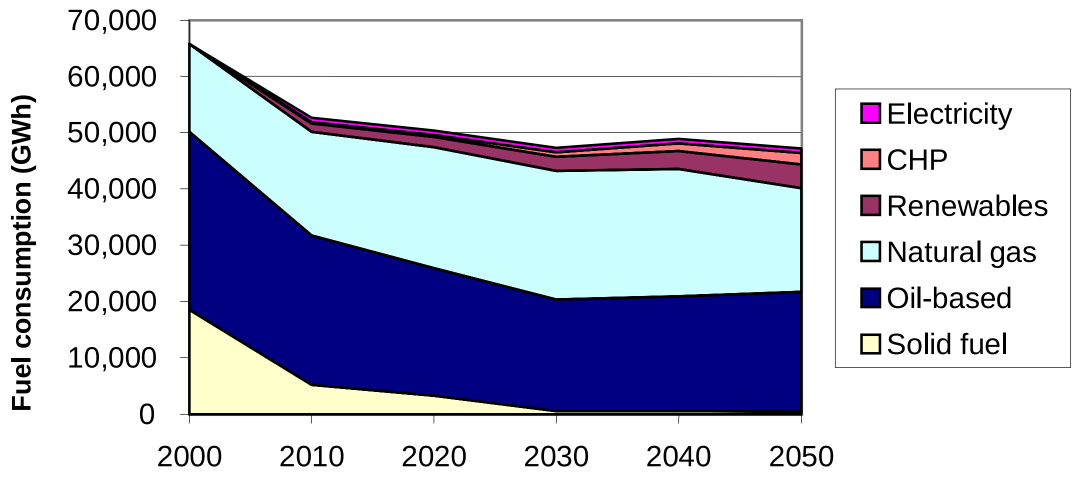


Figure A8 Fuel use by type under Global Sustainability



9 Alternative scenarios

Discussions produced some 80 ideas on how carbon emissions could be reduced by 2050. Table A4 outlines a small selection of these ideas as to how Northern Ireland could reduce its dependency on oil and gas, with a brief analysis of their advantages and disadvantages.

Table A4 Further options for reducing carbon emissions by 2050

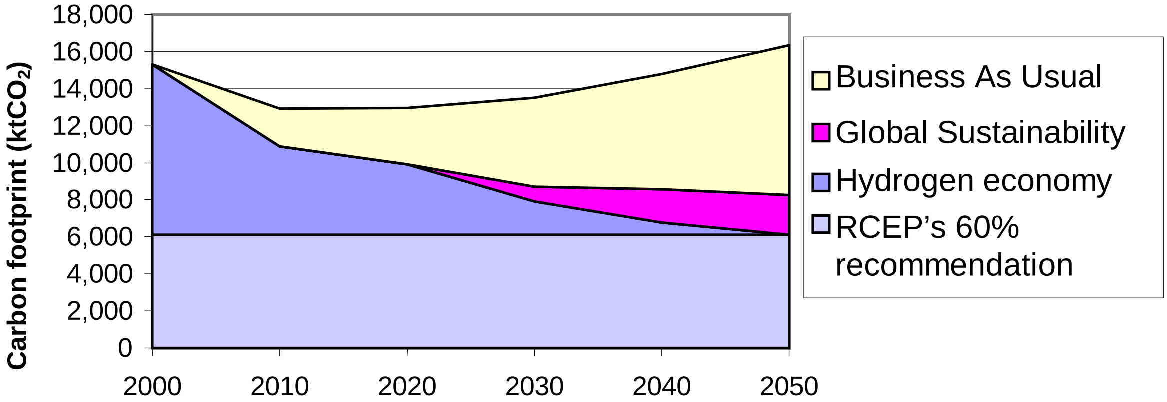
Option	Advantages	Disadvantages
'The hydrogen economy'	Enables exploitation of intermittent renewables	New infrastructure required? Technology not yet proven
Knock down inefficient offices/factories/homes	Creates local jobs Can redesign transport links	Expensive and not very popular! Disrupts profitable businesses.
Nuclear power (fission)	Existing technology Limited infrastructure costs	Environmental risks/costs High costs of waste disposal
Nuclear power (fusion)	Unlimited clean energy Uses existing infrastructure	Uncertain time horizon NI too small to justify reactor?
Rail tunnel to UK via Scotland or RoI	Removes freight from roads Could reduce air travel	Capital cost/long payback period Distance from EU markets

Of these ideas, the hydrogen economy stimulated the most discussion. Modelling was therefore carried out to understand the magnitude of the change needed to deliver the extra 14% reduction in carbon dioxide emissions over Global Sustainability needed by 2050 to reach the RCEP's 60% recommendation.

Figure A9 shows the envisaged timeline for the development of a hydrogen economy, which would need to be phased over 25 years to meet the RCEP's 60% recommendation. Under this scenario, hydrogen is derived from renewable energy using fuel cells and used to power vehicles. Hydrogen could also be added progressively to the natural gas system to reduce fossil fuel consumption across all sectors. The existing gas system could probably accommodate a 5–10% hydrogen dilution without requiring substantial investments in infrastructure.

The amount of hydrogen needed for this scheme has not been quantified, but to achieve the RCEP's 60% recommendation, the models suggest that some 80% of petrol and diesel vehicles would need to be replaced with hydrogen-powered vehicles to realise an additional reduction of 2,200ktCO_2. This could be reduced to 50% of vehicles if natural gas dilution rates similar to those in old town (coal) gas (i.e. 40%) were adopted. This would require an additional 3,000MWh of renewable capacity to generate 25,000GWh/year which, while technically feasible, is not a 'quick and easy' route to the RCEP's 60% recommendation.

Figure A9 Northern Ireland and the hydrogen economy



10 Costing the transition

A detailed assessment of the costs of transforming Northern Ireland into a low carbon economy would require an extensive review of the costs, performance and emissions of alternative supply and demand technologies, and likely rates of market adoption. Although such a review was beyond the scope of this study, a simple ballpark estimate of likely costs can be obtained by using the costs of abatement reported in national studies [10] commissioned by the Department of Trade and Industry (DTI) and the Department for Environment, Food and Rural Affairs (Defra) as part of the IAG study and the PIU review. This work showed it was technically possible to reduce UK carbon dioxide emissions by 60% by 2050 at an average cost to the UK economy of 0.01% to 0.02% of GDP. The total overall loss was between 0.5% and 2% of UK GDP by 2050, which is equivalent to around 2.5 months of lost growth[8].

Table A5 shows the marginal costs of abatement under Global Sustainability derived from this work, which are based on achieving reductions in UK carbon dioxide emissions of 30% by 2030, 45% by 2040 and 60% by 2050 in each sector of energy demand.

Table A5 Marginal costs to the UK of CO_2 abatement in different sectors under Global Sustainability

Sector	Cost (£/tonne of CO_2)		
	2030	2040	2050
Industry	85	35	57
Services	74	55	78
Domestic	56	90	144
Transport	37	89	124

Using the marginal abatement costs given in Table A5 for the UK to estimate the cost of moving to a low carbon economy gives the costs shown in Table A6[9] for Northern Ireland. Overall, this cost corresponds to £75/tonne of CO_2, which is similar to the figure of between £55/tonne and £82/tonne of CO_2 given in the 2003 Energy White Paper [11] for the UK as a whole.

These costs are ballpark figures that take no account of structural differences between Northern Ireland and the UK, and the greater economies of scale that are factored into the UK-wide abatement costs. The scenarios [12] on which the marginal costs are based also assume a substantial worldwide advance in, and reductions in the costs of, low carbon technologies. They also assume there are no limits on the supply of natural gas and oil.

[8] This conclusion had been reached after a detailed assessment using the International Energy Agency's MARKAL models and a database containing cost and performance data on current and prospective technologies for the supply, conversion, transmission and use of energy. This database had been compiled from a range of sources and was subjected to peer review by Government departments, industry and academia.

[9] The abatement costs shown in Table A6 were estimated by extracting the difference in carbon footprint between the hydrogen economy line and the Business As Usual line in Figure A9 at 2030, 2040 and 2050 broken down by sector, and then multiplying these figures by the abatement costs shown in Table A5.

Table A6 Estimated costs of moving to a low carbon economy in Northern Ireland

Sector	2050 target for $ktCO_2$/year reductions	Cost of CO_2 abatement (£ million)
Industry	1,229	86
Services	640	46
Domestic	2,118	184
Transport	6,310	461
Total	**10,297**	**777**

If a wider range of scenarios is considered [13], then the total cost to the UK of reducing CO_2 emissions by 60% by 2050 (i.e. by 238,000$ktCO_2$/year) ranges between £17 billion and £170 billion – although the majority of scenarios result in estimates of between £30 billion and £60 billion. The pro-rata cost for Northern Ireland from these latter figures is between £1.25 billion and £2.5 billion.

11 Concluding remarks

This annex describes the development of a set of scenarios that have been used to explore how carbon dioxide emissions in Northern Ireland might change between 2000 and 2050 under a range of different market conditions. These scenarios were constructed under the framework established by the UK Foresight Programme and the UKCIP's regional adaptation methodology.

These types of scenario have been widely used in UK national studies to understand the level of change needed to cut carbon dioxide emissions to achieve the 60% reduction recommended by the Royal Commission on Environmental Pollution. This study sought to adapt these scenarios to assist with the identification of policy options for the Carbon Trust in Northern Ireland and to facilitate the development of a vision for the development of a prosperous, low carbon economy in Northern Ireland by 2050.

An initial conclusion from the scenario development was that, if the economy continues to grow at current rates, Northern Ireland carbon dioxide emissions are set to return to, or exceed, year 2000 levels by 2050 unless major initiatives are undertaken to decouple economic activity and lifestyles from the consumption of high carbon fuels.

The scenarios explored a wide range of possible futures ranging from a rapidly growing, lightly regulated economy (World Markets) to a tightly regulated, lower growth economy (Local Stewardship). This latter scenario came closest to realising the 60% reduction in carbon dioxide emissions recommended by RCEP with a 54% reduction. Another scenario, Global Sustainability, illustrated how carbon dioxide emissions could be reduced by 46% while maintaining an attractive level of economic growth. However, this was only realised by assuming a step change in Northern Ireland's building regulations and the adoption of virtually all technically possible energy efficiency measures in all sectors. Thus, early action is needed to upgrade the building regulations to ensure these changes deliver the maximum possible change in energy demands and carbon emissions by 2050.

A number of options for achieving the RCEP's 60% recommendation were explored, including the development of a hydrogen economy in which hydrogen derived from renewable energy is used as a fuel by cars, and hydrogen is mixed into the natural gas system to reduce fossil fuel consumption across all sectors. However, radical change in technology would be needed for the hydrogen economy to succeed.

Several other options were also identified, but not taken further due to time constraints. However, there is scope within them for reaching the RCEP's 60% recommendation further work is needed to assess the technical feasibility, economic viability and political acceptability of these and other options.

The implications of reducing carbon dioxide emissions by 60% on the development of an All-Island energy market were briefly explored. The main conclusion was that the development of a low carbon economy could free up generating capacity in Northern Ireland that could be used to provide electricity to the RoI, and that an All-Island market might create a larger electricity network more able to exploit intermittent renewable energy sources from more remote parts of the island.

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Acronyms and abbreviations

BAU	Business As Usual
BRE	Building Research Establishment
CHP	combined heat and power
CO_2	carbon dioxide
(d)	delivered [energy]
Defra	Department for Environment, Food and Rural Affairs (London)
DETI	Department of Enterprise, Trade and Investment
DTI	Department of Trade and Industry (London)
FES	Future Energy Solutions
GDP	gross domestic product
GS	Global Sustainability
IAG	Interdepartmental Analysts Group
ICT	information and communications technology
kt	kilotonnes
LS	Local Stewardship
NI	Northern Ireland
NVQ	National Vocational Qualification
PIU	Performance and Innovation Unit
RCEP	Royal Commission on Environmental Pollution
RE	Regional Enterprise
RoI	Republic of Ireland
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research
UKCIP	UK Climate Impacts Programme
WM	World Markets

Appendix 1

Anticipated social and economic trends under the four UK Foresight scenarios for 2010

The UK Foresight Programme developed its four scenarios to cover the period up to 2020 and published a set of indicators of UK economic and social trends (see Table A7) to enable their use in a consistent way, including lists of declining and growth sectors (see Table A8). These indicators were the starting point for scenario development, although equivalent indicators for Northern Ireland were incorporated into the scenarios and models.

Table A7 Foresight Programme indicators of economic and social trends

Indicator (2010)	Today (2000)	World Markets	National Enterprise	Global Sustainability	Local Stewardship
GDP growth/year	2.5%	3.5%	2%	2.75%	1.25%
Investment (% GDP)	19%	22%	18%	20%	16%
Value added					
Services	66%	75%	68%	72%	70%
Production	27%	20%	25%	22.5%	22%
Construction	5%	4%	5%	4%	5%
Agriculture	2%	1%	2%	1.5%	3%
Transport					
Growth/year in passenger miles	2%	2%	1%	1.5%	0%
Congestion levels	6%	11%	13%	9%	5%
Social					
Unemployment	5%	5%	8%	4%	5%
% in poverty (<60% of median income)	18%	23%	25%	15%	10%
Life expectancy	67 years	68.5 years	67.5 years	69 years	68 years

Table A8 Foresight Programme lists of declining and growth sectors

Scenario	Declining sectors	Growth sectors
World Markets	Manufacturing Agriculture	Health and leisure Media and information Financial services Biotechnology/nanotechnology
National Enterprise (cf. Regional Enterprise)	Public services Civil engineering	Private health and education Domestic and personal services Tourism and retailing Defence and related industries
Global Sustainability	Fossil fuel technologies Traditional manufacturing	Education and training Large engineering New and renewable energy Information services
Local Stewardship	Retailing Tourism Financial services	Small manufacturing Food and organic farming Local services

Table A9 highlights some key differences between the NI and UK economies, which were considered during scenario development. These values have been compiled from the Office of National Statistics, the Northern Ireland Statistics and Research Agency (NISRA), DETI, the Department of Health, Social Services and Public Safety (DHSSPS) and other Government websites. Of particular note are the statistics on the transport sector, which is likely to expand as the NI economy grows and incomes/wealth (GDP) rise to the levels in the rest of the UK.

A range of other statistical data were used in scenario development. These are detailed in Appendix 2 along with the assumptions made under each scenario. In most cases, Northern Ireland economic statistics from 2000 to 2002 underpin the models, along with historical trends from recently published UK regional accounts for 2000.

Table A9 Key differences between NI and UK economies

Indicators		NI	UK	NI/UK ratio
Economic activity (2000)				
Gross Domestic Product (£ billion)		18	838	2.1%
Gross Valued Added (GVA) per head (£)		11,311	14,852	76.2%
% GVA (2000)				
A	Agriculture, fisheries and forestry	4%	1%	400%
C	Mining and quarrying	0.5%	0.5%	100%
D	Manufacturing	20%	19%	105%
E	Electricity, gas and water supply	2%	2%	100%
F	Construction	7%	5%	140%
G	Wholesale and retail	12%	12%	100%
H	Hotel and restaurants	3%	3%	100%
I	Transport, storage and communication	6%	8%	75%
J	Financial services	3%	6%	50%
K	Other business activities	14%	24%	58%
L	Public administration	10%	5%	200%
M	Education	7%	6%	116%
N	Health and social work	9%	7%	128%
Transport indicators (2000/01)				
Road fuel delivered (tonnes)		492,000	47,200,000	1%
Passenger journeys (air, rail and bus) (millions)		31	6,359	0.5%
Social indicators (2001/02)				
Unemployment rate (seasonally adjusted 2002)		5.3%	6%	88%
Average weekly household income		£347	£430	81%
Population (thousands)		1,678	58,656	3%
Percentage under 16		24%	20%	120%
Percentage at pensionable age or over		15%	18%	83%
Other indicators				
Occupied housing stock (thousands)		601	25,224	2.4%
Public sector employees (% of workforce)		31.7%	17.3%	183%

Appendix 2

Methodology and assumptions used in NI energy demand scenarios

This appendix sets out the approach for key assumptions and results derived from the development of a set of energy demand scenarios for Northern Ireland. Four scenarios, together with a Business As Usual reference have been developed, drawing on work carried out for the UK Technology Foresight Programme [12] and subsequently by the Prime Minister's PIU [7]. These studies developed scenarios that explored alternative drivers grouped under the themes of:

- **World Markets**: a world defined by an emphasis on private consumption and highly developed and integrated world trading systems

- **Regional Enterprise**: a world of consumerist and short-termist values coupled with policy-making systems that assert national and regional concerns and priorities

- **Global Sustainability**: a world in which social and ecological values are considered in economic decisions, and in which strong collective action through global institutions tackles environmental problems

- **Local Stewardship**: a world where stronger national and regional governance allows social and ecological values to play a strong role in the development of markets and behaviour.

The current work aims to apply these themes to Northern Ireland to develop internally consistent quantitative visions for energy demand to 2050.

This appendix begins by describing each scenario in more detail, setting out the main economic, social and environmental drivers expected to influence the level and pattern of energy demand. This is followed by a discussion of how these high level drivers have been translated into factors affecting energy demand.

General description of the scenarios

World Markets (WM)

This scenario depicts a world driven by material values, resulting in high levels of consumption and mobility. The trend towards globalisation in manufacturing and commerce continues at a pace – supported by a highly integrated world trading system – and the influence of national and regional governments on economic management declines. Global efforts towards sustainable development are not a major political goal though, with growing wealth, local environmental quality is highly valued.

Energy markets continue to be dominated by fossil fuels, particularly natural gas, although the sheer size of demand requires recourse to more remote sources. In the second half of the time period, additional sources of energy are needed in increasing quantities including non-conventional oil reserves and a return to coal.

The materialistic culture leads to a strong growth in demand for energy services from both individuals and organisations, with little concern for energy efficiency except where this meets the present criteria apparent in financial decision-making.

For the UK, overall economic growth averages 3.0% per year. Manufacturing industry grows below this rate and consequently accounts for a decreasing share of the total economy. Initially Northern Ireland's economy grows faster than the UK average, such that per capita GDP reaches the UK average by 2030. After 2030, Northern Ireland's economy grows at the same rate as the rest of the UK. The share of GDP accounted for by Northern Ireland manufacturing also declines such that it has the same share as the rest of the UK by 2030.

Encouraged by the dynamism of the Northern Ireland economy, population grows on average by 0.75% per year over the full 50-year period.

Regional Enterprise (RE)

This scenario envisages a world driven by material values combined with the pursuit of narrow national and regional interests. Economic policy aims to protect and support business against international competition. Sustainable development is not a major political goal and other environmental issues are secondary to wealth creation.

Constrained by capital availability, overall UK economic growth is sluggish and averages only 1.5% per year, with manufacturing industry retaining its share of GDP. The Northern Ireland economy grows a little faster at 2.0% per year, achieving some convergence with the UK in per capita terms. Northern Ireland manufacturing retains its share of economic activity.

Northern Ireland population growth follows recent trends, increasing by an average of 0.5% per year over the full 50-year period.

Global Sustainability (GS)

This scenario envisages a future in which stress is placed on balancing economic, social and environmental values on a global scale. There is a readiness to adopt sustainable technologies and patterns of behaviour.

The UK economy grows at an average rate of 2.75% per year, with manufacturing taking a smaller share but not declining as fast as in the World Markets scenario. The Northern Ireland economy grows slightly slower than the UK average due to the increasing cost of transporting goods to the UK and EU markets, but manufacturing retains its share of economic activity.

Northern Ireland population growth follows recent trends increasing by an average of 0.5% per year over the full 50-year period.

Local Stewardship (LS)

This scenario describes a world in which local and regional government is strong and places a high priority on social and environmental factors. Priority is given to using local resources with minimal environmental impact.

Economic growth is slow under this scenario, averaging 1.25% per year for the UK, but manufacturing increases its share of GDP. The Northern Ireland economy grows in step with the rest of the UK. Northern Ireland population growth is less than in recent years, increasing by an average of 0.25% per year over the full 50-year period.

Business As Usual (BAU)

Under BAU, current economic trends are assumed to continue as shown in Table A10. The main feature is the continuing growth of the service sector. This table also summarises the macro-economic parameters for all scenarios.

Table A10 Main macro-economic parameters assumed in the scenarios

UK	**Current**	**BAU**	**WM**	**RE**	**GS**	**LS**
GDP growth (% per year)	2.3	2.25	3.0	1.5	2.75	1.25
Population growth (% per year)	0.23	0.2	0.5	0.5	0.5	0.25
Northern Ireland						
GDP growth (% per year)	2.9	2.9	3.75	2.0	2.5	1.25
Population growth (% per year)	0.5	0.5	0.75	0.5	0.5	0.25
Structure of NI economy in 2050 (% of GDP)						
Agriculture	2.0	2.0	2.0	3.0	3.7	3.7
Manufacturing	21.3	20.0	16.5	19.0	17.5	21.8
Construction	7.0	6.0	6.0	7.0	5.0	5.0
Services	67.4	70.0	73.2	68.3	70.6	66.3
Other (energy and water)	2.3	2.0	2.3	2.7	3.2	3.2

Sector-specific scenario assumptions

This section describes the sector-specific assumptions made in the separate development of scenarios for energy demand for the four main sectors of consumption, namely:

- Domestic
- Industry
- Transport
- Commercial and public services.

Domestic sector

The domestic sector is complex and involves a mix of demands for energy services. In developing the scenarios, the sector was divided into four sub-sectors:

- Space heating
- Water heating
- Cooking
- Electrical lighting and appliances.

Space heating

Demand and the mix of energy sources used for space heating were assumed to be controlled by:

- Population
- Average household occupancy
- Choice of heating fuel
- Thermal efficiency of the existing housing stock
- Level of improvement in existing housing stock
- Demolition rate
- Thermal efficiency of new build
- Comfort level (internal temperature).

The thermal efficiency of the existing and new housing stock is a function of the insulation standard of the houses and the efficiency of the heating devices.

The above factors were taken as scenario variables as discussed below.

Water heating

It was assumed that water heating and space heating were provided by the same energy source. The level of energy demand was assumed to be determined by:

- Population
- Average household occupancy
- Demand for hot water per household for services (e.g. clothes washing)
- Personal demand
- The efficiency of the supply device.

These factors were taken as scenario variables as discussed below.

Cooking

The energy supply for cooking was assumed to come from the same source as that used for space and water heating. This is clearly a poor approximation because many households choose to use electricity while using another fuel for space/water heating. However, no data were available to support a more disaggregated estimate.

The level of energy demand was assumed to be determined by:

- Number of households
- Demand for cooking
- Efficiency of cooking devices.

These factors were taken as scenario variables as discussed below.

Electrical lighting and appliances

Electricity demand for the operation of lighting and appliances was assumed to be determined by:

- Number of households

- Demand for electrical services per household
- Efficiency of appliances/devices.

These factors were taken as scenario variables as discussed below.

Preparation of the domestic sector scenarios

The baseline for the scenario projections was taken to be the year 2000. The key data needed and the sources used to establish this baseline are listed in Table A11. Where year 2000 data were not available, but data for other years were, the baseline was estimated by interpolation or extrapolation. Where baseline data were not available for Northern Ireland, the data were estimated by scaling from UK data.

Table A11 Generic parameters and data sources used in preparing domestic sector demand scenarios

Parameter	Data source
Population	2001 Census
Number of households	2001 Census
Number of households using each fuel	Estimated from BRE data on current fuel mix
Demolition rate	FES data
Average internal temperature	Assumed equal to BRE estimate for GB
Proportion of fuel used for space heating	BRE estimates

Using an analysis made in support of the UK Energy Review [7], the ratio of potential heat demand for new build houses compared with the 2000 average was estimated separately for each heating source. The results are listed in Table A12 and take account of the standard of insulation, the efficiency of boilers, etc. The scenarios were used to investigate the implications of achieving different levels of energy efficiency for space heating in new build housing using the values in Table A12 as the maximum attainable. To simplify the calculation, central values for the maximum improvement level were used covering all four heating sources (i.e. natural gas, oil, solid fuel and electricity).

Table A12 Potential energy demand for space heating in new build housing relative to the year 2000 average

	Gas	Electricity	Solid fuel	Oil	Average
2010	20%	25%	27%	23%	24%
2020	16%	19%	21%	18%	18%
2030+	11%	15%	13%	12%	13%

Other work undertaken in support of the UK Energy Review was used to relate the demand for space heating to the average internal temperature. This assumed that the energy demand increased by 10% for each 1ºC rise in internal temperature.

The scenario assumptions for each of the variables described above are listed for 2050 in Table A13. Key features of these assumptions include:

- The population was assumed to grow fastest in the World Markets scenario due to increased immigration and reduced emigration encouraged by the faster economic growth. Population increased most slowly in the Local Stewardship scenario due to the low rate of economic development and the inward focus of policies in the region.

- The trend to lower household sizes accelerates in the World Markets scenario, but is slowed or halted in the Global Sustainability and Local Stewardship scenarios where the emphasis on social values and the community (combined with lower wealth creation in Local Stewardship) encourages greater family integration.

- The energy mix changes considerably as natural gas becomes available. This is assumed to occur to the same extent across all scenarios.

- The demolition rate is highest in the World Markets and Global Sustainability scenarios, driven in the former by a demand for better properties and in the latter by a desire to improve the housing stock. Demolition is lowest in the Local Stewardship scenario because the slow growth of the economy is creating insufficient wealth to do more.

- The average internal temperature maintained by householders increases most in the World Markets and Regional Enterprise scenarios where consumerist values dominate. The strong commitment to sustainable development in the Global Sustainability and Local Stewardship scenarios means that householders limit their demand for comfort.

- The strong commitment to sustainable development is manifested by greater improvements to the thermal efficiency of both existing and new houses in the Global Sustainability and Local Stewardship scenarios.

- Individual demand for energy for cooking falls in the World Markets scenario as greater wealth creation encourages more eating out and the purchase of pre-prepared food. The reverse is occurring in the Local Stewardship scenario.

Table A13 Parameters used in scenario analyses of domestic energy demand

	Current	BAU	WM	RE	GS	LS
Population growth rate (% per year)	0.5	0.5	0.75	0.5	0.5	0.25
Average household occupancy (people per household)	2.7	2.4	2.2	2.4	2.6	2.7
Heating fuel for existing houses (%)						
Natural gas	1	62	62	62	62	62
Solid fuel	44.5	5	5	5	5	5
Oil	41	20	20	20	20	20
Electricity	13.5	13	13	13	13	13
Heating fuel in new homes (%)						
Natural gas	60	70	70	70	70	70
Solid fuel	0	0	0	0	5	5
Oil	30	20	20	20	15	15
Electricity	10	10	10	10	10	10
Demolition rate (number per year)	1,000	1,000	2,000	1,000	2,000	500
Average internal temperature (°C)	17.5	18.5	20	20	18.5	18.5
Average thermal efficiency of new build*	100	50	60	60	20	40
Average efficiency improvement in existing housing stock*	100	50	70	80	40	60
Demand for hot water per household for services†	100	110	120	125	100	100
Personal demand†	100	120	150	150	100	100
Efficiency improvement of hot water supply†	100	85	85	85	75	80
Demand for cooking per person†	100	90	80	100	100	120
Efficiency improvement of cooking devices†	100	80	90	90	80	80
Demand for electrical services per household†	100	120	150	130	100	100
Efficiency improvement of electrical appliances†	100	85	75	75	65	75

*Percentage of year 2000 stock energy demand

†Year 2000 = 100

Industry sector (including agriculture and construction)

Manufacturing industry, agriculture and construction were considered separately during the scenario development, but for conciseness, these sectors are considered together here. The energy production industries are not considered here because they are examined in the supply side scenarios (see Annex E).

The main factors determining energy demand from manufacturing industry, agriculture and construction were assumed to be:

- Rate of economic growth
- Share of Northern Ireland GDP accounted for by the industry sectors
- Rate of change in energy intensity (i.e. energy consumption/value added), reflecting changes in products and production methods
- Amount of direct investment in energy efficiency methods and devices.

In addition, there is considerable potential for fuel switching as natural gas becomes available across Northern Ireland.

Different views were developed on the trends in these variables under each scenario.

World Markets

Under the World Markets scenario, NI industry is assumed to continue to operate in the same production areas, but to increase its growth rate to retain market share in an expanding world market. GDP growth for the UK overall is assumed to increase to 3.0% per year. This is significantly higher than the 2.2% per year attained by the UK between 1990 and 2000. Northern Ireland's GDP growth exceeded the UK average at 2.9% per year over this period. This differential is assumed to be maintained up to 2030 such that, by this date, Northern Ireland's GDP per capita matches the UK average.

Manufacturing industry grew more slowly – at an average of 2% per year – than the overall economy in both the UK and Northern Ireland between 1990 and 2000. It is assumed that this differential is maintained such that NI industry grows at two-thirds the rate of the overall economy. As a result, its share of GDP falls from the present 21.3% to 16.5% by 2050.

The energy intensity (total final energy consumption divided by sector value added) improved at an average rate of 1.5% per year in the UK between 1990 and 2000. The scenario assumes that global environmental issues such as climate change are given less priority than wealth creation. Consequently, there is no pressure – over and above commercial considerations – to increase energy efficiency. It is therefore assumed that this rate of improvement is maintained to 2050, but that there is no additional investment in energy efficiency.

The fuel mix in Northern Ireland differs considerably from that in the rest of the UK because natural gas has only recently become available. It is assumed that Northern Ireland will gradually adjust such that the fuel mix in the industry sector converges to that of the UK by about 2020 and thereafter stays roughly constant.

The main assumptions underlying the World Markets scenario are listed in Table A14.

Table A14 Main assumptions in the World Markets scenario for industry

	2000	2010	2020	2030	2040	2050
Population (thousands)	1,678	1,808	1,948	2,099	2,262	2,438
GDP*	100	149	222	330	455	627
GDP per capita*	100	138	191	264	337	431
Manufacturing value added (% of GDP)	21.3	20.3	19.4	18.4	17.5	16.5
Agriculture value added (% of GDP)	2.0	2.0	2.0	2.0	2.0	2.0
Construction value added (% of GDP)	7.0	6.8	6.6	6.4	6.2	6.0
Industry energy intensity*	100	86	74	64	55	47
Additional energy efficiency (% per year)	0.0	2.4	3.7	4.4	4.7	5.0

*Indexed so that year 2000=100

Regional Enterprise

Under the Regional Enterprise scenario, NI industry is assumed to attract a greater number of local entrepreneurs. As a result, industrial production grows fast enough to maintain its share of GDP while continuing to operate in the same areas. GDP growth for the UK overall is assumed to increase to 1.5% per year, lower than the 2.2% per year attained by the UK between 1990 and 2000. Northern Ireland's GDP growth is assumed to exceed the UK at an average of 2.0% per year up to 2050, reducing, but not eliminating, the deficit in GDP per capita between Northern Ireland and the UK average.

The trends in fuel mix and energy intensity are assumed to be the same as for the World Markets scenario, and no additional investment in energy efficiency is expected.

The main assumptions underlying the Regional Enterprise scenario are listed in Table A15.

Table A15 Main assumptions in the Regional Enterprise scenario for industry

	2000	2010	2020	2030	2040	2050
Population (thousands)	1,678	1,764	1,854	1,949	2,048	2,153
GDP*	100	122	149	181	221	269
GDP per capita*	100	116	134	156	181	210
Manufacturing value added (% of GDP)	21.3	20.8	20.4	19.9	19.5	19.0
Agriculture value added (% of GDP)	2.0	2.2	2.4	2.6	2.8	3.0
Construction value added (% of GDP)	7.0	7.0	7.0	7.0	7.0	7.0
Industry energy intensity*	100	86	74	64	55	47
Additional energy efficiency (% per year)	0.0	2.4	3.7	4.4	4.7	5.0

*Indexed so that year 2000=100

Global Sustainability

Under this scenario, the UK economy is assumed to grow at 2.75% per year and the Northern Ireland economy is assumed to grow at slightly less than this rate at 2.5% per year. Manufacturing industry grew more slowly than the overall economy both in the UK and Northern Ireland between 1990 and 2000, and this differential is maintained such that NI industry grows at 2.1% per year. As a result, manufacturing industry's share of GDP falls from 21.3% to 17.5% by 2050.

The energy intensity (total final energy consumption divided by sector value added) improved at an average rate of 1.5% per year in the UK between 1990 and 2000. The scenario assumes that global environmental issues such as climate change are given priority. Consequently, there is pressure, over and above commercial considerations, to increase energy efficiency. Therefore, it is assumed that a further cut in energy demand of 20% is gained through additional investment in energy efficiency.

The trends in fuel mix are assumed to be the same as for the World Markets scenario.

The main assumptions underlying the Global Sustainability scenario are listed in Table A16.

Table A16 Main assumptions in the Global Sustainability scenario for industry

	2000	2010	2020	2030	2040	2050
Population (thousands)	1,678	1,764	1,854	1,949	2,048	2,153
GDP*	100	128	164	210	269	344
GDP per capita*	100	122	148	181	220	268
Manufacturing value added (% of GDP)	21.3	20.5	19.7	19.0	18.3	17.5
Agriculture value added (% of GDP)	2.0	2.3	2.7	3.0	3.3	3.7
Construction value added (% of GDP)	7.0	6.6	6.2	5.8	5.4	5.0
Industry energy intensity*	100	86	74	64	55	47
Additional energy efficiency (% per year)	0.0	9.5	14.9	17.7	18.9	20.0

*Indexed so that year 2000=100

Local Stewardship

This scenario envisages the lowest rate of economic growth of 1.25% per year for both the UK and Northern Ireland. However, with the emphasis on local production, manufacturing industry increases its share of Northern Ireland's GDP from 21.3% in 2000 to 21.8% in 2050. Agriculture also increases its share of GDP, but construction declines to 5% by 2050 because the low rate of economic development and population growth limits the demand for new buildings.

The scenario assumes that environmental issues, including climate change, are given priority. Consequently, there is pressure, over and above commercial considerations, to increase energy efficiency. Therefore, it is assumed that a further cut in energy demand of 20% is gained through additional investment in energy efficiency.

The trends in fuel mix are assumed to be the same as for the World Markets scenario.

The main assumptions underlying the Local Stewardship scenario are listed in Table A17.

Table A17 Main assumptions in the Local Stewardship scenario for industry

	2000	2010	2020	2030	2040	2050
Population (thousand)	1,678	1,720	1,764	1,808	1,854	1,901
GDP*	100	113	128	145	164	186
GDP per capita*	100	110	122	135	149	164
Manufacturing value added (% of GDP)	21.3	21.4	21.5	21.6	21.7	21.8
Agriculture value added (% of GDP)	2.0	2.3	2.7	3.0	3.4	3.7
Construction value added (% of GDP)	7.0	6.6	6.2	5.8	5.4	5.0
Industry energy intensity*	100	86	74	64	55	47
Additional energy efficiency (% per year)	0.0	9.5	14.9	17.7	18.9	20.0

*Indexed so that year 2000=100

Transport sector

Scenario development of energy demand for this sector considered both passenger and freight transport.

For passenger transport, the scenarios were developed by considering:

- Possible future trajectories in overall demand for mobility
- The choice of transport mode
- The energy demand (fuel efficiency) of each of these modes.

The starting point was the assumption that the overall demand for mobility was linked to the size of population and individual wealth (i.e. per capita GDP).

For freight transport, the starting point was the assumption that the volume of freight transport was linked to the overall level of economic activity.

The energy required to meet any given demand for passenger mobility will depend on the mode of transport used and the efficiency of the technology. Thus, demand will be less if people choose to walk, cycle or use less energy-intensive public transport. In contrast, demand will be higher if they undertake an increasing proportion of their travel by car.

Having selected their mode of transport, the energy demand will also depend on the fuel efficiency of the technology selected and the pattern of behaviour in using the technology. For example, if, on average, people choose large cars in preference to smaller, more fuel efficient options, then the demand for energy will be greater. Also, if more cars are bought and there is less car sharing, then car utilisation will increase and so, too, will energy consumption.

Consequently, the parameters considered in developing the scenarios for passenger transport energy demand were:

- Population
- GDP
- Percentage of travel by mode (i.e. walking, cycling, bus, car, rail)
- Average car occupancy
- Average bus occupancy
- Average train occupancy
- Choice of car by fuel type (i.e. percentage of petrol and diesel)
- Car average fuel efficiency
- Bus average fuel efficiency.

It was assumed that there was little potential for increasing train fuel efficiency.

Air travel was considered separately; demand was assumed to be linked to the size of the population and the average wealth (i.e. per capita GDP).

The scenarios considered only the energy demand for freight transport by road and sea. Energy demand for road freight was assumed to be linked to the overall level of activity in the economy, and the improvement in fuel efficiency of freight vehicles. Energy for sea freight was assumed to stay flat, at the year 2000 level, across all scenarios.

World Markets

The specific assumptions made in the World Markets scenario are listed in Table A18. Key points to note are:

- An average individual's demand for terrestrial transport is expected to increase by 150% between 2000 and 2050. Demand for air travel will increase even more, by 450%, as the substantially increased wealth envisaged in this scenario causes people to take more foreign travel for both business and pleasure.

- Car utilisation increases at the expense of bus travel, while rail travel is unchanged.

- Walking and cycling show modest growth, mainly as a leisure activity.

- Car fuel efficiency improves by 30% over the period, with technical improvements being partially offset by people moving up to larger cars with more energy-consuming accessories such as air-conditioning.

- The balance of petrol to diesel cars stays roughly constant.

- Car occupancy falls as greater car ownership results in more driver-only journeys.

- There is a modest improvement in bus fuel efficiency and average occupancy remains constant on the declining number of routes that are operated.

- There is also a modest improvement in the fuel efficiency of road freight.

Regional Enterprise

The specific assumptions made in the Regional Enterprise scenario are listed in Table A19. Key points to note are:

- Demand for personal mobility is expected to be less than in the World Markets scenario, reflecting the slower rate of economic growth. An average individual's demand for terrestrial transport is expected to increase by only 40% between 2000 and 2050. Air travel increases more, by over 130%, as people seek to enjoy their increased wealth through more foreign travel.

- In common with the World Markets scenario, car utilisation increases at the expense of bus travel, while rail travel remains constant.

- Walking and cycling show modest growth, mainly as a leisure activity.

- Car fuel efficiency improves by 40% over the period, with technical improvements being partially offset by people moving up to larger cars with more energy-consuming accessories such as air-conditioning.

- The balance of petrol to diesel cars stays roughly constant.

- Car occupancy falls as greater car ownership results in more driver-only journeys. However, this is not so great as for the World Markets scenario since the lower GDP growth of the Regional Enterprise scenario means that car ownership does not increase as much.

- Also, in common with the World Markets scenario, there is a modest improvement in bus fuel efficiency and average occupancy remains constant on the declining number of routes that are operated.

- There is also a modest improvement in the fuel efficiency of road freight.

Global Sustainability

The specific assumptions made in the Global Sustainability scenario are listed in Table A20. Key points to note are:

- An average individual's demand for terrestrial transport is expected to increase by about 60% between 2000 and 2050. This reflects a desire to enjoy greater mobility as average personal wealth increases, but which is partially tempered by concerns over environmental impacts. For the same reasons, demand for air travel also increases, but only by about 60%.

- Car utilisation declines as there is a greater readiness to use public transport.

- There is a switch from petrol to more fuel-efficient diesel cars.

- Walking and cycling grow appreciably both for leisure and as a replacement for short car journeys (e.g. to clubs, school and work).

- Car fuel efficiency improves by 60% over the period due to a combination of technical improvements, driver behaviour and a preference for smaller, fuel-efficient cars.

- Car occupancy stays constant as greater car ownership is offset by an increased readiness to car share for certain journeys (e.g. to work, the school run).

- Bus occupancy increases as people favour public transport.

- There is a 30% improvement in the fuel efficiency of buses and freight vehicles.

Local Stewardship

The specific assumptions made in the Local Stewardship scenario are listed in Table A21. Key points to note are:

- An average individual's demand for terrestrial transport is expected to increase by about 40% between 2000 and 2050. This reflects the slow increase in average personal wealth, such that there is less disposal income available for transport in this scenario and a greater tendency to live close to the workplace. It also reflects concern over the environmental impact of travel. For the same reasons, demand for air travel increases by only around 10% over the period.

- Car utilisation declines as there is a greater readiness to use public transport.

- There is a switch from petrol to more fuel-efficient diesel cars.

- Walking and cycling grow appreciably both for leisure and as a replacement for short car journeys (e.g. to clubs, school and work).

- Car fuel efficiency improves by 50% over the period due to a combination of technical improvements, driver behaviour and a preference for smaller, fuel-efficient cars.

- Car occupancy stays constant as greater car ownership is offset by an increased readiness to car share for certain journeys (e.g. to work, the school run).

- Bus occupancy increases as people favour public transport.

- There is a 30% improvement in the fuel efficiency of buses and freight vehicles.

Table A18 Main assumptions made in the World Markets scenario for transport

	2000	2010	2020	2030	2040	2050
Terrestrial passenger transport demand (2000 = 100)	100	124	153	189	217	248
Percentage by petrol car	55.4	56.4	56.6	56.8	56.8	56.8
Percentage by diesel car	32.4	33.0	33.1	33.2	33.2	33.2
Percentage by bus	8.2	6.5	6.0	5.3	5.1	5.0
Percentage by rail	0.9	0.9	0.9	0.9	0.9	0.9
Percentage other (including cycling and walking)	3.1	3.2	3.4	3.8	4.0	4.1
Individual demand for air transport (2000 = 100)	100	176	262	353	440	549
Improvement in petrol car fuel efficiency (%)	0.0	10.0	20.0	25.0	27.5	30.0
Improvement in diesel car fuel efficiency (%)	0.0	10.0	20.0	25.0	27.5	30.0
Petrol car occupancy (passengers/car)	1.41	1.30	1.25	1.20	1.20	1.20
Diesel car occupancy (passengers/car)	2.28	2.00	1.75	1.50	1.50	1.50
Improvement in bus fuel efficiency (%)	0	10	15	15	15	15
Average bus occupancy (passengers/bus)	16.8	16.8	16.8	16.8	16.8	16.8
Improvement in road freight fuel efficiency (%)	0	10	15	15	15	15
Road freight demand (2000 = 100)	100	137	189	259	330	419

Table A19 Main assumptions in the Regional Enterprise scenario for transport

	2000	2010	2020	2030	2040	2050
Terrestrial passenger transport demand (2000 = 100)	100	107	115	123	131	140
Percentage by petrol car	55.4	56.4	56.6	56.8	56.8	56.8
Percentage by diesel car	32.4	33.0	33.1	33.2	33.2	33.2
Percentage by bus	8.2	6.5	6.0	5.3	5.1	5.0
Percentage by rail	0.9	0.9	0.9	0.9	0.9	0.9
Percentage other (including cycling and walking)	3.1	3.2	3.4	3.8	4.0	4.1
Individual demand for air transport (2000 = 100)	100	144	176	194	214	236
Improvement in petrol car fuel efficiency (%)	0.0	10.0	20.0	30.0	35.0	40.0
Improvement in diesel car fuel efficiency (%)	0.0	10.0	20.0	30.0	35.0	40.0
Petrol car occupancy (passengers/car)	1.41	1.40	1.35	1.35	1.30	1.30
Diesel car occupancy (passengers/car)	2.28	2.28	2.10	2.10	2.00	2.00
Improvement in bus fuel efficiency (%)	0	10	15	15	15	15
Average bus occupancy (passengers/bus)	16.8	16.8	16.8	16.8	16.8	16.8
Improvement in road freight fuel efficiency (%)	0	10	15	15	15	15
Road freight demand (2000 = 100)	100	112	127	142	160	180

Table A20 Main assumptions in the Global Sustainability scenario for transport

	2000	2010	2020	2030	2040	2050
Terrestrial passenger transport demand (2000 = 100)	100	110	121	134	147	162
Percentage by petrol car	55.4	51.3	44.0	38.0	32.4	28.0
Percentage by diesel car	32.4	34.2	36.0	38.0	39.6	42.0
Percentage by bus	8.2	8.0	10.0	12.0	14.0	15.0
Percentage by rail	0.9	2.0	3.3	4.0	5.0	6.0
Percentage other (including cycling and walking)	3.1	4.5	6.7	8.0	9.0	9.0
Individual demand for air transport (2000 = 100)	100	110	121	133	147	161
Improvement in petrol car fuel efficiency (%)	0.0	10.0	30.0	50.0	55.0	60.0
Improvement in diesel car fuel efficiency (%)	0.0	10.0	30.0	50.0	55.0	60.0
Petrol car occupancy (passengers/car)	1.41	1.41	1.41	1.41	1.41	1.41
Diesel car occupancy (passengers/car)	2.28	2.28	2.28	2.28	2.28	2.28
Improvement in bus fuel efficiency (%)	0	10	15	20	30	30
Average bus occupancy (passengers/bus)	16.8	16.8	20.0	23.0	23.0	23.0
Improvement in road freight fuel efficiency (%)	0	10	15	20	30	30
Road freight demand (2000 = 100)	100	116	134	155	180	208

Table A21 Main assumptions in the Local Stewardship scenario for transport

	2000	2010	2020	2030	2040	2050
Terrestrial passenger transport demand (2000 = 100)	100	107	115	123	132	141
Percentage by petrol car	55.4	51.3	44.0	38.0	32.4	28.0
Percentage by diesel car	32.4	34.2	36.0	38.0	39.6	42.0
Percentage by bus	8.2	8.0	10.0	12.0	14.0	15.0
Percentage by rail	0.9	2.0	3.3	4.0	5.0	6.0
Percentage other (including cycling and walking)	3.1	4.5	6.7	8.0	9.0	9.0
Individual demand for air transport (2000 = 100)	100	102	105	107	110	113
Improvement in petrol car fuel efficiency (%)	0.0	10.0	25.0	40.0	50.0	50.0
Improvement in diesel car fuel efficiency (%)	0.0	10.0	25.0	40.0	50.0	50.0
Petrol car occupancy (passengers/car)	1.41	1.41	1.41	1.41	1.41	1.41
Diesel car occupancy (passengers/car)	2.28	2.28	2.28	2.28	2.28	2.28
Improvement in bus fuel efficiency (%)	0	10	15	20	30	30
Average bus occupancy (passengers/bus)	16.8	16.8	20.0	23.0	23.0	23.0
Improvement in road freight fuel efficiency (%)	0	10	15	20	30	30
Road freight demand (2000 = 100)	100	113	128	145	164	186

Commercial and public services

The main factors determining energy demand from the commercial and public service sectors were assumed to be:

- Rate of economic growth
- Share of Northern Ireland GDP accounted for by the sectors
- Rate of change in energy intensity (i.e. energy consumption/value added), reflecting changes in the mix of services and energy efficiency.

In addition, there is considerable potential for fuel switching as natural gas becomes available across Northern Ireland.

Different views were developed on trends affecting these variables for each scenario.

World Markets

Under the World Markets scenario, GDP growth for the UK overall is assumed to increase to 3.0% per year. This is significantly higher than the 2.2% per year attained by the UK between 1990 and 2000. Northern Ireland's GDP growth exceeded the UK average at 2.9% per year over this period. This differential is assumed to be maintained up to 2030 such that, by this date, Northern Ireland's GDP per capita matches the UK average.

The commercial and services sectors grew faster than the overall economy in the UK between 1990 and 2000, at an average of over 5% per year. Northern Ireland's commercial and services sectors also grew faster than the overall economy, but less than for the UK at 3.5% compared with 2.9% for the total economy. It is assumed, in this scenario, that the commercial and services sector growth rate increases to 3.9% per year and, as a result, the sectors' share of GDP increases from the present 67.4% to 73.2% by 2050. This balances out the decline of industrial GDP in this scenario.

The energy intensity (total final energy consumption divided by sector value added) improved at an average rate of about 2.4% per year in the UK between 1990 and 2000. Data are not available to calculate this factor for Northern Ireland but, if assuming the ratio of intensity change to growth in value added is the same as for the UK, then the rate of intensity improvement would have been 1.75% per year.

The scenario assumes that global environmental issues such as climate change are given less priority than wealth creation. Consequently, there is no pressure, over and above commercial considerations, to increase energy efficiency. Therefore, it is assumed that energy intensity continues to decrease, but there is no additional investment in energy efficiency.

Northern Ireland has a fuel mix that differs considerably from the rest of the UK because natural gas has only recently become available. It is assumed that Northern Ireland will gradually adjust such that the sector uses a larger proportion of natural gas.

The main assumptions underlying the scenario are listed in Table A22.

Table A22 Main assumptions underlying the World Markets scenario for the commercial and services sectors

	2000	2010	2020	2030	2040	2050
GDP*	100	150	226	339	467	643
Commercial and services sectors' share of GDP (%)	67.4	68.6	69.7	70.9	72.0	73.2
Energy intensity*	100	84	70	59	49	41
Electricity share (%)	31.4	29.3	27.3	27.4	27.4	27.5

*Indexed so that year 2000=100

Regional Enterprise

Under the Regional Enterprise scenario, Northern Ireland's commercial and services sectors are assumed to maintain their share of GDP at 68.3%. Overall GDP growth for the UK is assumed to increase by 1.5% per year, which is lower than the 2.2% per year attained by the UK between 1990 and 2000. Northern Ireland's GDP growth is assumed to exceed the UK at an average of 2% per year up to 2050 – reducing, but not eliminating, the deficit in GDP per capita between Northern Ireland and the UK average.

The trends in fuel mix are assumed to be the same as for the World Markets scenario. Energy intensity is assumed to improve at a rate of 0.9% per year, in line with the slower growth rate, and no additional investment in energy efficiency is expected.

The main assumptions underlying the scenario are listed in Table A23.

Table A23 Main assumptions underlying the Regional Enterprise scenario for the commercial and services sectors

	2000	2010	2020	2030	2040	2050
GDP*	100	122	149	181	221	269
Commercial and services sectors' share of GDP (%)	67.4	67.6	67.8	68.0	68.1	68.3
Energy intensity*	100	91	83	76	70	64
Electricity share (%)	31.4	29.4	27.3	27.2	27.1	27.0

*Indexed so that year 2000=100

Global Sustainability

Under this scenario, the UK economy is assumed to grow at 2.75% per year and Northern Ireland's to grow at 2.5%. The commercial and services sectors grew faster than the overall economy both in the UK and Northern Ireland between 1990 and 2000, and this differential is maintained such that Northern Ireland's commercial and services sectors grow at an average of 2.3% per year. As a result, the commercial and service sectors' share of GDP increases from 67.4% to 70.6% by 2050.

The energy intensity is assumed to improve at an average rate of 1.5% per year. This is above the rate that would be expected with the rate of growth in the value added for the commercial and services sectors, and reflects an enhanced effort to save energy in line with the theme of the scenario. The trends in fuel mix and electricity's share of energy consumption are assumed to be roughly the same as under the World Markets scenario.

The main assumptions underlying the scenario are listed in Table A24.

Table A24 Main assumptions underlying the Global Sustainability scenario for the commercial and services sectors

	2000	2010	2020	2030	2040	2050
GDP*	100	128	164	210	269	344
Commercial and services sector's share of GDP (%)	67.4	68.1	68.7	69.3	70.0	70.6
Energy intensity*	100	86	73	63	54	46
Electricity share (%)	31.4	29.4	27.2	26.9	26.7	26.4

*Indexed so that year 2000=100

Local Stewardship

This scenario envisages the lowest rate of economic growth of 1.25% per year for both the UK and Northern Ireland. With the emphasis on local production, manufacturing industry increases its share of Northern Ireland's GDP from 21.3% in 2000 to 21.8% in 2050. Consequently, there is a fall in the share of GDP taken by the commercial and services sectors from 67.4% to 66.3% (equivalent to an annual growth rate of 0.9%).

