Sustainable Urban Infrastructure

Dublin Edition – a view to 2025

A research project commissioned by Siemens Limited - detailed findings

Foreword

It is increasingly clear that the battle for environmental sustainability will be won or lost in cities. Over half of the world's population now live in urban areas, a figure which will reach almost 60% by 2025.

Cities account for about 80% of greenhouse gas emissions and 75% of global energy consumption. Issues of water and waste management in cities are inter-related with carbon ones, as well as having their own important impact on the environment and quality of life.

While there is widespread acceptance that humanity must tackle the challenge of climate change, economic issues tend to take precedence, especially in difficult times – the premise being that we should fix the economy first and think about the environment later.

The reality is humanity cannot afford to wait. Climate change is happening and will pose catastrophic consequences unless we take action now. Studies show that it will cost the global economy much more in lost growth if we wait to solve these challenges.

Ireland is already exceeding its Kyoto target and will likely miss its EU 20-20-20 target, which will cost us in the form of carbon credits. With one quarter of Ireland's population living in the Dublin region, urban residents will be responsible for a large part of the associated emissions.

This report seeks to explore how technology can contribute to greater environmental sustainability in the Dublin region. By taking a holistic perspective and applying a quantitative analytical approach, it identifies a series of technological levers that can reduce greenhouse gas emissions and bring Ireland closer to its international targets. The encouraging message is that many of the identified levers not only help protect the environment, but also pay back from an economic point of view.

The research was carried out by a team from University College Dublin School of Electrical, Electronic and Mechanical Engineering, led by Professor Gerry Byrne and Dr. Donal Finn. Siemens would like to thank this team for their efforts in producing a most rigorous analysis. We would also like to acknowledge the support received from Dr Gerry Wardell and his team at CODEMA.

Siemens sees itself in the vanguard of the drive for sustainability. In commissioning this report, we want to make our contribution by helping stakeholders take informed decisions - decisions that could have economic and environmental ramifications for generations to come.

Dr. Werner Kruckow
CEO Siemens Limited
Dublin
Ireland

EXECUTIVE SUMMARY 04

Approach 04

Key finding 1
Ireland will struggle to reach its targets 06

Key finding 2
Dublin's emissions per capita are higher than comparable cities 07

Key finding 3
Dubliners have a choice: Pay the penalty or invest in sustainability 07

Key finding 4
Existing and proven technologies can provide solutions to significantly reduce Dublin's emissions 07

Key finding 5
Technological levers for a sustainable Dublin 08

- **Energy** 09
- **Transportation** 09
- **Buildings and Lighting** 10

Key finding 6
Economically profitable strategies also exist to

Table of Contents

substantially reduce water usage and waste to landfill 10

- Water 10
- Waste 11

Key finding 7
75% of these solutions will pay for themselves 12

Key finding 8
Fashionable solutions are often an expensive means of reducing carbon emissions 12

Key finding 9
Sustainability issues need to be seen holistically, not in silos 12

Key finding 10
A strong stimulus in economically difficult times 13

Looking forward
We have the technology - we can do it! 13

METHODOLOGY 14

DUBLINS SUSTAINABILITY CHALLENGE 16

ENERGY 18

TRANSPORT 26

BUILDINGS & LIGHTING 32

WATER 38

WASTE 42

CONCLUSION 44

LEVER SUMMARY 46

REFERENCES 48

GLOSSARY 49

APPROACH

Cities can play a decisive role in fighting climate change: over half of the world's population lives in urban centres today and the number is likely to grow to nearly 60% by 2025. Cities are responsible for some 80% and therefore, a disproportionate share of the world's greenhouse gas emissions [1].

Dublin as the capital and economic hub of Ireland can pave the way towards becoming a truly sustainable city. It is a formidable challenge, but not an insurmountable one and as this study will show, many of the solutions are already at hand.

For the first time for the Dublin region, more than 20 technological levers covering five sectors (buildings, energy, transportation, water and waste) have been examined for their potential to reduce greenhouse gas (CO_2) emissions along with the associated investment costs and benefits.

The study aims to illustrate the contribution that technology can make towards creating a more sustainable city. It is targeted at policy makers, planners, businesses, educationalists, consumers and concerned individuals - in short society as a whole. We hope it will assist them in making informed decisions concerning the deployment of technologies to reduce Dublin's relatively high per capita carbon emissions.

The encouraging message is that many of the levers that reduce energy and water consumption and improve waste management not only help protect the environment, but also can have an acceptable pay back period from an economic point of view.

Executive Summary

The figures quoted for the abatement potential of each technological lever[1] equate to the amount of CO_2 emissions that can be avoided in 2025. It is important to note that all of the levers would result in a reduction of CO_2 emissions from the time they are implemented. The abatement cost quoted for each technological lever shows the costs or net savings per tonne of CO_2 abated. All calculations[2] take into account both the investment and running costs of a particular lever and its reference technology. Where the cost is negative, it implies that the benefits associated with its implementation (energy savings, lower maintenance costs, etc.) are greater than those of the reference technology - it provides a net annual saving over the forecast period. When a lever cost is positive, this implies that carbon emissions will be reduced but the initial investment is high and will not be paid back before 2025.

[1] See glossary
[2] except those for electric cars

Key finding 1: Ireland will struggle to to reach its targets

Under the Kyoto Protocol, Ireland has committed to limiting greenhouse gas emissions to 13% above 1990 levels (56 Mt CO_2), equivalent to 62.8 Mt[3] CO_2 each year between 2008 and 2012 (See figure 1.1) [2].

To meet its commitments to the EU 20-20-20 Agenda, Ireland has to, by 2020, reduce its emissions by 20% relative to 2005 levels, to meet a target of 56 Mt CO_2, as well as increase its share of renewable energies in energy consumption to 16% (to contribute to the 20% overall target of the EU) [3, 4]. In addition to the EU 20-20-20 target, Ireland has set a national target of increasing the share of renewables in energy generation to 40% (double the EU target) by 2020.

If Ireland adopts a 'business as usual'[4] approach, it is predicted that it will exceed its Kyoto target by approximately 8.7 Mt CO_2 each year during the period 2008-2012 [2, 5].

In September 2008 the EPA predicted that even with all the 'additional measures'[5] planned by the Government that Ireland would fall short of the Kyoto target by approximately 7 Mt CO_2 each year over the five year period [2, 6, 7, 8].

While the most recent projections released by the EPA in March 2009 show that the economic downturn will have the temporary effect of lowering emissions, it will still be a challenge for Ireland to meet both its Kyoto and EU 20-20-20 obligations. Even assuming the most optimistic scenario where the 'additional measures' are implemented on time and realise their full anticipated emissions reductions, Ireland will still be over both its Kyoto target and EU 20-20-20 target [9].

It is imperative that the transitory reduction in emissions brought about by the economic downturn does not dilute the urgency of Ireland's need to lower its emissions. Ireland must continue to implement whatever measures are needed to decouple CO_2 emissions from economic activity, otherwise emissions will increase again as soon as the economy recovers, compounding the problem of CO_2 already in the atmosphere.

While there is no specific emissions target for Dublin, given that approximately one

Irish CO_2 emissions projections and targets

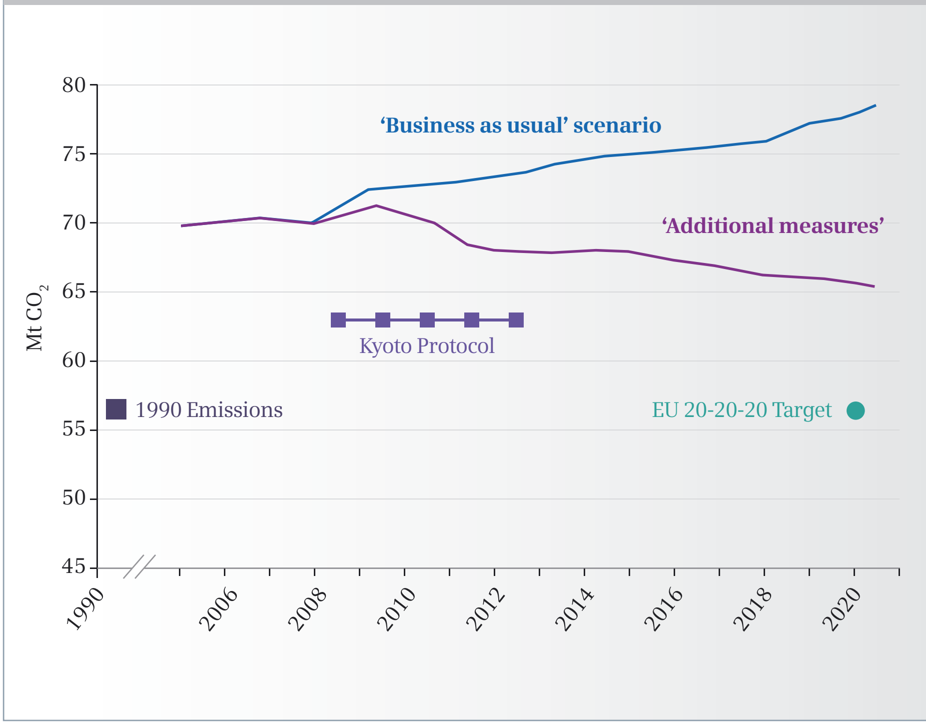

Figure 1.1 [2]

European cities: CO_2 emissions per capita 2005/06

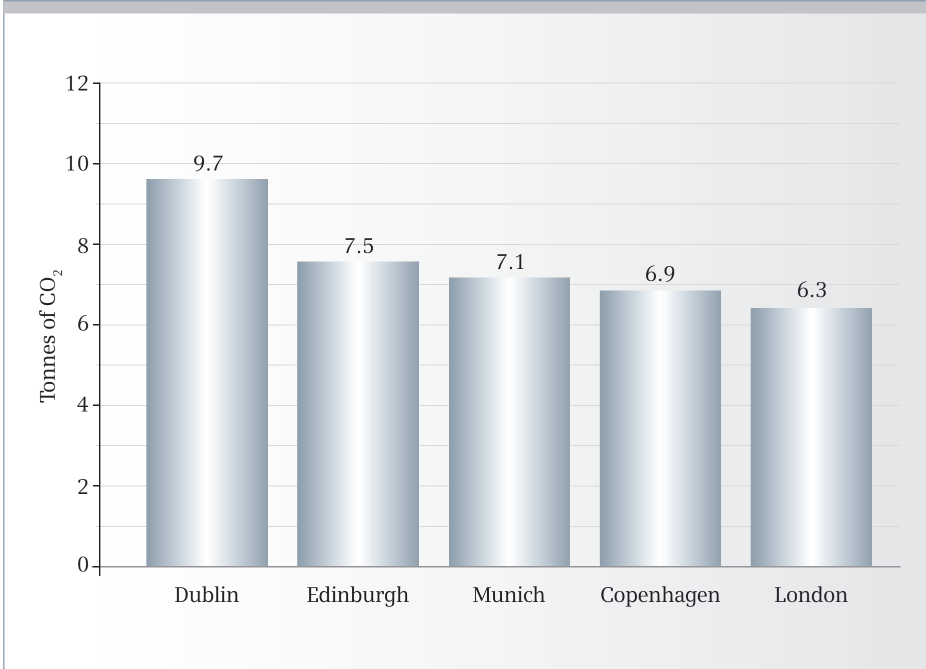

Figure 1.2 [1, 11, 12, 13]

[3,4,5] See glossary

quarter of the Irish population resides in the Greater Dublin Area and that its current emissions are approximately 13 Mt CO_2, in order to reach the EU 20-20-20 target, Dublin's share of the required reduction (20% relative 2005 levels) should amount to at least 2.6 Mt CO_2.

Key finding 2: Dublin's emissions per capita are higher than comparable cities

Dublin residents are responsible for emitting more carbon dioxide per capita than many other developed cities at 9.7 tonnes CO_2 per capita (2006) [10]. In London the per capita emissions are 6.3 tonnes per annum, while smaller cities, which are more comparable to Dublin such as Edinburgh and Munich, emitted 7.5 tonnes and 7.1 tonnes per capita respectively in the same year [1, 11, 12, 13].

Key finding 3: Dubliners have a choice: pay the penalty or invest in sustainability

Even in the most optimistic scenario, where the government's 'additional measures' have been implemented on time and realised their full anticipated emissions reductions, it is predicted that Ireland will fall short of its Kyoto target by around 7 Mt CO_2 each year over the Kyoto period. The latest projections by the EPA, which factor in the temporary impact of the economic downturn, predict that Ireland will still miss its Kyoto target by at least 1.3 Mt CO_2.

This could cost stakeholders in Ireland - businesses, consumers and government, between €156m and €840m over the five year Kyoto period (2008-2012), assuming an average price of €24/tonne of carbon [14], depending on the extent to which Ireland overshoots its Kyoto target.

In order to meet the Kyoto targets (under the 'additional measures' scenario) the Irish Government has indicated that it will purchase up to 3.6 million Kyoto units each year from 2008-2012 equating to approximately €433m over the five year period [6]. It has already set aside over €290m for the purchase of these carbon credits [6]. If Ireland fails to decouple economic growth from carbon emissions, any reprieve in penalty payments due to lowered emissions arising from the economic downturn will be short-lived as the burden will increase as economic growth recovers.

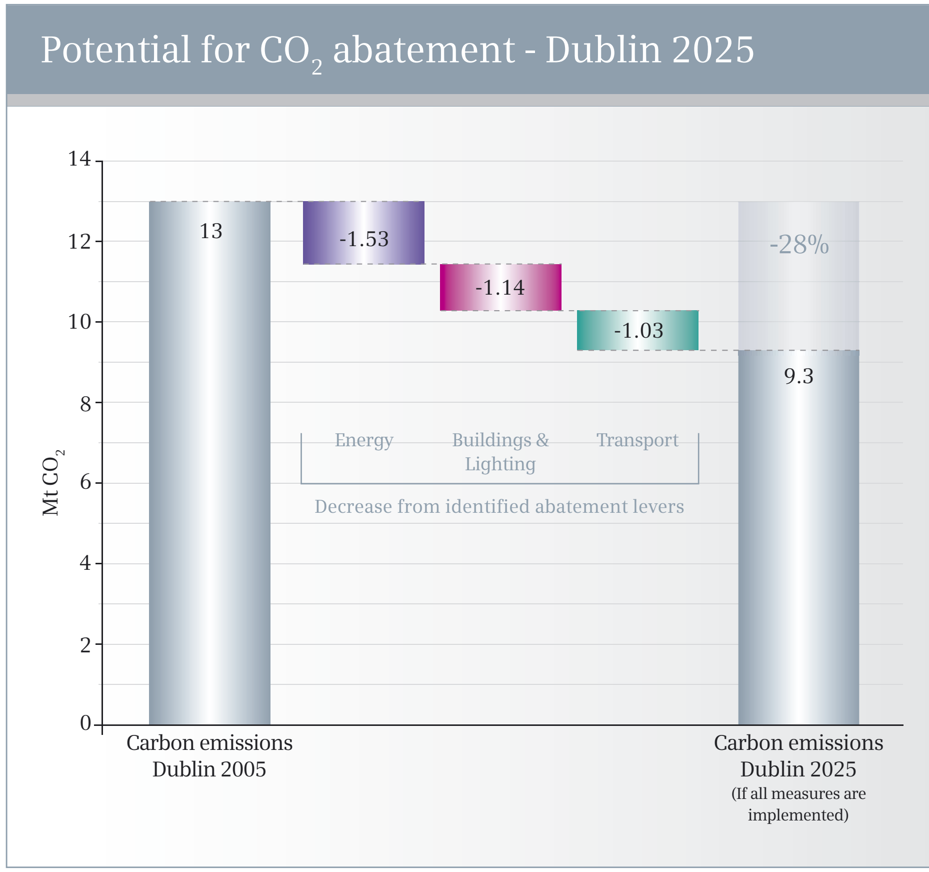

Figure 1.3

Local authorities, consumers and businesses therefore have two options: spend money on carbon credits, which will be mandatory in the future if carbon emissions limits are exceeded, or invest in technologies that will enhance the region's infrastructure and contribute towards the achievement of emissions targets.

It is demonstrated in this study that, instead of purchasing carbon credits, public authorities, businesses, industry and consumers should consider investing in technologies that would reap returns in the form of lower emissions and energy savings and benefit the economy through enhanced competitiveness and job creation, while also improving the quality of life.

Key finding 4: Existing and proven technologies can provide solutions to significantly reduce Dublin's emissions

This study outlines a number of technological levers that have the potential to significantly reduce carbon emissions in the Dublin region comprising the four local authority areas: Dublin City, Fingal, Dun Laoghaire-Rathdown and South County Dublin. The advantage of these levers is that the underlying technology, such as that behind wind turbines, efficient electrical appliances and hybrid vehicles, is already well researched and available today.

The 22[6] technological levers evaluated in this study, if fully implemented, could potentially abate 3.7 Mt CO_2 annually in Dublin in 2025, which corresponds to a 28% reduction of Dublin's emissions as well as reducing water consumption by 10% compared to 2005 levels (See figure 1.3) [2].