The energy intensity is assumed to improve at an average rate of 1.3% per year. This is above the rate expected for the rate of growth in the value added for the commercial and services sectors, and reflects an enhanced effort to save energy in line with the scenario theme. The trends in fuel mix are assumed to be roughly the same as under the World Markets scenario.

The main assumptions underlying the scenario are listed in Table A25.

Table A25 Main assumptions underlying the Local Stewardship scenario for the commercial and services sectors

	2000	2010	2020	2030	2040	2050
GDP*	100	113	128	145	164	186
Commercial and services sectors share of GDP (%)	67.4	67.2	67.0	66.8	66.5	66.3
Energy intensity*	100	88	77	68	59	52
Electricity share (%)	31.4	29.4	27.2	27.1	26.9	26.8

*Indexed so that year 2000=100

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Helpline 0800 58 57 94
www.thecarbontrust.co.uk/energy

NORTHERN IRELAND VISION STUDY

Annex B: Prospects for bio-energy in Northern Ireland to 2050

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CARBON TRUST

Making business sense of climate change

CONTENTS

Executive summary

This annex explores how bio-energy (energy from biological materials) can contribute to meeting the Royal Commission on Environmental Pollution's recommendation of reducing carbon dioxide emissions by 60% from current levels by 2050. The annex is written in the context of much other activity in Northern Ireland and should be seen as a contribution to this on-going debate rather than a definitive statement.

Modern bio-energy is a complex market that is relatively unfamiliar in Northern Ireland. Biomass fuels include residues from forestry operations, conversion products from sawmills (bark, chips and sawdust), agricultural wastes with low or negative value (poultry litter, mushroom compost and animal manure), straw and energy crops such as short rotation willow coppice and perennial grasses. The energy market sectors where bio-energy can contribute include utility-scale electricity generation (combustion processes, co-firing of biofuels with coal, gasification and pyrolysis), community heating, industrial heating, distributed power generation, combined heat and power (CHP), renewable transport fuels and domestic heating based on logs or pellets.

Wide-scale deployment of bio-energy in Northern Ireland will have an impact on sociological issues such as employment, wealth creation and living standards. It will also affect the regional trade balance and have displacement effects. Environmental impacts will arise from the use of natural resources, carbon dioxide emissions during the conversion of the crop to energy, and the generation of waste, traffic, noise and odour. The production and use of bio-energy could also affect biodiversity and land quality, and have a potential visual impact. Neither sociological nor environmental factors will act as constraints on future deployment.

The annex considers how the bio-energy industry could grow in Northern Ireland under the influence of the positive policy environment as described under the Foresight Programme's Local Stewardship and Global Sustainability scenarios.

Local Stewardship is possibly the most favourable scenario for bio-energy. A strong sense of ownership and local government support will favour the development of an extensive domestic and commercial heating sector. Pellet production will be extended to take in all available resources by 2025 and the products will be sold largely to the domestic sector, with lower quality product going to larger commercial and public sector buildings. By 2012, public sector purchasing policy is changed to include a presumption in favour of renewable energy. Energy crops are likely to be widely deployed by 2025 to supply fuel as heating markets expand. Until this time, the industry will not generally be constrained in terms of supplies, although local shortages may exist. Some industrial CHP may be deployed where there is a need to strengthen the network to support local economic activity. Utility-scale installations may be deployed where real benefit accrues to the local community; this may favour community heating in high density areas. Industrial CHP and heating will be strongly supported by Government initiatives due to the socio-economic benefits from local fuel production and the wider benefits of retaining businesses in the local area.

In the Global Sustainability scenario, Northern Ireland seeks to play its full part in resolving global environmental problems. The full range of options will be deployed, but with greater preference given towards utility-scale power generation projects to allow trading into EU green power schemes. Likely deployment of early co-firing to profit from Renewables Obligation Certificates will boost fuel supplies with the prospect of a sustainable pick-up of other technologies in the medium term.

Given the strong policy context implicit in these two scenarios, Northern Ireland could sustainably produce and use over 1.4 million dry tonnes of biomass fuel (7,822GWh/year) in 2050. This amount consists of some 1 million tonnes of energy crops, 250,000 tonnes of forestry residues and sawmill conversion product, and 150,000 tonnes of poultry litter and mushroom compost. This corresponds to approximately 150MW of electricity generation.

In 2012, the corresponding figures are 328,000 tonnes and 1,730GWh/year and consist largely of low-value agricultural residues and forestry and sawmill products.

Bio-energy could make a substantial contribution towards reducing Northern Ireland's carbon footprint in 2050. This conclusion is based on its industrial strengths and the excellent conditions for energy crops. The energy markets in Northern Ireland both now and under these two scenarios are more favourable to the use of biomass than many other areas of the UK. This is due to the limited penetration of natural gas in Northern Ireland and its essentially rural character.

The following key issues emerge from the study:

- Bio-energy can contribute substantially to a reduction in the carbon footprint in Northern Ireland, but a strong and co-ordinated policy initiative will be needed to achieve this.

- Energy crops are essential if bio-energy is to have a large impact on Northern Ireland's carbon emissions.

- Bio-energy will be able to contribute to the industrial heat and CHP, domestic and utility sectors. There is considerable enthusiasm in the industry and the public sector to support the development of the heating and CHP market.

- Co-firing wood and energy crops with coal in a power plant is a short-term option, which could provide an initial start-up market for the fuel supply industry.

- There will be a small net gain in employment, but there will be some displaced activities. The main impact may be more to preserve and secure employment in rural areas.

- There are many options for the disposal of farm livestock wastes, and anaerobic digestion for energy may not be the optimum for the farmer, whatever the carbon benefits. This whole area requires further study and the options need to be evaluated in both carbon and economic terms.

- The environmental impact of bio-energy deployment is generally positive, particularly where energy crops replace intensive agriculture. Where energy crops replace unimproved pasture, there may be a negative impact on biodiversity.

1 Introduction

The UK Government has adopted the recommendations of the Royal Commission on Environmental Pollution (RCEP) [1] on reducing carbon dioxide emissions to reduce the threat of global warming and climate change. RCEP recommends the development of a concerted, co-ordinated strategy that puts the UK economy on a path to reducing carbon dioxide emissions by some 60% from current levels by 2050.

This annex explores how bio-energy (energy from biological materials) can contribute to meeting this recommended reduction in Northern Ireland (NI). It is based on previously reported work and a study visit undertaken in February 2004.

This annex should also be read in context with other developments in Northern Ireland. The Department of Agriculture and Rural Development (DARD) is developing a strategy for biomass based on a comprehensive review of the practice and economics, particularly with regard to the new agricultural support mechanisms. The Northern Ireland Forest Service is reviewing its policy with a view to examining the energy potential, and the biomass industry in Northern Ireland is making great progress in the technology.

As with all renewables, the contribution of bio-energy to reducing the carbon footprint in Northern Ireland will depend upon the financial returns to the investor. These, in turn, depend on the measures put in place by government and the attitudes of the society that drive them. Scenarios or 'storylines' based on the UK Foresight Programme scenarios [2] have been developed to assess how bio-energy may be deployed in the medium and long terms.

The annex:

- Presents an overview of biomass resources that could be made available for energy generation in Northern Ireland
- Identifies the factors that determine how much each bio-material could contribute and the technology needed to gather it into useful quantities
- Explains how biomass can be delivered to the end-user
- Describes the technology needed to convert it into useful energy in four key market sectors
- Considers how the materials and technologies can be assembled into practical systems that could supply the energy that the markets require
- Examines the socio-economic effects of bio-energy
- Summarises the environmental impacts of each link in the bio-energy chain with reference to accepted indicators
- Explores the contribution that bio-energy could make to reducing the carbon footprint in Northern Ireland.

2 Biomass resources in Northern Ireland

This section describes the types of biomass fuels that may be available, including:

- Fuels from forestry operations and timber processing
- Fuels from existing farming operations
- A change in farming to produce crops specifically for energy.

Household/business wastes and landfill gas are not included as they are covered bin Annex E.

Residues from forestry operations

These are either by-products of timber harvesting and management or by-products of sawmilling.

Harvesting forests and woodlands

Wood that is used for fuel is normally the material left above ground from harvested trees or thinnings from management. This can be the tops of the stems and side branches, but also includes non-marketed, small roundwood timber[1] and poor quality final crops.

Most of the value in a tree lies in sawn timber and the amenity value of the forest. Over the past decade, a range of machinery and working methods that maximise the production of fuel grades have been demonstrated by the Forestry Commission and others[2].

Harvesting fuel from conventional forestry operations should always be integral to the whole process of managing the woodland. The chosen option will depend on:

- Terrain and soil type
- Environmental issues (risk to soil fertility, weather conditions, watercourses, wildlife habitats, etc.)
- End-user requirements
- Forest size and layout (provision of roadside facilities, siting of brash stores, etc.).

There are four main systems for harvesting wood fuel:

- **Second-pass residue harvesting.** The stem wood is first removed in a conventional harvesting operation. The wood fuel fractions are then removed later in a second operation in which they can be either chipped at the roadside or stump, or compressed into bales.
- **Whole-tree harvesting**. The whole tree is removed from the stump to the forest road and then divided into conventional stem wood and residues. The residue can then be chipped at the roadside or transported in unchipped form.
- **Whole-tree chipping (terrain chipping)**. The whole tree, usually of a small size, is felled and then chipped at the stump and the chips extracted to the timber landing area.

[1] Small stems cleaned of side branches with a diameter greater than 7–14cm.

[2] Particularly in Scandinavia.

- **Whole-tree chipping (landing chipping)**. The whole tree is felled and then extracted (off ground by a purpose-built forwarder to avoid contamination) to the timber landing area. The chipping of the whole tree takes place at the landing and the chips are blown into road transport.

Residue compression is a relatively new technology introduced in the Nordic countries, which has been developed solely for the energy market. The residue is compressed or baled into a cylindrical log (fibrelog) approximately 1 metre in diameter and 3 metres long, which is then brought to the roadside. This concept allows the full axle loading to be used for haulage to the power plant.

Extraction of forestry residues for fuel is relatively new to Northern Ireland and the market is expected to remain small for some years. Second-pass systems are the most likely until energy projects can be identified that require a dedicated long-term supply. At this point, dedicated machinery for integrated fuel production may become economically feasible.

Wood fuel from sawmills

Approximately 50% of the volume of stem wood that is sold to sawmills can be converted into timber in the form of planks, batons, etc. The remainder (known as the sawmill conversion product), which can include bark, chips and sawdust, is sold mainly for the manufacture of paper and panel boards. However, some is disposed of and changing market conditions mean that a proportion of these residues should be available for wood fuel markets. The most notable illustration of this change in markets is the recent decision by Balcas Timber Ltd in Enniskillen to divert 100,000 tonnes of conversion product to fuel a combined heat and power (CHP) installation and retail production. This installation will manufacture 50,000 tonnes/year of high-grade pellet fuel suitable for commercial and domestic heating.

The proportion of conversion products is higher in Northern Ireland than in other parts of the UK due to the relatively poor form of the feedstock.

Recent interviews suggest that up to a maximum of 200,000 oven-dried tonnes (ODT) of conversion products could be diverted to the energy market annually. Of this, approximately 100,000 tonnes would be of sufficient quality to manufacture domestic grade pellets. The rest would be more suited to chips or industrial grade pellets.

The extent of the forestry and sawmill residue resource in NI

The data in this section are drawn from a report on renewable energy in Northern Ireland published by the Department of Enterprise, Trade and Investment (DETI) in 2001 [3]. However, this work is in need of updating. The Forestry Commission[3] recently completed a study, in collaboration with the private sector on behalf of the Department of Trade and Industry's New and Renewable Energy Programme, which established the annual resource in England, Scotland and Wales as a function of the various small roundwood products and residue classes [4]. This methodology allows the resource to be gauged under different market conditions. The Northern Ireland Forest Service is urged to consider coming under the 'umbrella' of this study so that future work on resources can benefit from a common approach.

There were approximately 76,000ha of forest in Northern Ireland in 2001/02 [5]. What is uncertain is how much of this is managed, as clearly only forestry management and harvesting (clear-fell) activities would provide a resource.

[3] http://www.forestry.gov.uk/

Management activities for both coniferous and deciduous forests are carried out every 7–8 years, yielding an average 0.75 and 1.5 ODT/ha/year, respectively. The rotation period for coniferous forest (e.g. spruce) is 50–70 years. When clear-felled, it yields the equivalent of 1 ODT/ha/year. For the purposes of this study, only the thinnings from forestry management activities have been considered. These indicate that residues equivalent to approximately 50,000 tonnes/year of oven-dried wood might be available today.

Northern Ireland's forests are expanding at a rate of 800ha/year [6]. Additional forest residues are therefore likely to become available. At 5% of the land area, Northern Ireland does not have a large area of forest coverage in European terms and, at current rates of expansion, will only increase to approximately 8% in 2050. Many in the bio-energy field feel that a more aggressive expansion is justified, with energy products as a key aim.

Sawmill residues (including those from imported wood) can also be considered as a fuel. The current estimate for this resource is approximately 200,000 ODT/year, which is borne out by recent estimates from the industry of what could become available for energy [7].

If forestry and sawmill residues are combined, the maximum current total resource is equivalent to 250,000 tonnes/year of dry wood. Assuming an increase of 800ha/year in forestry and no growth in the sawmill output, then this would rise to 274,000 tonnes/year of dry wood in 2050.

Not all of this potential fuel could currently be exploited for energy owing to location, accessibility and competition from other sources within the wood industry. All recoverable wood fibre currently has a market, but this situation is changing as evidenced by the decision by Balcas Timber Ltd to diversify into fuel production. Other drivers could be increased harvests or the potential for revenue from the energy market driven by impending policy incentives such as the Renewables Obligation for electricity (see Annex E).

The resource could be expanded by bringing chipped forest residues across the border from the Republic of Ireland (RoI), where a large forest area is also felled. However, this may not be appropriate as the RoI also has incentives for renewables.

Arboricultural waste

This is the residue from arboricultural work and similar activities in parks and gardens. It is essentially the same as forestry residues, although the potential for contamination exists. The recent study for the DTI's New and Renewable Energy Programme [4] suggests that these materials will be accounted for in local recycling plans.

The quantities are unlikely to be large and the waste tends to be concentrated around population centres. Based on a population pro-rata basis with England, an estimated 10,000 tonnes/year may be available in Northern Ireland.

Because of the uncertainty and small size of this resource, it has not been included in the projections in this annex.

Agricultural wastes with low or negative value

These materials are currently disposed of by land spreading, which can cause environmental and biological security problems[4]. It is expected that other routes will have to be found in the medium to long term, and energy production offers a tested and permanent solution.

Poultry litter

Some 115,000 tonnes/year of used poultry litter and some 36,000 tonnes/year of excreta are available. Long-term changes in animal welfare may lead to poultry for egg laying being housed in barns with a litter base. It is therefore possible that increasing amounts of used litter would become available from egg-laying poultry in the future.

Spent mushroom compost

Mushrooms are grown on a compost made from a mixture of poultry litter and cereal straw. Spent compost currently represents a serious disposal problem in Ireland. Of the order of 200,000–280,000 tonnes/year are produced in the border counties, of which about half is from Northern Ireland. The conventional disposal route for this material is primarily through land spreading and landfill, often with adverse environmental impacts.

Depending on how it is handled and treated, the moisture content of spent mushroom compost can vary considerably. It had long been believed that the moisture content lay in the range 52–73%, with a corresponding gross calorific value (GCV) in the range 1.5-3.9GJ/tonne on an as-received basis. It had been thought possible to obtain material with a moisture content of 40%. Limited calorific value measurements carried out recently by different organisations have produced considerable variation (9.3–14.3GJ/tonne for the dried feedstock). When used to calculate the GCV of the as-received (wet) feedstock, this gives values in the range 5.0–8.5GJ/tonne. The most likely technical solution to the problem of varying moisture content would be to blend this material with poultry litter and/or wood to make a consistent fuel.

One option that is currently being considered is combustion in a power plant followed by the sale of ash by-products. However, the combustion characteristics of spent mushroom compost are not straightforward. A study by the Northern Ireland Centre for Energy Research and Technology (NICERT) at the University of Ulster found fluidised bed boilers to be the most suitable [8]. Poultry litter is burned successfully in England and Scotland in both grate boilers and fluidised bed units[5]. However, burning residues can bring problems of public acceptability, despite this positive experience; a commercial project was proposed in which spent mushroom compost was co-fired with municipal solid waste in an incinerator. While this may have made sound economic sense to the developer, it raised fierce opposition from the community.

On a smaller scale, Rural Generation Ltd in Londonderry has successfully demonstrated the use of a mixture of wood chip from energy crops and mushroom compost as a boiler fuel in small installations. While this approach may alleviate the problem to some extent, the overriding concern of most mushroom and poultry producers is to remove the material off-site as quickly as possible to reduce the risk of disease. This may mean revisiting the concept of a large central facility.

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[4] Typically, these are nutrient run-off into watercourses, odour and the possibility of disease transfer from poultry carcasses to cattle.

[5] http://www.fibrowatt.com/

Farm livestock manures

Northern Ireland produces about 0.94 million dry tonnes of farm livestock manures and bedding straw each year. Because these materials contain a high proportion of water, energy recovery is best achieved using anaerobic digestion. This is carried out in large insulated tanks at a temperature of 35°C over a period of up to 30 days. This process converts 40–60% of the organic matter into biogas – a mixture of approximately 65% methane and 35% carbon dioxide (CO_2). The biogas can be used for process heat and electricity generation by firing in a boiler or reciprocating engine.

In the anaerobic digestion process, the effluent may be mechanically separated to produce a liquid fertiliser and a fibrous solid soil conditioner. If stabilised and made pathogen-safe by pasteurisation, these materials could be regarded as higher value organic fertilisers and soil conditioners.

A wide variety of digester designs are available on the world market. Two scales of operation are appropriate for this material:

- Farm scale, where each farmer processes their own material and uses the energy for heating their property
- Centralised facilities where a single unit serves a local region.

Larger units could also treat large quantities of food processing and abattoir wastes, which would support local industry.

There are many hundreds of farm-scale projects in Germany, Denmark and Switzerland but relatively few centralised units. Holsworthy Biogas Ltd in Devon is a good example of a centralised community scheme that takes waste from farms and abattoirs in the area.

Environmental legislation[6] and the pressure to deal with farm wastes could be as important a driver as any income from energy. Implementation of the Integrated Pollution Prevention and Control (IPPC) and other EU Directives will increase the regulation of farm wastes in the UK and all farming activities could potentially require a waste management plan.

There are many options for the disposal of farm livestock wastes, and anaerobic digestion to produce energy may not be the optimum for the farmer, whatever the carbon benefits. This whole area requires further study and the options need to be evaluated in both carbon and economic terms.

Straw

This is the baled by-product of combinable crops. Interviews with DARD and the industry suggest that the current supply and demand in Northern Ireland are essentially in balance, with animal bedding taking most of the output. Straw is not regarded as a waste and none is expected to be available for energy use except minor quantities for ownuse applications in farmhouses and farm enterprises.

The situation could change if there is wide-scale deployment of oil seed rape for biodiesel production. Oil seed rape makes poor quality straw, which has little use other than for energy. It

[6] Sources of information include http://www.netregs.gov.uk/ and http://www.ehsni.gov.uk/

does, however, make quite a good fuel and has been burned successfully in the Ely straw-fired plant in England[7] [9].

Energy crops

Energy crops are grown specifically to produce energy. Although they currently make a negligible contribution in Northern Ireland, energy crops could offer a step change in the amount of energy produced from biomass in the medium and long term. They also offer environmental and ecological benefits and an alternative, sustainable use of the land resource in Northern Ireland. DARD is carrying out a comprehensive review of the role of bio-energy in Northern Ireland farming.

Energy crops can offer significant environmental benefits, especially where land has previously been farmed intensively. For example, it can provide landscape variety and a habitat for many species of plants, birds and other wildlife (thus increasing biodiversity). It is also a very low input crop compared with annual arable crops, thus maximising the net energy output.

Energy crops include:

- Wood crops such as short rotation willow coppice
- Perennial grasses similar to straw
- Annual crops whose seed can be used to produce liquid fue e.g. biodiesel production from oil seed rape (OSR) and ethanol from cereal.

Only short rotation willow coppice is being seriously considered in Northern Ireland at present, but this may change with time.

Short rotation coppice

Technically, the most advanced energy crop for northern European conditions is coppiced willow (*Salix* spp.) commonly referred to as short rotation coppice (SRC). This is a perennial crop harvested on a rotation of 2–4 years to provide a regular and constantly renewable supply of fuel. Information on the growth and utilisation of SRC is given in the Addendum and in guidance from the Department for Environment, Food and Rural Affairs (Defra) [10].

Establishment in Northern Ireland is likely to follow the same pattern as in the rest of the UK. Planter availability is limited, but DARD is expected to solve this problem by bringing a planter into Northern Ireland for the initial phases of any deployment. The work rate of a typical planting machine is about 6–8ha/day. DARD's mid-term vision for Northern Ireland is for 5,000ha by 2012; this may require additional machines.

Current commercial yields are around 8–10 ODT/ha/year. How will yields in Northern Ireland compare with the rest of the UK? Table B1 gives some results from Forest Research[8] site/yield trials in Northern Ireland obtained as part of long-term trials being undertaken by Forest Research at some 40 sites throughout the UK. This work is funded by the Department of Trade and Industry (DTI), Defra, the Forestry Commission and DARD.

[7] See http://www.eprl.co.uk/assets/ely/overview.html

[8] http://www.forestresearch.gov.uk/

Table B1 Estimated potential annualised yield of willow variety Jorunn*

	Annualised yield (ODT/ha/year)			
	1 year	**2 years**	**3 years**	**4 years****
Northern Ireland	8.2	9.9	10.4	15.5
UK average	7.1	9.1	9.8	15.1

* Estimates are based on an assumed three-year cutting cycle.

**First year of second cutting cycle.

There are three test sites in Northern Ireland at Loughall, Castlearchdale and Londonderry. Across varieties, the expected site index tends to be highest in northwest Britain and Northern Ireland. This is probably a reflection of the combination of high rainfall and the tendency for relatively low temperatures to reduce levels of pest and disease infestation. Overall, in Northern Ireland yields do not appear to be vastly above those in the rest of the UK; however, conditions in Northern Ireland are highly suitable for good growth.

The harvesting method chosen for Northern Ireland will affect the fuel supply strategy (future chipping requirements and storage strategy, etc.). Discussions with DARD and the industry suggest that a tractor-mounted harvester capability (with a modified header) would best match the pattern of farming in Northern Ireland, at least in the early phases of deployment. The agricultural contracting industry is strong in Northern Ireland and all stakeholders are confident that, provided the crop is sufficiently profitable, any machinery problems could be solved.

Storage/drying of SRC depends on the harvesting strategy, the scale/type of conversion technology, the degree of development of the fuel supply chain, etc. Natural air drying in the supply chain is usually encouraged by sticks in the field and loosely packed chip piles. Where a dry chip is needed, grain drying techniques can be used as at Rural Generation Ltd in Londonderry.

Transport to the end-user again depends on the strategies employed. In the early stages of deployment, the trailer option for small-scale/farm schemes seems likely to dominate in Northern Ireland. Larger schemes are likely to be in operation in England before Northern Ireland, so the technology should be available if needed. The industry is still in its infancy in the UK and many variations are being proposed to deliver the correct size and quality product to the end-user.

The DARD study is expected to deal with the issue of costs in some detail. Current indications are that, if the same support regime were available in Northern Ireland as in the rest of the UK, then chip would be available delivered to the end-user at a price of £40–50/ODT.

The industry believes that the low level of support for SRC is a significant barrier to progress in Northern Ireland. It could, however, be grown commercially now if the economics were right.

One way of improving the economics is to use the biofiltration properties of willows to treat effluents. Revenue can then be earned from disposal credits and the fuel value. There is particular promise in treating abattoir and food processing wastes, and the use of willow as a biofilter could represent a more cost-effective option than anaerobic digestion for these wastes. This needs to be established, but seems a promising development and would be a ‘first’ for Northern Ireland.

Farm effluent could also be treated in this way. Rural Generation Ltd feels that some experimental work in this area would be justified.

Perennial grasses

Another potential fuel crop that is being considered is the perennial woody C4 grass, Miscanthus. C4 plants have a more efficient photosynthesis mechanism than C3 plants, which are more common in the UK.

Reed Canary Grass, a native species, is showing some promise in recent research trials but is still some way from commercial deployment.

The growth of perennial grasses as a fuel crop is reviewed in a recent report to the DTI New and Renewable Energy Programme [11].

Potential deployment of energy crops

Agricultural land in Northern Ireland covers approximately 1 million hectares. However, not all of this area would be available for energy crops. Discussions with DARD suggest that around 70,000ha of this marginal land could be used in a long-term scenario. In the shorter term (i.e. 2012), it is more realistic to expect 5,000ha to be established. Nevertheless, it would not be unreasonable to expect that by 2025 this could triple to 15,000ha. By 2050, given an extreme case in which CO_2 reduction is the prime policy objective, there is no reason why the full 70,000ha should not be made available for bio-energy crops.

The current maximum yields of SRC are of the order of 10 ODT/ha/year. With successful R&D, SRC yields might be increased to 17 ODT/ha/year in the long term. The physiology of the plant is unlikely to allow increases beyond this on a commercial scale. Not all land will produce the maximum yield, however, and estimates should be reduced accordingly.

3 Tradable bio-energy fuels

The energy crop or residues have to be transformed into a tradable fuel – a form that can be used by the consumer in the energy market.

Logs

Logs are available in Northern Ireland, although the market is informal and not as widespread as in other parts of the UK. They are normally purchased for cash in 'trailer loads' in response to advertisements in Yellow Pages or local newspapers. There is no definition as to what constitutes a load, and neither the type nor the moisture content of the wood are normally specified.

A good quality firewood log will be cut, split and stored in the winter for use the following winter. Logs are generally 30-45cm long and about 8cm in diameter. Logs should be stored under cover, but with free ventilation so that they dry through natural convection and remain dry. Wet wood will not burn cleanly and may cause a fire risk by coating the inside of the chimney with unburned tar. Hardwoods are felt to give a better fire than softwoods and command a higher price.

Logs are a good fuel for domestic use in rural areas. However, quality standards and consumer information are essential if their deployment is to expand.

Wood chips

Chips are a bulk fuel produced by cutting wood in a size reduction device (a chipper) fitted with rotating blades. The product is wood pieces about 15–30mm × 5mm × 10mm. These normally have the same moisture content as the original wood, but can be dried by either natural airflow or drying floor systems.

Quality is always a problem, particularly the incidence of long pieces or slivers that can block automatic feeders. The UK trade association, British BioGen[9], has set out quality standards for three grades of chip and these would need to be promoted and used if deployment is to expand at the required rate.

Bulk density is very low and chips are normally supplied in trailers or lorries as a bulk product to larger installations.

The cost of wood chips at around £30/tonne means that they can provide heating at costs comparable with those of oil/natural gas for commercial users.

Wood pellets

Wood pellets are compressed woods made usually from sawdust and wood shavings. However, any biomass material (e.g. straw, forestry residues, specially grown energy crops, etc.) can be used to make such pellets. Typically, a pellet will be 6–12mm in diameter and 6–20mm long. They are made in the same type of equipment as extruded cattle feed.

[9] http://www.britishbiogen.co.uk/

Pellets have the advantages of being dry, consistent in shape and composition, and in a form that will flow freely from hoppers and through augurs. Their small size also makes them easy to ignite. These properties make them ideal as a fuel for automatic appliances.

Pellets have increased in popularity enormously in the past decade. They are traded within Europe and North America as a commodity in the same way as oil or coal.

Pellets are supplied in two main grades: Grade 1 for domestic use and Grade 2 for commercial/industrial use. The domestic grade should contain only clean stem wood with low ash and high density. This ensures that they flow easily through the equipment and do not degrade with handling. Commercial grades can contain some bark and may degrade to some extent during handling.

The European industry has set up a series of quality standards for pellets. These, and a general introduction to the subject, can be found in a report to the DTI New and Renewable Energy Programme [12].

Costs per unit of energy are somewhat more than natural gas, but are close to being competitive with heating oil at current price levels.

Pellets should have great potential in Northern Ireland. Competition from cheaper natural gas is limited geographically and a sizeable, state-of-the-art manufacturing plant near Enniskillen[10] will be producing over 40,000 tonnes/year of pellets in 2005.

Bales

These are the conventional bales as used in cereal production. For power plant use, the standard bale is the half-tonne Hesston bale. For smaller units, traditional smaller bales are used.

[10] Balcas Timber Ltd.

4 Markets and technologies

This section describes the technology needed by the energy market sectors where bio-energy can contribute. The four categories are grouped according to the type of enterprise involved.

Utility operations

Equipment is owned and operated by companies whose principal business is generating energy for sale to consumers. This includes power stations and district heating networks.

Owners of utility plant will purchase fuel on both long-term and short-term contracts, and are likely to buy a mix of fuels from whichever is the cheapest source.

Utility-scale electricity generation

Combustion processes

Biomass residues have been burned in power generation plant since the latter half of the 19th century. The cane sugar, timber and pulp industries all contain many examples. The biomass is burned on a grate where the fuel burns in a layer, with the air for combustion blown both through the grate and over the top of the fuel layer. Various types of grid or grate have evolved to move the fuel through the boiler and eventually remove the ash. While reliable and relatively inexpensive, grate-firing systems are also somewhat inflexible and are usually designed to cope with a limited range of fuels. The heat from combustion is converted to steam at high pressure in a boiler. This is, in turn, converted into electrical power by passing it through the turbine of a generating set.

Historically, biomass residues have had a low calorific value and power plants have been designed as disposal devices with low efficiencies. From the 1980s onwards, more modern plant has become available that is better suited to electricity generation. This plant has greater fuel flexibility, improved emissions characteristics and efficiencies of up to 30%. Most of these units have been deployed in the Nordic CHP market, although the UK also has an excellent portfolio of the more modern designs, notably in the Non-Fossil Fuel Obligation (NFFO) projects commissioned at Ely, Eye and Thetford in East Anglia, Glanford in Lincolnshire and Westfield in Fife.

The economic scale of operation of electricity-only generating plant is the subject of some debate. Experience in England suggests that the installation needs to be large to achieve an economic payback. For example, the plant at Ely is capable of exporting 36MWe and that at Thetford 38MWe. However, there is the danger of exceeding the fuel supply capability of the location (both Ely and Thetford are situated in the centre of the cereal and poultry litter producing areas of East Anglia). Other studies have recently suggested that smaller installations that operate as a cluster may be the way forward; so far, these are only studies, but a precursor project is being developed in Stafford using standardised modular boilers and energy crops.

Co-firing biofuels with coal is a good way of using biomass without incurring excessive, or any, capital costs. It could be extremely profitable in the period up to 2016 once renewable electricity generators in Northern Ireland are able to trade Renewables Obligation Certificates (ROCs) with the rest of the United Kingdom. The only power station in Northern Ireland that is suitable is Kilroot (see Annex E for information about Kilroot).

Where biomass quantities are small (2–5% of the energy value of the input fuel), the biomass is mixed with the coal at the mill inlet. This seems the most likely course of action at Kilroot. There are some complications with the grinding mills, but there is no reason to suppose that co-firing would not be a feasible way of generating large quantities of renewable energy at low cost in Northern Ireland.

Five percent of the capacity of Kilroot would be equivalent to generating 25MWe. This would require approximately 100,000 ODT/year of wood if operating for 8,000 hours/year and generating at 36% efficiency. This is a substantial quantity of wood, which would represent all of the available forestry residue resource and most of the sawmill residues. Translated into energy crops, it would represent 10,000ha.

Given the low level of bio-energy deployment and infrastructure development in Northern Ireland, co-firing is an opportunity that should be examined as a means to kick-start the industry. However, co-firing will not attract ROCs indefinitely and an exit strategy should be considered from the outset.

Alternatives to combustion: gasification and pyrolysis

Gasification and pyrolysis provide a means of using solid biomass fuel in modern gas turbines or engines designed for gaseous or liquid fuels. This improves efficiency and keeps biomass in the mainstream of energy conversion development.

Gasification is the main alternative to combustion for power generation. The process involves reacting the biomass in a gasifier with an air input that is sufficient to maintain a high reaction temperature without causing complete combustion. The low heating value gas that is formed can then be used in engines or turbines to generate power.

The electrical efficiency of a gasification-based combined cycle plant is much higher than that of a combustion-based steam cycle plant of the same scale. Thus, a 3MWe state-of-the-art combustion plant will give an efficiency of 21%, whereas a gasification plant would be capable of 30% efficiency. Capital costs should be similar, thus reducing the unit cost of the electricity.

Pyrolysis involves heating biomass in the absence of air to produce solid, liquid and gaseous fuels. Some developers in the UK have shown interest in so-called ‘fast’ pyrolysis processes, which produce a high proportion of liquid fuels that can be stored and transported easily, giving more flexibility in use. The pyrolysis liquid also contains resins and a number of speciality chemicals that may have the potential to increase revenues, although only food flavourings have so far been successful. A demonstration plant is under construction in Canada.

In general, Northern Ireland does not have any strengths in larger scale advanced processes and the resource does not provide any incentive to take the high risks involved in developing these technologies. A watching brief is probably the most appropriate course at present until the technologies are more mature.

Pyrolysis has some advantages for the Northern Ireland situation in that it offers a means of placing small amounts of renewable electricity at strategic locations on a rural electricity distribution system. However, the technology is some way from commercialisation, making a watching brief on developments the most sensible approach.

Community heating

Community or district heating is the supply of heat on a retail basis to consumers. The usual configuration is one or more heating boilers located in a boilerhouse that circulates hot water through a network of underground pipes. Consumers each have a meter and a heat exchanger that transfers the heat into their own central heating system.

This system is common in Scandinavia and other northern European countries, but has not been used to any extent in the UK because of the relatively temperate climate and the availability of natural gas. There are, however, a few schemes in Belfast using fossil fuel. They have not proved popular and most have been removed.

However, biomass brings a dimension of local ownership that may make it possible to revisit this concept, at least in community-owned schemes. The cost of installing the network is substantial, making it more likely that new installations will be in new, high-density housing schemes where the pipes can be installed before road surfacing.

The heat can be supplied into the system using either chip or pellet fired boilers. Both are well proven in other European countries.

With the cost of wood chips at around £30/tonne, these can provide heating at an operating cost comparable with that of oil/natural gas. However, both the capital and labour costs of such units are higher than those of a comparable oil/gas boiler. The cost of chip-fired units varies from £150 to £350 per kWth installed capacity, depending on site-specific factors. In Sweden, a complete 1.8MW mini district heating system (including a 4.5km distribution network) was costed at £1.3 million (i.e. £726/kW).

Wood pellet-fired boilers with fully automated operation for community heating at a small-to-medium scale are well developed in countries such as Sweden, Austria and Germany. However, the capital cost of such equipment is high at £200–£250 per kW of thermal output; this is likely to be a problem for application in the UK. To overcome this problem, some trials have been carried out in the UK by converting wood chip-fired stokers and coal-fired underfeed stokers to burn wood pellets. The results of such trials are very encouraging. For larger units, Swedish workers are investigating oil boiler conversion. These are being considered for summer use in district heating systems when the load is lower.

The DTI's Bioenergy Capital Grants Scheme[11] has produced a number of interesting schemes that could be replicated in Northern Ireland.

Industrial heating and CHP

This market sector consists of companies whose core business is something other than energy but which have access to biomass fuels. Until recently, the NI market was driven by the demand for heating and for waste disposal, and electricity was generated only on rare occasions from biomass fuels. The introduction of ROCs will probably transform this market, as a further substantial source of revenue is available to tip the balance of project economics.

[11] See http://www.dti.gov.uk/renew/eoi.htm

Industrial heating

This is well established in the woodworking sector, with many suppliers of chip, log and pellet boilers. High efficiency models can be found on the Energy Technology List[12].

Distributed power generation and CHP

CHP generation schemes have grown in the UK in recent years, particularly at industrial sites to provide both power and heat.

There is growing interest in small-scale distributed power plant fuelled by biomass in Northern Ireland. A typical application would be a CHP plant, off the gas grid, with an electrical output of less than 250kWe. In the UK, there is interest from housing developments such as the Beddington Zero Energy Development (BedZED) in south London[13] or from farmers seeking to add value to their energy crops (e.g. Brook Hall Estate, Londonderry[14]). There may be export opportunities to other European countries with similar policies and ambitions.

Distributed power generation uses equipment that is very small in conventional power station terms. Boiler plant and steam turbines are available commercially, but will have low electrical efficiencies, which reduces the income from ROCs. Technology companies, particularly those in Northern Ireland, are commercialising gasification processes that have better efficiency at smaller sizes, but are much less proven. These are described below as examples.

Boiler and steam turbine

This is a well-established option with countless installations worldwide; Balcas Timber Ltd in Enniskillen is the latest.

This application would use a water tube boiler or a firetube boiler with superheat for bio-energy applications. The turbine would typically be a single-stage industrial model, although a condensing stage could be added to maximise electricity generation. Talbott's Heating Ltd offers this option for its range of boilers targeted at the woodworking industry. There are many other suppliers throughout Europe.

As with all steam power options, heat taken from the turbine exhaust steam will reduce the amount of electricity produced.

Gasification options

Many gasification technologies are proposed for biomass. The most interesting in the context of industrial CHP is the fixed bed gasifier coupled to a reciprocating engine. These units are almost exclusively based on wartime designs developed in Germany, France and Sweden for automotive power. The shape of the reactor base ensures that the combustion and subsequent gasification reactions take place with sufficient intensity to create a fuel gas that is clean enough to be used in an internal combustion engine.

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12 See http://www.eca.gov.uk/

13 See http://www.bioregional.com/ or http://www.bedzed.org.uk/

14 See http://www.dti.gov.uk/NewReview/nr35/html/gasifier.html

Most applications over 250kWe tend to be multiples of a standard unit, allowing cost savings in fuel and ash handling and the electrical systems. Larger engines do not always imply cost savings, as the smaller units are based on mass-produced vehicle engines.

Other technologies may become available in the medium to long term, including Stirling engines and organic Rankine cycles. These technologies have not been included in this study because the data are uncertain and they are unlikely to substantially alter the overall picture. Fuel cells would make a substantial impact because they have a high (40–50%) electrical efficiency combined with small size, but they are unlikely to be available before 2025.

Table B2 summarises the technology options available together with their key parameters.

Northern Ireland industry

Northern Ireland is fortunate in having a strong base of small and medium-sized enterprises (SMEs) in this area. Rural Generation Ltd and Exus Energy Ltd are world leaders in their technology for CHP and their appreciation of the needs of the rural and farming economies. These two companies believe that local CHP and heating are feasible given the economic conditions in Northern Ireland. However, some policy measures are necessary to ensure a rapid take-up and a rate of growth that would generate adequate cash flow to finance future improvement. These include:

- An initial phase of capital grant-aided projects
- A presumption for renewable energy in public sector purchasing policy
- Support for energy crops at the same level as in England.

Table B2 Technology options for bio-energy industrial CHP

Technology	Capital cost (£k/kWe installed)	Electrical efficiency (LHV)	Overall efficiency	Technology status	Comments
Steam boiler and steam engine small (30kWe)	£6,500	8%	80–90%	Commercially available, but very few engine suppliers	Low grade hot water or steam for CHP. Higher grade steam reduces electrical efficiency.
Steam boiler and steam engine large (2MWe)	£1,800–£2,900	16%	80–90%	Commercially available, but very few engine suppliers	As above
Steam boiler and turbine (+ 1kWe)	£1,500	18%	80–90%	Commercially available, many suppliers	As above
Downdraft gasifier and reciprocating engine (100kWe)	£1,600–£2,800	24%	65%	Demonstration Two NI suppliers, more in EU	Potential for higher grade heat recovery from engine exhaust. Electrical efficiency unaffected by heat extraction.
Downdraft gasifier and reciprocating engine (250kWe)	£1,250–£1,660	25%	65%	Demonstration Two NI suppliers, more in EU	As above
Fixed bed gasifier and reciprocating engine (>1MWe)	£1,100–£1,500	26%	65–70%	Demonstration Four UK suppliers, two or three in EU	As above. May be aggregate of 250kWe units. Some single units in EU.
Hot air micro turbine cycle (100–250kWe)	'competitive'	25% estimated	70%	Development One supplier (Talbott's Heating Ltd)	Not available commercially, but promising. High grade waste heat as hot air. Electrical efficiency unaffected by heat extraction.

Renewable transport fuels

Until the Biofuels Directive [13], renewable transport fuels (RTF) from biomass did not receive much attention in the UK. This EU measure encourages Member States to ensure that at least 5% of their transport fuel requirements are met by biofuels by 2010.

The options are to produce locally, or to import from countries with more suitable conditions for production. The technology options are outlined below. Which, if any, are adopted in Northern Ireland has not been decided, while the relative merits of each option and of transport fuel versus heat and electricity are not fully understood. However, the land-based resource is fixed and the relative allocation between heat, electricity and transport will need to be decided.

- **Methane.** Landfill gas, sewage gas and other anaerobic digester gases can be cleaned, enriched and compressed for use in gas (methane) fuelled vehicles. There are pilot schemes in France and Sweden, and substantial interest from local authorities and waste management companies in the UK.

- **Hydrogen** is an energy vector[15] that is being examined by most OECD countries and by many energy companies as a possible long-term solution in the electricity, heating and transport markets where it would offer greenhouse gas abatement and other local air quality benefits. Hydrogen can be produced relatively simply from biomass by gasification. The process is analogous to that used for producing hydrogen from coal or oil. The technical challenge is to adapt the technology to a scale appropriate to biomass.

- **Liquid transport fuels** fall into two categories – alcohols and oils. The most common routes for preparing alcohols are biological and are based on the conversion of sugars, by fermentation, to ethanol. The procedure is easiest using the simple sugars from sugar cane and sugar beet. Fermenting starch from cereal grains is another well-known process. However, these simple sugar-based and starch-based processes both suffer from high capital and feedstock costs.

  The only other naturally occurring sugars are cellulose and hemi-cellulose. While these are a major constituent of all plant matter and are therefore cheap, they are the most difficult sugars to release and ferment. The most recent developments involve enzyme processes that release and break down cellulose without the use of acids.

  Alcohols and oils can also be produced from solid biomass via gasification. The raw gas produced is used as a feedstock for synthesising paraffins, methanol or ethanol. All of the gasification routes use well-tried industrial processes, but again the technical challenge is to adapt the technology to a scale appropriate to biomass.

- **Biodiesel** (fatty acid methyl ester) is obtained by the relatively simple process of esterifying vegetable oil with methanol and a catalyst. The basic oil is normally produced from rape seed in Europe and soya beans in the USA, although waste oil from restaurants or food processing is becoming an important feedstock source. Its advantages lie in the simplicity of production and the ability to substitute directly into the distribution chain. The disadvantages lie in the poor carbon balance and the resulting high cost of carbon abatement.

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[15] The 'carrier' of the energy (i.e. 'a means of storing and transporting energy').

Domestic heating

Biomass is suitable for both single dwelling and community heating applications. In recent years, the use of biomass has grown significantly for single dwelling heating in a number of countries in Europe and in North America. The increase in the use of pellets is most notable, going from zero to several hundred thousand tonnes per year, but other fuels have also enjoyed improved markets. This increase has been driven by market forces in North America and government initiatives in Europe; it has occurred largely in rural areas at the expense of heating oil and electricity.

Under all reasonable scenarios, at least 62% of domestic heating could be supplied by gas in the future (see Annex D). The balance will be supplied by oil and electricity with a small amount of coal. Based on experiences in Sweden, Denmark, Austria and the USA, it is reasonable to assume that biomass heating could take a significant share of the non-gas market. Pellets, in particular, would be well placed to take a market share.

Assuming a consumption of 5 tonnes of biomass per dwelling, the output from the new installation at Balcas Timber Ltd at Enniskillen could supply 10,000 homes; future extensions could supply a further 10,000 dwellings.

A short review of the various technologies is provided below.

- **Open fire heaters using logs.** Such heaters, although cheap and simple, have very poor efficiency of fuel utilisation, typically around 10–15% and should not be encouraged.

- **Closed appliances (stoves) using logs.** To overcome the problems of open fire-type heaters, closed appliances (stoves) have been developed that contain the burning fuel behind a door. A glass panel set in the door is aesthetically attractive.

  Heat transfer from such an appliance usually takes place by radiation and by convection of warm air from hot surfaces. A boiler can provide hot water or central heating. Efficiencies are high, at approximately 75%.

- **Ceramic storage heaters.** These well-known tiled stoves have become widespread in Scandinavia, Austria and Germany during the last two centuries. Each stove consists of a combustion chamber and a long flue path cast into a ceramic block weighing over 500kg. The exterior is traditionally covered with decorative tiling. The stove is fired with a single charge of wood at high temperature for just a few hours each day. The ceramic block then releases the heat slowly over 10–20 hours. Although expensive, these stoves are very efficient and clean burning. They are still sold today in a form that is not greatly different from the original concept developed in the 1790s.

- **Central heating boilers using logs**. These are common in Scandinavia, Austria and Germany. To guarantee a clean burn, they are fired for a few hours each day at maximum output. The heat generated is stored in a hot water accumulator and released on demand into a pumped central system. An accumulator should always be fitted to ensure good environmental performance. The accumulator also gives the opportunity to connect other energy sources such as solar or heat pumps. Boilers are often provided with oil burners for use in summer or electrical heaters in the accumulator.

- **Room heaters using wood pellets.** Wood pellets are now a major fuel source for heating in many parts of Europe (Sweden, Germany, Austria) as well as in the USA and Canada. Fully automated room heaters for single dwellings (unit size with thermal output in the range 3-10kW) are now a mature technology, with several thousand being used in these countries. They are attractive, with a glass-fronted combustion chamber, and convenient, with a fuel storage hopper that feeds the fire bed by gravity. The room temperature can be maintained by thermostatic control. Refuelling is usually by emptying a bag or bin of fuel into the top of the unit, although it is possible to arrange an auxiliary storage hopper on an outside wall for some units. They are often sold as a focal point for a room and as supplementary heating. There are many designs on the market, ranging from simple, manually ignited heaters with little fuel storage to sophisticated units with electric ignition and several days' auxiliary storage.

- **Pellet-fired central heating boilers.** These units are comparable to oil-fired heating systems in terms of convenience and achieve high thermal efficiency (around 90%+). They differ significantly from log-based systems in that they are based on designs for oil-fired boilers and do not need accumulators. They will follow the heat load by modulation. Ignition and control are automatic, but ash needs removing weekly. The storage bin will take up a considerable amount of space and, because it is connected to the boiler by an augur, its installation is less flexible than an oil tank. In Sweden, it is common to convert an oil-fired boiler to pellets by removing the oil burner and replacing it with a small pellet stoker and storage bin.

- **Wood chip systems.** Although the cost of wood chip (around £25–40 per dry tonne) is well below that of wood pellets, the wide variation in its quality (e.g. moisture content, size, calorific value, foreign matter such as mud, etc.) and handling problems makes it unsuitable for small single dwelling applications. Larger country houses and farm complexes may find it economic.

Table B3 gives a summary of the options for single dwellings. Table B4 offers a summary of fuel options.

Table B3 Biomass options for domestic heating

System	Typical costs	Installation	Burn time before refuelling	Refuelling	Other points
Room heater/ logs	£350–£1,000	150/200mm chimney	4 hours Will slumber overnight	Manual front door	Point source – needs air management and/or other heating source
Room heater/ pellets	£1,500–£2,000	100mm vent is adequate but Building Regulations may demand 150mm flue.	40 hours	16kg bags hopper	As above Needs specialist maintenance
Boiler/logs	£1,500–£3,000	150/200mm flue	12 hours	Manual door	Often multifuel Must have accumulator
Boiler/pellets	£3,000–£7,000	100mm flue Retrofit is possible for existing oil boiler.	3 days +	Bags into store or hopper	Fully automatic system

Table B4 Fuel options

	Retail market in NI (2004)	Cost
Logs	Yes, but very informal	1–3p/kWh
Chips	No	0.5–1 p/kWh
Pellets	Yes, just starting	2.2–3p/kWh

5 Socio-economic effects of bio-energy schemes

This section examines the effects of bio-energy schemes on the local or regional community. The effects covered by the term socio-economics include:

- Employment
- Wealth creation
- Regional trade balance
- Competitiveness
- Standard of living.

The most important of these effects for bio-energy schemes are summarised below. This section is not intended to act as a definitive study of this area, but rather to bring together the key issues for those unfamiliar with bio-energy and its potential impact. Tables B5 and B6 summarise the socio-economic effects of biomass feedstocks and conversion technologies, respectively.

Employment and wealth creation

Bio-energy schemes can result in additional local jobs through:

- People being employed in the start-up and operation of the project
- Direct and indirect employment on the project
- People employed in industries supplying goods and services to the project
- Induced employment. Additional jobs may be created in the local community as a result of increased spending due to the wealth created by the project. In some cases, the project will not provide additional jobs, but may help to safeguard existing jobs.

Finally, bio-energy projects could displace jobs from existing activities.

In summary:

- Production of forest residues leads to local job preservation for forestry workers and increased enterprise profits.

- If unused land is brought into energy crop production, this will create about nine local jobs per 500ha and increased income to the farmer.

- If land is converted from livestock production to energy crop production, there will be little change in local employment, but farm income will fall. This is mainly due to the current high level of subsidy for livestock farming. The Single Payment Scheme[16] is likely to make energy crops more competitive in the future.

- Building a 1MWe CHP plant will provide short-term local construction jobs and about two long-term jobs for its operation.

- Development of a small-scale (100–500kW) heating and/or CHP market or a domestic heating market will not provide local employment in operation, as systems are operated by existing

[16] See http://www.defra.gov.uk/farm/capreform/

staff or are automatic. Maintenance will be by the supplier. If the units are manufactured locally, this will provide employment.

- Use of biomass in coal-fired plant will make the plant more competitive and secure existing jobs.

- Biomass conversion capacity will lead to creation of a stable market for biofuels and thus will secure local jobs in the medium term.

Standard of living

- Energy crops provide an opportunity for rural diversification, opening new markets to farmers. This helps to support farming enterprise.

- Labour resources can be utilised at slack times of year in energy crop production, thus improving productivity and competitiveness.

- New skills are required for energy crop production and for operation of biofuels plants. This may encourage retention of skilled employees in the region, thereby enhancing social cohesion.

Regional trade balance

- Northern Ireland currently imports most of its fuel, with the main fuels being natural gas, coal and electricity. Production of fuel locally from energy crops will reduce imports, increase security of supply and increase diversity of supply.

- Development of small-scale CHP in Northern Ireland has export potential.

- Tourism should be considered in the context of energy crop production. The amenity value of existing forestry will improve with improved management. Public access to SRC may also be more acceptable to a landowner. SRC will have a visual impact; in small areas and lowland settings, this will generally be positive.