While this study focuses on technology, it recognises that technology alone can only partially contribute to overall CO_2 abatement. Behavioural change, though not considered explicitly in this study, is another key factor which needs to be considered in goals of CO_2 emissions reduction.

[6] See full list of technological levers on pages 18-19

Key finding 5: Technological levers for a sustainable Dublin

Across all infrastructure areas, there are some 22 proven technological levers discussed in this report that can substantially reduce carbon emissions, as well as reap returns in the form of energy savings. Not only do they contribute towards creating a sustainable city, they can also enhance Dublin's competitiveness in the international arena, which would increase investment, employment and prosperity, all the while improving quality of life for its citizens.

Figures 1.4 and 1.5 detail the key quantitative findings of the study:

Overview of identified CO_2 abatement levers - Dublin 2025

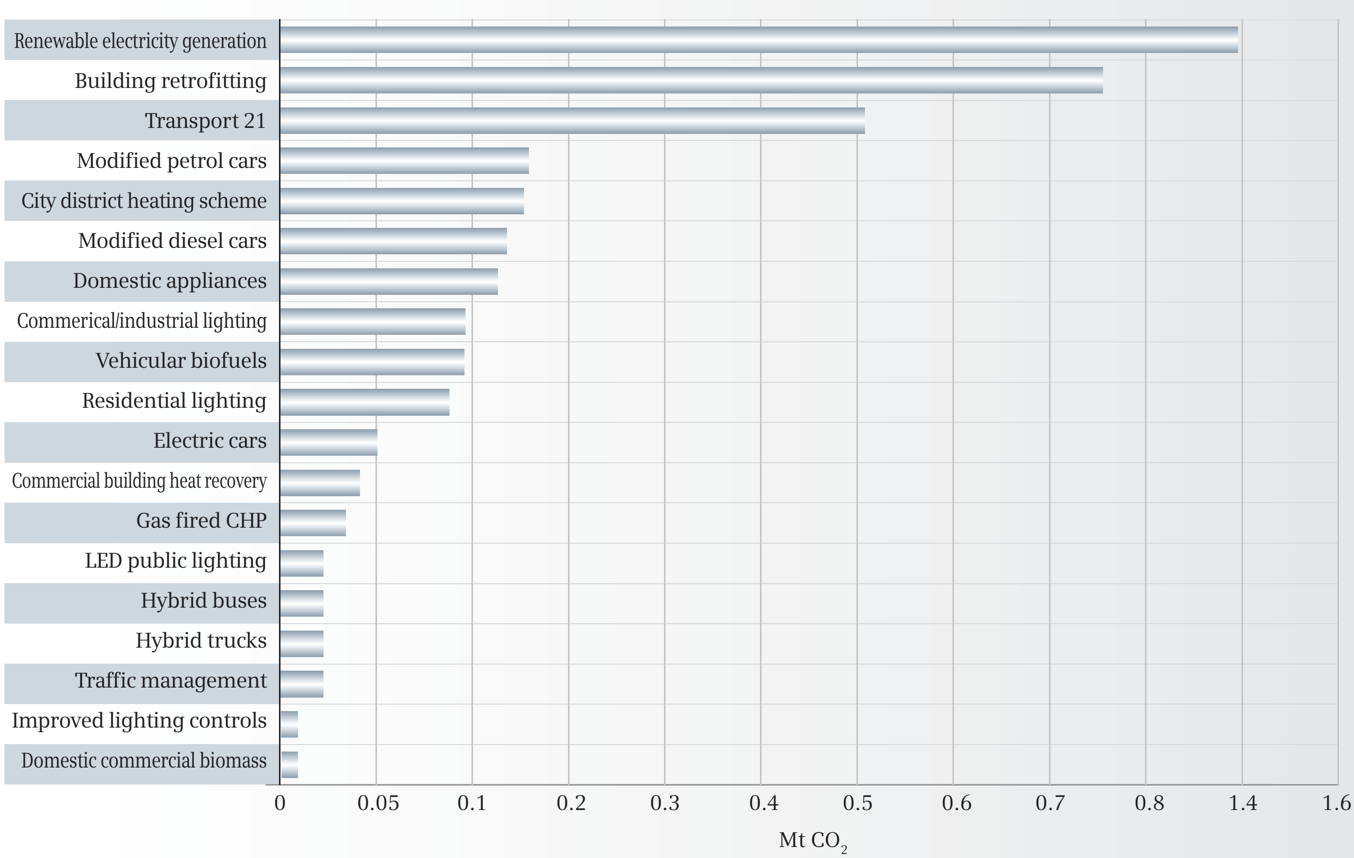

Figure 1.4

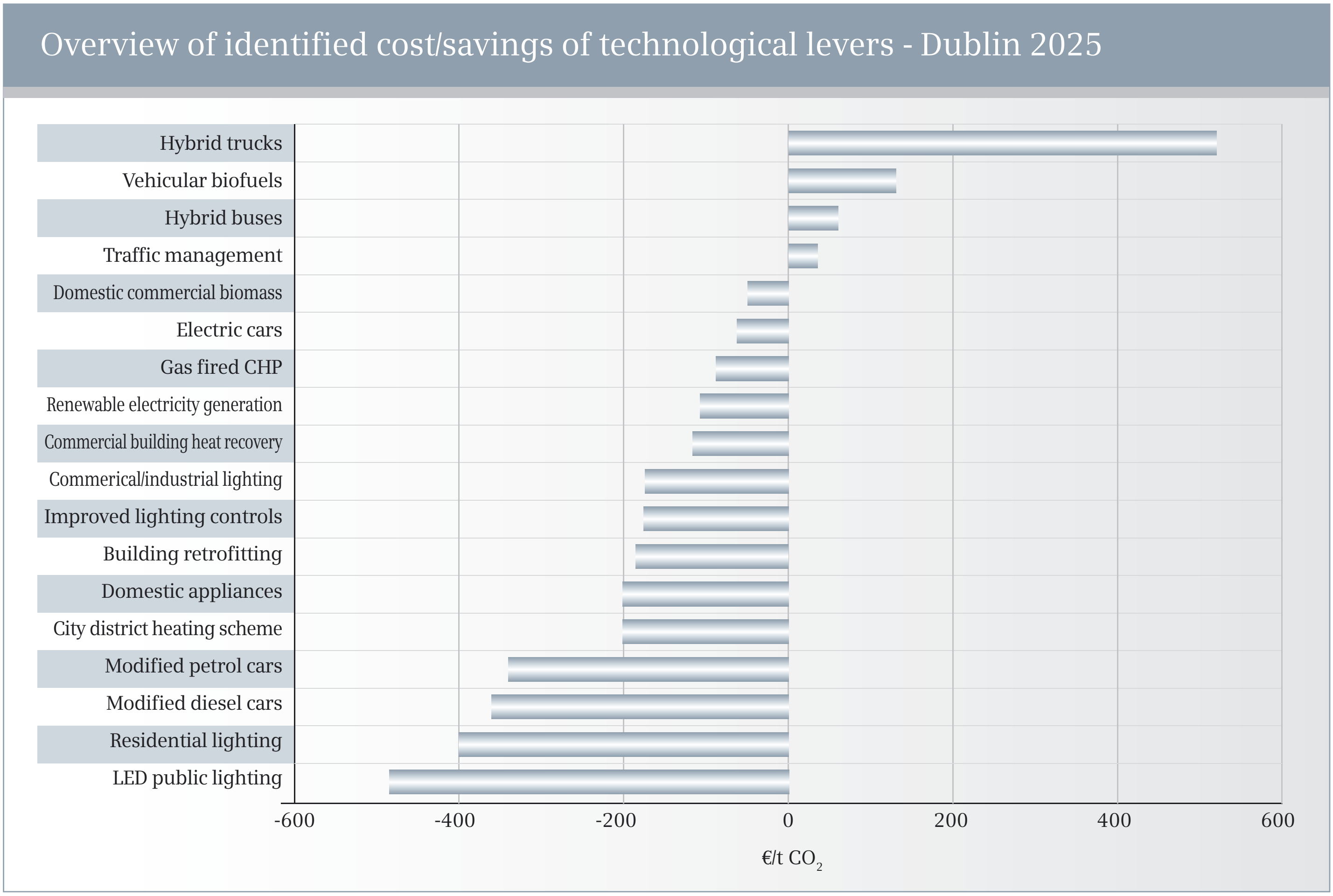

Figure 1.5

Energy

The greatest CO_2 abatement potential lies in the energy sector, which accounts for over 40% of the total reductions outlined in this study. CO_2 emissions could be reduced by 1.53 Mt annually by 2025, if levers that reduced Dublin's dependency on fossil fuels for electricity generation were implemented.

- If Ireland achieves its national target of 40% renewables contribution to the national grid by 2020, it will result in a reduction of 1.34 Mt CO_2 for the Dublin region [15]. To achieve this, renewable power connected to the grid will have to increase four-fold between now and 2020 from the current capacity of approximately 1,200 MW to an estimated 5,000 MW, consisting mostly of wind power [16]. The investment required in the period up to 2020 is approximately €9.45bn [16].
- A district heating system within the city would represent another major lever. It could abate 0.15 Mt CO_2 by utilising heat that would otherwise be dumped as a waste by-product of conventional electricity generation.
- Installation of a number of local gas fired combined heat and power (CHP) systems, with thermal capacity range of 0.5-10 MW, would also provide substantial potential for emissions abatement at 0.03 Mt CO_2. This would generate around €2.5m in savings annually for the investors.
- Addition of biomass boilers to the contributors of the district heating system would lead to an abatement of 0.01 Mt CO_2 and fuel savings of €500,000 annually.

Transportation

Over 65% of transport emissions in Dublin can be attributed directly to private cars [10]. Greenhouse gas emissions from transport could be reduced by 1.03 Mt CO_2 annually by 2025 through implementing the technological levers outlined in this study.

- The single most influential lever in the transport sector is the Transport 21 strategy. It has committed to develop two Metro lines in the Greater Dublin Area and to improving and extending the LUAS[7] services, as well as upgrading and improving the existing bus and DART[8] systems. The DART improvements include increased electrification of the system and the construction of an interconnector to link the planned Docklands railway station with Pearse and Heuston stations, as well as the LUAS and the planned Metro. If Transport 21 is fully implemented, the abatement potential would be 0.51 Mt CO_2 nationally, per year [17]. The total national investment for Transport 21 is estimated to be €34bn, of which €15.8bn

[7,8] See glossary

will be invested in public transport up to 2016 [17]. An abatement cost was not calculated due to the complex nature of the strategy.

- A number of fuel efficiency improvements associated with petrol engines have an abatement potential of 0.16 Mt CO_2, with annual running cost savings of €400 per car. Similar improvements applied to diesel cars would abate 0.13 Mt CO_2 and lead to annual savings of €360 per car.
- Increasing the share of biofuels in the fuel mix for vehicles to 12% by 2025 would lead to a reduction in carbon emissions of 0.12 Mt CO_2.
- The introduction of electric vehicles could reduce emissions by a further 0.05 Mt CO_2, if 12% of all cars were electric by 2025. (This study assumes that cars are charged primarily at night when electricity demand is lowest and that the electricity is generated from both fossil fuels [50%] and renewable sources [50%]).
- The introduction of a traffic management system in the Greater Dublin Area to improve traffic flow based on existing infrastructure has an abatement potential of 0.02 Mt CO_2.
- Replacing public buses with hybrid buses could abate an additional 0.02 Mt CO_2. Similarly replacing heavy commercial vehicles with hybrid drive vehicles could abate 0.02 Mt CO_2.

Note: For all calculations involving fuel, an oil price of $60 per barrel is assumed between 2005 and 2025 [18]. Higher energy prices (such as those experienced in 2008 when oil reached $120 per barrel) would lead to a significant decrease in the abatement costs of each technology. For example, at $60 per barrel, the abatement cost of replacing the existing bus fleet with hybrid diesel buses is €40/t CO_2 in 2025. However, if oil increases to $120 per barrel then the abatement cost of implementing hybrid buses becomes a saving of €110/t CO_2 in 2025 (see Figure 1.6).

Comparison of abatement cost variation (2025) based on crude oil prices

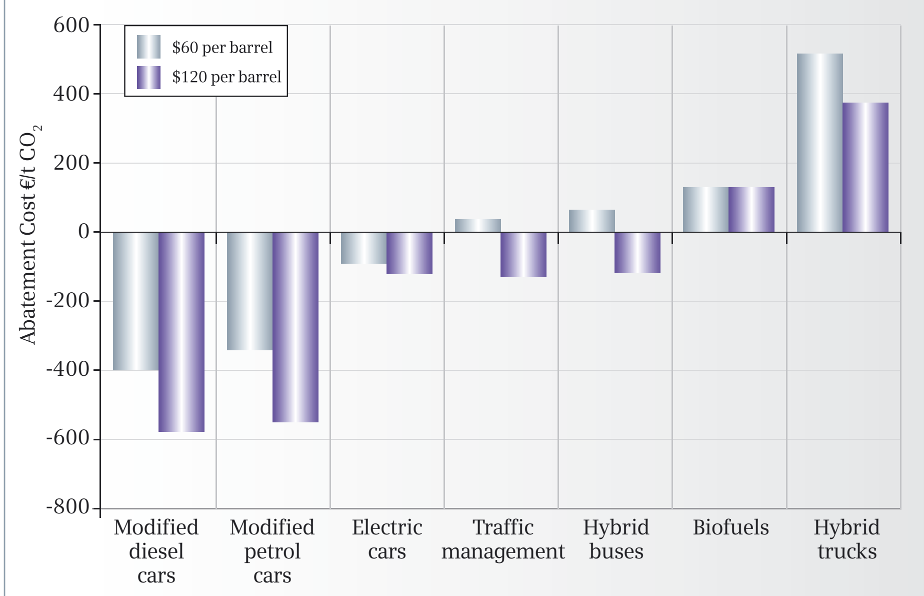

Figure 1.6

Buildings and Lighting:

The abatement potential of implementing certain technological levers in both residential and commercial buildings is 1.14 Mt CO_2 in 2025. For residential buildings, the key levers are insulation measures and energy management systems. Other levers include the replacement of sodium based lighting systems with LED alternatives.

- Retrofitting of buildings in the residential sector offers the largest single abatement potential with an annual reduction of carbon output by 0.78 Mt CO_2. This lever includes a number of insulation measures such as solid wall insulation, implementation of low-emissivity double glazing (energy efficient insulating glass) and draught proofing. Retrofitting could also save investors about €150m per year in energy costs net of investment.
- Upgrading to more efficient domestic appliances (washing machines, dishwashers, fridges) could provide a further reduction of 0.12 Mt CO_2 with annual energy savings for investors of €24m.
- More efficient lighting in buildings could lead to an annual reduction of 0.19 Mt CO_2 and save investors approximately €78m annually in energy and maintenance.
- Replacing sodium street lights with LEDs (light emitting diodes) has an annual abatement potential of 0.02 Mt CO_2 with savings of over €8m annually in energy and maintenance.
- Replacement of inefficient ventilation systems with heat recovery systems in commercial buildings would lead to an abatement of 0.04 Mt CO_2 with associated savings of €52m annually for investors.

Key finding 6: Economically profitable strategies also exist to substantially reduce water usage and waste to landfill.

Water

The average Dublin resident consumes 145 litres of water per day, which amounts to 53,000 litres per capita per year [19]. Dublin city loses 20% of its water due to leakages and in response the city council has put in place a Leak Reduction Programme [20]. While this goes some way to addressing the city's water issue, Dublin still faces future potential water shortages and should consider options for reduction

Levers that pay back their investment by 2025

- City district heating scheme
- Gas fired CHP
- Domestic commercial biomass
- Modified petrol cars
- Modified diesel cars
- Domestic appliances
- Residential lighting
- Building retrofitting
- Commercial building heat recovery
- Commercial/industrial lighting
- Improved lighting controls
- LED street lights
- Windows
- Dual flush toilets
- Aerated taps

Levers that do not pay back their investment by 2025

- Vehicular biofuels
- Hybrid trucks
- Traffic management
- Hybrid buses
- Water meters

on the demand side. Although businesses are charged water rates, Dublin is one of the few European cities where householders do not pay for water. Charging for water creates an incentive for people to consume less. This report identifies levers that can reduce water demand by more than 10% (6.8 million cubic metres) from 2005 levels per year by 2025.

- If domestic metering and charging (€0.0015/litre) were introduced they would lead to a reduction in water consumption of 4.3 million cubic metres in 2025.
- The implementation of other water saving devices, such as aerated taps and dual flush toilets, would lead to a combined saving of over 2.5 million cubic metres of water.
- Improved water pump efficiency would decrease the energy consumption of water stations, leading to reductions in CO_2 emissions associated with water production.

Waste

Irish people on average produce the largest amount of municipal waste in the EU at 824 kg per capita [21]. In 2007, residents of the Dublin region produced approximately half a million tonnes of household waste [21]. At present, any waste not recycled is sent to landfill which is not a sustainable option. While reducing the volume of waste is largely a behavioural issue, there are a number of interesting technologies for waste treatment. Waste to energy technologies can supply thousands of households with electricity and heat.