Displacement effects

- If energy crops replace livestock, then this will result in loss of business for the livestock processing industry.

- The electricity produced from biomass is predicted to be a small percentage of the total requirement in Northern Ireland. It is likely to replace imported electricity and, therefore, is unlikely to displace any jobs in the Northern Ireland electricity supply industry.

- The renewable transport fuel produced from used oil or oil seed rape is likely to be a small percentage of the total transport fuel use, and thus will not displace jobs in the refining industry.

- There is a danger that cheaper imported biofuels could undermine the production industry in Northern Ireland. This has already been observed in the co-firing market and in the production of biodiesel.

Table B5 Socio-economic effects of biomass feedstocks

Feedstock	Qualitative effect on socio-economics	Direct job creation	Indirect and induced job creation	Displaced activities?	References
Forest residues	Job retention in forestry industry Small additional job creation Enhanced profit for landowner Local production of fuel	About 1 per 5,000 ODT (or per MW)	No indirect, as existing equipment used. Some induced from increased profits from wood sales for energy.	None – additional to existing forestry operations, providing additional work for staff with same skills.	[14]
SRC	Job creation Farm diversification Reduced profit when replacing existing farming enterprises such as livestock or arable farming Increased profit when bringing set aside land into cultivation New skills Local production of fuel	2-6 per 500ha	About five per 500ha	If bringing unused land into production, will provide additional income/employment. If instead of livestock farming, likely to displace about nine jobs and, in current subsidy environment, lead to reduction in profits. However, introduction of Single Payment Scheme is likely to make SRC production more competitive.	[15,16]
Energy grasses	No studies to date Miscanthus probably similar to SRC Switchgrass and Reed Canary Grass are seeded crops, so requirements probably similar to arable crops			Grasses may be suitable for growing on set aside land, so that no activity will be displaced.	[11]
Oil seed rape	Job retention Local fuel production	Small areas likely to use existing labour. For larger areas, estimated three per 500ha.	Small indirect effects as likely to use existing equipment. Induced jobs estimated at three per 500ha.	Not if possible to grow on existing set aside land. However, likely suitable land would involve displacement of arable crops, which would lead to a reduction in profits.	[17]

Feedstock	Qualitative effect on socio-economics	Direct job creation	Indirect and induced job creation	Displaced activities?	References
Used edible oils	New market for an existing resource Maintains income for oil user Local fuel production	None	May have a small effect if income from oil sales for energy is more than current market.	Current market for animal feed is being phased out. New market will help maintain income.	

Table B6 Socio-economic effects of conversion technologies

Description	Qualitative effect on socio-economics	Direct job creation	Indirect and induced job creation	Displaced activities?	References
1MW CHP system	Some small increase in local employment Skilled labour opportunities Increased profits spent in local area leading to induced jobs Heat/electricity produced from local fuel replaces imported fuel Specialist equipment is imported	About two for each plant. In construction phase, mainly local labour assumed. In operation phase, some local operators, but specialist imported labour will be needed.	The plant will be profitable, leading to increased spending in the local region and estimated induced employment of one job per plant.	Fuels displaced are likely to be imported electricity and oil, so effect on regional jobs will be confined to reduction in distribution by road of oil supplies.	[14,15,18]
<500kWth heating boiler, running on wood chips or pellets	Use of local fuel Opportunity for local manufacture of boilers	0.1 direct jobs – normally part of job of existing maintenance staff. Indirect jobs could be important if boilers built locally and commissioned by local experts.	None from operation. If boilers are sourced locally, then greater profit in supply chain would lead to induced job creation.	Displaces maintenance of existing boiler.	[14]
100–500kW gasifier and CHP	Under development in Northern Ireland Possible boost for local sales and export potential	Potential for jobs in manufacturing, distribution and after sales servicing of units. Units are designed to operate unmanned, so no operational	Employment income and profits from unit production will lead to induced jobs if manufacturing remains local.	Potentially will displace heat production units. Effect on local economy will depend on whether such heat units are manufactured locally.	[18,19]

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Description	Qualitative effect on socio-economics	Direct job creation	Indirect and induced job creation	Displaced activities?	References
		jobs.			
Domestic-scale heating boiler	Will use local fuel (wood pellets) to replace coal or oil heating systems. However, wood pellets are currently more expensive than fossil fuels.	Potential for jobs if boilers manufactured locally. Installation and maintenance of boilers, and transport of fuel to consumer.	Provided boilers are manufactured and maintained locally.	Will displace the installation, and maintenance of fossil fuel boilers, and the fuel supply for these systems. Overall likely to be neutral for job gains/losses.	
Co-firing in large-scale coal-fired power station	May help preserve jobs at power station. Provides large stable market for biomass. However, there is a danger of lower priced biomass imports undermining local feedstocks.	None. Will be undertaken by existing power station staff.	Increased profit from power station will lead to increased local spending and thus induced jobs.	Biomass will be handled instead of coal. Small reduction in demand for coal.	
Production of biodiesel	Local production of transport fuels - security of supply. However, there is a danger of lower priced imports of feedstocks undermining local production. Contribution to meet EC requirement for renewable transport fuels. Employment if rape seed is processed locally.	Building and operating processing plant will create jobs.	Equipment likely to be imported. Job incomes and profits will lead to induced local employment.	OSR processing will be a new venture. The rape oil will displace a small proportion (<5%) of imported oil. Jobs may be displaced in processing of other agricultural products if OSR is produced in their place.	

6 Environmental impact of bio-energy projects

Like the previous section on socio-economic effects, this section is not intended to be an exhaustive treatment of the subject but a summary of the key features. Tables B8 and B9 summarise the environmental impacts of biomass feedstocks and conversion technologies, respectively. They draw heavily on the information in the report for the Environment Agency prepared by AEA Technology [20]. Further introductory material can be found in the series of information leaflets [14,21] published by the DTI following a consensus building exercise with non-governmental organisations (NGOs) and trade bodies.

Greenhouse gas impacts/use of natural resources

When energy crops are growing, they absorb CO_2 from the atmosphere. When the crop is converted to energy, the stored CO_2 is released to the atmosphere. Thus, overall the cycle is carbon neutral. Conversely, when fossil fuels are used, CO_2 is released to the atmosphere and will not be reabsorbed. Also, the fossil fuel source cannot be replaced. Energy crops thus reduce CO_2 emissions and conserve natural resources.

There are some CO_2 emissions from the use of fossil fuels and other materials during the production of energy crops and the construction/operation of the power plant. These CO_2 emissions need to be included in an estimate of total carbon emissions. CO_2 emissions have been estimated in a number of studies. Table B7 gives some relevant values from a recent study commissioned by Defra.

Table B7 Carbon dioxide emissions associated with energy production by various routes [22]

Production method	**Carbon footprint (kgCO_2/MJ)**
CHP at medium scale fed with wood chips	0.005*
Small-scale heating fed with wood chips	0.005*
Large-scale electricity production from wood chips	0.016
Electricity from UK grid supplies 1996	0.150
Industrial CHP	0.100
Heat from small oil-fired boiler	0.104

* Estimated.

Production of energy crops

- There will be a visual impact when growing energy crops. SRC is like young trees and is most suitable as a lowland crop where it can be planted as a mixture of varieties and plantation shapes to enhance appearance [23]. Energy grasses are like conventional arable crops in appearance.

- Growing energy crops on former arable land or improved pasture is generally beneficial to both land quality and biodiversity. Unimproved pasture should be avoided. Energy crops can also be used to reduce run-off since they have extensive root systems and are perennial.

- There will be some nuisance associated with energy crops in terms of noise and dust during agricultural operations. This will be mainly similar to other crops, but chipping at the forest or farm may be particularly disruptive. If treated sewage is used as a fertiliser, there will be odour.

- The input of agrochemicals to the crop must be minimised to gain maximum CO_2 savings.

- Storage of crops will usually be on the farm or in the forest and will be in stacks or heaps similar to other agricultural/wood products.

Conversion

- Biomass fuel has a low density; transport distance should therefore be minimised to reduce transport fuel use and road congestion. Methods are being developed to increase the density of the fuels.

- Biomass plant should be sited carefully to be close to the heat market for CHP and to a connection to the electricity distribution grid.

- Sites should have good transport links and be of low biodiversity value.

- Plant will generally have solid, liquid and gaseous emissions. Emissions to air will be regulated for large-scale and medium-scale plant. Emissions vary for domestic-scale boilers.

- There are a range of potential uses for biomass ashes, including fertilisers and a component of aggregates. If a market cannot be found, the ash may require disposal to landfill.

- Liquid wastes will require disposal.

- Plant is modern and compact in appearance. Storage will be required for the biomass fuel.

Table B8 Environmental impacts of biomass projects: production of feedstocks

Feedstock	Greenhouse gas impacts/use of natural resources	Emissions/ waste	Traffic	Biodiversity	Land quality	Visual impact	Noise	Odour
Extraction of residues	Diesel fuel in machinery engines leading to CO_2 emissions associated with removing residues and processing ready for transport. Emissions estimated at 19kgCO_2/ODT.	Exhaust emissions to air. Dust produced locally.		Extraction must leave a proportion of residues to ensure a habitat for existing wildlife. Allowing more light may present opportunities to other species	Care should be taken to leave sufficient residues for nutritional requirements of forest. Additional traffic should follow good practice for forestry extraction to minimise soil compaction and run-off.	Should improve the appearance of the forest by removal of thinnings and brash.	Associated with any chipping operations at the forest roadside.	
Production of SRC, energy grasses	Crops absorb CO_2 while growing. Reduced use of agrochemicals and reduced tillage will reduce fossil fuel consumption and greenhouse gas emissions compared with other arable crops. Emissions	Run-off of agrochemicals will be reduced relative to arable crops due to reduced input and perennial nature of crops.		Growing energy crops on former arable land or improved pasture will lead to an increase in biodiversity. Growing on unimproved pasture is not recommended.	Soil structure and fertility of ex-arable land may be improved. Soil erosion will be reduced.	SRC is like a young wood, and is most suitable as a lowland crop. A mix of varieties and varied shapes of plantation can enhance appearance. Energy grasses are more like conventional		If sewage sludge is used to fertilise the crop, there will be an odour.

Feedstock	Greenhouse gas impacts/use of natural resources	Emissions/ waste	Traffic	Biodiversity	Land quality	Visual impact	Noise	Odour
	estimated to be about 25–30kgCO_2/ODT for SRC and Miscanthus.					field crops, although Miscanthus can reach 4m in height.		
Harvesting of energy crops	CO_2 emissions associated with fossil fuel use for harvesting and processing. Chipping at the roadside is a particularly high producer of CO_2 emissions. Emissions estimated to range from 3–8kgCO_2/ODT, depending on crop and whether it is chipped or baled.	Exhaust emissions to air. Dust produced locally.	Transport to store similar to other crops. Wood chips are low density and so require more vehicle movements.	Should try to ensure a different area of coppice is harvested each year to retain different types of cover for wildlife.	Timing of harvesting important to minimise compaction of soil.	Harvesting a different area of coppice each year helps to enhance the overall appearance of the SRC. After harvest, energy grasses have the appearance of arable stubble fields.	Associated with harvesting machinery and any in-field chipping operations.	
Transport and storage	Use of fossil fuels for transport leads to CO_2 emissions. Quantity is dependent on	Exhaust emissions. Biomass should be netted to avoid any wind blown nuisance	Biomass will be collected from farm or intermediate store by heavy goods		Biomass stored on field may be collected by HGVs. Hard standing close to gate avoids compaction and	Biomass stacks may be stored on field or in the forest, in a similar way to existing field		

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Feedstock	Greenhouse gas impacts/use of natural resources	Emissions/ waste	Traffic	Biodiversity	Land quality	Visual impact	Noise	Odour
	distance transported and density of biomass. Estimated to be between 3–16kgCO_2/ODT.		vehicles (HGVs) like other crops.		run-off from biomass awaiting collection.	storage for straw or wood.		

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Table B9 Environmental impacts of biomass projects: conversion to energy

Plant	Greenhouse gas impacts/use of natural resources	Emissions/waste	Traffic	Biodiversity	Land quality	Visual impact	Noise	Odour
Construction of 1MW CHP plant	Direct CO_2 emissions from construction operations and indirect emissions from materials required for construction.	Exhaust emissions Dust	Deliveries of materials and equipment. Construction plant.	Construction sites should be chosen to avoid areas of high biodiversity value.		Small modern industrial plant.	As associated with small construction project.	
Operation of 1MW CHP plant	Use of consumables in plant leads to CO_2 emissions. Estimated emissions for construction and operation are estimated to be about 1kgCO_2/GJ.	Discharges to air below levels agreed in operating licence. Main solid waste product is ash. This may be landfilled, but currently markets are being sought (e.g. fertiliser or input to construction materials).	About two deliveries by HGVs daily.				Will need to meet noise emission levels set by regulator.	
Installation of domestic wood boilers	Materials and energy required to produce the boiler lead to indirect CO_2 emissions.		Delivered by HGVs.					
Operation of domestic wood boilers	Replaces fossil fuel by wood fuel thereby saving CO_2 emissions. Estimates of CO_2 emissions from	Emissions to air and ash. Ash would normally be used as fertiliser.	Similar to delivery of oil/coal for heating.					

Plant	Greenhouse gas impacts/use of natural resources	Emissions/waste	Traffic	Biodiversity	Land quality	Visual impact	Noise	Odour
	construction and operation of small-scale heating boilers are about 3kgCO_2/GJ.							
Installation of small-scale gasifier	CO_2 emissions from construction of housing and indirect emissions from equipment manufacture.		Delivered by HGVs.					
Operation of small-scale gasifier, <500kWe	Reduces CO_2 emissions by replacing fossil fuel with biomass. Some use of consumables leads to CO_2 emissions.	Emissions to air and ash production. Markets are being sought for ash. Some technologies produce liquid waste.	1–3 deliveries per week.					
Operation of 500MWe coal-fired power station, using 5% biomass for co-firing	Reduces CO_2 emissions by replacing some coal with wood.	Impacts on air emissions and efficiency of combustion currently being assessed. Impact of wood content on ash may affect suitability of ash for current markets.	Additional HGV traffic, as wood delivered by road and has lower energy density than coal.					

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7 Bio-energy's contribution to reducing NI's carbon footprint

This section discusses how bio-energy may develop in the future under different scenarios. The four scenarios developed by the UK Foresight Programme [2] form the starting point for those used in this study. These scenarios identify key social and economic trends and then explore how these might change under different political priorities, markets conditions and social attitudes. Bio-energy can also contribute to these scenarios as a result of basic mechanisms of price, particularly in the heating market, should oil become in short supply. The scenarios used in this study, which are described in more detail in Annex A, are:

- World Markets
- Regional Enterprise
- Global Sustainability
- Local Stewardship.

Table B10 summarises the current status of the different market sectors for bio-energy.

Table B10 Current status of market sectors

Market sector	**Status**
Utility-scale electricity generation	• No deployment • Some initial thoughts and plans for installations that will resolve environmental problems
Industrial heat and CHP	• No deployment • Plans for smaller CHP well advanced and growing interest in the public sector
Domestic and commercial heating	• Small numbers of installations in rural areas • Fuel supply on a largely informal basis • Advanced planning for pellet supply industry but no supply as yet
Renewable transport fuels	• No deployment • Situation under review

Bio-energy storylines in response to the Foresight scenarios

This is a qualitative exercise that aims to put in place the basis of a discussion of the direction of developments to 2050 rather than quantitative predictions of markets. We have used 2004 as the baseline rather than 2000, but the data are essentially unchanged.

- **World Markets**. There is very little deployment under this scenario. Energy price levels will not support the development of energy crops, and forests will be managed purely for amenity and timber value. Two or three agricultural waste incineration plants may be built, primarily for environmental reasons, but no further utility-scale installations. The use of wood for heating will remain a small-scale activity in rural areas, but may gain some ground as a result of fluctuating oil prices. Pellet production may cease because the price support may not be available to pay for the perceived value over heating oil. Industrial use of biomass is unlikely to be installed unless the oil price rises substantially.

- **Regional Enterprise**. Bio-energy is supported by local mechanisms to the extent that it is able to contribute to security of supply concerns. In practice, this is likely to be minimal due to the low level of resources. Two or three agricultural waste incinerators may be built to resolve acute environmental concerns. Heating in rural areas could be supported as a domestic fuel outside of the gas network, and this support could be adequate to ensure the continuation of a local pellet industry and a more formalised log supply structure. Some public procurement may be possible to underpin the market. Energy crops are unlikely to be developed, except where they can contribute to the resolution of environmental problems. The developments above are all NI strengths and this will be key to progress in these areas. Co-firing may be deployed, but there would be concern over the continuation of the fuel supply market when the incentives cease.

- **Global Sustainability.** In this scenario, Northern Ireland seeks to play its full part in resolving global environmental problems. The full range of options will be deployed but with more preference towards utility-scale power generation projects, allowing trade into EU green power schemes. Likely deployment of early co-firing to profit from ROCs will boost fuel supply, with the prospect of a sustainable pick-up of other technologies in the medium term.

- **Local Stewardship.** This is possibly the most favourable scenario for bio-energy. A strong sense of ownership and local government support will favour the development of an extensive domestic and commercial heating sector. Pellet production will be extended to take in all available resource by 2025; the products will be sold largely to the domestic sector, with lower quality product going to larger commercial and public sector buildings. By 2012, public sector purchasing policy is changed to include a presumption in favour of renewable energy. Energy crops are likely to be widely deployed by 2025 to supply fuel as heating markets expand. Until this time, the industry will not generally be constrained by fuel supplies, although local shortages may exist. Some industrial CHP may be deployed where there is a need to strengthen the network to support local economic activity. Utility-scale installations may be deployed where real benefit accrues to the local community; this may favour community heating in high density areas. Industrial CHP and heating will be strongly supported by government initiatives due to the socio-economic benefits from local fuel production and the wider benefits of retaining businesses in the local area.

Fuel resource storylines

Table B11 indicates the maximum fuel resources thought likely to be available now and in the future (2012, 2025 and 2050). This is based on the following assumptions:

- Low or zero value agricultural wastes are all available for energy
- Forestry expands by 800ha annually
- Average SRC yields in Northern Ireland are 10 ODT/ha in 2012, 13 ODT/ha in 2025 and 15 ODT/ha in 2050.

Table B12 shows the maximum contribution assuming an aggressive policy stance in line with the Global Sustainability or Local Stewardship scenarios. It does not take into account the wide scale production of oil seed rape or grain for transport fuels. If taken up, these could replace the area taken up by SRC willow. Table B13 shows the likely deployment in terms of the amount of fuel and energy output from each biofuel in 2004, 2012, 2025 and 2050.

Table B11 suggests that Northern Ireland could sustainably produce and use over 1.4 million dry tonnes of biomass fuel (7,822GWh/year) in 2050. If 1.4 million dry tonnes were burned in a conventional power station similar to the one at Ely in England, it would represent 200MWe generating capacity.

Table B11 Maximum available fuel resources to 2050

Biofuel	2004		2012		2025		2050	
	ODT/year	GWh/year	ODT/year	GWh/year	ODT/year	GWh/year	ODT/year	GWh/year
Forestry residues	50,000	264	54,000	285	61,000	322	74,000	391
Sawmill conversion product	200,000	1,056	200,000	1,056	200,000	1,056	200,000	1,056
Cereal straw	0	0	0	0	0	0	0	0
Mushroom compost and poultry litter	158,000	834	158,000	834	158,000	834	158,000	834
Energy crops	0	0	50,000	264	195,000	1,029	1,050,000	5,542
Total	**408,000**	**2,154**	**462,000**	**2,439**	**614,000**	**3,241**	**1,482,000**	**7,823**

Table B12 Potential deployment under Global Sustainability or Local Stewardship scenarios as percentage of assumed maximum available

Biofuel	2004	2012	2025	2050
Forestry residues	0	40%	50%	75%
Sawmill conversion product	25%	50%	100%	100%
Cereal straw	0	0	0	0
Mushroom compost and poultry litter	0	100%	100%	100%
Energy crops	0	5%	20%	100%

Table B13 Deployment under Global Sustainability or Local Stewardship scenarios in terms of use and output

Biofuel	2004		2012		2025		2050	
	ODT/year	GWh/year	ODT/year	GWh/year	ODT/year	GWh/year	ODT/year	GWh/year
Forestry residues	0	0	20,000	106	30,000	158	50,000	264
Sawmill conversion product	50,000	264	100,000	528	200,000	1,056	200,000	1,056
Cereal straw	0	0	0	0	0	0	0	0
Mushroom compost and poultry litter	0	0	158,000	834	158,000	834	158,000	834
Energy crops	0	0	50,000	264	195,000	1,029	1,050,000	5,542
Total	**50,000**	**264**	**328,000**	**1,732**	**583,000**	**3,077**	**1,458,000**	**7,696**

Technology storylines for Global Sustainability/Local Stewardship scenarios

Table B14 summarises the technology storylines for the four main technologies under the Global Sustainability/Local Stewardship scenarios for 2012, 2025 and 2050.

Table B14 Technology storylines under the Global Sustainability/Local Stewardship scenarios

Technology	2012	2025	2050
Utility-scale electricity generation	Co-firing drives energy crop deployment. 25,000 tonnes of pellets to co-firing. Agricultural wastes used for power. One merchant plant.	Co-firing stopped in 2016. Utility plant has taken up load from co-firing after a dip. SRC is a growing industry.	Generation is constrained by resource, so move is toward higher efficiency installations. First generation replaced by new technology.
Industrial heating and CHP	Combination of ROCs and capital drive CHP deployment and, with it, local engineering.	CHP and commercial/public sector heating expand to use resource from co-firing after a dip.	All available heat loads are supplied by CHP using fuel cells and other innovations.
Domestic and commercial heating	25,000 tonnes of pellets to domestic heat.	100,000 tonnes of pellets into domestic market. 100,000 tonnes of pellets into commercial heating, Innovation moves rapidly with the increase in cash flow.	
Renewable transport fuels	Decisions taken whether the optimum is to import or produce locally.		

8 Conclusions and industry views

Bio-energy could make a substantial contribution towards reducing Northern Ireland's carbon footprint by 2050. This conclusion is based on Northern Ireland's industrial strengths and the excellent conditions for energy crops.

Local Stewardship is possibly the most favourable scenario for bio-energy in Northern Ireland, although bio-energy would be part of Northern Ireland's strategy for resolving global environmental problems under the Global Sustainability scenario. Given the strong policy context implicit in these two scenarios, Northern Ireland could sustainably produce and use over 1.4 million dry tonnes of biomass fuel (7,822GWh/year) in 2050. This amount consists of some 1 million tonnes of energy crops, 250,000 tonnes of forestry residues and sawmill conversion product, and 150,000 tonnes of poultry litter and mushroom compost. This corresponds to approximately 150MW of electricity generation. In 2012, the corresponding figures are 328,000 tonnes and 1,730GWh/year and comprise largely low-value agricultural residues and forestry and sawmill products.

The energy markets in Northern Ireland both now and under these two scenarios are more favourable to the use of biomass than many other areas of the UK. This is due to the limited penetration of natural gas in Northern Ireland and its essentially rural character.

The following key issues emerge from the study:

- Bio-energy can contribute substantially to a reduction in the carbon footprint in Northern Ireland, but a strong and co-ordinated policy initiative will be needed to achieve this.

- Energy crops are essential if bio-energy is to have a large impact on Northern Ireland's carbon emissions.

- Bio-energy will be able to contribute to the industrial heat and CHP, domestic and utility sectors. There is considerable enthusiasm in the industry and the public sector to support the development of the heating and CHP market.

- Co-firing wood and energy crops with coal in a power plant is a short-term option, which could provide an initial start-up market for the fuel supply industry.

- There will be a small net gain in employment, but there will be some displaced activities. The main impact may be more to preserve and secure employment in rural areas. Socio-economic considerations will not be a constraint to deployment.

- There are many options for the disposal of farm livestock wastes, and anaerobic digestion for energy may not be the optimum for the farmer, whatever the carbon benefits. This whole area requires further study and the options need to be evaluated in both carbon and economic terms.

- The environmental impact of bio-energy deployment is generally positive, particularly where energy crops replace intensive agriculture. Where energy crops replace unimproved pasture, there may be a negative impact on biodiversity. Environmental considerations will not be a constraint to deployment.

Discussions with industry have highlighted the following key messages, which should be emphasised particularly with reference to an action plan.

- Public purchasing policy should assist the deployment of renewable energy and, in particular, heating and CHP. Raising the awareness of bio-energy amongst officials is seen as a priority and essential.

- The forthcoming DARD biomass strategy is welcomed, as past Government support for bio-energy has been seen as complex and split over too many departments.

- The current support level for SRC is seen as too low compared with that in England.

- The introduction of Northern Ireland Renewables Obligation Certificates (NIROCs) from April 2005 will make a significant improvement to the economics of CHP.

- Capital grants would be an important incentive in the early days of the industry to overcome initial resistance.

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Acronyms and abbreviations

CHP	combined heat and power
CO_2	carbon dioxide
DARD	Department of Agriculture and Rural Development
Defra	Department for Environment, Food and Rural Affairs (London)
DETI	Department of Enterprise, Trade and Investment
DTI	Department of Trade and Industry (London)
GCV	gross calorific value
HGV	heavy goods vehicle
NI	Northern Ireland
ODT	oven-dried tonnes
OSR	oil seed rape
RCEP	Royal Commission on Environmental Pollution
ROC	Renewables Obligation Certificate
RoI	Republic of Ireland
SRC	short rotation coppice

Addendum: Growth and utilisation of short rotation willow coppice

Establishment and initial growth

The crop is established during the spring (March–June). The standard commercial practice is to plant some 15,000–20,000 cuttings per hectare using specialist machines developed in Sweden. Simpler, cheaper planting techniques such as placing long rods or short pieces (billets) in a furrow have been trialled in the UK, but the results are so far inconclusive.

UK practice has been to cut back after one year close to the ground, which results in the formation of multiple shoots (i.e. to coppice). These multiple shoots stay in the juvenile phase of fast growth, which is partly why this system has a high dry matter yield.

Recent trials have shown that low till/direct drill options are not practicable on grassland and that traditional cultivation is necessary.

Harvesting/collection

Following cutback or the first harvest after two years, the crop then grows for another 2–3 years. The fuel is then harvested by cutting the stems close to the soil level. The cut stems again form multiple shoots that grow on for a further cycle to become the next harvest. The crop has a predicted lifespan of around 20 years. The shoots are harvested during the winter, when the leaves have fallen as chips, short billets or as whole stems (25–50mm diameter and 3–4 metres long).

Harvesting machinery

Commercial options are either a cut and chip forage/tractor mounted harvester with modified header (e.g. Claas Jaguar) or an Austoft sugar cane harvester with or without a modified header. Other options include full-length sticks, bundling and baling.

A general treatment of the crop as it is grown in the UK can be found in:

- *SRC for energy production.* Good Practice Guidelines. British BioGen. 1999.
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NORTHERN IRELAND VISION STUDY

Annex C: Prospects for the commercial, public and agriculture sectors to 2050

Document Reference	**NIVision/4**
Date	**29/03/2005**
Report Status	**FINAL**

CTC520C

IMPORTANT NOTICES

CONTENTS

Index to additional briefing materials

Executive summary

As part of the Northern Ireland Vision Study, this annex evaluates the potential for the commercial, public and agriculture sectors to achieve the 60% reduction in carbon dioxide emissions by 2050 recommended by the Royal Commission on Environmental Pollution (RCEP).

The commercial sector in Northern Ireland consists of a number of sub-sectors: retail; hotels, inns and restaurants; commercial offices; and others such as sports, heritage and entertainment. The public sector in Northern Ireland is larger pro-rata in terms of its population than the rest of the UK. It includes schools, further and higher educational establishments, Government buildings, healthcare, public offices, public sports buildings, and water services.

The baseline figure for the carbon footprint for commercial and public buildings in Northern Ireland in 2000 was established by adjusting data for 2002 (obtained from the Northern Ireland Energy Study 2002) to allow for changes due to fuel switching. In 2000, the commercial sector used 1,853GWh delivered (d) of energy (47% oil, 25% electricity, 16% solid fuel and 12% natural gas) and had a carbon footprint of 711 kilotonnes of carbon dioxide ($ktCO_2$). The public sector used 2,113GWh(d) of energy (47% oil, 37% electricity, 13% natural gas and 3% solid fuel) and had a carbon footprint of $906ktCO_2$. Natural gas was not introduced into Northern Ireland until 1996.

In 2002, the agriculture sector in Northern Ireland accounted for 2.5% of total gross value added (GVA) compared with 0.8% for the UK. The total direct energy consumption for the sector in 2000 is estimated to be 690GWh(d) (40% oil, 32% electricity, 15% solid fuel, 7% natural gas and 6% renewables and waste) and its carbon footprint to be $277ktCO_2$.

A scenarios-based approach was developed to determine how the RCEP's 60% recommendation could be met. Two scenarios were modelled in detail: Business As Usual (BAU) and Low Carbon Economy (LCE)[1].

Under the BAU scenario, current trends were assumed to continue and modelling suggests that the RCEP's 60% recommendation would be missed by a considerable margin.

However, the Low Carbon Economy scenario indicates that the 60% recommendation could be met before 2050. The vision is of a radically different society in which sustainability is inherently important. All new commercial and public buildings would be net zero carbon; they would be super-insulated and orientated to make maximum use of solar gains and daylight, and ventilated naturally. All power requirements within the buildings would be less due to building techniques and highly efficient technologies. Any requirement for heat and power would be self-generated using solar water heating, heat pumps, photovoltaics, wind turbines and/or hydrogen fuel cells. Many existing buildings would generate their own heat and power, and any additional power required from the grid would be generated using renewables (perhaps via hydrogen).

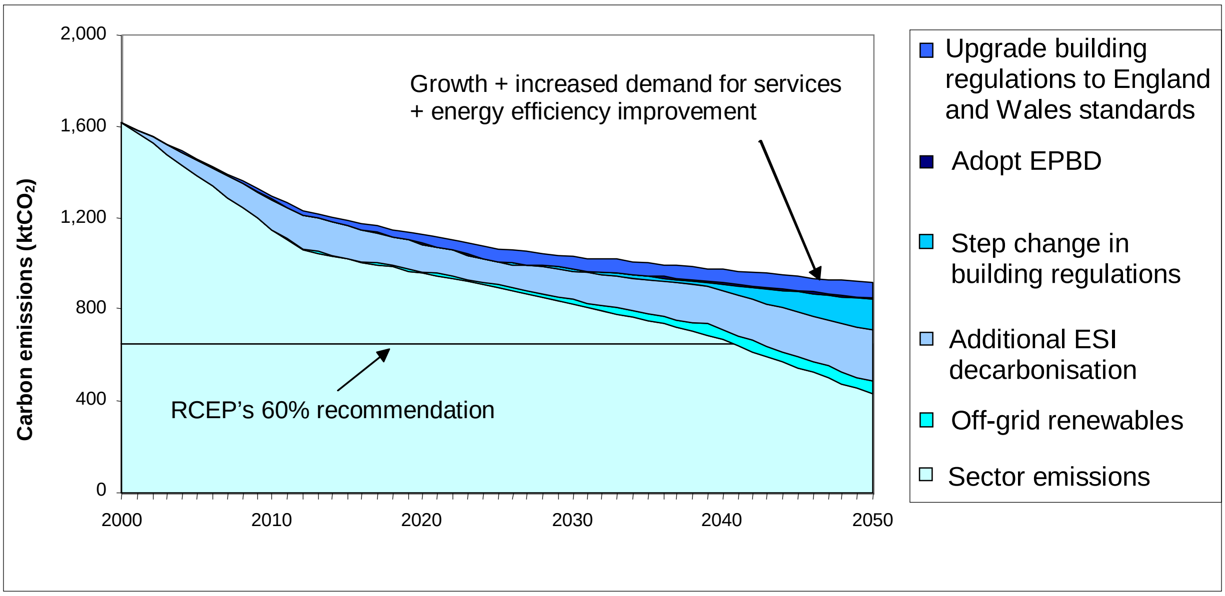
As shown in the roadmap below, the following measures would be required for commercial and public buildings in Northern Ireland to realised a 60% reduction in carbon emissions by 2050:

- A step change in the building regulations to require all new buildings to be net zero carbon
- Implementation of the EU Energy Performance of Buildings Directive (EPBD)
- Additional reductions in the carbon footprint of the electricity supply industry (ESI)
- Increased use of off-grid renewables and combined heat and power (CHP)

[1] *Editorial note*: The Low Carbon Economy scenario is the same as the Low Carbon Timeline shown on Figure 4 of the Main Report and is a lower carbon extension of the Global Sustainability scenario developed in Annex A. Annex A also contains details of the modelling work done on the other Foresight Programme scenarios.

- Adoption of cost-effective and All Technically Possible energy efficiency measures.

A roadmap for low carbon commercial and public sectors in Northern Ireland*



*Where one policy/action supersedes another, the savings are only attributed to the new policy/action.

As most buildings are designed to last at least 50 years, urgent action is needed to:

- Develop a route map for future improvements to the building regulations in Northern Ireland
- Review current building regulations and make a step change in performance
- Provide incentives for developers to go beyond the minimum specification
- Ensure energy efficiency measures are retrofitted during refurbishment
- Provide training in energy efficient practices for builders, architects and engineering consultants.

1 Introduction

The UK Government has adopted the recommendations of the Royal Commission on Environmental Pollution (RCEP) [1] on reducing carbon dioxide emissions to reduce the threat of global warming and climate change. The RCEP recommends the development of ‘a strategy which puts the UK on a path to reducing carbon dioxide emissions by some 60% from current levels by about 2050’.

This annex, which is underpinned by detailed modelling work, discusses how the commercial, public and agriculture sectors in Northern Ireland could reduce their carbon emissions to realise this challenging recommendation. Its production involved the following tasks:

- Defining the commercial, public and agriculture sectors in Northern Ireland
- Establishing a baseline for the sectoral carbon footprint in Northern Ireland for 2000
- Producing a bottom-up model of Business As Usual (BAU)
- Exploring other bottom-up scenarios
- Developing the most optimistic scenario
- Identifying the constraints and barriers that limit the rate of change
- Estimating the likely Northern Ireland (NI) carbon emissions up to 2050.

The annex considers a number of scenarios in order to produce projections of how Northern Ireland’s carbon footprint might change to 2050. Two scenarios (Business As Usual and Low Carbon Economy) and the assumptions made under these scenarios are considered in detail. The baseline year for all the scenarios is 2000.

The annex is concerned with the following ‘time periods’: 2000 to 2012, 2012 to 2025, and 2025 to 2050. Up to 2025, it is possible to make reasonable assumptions based on past trends and likely future developments, and energy efficiency technologies that are already available or in development. However, beyond 2025, the picture becomes inherently ‘blurred’ as technologies that we cannot possibly imagine will come into existence as we approach 2050. A more generalised approach has, therefore, to be adopted after 2025.

2 Commercial, public and agriculture sectors in Northern Ireland

It is helpful to identify the various sub-sectors within the commercial and public sectors in order to build more specific scenarios that reflect specific changes in the economy or society. For example, increased disposable income may lead to increased participation in leisure activities and thus increase energy consumption in this sub-sector.

Commercial sector

The commercial sector can be divided into the following sub-sectors:

- Retail
- Hotels, inns and restaurants
- Commercial offices
- Other commercial (sports, heritage and entertainment, transport/communications and miscellaneous).

Examples of these sub-sectors are given in Table C1.

Table C1 Sub-sector definitions*

Sub-sector	**Description/examples**
Retail	Bakeries, banks, betting shops, building societies, CTNs†, department and general, estate agents, food retailers, hairdressing salons, hirers of electrical appliances, laundries and launderettes, other personal services, other retail, post offices, repairs (not vehicle), takeaway food shops, vehicle showrooms
Hotels, inns and restaurants	Boarding houses, cafés, camping and caravan sites, hostels, hotels, motels, pubs, restaurants, wine bars
Commercial offices	Commercial offices, insurance and other business services, printing and publishing/photographic processing
Sports	Club houses, leisure centres, other leisure, other sporting, sports centres, stadium, swimming pools
Heritage and entertainment	Amusement arcade, bingo, churches, cinema, holiday centre, libraries, museums, night club, theatre
Transport/communications	Airport terminals, bus stations car parks, petrol stations, railway stations, road haulage, telephone exchanges

*Where possible/applicable, the sub-sectors used by the Carbon Trust have been used for consistency.

†Confectioners, tobacconists and newsagents

Public sector

The public sector in Northern Ireland is large compared with the UK when considered pro-rata on a population basis. It also includes some processes[2], some sports buildings, and a small number of other buildings such as publicly owned hotels. For ease of use, the same sub-sectors as those used in the Northern Ireland Energy Study 2002 [2] have been used. These are:

- Education (schools, further and higher education)
- Government buildings
- Healthcare
- Public offices
- Public sports buildings
- Other (e.g. libraries, museums and publicly owned hotels, water services).

Agriculture sector

In 2002, the agriculture sector in Northern Ireland accounted for 2.5% of total gross value added (GVA) compared with 0.8% for the UK [3]. Table C2 gives some key facts about agriculture in Northern Ireland compared with the UK and the Republic of Ireland (RoI). Extensive statistics about NI agriculture are available on the Department of Agriculture and Rural Development's website (www.dardni.gov.uk).

[2] Mainly the Department for Regional Development's roads and water services, plus the Department of Education's 'meal kitchens'.

Table C2 Agriculture key facts, 2002 [3]

	NI	UK	RoI
Agriculture as percentage of total GVA	2.5	0.8	3.2
Employees in agriculture	34,000#	390,000	121,000
% of total civil employment	4.8#	1.4#	6.9
Agricultural area (ha)	1,068,000	17,154,000#	4,443,000†
% of total area	78.7	70.4	63.1†
Farms	28,500	232,000†	142,000†
Average agricultural area (ha)	37.4	71.6†	31.4†
Average enterprise size:			
Dairy cows	60	73†	37†
Beef cows	19	28†	14†
Sheep	246	510†	158†
Pigs	653	576†	1,345†
Laying hens	1,789	1,482†	215†
Broilers	38,474	53,508†	12,078†
Cereals (ha)	11.1	50.8†	18.9†
Potatoes (ha)	6.7	11.5†	2.8†

#2001
†2000

3 Reviewing the baseline

The Northern Ireland Energy Study 2002 [2] indicates that the commercial and public sectors account for around 12% of total energy consumption and 13% of Northern Ireland's total carbon footprint in 2002.

Because the Northern Ireland Energy Study gives figures for 2002 and this annex considers a baseline of 2000, data for 2002 have been back-calculated to give 2000 figures (see Section 5 of Annex A).

Commercial sector

Figure C1 shows relative energy use by the sub-sectors in 2000, while Table C3 gives the fuel split, energy consumption and carbon dioxide emissions for the commercial sector.

Figure C1 Distribution of energy use in the commercial sector

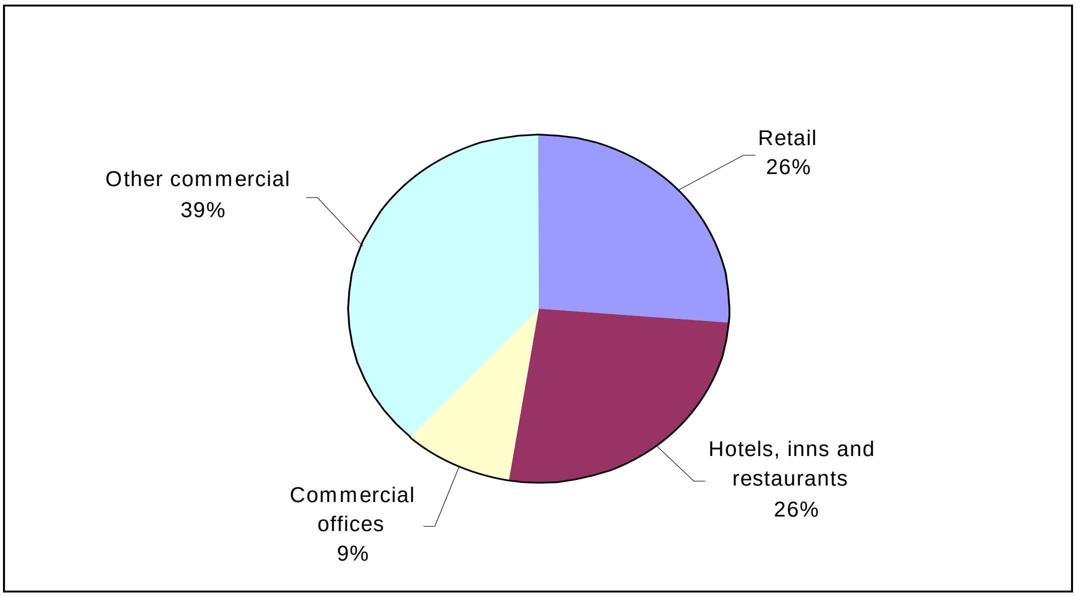


Table C3 Fuel split, energy consumption and carbon dioxide emissions for NI commercial sector in 2000

Fuel type	% of total energy	Energy use GWh(d)*	Carbon footprint $ktCO_2$
Electricity	25	469	350
Natural gas	12	222	42
Oil	47	872	222
Solid fuel	16	290	97
Total	**100**	**1,853**	**711**

*Figures for energy use can be given either based on metered values, i.e. delivered (d) or 'as supplied', or as primary (P) equivalent. The difference between primary and delivered energy is largely used to account for generation efficiencies in electricity.

Public sector

Figure C2 shows relative energy use by the sub-sectors in 2000, while Table C4 gives the fuel split, energy consumption and carbon dioxide emissions for the public sector.

Figure C2 Distribution of energy use in the public sector

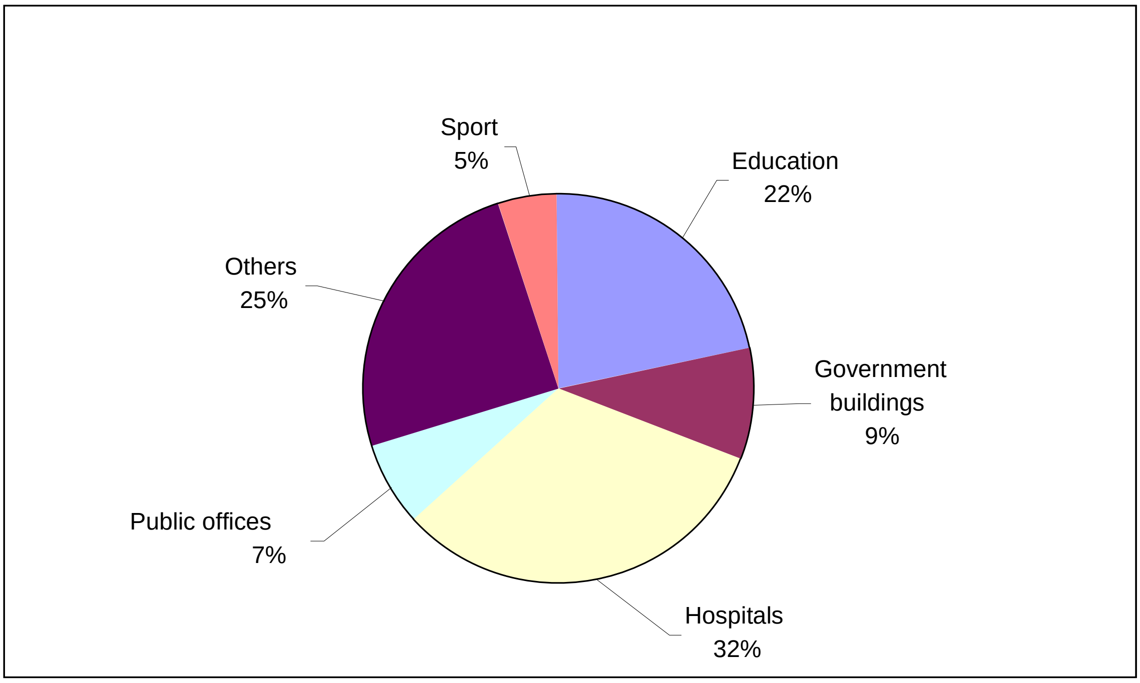


Table C4 Fuel split, energy consumption and carbon dioxide emissions for NI public sector in 2000

Fuel type	% of total energy	Energy use GWh(d)	Carbon footprint $ktCO_2$
Electricity	37	774	578
Natural gas	13	285	54
Oil	47	983	250
Solid fuel	3	71	24
Total	**100**	**2,113**	**906**

Agriculture sector

The NI Energy Study did not explicitly cover agriculture in its breakdown of energy demand, and research to date indicates that such information may not be available for Northern Ireland.

Energy data for the sector have therefore been estimated based on:

- The ratio of agriculture GVA in Northern Ireland and the UK [3]
- Total direct energy consumption by UK agriculture (13,501GWh)[3] in 2000 [4]

[3] 6,778GWh oil, 4,528GWh electricity, 1,306GWh natural gas, 861GWh biomass and 28GWh coal

- The different fuel split in Northern Ireland.

The estimates are given in Table C5, which gives a carbon footprint for this sector of 276ktCO_2 in 2000.

Table C5 Fuel split, energy consumption and carbon dioxide emissions for NI agriculture sector in 2000

Fuel type	% of total energy	Energy use GWh(d)	Carbon footprint ktCO_2
Electricity	32	219	163
Natural gas	7	9	9
Oil	40	276	70
Solid fuel	15	101	34
Renewables and waste	6	44	0
Total	**100**	**649**	**276**

4 Business As Usual scenario

A bottom-up Business As Usual (BAU) scenario acts as a starting point to show what might happen if Northern Ireland carries on as it is now. The basic assumption in this scenario is that current trends in sector growth, demand for energy, and improvements in energy efficiency continue into the future. In addition, this scenario considers the impact of two relevant policy actions:

- Upgrading NI's building regulations to England and Wales standards as laid down by the building regulations 2000[4]

- Adopting the EU Energy Performance of Buildings Directive (EPBD) [5].

Sector growth rates

Economic growth remains a priority under the BAU scenario and it was therefore assumed that the commercial sector would grow 25% in the 12 years between 2000 and 2012, 26% in the 13 years between 2012 and 2025, and a further 26% in the 25 years between 2025 and 2050. It is also assumed that annual growth rates cannot be sustained and eventually begin to slow down. This slow-down is consistent with population projections for Northern Ireland by the Government Actuary [6], which indicate a decrease in the working age population after about 2020 that is consequently assumed to affect commercial and public sector growth. For the public sector, growth was considered to be much lower at around half the above rates.

These growth rates reflect both increases in the 'size' of the sector (i.e. floor area) and an increase in energy consumption due to increased demand for services (e.g. IT, air-conditioning, new equipment, etc.).

Energy efficiency savings

Savings due to energy efficiency of around 10% were assumed between 2000 and 2012, based on half the cost-effective potential being taken up (see the Appendix for a summary of cost-effective and All Technically Possible savings)[5]. This 10% improvement in energy efficiency was also applied to the 2012–2025 and 2025–2050 periods. The slow-down in uptake represents the assumptions that 'quick-win' measures are generally taken up early on and that new technologies offering the same quick-win solutions will not necessarily carry on entering the market to 2050[6].

[4] Building regulations in Northern Ireland are currently in the process of being updated to align with those in England and Wales, but the new regulations will still lag behind those in Scotland, Scandinavia and Switzerland in terms of minimum design specifications for energy efficiency and carbon footprint.

[5] The cost-effective potential was based on detailed cost abatement analyses of around 50 energy saving measures (e.g. compact fluorescent light bulbs and enhanced levels of fabric insulation) at a 6% discount rate. The maximum potential savings achievable from the simultaneous application of all energy efficiency measures were calculated from the cost abatement curves. These savings take into account thermal interactions and overlaps between products [7].

[6] Because the cost-effective potential has been based on UK figures, it may be a slight underestimation as measures are likely to be more cost-effective in Northern Ireland due to the higher fuel prices compared with the UK as a whole. On the other hand, the higher fuel prices in Northern Ireland mean that many cost-effective energy saving measures may have already been taken up – thus reducing the scope to some extent. It was, however, beyond the scope of this study to model these effects in detail.

The impact of fuel use

The fuels used by these sectors directly affect the carbon footprint. For electricity, carbon emissions change over time as the fuel mix used for generation changes. The proportion of electricity consumed is also important as it has higher carbon emissions per unit of fuel used.

The proportion of gas used in Northern Ireland is an important consideration. Due to the relatively recent introduction of gas in 1996, there remains a huge scope to expand the use of gas in place of other fossil fuels (mainly oil) with a higher carbon emission factor.

For the BAU scenario, it was assumed that:

- The share of electricity will increase to 34% by 2025 (reflecting the assumed increase in demand for electricity-consuming products and services)

- The use of gas (predominantly as a replacement for oil) will increase from 12% in 2000 to 55% of total energy use by 2050. The upper value is based on the fact that the UK proportion of gas in the public and commercial sector is currently around 51% [7].

Policy actions

The savings generated by improving the building regulations were determined by assuming the same level of savings in Northern Ireland on a pro-rata basis as calculated for the regulatory impact assessment carried out when the Building Regulations 2000 were introduced in England and Wales [8].

The improved regulations are expected to come into force in Northern Ireland in 2005, with savings from 2006. Carbon savings were calculated to be around 13% compared with previous regulations and to affect approximately a 2% per year replacement rate of the Northern Ireland commercial and public building stock[7]. This replacement rate mainly reflects new build, but includes some major refurbishment.

Conservative levels of savings through adoption of the EPBD[8]were assumed, as the full extent of its implementation has not yet been determined. It was assumed that carbon savings of around 4% could be achieved.

Figure C3 shows the impact of these two policy actions on reducing the carbon footprint of the commercial and public sector in Northern Ireland. The top line on the graph indicates where Northern Ireland's carbon emissions might be due to the sector growth and uptake of energy efficiency measures discussed above. This line also takes into account the carbon savings achieved due to fuel switching to gas in the electricity supply industry (ESI); this switch is termed decarbonisation.

- Without upgrading the building regulations, the carbon footprint will increase after 2012.