- The implementation of an incinerator in Dublin (due to open in 2012), could convert up to 600,000 tonnes of waste each year into energy, providing enough electricity to power up to 50,000 homes. It could also provide hot water for district heating schemes in the area for up to a further 60,000 homes [22].
- In addition to incineration, anaerobic digestion is an appropriate treatment for what is unable to be recycled.
- Nonetheless recycling is the cheapest and most sustainable solution to diverting waste from landfill as long as the waste being recycled is treated in an environmentally friendly way. Last year 40% of Dublin's municipal waste was diverted from landfill and sent to be recycled [23].

Water reduction potential in 2025

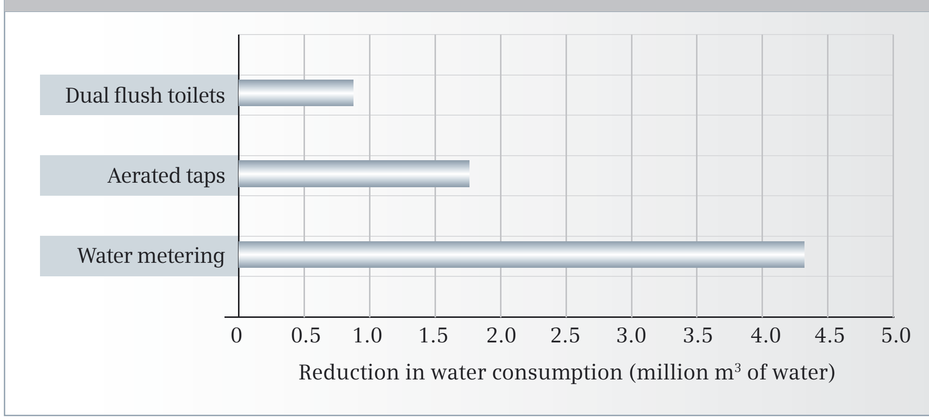

Figure 1.7

Water reduction costs in 2025

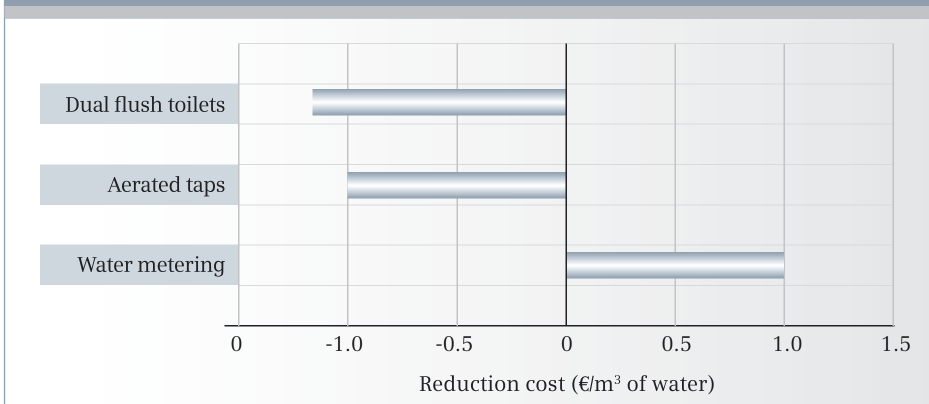

Figure 1.8

Key finding 7: 75% of these solutions will pay for themselves

Our study shows that the required incremental investment for all the levers outlined in this study (excluding Transport 21, renewable electricity generation and the infrastructure to support electric cars) amounts to approximately €2.6 billion until 2025, which is less than 1% of Ireland's projected GDP over the same time period [24]. This is roughly in line with the findings of the Stern report [25], which places the cost of slowing the impact of greenhouse gases at approximately 1% of global GDP per year. Should nothing be undertaken, the Stern Report estimates that an unchecked rise in global temperatures could cost up to 5 -10% of the global GDP.

A significant number of the levers discussed require large initial investment, yet 75% of them would pay back their capital cost within 10-15 years. These levers would also deliver approximately €430m in savings per year by 2025 through reductions in energy and fuel consumption.

Therefore, investment in these technologies (as opposed to paying carbon penalties) makes strong economic sense as well as helping towards meeting Ireland's emissions targets.

Key finding 8: Fashionable solutions are often an expensive means of reducing carbon emissions

Some technologies, despite being perceived at the cutting edge of green, are not yet capable of reducing carbon emissions in a cost effective way. For example in Ireland, photo-voltaic (PV) cell electricity generation systems, and hybrid cars, whether petrol based or diesel, are all still more expensive than other approaches to energy generation, or transport [1].

Of course, technological development is rapid. Between 1975 and 2003, for example, the cost per kWh of solar PV dropped by over 90% [1]. Nevertheless, many fashionable green technologies are likely to remain expensive choices in this forecast period. So while they play a visible, symbolic role in efforts to combat climate change, it is out of proportion to their current contribution.

Key finding 9: Sustainability issues need to be seen holistically, not in silos

Many sustainability challenges are interconnected in surprising ways, requiring complex thinking to develop solutions. One example for Dublin is in the area of traffic management. More efficiency here would improve the flow of vehicles and could potentially abate 0.02 Mt of CO_2 emitted. On the other hand, making roads easier to navigate might lure users of public transport back into their cars. Of course, making public transportation more attractive or discouraging individual transportation through toll systems where alternative options are available, can prevent this from happening. For example, in London, the introduction of a congestion charge proved successful in discouraging commuters from travelling by private car.

Similarly, although gas-fired CHP is currently one of the most promising decentralised energy generation technologies for Dublin, its ecological viability depends on the carbon intensity of the alternatives available. If the national carbon emissions from electricity generation are below a certain amount (0.22 t/MWh), then gas-fired CHP would provide no carbon benefit at all. For example, in countries such as France, where nuclear power is responsible for a large proportion of electricity generation, the carbon intensity of the national grid is very low. In such countries/cities, the installation of gas fired CHP would not be beneficial.

A similar, but positive, connection is seen in waste: using advanced waste treatment such as anaerobic digestion not only reduces the need for landfill, but also reduces the methane (a greenhouse gas 21 times more detrimental to the environment than CO_2) emitted from dumps and creates biogas that can be used to replace other fossil fuels.

Key finding 10: A strong stimulus in economically difficult times

The global financial crisis and economic downturn have displaced the challenge of climate change in the headlines. In many economies, including our own, the question has been posed: "Can we tackle the climate challenge and the economic crisis - at the same time?" The key message of this study is that "Yes we can!"

Economic growth and fighting climate change are not mutually exclusive. Technology is the key to reducing greenhouse gas emissions and it is also the engine that drives modern knowledge-based economies. Climate change is happening now and will pose catastrophic consequences for all of us if we fail to act decisively today. Investing in technology, along with behavioural changes are collectively the best way for Ireland to tackle its emissions targets head on.

The lowered emissions arising from the economic downturn is a transitory effect that must not deflect from the urgency of the situation or lead to complacency among society and political leaders. Any reprieve will be short-lived so we should not delay in taking action on climate change, otherwise we will be faced with a situation of even higher emissions once the economy picks up again. We must continue to implement the measures at our disposal to reduce emissions and prepare the way for low carbon economic growth.

Implementing the various technological levers will help create jobs, particularly welcome in the current economic climate. Investing in the region's infrastructure will also improve the general quality of life for city residents and increase Dublin's appeal as a "city state" in the battle for attracting future foreign investment.

Retrofitting of buildings, energy performance management and lighting projects would provide a welcome stimulus to the construction sector. Large scale infrastructure projects in areas such as renewable energy, district heating and public transportation have the potential to deliver thousands of jobs.

Looking forward - We have the technology - we can do it!

Making the case for change may appear straightforward because most of the levers that cut carbon emissions pay for themselves eventually through reduced energy consumption. Nonetheless, given the complexity of urban society and the varied stakeholders involved in making sustainability-related decisions, implementing them is a challenge.

Government and local authorities have a key role to play in making sustainable strategies successful through incentives, information and regulation. The public sector also is uniquely placed to lead by example and we welcome many of the positive initiatives already underway in this regard, such as the York Street Redevelopment.

Dublin's four local authorities and national government must continue to assume a leadership role by driving the adoption of technological levers and promoting behavioural change. Consumers, as businesses and individuals, must be exposed to information which explains their role in reducing carbon emissions through different lifestyle choices and purchasing decisions.

It is important that any new strategies/policies address the gaps between those who invest in the sustainable solutions and those that receive the financial benefits. For example, the cost of insulating rented accommodation lies with the landlord, yet the tenant receives the energy saving benefits through cheaper bills. The introduction of the Building Energy Rating (BER) encourages landlords to make such investment.

This study is a stepping stone for Dublin, shedding light on major challenges inherent in creating a sustainable city. By investing in the technological levers and encouraging behavioural change through strong public policy, there is a real opportunity to put Dublin at the vanguard of sustainable development.

Methodology

Sustainable development can be defined in numerous ways, but it is frequently expressed as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [26].

This study follows a methodology used in an earlier study commissioned by Siemens for the city of London [1]. Relevant technological levers used in the London study were transposed to Dublin based on assessment of associated assumptions and raw data. This report focuses on the Dublin region, which consists of the four county council areas. It examines CO_2 emissions associated with energy production and energy demand (buildings and transport), as well as assessing the role of water consumption and waste disposal in the region. It focuses on the direct impact the region exhibits, but does not consider indirect carbon emissions such as those embedded in manufactured goods consumed in the city but produced elsewhere.

Environmental issues such as noise and electromagnetic pollution are not considered. Similarly, the broader economic or social aspects of sustainability, such as poverty, inequality, health and human rights have not been considered. Instead, the report seeks to provide a clear environmental profile of where Dublin stands today, and how the use of a variety of technologies can help achieve key sustainability goals by 2025.

In order to assess the value of adopting possible methodologies that possess the potential to improve sustainability performance over time, the report projects a likely scenario, or baseline, for each sustainability area through to 2025. A 'constant technology adoption' approach is utilised, which assumes that the current level of technological adoption will remain unchanged between now and 2025. For instance, the energy efficiency of newly built houses will remain unchanged from their efficiency today and consumers will continue to purchase appliances with the same energy efficiency as they do presently.

As a result, the baseline takes the increased adoption of the technologies of today into consideration, but does not reflect any improvements in their efficiency. In addition, no further measures beyond those already decided upon or implemented are taken into consideration. This means that the calculations take likely changes into account, such as the impact of power plants currently under construction that will come online during the forecast period, but does not speculate on possible measures that may or may not be introduced. Consequently, the estimates provided can be considered to be conservative.

For each infrastructural area detailed in this report, excluding waste, graphical representations of the abatement potential and associated cost implications are provided. Interdependencies between the technological levers are not considered (except in the water sector where water metering is linked with all other levers). The key findings documented are the abatement potential and the abatement cost of each lever. The abatement potential refers to the amount of CO_2 emissions in mega-tonnes (Mt) that can be reduced per year by implementing each lever while the abatement cost refers to the cost or saving in euros per tonne of CO_2 abated. These savings or improvements are calculated in comparison to the reference technology in the baseline scenario. The running and investment costs associated with each technological lever, in comparison to its corresponding reference technology, are taken into consideration during calculations. A negative abatement cost implies that the financial benefits associated with its utilisation (energy savings, reduced maintenance costs, etc.) exceed those of the reference technology over time.

For all calculations involving fuel, an oil price of $60 per barrel is assumed between 2005 and 2025, based on a forecast by the International Energy Agency [18]. Higher energy prices (such as those experienced in 2008 when oil reached $120 per barrel) would reduce their abatement costs, making them more economically attractive. Similarly electricity/gas prices quoted by Sustainable Energy Ireland were used in all energy calculations.

It should be noted that all investments calculated in this report refer to the additional capital expenditure required over and above the baseline assumption of constant technology adoption. In some cases (e.g., insulation), no investment costs are assumed in the baseline which means that the figures refer to the total investment cost associated with the implementation of that lever (e.g., installing the insulation). In other instances (e.g., energy-efficient appliances), where investment will occur over the period in any case (but on an


Image courtesy of Dublin City Council

alternative technology), the investment reported is the difference between expenditure in the baseline and the additional expenditure associated with the acquisition of the more efficient technology.

In total, this report identifies 19 technological levers, that possess the potential to reduce greenhouse gas emissions across buildings, transport and energy supply. Levers with the potential to reduce water demand are also suggested, as are possible strategies for the reduction and treatment of waste. In selecting all of the technological levers, only technological solutions that, according to current knowledge, possess the ability to have an influence by 2025 are considered. Emerging technologies, where costs and benefits cannot be reasonably assessed, are excluded from consideration.

Behavioural change, in terms of people having to change normal habits (e.g., altering driving patterns or turning down thermostats) is not considered as such activity cannot be subjected to the same rigorous and objective analysis as the technological levers. The only behavioural change included is that attributed to the purchasing decisions (e.g., choosing to change a boiler or buying a car with better fuel efficiency). Furthermore, assumptions about realistic implementation rates for the technologies are made, such as the proportion of cars that will be powered by hybrid engines by 2025.

KEY POLICY DOCUMENTS

The National Climate Change Strategy 2007-2020 [27]	Outlines and analyses domestic policy to achieve EU targets (20-20-20) and the Kyoto Protocol.
National Development Plan 2007-2013 [28]	Major focus of this plan is on investment in physical infrastructure to support progress, education, science, technology and innovation. It also summarises the government funds set aside for purchase of carbon credits, waste management and water treatment.
Energy White Paper: 'Delivering a Sustainable Energy Future for Ireland' [7]	Sets out substantial and ambitious targets including: • 15% electricity generation from renewables by 2010; 33% by 2020 - increased to 40% in December 2008. • Installed capacity of combined heat and power (CHP) target: 400MW by 2010, 800MW by 2020. • 500MW capacity from ocean energy by 2020. • 5.75% penetration of biofuels by 2010.
Dublin City Council Climate Change Strategy [29]	Focuses on action items set out in five main sectors: energy, planning, transport, waste management and biodiversity for Dublin city.
EU Biofuels Directive [30]	Target of 5.75% of petrol and diesel consumption in transport to be replaced by biofuels in 2010.
EU Landfill Directive [31]	Target to reduce the amount of national waste sent to landfill from 1,300,000 tonnes of waste in 1990 to 450,000 tonnes in 2016.

Dublin's Sustainability Challenge

Cities are the largest contributors to global climate change. Although they cover just 1% of the earth's surface, they account for 80% of the world's greenhouse gas emissions and consume 75% of energy used. Their population density gives rise to a number of environmental challenges ranging from potential water shortages to trapped heat between buildings. That is why sustainable solutions for metropolitan areas are more important than ever.

As the capital and economic hub of Ireland and home to a quarter of its population, this report draws extensively on the experience of Dublin as a primary case study. While Dublin has a range of sustainability issues common to many other urban areas, the city faces its own unique challenges.

Unlike other European countries, Ireland experienced rapid economic growth during the 1990s, which was preceded by a period of lack of infrastructure spend. This created its own environmental side effects. Greater prosperity brought with it a construction boom, an increasing population, urban sprawl and severe traffic congestion, all of which contributed to an increase in emissions in the Dublin area.

As a result, Dublin per capita emissions at 9.7 tonnes are higher than many other developed cities. In London the per capita emissions are 6.3 tonnes per annum, while smaller cities, which are more comparable to Dublin such as Munich and Edinburgh, emit 8.5 and 7.5 tonnes per annum respectively.*

While cities and urban areas are part of the climate change challenge, they can also offer opportunities for sustainable living. Through better transport planning, better building design and retrofitting, along with more efficient energy generation and usage, cities by their population density and economies of scale, can foster

* Figures quoted from 2006

greener lifestyles.

The Government's Transport 21 strategy, which is designed to address Ireland's transport infrastructure deficit, includes plans to improve public transport in Dublin and ease congestion in the city. Transport emissions have seen the most notable increase over the past decade and currently account for 23% of Dublin's total emissions at 2.9 Mt CO_2 - 87% of which can be attributed directly to private cars and road freight.

A large amount of Dublin's emissions come from buildings - annual per capita tonnes from these are 5.4 tonnes compared to 2.6 in Stockholm. Dublin's low performance arises mostly from wasted heating energy, which results in the city emitting more CO_2 per person than Stockholm, despite its milder climate. CODEMA's 'Energy Smart Community' plan to retrofit clusters of houses of the same type and age to make them more energy efficient, testify to Dublin's ambitions towards sustainability. CODEMA is a leading agency for energy and sustainability in Dublin.

While many stakeholders influence sustainable policy, the advantage of cities is that they have the opportunity to take a holistic approach. Dublin has already undertaken many initiatives to address environmental issues, including Dublin City Council's programme for sustainability and the activities of CODEMA.

This report seeks to support Dublin and other cities in theirs efforts, by examining how technology can help create a sustainable future. We invite you to consider the solutions offered in the following chapters in the areas of energy, transport, buildings and lighting, water and waste, where we present the first comprehensive analysis of costs and CO_2 abatement potentials of various technologies for the Dublin region.