- Taking into account upgraded building regulations and adoption of the EPBD, the carbon footprint will decrease overall by around 33% between 2000 and 2050 under the BAU

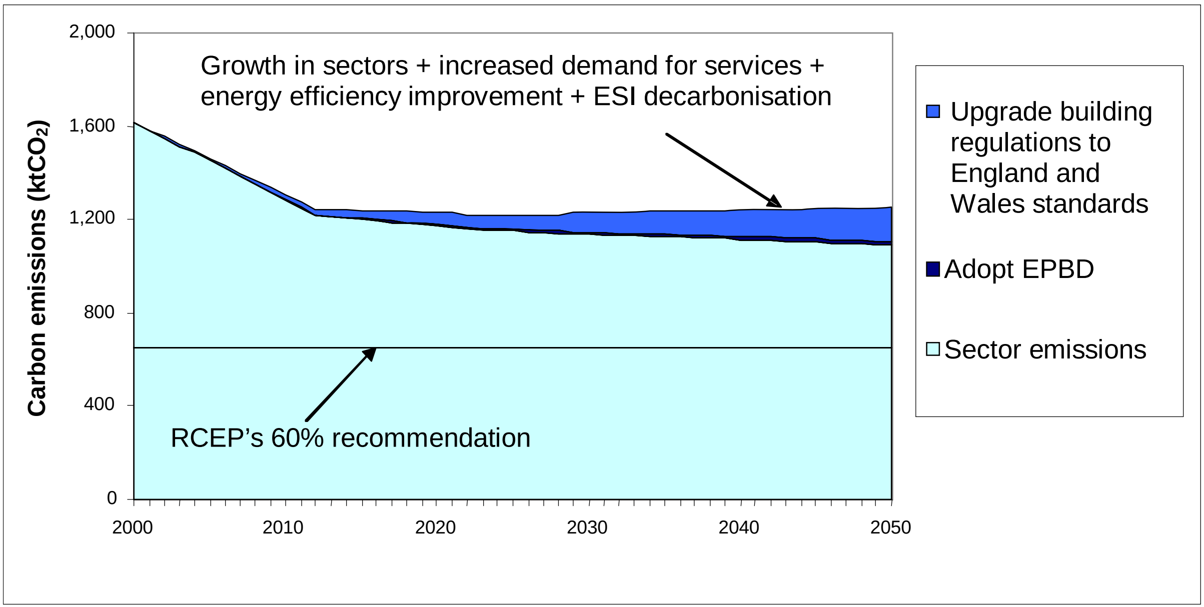
[7] The replacement rate is assumed to be similar to that in the UK (research indicated that figures specific to Northern Ireland may not be available).

[8] The Directive requires all new buildings greater than 1,000m^2 to consider 'alternative systems' such as renewable energy, combined heat and power (CHP) and heat pumps. When existing buildings greater than 1,000m^2 undergo major renovation, there is a requirement to upgrade the energy performance to minimum standards. An 'Energy Performance Certificate' will be required for buildings constructed, sold or rented out; the certificate should be clearly displayed in buildings greater than 1,000m^2 that have public access. The Directive will also require regular inspection of boilers and air-conditioning systems by independent experts.

scenario. Much of this initial reduction is due to the increase in the use of gas – both as a heating fuel and in electricity generation.

- After 2025, however, the carbon footprint starts to level off and it is clear that the RCEP's 60% recommendation will be missed by a considerable margin.

Figure C3 Potential reductions in the carbon footprint for the NI commercial and public sectors (under BAU)



5 Low Carbon Economy scenario

The Low Carbon Economy (LCE) scenario is a bottom-up scenario that represents a future where society views sustainability as more important than economic growth. This fundamental change in society's attitude is assumed to combine with the impact of more specific changes in the building stock in Northern Ireland and the uptake of cost-effective and All Technically Possible energy efficiency measures (see the Appendix) to bring about a rapid transformation to a low carbon economy. This is brought about by:

- Lower growth
- Lower demand for energy consuming services
- A very high uptake of energy efficiency measures, with the current technical potential of around 35% (see the Appendix) being nearly reached between 2025 and 2050.

The social changes envisaged for the LCE scenario are reflected in the medium growth and lower number of people working in the commercial and public sectors in Northern Ireland. A reduction of around 15% in sector growth and demand for energy relative to the BAU scenario is assumed for each time period. Education, training and information services are assumed to be growing at a faster rate than the other sectors (this is a reflection of the higher growth sectors assumed in the Foresight Global Sustainability scenario; see Annex A).

Step change in the building regulations

As in the BAU scenario, Northern Ireland's building regulations are assumed to be upgraded to England and Wales standards in 2005, with savings from 2006. With the LCE scenario, however, there is a growing realisation that more needs to be done to continue reducing the carbon footprint well into the future. A step change in the building regulations is therefore introduced in 2039, with savings from 2040. This step change requires all new buildings to be net zero carbon (see Box C1) and is based on the premise that:

- The building is designed to require as little energy as possible
- The energy consuming services and equipment required within the building are the most efficient possible
- The energy that is required is generated from renewable sources.

The building does not, therefore, use more energy than it produces. In addition, the building would need to be operated effectively (e.g. through a Building Management System) and the implementation of net metering[9] would be required. The way that each individual building achieves this is likely to vary on a case-by-case basis, but a number of the options or techniques listed in Table C6 would probably be adopted.

[9] Net metering allows end-users to sell locally generated electricity to their electricity supplier when it is not required and to buy it back at the same price when they are not generating enough locally (e.g. at night).

Table C6 All Technically Possible (ATP) options for reducing the commercial and public sector carbon footprint by 2050

Area	Examples
Passive building design	Naturally ventilated buildings Orientation of buildings Maximising solar gain and natural daylight Use of the stack effect Narrow plan width buildings Buildings with high thermal capacity (exposed/semi-exposed ceilings) Effective solar shading
Building envelope	Enhanced thermal insulation Superior levels of glazing (e.g. triple glazing with argon fill)
Sources of energy	Photovoltaic cells Solar hot water heating Micro-CHP Heat pumps Wind generators Wood/biomass burning stoves Hydrogen-powered fuel cells

Box C1: Net zero carbon buildings

Net zero carbon buildings are those that do not use more energy than they produce. Two examples of such buildings are given below.

Rocky Mountain Institute Headquarters, USA, is home of the co-founder, Amory Lovins, and the headquarters for part of the Institute. Built in 1984 with additional refurbishments and improvements over the years, this 4,000ft^2 building is super-insulated and solar-heated – in fact, it is so good at capturing and retaining heat that it rarely needs its wood-fuelled stoves to be in operation. Its thermal performance is also due to the advanced windows, which are krypton-filled and lose only around a tenth as much heat as single-glazing and let in three-quarters of the visible light and half the total solar energy. The building is orientated south to maximise solar radiation and is thus almost entirely lit by daylight. It has curved walls to dampen interior noise and a central greenhouse, which serves to humidify the building. In addition, the building has banks of both tracking photovoltaic arrays and tilting arrays, with the latter meeting around a third of the building's electricity demand (most of this is for the Institute's office). The building design has resulted in energy savings of 99% for space and water heating, and 90% for household electricity.
Source: http://www.rmi.org/sitepages/pid800.php [accessed 1 March 2005]

The Andrus Center for Global Outreach, USA, is an office building constructed in 2001. The 10kW wind generator generates twice as much energy as the building uses. The building itself has been highly insulated, the windows are triple-glazed and filled with argon, all light fittings are energy efficient fluorescents and solar panels on the roof heat water that is stored in an insulated holding tank before being pumped though radiant-heat tubing in the floor.
Source: http://www.future.org/pages/06_about_us/06_zero_energy_office.html [accessed 1 March 2005]

Increased use of off-grid renewables

The Low Carbon Economy scenario also assumes that there is a rapid increase in the use of off-grid renewables for existing buildings so that 10% of the total energy demand is supplied from these sources by 2050.

The implementation of net metering is important when utilising off-grid renewables and should perhaps be considered as a standard requirement on new buildings in the immediate future in readiness for such an expansion.

It is still assumed that the conservative savings potentially generated by adopting the EPBD are achieved under the LCE scenario. However, after the implementation of the step change in building regulations, the EPBD savings would only be valid for the refurbishment of existing buildings.

In this scenario, both the use of renewable energy resources to generate grid electricity and CHP are exploited to the full and this is reflected in the carbon emission factor attributed to electricity. The carbon emissions produced per unit of electricity consumed are expected to decrease by 76% between 2000 and 2050.

Potential reductions in the carbon footprint to 2050

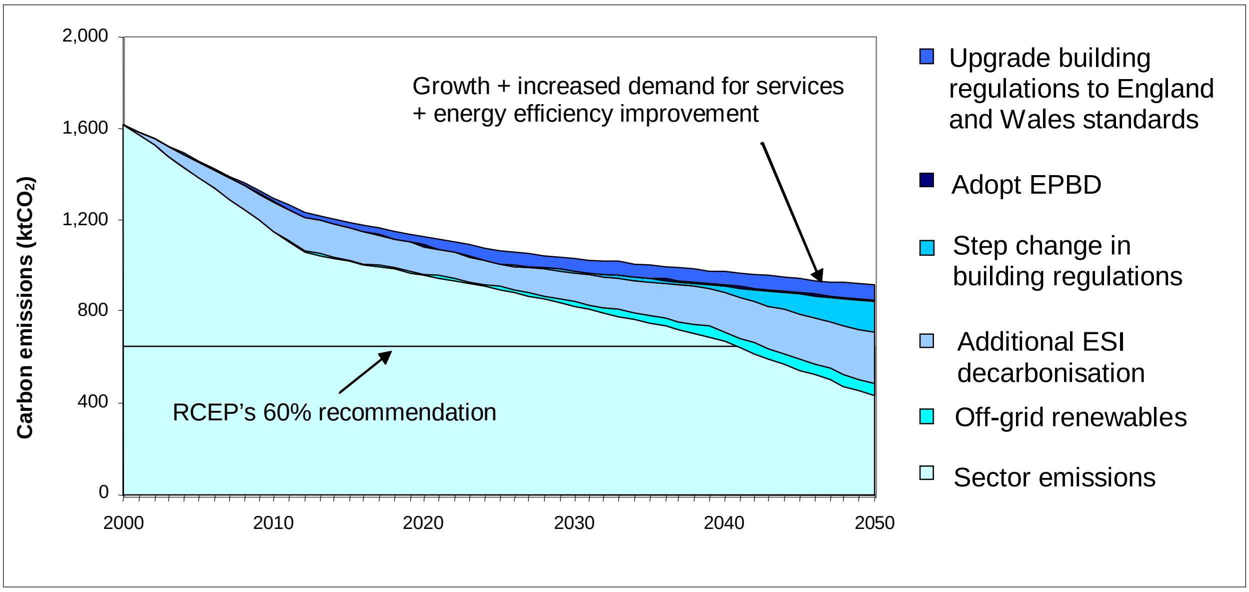
Figure C4 shows the results for the bottom-up modelling of the Low Carbon Economy scenario. The top line shows the decrease in the carbon footprint that might be gained from:

- Lower growth in the commercial and public sectors
- Lower growth in demand for energy consuming services
- High uptake of energy efficiency measures.

In order to demonstrate the differences in the carbon emission factors between the two scenarios, this line assumes the same levels of fuel switching (for electricity generation and heating fuels) as for the BAU scenario.

The step change in building regulations by 2040 makes a dramatic contribution to shifting the carbon footprint further towards meeting the RCEP's 60% recommendation. The impact of the additional decarbonisation of the electricity supply industry (ESI) also demonstrates the huge impact this could have on decreasing Northern Ireland's carbon footprint.

Figure C4 Potential reductions in the carbon footprint for the NI commercial and public sectors (under LCE)*



*Where one policy/action supersedes another, the savings are only attributed to the new policy/action.

The modelling shows that the Low Carbon Economy scenario has the potential to reduce Northern Ireland's carbon footprint by more than 60% by 2050. However, the route to these dramatic reductions is ambitious and will require radical changes to be implemented across the board – including changes in society and the way we view sustainability. In order to achieve the carbon savings demonstrated, the mechanisms need to be developed now as the lead-in time for many of the options could be considerable. Furthermore, the long lifetime of buildings means that much of what we build now will still be standing in 2050 (see Box C2).

Box C2: Changes in Northern Ireland's construction industry – the Low Carbon Design Initiative

Positive changes are already beginning to take place in Northern Ireland's construction industry with the development of the Low Carbon Design Initiative (LCDI). This is a Carbon Trust programme of project-based support and advice designed to bring forward a new generation of low carbon buildings in Northern Ireland. The approach has already been adopted by one of its key public sector client targets, the Department of Education, Northern Ireland.

Commissioning buildings on the basis of demanding performance specifications is at the heart of the LCDI, which has developed a library of room data sheets that clients can draw upon when developing their own project brief. The data sheets set low-energy standards for a wide range of building types. The LCDI approach is to work with public and private sector clients to help develop more demanding, but achievable, project briefs and to encourage them to invite design tenders on the basis of these higher performance targets. It also supports design consultants with expert project-based support and a series of free design master classes. It will work through the supply chain by offering practical demonstrations to contractors on the delivery of specific performance specifications, such as airtightness.

Such an initiative could have a major impact on reducing Northern Ireland's carbon footprint well into the future, as it is a significant move towards the low and zero carbon buildings discussed above.

6 Scenarios for the agriculture sector

Despite some growth and contraction, the total energy consumption in the UK agriculture sector has actually changed very little over the last ten years [4,9]. The BAU scenario therefore assumes no growth in this sector in Northern Ireland. The same improvement in energy efficiency in each time period is assumed for agriculture as for the commercial and public sector under the BAU scenario.

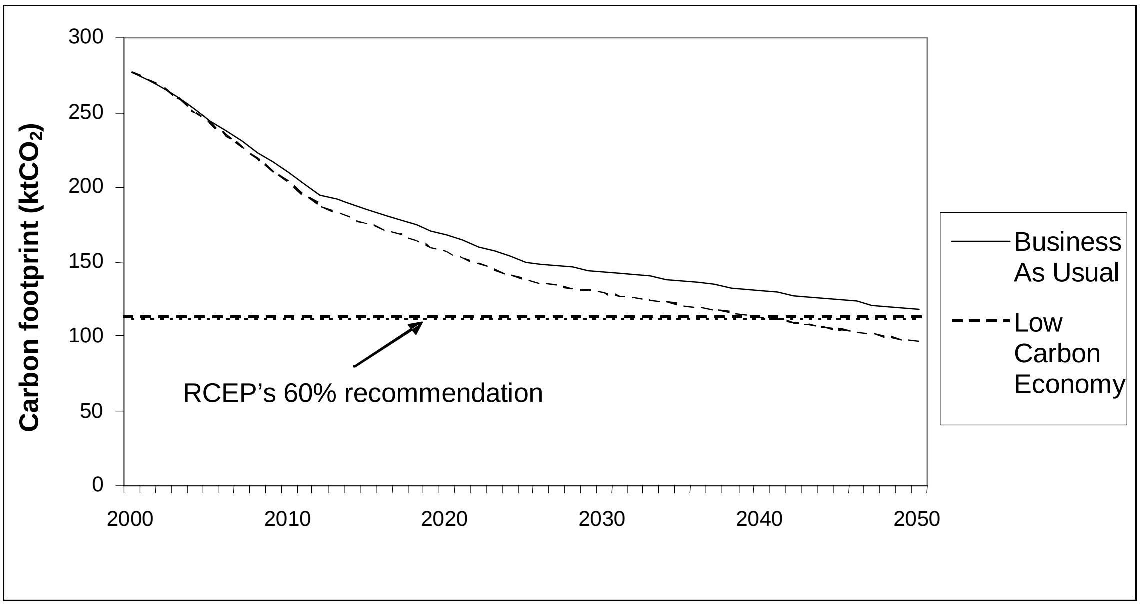
The Low Carbon Economy scenario represents no growth in this sector[10]. The same assumptions as for the commercial and public sectors under this scenario are used:

- The same relatively high energy efficiency savings (savings of 10–20% are considered simple savings for the sector to achieve, with some specific measures giving higher savings [10])

- The substantially lower carbon emission factors for electricity (due to the dramatic increase in the use of renewable energy in electricity generation).

Figure C5 shows the trend in the carbon footprint for the agriculture sector for the BAU and LCE scenarios to 2050. The general trend is downwards because no growth has been factored in for this sector and there is a decrease in carbon emission factors for electricity over time and some switching to gas. Modelling suggests that the RCEP's 60% recommendation would be met under the Low Carbon Economy scenario by about 2040 and would be within grasp under the BAU scenario by 2050.

Figure C5 Carbon footprint to 2050 for each scenario for the NI agriculture sector



[10] It was outside the scope of this study to model what might happen in the agriculture sector scenarios if there is a dramatic increase in the use of biomass crops for power generation.

7 The vision for the development of low carbon commercial and public sectors in Northern Ireland

The Low Carbon Economy scenario indicates that a 60% reduction could be realised before 2050. The vision is of a radically different society in which sustainability is inherently important.

All new commercial and public buildings will be net zero carbon; they will be super-insulated and orientated to make maximum use of solar gains and daylight, and will also be naturally ventilated.

All power requirements within the buildings will, therefore, be lower due to building techniques and highly efficient technologies. Where heat and power are required, they will be self-generated using solar water heating, heat pumps, photovoltaics, wind turbines or hydrogen fuel cells. Many existing buildings will generate their own heat and power, and any additional power taken from the grid will be generated using renewables or perhaps via hydrogen.

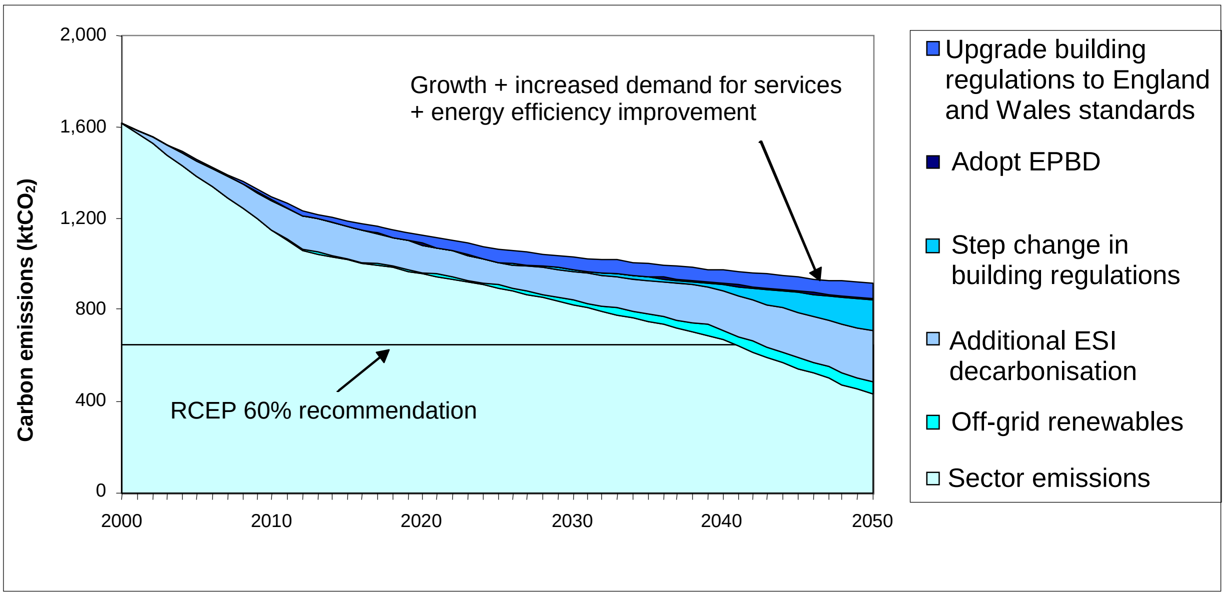
To be on the path to a low carbon future by 2050, the following 'actions' would need to happen as soon as possible in order to reduce carbon emission by 60% by 2050:

- Upgrade the building regulations to require all new buildings to be net zero carbon
- Continue to develop the Low Carbon Design Initiative and support other moves towards net zero carbon buildings
- Determine the best ways of 'future proofing' buildings that are being constructed now and are likely to still be standing in 2050 (e.g. require all new buildings to have net metering)
- Ensure energy efficiency measures are retrofitted during refurbishment
- Provide training in energy efficiency practices for builders, architects and engineering consultants
- Provide incentives for developers to go beyond the minimum specifications of the building regulations
- Start to implement changes in the way the construction industry operates (e.g. performance-based fees)
- Develop awareness of the issues and start a marketing campaign to capture the hearts and minds of the population
- Make the public sector lead the way through sustainable/energy efficient procurement and the specification of low/zero carbon buildings
- Encourage R&D into carbon saving/energy efficient technologies and techniques
- Require better labelling of equipment to facilitate a market transformation towards more energy efficient products
- Intervene to remove the least efficient products from the market

- Integrate sustainability more fundamentally into education
- Consider the potential changes in energy vectors[11] that may be required in order to meet the targets (e.g. the move to a hydrogen economy).

These actions are combined in the roadmap shown in Figure C6.

Figure C6 A roadmap for realising a 60% reduction in carbon dioxide emissions by 2050 in the commercial and public sectors in Northern Ireland



*Where one policy/action supersedes another, the savings are only attributed to the new policy/action.

[11] The 'carrier' of the energy, i.e. 'a means of storing and transporting energy' [11].

8 Constraints and barriers limiting the rate of adoption

There are likely to be significant barriers to change and to the uptake of energy efficiency measures (see Box C3). These barriers might include:

- Cost (perceived or actual) of energy efficiency measures
- Long payback periods
- Resistance to change
- Lack of education and awareness
- Perceptions
- Costs of R&D to produce low carbon/energy efficient technologies
- Lack of local support for new techniques leading to a tendency to adopt simpler, well-proven technologies.

To help overcome some of these barriers, a Low Carbon Economy scenario could require:

- Purchasing guidelines/requirements for equipment
- Better labelling of equipment to facilitate a market transformation towards more energy efficient products
- Intervention to remove the least efficient products from the market.

The public sector in the UK is already leading the way by developing sustainable procurement guidelines for Government [12]. It may be that the public sector will continue to demonstrate the route ahead in the uptake of energy efficiency measures and also in specifying near to net zero carbon buildings in the immediate future.

A further benefit would be a complete change in the way the whole construction industry operates, such as the introduction of performance-based fees to encourage sustainable design and ensuring architects receive appropriate training in designing such buildings [13].

In terms of social barriers to change, it may be that energy inefficiency will become socially unacceptable and that people will take more responsibility for the energy they use and the carbon emitted. This is likely to require both education and transparency of energy use (e.g. in consumers' bills). It may necessitate a focused 'marketing of sustainable behaviour', which could involve using psychological tools to encourage sustainable behaviour (e.g. commitment, prompts, norms and incentives)(see [14] for more details).

Box C3: Barriers to the uptake of energy efficient measures

Barriers to the uptake of energy efficient measures refer to the apparent gap between what is possible in terms of energy efficiency, and what actually happens. The table below looks at the three 'categories' of barrier – market failures, organisational failures and rational behaviour – and gives examples of how these barriers might operate in practice.

Category	**Particular instance**
Barriers representing market failures	• Positive externalities of adopting energy efficient technologies • Adverse selection in energy services markets • Moral hazard and principal-agent relationships in energy services markets • Split incentives in energy services markets
Barriers representing organisational failures	• Imperfect information on organisational energy use • Moral hazard and principal-agent relationships within organisations • Split incentives within organisations
Barriers representing rational behaviour	• Heterogeneity (i.e. energy efficiency may be cost-effective on average, but not always in each individual circumstance) • Hidden costs (e.g. overhead costs, disruption) • Risk (technical or business) • Access to capital

Source: *Barriers to energy efficiency in public and private organisations*. S. Sorrell *et al*. [15]

9 Concluding remarks

This annex has established a sub-sectoral breakdown of energy consumption by fuel type and the carbon footprint in commercial and public buildings in Northern Ireland for 2000.

Using the scenario-based approach, we have looked forward to 2012, 2025 and finally to 2050, and at the prospects for the development of a low carbon economy in Northern Ireland that would realise a 60% reduction in carbon emissions relative to 2000. Two scenarios have been modelled in detail – Business As Usual and Low Carbon Economy.

The Business As Usual scenario suggests that the RCEP's 60% recommendation would be missed by a considerable margin. Modelling using the Low Carbon Economy scenario shows that the RCEP's 60% recommendation could be met, but that the changes required are radical and ambitious. The Low Carbon Economy scenario is based on a society that is very different from today's, and where sustainable development and society's attitude to the environment and combating climate change are markedly different. As well as the changes in society's attitudes, additional carbon-reducing measures will be required to meet the RCEP's 60% recommendation. These measures are:

- A step change in building regulations
- Implemention of the EPBD
- The uptake of off-grid renewables for existing buildings
- A huge influx of renewables in the electricity supply industry.

This project has highlighted a number of areas where specific information was not available for Northern Ireland; many estimates and assumptions were therefore necessary to determine even baseline figures. A programme of data collection and analysis is recommended to allow a more accurate determination of the baseline and the ability to monitor progress in meeting the RCEP's 60% recommendation.

Some work has been undertaken for the agriculture sector in Northern Ireland, but a more detailed analysis is outside the scope of this study. No growth in size or energy demand was assumed for this sector; therefore, even the BAU scenario is relatively positive due to savings made through energy efficiency and fuel switching.

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Acronyms and abbreviations

ATP	All Technically Possible
BAU	Business As Usual
CHP	combined heat and power
CO_2	carbon dioxide
CTN	confectioner, tobacconist and newsagent
(d)	delivered [energy]
EPBD	Energy Performance of Buildings Directive
ESI	electricity supply industry
GVA	gross value added
kt	kilotonnes
LCDI	Low Carbon Design Initiative
LCE	Low Carbon Economy
NI	Northern Ireland
RCEP	Royal Commission on Environmental Pollution
RoI	Republic of Ireland

Appendix

Cost-effective and All Technically Possible savings

Table C7 summarises cost-effective and ATP carbon reductions in the UK as a percentage of total emissions. The cost-effective potential is given at a 6% discount rate.

For Northern Ireland, these figures could be used as a starting point, although some adjustments are likely to be necessary (if this is possible) to incorporate the fact that energy is more expensive in Northern Ireland than in mainland UK. The cost-effective potential in Northern Ireland could, therefore, be slightly higher, but some cost-effective opportunities might have already been taken up as a result of the energy cost driver.

Table C7 Cost-effective and ATP carbon savings in the UK in 2000 [7]

End-use	Cost-effective potential (as % of total carbon emissions)	Technical potential (as % of total carbon emissions)
Computing	2	2
Lighting	10	11
Refrigeration	1	1
Other	1	2
Heating	7	18
Cooling	1	1
Total	**22**	**35**

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Helpline 0800 085 2005
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NORTHERN IRELAND VISION STUDY

Annex D: Prospects for the domestic sector to 2050

Document Reference	**NIVision/5**
Date	**29/03/2005**
Report Status	**FINAL**

CTC520D

IMPORTANT NOTICES

CONTENTS

Executive summary

This annex discusses how Northern Ireland's domestic sector could reduce its carbon footprint by 60% by 2050 in line with the recommendations made by the Royal Commission on Environmental Pollution (RCEP) and presents a roadmap for reaching this challenging target.

The domestic sector is the largest energy-consuming sector in Northern Ireland. According to the Northern Ireland House Condition Survey, there were 647,500 dwellings in Northern Ireland in 2001. Approximately 10,000 new homes were built every year between 1996 and 2001, and the number of dwellings is predicted to be around 716,500 units by 2012. The population is also predicted to increase from 1,697,800 in 2000 to 1,778,300 by 2015, but the demographic changes mean that there is greater demand for smaller properties suitable for one or two people. This gradual increase in the size of the domestic sector means that energy savings made by individual households may not lead to an overall reduction in the sector's energy use.

The main uses for fuel in the domestic sector are space heating, water heating, cooking, lighting and running domestic appliances. There has been considerable fuel switching since the early 1990s from solid fuel to oil-fired central heating. Natural gas is not yet a major source of fuel for the domestic sector, but its use is increasing as the gas network in Northern Ireland expands.

Historically, dwellings in Northern Ireland have a larger floor area and higher energy consumption than in the rest of the UK and many of the older properties tend to have poor insulation, limited double-glazing and inefficient space and water heating systems. The 10,000 or so houses built each year since 1996 are specified to a higher standard and have lower energy consumption. In 2002, the Northern Ireland domestic sector had an estimated energy consumption of 17,590GWh delivered (d). The fuel split for that year gave a carbon footprint of 6,570 kilotonnes of carbon dioxide ($ktCO_2$). The energy consumption of the housing stock fell by 13% between 1996 and 2001 (a reduction of 2,000$ktCO_2$ in the carbon footprint) due to energy efficiency initiatives and fuel switching.

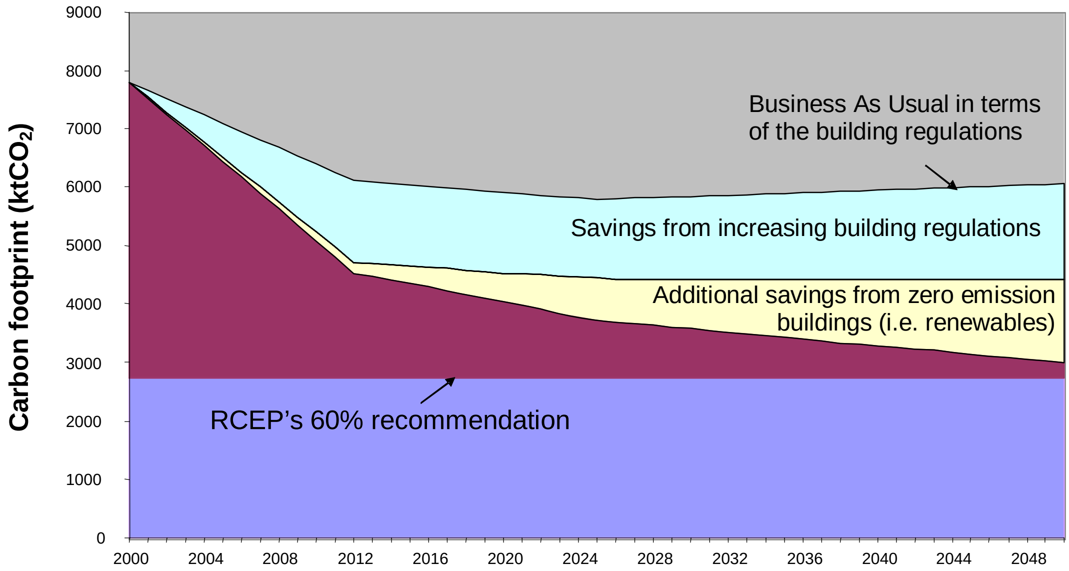
Another key factor when considering the potential for the domestic sector to reduce its carbon footprint is the fact that most of today's dwellings will still be part of the housing stock in 2050. Refurbishment to higher energy efficiency standards and greater use of off-grid renewables are thus as important as the specifications for new build. This will demand considerable education of householders and planners, and improved training for installers, architects and engineering consultants.

When looking just at the physical characteristics of the housing stock in Northern Ireland, modelling suggests that only the UK Foresight Programme's Global Sustainability scenario would deliver a carbon footprint that delivers the RCEP's 60% recommendation by 2050.

A set of scenarios that take the building regulations from their current position (Business As Usual) via an option that assumes a increased standard of building compared to today (i.e. meeting or exceeding present standards in England and Wales) to the step change case of zero carbon emission dwellings (the Low Carbon Economy) are then superimposed on these physical parameters. The Low Carbon Economy scenario assumes that all the power required by the buildings is generated locally or remotely by renewable sources.

The Low Carbon Economy scenario shows the carbon footprint decreasing by 57% by 2050. The roadmap below shows how this can be achieved.

A roadmap for reaching the RCEP's 60% recommendation by 2050 in the NI domestic sector



The vision for the domestic sector in 2050 is of dwellings using hydrogen or electricity generated locally or remotely by renewables. Dwellings will be orientated to take advantage of solar gains and the fabric will be well insulated. Hot water will be heated by solar panels or photovoltaics. Demand for heating will be less due to the high levels of insulation, and combined heat and power (CHP) will be important. New dwellings will be carbon neutral and not contribute to the carbon footprint.

A step change in the building regulations from 2012 to demand zero emission buildings will achieve most of the required reduction in the carbon footprint. To achieve the 60% reduction in the carbon footprint of the domestic sector by 2050, demolition rates of older and energy-inefficient buildings will have to increase or more householders will need to be motivated to use renewable energy from before 2012.

1 Introduction

The UK Government has adopted the recommendations of the Royal Commission on Environmental Pollution (RCEP) [1] on reducing carbon dioxide emissions to reduce the threat of global warming and climate change. The RCEP recommends the development of a concerted, co-ordinated strategy that puts the UK economy on a path to reducing carbon dioxide emissions by some 60% from current levels by about 2050.

This annex, which is underpinned by detailed modelling work, discusses the potential contribution of the domestic sector to the development by 2050 of a Low Carbon Economy in Northern Ireland that would meet this challenging target. Its production involved the following tasks:

- Reviewing the baseline and identifying underlying trends in energy efficiency in the domestic sector
- Developing a Business As Usual (BAU) scenario from current trends
- Reviewing various economic scenarios using physical characteristics
- Looking at scenarios related to changes in the building regulations in Northern Ireland (NI)
- Comparing the economic scenarios and building regulation scenarios
- Establishing the constraints and barriers that limit the rate of change
- Identifying mechanisms/options for increasing the uptake of measures.

2 Sector description

According to the *Northern Ireland Energy Study 2002* [2], the domestic sector is the largest of the five energy-consuming sectors in Northern Ireland[1]. The NI Energy Study estimates the number of dwellings in Northern Ireland in 2002 as 656,450 (see Table D1). This figure is obtained from a balance of the demolition of older stock (pre-1918) and the building of new units.

Table D1 Estimated number of dwellings in Northern Ireland for 1996, 2001 and 2002*

Stock	1996	2001	2002 (extrapolated)
Pre-1980	477,400	473,200	472,200
1980–1996	125,100	119,300	125,100
1996+	0	55,000	59,150
Total	**602,500**	**647,500**	**656,450**

*Data obtained or extrapolated from Northern Ireland Housing Executive (NIHE) survey data [3,4]

Table D2 shows the composition of the housing stock in 2001 as found by the NIHE's Northern Ireland House Condition Survey (NIHCS) [4]. More than half of all dwellings are owned by their occupiers, 18% are owned by the Northern Ireland Housing Executive, and 5% are vacant. Dwellings built since 1980 represent 27% of the housing stock, but the 116,400 dwellings that were built before 1919 represent 18% of the stock. Bungalows and terraced houses between them make up over half of the stock. Bungalows (24% of the stock), in particular, are far more common than in the other countries of the UK (the next highest percentage is 11% in Wales).

Table D3 gives population estimates and forecasts obtained from an NIHE publication, *The Northern Ireland housing market. Review and perspectives 2003–2006* [5]. However, a Northern Ireland Statistics and Research Agency (NISRA) press release [6] gives the estimated population on 30 June 2002 as 1,696,600, which is slightly lower than might be expected from the figures given in Table D3[2]. The figure for 2002 is an increase of 7,300 (0.4%) on the 2001 population of 1,689,300 and an increase of 73,400 (4.5%) on the 1992 population of 1,623,300. According to NISRA, the increase between 2001 and 2002 is the result of 21,500 births, 14,200 deaths and a net inward migration of 100 people [6].

Table D3 shows a steady increase in the total population of Northern Ireland between 2000 and 2015, but not in all categories (the number of pensioners is increasing while the number of children is declining). Comparable data on the growth in the number of households are not available, but figures from the Department of the Environment in Northern Ireland give the number of housebuilding completions between 1998/1999 and 2001/2002 shown in Table D4. These dwellings are typically smaller and built to a higher standard than pre-1996 [2]. The NI Energy Study [2] predicts that the total number of dwellings will rise to 716,500 units by 2012.

Considerable statistics and information relevant to the domestic sector in Northern Ireland are available from NIHE (www.nihe.gov.uk) and NISRA (www.nisra.gov.uk).

[1] The others are industry, commercial & buildings, public sector and transport.

[2] *Editorial note:* Since this annex was prepared, NISRA has revised down the projection for 2015 by 27,000 to correct an overestimate of immigration levels. The NIHE has also revised its estimates of housing need to 2015. For details see, *The Northern Ireland housing market. Review and perspectives 2005–2008 (*Northern Ireland Housing Executive: http://www.nihe.gov.uk/publications/reports/HMR2005_2008.pdf). The effect of these changes on the long-term projections presented in this report is considered relatively small.

Table D2 Dwellings by ownership, age and type from the NIHCS Survey 2001 [4]

	Number of dwellings
Owner occupied	432,300
Private rented (and others)	49,400
NIHE	116,000
Housing associations	17,900
Vacant	31,900
Pre-1919	116,400
1919–44	69,100
1945–64	127,800
1965–80	159,900
Post-1980	174,300
Bungalows	157,000
Terraced houses	200,300
Semi-detached houses	123,500
Detached houses	115,000
Purpose-built flats	43,700
Converted flats	8,000
Total	**647,500**

Table D3 Northern Ireland population: 2000-2015

	2000	2005	2010	2015
Children	408,000	381,800	358,500	343,100
Working age	1,030,600	1,069,700	1,096,000	1,132,600
Pensioners	259,200	275,500	299,000	302,600
Total	**1,697,800**	**1,727,000**	**1,753,500**	**1,778,300**

Table D4 Housebuilding in Northern Ireland

Period	Completions (all dwellings)
1998/1999	9,638
1999/2000	10,399
2000/2001	11,668
2001/2002	13,432

3 Reviewing the baseline

The domestic sector in Northern Ireland is a diverse one containing many households whose individual decisions affect its overall energy consumption. The gradual increase in size of the domestic sector means that savings made by individual households may not lead to an overall reduction in the sector's energy use.

The main uses for fuel in the domestic sector (see Figure D1) are:

- Space heating – a major energy end use, accounting for 60% of total UK domestic delivered energy
- Water heating – this typically accounts for 20–25% of domestic energy use in the UK
- Cooking – energy use for cooking is small (only 3% for the UK) and it is split between gas and electricity
- Lighting and domestic appliances – such as lighting, TV, radio, computers, refrigeration, etc. They are typically all-electricity (13% of domestic energy).

Figure D1 Northern Ireland domestic fuel split by end use - 2002 [2]

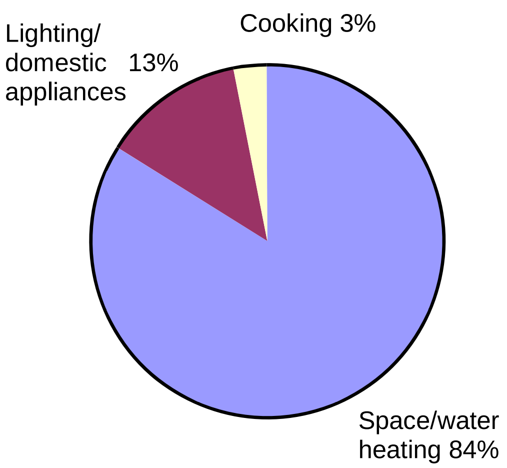
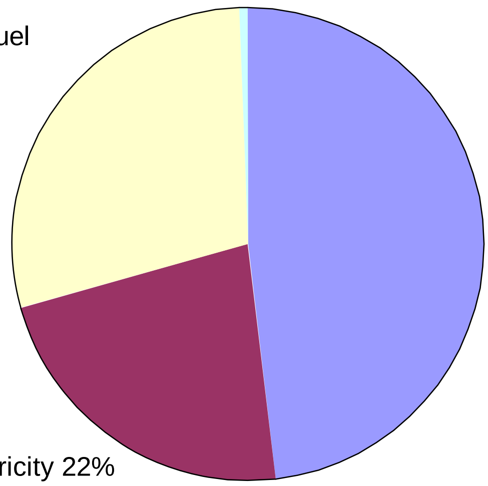


Figure D2 shows the fuel split for the NI domestic sector in the baseline year 2000[3]. The number of dwellings in 2000 has been estimated by assuming the increase in dwellings between 2001 and 2002 will be the same as the decrease in dwellings between 2001 and 2000.

[3] Taken from Section 5 of Annex A.

Figure D2 Northern Ireland domestic fuel split by type in 2000



NI home energy surveys [3] suggest that there has been considerable fuel switching since the early 1990s – mainly older solid fuel units being replaced by more modern and efficient oil-fired units for heating. More recently, natural gas has captured some of the domestic market and this trend is expected to continue as the gas network expands.

Historically, domestic houses in Northern Ireland have had a larger floor area and used more energy than in the rest of the UK; older houses, especially, tend to have poor loft and wall insulation, limited double-glazing and inefficient space and water heating systems. The situation was exacerbated by relatively high unit fuel costs (typically 30–40% higher than mainland UK), plus harsher weather conditions (particularly wind and rain). Houses built since 1996 have tended to be specified to a better standard, but building regulations are currently less stringent than those in England and Wales. However, the Department of Finance and Personnel (DFP) is currently consulting on proposals to introduce enhanced standards of thermal efficiency in buildings from January 2006 that will bring Northern Ireland into line with England and Wales[4].

In recent years, a number of initiatives have been launched to improve domestic energy efficiency. In line with the Home Energy Conservation Act 1995 (HECA), NIHE has set a target to improve the average energy efficiency of its pre-1996 domestic stock by, on average, 34% from a baseline year of 1996[5]. By 2001, cumulative savings of 13% had been achieved, mainly through replacing older (generally solid fuel) heating with more modern oil-fired heating, plus improved loft and cavity wall insulation and double-glazing installation. The Appendix gives data on fuel use and the extent of energy efficiency measures in NI housing stock in 2001.

Between 2002 and 2012, it is expected that some older (and typically less efficient) dwellings will be demolished and that other older dwellings will continue to be upgraded. Many of the newer units will typically be smaller dwellings (reflecting changes in population demographics) and will be built to tighter insulation regulations (closer to or better than those already in place within the rest of the UK). NIHE is expected to achieve or come close to its 34% improvement target by 2012.

The baseline developed for the NI Energy Study [2] gives an estimated energy consumption of 17,590GWh delivered (d) for the domestic sector in 2002. The NI Energy Study gives a carbon footprint for the domestic sector of 1,791 kilotonnes of carbon (ktC) or 6,570 kilotonnes of

[4] For details, see http://www2.dfpni.gov.uk/buildingregulations/consultation.htm [accessed 1 March 2005]

[5] A deadline date was not specified by HECA, but could be considered to be by 2012.

carbon dioxide ($ktCO_2$) in 2002. The estimated energy consumption for 2002 (see Table D5) is the average derived from data given in two different sources:

- NIHE survey findings published in its series of Home Energy Conservation Reports [3]
- BRE's Domestic Energy Fact File for Northern Ireland [7][6].

Table D5 NI domestic energy consumption data [2]

Data source	**GWh(d)**	
	1996	**2002 (estimated)**
Home Energy Conservation Report 2002	22,111	19,457
Domestic Energy Fact File	15,349	15,722
Average	**18,730**	**17,590**

It is difficult to arrive at a robust total energy consumption figure for the domestic sector in Northern Ireland. As can be seen from Table D5, there is an unexplained difference between the two sets of figures. The figures from the Home Energy Conservation Report 2002 are based on a bottom-up analysis of the Northern Ireland House Condition Survey [4], while those from the Domestic Energy Fact File are based on a top-down analysis from the Digest of United Kingdom Energy Statistics (DUKES) [8]. This difference in approach is further complicated by the difference in trends: one shows a decrease in energy consumption between 1996 and 2002, and the other shows an increase.

It is beyond the scope of this study to establish the cause of this discrepancy. However, it demonstrates the need for additional data to be collected now in order to verify any future savings. In the domestic sector, the rate of increase in the number of households is critical because the energy consumption per household may decrease but the total consumption will increase due to the increasing number of households. This factor may be part of the problem, but it is more likely to be due to the inaccuracy of fuel consumption figures – possibly related to unofficial fuel imports, which are unaccounted for.

The approach adopted by this annex is in line with the Northern Ireland Energy Study [2] and is based on consistency rather than on making the absolute base figure critical to comparisons. An average of the two figures from the NIHE survey and the Domestic Energy Fact File has been used to calculate the average energy consumption per household for pre-1996 dwellings of 32.9MWh/dwelling, and improvements have been based on this figure[7]. A decrease in energy consumption per household is assumed, but overall trends depend on the figures used for growth in the housing stock, which vary under different economic scenarios.

[6] See http://www.defra.gov.uk/environment/energy/research/domestic/ for a summary of the Domestic Energy Fact File 2003 for England, Scotland, Wales and Northern Ireland.

[7] This compares with an average of 27MWh in the Domestic Energy Fact File 2003.

4 The outcome under different scenarios

The domestic sector's contribution to reducing Northern Ireland's carbon footprint to 2050 will depend on a number of factors including:

- Population changes
- Fuel switching
- The number of dwellings[8]
- The energy efficiency of both new and existing dwellings.

The building regulations have a major impact on the specification of new buildings and thus their thermal efficiency. In order to take account of these inter-related factors during modelling, the approach taken by this study has been to superimpose three different scenarios for improvements to the building regulations in Northern Ireland on economic scenarios (see Annex A) based on factors specific to Northern Ireland.

Building regulations scenarios

Three scenarios have been considered.

The '**no improvements'** scenario assumes that the savings due to energy efficiency and fuel changes identified under HECA take place in NIHE stock only. This provides a useful baseline projection that illustrates the effects of improvements to the building regulations.

These savings have been extended to the whole stock for the '**increasing building regulations**' scenario. This scenario also assumes that the building regulations in Northern Ireland come in line with those for England and Wales[9] as proposed and go beyond this by 2025, thus decreasing the average energy consumption per household. The carbon footprint decreases partly because of lower energy consumption, but mainly due to fuel switching.

In the '**step change**' scenario (the Low Carbon Economy (LCE) scenario), it is assumed that the building regulations will require zero emission houses using renewable energy sources, photovoltaics, solar panels from 2012. However, energy will still be being used in those houses built before 2012 to the same extent as the 'increasing building regulations' scenario. The 'step change' scenario, therefore, shows the additional gains that can be made by using all forms of renewables and combined heat and power (CHP).

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[8] Changes in the size of the housing stock are related to the building of new dwellings and the demolition of older properties.

[9] Information about the current building regulations in England and Wales are given on the website of the Office of the Deputy Prime Minister (ODPM) at:
http://www.odpm.gov.uk/stellent/groups/odpm_buildreg/documents/sectionhomepage/odpm_buildreg_page.hcsp

Economic scenarios

These scenarios are based on figures for the domestic sector (see Table D6) taken from Annex A. Energy and carbon emission figures have been calculated for the baseline year 2000 and the year 2050 for the following scenarios[10]:

- Business As Usual (BAU)
- World Markets (WM)
- Regional Enterprise (RE)
- Global Sustainability (GS)
- Local Stewardship (LS).

Energy and carbon have only been calculated for 2000 and 2050 under the economic scenarios because these are only a guideline for comparison with the building regulation scenarios. The efficiency savings and changes in demand for heating, hot water, cooking, lighting and appliances are then applied to the energy figures. The carbon figures are calculated by looking at the fuel mix for old and new build houses.

Improved efficiencies in heating, lighting and appliances will reduce energy consumption, but demand may well increase with greater affluence and higher expectations. There is a general trend to lower occupancy and smaller homes. Although smaller homes require less energy for heating, the energy needed per person may rise.

The calculations are based on physical changes to the NI housing stock rather than the economic conditions described in Annex A. The population growth and occupancy level given in Table D5 make it possible to work out what the dwelling stock in 2050 needs to be. The number of new build houses can be calculated after taking account of the number of demolitions.

[10] An explanation of what these represent can be found in Annex A.

Table D6 Parameters used in scenario analyses of domestic energy demand*

	Current (2000)	2050				
		BAU	WM	RE	GS	LS
Population growth rate (% per year)	0.5	0.5	0.75	0.5	0.5	0.25
Average household occupancy (people per household)	2.7	2.4	2.2	2.4	2.6	2.7
Heating fuel for existing houses (%)						
Natural gas	1	62	62	62	62	62
Solid fuel	44.5	5	5	5	5	5
Oil	41	20	20	20	20	20
Electricity	13.5	13	13	13	13	13
Heating fuel in new homes (%)						
Natural gas	60	70	70	70	70	70
Solid fuel	0	0	0	0	5	5
Oil	30	20	20	20	15	15
Electricity	0	10	10	10	10	10
Demolition rate (number per year)	1,000	1,000	2,000	1,000	2,000	500
Average internal temperature (°C)	17.5	18.5	20	20	18.5	18.5
Average thermal efficiency of new build*	100	50	60	60	20	40
Average efficiency improvement in existing housing stock*	100	50	70	80	40	60
Demand for hot water per household for services†	100	110	120	125	100	100
Personal demand†	100	120	150	150	100	100
Efficiency improvement of hot water supply†	100	85	85	85	75	80
Demand for cooking per person†	100	90	80	100	100	120
Efficiency improvement of cooking devices†	100	80	90	90	80	80
Demand for electrical services per household†	100	120	150	130	100	100
Efficiency improvement of electrical appliances†	100	85	75	75	65	75

* Percentage of year 2000 stock energy demand.

† year 2000=100

Business As Usual outcome

The economic Business As Usual scenario factors in:

- Decreasing occupancy (due to demographic changes in the NI population)
- Changing fuel mix (e.g. the expansion of the gas network will allow the introduction of modern, energy efficient technologies such as combi boilers, condensing boilers and domestic CHP)
- Changes in thermal efficiency

- Increased efficiencies in heating systems and electrical appliances.

For the building regulations scenarios, the 'no improvements' scenario includes changes to the fuel mix and limited increases in the efficiency of heating systems and electrical appliances, but there are no changes to the building regulations to drive carbon reductions. Lower household energy consumption is due only to energy saving measures, and the decline in the carbon footprint per household is mainly due to fuel changes. The 13% improvement in NIHE housing stock between 1996 and 2001 represents a saving of 2,000ktCO_2 and includes savings due to fuel switching. The Northern Ireland Energy Study [2] considers that this degree of saving is possible across the whole stock rather than just the NIHE stock.

The introduction of energy efficient appliances and more efficient heating systems will decrease the amount of energy consumed per household, although other economic factors may increase demand. Higher demand for hot water and electrical appliance use is modelled in the economic scenarios.

Energy consumption by the NI domestic sector will increase due to a rise in the number of households (even where older, less energy efficient dwellings are replaced by new, better-insulated ones). Houses built since 1996 will have a lower energy consumption than those built before this date, and changes to the building regulations will reduce energy use further.

Comparison of economic and building regulations scenarios

Table D7 gives the predicted carbon footprint for the NI domestic sector under these building regulations scenarios and the BAU economic scenario.

Figure D3 compares the impact of the economic and building regulations scenarios on the carbon footprint of the NI domestic sector. It shows the economic scenarios as straight lines between 2000 and 2050; a linear relationship is not what is expected to happen between these dates, but the lines provide a point of comparison with the building regulations scenarios.