Energy

This section summarises the abatement potential and abatement cost of technological levers, which could be implemented both at a regional level (throughout the four county councils) and nationally, in order to reduce carbon emissions in the energy sector. The main issue Ireland faces in the energy supply sector is the high proportion of fossil fuels in the national grid mix. In 2006, 92.5% of the Irish grid was supplied with electricity generated by fossil fuels, 45.3 % of which was from natural gas.

Key findings:

- The CO_2 emissions associated with the supply of energy in the Dublin region, in which fossil fuels currently play a dominant role, could be reduced by 1.53 Mt by 2025, if all measures outlined in this section were implemented.
- Of those examined, the lever that would have the largest impact on Dublin's emissions, would be the increase in the share of renewables feeding the national grid to 40% by 2020. This would lead to an abatement of 1.34 Mt CO_2 for Dublin alone, which accounts for 40% of the total savings outlined in this report. The investment required to implement the required capacity in the period up to 2020, is estimated to be €9.45bn [15].
- The implementation of a citywide district heating system in Dublin offers the next highest abatement potential. This system would abate 0.15 Mt CO_2 in 2025, while utilising heat resulting from electricity generation that would otherwise be unused and wasted.
- Installation of a number of gas fired combined heat and power (CHP) plants (with thermal capacity range of 0.5-10 MW) would provide substantial potential for emission abatement at 0.03 Mt CO_2. This would lead to savings of up to €90 per tonne abated.
- Addition of biomass boilers to the district heating system (approximately 5% of the installed district heating system's capacity) would lead to an abatement of 0.01 Mt CO_2.

With regard to electricity consumption, Dublin does not rank as particularly wasteful from a global perspective, compared to other developed cities. The average Dublin resident uses 5.65 MWh annually, which is less than equivalent personal usage in New York, Tokyo or Paris, all of which consume more than 6 MWh per capita, but slightly higher than that of Londoners at 5.3 kWh [1].

However, carbon emissions associated

Summary of energy technological levers		Abatement potential	Abatement costs	Required investment
Lever name	**Brief description**	Mt CO_2 in 2025	€/t CO_2	€m
ENERGY				
Renewable electricity generation	Increasing the share of renewables, which supply the Irish grid to 40% by 2020	1.34	-110	9450
District heating	Implementation of district heating system of thermal capacity 535MW	0.15	-200	780[1]
Gas fired CHP	Implementation of a number of gas fired CHP plants each with capacities of between 0.5-10MW Total capacity 100MW	0.03	-90	27
Commercial/domestic biomass	Incorporation of biomass boilers district heating system with installed capacity 26MW	0.01	-50	4

Figure 4.1

[1] There are many factors which influence the required investment for the district heating system such as retrofitting the power stations at Poolbeg. Due to the complex nature of the network the total investment given is a rough estimate.

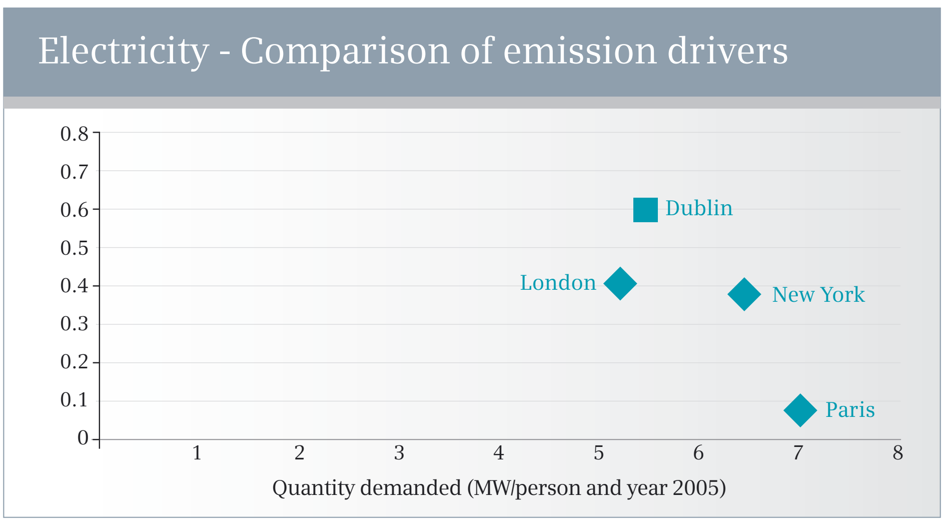

Figure 4.2

with electricity use in Dublin are directly driven by the carbon intensity of Ireland's grid mix. Over 90% of Irish electricity comes from fossil fuels as follows: 46.4% natural gas, 24.3% coal, 13.3% oil and 8.5% peat. Renewables account for 4.5% of the total and electricity imports make up the remainder [32].

Overall, the proportionate use of fossil fuel in Ireland is significantly higher than in other countries. As a result, Dublin's electricity has the highest carbon intensity, at 0.54 tonnes of CO_2 per MWh, among the cities reviewed for this study [33]. This surpasses that of London by nearly 35% (0.4 tonnes CO_2 per MWh) and is considerably higher than Paris (0.07 tonnes CO_2 per MWh), which has one of the lowest carbon intensive electricity mixes [1]. This can be attributed to the role nuclear energy plays in electricity generation in France; approximately 80% of French electricity is generated through nuclear power.

Given increasing energy demand, the volatility of world energy prices and Ireland's vulnerability to security of supply issues and the unsustainable nature of CO_2 emissions over the long-term, Dublin should assess its energy supply options and take this opportunity to improve the overall sustainability of the city.

Identified reduction potential: It is important to highlight that the megawatt avoided – or "negawatt" as it has been termed, is by far the most effective and sustainable way to secure low-carbon electricity supply, given that many options for making power generation less carbon-intensive are expensive [34]. Demand reduction should, therefore, be a key component of any sustainable electricity supply strategy.

This chapter deals with the technology options that can make electricity production for the greater Dublin area less carbon-intensive, initially by considering those levers that the city can influence directly at a local level, before considering what could be achieved at a national level. Four technological levers were considered as follows: power generation through renewable sources, gas engine CHP, commercial/domestic biomass and district heating as outlined in Figure 1.1. Considering all of these strategies, the technology levers outlined in this chapter offer a total abatement potential of approximately 1.53 Mt CO_2.

Power Generation Dublin: Dublin city contains four generation sites all located in the Dublin docklands area. The four stations have a combined capacity of approximately 1600 MW and currently supply approximately 22% of total Irish electricity production. The Electricity Supply Board (ESB) operates three stations in the Poolbeg area, an older thermal station (461 MW) and a combined cycle gas station (470 MW) at Poolbeg as well as a 266 MW gas fired station at North Wall. The ESB has announced that the thermal station will be decommissioned in the next five to 10 years, with an estimated reduction in emissions of 0.9 – 1.3 Mt CO_2 per annum. This is in line with the White Paper forecast, which assumes from 2008/2009 onwards, that no electricity in Ireland will be generated by oil-fired systems [7]. In addition to the three ESB stations on the Poolbeg Peninsula, another company, Synergen, houses a 400 MW gas-fired combined cycle plant [35].

At a city-level, Dublin has a range of options available for introducing less carbon-intensive technologies for power generation, which are summarised in Figure 1.1. The National Climate Change Strategy (NCCS) has set the following targets for energy supply in Ireland between 2007 and 2020 as follows [27]:

- 15% of electricity to be generated from renewable sources by 2010 and 33% by 2020. (Since the publication of the strategy the 2020 target has been increased to 40% by the Irish Government, some 20 % above the EU target).
- Biomass to contribute up to 30% of energy input at peat stations by 2015.
- Combined heat and power: 400 MW installed capacity by 2010, 800 MW by 2020.
- National Ocean Energy Strategy – this is a four phase strategy which provides support for the development of a 10 MW pre-commercial grid connected to a full-scale array of ocean energy converters between 2011 and 2015, the results of which will determine the total capacity that will be feasible for Ireland.

These targets, though not all applicable in Dublin, will at the very least indirectly affect the carbon intensity of the electricity consumed in the Dublin region and its associated emissions.

Increasing electricity generation from renewable sources provides the most effective way of reducing greenhouse gas emissions from power generation. If Ireland meets its 2020 target of 40% renewables contribution to the national grid, it will result in a reduction of 4.00 Mt CO_2 nationally or 1.34 Mt CO_2 for the Dublin region (assuming all areas within Ireland are supplied with an equal proportion of electricity generated from renewable sources) [15]. To achieve this, renewable power connected to the system will have to increase four-fold between now and 2020, from the current capacity of almost 1,200 MW to an estimated 5,000 MW, consisting mostly of wind power. Onshore wind energy accounts for the highest percentage of electricity produced by renewable sources in Ireland (65.5%) [32]. However, due to relatively low winds speeds in the Dublin region (less than the required 5.5 m.s-1), coupled with planning and technology issues, the widespread deployment of wind generation in the Dublin region has not been feasible.