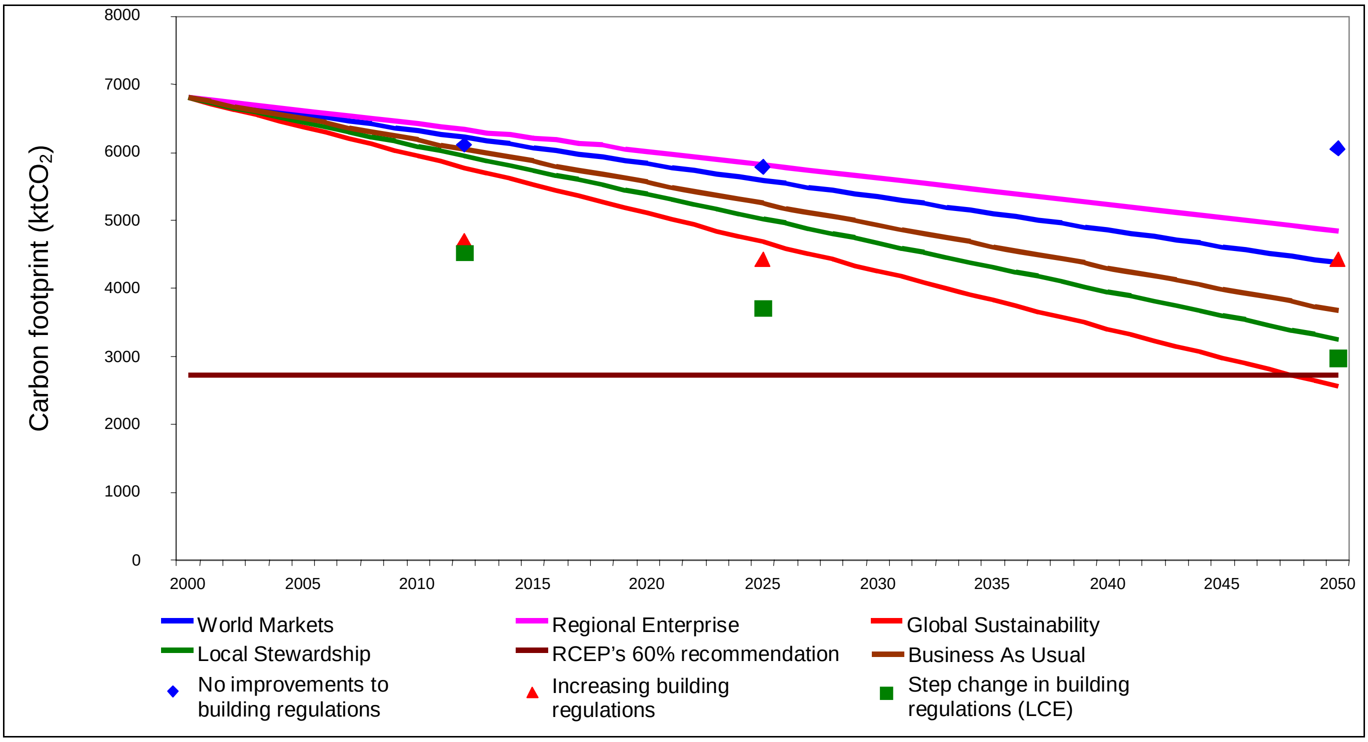
Table D7 NI domestic sector carbon footprint for the building regulations scenarios

Scenario	Carbon footprint (ktCO_2)			
	2000	2012	2025	2050
BAU scenario*	7,798	6,155	5,134	6,033
No improvements to building regulations	7,798	6,110	5,784	6,054
Increased building regulations	7,798	4,709	4,429	4,422
Step change in building regulations (LCE)	7,798	4,534	3,715	2,990

* Given for comparison.

If no improvements are made to the building regulations, the carbon footprint of NI housing stock will fall slightly until 2025 due to fuel switching, but will then rise due to the increasing number of households. By 2050, it will lie outside the range of all the economic scenarios. This suggests that, before this point, there will be economic conditions which make it unfavourable to keep building and demolishing buildings at the assumed rate of 8,500 new builds per year and 2,500 demolitions.

Figure D3 Comparison of economic and building regulations scenarios



The scenario under which building regulations increase thermal insulation also gives a slight decrease in the carbon footprint up to 2025, but increases beyond that. By 2050, it is in line with the World Markets scenario.

The step change scenario (the LCE scenario) also gives a declining carbon footprint until 2025, which continues to fall – albeit more gradually – until 2050 where it approaches the RCEP's 60% recommendation and shows a close fit to the Global Sustainability scenario. The LCE scenario will continue to show a decrease in the carbon footprint beyond 2050 as older dwellings are demolished and replaced by zero carbon-emission stock.

When looking at just the physical characteristics of the housing stock, only the Global Sustainability scenario is shown to deliver a carbon footprint that achieves the RCEP's 60% recommendation by 2050. The LCE building regulations scenario delivers a 57% saving, which compares quite closely and is within the accuracy of the estimation of the baseline carbon footprint. However, it does imply that the Global Sustainability economic scenario must include a step change level in the building regulations if it is to be achieved.

5 The vision for the development of a low carbon domestic sector in Northern Ireland

In order to achieve a Low Carbon Economy by 2050, a start must be made as soon as possible in upgrading existing houses and flats to make them highly insulated buildings. All new buildings must be built to the highest insulation standards. Thus, there is a need to:

- Ensure energy efficiency measures are retrofitted during refurbishment
- Provide incentives for developers to go beyond the minimum specification
- Develop a route map for future improvements in the building regulations.

People will also need to be encouraged to:

- Change their behaviour to reduce energy consumption (e.g. greater use of heating controls, turning off unnecessary lights, etc.)
- Install cost-effective energy saving measures (e.g. better insulation and more efficient heating systems and appliances)
- Accept signs of carbon saving such as solar panels and photovoltaics on their houses.

Increasing prosperity means that new homes are being built in record numbers in Northern Ireland. While this trend will continue as the economy develops, there is considerable scope to adjust planning guidelines to improve sustainability. Examples include:

- Checking there is adequate local provision of education facilities
- Ensuring the provision of community bus services for new developments
- Including provision for local services (e.g. corner shops, community centres, etc).
- Encouraging new developments close to business parks, shops and leisure centres
- Using planning gain from rural sites to diminish the extent of the redevelopment of urban sites.

Energy consumption can be reduced on an individual dwelling basis by improving its insulation. For many existing dwellings, this can be achieved by adding cavity wall insulation, double-glazing and additional loft insulation. The Appendix gives the figures from the *Northern Ireland House Condition Survey 2001* [4] showing the numbers and percentages of properties lacking such measures in 2001 – and thus the potential for improvement.

Energy efficiency measures will become more cost-effective as fuel prices increase, while the installation of more expensive energy efficiency measures such as high efficiency condensing boilers can be encouraged through the use of grants. Research carried out by BRE for the Department for Environment, Food and Rural Affairs (Defra) [9] suggests that 0.03PJ of energy saving can be expected for each million pounds of grant expenditure.

Fuel switching is another way in which the carbon footprint can be reduced. The expansion of the gas network gives Northern Ireland the opportunity to move away from solid fuel and oil for space heating[11] as the gas network is extended.

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[11] See the Appendix for information from the *Northern Ireland House Condition Survey 2001* [4] on the numbers and percentages of properties using different fuels for heating.

The fuel used by the electricity supply industry in the generation of electricity also has an impact on the carbon emissions from the domestic sector. As more electricity is generated at power stations fuelled by natural gas or renewable energy sources, the emissions from electricity used in the domestic sector will fall.

In a Low Carbon Economy, power would be generated locally or remotely by off-grid renewable sources. Hydrogen or renewably generated electricity would be the main source of power.

Improvements to the building regulations are an ideal way of regulating thermal efficiency and thus reducing the average energy consumption of the housing stock. A Low Carbon Economy demands a step change in the building regulations to produce houses with zero net carbon emissions. Schemes already exist for housing producing zero carbon emissions. These rely on:

- Renewable energy (e.g. the use of photovoltaics, solar water heating as well as micro-CHP)

- High levels of insulation to maintain temperatures at an acceptable level in all climatic conditions.

Flagship projects would provide motivation at all levels by demonstrating that such dwellings can be built and that the skills are available to design them. Projects such as the innovative zero energy development of studio apartments by the Peabody Trust at Beddington[12] in south London or the proposed hydrogen-powered eco-village covering seven acres in Nottinghamshire would show a commitment to the way forward to a Low Carbon Economy in Northern Ireland.

Training is required at many levels in order to develop a Low Carbon Economy in Northern Ireland. Plumbers, engineering consultants and architects all need to be trained in energy efficient design and practices. Professionals also need to be motivated to place energy efficiency high on their list of design priorities. The Carbon Trust's Low Carbon Design Initiative (LCDI) is already working to address this issue.

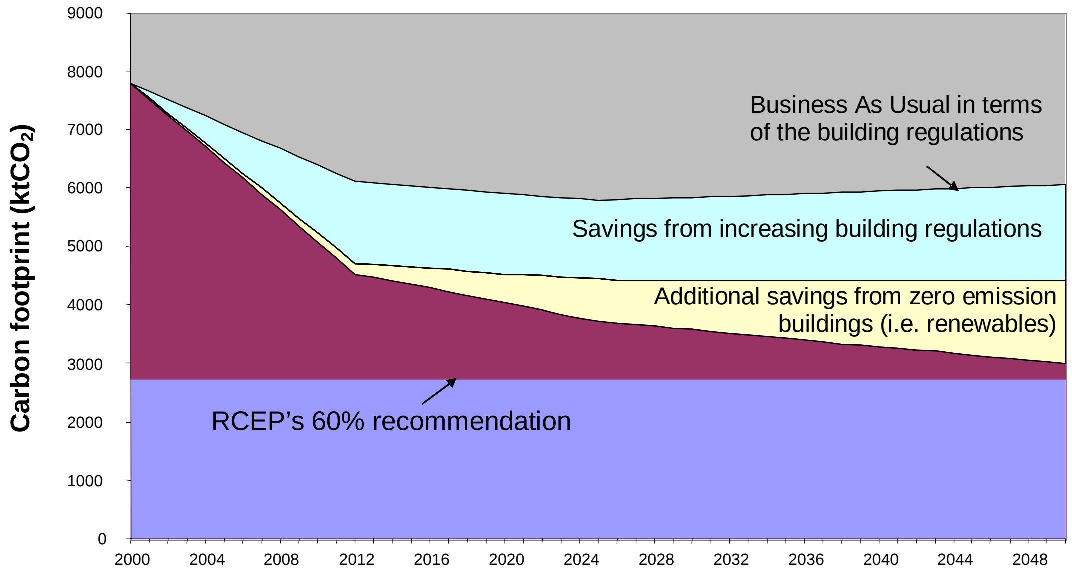
Homeowners, too, need to be educated to see signs of energy efficient design as a desirable quality in a home. Through Defra's Market Transformation Programme (www.mtprog.com), they are being provided with information to help them choose more energy efficient products.

Modelling shows that increasing the building regulations to beyond current standards in England and Wales by 2025 would go some way to achieving the RCEP's 60% recommendation. But even a step change in the building regulations to require the building of zero emission houses (incorporating hydrogen or electricity generated locally or remotely by renewables) from 2012 will not be quite enough to generate the 60% carbon saving that would transform Northern Ireland into a Low Carbon Economy (see Figure D4). A further 3% saving in carbon emissions would be necessary. This could be achieved by increasing the replacement rate of the housing stock. An alternative is to create conditions that encourage individual householders to use renewable energy before 2012 (e.g. installing solar water heating panels). This would be likely under the Global Sustainability economic scenario as everyone would be encouraged to do all that is possible to protect the environment.

Figure D4 presents a roadmap for the development of a Low Carbon Economy in the NI domestic sector.

Figure D4 A roadmap for reaching the RCEP's 60% recommendation by 2050 in the NI domestic sector

[12] http://www.bedzed.org.uk/ or http://www.bioregional.com/


Carbon footprint (ktCO2)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2000
2004
2008
2012
2016
2020
2024
2028
2032
2036
2040
2044
2048
Business As Usual in terms of the building regulations
Savings from increasing building regulations
Additional savings from zero emission buildings (i.e. renewables)
RCEP's 60% recommendation

6 Constraints and barriers limiting the rate of adoption

There are a number of barriers to the development of a Low Carbon Economy in the NI domestic sector.

A major issue is the slow change in the housing stock. NI has a large number of dwellings (647,000 according to the NIHCS [4]) and only a few are demolished each year[13]. Dwellings that are now being built will still be part of the housing stock in 2050. The housing stock is also increasing due to the growth in the population and the trend towards smaller households.

Fuel poverty is another important issue when considering reductions in energy consumption. Fuel-poor households are those that spend more than 10% of their income to heat their homes to an acceptable standard. Although schemes for addressing fuel poverty may initially lead to higher energy use as increased comfort levels are achieved, the aim is to introduce efficiency measures into these households in order to decrease their fuel bills. The alternative to increasing thermal efficiency is to lower fuel prices, but this is not an option when energy savings need to be delivered. However, increasing fuel prices to drive energy efficiency is not an option either as this would take fuel-poor households back into fuel poverty.

There are several economic barriers to change. Some of the most cost-effective energy efficiency measures are expensive to install. Because heating systems tend to be replaced only once every 15–20 years, it takes a long time to increase the overall heating efficiency of the housing stock. In areas that do not currently have a gas supply, the opportunity to reduce emissions by fuel changes will be missed as oil-fired boilers are being installed. These have a larger carbon footprint than gas. Correct sizing of boilers (an important element of training for installers and specifiers) is also important because boilers run less efficiently at part-load.

Some dwellings are more difficult to insulate. For example, dwellings with solid walls can be much more expensive to insulate than those with cavity walls and, for some properties with solid walls, impossible.

In some areas of Northern Ireland there is a limited choice of fuel supply, making it difficult to make carbon savings by swapping fuels. This should improve as the gas network is extended to cover more of Northern Ireland.

Structural changes such as increasing external wall insulation can be difficult and costly. Some measures, such as window replacement with double-glazed units, can be included in refurbishment projects, but the savings tend to be small.

Although there are a number of energy efficiency grant schemes available in Northern Ireland, these are sometimes insufficient to help meet the initial cost even when the fuel savings would give a relatively short payback on the capital cost.

Economic reasons do not always drive decisions in the domestic sector. A measure such as double-glazing, which is seen as desirable, may be installed in situations where the same amount of money could achieve higher energy savings elsewhere with measures that are less visible.

There is a resistance to change, particularly when the capital costs are high. In some situations, people prefer to replace 'like with like' because what they have has proved reliable. New technologies are often not understood and seen as too complicated. People also hear stories from others who have had a bad experience of a new technology, which might not have been due to technological developments but to lack of training by the installer. For example, condensing boilers were originally seen by some people to be unreliable and some plumbers

[13] Between 1996 and 2001, the pre-1980 stock had been reduced by some 4,300 dwellings [3] and around 2,500 demolitions per year are predicted by 2012 [2].

perpetuated this myth by not recommending them because of their lack of experience in installing them.

7 Concluding remarks

The domestic sector tends to be a difficult market to motivate because it is so diverse and decisions are made many by different individuals. However, legislative measures such the building regulations can be used to target energy efficiency in new build and refurbishment projects.

In the NI domestic sector, a carbon footprint giving a 60% saving from 2000 is only achievable by 2050 under a Global Sustainability scenario. This scenario envisages a society in which environmental values are balanced against economic and social values on a global scale. This would encourage favourable attitudes to the use of energy saving measures. A step change in the building regulations to demand zero carbon-emission houses would come close to achieving the RCEP's 60% recommendation by 2050, but immediate change is vital due to the long life of housing stock.

Motivation is a key element in this sector. The enthusiastic uptake of double-glazing has shown that people do not necessarily go for the cheapest and most cost-effective measures.

Market transformation measures, such as better labelling, would allow a more informed choice. A society where global sustainability is important would lead to greater use of lower energy appliances. An increase in general awareness of sustainability issues associated with energy consumption would also lead to a society where people would want to be seen to have photovoltaics and solar water heating. They would also be more likely to press for renewable energy even at a higher cost.

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Acronyms and abbreviations

BAU	Business As Usual
CO_2	carbon dioxide
CHP	combined heat and power
(d)	delivered [energy]
Defra	Department for Environment, Food and Rural Affairs (London)
DFP	Department for Finance and Personnel
GS	Global Sustainability
HECA	Home Energy Conservation Act
kt	kilotonnes
LCE	Low Carbon Economy
LS	Local Stewardship
NI	Northern Ireland
NIHCS	Northern Ireland House Condition Survey
NIHE	Northern Ireland Housing Executive
NISRA	Northern Ireland Statistics and Research Agency
RCEP	Royal Commission on Environmental Pollution
RE	Regional Enterprise
WM	World Markets

Appendix

Key figures from the Northern Ireland House Condition Survey 2001 [4]

	Number	Percentage
Fuel/main heat source		
Mains gas	20,600	3
LPG bottled gas	5,700	1
Solid fuel boiler	92,300	14
Fuel oil	377,800	58
Dual-fuel	61,500	10
Electric	53,800	8
Other	3,600	<1
All central heating	**615,300**	**95**
Open fire	18,700	3
Solid fuel stove/space heater	8,600	1
Other	4,900	1
Non-central heating	**32,200**	**5**
All dwellings	**647,500**	**100**
Wall insulation		
Full cavity wall insulation	324,300	50
Partial cavity wall insulation	37,900	6
Dry lining/external wall insulation	29,700	5
No wall insulation	255,600	39
Loft insulation		
<100 mm	135,800	21
100–150 mm	343,500	53
>150 mm	22,500	4
Thickness unknown	25,000	4
No insulation	34,700	5
No loft	86,000	13
Double-glazing		
None	202,400	47
Part	142,800	22
Full	302,300	31
All dwellings	**647,500**	**100**

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Helpline 0800 085 2005
www.thecarbontrust.co.uk

NORTHERN IRELAND VISION STUDY

Annex E: Prospects for power supply in Northern Ireland to 2050

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CONTENTS

Executive summary

This annex examines the likely trends in power supply in Northern Ireland through to 2012, 2025 and 2050 in the light of four scenarios for possible economic and social development adapted from the UK Foresight Programme. A Business As Usual scenario with additional energy efficiency measures is also considered.

The annex summarises the key issues and the implications for the power supply sector's likely carbon dioxide emissions in each of these years in the light of the recommendation of the Royal Commission on Environmental Pollution (RCEP) of a 60% reduction in carbon dioxide emissions by 2050. Based on the assumptions from the scenarios, a series of possible power mixes to meet the forecast peak demand are identified.

Northern Ireland is not well endowed with indigenous sources of fossil fuels, but it does posses significant renewable energy resources, being in one of the windiest locations in Europe. There is also potential for the exploitation of tidal stream, wave energy and biomass.

In 2000, the generation of electricity was dominated by two large power stations: Ballylumford, fuelled by gas and Kilroot, fuelled by coal. These stations generated over 80% of Northern Ireland's electricity during the year. Using emissions data from the National Atmospheric Emissions Inventory, carbon dioxide emissions for power generation in Northern Ireland in 2000 were calculated as being around 0.79kg of carbon dioxide per kWh delivered.

By the end of 2004, a number of changes had occurred that have (or will have) a significant impact on the carbon intensity of power generation in Northern Ireland. The Belfast West coal-fired station has closed and a new combined cycle gas turbine (CCGT) was commissioned at Ballylumford in the autumn of 2003. Construction is underway on another CCGT power station at Coolkeeragh, which is scheduled to be commissioned in the spring of 2005. The two CCGTs will deliver 1000MW of generating capacity. Since 2002, the 500MW Moyle interconnector with Scotland has linked Northern Ireland with the mainland power grid. A renewable energy obligation similar to that in England, Wales and Scotland is to be put in place starting in April 2005. The implementation of the EU's Large Combustion Plants Directive has lead to the decision to fit flue gas desulphurisation equipment at the Kilroot coal-fired plant. Taking into account these developments, carbon dioxide emissions in 2012 are predicted to be in the range 0.37kg to 0.41kg of carbon dioxide per kWh delivered; a 40–50% reduction compared with 2000.

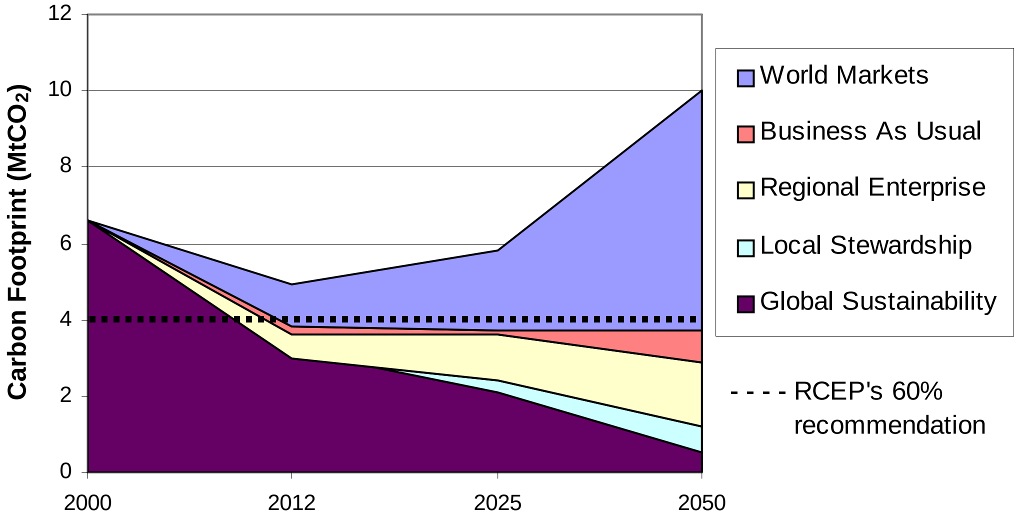
In the period to 2025, any change in carbon intensity is likely to be less dramatic than between 2000 and 2012. A further reduction is likely to result if the renewables obligation is successful and technologies such as offshore wind and tidal stream can be developed economically and integrated into the Northern Ireland distribution system.

The integration and control of the renewable sources (likely to be dominated by wind which is intermittent) would be significantly enhanced by the integration of the Northern Ireland system with that of the Republic of Ireland. It may be that energy storage devices, possibly based around the beginnings of a hydrogen economy, could also offer a cost-effective contribution to managing the system.

The period through to 2050 is the most difficult to predict. The key factors in the evolution of the power system will be the continued availability of natural gas at competitive prices and the success of the various renewable energy technologies, and whether they can develop to the point where they can supply a significant percentage of the total demand. Related to this will be the further development of hydrogen as an energy carrier and whether it makes significant inroads into the gas market. Should renewables be successful commercially, they could dominate the power supply sector. If not, it is likely that a limited range of renewables in combination with high efficiency gas-fired combined cycle stations and/or a small number of nuclear stations will dominate the electricity supply system in Northern Ireland.

A roadmap for the predicted change in carbon dioxide emissions of the Northern Ireland power sector is presented below for the five different scenarios examined. Only the World Markets scenario fails to meet the RCEP's 60% recommendation.

Carbon dioxide emissions of energy supply in Northern Ireland to 2050



1 Introduction

This annex summarises baseline data and the prospects for future development of power generation including renewables and low carbon technologies in Northern Ireland to 2050. The target of a reduction in carbon dioxide emissions of 60% from 2000 levels by 2050 as recommended by the Royal Commission on Environmental Pollution (RCEP) [1] is achievable in Northern Ireland and reducing demand is a key element in achieving this.

In 2001, the Environment Agency's Sustainable Development Unit outlined its vision for energy policy up to 2050 [2] and showed how fossil fuel consumption (and associated emissions) could be reduced by 75% through:

- A 50% reduction in overall demand for energy
- A 50/50 split in the provision of energy by fossil fuels and renewable sources.

Similar reductions could be achieved in Northern Ireland (NI) by applying the same conditions of a 50% reduction in consumption and a 50/50 split in the provision of energy by fossil fuels and renewables. Indeed, Northern Ireland should consider going beyond the 50/50 split given:

- Its lack of indigenous fossil fuel resources
- The fact that gas for electricity generation will progressively be sourced from more distant locations and Northern Ireland will be at the extreme end of the supply lines and therefore more likely to experience disruption of supply.

Achieving such a reduction will depend on developing the political and public consensus to allow its delivery alongside the correct planned development and investment decisions. The cost of the various actions necessary to reduce emissions will be a major factor. However, taking no action is not seen by most of the scientific community as an option given the well-publicised effects of long-term climate change.

This annex summarises where Northern Ireland is now in terms of energy supply and maps out the likely paths over the next 50 years[1]. It sets out a series of actions that need to be taken – some immediately and some in the near future – if the low carbon economy that is necessary to counter climate change is to be delivered within the specific context of Northern Ireland. For example, solar photovoltaics could potentially play a huge role in providing low or zero carbon energy. However, while Northern Ireland could use the technology if or when it becomes economically viable, the current centres of development of the technology and the best geographical locations for its exploitation are elsewhere. On the other hand, Northern Ireland has tidal, wind and biomass resources, together with skills that could enable it to play a leading role in taking forward technologies for the exploitation of these resources. This annex concentrates on these resources and skills, and the issues and barriers to their development and exploitation in Northern Ireland.

The annex's objectives are to:

- Summarise the indigenous energy resources in Northern Ireland
- Set out the baseline (year 2000) situation and utilisation of the relevant technologies
- Review the likely developments to 2012 based on:
  - Current knowledge of technologies
  - Likely commercial prospects

[1] The further into that period, the more uncertain predictions made today become.

– Support mechanisms that current apply and that are under development
– The particular situations applicable to Northern Ireland[2] that could affect the development and uptake of particular technologies.

- Review further developments and barriers to 2025 based on:
  – The 2012 scenarios
  – The technologies that are likely to be commercially available by 2025
  – The infrastructure changes that may have occurred
  – The particular situation of Northern Ireland.
- Determine what additional developments in technologies or other measures would need to occur and/or be introduced to allow Northern Ireland to achieve the 60% reduction target envisaged in the RCEP paper [1] and the UK Government's Energy White Paper [3] by 2050 based on:
  – The 2025 scenarios
  – The particular situation of Northern Ireland
  – Social, political and commercial changes that could impact over the period.
- Define a series of actions that need to be taken to deliver a low carbon economy in Northern Ireland, based on the conclusions drawn on the likely technologies to be exploited at a given level and the barriers to, and opportunities offered by, these technologies.

The forecasts for electricity mix are presented as pie charts for the different scenarios in 2012, 2025 and 2050. The renewable energy component is broken out from the pie chart on the right-hand side of each figure to show the breakdown across combined heat and power (CHP), renewable energy and waste-to-energy technologies. The figures in the pie charts have been rounded to improve readability and thus do not necessarily add up to 100%.

[2] These include Northern Ireland's situation within the UK, its interconnection with UK and Republic of Ireland (RoI) energy systems, its size, its economic structures, its geography, the availability of European grants, etc.

2 Indigenous resources for power generation in Northern Ireland

Northern Ireland is not well endowed with indigenous sources of fossil fuels, but it does posses significant renewable energy resources. It is one of the windiest locations in Europe and there is potential for the exploitation of tidal stream, wave energy and biomass.

Fossil fuel resources

Lignite and peat are potentially available fossil fuel resources. However, their exploitation for the generation of energy is likely to have a significant negative environmental impact and be resisted strongly by environmental and planning groups. The exploitation of peat and lignite is therefore are considered unlikely (see Section 5).

Renewable energy resources

The renewable energy resources that are potentially available in Northern Ireland have been reviewed in a number of studies [4–8]. This annex highlights only the key issues, pointing out where there is uncertainty or disagreement between the various studies, and summarises the range of resource numbers for the various relevant technologies.

For the purposes of this study, renewables are defined as energy derived from the sun, wind, wave, tides and biomass. Low carbon technologies include energy derived from wastes, fuel cells and hydrogen[3].

Wind

Wind energy is by far the most significant renewable energy resource in Northern Ireland. Wind energy can be exploited both onshore and offshore; the latter has more onerous technology requirements, but usually has the benefit of a proportionally greater load factor (the wind is steadier and blows at a suitable level for a greater proportion of the time than onshore).

Wave and tidal

There is potentially a significant wave and tidal stream resource off the Northern Ireland coast. The technology to exploit these resources is, however, at an early stage of development and will be subject to meeting environmental concerns as the majority of sites are in protected areas. It is therefore difficult to assess the degree to which they could be exploited and the timescales.

Biomass

Energy from biomass already has a role in Northern Ireland's significant rural economy and this could be developed further. In particular, those regions of Northern Ireland where expansion of the gas network is unlikely to be economic are potential areas where energy from biomass (both heat and electricity) could become a key player. Biomass exploitation also helps the rural economy in creating and sustaining employment and business activity. The particular benefits of biomass exploitation in Northern Ireland are discussed in Annex B.

Hydropower

Plans in the 1950s to develop large-scale hydroelectric power generation projects in Northern Ireland on the River Mourne and the Lower Marne were not taken forward for environmental reasons. This is likely to remain the case. Exploitation of hydropower in Northern Ireland is

[3] Fuel cells and hydrogen are not energy sources in themselves; the former is an energy conversion device converting chemical energy (e.g. fossil fuels or hydrogen) to electricity while hydrogen is an energy carrier produced by, for example, electrolysis of water or from fossil fuels.

therefore limited to small and micro hydro sites. There are presently of the order of 25 schemes operating with capacities ranging from 0.8MW down to 3kW. Although able to make a useful contribution, hydropower in Northern Ireland is always likely to be limited to less than 10MW total capacity.

Solar energy

The other main renewable energy source is solar energy. The geographical position of Northern Ireland does not make it a prime candidate for the exploitation of solar energy, either directly through solar water heating or indirectly through photovoltaic (PV) electricity generation. If the predicted reduction in cost for PV materialises and fossil fuel prices rise (through depletion of resources or taxation because of environmental impact), then there could be some economic application of PV in the later period covered by this study (i.e. beyond 2020). Solar water heating is currently a mature technology, but current payback periods make it relatively uneconomic. As with PV, rising fossil fuel prices could drive its exploitation but, as this study focuses on electricity generation, it is not considered further here.

Geothermal energy

Geothermal energy can be exploited in a number of locations around the world, but the UK has only limited low-grade geothermal sources. All possible sources in Northern Ireland are far from being exploitable economically, both today and in the foreseeable future.

Ground source heat pumps are a related technology that essentially exploits the heat buffer capacity of the ground close to the surface. They can boost heating systems in winter and cooling systems in summer. Current payback periods are poor and, again, they are not examined in this annex because they are not sources of electricity generation.

Waste-to-energy resources

Landfill gas

The wastes produced by all forms of human activity can, in a number of cases, be exploited to provide energy. In particular, landfilled waste produces methane – a gas that is 20 times more potent as a greenhouse gas than carbon dioxide. Legislation therefore requires landfill gas to be collected and flared to convert it to carbon dioxide (CO_2). Rather than just flaring it, however, it can be cleaned up and combusted in a gas engine to provide electricity generation. No landfill sites in Northern Ireland currently produce electricity, but the potential exists for them to do so.

Waste combustion

The EU Landfill Directive aims to reduce the amount of biodegradable waste going to landfill. This will require greater recycling and the use of other disposal methods. Following waste reduction and minimisation, there is a role for waste combustion in purpose-built plants to provide electricity generation but, as with landfill gas, there are currently no operating plants in Northern Ireland. However, the resource is there. Waste-to-energy capacities are forecast in this annex in the context of the overall waste strategy for Northern Ireland [9] and municipal waste arisings data [10].

Anaerobic digestion

Human and animal waste can be collected in an anaerobic digester to produce methane. This, like landfill gas, can be burnt in an engine to provide electricity. Northern Ireland has a potential resource that could be exploited by this technology. This is discussed further in Annex B.

Table E1 summarises the resources available in Northern Ireland in terms of renewable energy and waste-to-energy.

Table E1 Estimates of NI renewable energy and waste-to-energy resources (from published data) in MW of generation capacity

	Source				
	ETSU/DTI/ NIE (1993) [4]	ETSU/WREAN/ DED/NIE (1999) [5]	ETSU/WREAN/ DED/NIE (1999) [5]	PB Power (2003) [8]	Action Renewables* (2004) [11]
Year	**2000**	**2010**	**2025**	**2010**	**2012**
Wind onshore	50	60	60	587–684	565
Wind offshore	0	n/a	n/a	200	500
Biomass	20	17	27	20	18.1
Wave	0	0	0	0	0
Small hydro	6	6	6	0	8.3
Tidal stream	0	0	0	n/a	0
Geothermal	0	0	0	0	0
Solar PV	0	0	0	0	0
Landfill gas	10	10	20	9.1	23.7
Waste combustion	10	18	35	16.6	13
Anaerobic digestion	3	4	5	7.6	5

* Action Renewables is a joint initiative in Northern Ireland between the Department of Enterprise, Trade and Investment (DETI) and the Viridian Group.

There are some notable differences in the figures presented in these reports. The most obvious is the different assessments of the potential for wind (both onshore and offshore). The ETSU figures from both the 1993 and 1999 reports [4,5] are based on the resource being constrained by the capability of the NI grid to accept wind generation. This was based on advice at the time from Northern Ireland Electricity (NIE). Offshore wind was not considered in 1993 by ETSU but, in 1999, it was noted as a potential resource although its magnitude was not assessed.

For the other renewables, the studies produced generally consistent assessments of the potential resources.

The data in Table E1 confirm that wind will always be the dominant potential resource in Northern Ireland. However, significant contributions are potentially available from biomass and, depending on technology development, from tidal stream and wave.

Energy-from-waste technologies could contribute another 40–60MW of total capacity.

3 Year 2000 power generation baseline

In 2000, Northern Ireland had four power stations situated at Coolkeeragh, Ballylumford, Kilroot and Belfast. Table E2 shows the input fuels used by these power stations, together with the other forms of power generation and connections that contributed to the total power supplied through the distribution network in Northern Ireland in that year. Generation was dominated by two large power stations – Ballylumford, fuelled by gas and Kilroot, fuelled by coal.

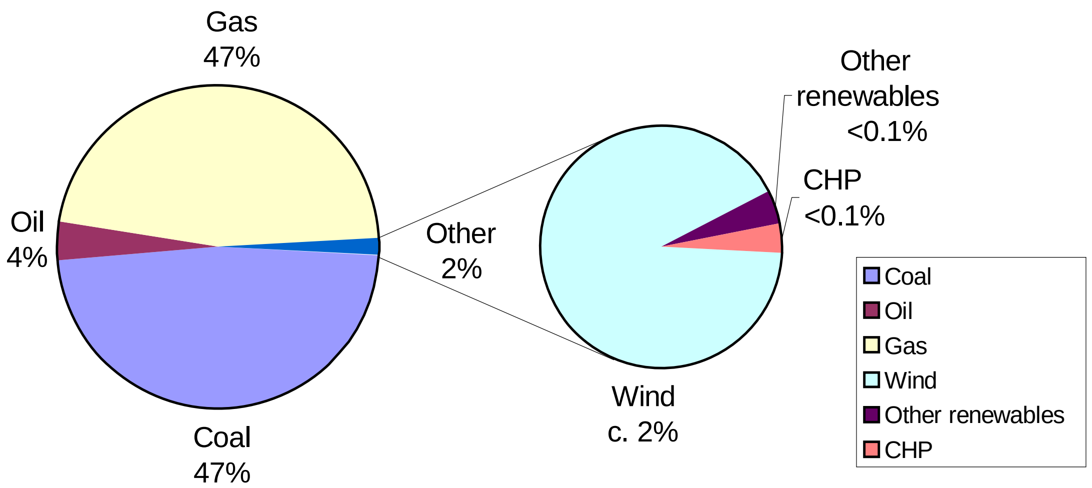
Figure E1 shows the relative outputs by fuel for NI power generation in 2000.

The output of the generators in MWh has been estimated from data in the National Atmospheric Emissions Inventory (NAEI)[4] [12] for each generator and a figure for the carbon output per kWh of delivered energy for the given technology. These data have been cross-checked with data from the Digest of UK Energy Statistics (DUKES) [13] and NIE.

A carbon dioxide intensity for overall power generation can be derived by dividing the total MWh of energy generated from all the power stations in Northern Ireland in 2000 by the total emissions from these stations during the same period. This figure is for direct emissions only; it does not take into account the carbon emitted in constructing the power stations and generators, nor any energy associated with disposal of waste materials from power generation (i.e. it is not whole-life emissions data).

The data show overall carbon dioxide emissions for power generation in Northern Ireland in 2000 of 0.790kg of carbon dioxide per kWh delivered (d).

Figure E1 Relative outputs by fuel for NI power generation in 2000



In 2000, peak demand on the NI electricity system did not exceed 1,450MW and demand only exceeded 1,000MW for 42% of the time. Given that the capacity of plant plus interconnector capacity was around 2,400MW, there was a significant margin of reserve capacity in Northern Ireland in 2000.

[4] See http://www.naei.org.uk/

Table E2 Electricity generators and other sources of electricity in Northern Ireland in 2000

Generator(s)	Fuel source	Capacity (MW)	Output (MWh/year)	Emissions (tonnes CO_2)	Emissions (tonnes Carbon)
Ballylumford*	Gas	951	3,988,000	2,500,000	682,000
Belfast West†	Coal	120	1,063,000	990,000	270,000
Coolkeeragh	Oil	240	349,000	330,000	90,000
Kilroot	Coal	520	3,008,000	2,800,000	764,000
Renewable	Wind	15.23 (DNC)	119,036	n/a	n/a
Renewable	Small hydro	1.965	6,098	n/a	n/a
Renewable	Biomass	0.304	444	n/a	n/a
Renewable	**Total**	**17.5**	**125,578**	**n/a**	**n/a**
CHP (27 units)	Coal/oil/gas	n/a	4,900	<3,000	<1,000
Interconnector (I) Moyle	Various	Under construction#	0	0	0
Interconnector (II) RoI	Various	300	100,000 (export to RoI)	-	-
Total (rounded)		**2,148**	**8,638,000**	**6,620,000**	**1,806,000**

DNC = declared net capacity; RoI = Republic of Ireland

* Ballylumford is the largest power station in Northern Ireland, with six generating units. It has dual fuel boilers (as the main plant) fired with natural gas and, when required (e.g. during interruptions to the gas supply), with heavy residual fuel oil.

† Now closed.

The 500MW Moyle interconnector with Scotland has linked Northern Ireland to the mainland power grid since 2002.

The level of peak demand has implications for the economics of the different plants operating on the system, especially post-2008 when the combined cycle gas turbine (CCGT) plants at Ballylumford and Coolkeeragh[5] are fully operational and significant renewables may be being commissioned (see Section 4).

The two CCGTs will have a combined capacity of 1,000MW and will be run as base load plant. They should therefore meet most, if not all, of Northern Ireland's average electricity demand. The addition of renewables, which will also need to operate whenever they can (restricted only by resource availability, wind blowing, tides, etc.), and the probable continued use of the Kilroot coal plant to meet peak demand, mean that Northern Ireland will need to export power either to Scotland or RoI. This has already started, with the announcement in 2003 that NIE had signed a three-year, £30 million cross-border electricity supply deal with the Irish Republic's Electricity Supply Board (ESB) using power from the Ballylumford gas-fired power station.

[5] The CCGT power station at Ballylumford, with a capacity of 600MW, was commissioned in the autumn of 2003. A second station at Coolkeeragh, with a capacity of 400MW, is due to be commissioned in spring 2005.

4 The energy demand scenarios

The four scenarios developed by the UK Foresight Programme [14] form the starting point for those used in this study. These scenarios identify key social and economic trends and then explore how these might change under different political priorities, markets conditions and social attitudes. The scenarios used in this study, which are described in more detail in Annex A, are:

- World Markets
- Regional Enterprise
- Global Sustainability
- Local Stewardship.

In the following visions for 2012, 2025 and 2050 (see Sections 5–7), a vision based around Business As Usual (BAU) is proposed and its possible variation for each of the four scenarios is outlined.

There are two major issues for each scenario:

- The effect on overall demand for electricity and hence the level of supply required
- The effect on type of power generation plant constructed and/or operated.

The 'Business As Usual' with additional energy efficiency measures and the four UK Foresight scenarios adapted for Northern Ireland would suggest the overall power sector demand shown in Table E3.

Table E3 Predicted overall NI power sector demand for the various scenarios*

Scenario	Approximate change
Business As Usual	1% per year growth in overall demand
World Markets	2% per year growth in overall demand
Regional Enterprise	0.75% per year growth in overall demand
Global Sustainability	0% per year growth in overall demand
Local Stewardship	0.5% per year decrease in overall demand

* The annual percentage demand growth has been taken from the scenario modelling study that complements this work. The model shows some variations in growth rate over the different decades, but these are not large. Thus, for simplicity, average rates per decade have been used for the estimations in this annex.

The power mix under the scenarios is considered for 2012, 2025 and 2050. Below is an outline of the broad thrusts of what each scenario might mean for the evolution of power mix in Northern Ireland. Their implications for the power mix in 2012, 2025 and 2050 are discussed in Sections 5, 6 and 7, respectively.

- **World Markets** is likely to favour the use of gas, perhaps mitigated by growing concerns over security of supply post-2012. Under this scenario, there is likely to be minimal exploitation of renewable energy sources until their economics become more comparable with fossil fuels.

- **Regional Enterprise** would favour indigenous sources, but Northern Ireland is not well endowed with fossil fuel energy resources. Investment in renewables will be limited due to constraints on public funding.

- **Global Sustainability** will favour the utilisation of renewable energy sources and increased restrictions on the exploitation of fossil fuels.

- **Local Stewardship** will favour indigenous resources, but investment constraints are likely to limit the exploitation of renewables. An exception to this could be biomass, where job creation could be significant and favoured under the scenario's conditions.

5 The vision for 2012

The likely trends and factors in the development of power generation in Northern Ireland to 2012 are defined in a consultation paper issued by Department of Enterprise, Trade and Investment (DETI) in April 2003 [15]. The outcome of this consultation will form the basis of 'Business As Usual' for the period 2000–2012.

Key issues will be:

- Growth in the use of gas for power generation
- Growth of the gas network
- Regulatory and taxation restrictions on the use of fossil fuels
- Relative energy prices (particularly the price of gas)
- Historical energy contracts
- Role of interconnectors and energy imports
- Level to which wind resources can be exploited
- Potential for offshore wind and its interaction with onshore wind and the network
- Exploitation of biomass and its economics
- Effect of the NI renewables obligation and its interaction with the English, Welsh and Scottish obligations
- Energy from waste exploitation
- Penetration of micro CHP based initially on gas
- Contribution of exploiting these technologies to the wider NI economy and social infrastructure.

Proposed DETI strategy to 2012

The DETI's consultation document [15] proposes an energy strategy to 2012 that includes as its key challenges:

- Ensuring that the costs of energy are reduced
- Facilitating greater cross-border trading and expanding transmission capacity
- Ensuring security and diversity of supply
- Encouraging the reduction of greenhouse gas emissions
- Expanding the gas network and providing opportunities for fuel switching
- Encouraging generation from renewable energy sources and overcoming the cost, planning and grid connection and operation issues associated with the technologies.

The first of these challenges is critical. All of the others involve investment to varying degrees. To deliver a lower carbon and hence a more sustainable energy system, while reducing energy prices in the short to medium term, presents a significant challenge. It means that all potential developments must be compared rigorously to ensure that the lowest cost options with the greatest potential for carbon reduction are pursued. Similarly, some environmentally desirable but relatively expensive options will need to be put to one side unless sources of funding independent of (or supplementing) consumers and public funds can be used (e.g. European Structural Funds).

Forecast demand in 2012

The DETI forecasts [15] that peak demand will increase from around 1,600MW in 2000 to 1,900MW in 2012 as demand continues to grow at about 2% per year. The energy output in 2000 was 8,294GWh [13]. The four Foresight scenarios adapted for Northern Ireland suggest the figures given in Table E4.

Table E4 Forecast demand for Northern Ireland in 2012

Scenario	Rate of growth	MW	GWh
DETI strategy consultation [15]	2% per year growth	2,000	10,500
Business As Usual	1% per year growth	1,800	9,300
World Markets	2% per year growth	2,000	10,500
Regional Enterprise	0.75% per year growth	1,750	9,000
Global Sustainability	0% per year growth	1,600	8,300
Local Stewardship	0.5% per year decrease	1,500	7,800

The power sector in 2012

Table E5 shows the likely generating capacity in Northern Ireland from various sources for 2012. The estimated data produce overall carbon dioxide emissions for power generation in Northern Ireland in 2012 of 0.37–0.41kg of carbon dioxide per kWh delivered. This is a 40–50% reduction compared with 2000.

Table E5 Likely maximum electricity generating capacity in Northern Ireland in 2012*

Generator(s)	**Fuel source**	**Capacity (MW)**	**Output (MWh/year)**	**Emissions (tonnes CO_2)**	**Emissions (tonnes Carbon)**
Ballylumford	Gas (CCGT)	600	3,679,000	1,519,100	414,300
Coolkeeragh	Gas (CCGT)	400	2,453,000	1,012,917	276,250
Kilroot	Coal (FGD)	520	500,000	465,153	126,860
Various	Wind (onshore)	200–600	525,000 to 1,600,000	0	0
Various	Wind (offshore)	150	525,000	0	0
Various	Landfill gas	9	63,000	0	0
Various	Small hydro	5	25,000	0	0
Various	Energy from waste	8	56,000	0	0
Various	Sewage gas	3	21,000	0	0
Various	Biomass	10†	66,000	0	0
Various	Tidal stream	100#	438,000	0	0
CHP	Coal/oil/gas	50	200,000	140,000	38,180
Domestic/micro CHP	Gas	50–100	200,000 to 400,000	200,000	60,000
Interconnectors (RoI)	See below	600	30,000	18,847	5,140
Moyle interconnector (with Scotland)	See below	500	670,000	288,933	78,800
Estimated maximum total (rounded)		**3,200 to 3,700**	**9,000,000 to 10,000,000**	**3,650,000**	**1,000,000**

* The numbers in this table are drawn from *Northern Ireland Energy Study 2002* [16] and references 4, 5 and 8.

† Biomass sources include short rotation coppice, wood residues, poultry litter and agricultural wastes. Of these, only agricultural wastes (5MW) and poultry litter (5.8MW) are considered marginally economic for grid-connected power sources.

Based on data in the *Tidal stream report* published in June 2003 [17].

The likely supply mix in Northern Ireland in 2012 under the different scenarios is presented in Figures E2–5 and can be compared with that for 2000 shown in Figure E1. The renewables data are taken from three reports published in 2003 [8,15,17]. The renewables capacities presented in these reports are generally considered to be optimistic views of commissioned plant by 2012; grid integration on a local and national scale and land-use planning approvals are likely to limit the commissioned capacity, at least in the period to 2012.

This analysis shows that the most important renewable energy source in Northern Ireland is wind. The key factors in its exploitation will be:

- The availability of subsidies/grants
- The degree to which it can be managed as an increasing percentage of the overall power mix on the relatively small NI network

- The public acceptability of significant numbers of wind farms.

There are no commissioned landfill gas projects to date in Northern Ireland[6], although two with a combined capacity of 6MW were awarded contracts under the NI Non-Fossil Fuel Obligation (NFFO) orders. A 6MW waste-to-energy plant was also awarded a contract, but this has also failed to proceed.

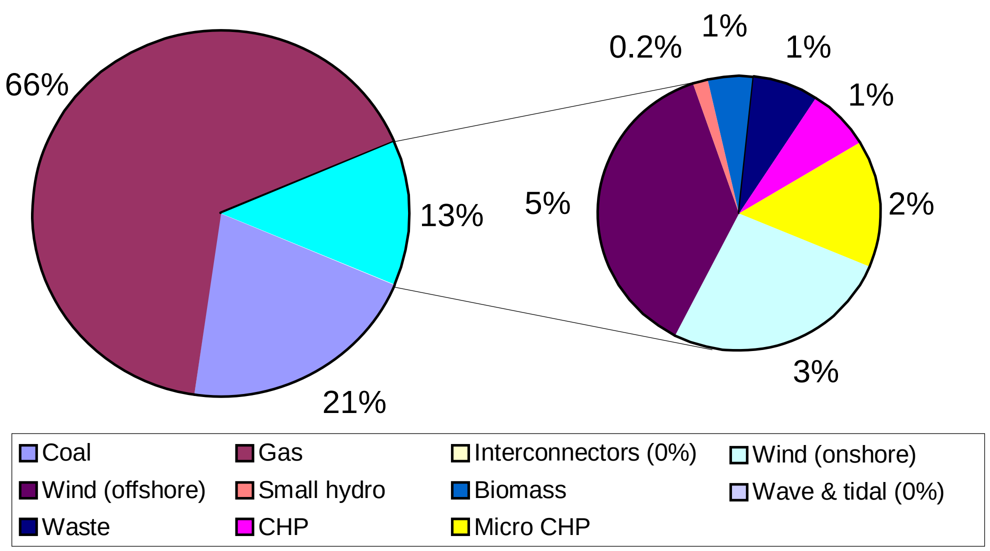
While biomass is unlikely to be a major contributor to the overall NI electricity supply market, it could have an important role in rural areas for power, heat supply and in supporting the rural economy (especially in areas not reached by the gas grid); it is discussed in more detail in Annex B.

An alternative may be the export of electricity from Northern Ireland to RoI.

The scenarios

World Markets (Figure E2) is likely to favour the use of gas. Under this scenario, there is likely to be minimal exploitation of renewable energy sources until their economics become more comparable with fossil fuels. The associated significant growth in demand under this scenario (2,000MW and 10,500GWh) may also create the conditions for a further CCGT to find a place in the market. The total carbon dioxide emissions would be of the order of 5.0 million tonnes in 2012.

Figure E2 Electricity generation mix in 2012 in the World Markets scenario



Regional Enterprise (Figure E3) would favour indigenous sources. Investment in renewables will be limited due to constraints on public funding. The reduced growth in demand under this scenario compared with World Markets, and the DETI consultation assumptions would suggest that the 2012 demand of 1,750MW and 9,500GWh could be met by:

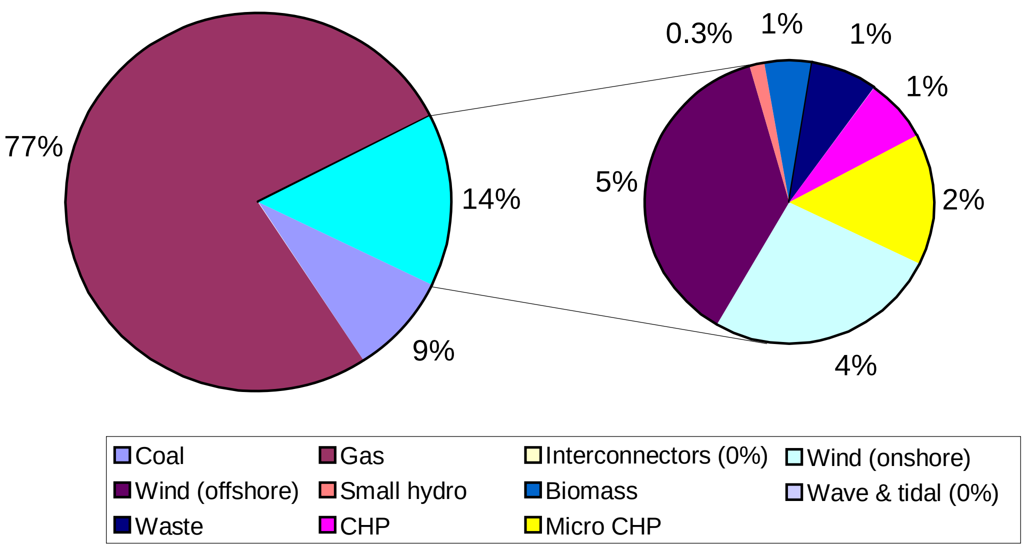
- The CCGTs
- The limited renewables and CHP that were commissioned given investment constraints (say 100–200MW)

[6] These have so far proved the cheapest and most common renewable energy projects in mainland UK.

- Flows through the Moyle interconnector and Kilroot operating flexibly to meet demand peaks.

The total carbon dioxide emissions would be of the order of 3.6 million tonnes in 2012.

Figure E3 Electricity generation mix in 2012 in the Regional Enterprise scenario

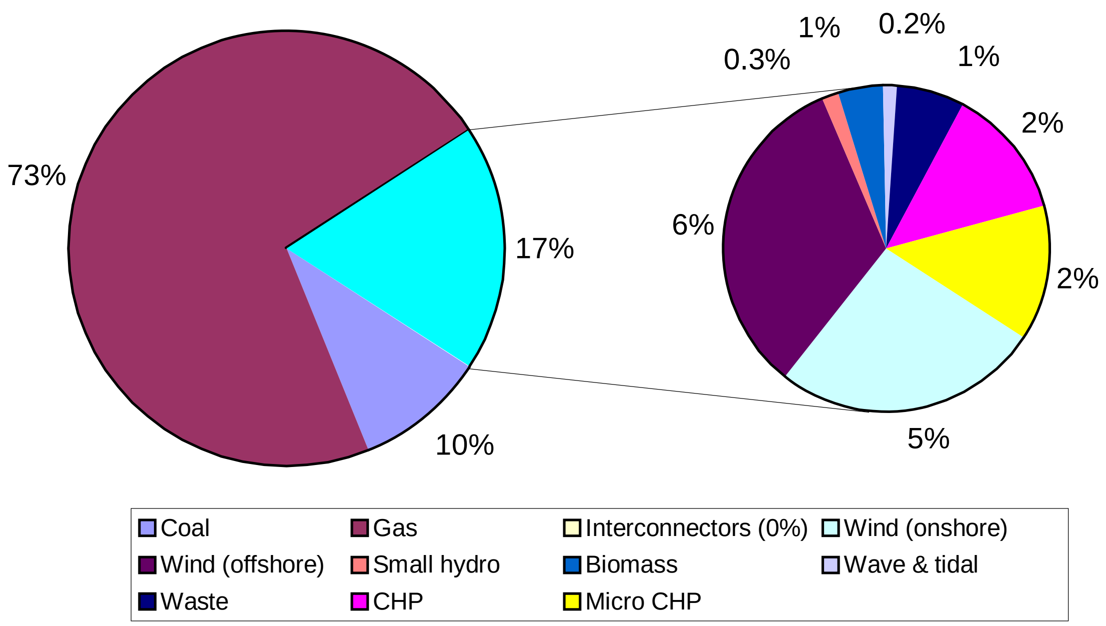


Global Sustainability (Figure E4) will favour the utilisation of renewable energy sources and increased restrictions on the exploitation of fossil fuels. Under this scenario (peak demand of around 1,600MW and 8,300GWh), it is more likely that Kilroot's running hours will be restricted. The renewables build will be higher, but constrained by investment limitations. Peak demand will be met by:

- The CCGTs
- Renewables (mostly wind) and CHP totalling 100–300MW
- Flows through Moyle and perhaps Kilroot (with FGD).

If Kilroot is forced to run for only restricted hours, there may be demand for a new additional CCGT – unless the renewables obligation realises a significant proportion of the potential capacity. Higher proportions of renewables would raise questions over peaking plant and the way the interconnector was operated. The total carbon dioxide emissions would be of the order of 3.2 million tonnes in 2012.

Figure E4 Electricity generation mix in 2012 in the Global Sustainability scenario

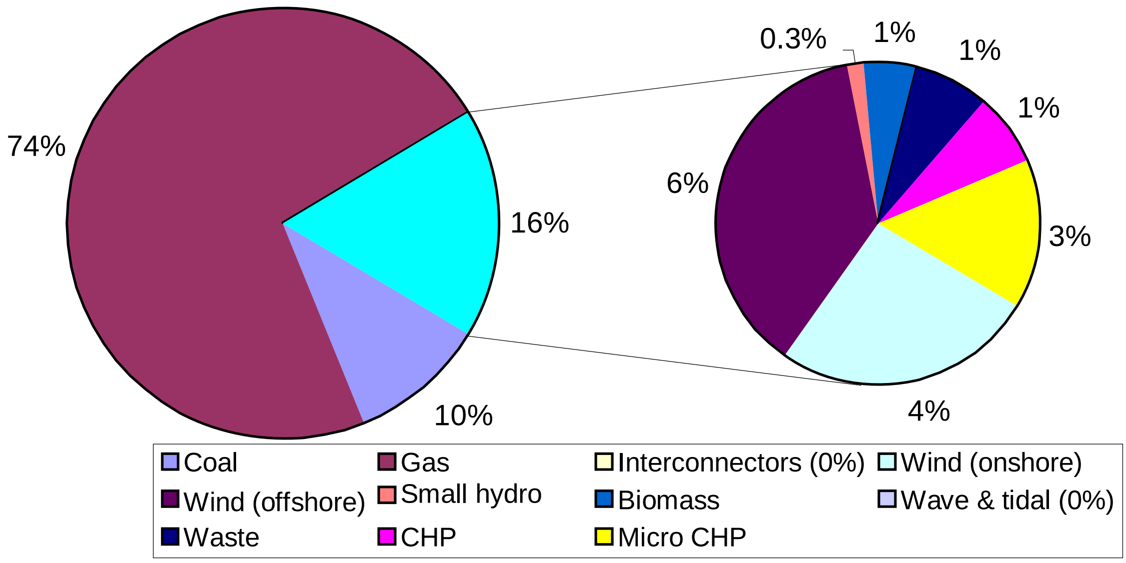


Local Stewardship (Figure E5) will favour indigenous resources, but investment constraints are likely to limit renewables exploitation. An exception to this could be biomass, where job creation could be significant and favoured under the scenario's conditions. The peak demand of around 1,500MW and 7,800GWh could be met by:

- The current CCGTs
- The interconnectors and limited increases in renewables.

Kilroot could also be retained as peaking plant, running for between 1,000 and 2,000 hours a year. The total carbon dioxide emissions would be of the order of 3 million tonnes in 2012.

Figure E5 Electricity generation mix in 2012 in the Local Stewardship scenario



The role of interconnection in the NI system

Northern Ireland's interconnections with the power systems of mainland UK (via the Moyle interconnector to Scotland) and the Republic of Ireland (via a number of cross-border connectors) were either upgraded or reinstated between 2000 and 2002. The way these interconnectors are operated will have a significant effect on the way power is managed in Northern Ireland and the amounts of intermittent renewables that can be safely operated on the NI system.

During the first decade of the 21st century, the interconnectors will have a key role in ensuring that peak demand in NI can be met. Beyond 2010, and in the absence of any further new plant beyond the current two CCGTs under construction, the interconnectors may again be required to ensure forecast peak demands can be met. However, should the renewables obligation be successful, then the role of the interconnectors could be focused – alongside the Kilroot coal plant – on providing stability to a system with a relatively high penetration of intermittent renewables.

All-Island system

The potential requirement to operate a large amount of intermittent power on the small NI system would be very difficult without the interconnectors with Scotland and RoI. These difficulties would be significantly reduced if the power network in Northern Ireland and RoI was operated as one integrated system. The DETI's consultation paper [15] proposed that progress is encouraged towards a single market and this was confirmed by the publication in November 2004 of *All-Island energy market – a development framework* [18].

Energy storage

The potential growth of renewables means that a significant component of the power generation mix will be a less predictable output than that of plant that uses a storable fuel (e.g. coal, gas, biomass). Wind, wave, tidal and CHP are the main sources that fall into this less predictable category. At present, the electricity system is designed to handle robustly any variations in demand from consumers and to remain stable.

Small amounts of less predictable generation can be handled as if it were 'negative' consumer demand. But when wind energy, for example, becomes a significant proportion of the total supply, the system will need to be able to manage large variations in wind power output over relatively short periods of minutes. In addition, the system will need to be able to manage robustly changing inputs from industrial and commercial CHP plants, and local variations from small distributed generators such as micro CHP (e.g. household) and photovoltaic generation.

Short-term variations in supply are currently managed by a variety of methods. For example, a coal plant maintains 'spinning reserve' whereby the plant is only partly loaded and can be rapidly brought up or down in output. Pumped storage uses cheap electricity generated at off-peak periods to pump water into an elevated reservoir; when a peak in demand occurs, the gravitational energy stored in the water is converted back to electricity by allowing the water to flow downhill through a turbine.

It has generally proved easier to store energy as the input fuel (coal, gas, oil) rather than generate electricity and store that if demand is not present to match the generation. With the forms of sustainable generation now coming online, combined with the greatly increased numbers of generators of smaller capacity, the overall electricity network would benefit from having the capability to store electricity – assuming this can be done at an economic cost.

Until recently, the leading technology for storage was a flow fuel cell named 'Regenesys', which was being developed by RWE Innogy (now RWE npower). However, RWE announced late in 2003 that it was ceasing development of this technology, which was at the stage of commissioning a utility-scale demonstrator in the UK and USA. The sodium sulphur battery is another technology that has been demonstrated at utility scale.

Hydrogen

Both of these technologies and a number of others (compressed air, flywheels, etc.) are seen as intermediate technologies that will satisfy niches in the storage market prior to the development of the hydrogen economy. Hydrogen has the highly desirable property when burnt of producing water and very little, if any, contaminants.

Hydrogen is not a fuel in the sense of coal, oil or renewables. It does not occur in any significant quantities on its own, but has to be made by either chemical or electrochemical reactions. For this reason, it is often referred to as an energy vector or energy carrier.

At present, the most economical way of making hydrogen is from fossil fuels. While this hydrogen produces only water at the final point of combustion, its manufacture produces carbon dioxide and hence it is not a carbon-free fuel. Hydrogen can be made by electrolysis of water using electricity generated by renewables, but this route is more expensive than the fossil fuel option and is likely to remain so until fossil fuel costs rise significantly.

Hydrogen offers the overall benefit that it can be used in a range of technologies and a wide range of applications. Hydrogen produced from renewable electricity at times of over supply of electricity could be stored and used as a transport fuel, or fed back through fuel cells to generate electricity at times of peak demand.

A number of countries are building demonstration-scale hydrogen generation and storage plants that will allow the overall economics and technical feasibility of the technologies involved to be assessed. Iceland has set itself the goal of developing a hydrogen economy within the next 30 years. Similar efforts are underway in Hawaii, while Germany, Norway[7], Japan and the USA (amongst others) are developing significant research programmes to investigate a range of issues

[7] See http://www.afsa.org/fsj/dec03/sigfusson.pdf

associated in developing the technology and infrastructure required to deliver a hydrogen economy.

Early developers such as Iceland, Norway and Hawaii are using an indigenous resource; geographical and technology advantages allow them to develop the systems more economically than would be the case elsewhere. Iceland, Norway and Hawaii all have access to low-cost renewable energy from hydro schemes and, in the case of Hawaii and Iceland, geothermal sources. Norway also has the leading expertise in electrolysis plant through Norsk Hydro. Geographically, both Iceland and Hawaii are remote and can develop self-contained transport systems utilising hydrogen as the prime fuel.

It currently costs two to three times as much to produce hydrogen from fossil fuels as petrol, and a hydrogen-powered bus costs six times as much as a standard vehicle. However, costs will fall as the technologies become mass-produced and, in locations with access to low-cost renewable energy, the technology has the greatest chance of being economic.

Northern Ireland potentially has access to plentiful supplies of electricity from renewable energy, but not presently at a similar cost advantage to the countries listed above. Northern Ireland also has a transport system that is strongly integrated with the rest of the UK and RoI. It is therefore unlikely that there would be a significant market for hydrogen-fuelled cars, etc. without wider adoption of the technology in the UK and RoI. However, Northern Ireland could lead the UK in developing both the technology and the basis of a hydrogen storage system on a smaller scale by being an early demonstrator of the technology utilising local transport fleets (rail, buses, delivery vehicles, taxis) powered by hydrogen.

Other issues

- **Gas network expansion**. The 400MW CCGT plant currently under construction at Coolkeeragh is central to the development of a new gas pipeline to the northwest (it will provide an anchor load necessary to make the extension of the gas pipeline viable). The wider availability of gas could enable a significant uptake of microgeneration. The marketing of such systems is starting in mainland UK and, if successful there, suppliers are likely to look towards Northern Ireland in the later part of the current decade.

- **Large Combustion Plants Directive**. The large coal-fired power station at Kilroot is subject to the Large Combustion Plants Directive[8] and a decision has been made to fit it with FGD equipment, rather than to convert it to an alternative fuel or to close it down. This decision may have a knock-on effect on the growth of renewables and the way the interconnectors are operated.

- **Security of supply issues**. Once the Coolkeeragh CCGT comes online, Northern Ireland will have a system which is of the order of 60% fuelled by gas. If Kilroot is eventually converted to gas firing or further new build is commissioned, this figure would rise even further. For a system that is on the edge of the European gas networks with supplies increasingly being sourced further away, this raises obvious security of supply issues. In the medium term, this situation could be mitigated by the coming online of the Corrib gas field in RoI and the possible use of the proposed south–north pipeline to access this gas. However, the uncertainty in the line being constructed and the unknown extent of the reserves in the Corib field mean that this is not necessarily a total solution.

- **The Renewables Obligation**. The DETI consultation paper [15] proposed a Northern Ireland renewables obligation that will oblige NI suppliers to purchase 6.5% of their total supplies from eligible renewables by 2012. The document also proposed a target of 12% by 2012.

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[8] See http://www.defra.gov.uk/environment/airquality/lcpd/

A renewable energy obligation similar to that in England, Wales and Scotland is to be put in place starting in April 2005. This additional capacity will be achieved by the Office for the Regulation of Electricity and Gas (OFREG) (http://ofreg.nics.gov.uk/) issuing Northern Ireland Renewables Obligation Certificates (NIROCs) that would be valid in the Scottish, English and Welsh markets, where there is currently a shortage of eligible renewables to meet the obligations already in place. This shortage of eligible renewables is predicted to continue beyond 2007, but with perhaps some decrease in price from the current £40–50/MWh [19]. The potential effect on this price by the eligibility of NIROCs in the other markets requires investigation, but other factors (e.g. co-firing of traditional power stations with biomass) are probably more significant. The introduction of the NIROC market could have implications for moves to an All-Island market as ROC electricity can presently only be sold in the UK market.

- **Other fuels (lignite)**. There are lignite deposits to the north and east of Ballymoney in County Antrim. In 2002, an application was made for planning permission for a mine and a 500MW power station on the same site. A lignite plant has also been proposed in the Greater Belfast area [20]. Exploitation of this resource, which could probably be carried out at a relatively low economic cost, would have significant implications for the environment and emissions in NI (unless carbon capture was engineered into the plant design). These plants are currently on hold and are unlikely to go ahead pre-2010, if at all.

6 The vision for 2025

Forecast demand in 2025

Continuation of the DETI's 2012 growth forecast and the four Foresight scenarios (as adapted for Northern Ireland) would suggest the overall electricity demand levels (both peak MW and overall annual demand) shown in Table E6.

The likely BAU capacity is presented in Table E7, which is based largely on the existing power plants and likely exploitable renewable resources. Following Table E7 are some comments on how the likely capacity might be exploited under the scenarios.

Table E6 Forecast demand for Northern Ireland in 2025

Scenario	Rate of growth	MW	GWh
DETI strategy consultation [15]	2% per year growth	2,625	13,600
Business As Usual	1% per year growth	2,052	10,600
World Markets	2% per year growth	2,625	13,600
Regional Enterprise	0.75% per year growth	1,929	10,000
Global Sustainability	0% per year growth	1,600	8,300
Local Stewardship	0.5% per year decrease	1,412	7,300

Likely generation capacity in 2025

A possible baseline scenario for generating capacity in 2025 is presented in Table E7, which can be compared with that for 2000 and 2012 in Tables E2 and E5, respectively. This broad mix of generation capacity for 2025 would have carbon dioxide emissions in the range 0.28–0.37kg of carbon dioxide per kWh delivered.

Table E7 Likely maximum electricity generating capacity in Northern Ireland in 2025

Generator(s)	Fuel source	Capacity (MW)	Output (MWh/year)	Emissions (tonnes CO_2)	Emissions (tonnes Carbon)
Ballylumford	Gas (CCGT)	600	3,679,000	1,519,100	414,300
Coolkeeragh	Gas (CCGT)	400	2,453,000	1,012,917	276,250
Additional base	Gas (CCGT)?	500	3,000,000	1,200,000	327,000
Peaking plant	(assume CCGT)	500	500,000	200,000	54,545
Renewable	Wind (onshore)	200–600	525,000–1,600,000	n/a	n/a
Renewable	Wind (offshore)	150	525,000	n/a	n/a
Renewable	Small hydro	<1	<10,000	n/a	n/a
Renewable	Biomass	10	66,000	n/a	n/a
Renewable	Tidal stream	100–650*(?)	400,000-2,000,000	n/a	n/a
Renewable	Wave	100	400,000	n/a	n/a
Renewable	Solar energy	10	??	n/a	n/a
Renewable	Waste-to-energy	10	??	??	??
Microgeneration	Gas/biomass	??	??	??	??
Various	Interconnectors (RoI)	1000	Net at zero	–	–
Various	Moyle (interconnector with Scotland)	500	670,000	146,666	40,000
Estimated maximum total (rounded)		**>4,000**	**8,000,000-14,000,000**	**4,000,000**	**1,100,000**

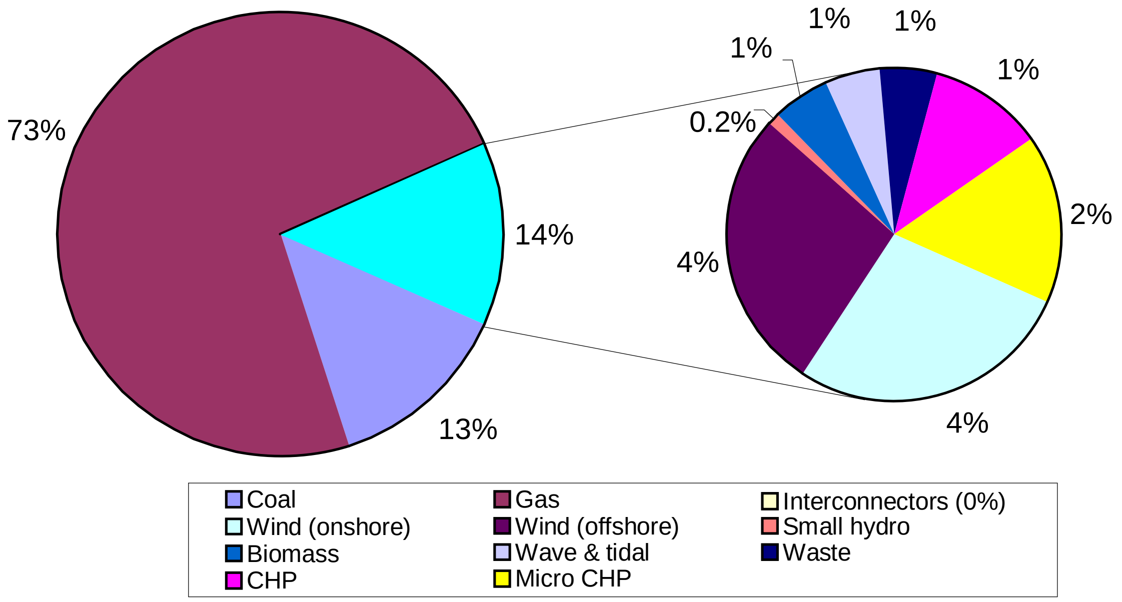
* Estimate based on data given in *Tidal stream report* [17].

Power mix in 2025 under the scenarios

Business As Usual will be very similar to the World Markets scenario below, although growth will be lower. The overall peak demand and total requirement (2,052MW and 10,600GWh, respectively) will therefore be less, but the mix of generation will be similar. The carbon dioxide emitted under this scenario would be of the order of 3.7 million tonnes/year.

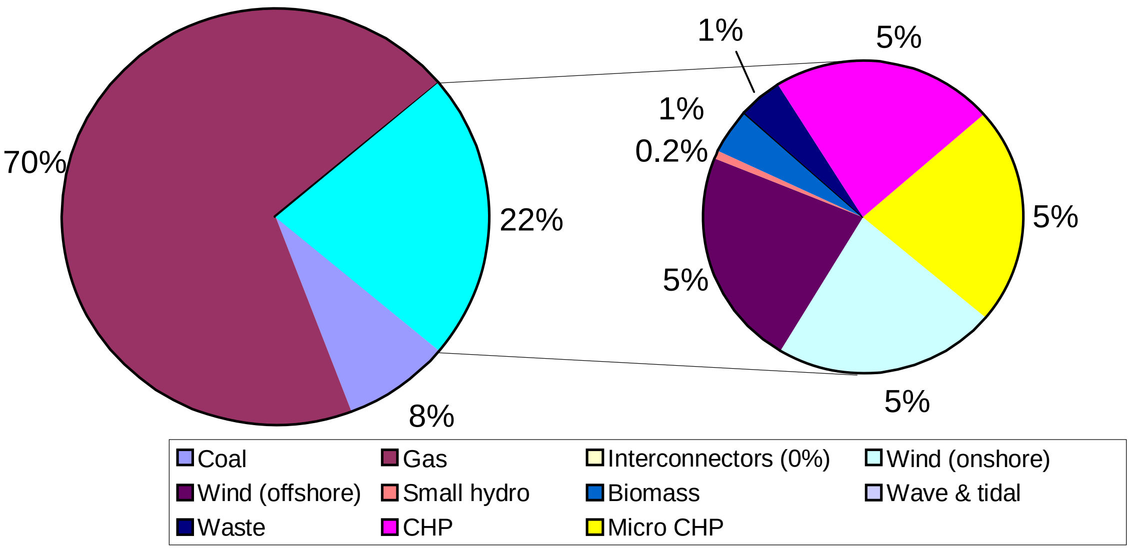
World Markets (Figure E6) is likely to continue to favour the use of gas. Under this scenario, there is likely to be minimal exploitation of renewable energy sources until their economics become more comparable with fossil fuels. The associated significant growth in demand under this scenario (peak demand of 2,625MW and a total requirement of 13,600GWh) may also create the conditions to enable further CCGTs to find a place in the market. The Kilroot coal plant will have reached the end of its life, but there will be a need for plant that can operate flexibly to balance the system, given the desirability of operating CCGTs and renewables as base load. Alternatively, electrolysis of renewable electricity may provide hydrogen as an energy carrier and storage medium. However, the economics of this process are still likely to be worse than the use of gas at this time. The carbon dioxide emitted under this scenario would be of the order of 5.8 million tonnes/year.

Figure E6 Electricity generation mix in 2025 in the World Markets scenario



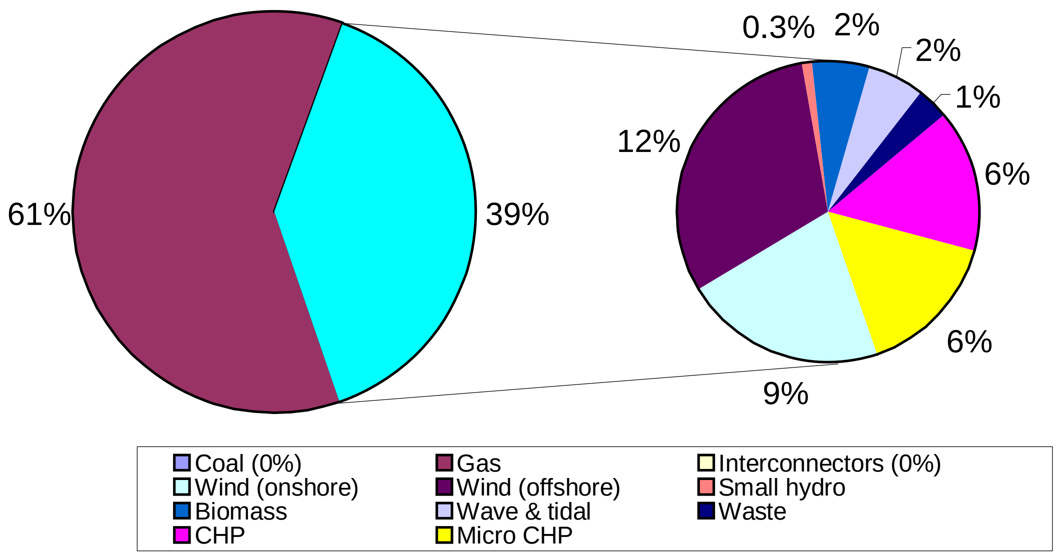
Regional Enterprise (Figure E7) would favour indigenous sources, but Northern Ireland is not well endowed with these. If environmental concerns are reduced, then the region's lignite resources could be exploited beyond 2025 as gas prices start to rise. Investment in renewables will be limited due to constraints on public funding. The reduced growth in demand under this scenario compared with the World Markets and the DETI consultation assumptions would suggest that the 2025 peak demand of around 1,929MW and a total requirement of 10,000GWh could be met by the CCGTs, the renewables and CHP commissioned by this time (assume limitations on investment of say 200–400MW), plus flows through the interconnectors. The carbon dioxide emitted under this scenario would be of the order of 3.6 million tonnes/year.

Figure E7 Electricity generation mix in 2025 in the Regional Enterprise scenario



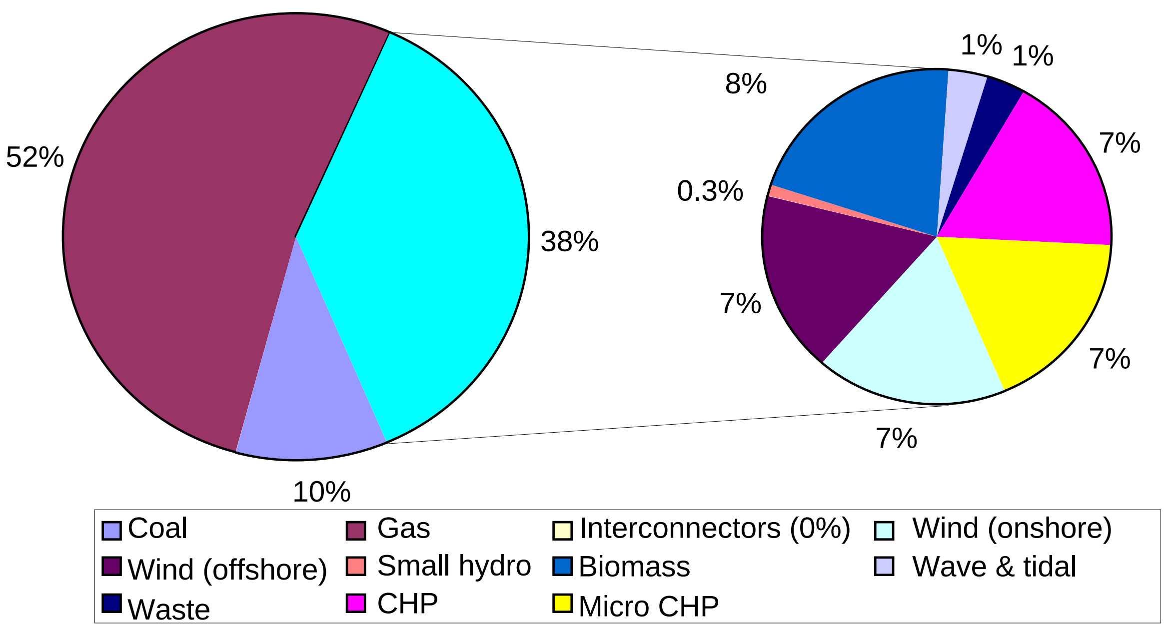
Global Sustainability (Figure E8) will favour the utilisation of renewable energy sources and increased restrictions on the exploitation of fossil fuels. Under this scenario, the peak demand is forecast to be around 1,600MW and overall demand to be 8,300GWh. The renewables build will be higher, but constrained by investment limitations. Peak demand will be met by the CCGTs, renewables (mostly wind) and CHP totalling 100–300MW, and flows through the Moyle interconnector. There may be demand for a new additional CCGT unless the renewables obligation realises a significant proportion of the potential capacity. Higher proportions of renewables would raise questions over peaking plant and the way the interconnector is operated. Again, there is the potential for the start of a hydrogen economy, but this is considered unlikely given investment constraints and the limited size of the NI/RoI markets. Demand side management at a significant level may be possible under this scenario, thus minimising the need for peaking plant. The carbon dioxide emitted under this scenario would be of the order of 2.1 million tonnes/year.

Figure E8 Electricity generation mix in 2025 in the Global Sustainability scenario



Local Stewardship (Figure E9) will favour indigenous resources, but investment constraints are likely to limit renewables exploitation. An exception to this could be biomass, where job creation could be significant under the scenario's conditions. The CCGTs plus the interconnectors, along with limited increases in renewable capacity, could meet the overall annual requirement of 7,300GWh and the peak demand of around 1,400MW. As in the other scenarios, peaking plant would be an issue, although there could be a greater potential for demand side management at a range of levels that would mitigate the need for such plant. The carbon dioxide emitted under this scenario would be of the order of 2.4 million tonnes/year.

Figure E9 Electricity generation in 2025 in the Local Stewardship scenario



7 The vision for 2050

Forecast demand in 2050

The continuation of the DETI's 2012 growth forecast and the four Foresight scenarios (as adapted for Northern Ireland) would suggest the overall electricity demand levels in 2050 shown in Table E8. A possible view on where capacity may be derived is presented in Table E9. Following Table E9 are some comments on how the likely capacity might be exploited under the scenarios.

Table E8 Forecast demand for Northern Ireland in 2050

Scenario	Rate of growth	MW	GWh
DETI strategy consultation [15]	2% per year growth	4,300	22,300
Business As Usual	1% per year growth	2,631	13,600
World Markets	2% per year growth	4,300	22,300
Regional Enterprise	0.75% per year growth	2,325	12,000
Global Sustainability	0% per year growth	1,600	8,300
Local Stewardship	0.5% per year decrease	1,245	6,450

Likely generation capacity in 2050

The period through to 2050 is the most difficult to predict. The key factors in the evolution of the power system in Northern Ireland will be:

- The continued availability of natural gas at competitive prices
- The success of the various renewable energy technologies and whether they can develop to the point where they can supply a significant percentage of the total demand
- The development of hydrogen as an energy carrier and whether it makes significant inroads into the gas market.

If renewables are generally successful commercially, then they could dominate the power supply sector. If not, the electricity supply system is likely to be dominated by a limited range of renewables in combination with high efficiency gas-fired CCGT power stations and/or a small number of nuclear stations.

A possible baseline scenario for generating capacity in 2050 is presented in Table E9. This would give carbon dioxide emissions in the range 0 to 0.2kg of carbon dioxide/kWh. The baseline scenario for 2050 can be compared with those for 2000, 2012 and 2025 in Tables E2, E5 and E7, respectively.

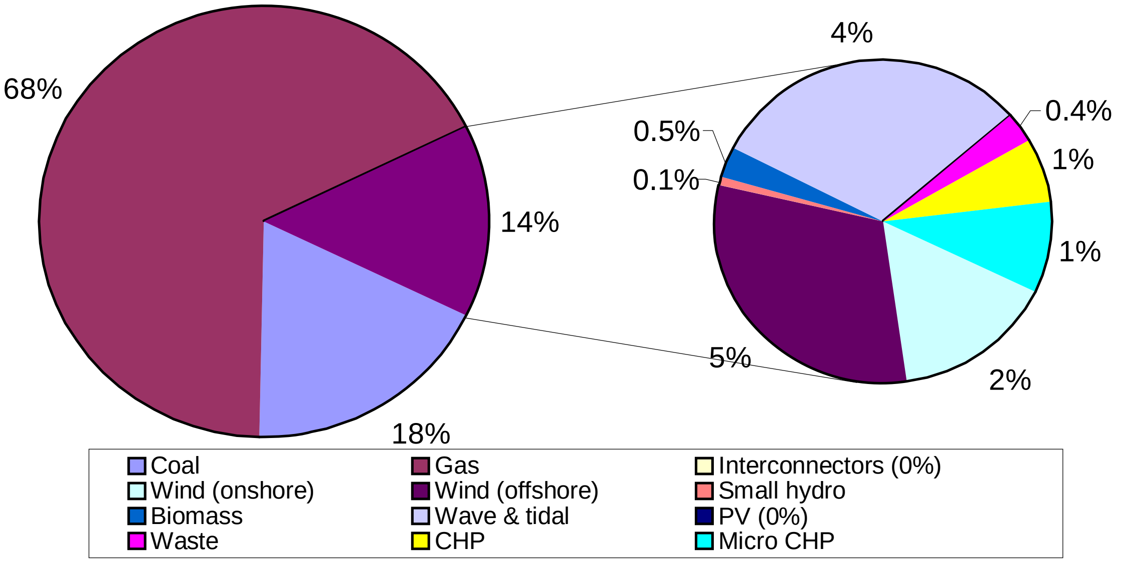
Table E9 Likely maximum electricity generating capacity in Northern Ireland in 2050

Generator(s)	Fuel source	Capacity (MW)	Output (MWh/year)	Emissions (tonnes CO_2)	Emissions (tonnes carbon)
Base load plant	Gas/nuclear	100–500	800,000–4,000,000	0 to 1,000,000	0 to 250,000
Base load plant	Gas/nuclear	100–500	800,000–4,000,000	0 to 1,000,000	0 to 250,000
Plus as above to meet demand scenario	Gas/nuclear	100–500	800,000–4,000,000	0 to 1,000,000	0 to 250,000
Peak plant	Gas/hydrogen/coal	0–200	??	??	
Renewable	Wind (onshore)	0–500	0–1,500,000	n/a	
Renewable	Wind (offshore)	0–500	0–2,000,000	n/a	
Renewable	Tidal current	0–200	0–800,000	n/a	
Renewable	Wave	0–200	0–800,000	n/a	
Renewable	Small hydro	0–20	0–80,000	n/a	
Renewable	Biomass	0–200	0–1,000,000	n/a	
Renewable	PV	0–200	0–200,000	n/a	
Domestic CHP	Gas/hydrogen	0–1000	0–2,000,000		
Interconnectors (RoI)	–	500	Balancing Net to zero		
Interconnectors with Scotland	–	500	Balancing Net to zero		
Estimated maximum total (rounded)		**Up to 5,000**	**2,500 to 22,500**	**0 to 3,000,000**	**0 to 750,000**

Power mix in 2050 under the scenarios

The **World Markets** (Figure E10) scenario is likely to favour the use of gas beyond the time of the other three scenarios. By 2050, any gas that is available will be coming from remote locations and there must be questions over price and security of supply. If gas is severely depleted by this time, then the likely source of base load electricity will be either renewables (mostly wind but with limited wave, tidal stream and biomass depending on which, if any, of these technologies have reached technical maturity at an economically competitive price) or, if renewables have failed to fulfil their promise, nuclear plant. In either of the latter cases, the carbon emissions would be minimal as all the technologies are either carbon-free or carbon-neutral. The peak demand under this scenario could be very high (4,300MW) with an overall annual requirement of 22,000GWh, and this is unlikely to be mitigated by demand side management. Peaks could be met through hydrogen-fuelled peaking plant, with the hydrogen produced from the nuclear or renewables sources. However, the carbon dioxide emissions for this scenario could be as high as 10 million tonnes/year if gas remains as the base load plant or a significant component of it.

Figure E10 Electricity generation mix in 2050 in the World Markets scenario

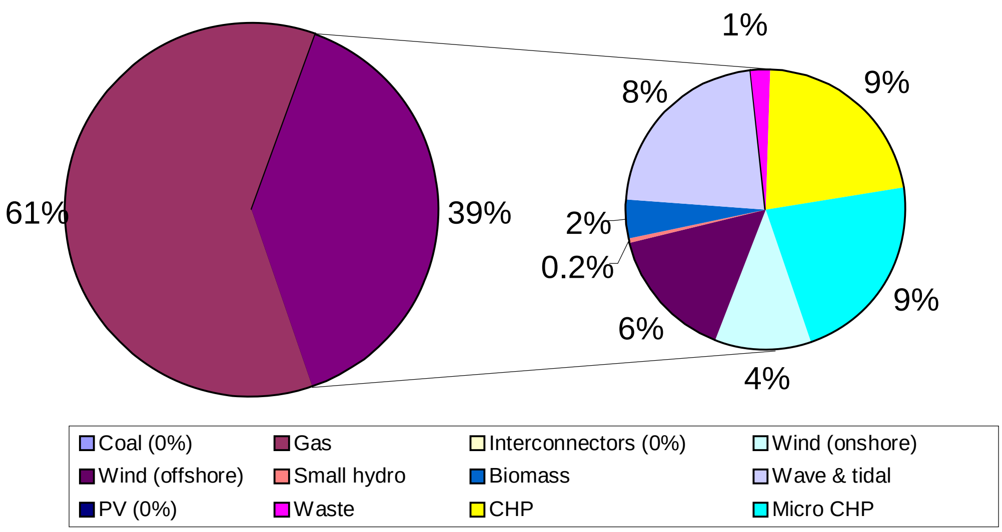


The **Regional Enterprise** (Figure E11) scenario favours indigenous sources, but Northern Ireland is not well endowed with energy resources apart from wind energy. If environmental concerns are reduced, then the region's lignite resources could be exploited beyond 2012–2025 as gas prices start to rise. Investment in renewables will be limited due to constraints on public funding. The reduced growth in demand under this scenario compared with World Markets and the DETI consultation assumptions would suggest that the 2050 peak demand of 2,325MW and overall annual requirement of 12,000GWh could be met by:

- The limited renewables and CHP commissioned by this time (say, 500–1,000MW)
- Flows through the interconnectors with UK and RoI.

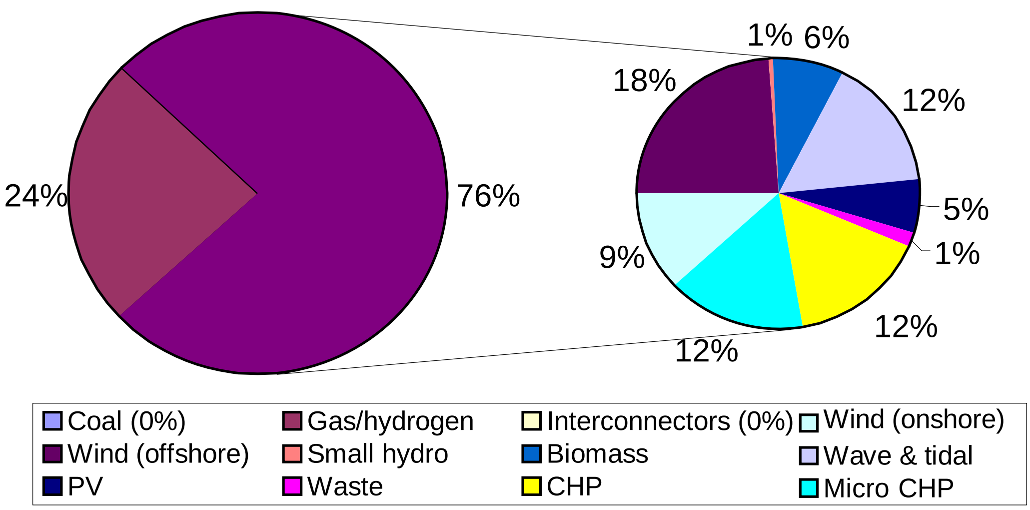
The carbon dioxide emissions under this scenario are estimated as 2.9 million tonnes/year.

Figure E11 Electricity generation mix in 2050 in the Regional Enterprise scenario



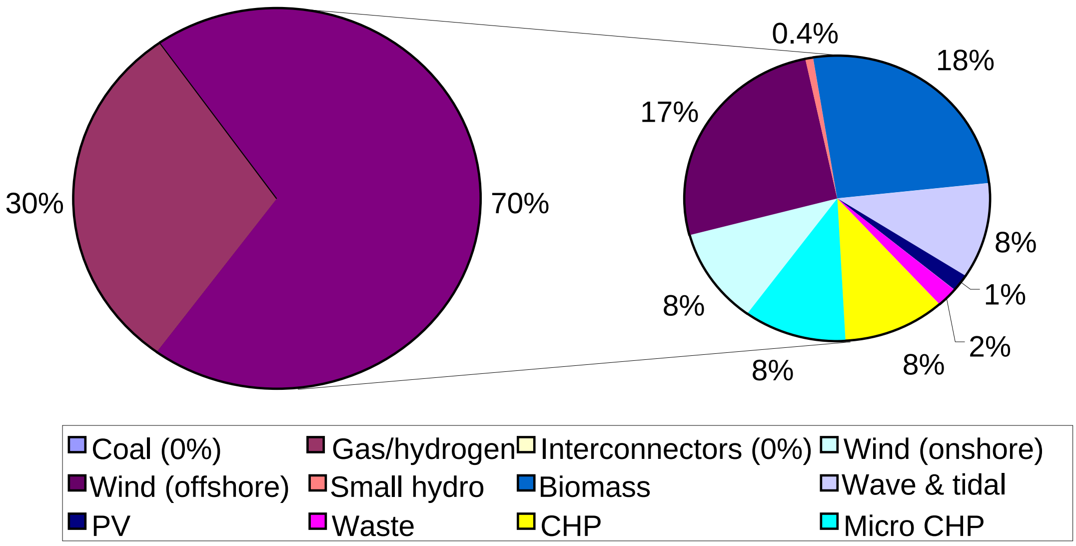
Global Sustainability (Figure E12) will favour the utilisation of renewable energy sources and increased restrictions on the exploitation of fossil fuels. Under this scenario (peak demand of around 1,600MW and annual requirement of 8,300GWh), the renewables build will be higher than for the previous scenarios but constrained by investment limitations. Peak demand will be met by the renewables (mostly wind), with peaks in demand and times of low renewables output satisfied through gas-fired plant with carbon capture, energy storage using hydrogen or electrochemical systems and flows through the interconnectors. If renewables have not developed to the necessary technical and commercial level, then nuclear fission plant could be required. The carbon dioxide emissions under this scenario will be less than 0.8 million tonnes/year, with the carbon probably being captured and not released to the atmosphere.

Figure E12 Electricity generation mix in 2050 in the Global Sustainability scenario



Local Stewardship (Figure E13) will favour indigenous resources, but investment constraints are likely to limit renewables exploitation. By 2050, however, a number of renewable technologies are likely to have reached an advanced stage of maturity and be economically more desirable than other energy sources. Job creation from biomass could be significant and favoured under the scenario's conditions. The peak demand of around 1,245MW and annual requirement of 6,400GWh under this scenario could be met by purely renewable sources, with advanced demand side management and energy storage using hydrogen or electrochemical systems managing variations in supply and demand. The carbon dioxide emissions for this scenario are estimated as 0.8 million tonnes/year.

Figure E13 Electricity generation mix in 2050 in the Local Stewardship scenario



8 Actions required to achieve a reduced carbon supply side system

A range of actions will be required if the Northern Ireland electricity supply system is to deliver a low carbon system by, or before, 2050. Early action is required in a number of areas (see below) to put the system on the right pathway.

Political

At the political level, the legislature needs to:

- Give a clear undertaking that it is committed to developing a low carbon energy system

- Put in place the structures to explain to the people of Northern Ireland why this is being done and what the short-term and long-term benefits and drawbacks will be.

In the short term, this will require the Northern Ireland renewables obligation to progressively increase the percentage of electricity that power supply companies operating in Northern Ireland obtain from renewable energy sources.

Alongside the obligation, the Government should set up a high level group of administrators and industry leaders to:

- Oversee the development of a low carbon supply side

- Advise on necessary actions

- Assess and report on progress towards the goals set by the overall Government policy.

In addition:

- It is expected that work would be required as a matter of high priority to investigate the necessary infrastructure modifications and system changes required to allow a significant proportion (up to 40% or more) of Northern Ireland's electricity to be delivered from wind energy, and later tidal and wave

- Initiatives should be put in place to build a consensus across Northern Ireland for the development of onshore renewables and to agree a positive land use planning regime that can deliver increased capacity but still protect the most sensitive areas of the country

- Government should consider introducing a presumption towards installing and utilising renewable energy in all public-funded buildings and organisations.

Regulatory

Regulators should continue to develop regulatory structures that support the development of renewables and other sustainable energy systems. Regulators will need to be creative in seeking solutions to the requirement to maintain high quality power supplies while allowing the development and testing of novel network solutions. The Office of Gas and Electricity Markets (OFGEM) in London has postulated the concept of registered power zones[9] where renewables and other new distributed technologies can be tested and demonstrated for mainland UK. These developments should be monitored and similar or enhanced systems put in place as soon as possible in Northern Ireland.

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[9] See, for example, *Innovation and registered power zones*, a discussion paper published by OFGEM (www.ofgem.gov.uk) on 16 July 2003.

Within the remit given them by Government, regulators should work to maximise the development of a range of renewable energy technologies while monitoring overall cost. The immediate lowest cost option should not always be the preferred one.

Commercial

The renewable and sustainable energy industry in Northern Ireland should work with the Carbon Trust and Northern Ireland Government through a sustainable energy board. This board would:

- Oversee the co-ordinated development of sustainable energy in Northern Ireland
- Provide a forum for addressing key issues and barriers to achieving a growing proportion of sustainable generation in Northern Ireland.

The Government should consider the scope for enlarging schemes such as the Clear Skies[10] initiative with the objective of engaging the Northern Ireland public in the benefits and issues in developing a more sustainable energy system.

Technical

A number of issues need to be addressed immediately to set Northern Ireland on the path to achieving the goal of a 60% reduction in CO_2 emissions by 2050. These are:

- **Grid capacity for wind energy**. Wind energy is the dominant renewable energy resource in Northern Ireland. At present, however, the Northern Ireland system has limited capability to accept significantly more wind energy than is currently in the planning and construction phase. The Northern Ireland electricity network system operator should be asked to develop a range of technical solutions to the problem, with costings. These should then be debated with the relevant players to develop a long-term strategy that allows for significant growth in onshore and offshore wind capacity in Northern Ireland.

- **Energy and electricity storage**. The Northern Ireland electricity network system operator should also be asked to lead a group that investigates the role of storage within the Northern Ireland system, and assesses the need for storage and the options that are likely to be available within the timescale of the next ten years.

- **Biomass**. The Department of Agriculture and Rural Development (DARD) should lead a group that looks at exploiting the wide range of bio-energy skills and technology options developed or being developed in Northern Ireland. Northern Ireland could, over the next ten years, develop significant power and heat generation capacity based on biomass. The expertise presently available and further developed by exploiting the resource available in the country could provide a sustainable industry that could access markets in the rest of the UK and beyond. Biomass is discussed in detail in Annex B.

- **Wave and tidal**. There is the potential for significant exploitation of wave and tidal energy around the coast of Northern Ireland. The Government should lead work with environmental groups and the various organisations funding research to locate, monitor and assess suitable test sites that meet the needs for a potentially suitable level of energy capture and are also acceptable to environmentalists. This will build on the expertise at the University of Belfast and the engineering and construction skills present in Northern Ireland. Building this expertise around a centre with some form of core funding would be a possible option, but this may be inhibited by the presence of a UK Government wave test centre in the Orkneys.

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[10] See http://www.clear-skies.org/

- **CHP**. The Carbon Trust should lead a review of Northern Ireland industry that examines the potential for good quality CHP and publicises the benefits of CHP operation. The introduction of the European Union Emissions Trading Scheme (EU-ETS)[11] and its effect on electricity prices could improve the current poor economic position of CHP, leading to significant growth in capacity. This improvement would be enhanced by improved electricity network connection and operation rules brought forward by OFREG.

- **Waste-to-energy**. The Department of the Environment should work with NI local authorities to build a consensus on waste recycling and waste disposal that maximises the economic level of recycling, but accepts that there will still be residual waste that could be combusted.

[11] See http://www.defra.gov.uk/environment/climatechange/trading/eu/index.htm

9 Conclusions

The power sector should be capable of delivering a 60% reduction in carbon dioxide emissions by 2050 under a range of scenarios (see Figure E14). The power mix will be determined, in the first half of the period studied, by the level of subsidy and regulatory incentive provided for low carbon renewable and CHP technologies. Growth will be constrained by the acceptance of the NI public expressed via the planning process and the ability of the NI electricity system to accommodate and manage largely intermittent sources. The high degree of interconnection with the rest of the UK and RoI should assist in this process, as will further integration of the NI and RoI electricity markets and systems.

Beyond 2025, the key factors will be whether the various renewable technologies have achieved the anticipated cost reductions. The mixes proposed in this study assume that all will show a degree of cost reduction but, in reality, some of the technologies may well fall aside as their costs cannot be reduced to an economic level.

Overlaying this situation is the price of gas (the dominant fuel), which, in turn, is linked to the price of oil. The currently accepted view is that gas will remain cost competitive with renewables well into the middle of this century. However, the gas will be sourced from further and further away from the UK. Whether this will be acceptable from a security of supply point of view is a key point of debate and is a political–economic decision.

In practice, the Carbon Trust has limited influence on the development of the power mix beyond its present course of:

- Encouraging the uptake of existing sustainable technologies
- Providing R&D funding to develop new sustainable technologies
- Pushing for regulatory and commercial changes that allow smoother integration.

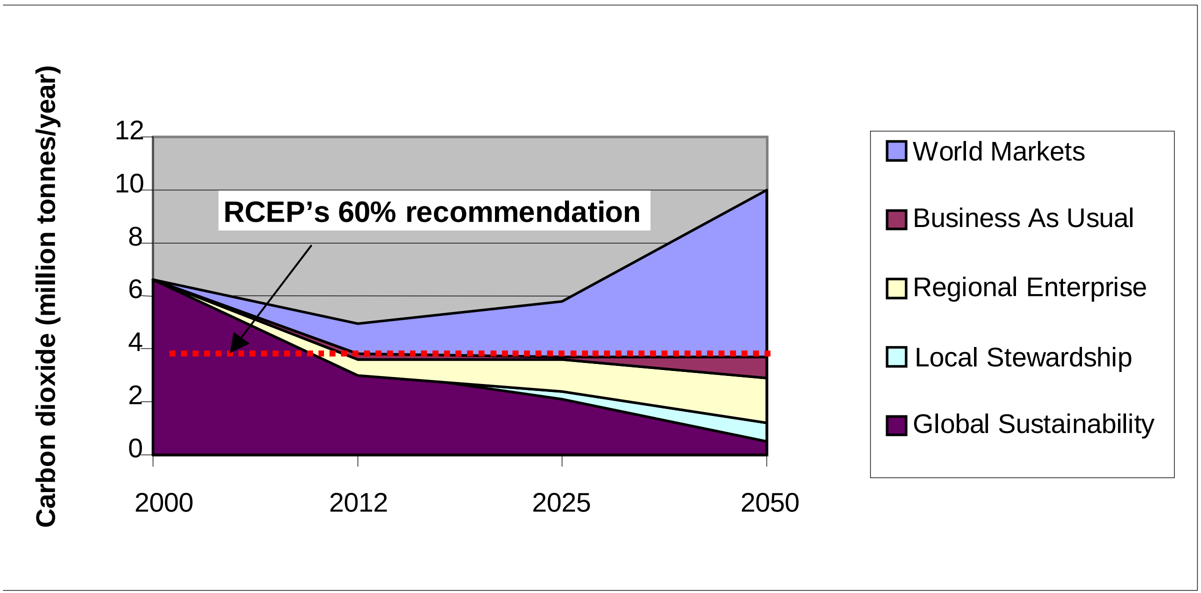
The Carbon Trust's main role is to help reduce energy demand across all sectors. This will ensure that the renewable resources that can be developed economically within Northern Ireland with the funds that will be available meet the largest possible percentage of the total demand.

Demonstration of the ability of hydrogen to act as an energy carrier and storage medium is necessary in the short to medium term. Given its location and good renewable resources, Northern Ireland could be an excellent place to do this.

Biomass as a fuel should be examined in the context of the economy of the western part of Northern Ireland. It has the potential to become a key part of the local economy in an area where extension of the gas grid is unlikely to be economic and where it could displace oil, which has a higher carbon emission factor.

Further work on the integration of wind into the energy supply system and how its presence can be maximised without causing instability should be taken forward as a matter of urgency. Under all the scenarios, onshore and offshore wind are the dominant resource for exploitation in Northern Ireland.

Figure E14 Carbon dioxide emissions of energy supply in Northern Ireland to 2050



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Acronyms and abbreviations

BAU	Business As Usual
CCGT	combined cycle gas turbine
CHP	combined heat and power
CO_2	carbon dioxide
(d)	delivered [energy]
DED	Department of Economic Development
DETI	Department of Enterprise, Trade and Investment
DNC	declared net capacity
DTI	Department of Trade and Industry (London)
FGD	flue gas desulphurisation
NI	Northern Ireland
NIE	Northern Ireland Electricity
NIAER	Northern Ireland Authority for Energy Regulation
NIROC	Northern Ireland Renewables Obligation Certificate
OFREG	Office for the Regulation of Electricity and Gas(the public face of NIAER)
PV	photovoltaic
RCEP	Royal Commission on Environmental Pollution
ROC	Renewables Obligation Certificate
RoI	Republic of Ireland
WREAN	Western Regional Energy Agency and Network

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Helpline 0800 085 2005
www.thecarbontrust.co.uk

NORTHERN IRELAND VISION STUDY

Annex F: Prospects for the industrial sector to 2050

Document Reference	**NIVision/7**
Date	**29/03/2005**
Report Status	**FINAL**

CTC520F

IMPORTANT NOTICES

CONTENTS

Executive summary

This annex discusses how Northern Ireland's industrial sector could reduce its carbon footprint by 60% by 2050 in line with the recommendations made by the Royal Commission on Environmental Pollution (RCEP), and presents a roadmap for reaching this challenging target. For the purposes of this study, the Northern Ireland industrial sector consists of mining & quarrying, manufacturing and construction. Other industries are included within the scope of other annexes. There are over 11,500 VAT-registered companies within Northern Ireland's industrial sector, but most industrial businesses are small or very small. There are no major high temperature process sites in Northern Ireland.

The baseline figure for the carbon footprint for the Northern Ireland industrial sector in 2000 was established by adjusting data for 2002 (obtained from the *Northern Ireland Energy Study 2002*) to allow for changes due to fuel switching. In 2002, the industrial sector in Northern Ireland employed 130,000 people and had an energy consumption of 6,737GWh delivered (d) at a cost of £220 million. The sector's carbon footprint for 2002 was 2,860 kilotonnes of carbon dioxide ($ktCO_2$). Three sub-sectors (food & drink, engineering and textiles) are responsible for 76% of industrial energy use and 52% of the gross value added (GVA) of Northern Ireland industry. Only 20% of industrial units have energy bills of more than £250,000/year and only 5% have annual bills of over £1 million. Energy use in industrial buildings is nearly double that of the UK average, reflecting the smaller size and scale of industrial processes in Northern Ireland.

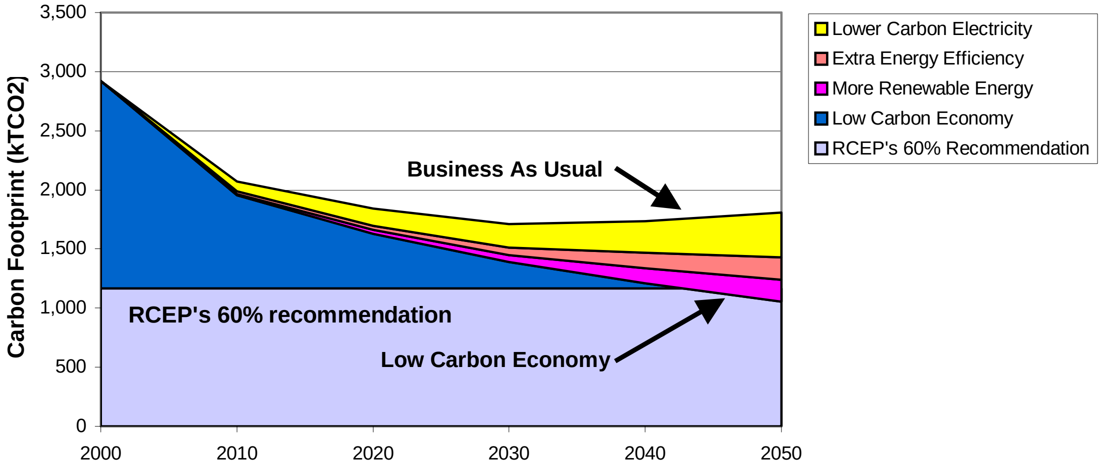
Under a Business As Usual (BAU) scenario, the sector's carbon footprint will continue to decrease over the next 50 years due to the expansion of the gas network, increased energy efficiency and structural changes within industry. The sector's energy intensity is predicted to be 36% less than in 2000 under the BAU scenario as a result of changes due to new technology, consumer demand and legislative/policy drivers. By 2050, the industrial carbon footprint is expected to be 38% less than the baseline – even after allowing for a 44% growth in real terms in GVA over the next 50 years.

Some additional measures will be necessary if the industrial sector is to realise a 60% reduction in its carbon footprint by 2050. After a review of All Technically Possible options for reducing the carbon footprint by 2050, the study identified eight extra measures. Further decarbonisation of the electricity supply industry, increased penetration of combined heat and power (CHP) (particularly for smaller thermal loads) and increased use of off-grid renewable energy sources are considered to be the most cost-effective way of reducing the carbon footprint of the industrial sector by a further 22% beyond the substantial improvement possible under the BAU scenario. The Low Carbon Economy scenario[1] envisaged for Northern Ireland for 2050 would involve a balanced set of measures biased towards these three options.

[1] *Editorial Note*: The Low Carbon Economy scenario is the same as the Low Carbon Timeline on Figure 4 of the Main Report and it is a lower carbon extension of the Global Sustainability scenario developed in Annex A. Annex A also contains details of the modelling work done on the other Foresight Programme scenarios.

The roadmap below shows how the RCEP 60% recommendation could be achieved in the industrial sector. Increased energy efficiency is a key component of this roadmap, which envisages major investment in energy efficient buildings and plant, increased thermal integration on business parks, and supply chain measures to alter the specification of products and services to favour those suppliers that use lower carbon technologies.

A roadmap for a low carbon industrial sector in Northern Ireland



The introduction of natural gas has created a unique opportunity for industry to simultaneously reduce its energy costs and improve energy efficiency. However, intense competition, skill shortages and the high cost of capital mean that many businesses are currently unable to invest in major new plant and machinery. These issues need to be addressed by:

- Improving the skills and training of local energy efficiency consultants
- A marketing campaign to tackle the 'like for like' replacement culture
- Supply chain initiatives to reduce the cost of more energy efficient products
- Establishing a loan fund to facilitate the purchase of major plant items
- Providing energy efficiency design audits for new plant and machinery.

A second key measure for the sector is increased use of off-grid renewable energy sources and the development of hydrogen-based fuels to displace the use of heavy fuel oil in areas away from the gas network, and the use of derv in stand-by generator sets.

A third key measure is the stimulation of innovation and the development of new partnerships between equipment suppliers, end-users, academics and distributors aimed at decarbonising entire sections of Northern Ireland's supply chain. Such partnerships will not only be vital in reducing the carbon footprint of the industrial sector, but in maintaining the prosperity of the Northern Ireland economy in a low carbon future.

1 Introduction

This annex discusses how Northern Ireland's industrial sector could reduce its carbon footprint by 60% between 2000 and 2050 in line with the recommendations made by the Royal Commission on Environmental Pollution (RCEP) [1] and presents a roadmap for reaching this challenging target.

The structure of this annex, which is underpinned by detailed modelling work, broadly reflects the methodology used (see Figure F1). This involved the following tasks:

1 Defining the boundaries of Northern Ireland's industrial sector

2 Reviewing the baseline and identifying underlying trends in energy efficiency

3 Developing a Business As Usual (BAU) scenario/projection from current trends

4 Assessing the ultimate scope for carbon reduction (All Technically Possible)

5 Exploring what restricts the cost-effectiveness of particular measures

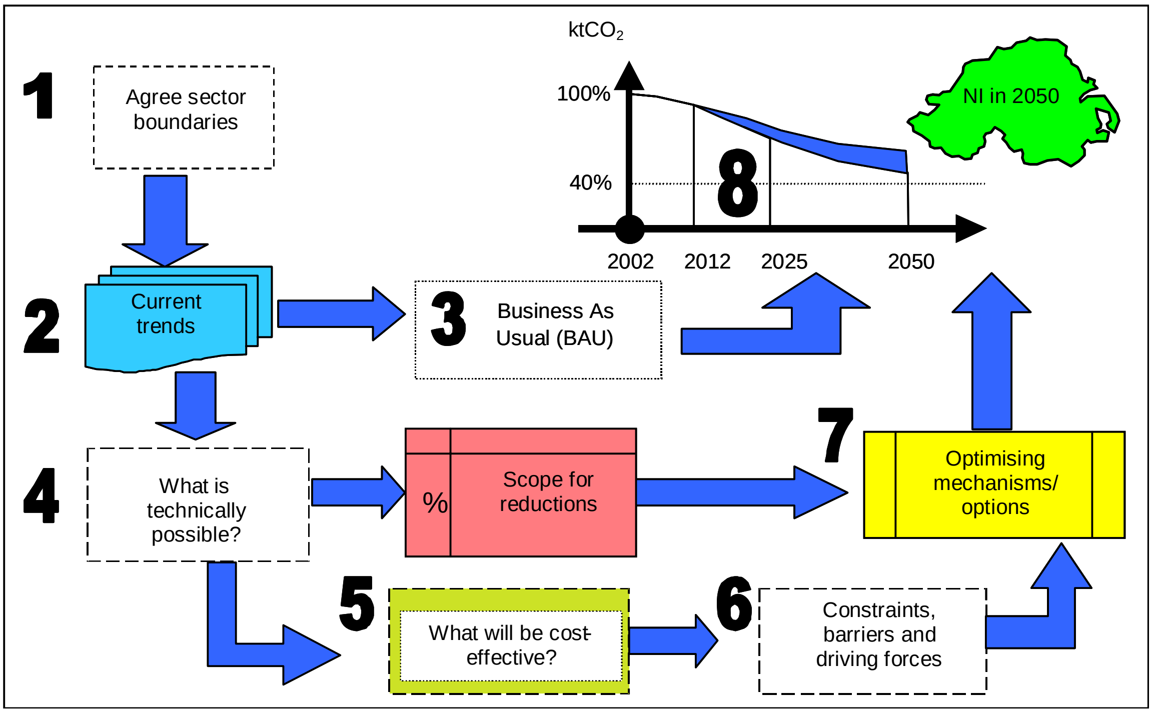
6 Establishing the constraints and barriers that limit the rate of change

7 Identifying ways of optimising the uptake of measures

8 Estimating the likely Northern Ireland (NI) carbon emissions for 2012, 2025 and 2050.

The annex ends with a discussion of underlying assumptions behind the predictions of likely industrial carbon footprint under the Business As Usual and Low Carbon Economy scenarios.

Figure F1 Methodology



2 Sector description

For the purposes of this study, the Northern Ireland industrial sector is deemed to consist of mining & quarrying, manufacturing and construction. Information on the electricity supply industry, gas distribution and other utilities is given in Annexes E (Energy supply) and B (Bio-energy), while Annex C (Commercial and Public) covers agriculture, fishing/forestry and the water industry (a public service in Northern Ireland).

A breakdown of the sector by manufacturing process and employment size band is given in Table F1, which highlights two key characteristics of the industrial sector in Northern Ireland:

- There are no major high temperature process sites in Northern Ireland
- The vast majority of industrial businesses are small or very small.

Table F1 Size of industrial business units by process

SIC[2]	Type of process	Employee size band				
		1-9	**10-49**	**50-249**	**250+**	**Total**
10/14	Minerals (mining & quarrying)	90	50	5	0	145
15–26	Low temperature process industries	1,390	620	190	35	2,235
27/28	High temperature process industries	560	160	20	0	740
29-35	Engineering industries	510	160	35	30	735
36/37	Other manufacturing	450	90	15	0	555
45	Construction	6,900	890	80	0	7,870
	Total	**9,900**	**1,970**	**345**	**65**	**12,280**

An analysis of turnover statistics shows that 87% of industrial units have turnovers of less than £1 million (see Table F2). Since energy represents, on average, only 1.1% of turnover, most of these businesses will have energy bills of less than £10,000/year. This means that only 10–15% of sites in the NI industrial sector will have been contacted directly by the Carbon Trust[3], although some may have received advice via energy advice centres or Local Enterprise Development Unit (LEDU) business consultants.

[2] Standard Industrial Classification (2003)

[3] Government-funded energy efficiency programmes have generally not targeted sites with energy bills below £20,000/year.

Table F2 VAT registered companies by turnover size and group

Group	Turnover size band (£ thousand)							
	0-49	50-99	100-249	250-499	500-999	1,000-4,999	5,000+	Total
Mining/quarrying and utilities*	15	10	20	15	20	25	15	120
Manufacturing	545	665	900	550	410	540	235	3,845
Construction	1,745	1,820	1,885	880	620	570	110	7,630
Total	**2,305**	**2,495**	**2,805**	**1,445**	**1,050**	**1,135**	**360**	**11,595**

* Includes Division 40/41 – electricity supply, gas and utilities, which consist of around 75 companies.

3 Reviewing the baseline

Analysis of the baseline

The baseline for this study is 2000. The *Northern Ireland Energy Study 2002* [2] gives data on energy demand by the industrial sector for 2002. Assuming that the sector's energy demand did not change significantly between 2000 and 2002, then its carbon footprint will have decreased by only around 1–2% as a result of fuel switching (in both the electricity supply industry and the industrial sector).

The baseline data provided by the NI Energy Study are summarised in Table F3, together with data on employment numbers and gross value added (GVA).

Table F4 provides a breakdown of energy use by sub-sector, together with some comments on the relative size and nature of the industry compared with the rest of the UK. Three sub-sectors (food & drink, engineering and textiles) are responsible for 67% of industrial energy use and 52% of the GVA of NI industry.

Based on the sector's GVA, the construction industry should represent about 4% of industrial energy use, but the industry does not feature in the NI Energy Study because it only has a small number of large companies. However, a review of the underlying dataset allows the construction and the timber products sub-sectors to be separated from the minerals and engineering sub-sectors (see Figure F2).

Figure F2 Industrial energy use by sub-sector group (adjusted)

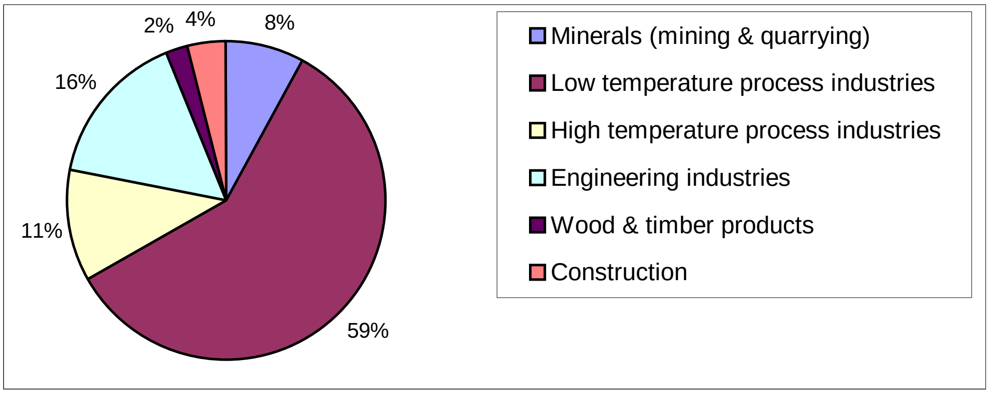


Table F3 Sector turnover, employment and carbon emissions in 2002

Sector	No. of employees*	GVA	Energy use GWh(d)†	Electricity (%)	Fossil fuel (%)	Energy bill	Carbon footprint ($ktCO_2$)#
Industry	130,000	£5,089 million	6,737	34	66	£220 million	2,860
Commercial	257,000	£6,505 million	2,582	25	75	£82 million	994
Public	234,000	£5,037 million	2,113	25	75	£70 million	913
Transport	28,000	£1,043 million	11,054	0	100	£249 million	2,698
Domestic	0	–	17,590	23	77	£499 million	6,571
Other	17,000	£389 million					824
Total	**666,000**	**£18,063 million**	**40,076**	**19**	**81**	**£1,120 million**	**14,860**

* Rounded to nearest thousand.

† Figures for energy use can be given either based on metered values, i.e. delivered (d) or 'as supplied', or as primary (P) equivalent. The difference between primary and delivered energy is largely used to account for generation efficiencies in electricity.

kilotonnes (kt) of carbon dioxide (CO_2)

Table F4 Breakdown of industrial energy use by sub-sector*

Sub-sector	GWh (d)	% of UK	No. of large sites	Comments
Ceramics	82	0.9	1	Uses a lot of fossil fuel for drying and firing
Chemicals	260	0.5	1	Does not include DuPont (included in textiles)
Engineering	1,414	5.3	8	Diverse sector, with many high-technology operators
Food & drink	2,174	5.0	13	Double UK pro-rata
Foundry	214	3.5	2	Basically two 'key' operators on three sites
Glass	381	6.2	1	Small, energy-intensive sector
Minerals	608	4.4	2	Dominated by Lafarge Cement
Non-ferrous metals	22	0.6	0	Very small, no major primary/secondary melter
Paper & board	109	0.5	0	No integrated or large paper mills
Rubber & plastics	472	2.6	3	Rubber dominated by Michelin
Steel	60	0.1	0	Small, no major primary or secondary melters
Textiles	941	11.3	5	Still major industry in NI, despite UK downturn
Total	**6,737**	**2.3**	**36**	

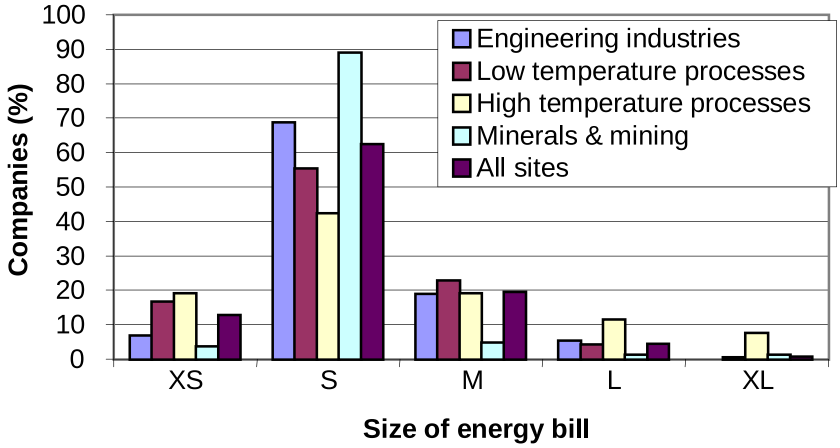
* These figures were derived using a combination of 'bottom-up' data provided by energy suppliers and Energy Surveys from the Carbon Trust, and 'top-down' estimation using statistical apportionment methods.

Analysis of industrial energy use by bill size and end use

Further analysis (see Figure F3) of the Northern Ireland Energy Study dataset [2] shows that only 20% of industrial units have energy bills of over £250,000/year – the point at which current good practice guidance recommends the adoption of a formal energy policy, the setting of energy saving targets and the appointment of an energy manager. Only 5% have energy bills over the £1 million/year 'threshold' for a full-time energy manager.

The Northern Ireland Energy Study covered 635 sites (or groups) on industrial electricity and gas tariffs; this represents around 5% of industrial units identified in Tables F1 and F2. The remaining 11,500 industrial business units fall into the XS category for Figure F3.

Figure F3 Size of energy bill by process type

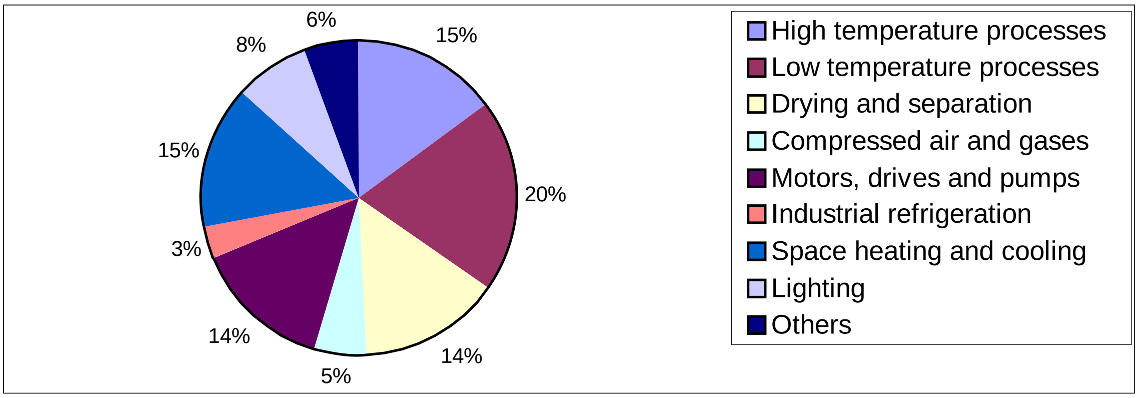


Key	Size
XS	<£25,000
S	<£250,000
M	<£1 million
L	<£5 million
XL	>£5 million

Data on energy consumption by industrial process in Northern Ireland are not readily available and UK data cannot be mapped onto NI because of the differences in energy intensities and fuel mix. However, Figure F4 provides an estimate of industrial energy use by process type based on data from the Northern Ireland Energy Study and expert knowledge.

This estimate highlights the fact that energy use in industrial buildings is nearly double that of the UK average of 11%, reflecting the smaller size and scale of industrial processes. It also provides an initial basis for assessing the potential carbon savings through higher efficiency boilers and steam systems, motors and drives, and drying.

Figure F4 Estimate of energy use by process/technology



UK/NI comparison

The carbon intensity of the NI industrial sector in terms of carbon emissions per unit value added is only 66% of the UK average (see Table F5). This can be attributed to a lack of major energy-intensive sites in Northern Ireland and the focus of NI regional development agencies on attracting high value-added industries. However, comparison of the Northern Ireland and UK carbon emissions per kWh ratio shows that there is scope to reduce carbon emissions by 22% through fuel switching.

Table F5 Energy use and carbon intensity ratios in NI and the UK (2000)

	UK	NI	Ratio (%)
GVA (£ million)			
Mining & quarrying	4,281	103	2.4
Manufacturing	153,671	3,731	2.4
Construction	44,047	1,264	2.9
Total	201,999	5,098	2.5
% of economy	25%	28%	112
Energy use			
Energy bill (£ million)	5,940	220	3.7
GWh (d)	420,750	6,737	1.6
Carbon use ($ktCO_2$)*	149,683	2,920	2.0
% of delivered energy	15%	11.3%	75
Energy intensity/productivity			
Energy intensity in energy used (£)/GVA (£)	2.9%	3.7%	126
Energy price (p/kWh)	1.4	3.3	231
Price adjusted intensity ratio	2.9%	1.6%	54
Carbon intensity			
$kgCO_2$/£ value added	0.74	0.49	66
$kgCO_2$/kWh	0.36	0.43	122

* UK industrial emissions are derived from the National Atmospheric Emissions Inventory 2000 (version published in 2002); see http://www.naei.org.uk/reports.php

4 The Business As Usual (BAU) outcome

According to national statistics, UK industrial energy use decreased by 3.7% per year over the last decade. Once changes in product mix/output and structural changes are discounted, the underlying rate of energy efficiency improvement was 0.5% per year. The UK Climate Change Programme (CCP) aims to increase this rate to 1% per year.

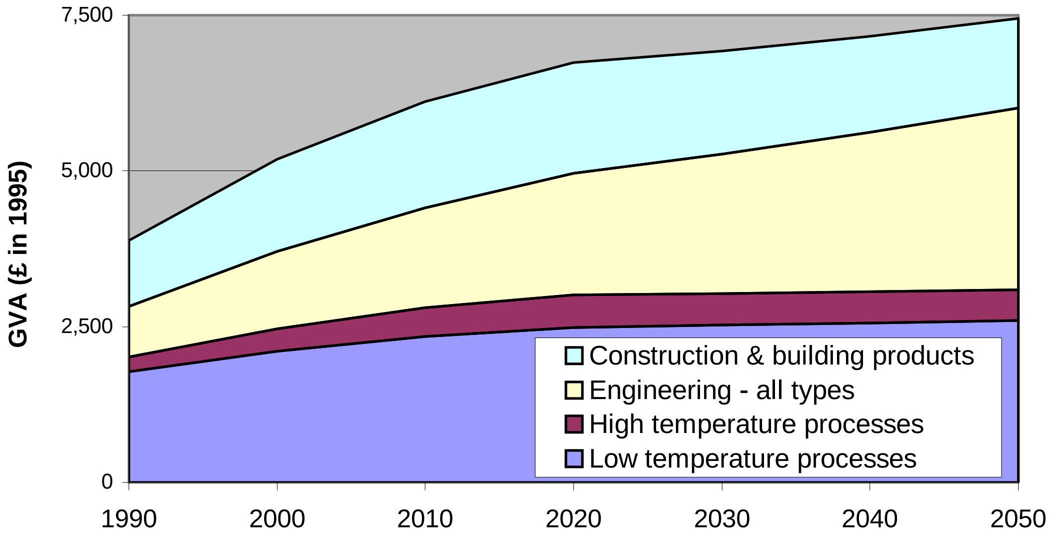
Although similar data are not available for Northern Ireland, the results of Energy Surveys from the Carbon Trust suggest that a similar rate improvement can be realised at larger industrial sites in Northern Ireland. However, the lower intensity of industry means that the scope for and cost-effectiveness of energy-saving projects will be lower (around 0.75% per year).

Two factors specific to Northern Ireland make it difficult to predict the effects of changes in product mix/output and industrial structure:

- The expansion of the gas network is encouraging industrial sites to invest in new boilers and burners, which usually improve energy efficiency
- The economy is growing rapidly as a result of the improved security and companies are investing in new plant and equipment to increase capacity.

It seems unrealistic to adopt the standard BAU assumption that current average growth rates of 3.4% per year will continue from now to 2050. Hence, an alternative BAU scenario is used. This assumes that the rate of industrial growth will progressively decrease over the 50-year period as the Northern Ireland economy aligns with trends in the UK economy (see Figure F5). Under this scenario, Northern Ireland reaches 3.2% of the UK total industrial GVA and 3% of the UK population by 2050.

Figure F5 Industrial growth under BAU



Some sub-sectors will grow while others decline (see Figure F6), but the overall trend is upwards. This is in contrast with the UK-wide picture, where industry is forecast to decline steadily as the economy switches from older, more energy-intensive industries to higher value-added services.

Figure F6 Changes in NI industrial structure to 2050

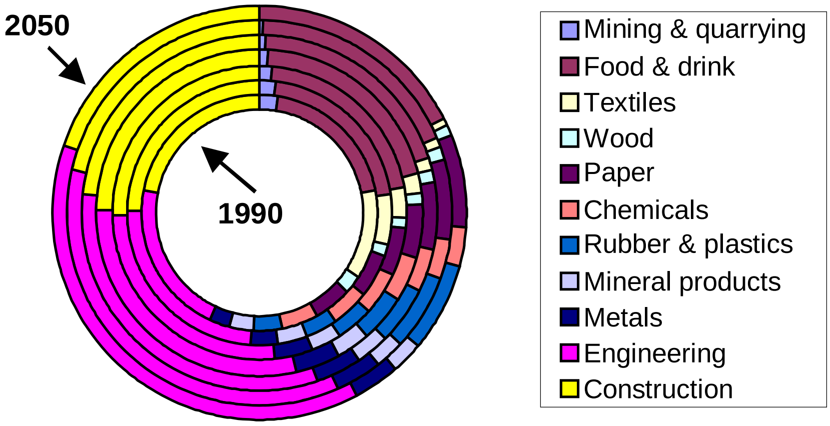


Table F6 shows the rates of change of energy intensity assumed under the BAU scenario. These are slightly different to the 'targets' set by the Northern Ireland Energy Study [2] because they include the effects of changes in product mix/output and structure.

Table F6 Changes in energy intensity under BAU*

Sub-sector	2000-12	2012-25	2025-50	Total
Mining & quarrying	-8.3%	-3.9%	-2.3%	-13.9%
Food & drink	-16.5%	-7.9%	-4.7%	-26.4%
Textiles	-16.5%	-7.9%	-4.7%	-26.4%
Wood	-8.3%	-3.9%	-2.3%	-13.9%
Paper	-16.5%	-7.9%	-4.7%	-26.4%
Chemicals	-16.5%	-7.9%	-4.7%	-26.4%
Rubber & plastics	-13.8%	-6.6%	-3.9%	-22.4%
Minerals including glass and ceramics	-11.0%	-5.3%	-3.1%	-18.2%
Metals	-13.8%	-6.6%	-3.9%	-22.4%
Engineering	-13.8%	-6.6%	-3.9%	-22.4%
Construction	-8.3%	-3.9%	-2.3%	-13.9%
Industry total	-21.0%	-12.1%	-8.8%	-36.2%

* These figures assume that improvements in energy intensity will progressively diminish with each decade.

These reductions in energy intensity will be stimulated by a variety of changes in market conditions including new technology and consumer taste. Another factor will be legislative/policy drivers such as:

- Stricter building, and health and safety regulations
- Extension of the Climate Change Programme[4] to 2025–2050
- EU environmental directives (noise, emissions, waste)

[4] For details of the current Programme, see http://www.defra.gov.uk/environment/climatechange/

- EU technical standards (product liability, CE marking)

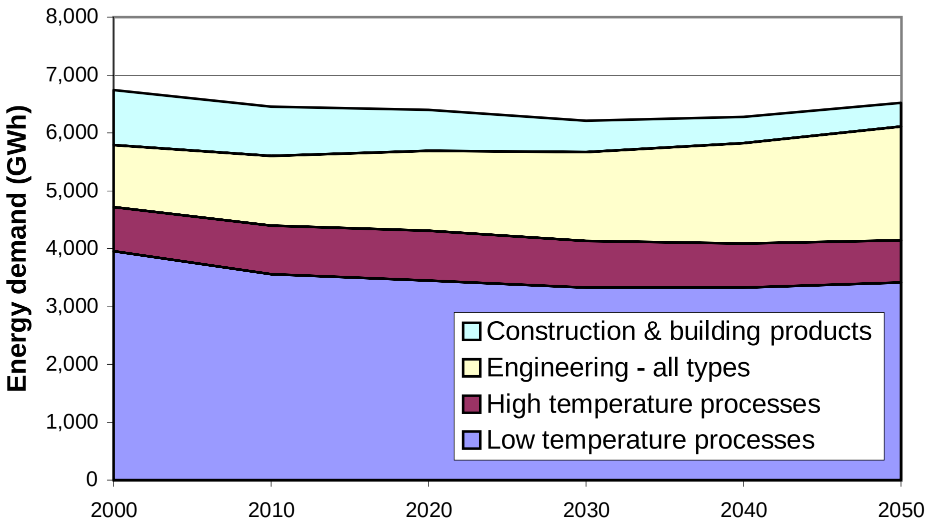
- Measures to conserve water and other natural resources.

A full discussion of the relative importance of these drivers is beyond the scope of this study, but the first three are key to improving industrial energy efficiency.

Figure F7 shows the anticipated industrial energy demand under the BAU scenario, which decreases slightly up to 2025 before starting to increase. By 2050, the industrial demand is expected to be similar to industrial energy demand in 2000. Figure F8 shows the corresponding industrial carbon footprint. This decreases by 38% between 2000 and 2050, mainly as a result of fuel switching and continued reductions in the carbon footprint of the electricity supply industry[5].

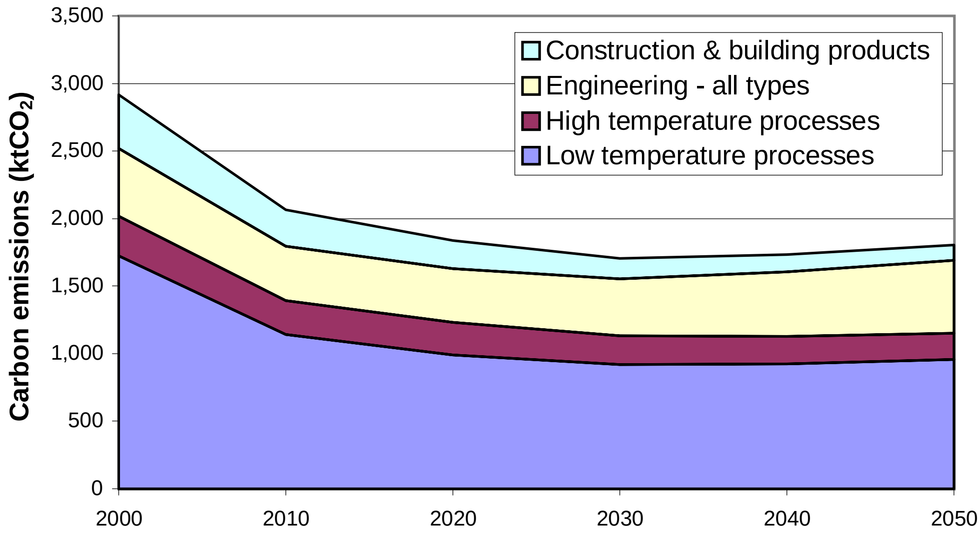
This analysis is based on a number of assumptions relating to the expansion of the gas network, the growth of the economy and a 18% penetration rate for combined heat and power (CHP), which is only cost-effective at larger industrial sites in the food & drink, textiles and chemicals sub-sectors under the present regulatory structure.

Figure F7 Industrial energy demand 2000-2050 under BAU



[5] The carbon footprint of the electricity supply industry is assumed to decrease from 0.2kg carbon per kWh(d) to 0.1kgC/kWh(d) by 2050 (in line with BAU predictions in Annex A).

Figure F8 Industrial carbon emissions 2000-2050 under BAU



5 The All Technically Possible (ATP) outcome

Based on the conclusions outlined in Section 4, some additional measures will be needed if the industrial sector is to realise a 60% reduction in its carbon footprint by 2050. The Business As Usual scenario is based on the assumption that the Climate Change Programme will continue at least to 2025 and probably to 2050. The remaining challenge, therefore, is to identify new measures not already covered by this scenario.

Table F7 lists a range of additional measures that could be used to reduce the carbon footprint of industry, along with an estimate of their likely impact and a brief commentary on the degree of difficulty and commercial feasibility of each suggestion. Each measure is considered technically feasible by 2050, but more radical measures such as dematerialisation of the supply chain and widespread construction of zero carbon-emission factories are likely to be on-going tasks until at least 2100.

Table F7 All Technically Possible options for reducing the industrial carbon footprint by 2050

Measure	Impact	Comments
1 Further decarbonisation of electricity supply industry	20–50%	Depends on intermittent energy sources. Will increase energy prices substantially.
2 Increase CHP penetration to small heat loads (50,000kW/£10,000)	5–10%	Needs lower cost technology or subsidy. Will increase energy prices and reduce growth.
3 Increased use of off-grid renewable energy sources	2–10%	For example, biomass, wood waste, solar heating, PV. A more expensive option requiring incentives.
4 Extend gas network to all sites with energy bills over £10,000/year	2–5%	Expect 80% to be in range by 2030. Needs subsidy to reach southwest and rural areas.
5 Additional energy efficiency through alternative processes	5–10%	Depends on complete retooling and/or development of cost-effective alternatives.
6 Thermally integrated business clusters (recycling waste heat)	2–5%	Already carried out at large chemicals sites in the UK. Depends on relocation of smaller businesses.
7 Dematerialisation and/or optimisation of supply chain	0–20%?	Involves extensive product/process redesign. May already be covered by BAU scenario.
8 Zero carbon-emission factories using hydrogen from renewables	10–25%?	Should be able to adapt boilers and furnaces. Only suitable for larger processes/sites.

The first three measures, which are discussed in more detail in Annexes B and E, are considered to be the most cost-effective methods of reducing the carbon footprint of the industrial sector by an extra 22% beyond the substantial improvements in energy efficiency outlined under the BAU scenario.

The development and introduction of alternative processes and/or products with lower carbon footprints are important topics that will involve considerable R&D. Much of this will be specific to individual companies: those that lead the way stand to realise a substantial profit by patenting and licensing the technology to others. Other projects such as decarbonisation of the supply chain will require extensive collaboration between equipment suppliers, end-users, academics and distributors.

6 The vision for the development of a low carbon industrial sector in Northern Ireland

The relative cost-effectiveness of each measure listed in Table F7 decreases significantly as higher levels of savings are required from it. Hence, a basket of measures is likely to be necessary to realise a cost-effective solution. This would also avoid over-reliance on any one measure.

To achieve a low carbon economy, the NI industry sector needs to adopt a reasonably balanced set of measures that is biased towards increased utilisation of renewable energy and increased CHP penetration (see Figure F9). It assumes that:

- The electricity supply industry (ESI) is able to reduce its carbon footprint (in kg of CO_2 per kWh) to the levels indicated in the Global Sustainability scenario in Annex E
- NI industry is able to reduce its electricity demand by 7% through increased use of CHP and off-grid renewables[6].

Recycling waste heat from one business to another has traditionally been hard to achieve, but should be possible on larger business parks or by the co-location of small businesses around high temperature sites. This could probably realise another 2% reduction in the carbon footprint, particularly if facilitated through a register of waste heat sources and if this waste heat were classed as a renewable energy for Climate Change Levy (CCL) purposes. The development of a register of waste heat sources would also encourage the co-location of smaller energy users around high temperature sites.

Supply chain optimisation[7] focused on specific technologies (e.g. petrol-driven mobile plant as used in the construction sectors) could provide the remaining 1% needed to reach the RCEP's 60% recommendation. The conversion of some high temperature processes to burn hydrogen[8] could generate a little headroom to cover shortfalls in other sectors.

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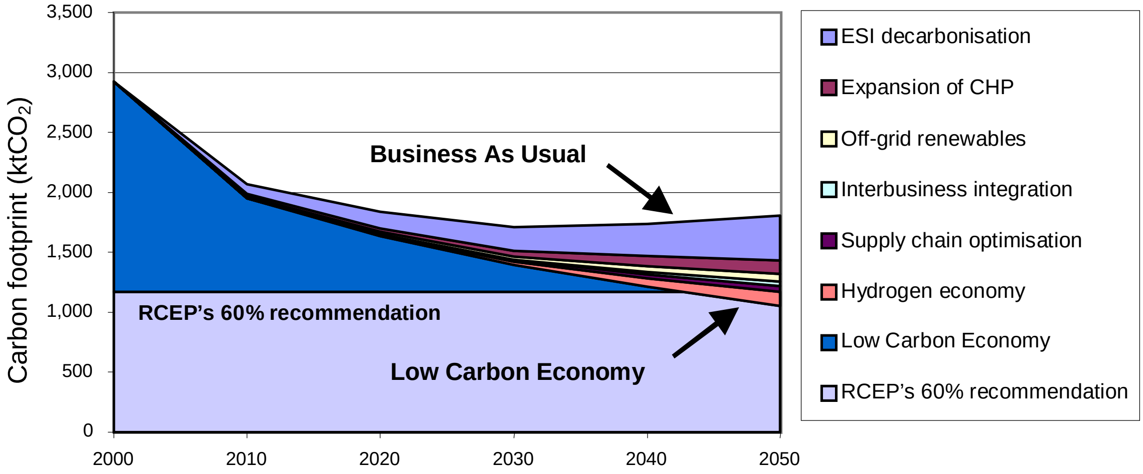
[6] This is in addition to around 5% of on-grid renewables included in the BAU scenario.

[7] Supply chain optimisation involves changing product or service contract specifications to encourage contractors to use lower carbon processes or utilities. In the construction industry, for example, this might necessitate the provision of electricity connections to avoid the need for petrol-driven plant.

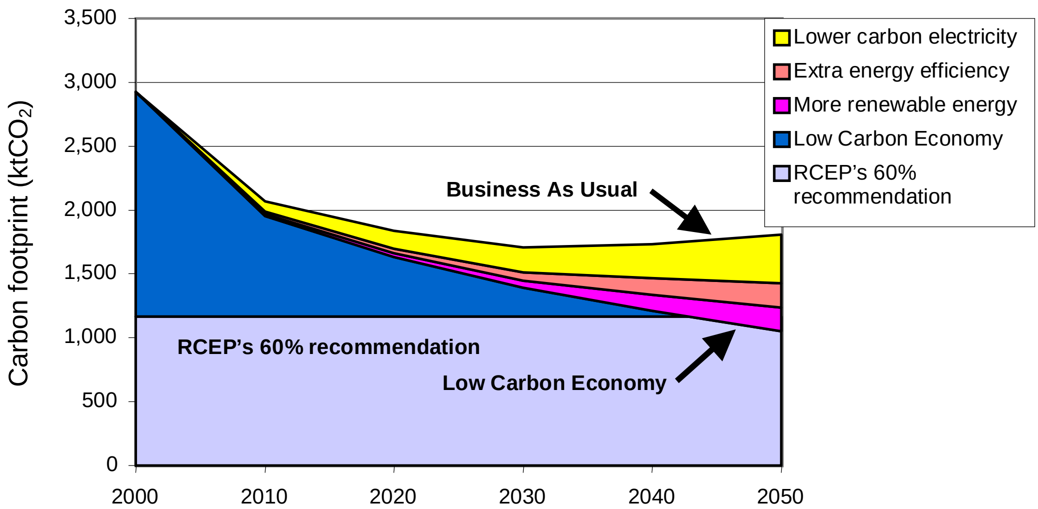
[8] It is envisaged that hydrogen generated from local renewable sources would only be used to displace the use of heavy fuel oil on industrial sites that are not connected to the gas network.

Figure F9 A roadmap for reaching the RCEP's 60% recommendation by 2050 in NI industry



The relative contributions of energy efficiency and renewable energy to the roadmap can be illustrated by grouping off-grid renewables and the hydrogen economy under the heading of 'more renewable energy', and supply chain optimisation, inter-business integration and the expansion of CHP under the heading of 'extra energy efficiency', as shown in Figure F10[9].

Figure F10 Relative importance of energy efficiency and renewables to the roadmap



[9] Lower carbon electricity is shown separately as it involves a mix of fuel switching and renewable energy.

7 Constraints and barriers limiting the rate of adoption

In an ideal world, energy users would adopt all cost-effective energy saving and carbon emission reduction measures, and these measures would be progressively built into the technological base and fitted as standard. Some users would be early adopters of new technology, while some would delay adoption until forced into using new technology by regulatory pressures or technological obsolescence.

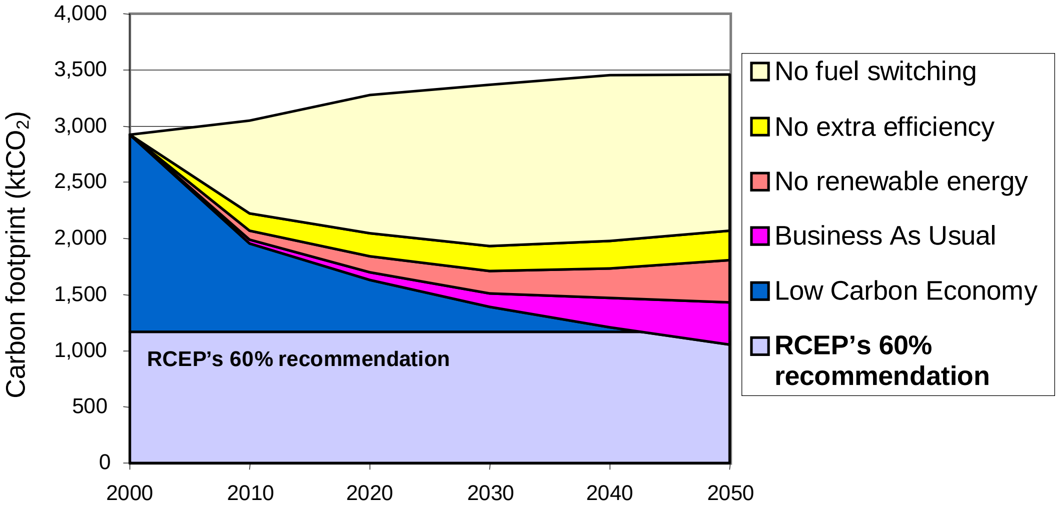
By 2050, however, it is reasonable to assume that most of the technologies and processes that industry uses today will have been replaced by newer technologies. Some factors will limit, prevent or promote change. These factors include:

- The costs and benefits of the technological improvement
- Availability of investment funding and other calls on finance
- Degree of competitive, regulatory and social pressures for change
- Lack of an infrastructure to support advanced technologies
- Local knowledge, engineering and project skills base.

The recent introduction of natural gas to Northern Ireland is a key factor pushing the industrial sector towards a lower carbon future. Figure F11 illustrates the sensitivity of the scenarios discussed in this annex to the availability of natural gas. This annex has assumed that the gas network will expand until 80% of industry is within reach of a pipeline. If a lower coverage is planned, these predictions would need to be revised substantially.

Achievement of the RCEP's 60% recommendation will also depend heavily on the exploitation of Northern Ireland's many sources of renewable energy and their cost-effectiveness. Increased energy efficiency is also important and needs to be realised as early as possible to avoid the possibility of new CHP systems and boilers being oversized relative to process demands.

Figure F11 Impact of natural gas on future carbon emissions from NI industry



8 Concluding remarks

This annex presents a vision of how a low carbon, energy efficient and prosperous industrial sector could be developed within Northern Ireland by 2050. Realising this vision is a challenging task that will involve a wide range of measures including:

- Ensuring the uptake of all cost-effective energy efficiency measures
- Increasing the use of CHP substantially
- Exploiting a wide range of indigenous renewable energy sources
- Extending the natural gas network to reach 80% of industrial sites
- Stimulating changes in energy consumption in small business units
- Encouraging inter-business integration and supply chain optimisation.

This annex has not explored the interactions between these measures, as this would require a detailed study of their technical feasibility and economic viability. A 'broad brush' approach has been used to outline the 'art of the possible' that can be followed up by the development of detailed models and targets. A census-style approach using a geographical information system (GIS) to map the sector's energy use and carbon emissions would be a valuable additional tool for identifying business integration opportunities and targeting the resources available to the Carbon Trust in Northern Ireland.

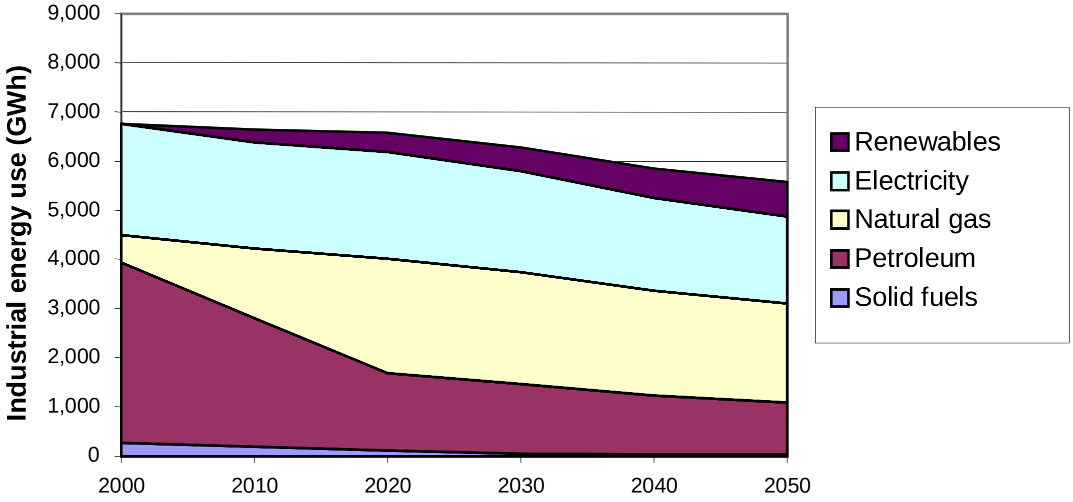
This annex has outlined some constraints and barriers to implementation of the roadmap, and highlighted the unique opportunity provided by the introduction of natural gas for industry to simultaneously reduce its energy costs and improve energy efficiency. However, intense competition, skill shortages and the high cost of capital mean that many businesses are currently unable to invest in major new plant and machinery.

These issues need to be addressed by:

- Improving the skills and training of local energy efficiency consultants
- A marketing campaign to tackle the 'like for like' replacement culture
- Supply chain initiatives to reduce the cost of more energy efficient products
- Establishing a loan fund to facilitate the purchase of major plant items
- Providing energy efficiency design audits for new plant and machinery.

One important issue that this annex has not addressed is the issue of security of supply and the fundamental longer-term sustainability of current industrial-style production. Ultimately, more radical measures may be required to cope with declining oil and gas reserves, but these challenges are more likely to become significant around 2050 than in the immediate future and, hence, have not been included in the roadmap. However, this annex envisages a declining dependency on fossil fuels over the next 50 years (see Figure F12) – a trend that could be continued beyond 2050 – by the development of a hydrogen-based economy and zero carbon-emission factories. This would also probably necessitate a much more fundamental industrial and social reorganisation, as the distance from natural resource to end-consumer would also need to be minimised.

Figure F12 Industrial fuel mix to 2050 under the roadmap



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1. *Energy – the changing climate*. Royal Commission on Environmental Pollution (RCEP). June 2000.

2. *Northern Ireland Energy Study 2002*. The Carbon Trust. October 2003.

Acronyms and abbreviations

ATP	All Technically Possible
BAU	Business As Usual
CHP	combined heat and power
CO_2	carbon dioxide
(d)	delivered [energy]
ESI	electricity supply industry
GVA	gross value added
kt	kilotonnes
NI	Northern Ireland
RCEP	Royal Commission on Environmental Pollution

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Helpline 0800 085 2005
www.thecarbontrust.co.uk

NORTHERN IRELAND VISION STUDY

Annex G: Prospects for energy savings in transport to 2050

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CONTENTS

Index to additional briefing materials

Executive summary

This annex explores what would be required to achieve reductions in the projected carbon emissions from transport in Northern Ireland in line with the recommendations of the Royal Commission on Environmental Pollution (RCEP). The annex examines energy use by the main modes of transport (road vehicles, rail, aircraft and shipping).

Transport currently produces around 12% of Northern Ireland's carbon dioxide emissions. However, this contribution is set to rise as traffic continues to grow. For the UK as a whole, transport already accounts for 25% of total carbon emissions – an indication of what is likely to happen in Northern Ireland as its economy and levels of development converge with those of the rest of the UK.

The transport sector in Northern Ireland used a total of 1,041 kilotonnes of fuel in 2002 and accounted for a total of 915 kilotonnes of carbon emissions. The main contributions to transport carbon emissions were cars (54%), aviation (28%), road haulage (15%) and buses (2%). Rail and marine use are estimated to be less than 1% each and thus were not analysed in any further detail. Aviation is difficult to tackle at the Northern Ireland level, especially when economic growth can only stimulate demand for air travel to the rest of the UK.

A hierarchy of the factors affecting transport energy use shows that vehicle technology and fuel are only two of many issues that determine energy consumption. Others are the motivations for travel, the location and accessibility of the end-point of travel, the mode of transport, vehicle utilisation, consumer choice and driver behaviour.

The underlying trends in transport use are generally towards increasing emissions. Analysis of travel patterns shows that, while Northern Ireland is currently behind the rest of the UK in terms of car ownership and total annual distances travelled, economic growth will cause these to converge. Although trip distances are shorter than in the rest of the UK and a third of journeys are less than two miles, walking and cycle use are also lower than in the rest of the UK. This leads to a risk that increasing car ownership will exacerbate the problem of short journeys being made by car unless measures to promote walking and cycling are put in place. A further problem is that, while improvements in vehicle technology are leading to significant increases in fuel efficiency in the most efficient cars, increased sales of larger inefficient vehicles mean that the average fuel efficiency of the UK vehicle fleet is not benefiting from the technology improvements.

A Business As Usual scenario would see a steady increase in carbon dioxide (CO_2) emissions, with improvements in vehicle technology constrained by consumer choice and overtaken by ever increasing road and air traffic; CO_2 emissions from transport in NI would more than double by 2050, in line with a projected 100% increase in road traffic by that date.

Options for a low carbon economy range down the hierarchy from land use planning decisions that tackle the demand for travel, through measures that encourage modal shift, to technological changes that could reduce emissions. Action will be required in all these areas to achieve the significant shift needed to meet the RCEP's 60% recommendation. As the roadmap below shows, carbon emissions will be more or less stable for around 30 years under the Low Carbon Economy scenario[1], but will then start to rise away from the RCEP's 60% recommendation as traffic levels increase.

[1] *Editorial note*: The Low Carbon Economy scenario is the same as the Low Carbon Timeline on Figure 4 of the Main Report and it is a lower carbon extension of the Global Sustainability scenario developed in Annex A. Annex A also contains details of the modelling work done on the other Foresight Programme scenarios.

In many ways, the fact that Northern Ireland has lagged behind the UK economy provides a range of opportunities to pursue new approaches and avoid the mistakes that have been made elsewhere. Land use planning and urban design decisions are fundamental in determining people's travel behaviour. Given the major changes that are likely to take place as Northern Ireland's economy grows and new development takes place, it is important that transport and land use are planned for sustainability from the beginning.

Key elements of a long-term vision are therefore:

- Land use planning decisions that seek to minimise future demand for travel while facilitating walking, cycling and the use of public transport

- Transport planning decisions that seek to manage traffic levels and encourage sustainable modes, rather than stimulate demand for further traffic growth

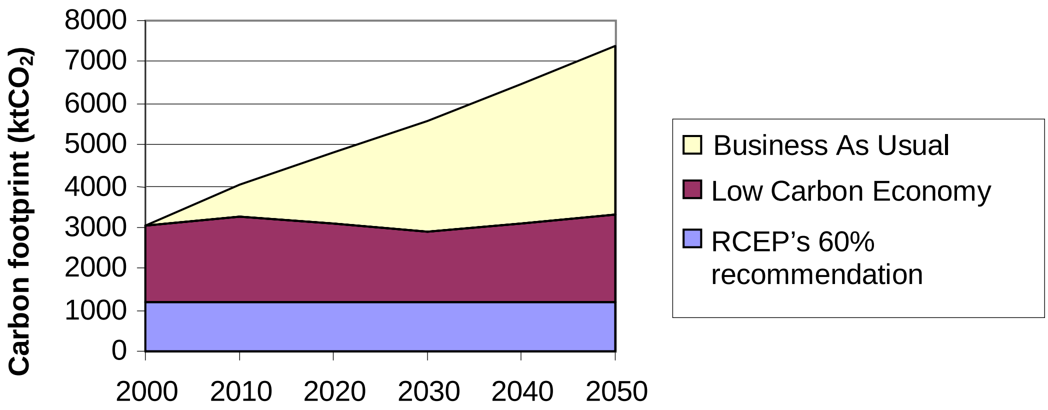
- Best practice measures to help industry make efficient use of transport capacity and fuel

- Consumer incentives (including fiscal measures) to ensure that more efficient vehicles are purchased and the potential benefits of new technology are realised in practice

- Behavioural change campaigns to deliver short-term improvements and to support the longer-term measures

- Research and support for the development of new low carbon fuels and technologies in the context of the wider energy supply situation.

A roadmap for approaching the RCEP's 60% recommendation by 2050 in the NI transport sector



1 Introduction

This annex explores what would be required to achieve reductions in the projected carbon emissions from transport in line with the recommendations of the Royal Commission on Environmental Pollution (RCEP) for a 60% reduction by 2050 [1]. The annex presents an overview of energy consumption in transport in Northern Ireland, the factors that affect this energy use, current trends and the measures that might be employed to achieve savings in this area. The timescale under consideration is from the present to 2012, 2025 and 2050.

For the UK as a whole, transport contributes to nearly 25% of carbon dioxide (CO_2) emissions; road transport contributes to 85% of this. Cars emit around half of all transport emissions [2]. The trend across the UK is for the transport contribution to total greenhouse gas emissions to increase. There are two main reasons for this:

- Road and air traffic are forecast to grow for the foreseeable future
- The 'dash to gas' has reduced the carbon intensity of energy used in the other sectors.

The aims of this study were to:

- Identify sources of data on transport and fuel consumption in Northern Ireland (NI), using suitable methods to disaggregate UK level data where necessary
- Estimate a breakdown of energy use by different modes within the transport sector
- Provide an overview of the main factors and trends that affect energy use in transport
- Identify factors that distinguish transport in Northern Ireland from that in the UK mainland
- Provide an overview of relevant sustainable transport measures and policies
- Provide a set of recommendations that would lead to reduced carbon emissions from transport in Northern Ireland.

The structure of this annex broadly reflects the methodology used as a framework for discussions. This involved the following tasks:

- Determining the distances travelled by different modes of transport in Northern Ireland in 2002
- Estimating energy use by different modes of transport in Northern Ireland in 2002
- Identifying the hierarchy of factors affecting transport energy use
- Reviewing trends in journey distances and traffic levels
- Identifying All Technically Possible (ATP) measures to reduce transport energy use in Northern Ireland
- Examining Low Carbon Economy options for transport
- Preparing projections for 2012 and post-2025
- Considering the barriers to reducing transport energy use in Northern Ireland
- Identifying the factors unique to Northern Ireland
- Developing recommendations for the future.

2 Sector definition

This annex looks at the energy used by the main modes of transport:

- Road vehicles
- Rail
- Aircraft
- Shipping.

Appropriate categories of vehicle and journey type are used to segment this energy consumption so that suitable energy-saving measures can be identified and targeted.

Table G1 gives a breakdown of road vehicle types in Northern Ireland classified by body type.

Table G1 Vehicle numbers in Northern Ireland by body type [3]

Body type	Number of licensed vehicles
Car	650,323
Taxi	379
Motorcycle	17,873
Light goods vehicle	61,603
Heavy goods vehicle	19,963
Bus/coach	5,350
Agricultural	7,878
Other	3,872
Total	**767,241**

There is a comparatively limited rail network of 211 route miles and 22 stations. All trains are diesel-powered; in 2001, there were 35 locomotives and 78 passenger coaches. Older rolling stock is being replaced by new diesel multiple units.

Air transport is based at the three airports:

- Belfast International Airport
- Belfast City Airport
- City of Derry Airport.

There were 82,936 air transport movements (landings and takeoffs) during 2001. Air travel has grown rapidly in recent years; in 2001, 5 million passengers used Northern Ireland airports – an increase of 8% compared with 2000.

Shipping consists of ferry services from Belfast to mainland UK and the Isle of Man, as well as freight shipments to the UK and overseas. A detailed breakdown of shipping movements was not possible from readily available data and was not considered a priority because the total fuel consumed by NI shipping is estimated from UK total figures to be less than that used by buses.

A range of information was sought in order to produce a breakdown of energy use by mode. Available data sources do not break down UK transport fuel use at the Northern Ireland level. Approximations therefore had to be made from published information on distances travelled by different modes, fuel sales by type and average figures for the fuel efficiency of different vehicles.

Travel distances by mode

The comparison of personal travel data for Northern Ireland [4] and the rest of the UK [5] given in Table G2 shows that both average annual distances travelled and average journey length are lower in Northern Ireland. However, as car ownership grows towards the norm for mainland UK, annual travel distances are likely to increase – further increasing energy consumption.

Cycle ownership and use in NI are much lower than the mainland UK total; yet over a third of journeys are under 2 miles – a distance well suited to cycling. Total walking distance is also significantly lower.

Table G2 Travel distances by mode

	Miles per year per person	
Mode	**NI [4]**	**GB [5]**
Walking	146	189
Cycle	19	39
Car	4891	5354
Motorcycle	20	29
Other private (van, lorry, minibus, caravan, etc.)	345	235
Bus	415	341
Rail	53	425
Taxi	73	61
Other	25	48
Total	**5,987**	**6,721**
Average journey length	**6.1**	**6.7**

Energy consumption by mode

Statistics are available from the Department for Transport (DfT) on UK transport energy consumption by mode [6] (see Figure G1). Further analysis was needed to derive an approximate breakdown of energy consumption at the Northern Ireland level because not all the data are currently disaggregated at that level.

The consultation paper on the new energy strategy for Northern Ireland [7] reported that transport contributed 12% of Northern Ireland's greenhouse gas emissions in 1995, with an apparently reduced contribution of around 8% in 1998. However, as these figures are derived from fuel sales, this apparent decrease is assumed to be attributable to an increase in cross-border fuel sales and fraud due to the greater disparity in fuel duty levels between Northern Ireland and the Republic of Ireland. An estimate of the true level of transport fuel consumption was made as part of the earlier work for the *Northern Ireland Energy Study 2002* [8], of which the workings are reproduced in the Appendix to this annex. These figures show a road transport contribution of around 0.7 million tonnes of carbon per year; this rises to 0.9 million tonnes of carbon per year if an estimated figure for air transport is included.

Figure G1 UK petroleum consumption by mode 2001

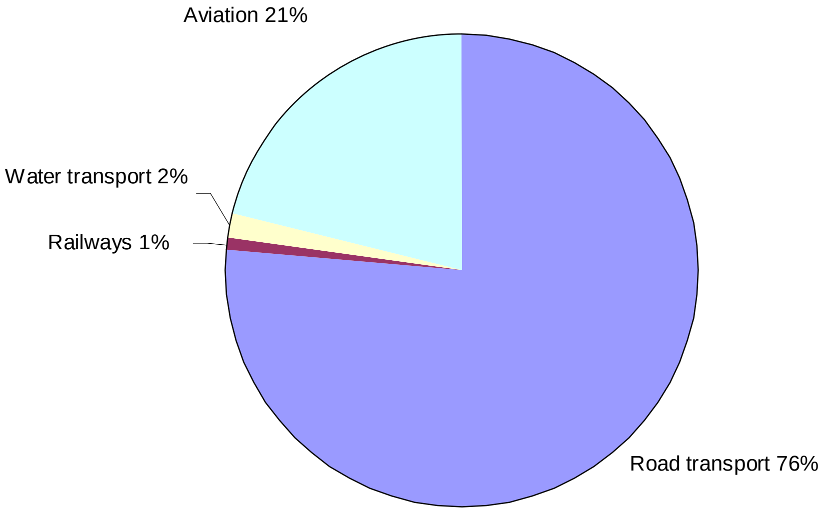
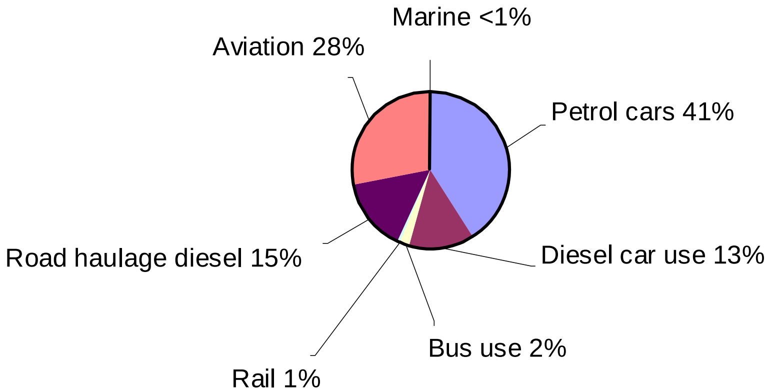


Figure G2 and Table G3 summarise the results of this analysis (see the Appendix for an explanation of the calculations). Given the difficulties of reducing air travel at a Northern Ireland level, the relative contributions from the land transport sectors would suggest that the priorities for action within NI are therefore car travel and road haulage.

Figure G2 Northern Ireland transport fuel use by sector



Although the figures in Table G3 are based on a number of assumptions, the results show a similar pattern to the UK breakdown, with over 70% of CO_2 emissions from transport coming from road transport. However, the estimates are based upon fuel deliveries (corrected for fraud and cross-border shopping), but do not take account of fuel legitimately imported in vehicle fuel tanks. This is likely to be significant for long distance road haulage. Thus, this method is likely to have considerably underestimated the total fuel used by road hauliers within Northern Ireland.

Table G3 Estimated breakdown, by mode of transport, and by fuel delivered to Northern Ireland[7]

	Amount of fuel		CO_2	Energy	% of total
	kt*	million litres	kt	TJ	
Total petrol delivered[1]	418	565	1,306	19,781	41.2
Total diesel delivered[1]	323	385	1,031	14,613	30.5
of which:					
Diesel car use[2]	122	165	442.2	6,270	13.1
Bus use[3]	19.74	23.5	62.98	893	1.9
Rail[4]	5.9	7.0	18.8	267	0.6
Road haulage[5]	175.4	189.5	508	7,200	15.0
Aviation[6]	300	357	957	13,571	28.3
Total†	**1,041**	**1,307**	**3,294**	**47,965**	**100**

* kt = kilotonnes

† Total petrol delivered + total diesel delivered + aviation

1 Estimated using official figures for petrol and diesel deliveries, together with estimates by HM Customs & Excise of fraud and cross-border shopping.

2 Estimated from percentage of diesel cars in NI fleet and UK average miles per gallon (mpg) data for petrol and diesel cars.

3 Calculated from figures for annual total bus-miles and assumed average bus mpg.

4 Calculated from passenger mile data, using typical energy efficiency figures per passenger km for diesel trains.

5 Assumed to be diesel remaining after 2, 3 and 4 are subtracted from 1.

6 Estimated using air traffic movements for UK airports and total UK aviation fuel figures.

7 Shipping data were investigated, but no robust methodology could be identified for estimating marine fuel attributable to NI. Total fuel consumption by UK shipping is 840kt/year; the percentage attributable to NI is unlikely to be more than 1–2% of this and therefore contributes less than buses.

3 Reviewing the baseline

Transport energy use is affected by a hierarchy of factors (see Figure G3), of which technology is just one. The starting point is the demand for goods, services, employment, visiting people, etc. The extent to which people need to travel in order to gain access to these depends on the availability and location of schools, shops, housing, employment, etc., and determines the ‘demand for transport’.

Transport can take place by a variety of modes, whose energy efficiency depends on the vehicle’s utilisation (how well loaded it is) and its fuel efficiency. Fuel efficiency is, in turn, determined by technology, consumer choices, driving style and other user factors.

Energy-saving measures can be applied at different levels in the hierarchy. In general, those ‘demand’ measures at the top of the hierarchy will have the greatest impact in the longer term. However, the user measures nearer the bottom will be easiest to deliver in the shorter term. These can be grouped into categories, as shown in Table G4, each with examples of the indicators by which they can be measured. The examples given include both passenger and freight transport.

The factors thus form a hierarchy through the modes chosen to the efficiency and utilisation of the vehicles that are used. Table G4 helps to identify potential opportunities for savings. The higher up the hierarchy a saving can be made, the greater will be the potential saving (i.e. avoiding making a journey saves much more fuel than making the same journey more efficiently). However, it is also necessary to consider the ease with which different measures can be applied across large numbers of users; a small percentage improvement in the average mpg of the whole vehicle fleet could yield greater savings than a large increase in rail travel.

Figure G3 Hierarchy of factors affecting transport energy use

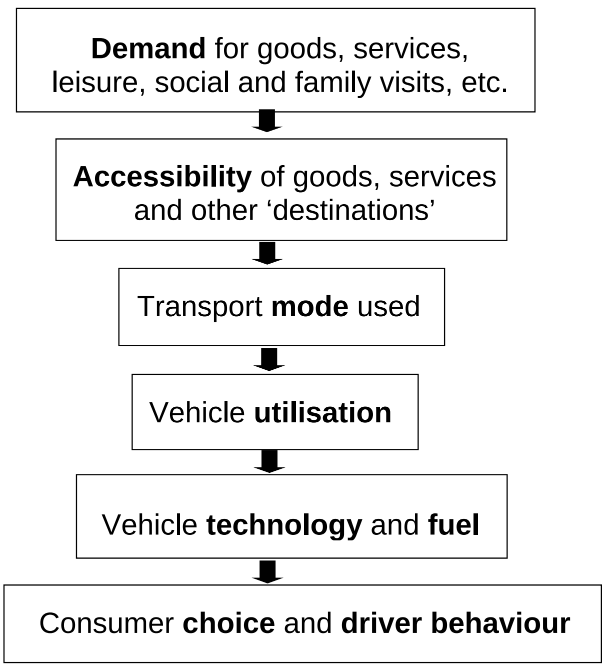


Table G4 Factors affecting energy use in transport

	Underlying factors	**Examples of indicators**
Demand for travel	• Availability of and distance to services, employment, schools, etc. • Demand for different products • Land use and development patterns • Personal choice • Cost of transport alongside other operational considerations	• Total distance travelled for different journey purposes per person • Number of trips made for different journey purposes per person • Average trip length per journey type (e.g. home to work, to shops, to school, etc.) ▪ Quantity of freight transported (e.g. million tonnes/km)
Transport mode (e.g. by car, train, lorry, bicycle)	• Personal preferences and habits – ‘cultural norms’ • Availability of different transport services • Price	• Distance travelled by each mode • Vehicle km • Percentage of trips by each mode • Tonnes/km by each mode
Utilisation (e.g. how efficiently the vehicle is loaded)	• Efficiency of distribution system • Relative cost of fuel and vehicle compared with other business drivers • Ability to match public transport vehicles to passenger demand • Type of journey (e.g. cars are better loaded for holiday trips than for business trips)	• Passengers per vehicle • Tonnes (or pallets) per vehicle • Percentage of maximum capacity
Fuel efficiency of vehicle	• Engine technology • Fuel type • Aerodynamics • Accessories (e.g. air-conditioning) • Weight • Performance	• Miles per gallon • Litres/100km
User factors	• Driving style • Traffic conditions and speed • Maintenance	• Percentage change in fuel efficiency • mpg in use

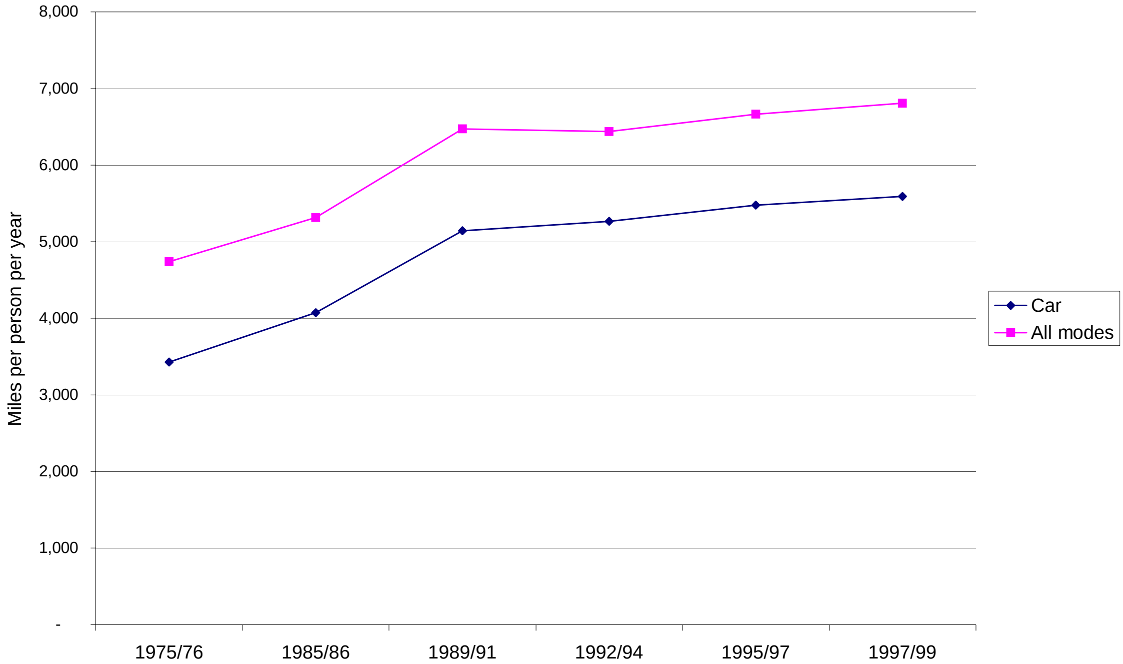
4 The Business As Usual (BAU) outcome

Journey distances and traffic levels

Traffic levels are increasing and individuals are travelling further (see Figure G4)). There has also been a corresponding increase in the distance travelled, for many products, between the manufacturer and the consumer. The underlying reasons include:

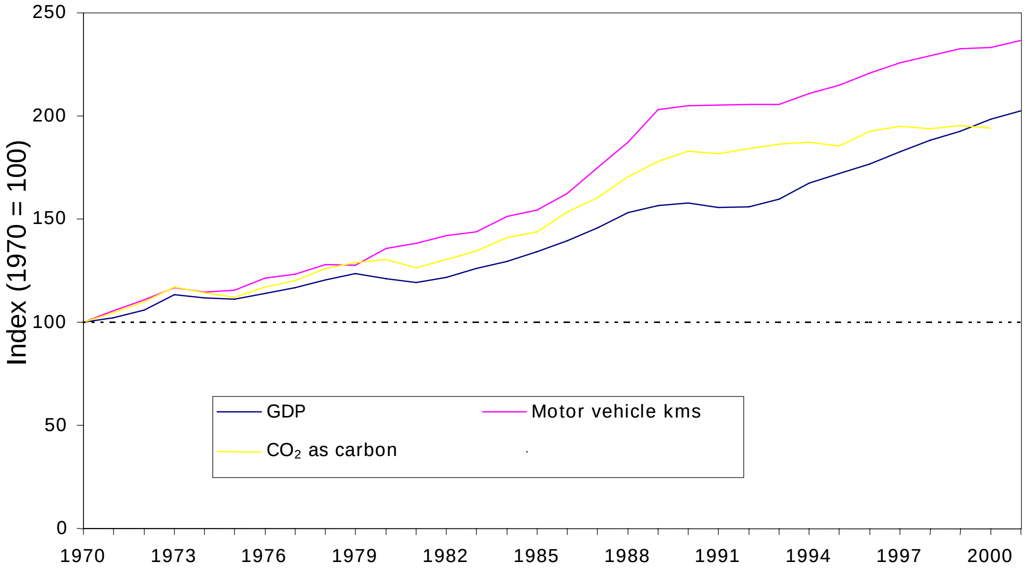
- A steady increase in car ownership
- A transfer from other modes
- Changes in travel patterns that lead to increased travel distances for the same journey purposes (e.g. short walking trips to local shops are replaced by longer car trips to out-of-town stores).

Figure G4 Road traffic distances by car and all modes [6]



Road traffic growth in mainland UK has historically followed gross domestic product (GDP) (see Figure G5) but, since 1993, there has been some uncoupling of road traffic growth from economic growth (motor vehicle traffic increased by 15% to 2001 while GDP increased by 27%) [9]. This link will have to be broken if unsustainable levels of traffic growth are not to continue into the future. Between 1970 and 2000, CO_2 emissions from road transport increased by 94% [9].

Figure G5 Trends in mainland UK road traffic numbers and GDP [9]



The trend towards increased journey length is strongly associated with land use planning and the form of urban development. Even with recent changes in DfT planning policy guidelines, there is still a trend towards out-of-town developments and low density housing, which encourages increased travel. The link between the form of urban development and transport energy consumption was investigated by Newman and Kenworthy in the late 1980s [10]. When comparing data from 32 cities across the world, they found a clear inverse relationship between urban density and petrol consumption per capita. Their work was quoted in *Towards an urban renaissance - the final report of the Urban Task Force* [11], which sets out in detail the links between land use planning, transport planning, energy use and policy, and provides a helpful basis for a vision for Northern Ireland's future development.

5 The All Technically Possible (ATP) outcome

Measures that focus solely on technological change are likely to have only a limited impact on transport energy use in Northern Ireland and the maximum benefits will be achieved by a range of measures working together. The types of measure that can be applied are listed in Table G5, which gives examples of how these measures are being applied in practice.

Greater benefits could be achieved by combining a number of different measures. For example, converting diesel vehicles to run off liquefied petroleum gas (LPG) can actually increase CO_2 emissions. However, by enabling city centre buses and delivery vehicles to run more quietly and with lower particulate and NOx emissions, LPG makes it easier to introduce traffic restraint and other measures to provide an improved urban environment. Similarly, improved public transport or cycling provision may have only a small impact on traffic levels by themselves, but in combination with other sustainable transport planning measures, they can help to create a sustainable urban environment.

The (regulated) structure of the public transport industry in Northern Ireland makes it easier to integrate services than in the rest of the UK and gives greater control over vehicle specification (thus making it easier to introduce new technology). Northern Ireland's current position, with a lower than UK average travel distance and generally more compact form of urban development, is a good starting point to build on.

Table G5 Summary of measures to reduce transport energy use in Northern Ireland

Type of measure	Potential savings	Timescales	Examples/further information
Technology and fuels			
Improved technology, e.g. more efficient engines	Savings of 25% by 2012 are already agreed with the EU car industry, but benefits may be lost if consumers choose larger, less efficient vehicles.	Potential for significant impact by 2025	The Cleaner Vehicles Task Force has reported on trends in vehicle fuel efficiency [12].
New technology, e.g. fuel cells	Dependent on ultimate fuel source, i.e. whether fossil fuel, nuclear or renewable.	Unlikely to have a major impact before 2025	*Powering future vehicles strategy* [13] sets out the Government's proposed framework for the UK's shift to low carbon vehicles and fuels.
Alternative fuels, e.g. LPG, compressed natural gas (CNG), biodiesel	• LPG provides around 15% CO_2 savings over petrol, but is less efficient than diesel. • CNG provides CO_2 gains over petrol and diesel.	Unlikely to gain a significant share of the market	TransportEnergy's PowerShift programme (http://www.powershift.org.uk/) provides grants to fund conversion to gas fuels. Road gas fuels are subject to a low level of duty, but this is under review by HM Treasury.
Behavioural change/ consumer choice/fleet best practice			
Purchasing smaller, more efficient cars	The current wide range in car mpg from <20mpg to >60mpg suggests large potential savings if consumers opt for more efficient vehicles.	Significant change possible taking account of market replacement cycle of about 5 years	Encouraged by fiscal measures such as graduated vehicle excise duty (VED), CO_2 based company car taxation and the level of fuel duty.

Fuel efficient driving	Savings of at least 5% can be achieved, especially where supported by monitoring systems.	Savings can be achieved immediately.	Currently promoted to fleets in England (both light and heavy vehicles) through programmes such as TransportEnergy BestPractice (http://www.transportenergy.org.uk/moreefficient/) and SAFED (Safe and Fuel Efficient Driving). (http://www.safed.org.uk/)
Best practice in vehicle fleet management	Savings of 10% are commonplace; usually achieved through a number of measures including fuel efficient driving, fuel monitoring, improved logistics, etc.	Significant savings possible by 2012	As above
Traffic flow and speed management measures	Most vehicles achieve maximum fuel efficiency when traffic is flowing steadily and maximum speed is held below 60mph.	Speed management systems (e.g. variable speed limits on motorways) can be implemented over a comparatively short timescale.	The RCEP's 18th report, *Transport and the environment* [14], advocated speed management both for traffic management and reducing carbon emissions. The EU MASTER project investigated the effectiveness of different speed management tools and strategies (http://www.vtt.fi/rte/projects/yki6/master/master.htm).
Travel plans	Some travel plans have achieved reductions in car use of around 10% at some sites [15].	Significant savings possible by 2012; furthermore, by influencing future travel patterns, it is possible to reduce some of the forecast traffic growth post-2012.	Travel plans are currently promoted in England on behalf of DfT through the TransportEnergy BestPractice programme (http://www.transportenergy.org.uk/)
Travel awareness measures	Modal shifts of over 10% have been achieved in travel awareness campaigns without changes to infrastructure.	Benefits can be achieved in the short term, but need to be sustained with on-going efforts.	TravelSmart – an individualised marketing and successful behaviour change programme from Australia – is being tried at various locations in the UK [16].

Transport demand management			
Land use planning	This affects future travel patterns and therefore has more impact on the forecast traffic increases.	Particularly important in reducing forecast traffic growth post-2012.	English planning policy guidance has been recently updated to encourage more sustainable development [17].
Improved public transport infrastructure	Because public transport accounts for a very small percentage of journeys, very large percentage modal shifts are needed to make a significant impact on total traffic levels and emissions.	Major public transport schemes have long lead times, thus cannot have a significant impact before 2012.	The DfT's transport appraisal guidance (GOMMMS) provides information on how to assess the impact of infrastructure measures [18].
Encouraging cycling and walking	The UK has higher levels of car use for short journeys than in many other EU countries.	'Soft modes' can be promoted more quickly; the English Transport Ten Year Plan has a target to treble cycling by 2010 [19].	Cycling is being promoted in England by the National Cycling Strategy Board and Cycling Development Team [20].

6 The vision for the development of low carbon options for transport

Technologies and fuels

There are a number of technological approaches to reducing CO_2 emissions from vehicles.

- Improved engine technology and vehicle design can increase the intrinsic energy efficiency
- Low carbon fuels can reduce the CO_2 emitted for a given amount of energy consumed
- Biofuels ensure that there is no net emission of CO_2 to the environment
- Hydrogen generated from renewable energy sources would also avoid net carbon emissions.

The UK Government's powering future vehicles (PFV) strategy [13] aims to promote the development and introduction of low carbon vehicles and fuels. The work is steered by the Low Carbon Vehicle Partnership (http://www.lowcvp.org.uk/). The first annual report on the PFV strategy was published in October 2003 [2][2].

One advantage of using hydrogen as a transport fuel is that it can facilitate sustainable energy sources such as wind turbines or tidal power. The power output of these energy sources fluctuates rapidly, making it difficult to use them for more than a small proportion of electricity demand. However, if wind energy is used to produce hydrogen for transport fuel, production can vary with power availability and the fuel can be stored for use when needed, although conversion to a hydrogen economy would require:

- The development of power generation, electrolysis, hydrogen transport and storage technologies
- Major changes to the global automotive industry.

These factors limit the ability of a small region such as Northern Ireland to move ahead of the rest of the industrialised world. Nonetheless, it is important for the potential use of hydrogen as a transport fuel to be taken into account in planning the future of Northern Ireland's energy supply.

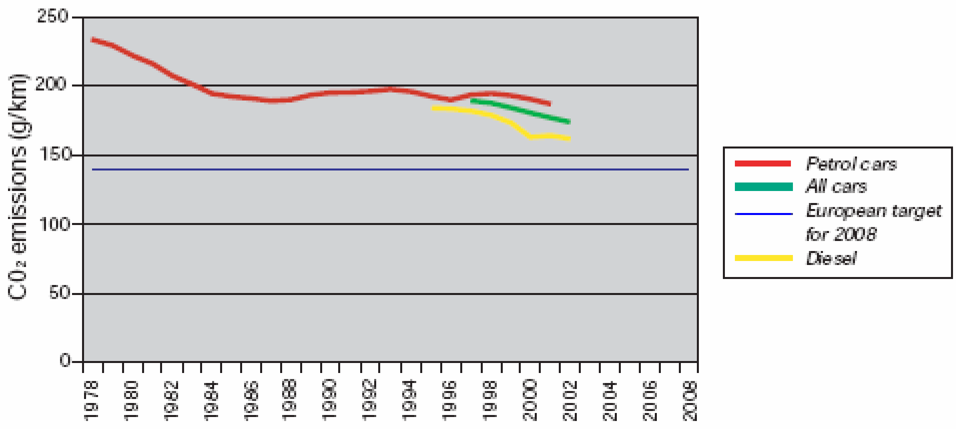
Improved vehicle technology does not necessarily lead directly to improved vehicle fuel efficiency. The values for the average mpg of UK cars over 20 years to 1998 (see Figure G6) show that, during the late 1980s and early 1990s, average fuel efficiency actually fell [13].

Part of the problem is that there have been other changes in vehicle design: they are often more powerful and better specified with more fuel-consuming accessories (e.g. air-conditioning), and have additional safety features which can increase weight. For example, there was a 30% increase in the weight of equivalent models between the 1980s and the 1990s.

However, the average trend masks what has become a very wide range in the fuel efficiency of cars – from 60+mpg for super minis through 45 mpg for mid-range cars to off-road vehicles that deliver less than 20mpg. The upper range of efficient conventional technology overlaps with the efficiency of current hybrid vehicles, suggesting that new technologies provide an opportunity for on-going increases in fuel efficiency but are unlikely to deliver a step change in performance. Fuel economy data for new cars are available on the Vehicle Certification Agency website (http://www.vca.gov.uk/carfueldata/index.shtm).

[2] *Editorial note*: The second annual report was published in October 2004 (see Addendum).

Figure G6 Average CO_2 emissions for new cars sold in the UK [13]



The potential impact of the increased popularity of large four-wheel drive vehicles – also known as sports utility vehicles (SUVs) – provides a good example of how consumer choices can negate the benefits of improved technology. In the USA, such vehicles account for around half of all 'car' sales; this has led to a significant increase in vehicle fuel consumption.

In contrast, the much greater importance given by the UK road haulage industry to running costs and improved technology has led to overall improvements in fuel economy. Between 1992 and 1998, the average fuel efficiency for all rigid vehicles increased from 7.9 to 8.5mpg, while fuel efficiency for articulated vehicles increased from 6.9 to 7.7mpg over the same period [12].

The EU has reached a voluntary agreement with the car industry to deliver a 25% improvement in average fuel efficiency by 2008. However, this figure is considerably less than the variation in fuel efficiency between existing types of car. Thus, there is potential for a much greater improvement if consumers could be persuaded to switch to smaller, more efficient models. Conversely, if the UK car market becomes more like that in the USA, with a move to bigger, less efficient vehicles, then the voluntary agreement may not deliver a reduction in CO_2 in practice. Some measures that could influence these consumer factors are discussed below.

Forecasts for a Low Carbon Economy

Projections for 2012

Over the coming decade, it will be difficult to achieve significant change in those factors near the top of the hierarchy (see Figure G3). This is because it takes a long time for land use and transport planning measures to be implemented and to have an impact. This means that the basic drivers of transport demand by 2012 will be based on the situation today.

There are 'ten year plan' targets for significant increases in public transport use in England [19]. Even if these are achieved, however, they will not make a significant impact on total transport fuel use due to the already very small modal share of public transport (see Table G3). But there is potential for changing short car journeys into walking or cycling trips; in the UK (including NI), cars are used for a higher proportion of short journeys than is the case in many other EU countries.

Given the length of the replacement cycle in the car industry and the time it takes to introduce new models into the market, there will not be radical changes in the technology of the cars in use in 2012.

The EU wide agreement with the car industry to increase the average fuel efficiency of new cars by 25% could offset the forecast 10% traffic growth. Consumer choice over the next few years, however, will determine how this affects the average mpg of the UK car fleet. In the USA, the market preference for large SUVs has actually led to a worsening average mpg in recent years.

There is potential to introduce speed management measures over this timescale, particularly those focused on enforcing speed limits on high-speed roads. Indeed, speed management was advocated by the RCEP in 1994 in its 18th report, *Transport and the environment* [14]. However, political concerns about speed enforcement are likely to limit the potential in practice.

Box G1: Projections for 2012

- UK road traffic is forecast to increase by around 10%.
- Engine and fuel technology will be similar to the current market, although hybrid vehicles and other new technologies will start to appear in small numbers, particularly in public transport.
- Personal travel will be largely determined by current land use patterns.
- Modal shift targets will have only a small impact on total fuel use, with the greatest potential for change with short journeys.
- Vehicle mpg will be determined by purchasing behaviour over the next few years. Note the wide range in fuel efficiency of current vehicle models from 15mpg (SUV) to 60mpg (diesel hatchback).
- There is further potential for short-term changes in travel behaviour through appropriate promotional measures.
- Speed management measures could be introduced within this timescale and would help to limit emissions from motorways and other major roads.
- Optimistically, increased vehicle mpg could offset traffic growth by 2012.

Projections for 2025 and 2050

Post-2020, the full impact of technological, social, economic and land use changes will start to affect trends.

The current long-term traffic forecasts predict that road traffic could double by 2050; air travel will have doubled before then. Whether this traffic growth actually takes place will be determined by choices in land use and transport planning over the next few decades, as well as longer term trends in the cost of fuel as oil production peaks and then declines.

Vehicle technology is likely to change radically over the period, most likely starting with diesel–electric hybrids, and possibly followed by fuel cells or batteries. Hydrogen as a road transport fuel may arrive – initially confined to larger fleet vehicles (including buses) in urban areas. However, the practical problems with hydrogen as a vehicle fuel may lead to the ‘hydrogen economy’ being represented by secondary hydrocarbon fuels produced using renewable hydrogen as a feedstock.

A further change in technology, whose impact is very difficult to forecast, is the possibility that in-vehicle automation and navigation systems could increase the vehicle-carrying capacity of the road network and, in the longer term, could even permit the completely driverless operation of road vehicles. This would blur the distinction between private cars, taxis and public transport vehicles. This technology also facilitates the use of traffic flow and speed management measures to improve vehicle fuel efficiency.

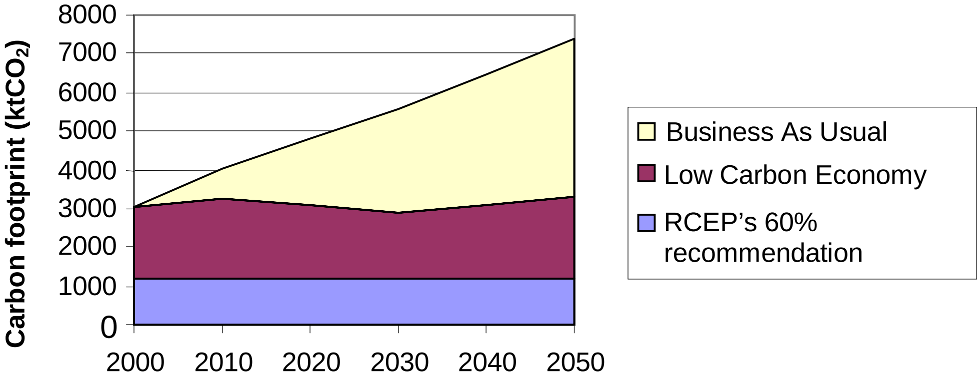
Box G2: Projections for 2025 and 2050

- UK road traffic growth forecast to be >50% by 2025 and 100% by 2050.
- Global oil prices are likely to rise as production peaks and declines.
- New engine technology could potentially enter the market in significant numbers from around 2020 (probably diesel hybrids initially).
- There is scope for significant improvements in car mpg, if consumers accept it (a fleet average of 100mpg could be possible by 2050).
- Land use and transport planning decisions made over the coming decade will affect travel demand throughout the century.
- There is potential for significantly increased walking and cycling for local journeys if priority is given to creating ‘liveable communities’.
- Major changes in work patterns and lifestyle should be expected (including teleworking and a continuing trend away from a manufacturing economy).
- Developments in car navigation and control technology could lead to fully automated vehicles, which would radically change the way people use their cars and blur the distinction between private and public transport.

Roadmap for 2050

Based on these projections, the roadmap presented in Figure G7 shows that the NI transport sector will not reach the RCEP’s 60% recommendation by 2050. The BAU scenario would more than double transport CO_2 emissions by 2050, in line with the projected 100% increase in road traffic by that date. The Low Carbon Economy scenario assumes that energy savings can be made by adopting a range of measures and concludes that carbon emissions can be stabilised for approximately 30 years but that, after then, the carbon footprint will increase as traffic levels increase.

Figure G7 A roadmap for approaching the RCEP's 60% recommednation by 2050 in the NI transport sector



Enabling change

The various measures to reduce transport energy use summarised in Table G5 are divided into three categories:

- Technology and fuels
- Behavioural change/consumer choice/fleet best practice
- Transport demand management.

Education and driver training will both be essential in reducing vehicle energy use by 2050. Much greater adoption of travel plans and best practice in vehicle fleet management (currently being promoted by the DfT's TransportEnergy BestPractice programme [15]) will also help to reduce consumption by business users. Wider uptake of schemes to promote cycling, walking and greater use of public transport (e.g. Sustrans [16], the National Cycling Strategy [20] and the DfT's ten year plan [19]) will also be required.

Increased personal mobility is a consequence of increasing wealth and education, while business also benefits from the increased flexibility delivered by employees with their own cars and whose mobility is not dependent on public transport. The resulting decline in travel by bus and train requires special measures to reverse, including:

- Reducing on-street parking and increasing off-street parking charges
- Additional tax breaks on car sharing and community car pool schemes
- Making 'pool' cars more financially attractive than use of own transport for business use
- Providing on-board computer workstations on long distance trains
- Hard-hitting advertising campaigns.

For those who live outside Belfast and its environs, the concentration of professional and business services in Belfast necessitates frequent travel by car which, in turn, causes the congestion that makes travel by bus and cycle unattractive to those living in Belfast. Hence, viable and attractive alternatives to car use could include:

- Public transport with integrated rail, tram, bus and air network services
- Cycle and bus priority lanes, traffic-free zones and congestion charging
- Broadband digital highways to reduce the need for business travel
- Teleworking service centres to reduce commuting and business travel
- Local leisure and shopping facilities (to cut down on non-business travel).

7 Constraints and barriers limiting the rate of adoption

The structure of the transport energy 'market' is complex, with a large number of end-users – from private individuals to large organisations – whose use of transport fuel is influenced by a wide range of factors. Some of these are technological, while others are down to individual travel behaviour and consumer choices. Land use planning and urban design have a major influence on travel patterns.

Not all of these factors can be influenced directly by the Carbon Trust in Northern Ireland. Many need to be tackled at a regional and UK Government level, and some can only be addressed through international action. Furthermore, the great variety of types of end-user means that some groups, such as large organisations, can be targeted much more easily than others. It is therefore necessary to consider which measures and target audiences should be the priority when developing a strategy for reducing transport energy use in Northern Ireland.

Although sustainable transport policies in the UK and elsewhere have many general principles in common, certain features of the NI economy and situation distinguish it from other regions and will affect strategies to reduce energy use by the transport sector. Key factors include:

- Cross-border trading limits the scope for certain fiscal measures (especially fuel taxation)
- The globalised nature of the car industry limits the scope of Northern Ireland to pursue the use of alternative vehicle fuels independently
- The economic pressures as Northern Ireland shifts from dependence on manufacturing to a more diverse, service-based economy will raise the importance of 'best practice' measures that help to improve the economic viability of businesses
- As the economy grows, Northern Ireland is going to go through major development pressures and land use changes. Land use planning measures (sustainable towns) can bring together a whole range of environmental, energy-saving and social benefits.

This annex does not include much discussion about air travel even though it is estimated to contribute to more than a quarter of Northern Ireland's current CO_2 emissions. Air traffic is forecast to more than double by 2030. The 9th report from the House of Commons Environmental Audit Select Committee [21] concluded that: 'Were such growth to occur, it could totally destroy the Government's recent commitment to a 60% cut in carbon dioxide emissions by 2050'. However, little can be done to control the forecast growth at the Northern Ireland level alone.

8 Concluding remarks

This annex identifies some key recommendations for the Carbon Trust in Northern Ireland to consider when planning its future activities in the transport sector. To assist this process, some examples have been provided from measures that have been successfully applied in other UK programmes and which could be transferred to Northern Ireland without much difficulty.

The fact that Northern Ireland has lagged behind the mainland UK economy provides a range of opportunities to pursue new approaches and avoid the mistakes that have been made elsewhere. Land use planning and urban design decisions are fundamental in determining people's travel behaviour. Given the major changes that are likely to occur as Northern Ireland's economy grows and new development takes place, it is important that transport and land use are planned for sustainability from the beginning.

Key elements of a long-term vision are therefore:

- Land use planning decisions that seek to minimise future demand for travel while facilitating walking, cycling and the use of public transport

- Transport planning decisions that seek to manage traffic levels and encourage sustainable modes, rather than stimulate demand for further traffic growth

- Best practice measures to help industry make the most efficient use of transport capacity and fuel

- Consumer incentives (including fiscal measures) to ensure that more efficient vehicles are purchased and the potential benefits of new technology are realised in practice

- Behavioural change campaigns to deliver short-term improvements and to support longer-term measures

- Research and support for the development of new low carbon fuels and technologies in the context of the wider energy supply situation.

Specific recommendations for the Carbon Trust for Northern Ireland are:

- Undertake further assessment of the energy implications of land use planning and urban design, building on the work of the Urban Task Force as set out in *Towards an urban renaissance* [11] and involving dialogue with appropriate organisations and stakeholders in these disciplines

- Consider opportunities for Northern Ireland to have greater involvement in the UK PFV strategy (e.g. participating in trials of hybrid and other new technologies in buses taking advantage of NI's regulated bus industry)

- In partnership with the Energy Saving Trust and other key stakeholders, introduce the promotion of best practice measures in transport, building on the work that has been developed over the last decade in the rest of the UK.

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Acronyms and abbreviations

ATP	All Technically Possible
BAU	Business As Usual
CNG	compressed natural gas
CO_2	carbon dioxide
DETI	Department of Enterprise, Trade and Investment
DTI	Department of Trade and Industry (London)
DfT	Department for Transport (London)
GB	Great Britain (i.e. mainland UK)
GDP	gross domestic product
LPG	liquefied petroleum gas
mpg	miles per gallon
NI	Northern Ireland
NOx	nitrogen oxides
PFV	Powering Future Vehicles [strategy]
RCEP	Royal Commission on Environmental Pollution
SUV	sports utility vehicle
TOE	tonnes of oil equivalent

Appendix

Estimating the breakdown by sector of transport energy use in NI

Petrol and diesel (footnote 1 in Table G3)

NI transport statistics for 2001–2002 [3] provide data on deliveries of petrol and diesel. However, it is known that fraud and cross-border shopping account for a significant amount of the fuel used in Northern Ireland. A 2002 report from HM Customs and Excise [22] estimated revenue loss from fraud and legitimate cross-border shopping on petrol and diesel as £380 million for 2000 (up from £140 million in 1998). HM Customs estimates the total revenue from hydrocarbon oils duty in Northern Ireland at around £750 million. From the losses estimated by HM Customs, we calculated total fuel consumed as shown in Table G6.

Table G6 Estimated petrol and diesel use in NI (2001/2002)

Fuel type	Fuel quantity		Carbon emissions	Energy
	kt	x 10^6 litres	$ktCO_2$	TJ
Petrol	418	565	1,306	19,781
Diesel	323	385	1,031	14,613
Total	**741**	**950**	**2,337**	**34,394**

Diesel car fuel use (footnote 2 in Table G3)

Available diesel fuel use data are not segmented into road haulage, bus, car use, etc. Furthermore, NI transport statistics do not provide vehicle distance data for road haulage in NI. It was therefore necessary to estimate the breakdown from other sources of information.

NI transport statistics for 2001–2002 [3] report that 36.9% of NI cars are diesel. DfT statistics for 2002 [23] state that the average UK petrol car delivers 32mpg and the average diesel car, 40mpg. Therefore, diesel cars have 1.25 times the efficiency of petrol ones.

Given that the total petrol consumption has only been used by cars, it is possible to estimate the amount of diesel used by cars as follows:

Fuel use by diesel cars = Fuel use by petrol cars × % diesel cars in fleet × Relative efficiency of diesel cars

This gives the estimate of non-car diesel use given in Table G7.

Table G7 Estimated diesel use by cars in NI

Fuel type	Fuel quantity		Carbon emissions	Energy
	kt	x 10^6 litres	$ktCO_2$	TJ
Cars	122	165	443	6,277
Non-car use	201	219	588	8,336

Non-car use is mostly haulage and buses, and amounts to about 60% of NI diesel deliveries. By comparison, DfT statistics for 2002 [23] estimate the following breakdown of diesel fuel by use for the whole UK:

- Goods vehicles: 68%
- Buses and coaches: 7%
- Remainder (mainly diesel cars and taxis): 25%.

Once bus and rail estimates have been determined, road haulage diesel use can then be calculated.

Bus travel (footnote 3 in Table G3)

NI travel data [4] provide the following:

- Total passenger journeys: 65 million
- Total bus miles: 41.4 million.

Assuming an average fuel efficiency of 8mpg for buses, this means that the total fuel used by NI buses is 23.5 million litres or 6% of total diesel consumption (this is reasonably close to the 7% quoted for the UK as a whole).

Rail travel (footnote 4 in Table G3)

- Passenger journeys: 6.2 million
- Passenger miles: 158.9 million (267 million passenger km).

Energy consumption data for railways are difficult to obtain. Various estimates can be made from quoted figures for energy use per passenger km, calculated for different occupancy rates. Assuming typically 1MJ per passenger km (London Research Centre estimate), this gives 267TJ for rail travel in Northern Ireland or 0.7% of total petrol and diesel deliveries.

Road haulage (footnote 5 in Table G3)

Road haulage is assumed to account for the diesel fuel remaining after subtracting use by diesel cars, buses and trains.

Air travel (footnote 6 in Table G3)

Table 7.4 of Transport Statistics Great Britain: 2002 edition [23] states that Northern Ireland generates 2.6% of UK air passengers. Therefore, as a simple approximation, we can allocate 2.6% of UK aviation fuel use and CO2 emissions to Northern Ireland. However, this ignores the contribution from air freight, which is concentrated in south-east England.

Total UK aviation fuel use in 2002 was 11.42 million tonnes of oil equivalent (TOE). Therefore, using this approximation, the NI contribution equals 0.3 million TOE (300kt) in 2002; this is equivalent to around 40% of total NI petrol and diesel consumption. By comparison, UK energy statistics [24] for 2002 show that aviation fuel use was nearer to 33% of petrol and diesel consumption.

Shipping (footnote 7 in Table G3)

Total annual petroleum use by UK shipping is 0.84 million TOE.

According to DfT's provisional port statistics for 2002, the Port of Belfast carried 2.4% of UK shipping tonnage. However, because this does not include passenger ferries, it can only be used for order of magnitude estimates.

Other information sources

- *Our energy future – creating a low carbon economy*. DTI White Paper. February 2003. http://www.dti.gov.uk/energy/whitepaper/index.shtml

Addendum: Useful material published after the preparation of the annex

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