Besides wind, solar energy is the most high profile of renewable technologies to date. Solar thermal power is another electricity generation alternative to fossil fuels. Solar roof panels for hot water production have been installed in existing buildings within some recent developments in the Dublin region, such as the York Street redevelopment initiative [29]. Another alternative energy source can be found in the Ringsend wastewater treatment plant, where the city is recovering the methane that is formed when sludge is treated and the methane gas is burned for electricity production.

However, the overall carbon abatement potential of some of these technologies is relatively limited and the potential for their installation varies largely according to climate. For instance, solar energy production in southern European latitudes would be twice as productive compared to Ireland. Despite these issues, the uptake of renewable energy remains high.

By contrast, the introduction of combined heat and power (CHP) in its various forms, gas-engine, biomass, waste to energy, etc, collectively offer far greater abatement potential, approximately 0.19 Mt CO_2 annually by 2025. In the right circumstances, CHP can be an economic means of improving the efficiency of energy use and achieving environmental targets for emissions reduction. CHP usually involves the burning of fossil fuels, but heat and electricity can also be produced from biomass (including biogas and waste). Of the various CHP options, gas-engine holds the greatest potential for the greater Dublin region, particularly for mixed residential and commercial use.

In order to stimulate the development

of CHP plants, the Irish Government is offering support under the CHP Deployment Programme [36]. This scheme includes support for a wide range of CHP installations, from small scale CHP to large scale biomass-fed CHP, as well as additional research and development supports. The Government target for CHP is to achieve an installed capacity of 400 MW by 2010 and 800 MW by 2020 [7].

Currently, there are 72 CHP plants located in the Dublin region, nearly all of which are gas fired and typically provide a capacity between 0.1 and 10 MW. The total capacity of these 72 plants is 35.8 MW, which accounts for 11.5% of total Irish capacity. This may appear disproportionately small, considering the high population density of the Dublin region, but can be explained by the predominance of a large number of relatively small units in the services sector, whereas the bulk of large industrial CHP tends to be located outside the Dublin region. The main CHP users in the Dublin region tend to be in the services sector and include: hotels, hospitals and leisure centres [36].

The economics of CHP as a source of heat and power depend on the particular fuel being used and the size of the operation. The benefits of CHP are heavily influenced by the correct deployment within its context. First, CHP requires a particular usage pattern. As the name itself suggests, CHP works best in situations where there is a simultaneous demand for heat and power. In effect, the waste heat from power generation, whatever the fuel, ceases to be waste because the heat is actually a required outcome. On a neighborhood scale, in order to provide a consistent, high demand for heat, CHP consumers should be a mix of residential, commercial and industrial users. If correctly combined, the varying demands of these groups would ideally provide a relatively steady demand throughout a typical 24 hour cycle. The lack of energy-intensive industry in Dublin, however, while reducing overall emissions, also reduces the scope for CHP, by taking one possible element out of the user mix. Nevertheless, opportunities still exist. For example, large commercial/residential developments like Elm Park, Booterstown, fit the brief for CHP use.

Second, to be more economically attractive, CHP plants should sell excess electricity to the national grid where feasible. Between the 72 CHP plants in the Dublin region, 1630 MWh of electricity is exported to the national grid on an annual basis [37].

Third, the carbon benefit of CHP depends on the grid mix of the electricity that it replaces. For example, gas-engine CHP, the most effective and financially attractive form for existing building stock in the Dublin region, only reduces CO_2 emissions in situations where the grid provides electricity with carbon intensity greater than 0.22 tonnes of carbon per MWh [1]. This makes it suitable for Dublin, as the carbon intensity of the grid is expected to remain markedly higher than that for the foreseeable future. However, it would not provide carbon benefits in cities with less carbon-intensive electricity, such as Paris, where a comparable gas-fired CHP installation would have the effect of increasing overall carbon emissions.

If CHP capacity in the Dublin region was to be increased from 35.8 MW to 100MW by 2015, it would lead to a reduction in CO_2 emissions of 0.03 Mt. This strategy is based on installing a number of CHP plants of capacities between 0.5-10 MWe throughout the Dublin region. This increase in CHP capacity would assist Ireland in meeting its 2010 and 2020 targets of 400MW and 800MW nationally, as well as leading to cost reductions of approximately €90 per tonne of CO_2 abated.

Dublin district heating system: Possibly the most significant change that is planned for Dublin's energy supply is the proposal to implement a citywide district heating system in the coming decade. District heating is a system for distributing heat generated in a centralised location for residential and commercial heating requirements such as space heating and water heating. It allows the efficient use of thermal energy from CHP plants, refuse incineration plants, waste heat from industrial processes, natural geothermal heat sources, renewables like wood waste and residues as well as coal and peat.

District heating (and CHP) offer advantages in terms of higher energy efficiency, and reduced consumption of energy resources. It can also offer capital cost savings and reduced operating and maintenance costs. The proposed district heating network for Dublin will circulate hot water in an underground, pre-insulated pipe system (with supply and return lines). Despite the mild Irish climate, heating is necessary for several months of the year and domestic hot water is needed year round. In addition, there is a demand for cooling of hotels, offices and shopping centres during the summer season [38].

The initial development and propagation of a district heating scheme in Dublin could provide an essential and more sustainable energy efficient utility to a wide range of customers in the city.

Currently, the most extensive proposal for Dublin's district heating (Citywide District Heating Network) has a thermal capacity of 285 MW and includes input from the following: the planned waste-to-energy plant at Poolbeg, a central boiler station, Spencer Dock reserve boilers, Gatepower (Guinness), St. James Hospital energy centre and Heuston Square. As yet, there are no definite plans to include thermal power from the dockland generating stations. However, both facilities at North Wall and Poolbeg have recently indicated that they would be willing to evaluate possible connections to the network in the medium to long-term [38]. If this was to occur, the system would have a potential capacity of at least 535 MW [38]. Assuming this total capacity of 535 MW, there is potential for 0.13 Mt CO_2 to be abated. By 2025, this would have the potential to give rise to a saving of €200 per tonne of CO_2 abated.

The proposed waste to energy (WtE) plant (incinerator) at Poolbeg is currently expected to have a maximum thermal capacity of up to 150 MW. This maximum thermal output from the WtE plant alone will have the potential to supply the average annual heating requirements of 60,000 homes through the installation of the district heating network. It will also contribute an abatement of 0.04 Mt CO_2.

Commercial/domestic biomass: Biomass CHP could be incorporated into the proposed district heating system. Every kWh of heat replaced by biomass fuel represents a saving of fossil resources and a reduction in CO_2 emissions – the combustion of biomass is said to emit 0.025kg CO_2/kWh - about one-eighth of the emissions of natural gas [39]. Taking into consideration the total thermal capacity of the Dublin District Heating system (535 MW), there is scope for substitution up to 5% using biomass boilers. If this was implemented, it would lead to an additional reduction in emissions of 0.01 Mt of CO_2 in 2025, while leading to savings of €50 per tonne of CO_2 abated in the same year.

Future Expansion of the Network: Once a district heating network is established in the Dublin docklands, it is likely that district heating will be extended further. Other compatible developments, which could join the network, include [38]: Elm Park, developments at Dublin Port and older housing in the Ringsend and Irishtown areas of the south city or East Wall on the north side.

Irish National Grid Mix: The national grid presents a substantial opportunity for carbon abatement. Ireland's grid mix is already set to move away from coal and peat to gas, while introducing a higher proportion of renewable energies as discussed previously. Given the momentum for an increased share of renewable power generation by both the national government (40% by 2020) and the EU (20% by 2020), it is likely that renewable energy sources is one change which will have a huge impact on the national grid's carbon intensity in the coming years.

The traditional electrical grid, in which electricity is generated and then distributed across the country from large centralised facilities, is facing change in the coming decade. On one hand, demand patterns are likely to change with the use of energy-efficient appliances which will effect usage volumes and load distribution. On the other hand, electricity is now being generated in a less predictable manner, both time and spatially. Incorporating all these factors into the grid in a way that meets changing demand patterns, requires a novel way of managing electrical distribution. A concept that is beginning to gain attention is that of transforming the traditional national grid into a super-efficient and intelligent grid system [40].

The starting point for an intelligent power grid concept is smart metering. This entails installation of advanced meters in each home, with an in-house display, which will give consumers more choice and influence their behaviour around how they use electricity. Where there is a fully connected system, it becomes possible to exercise the ultimate control in a single energy market,

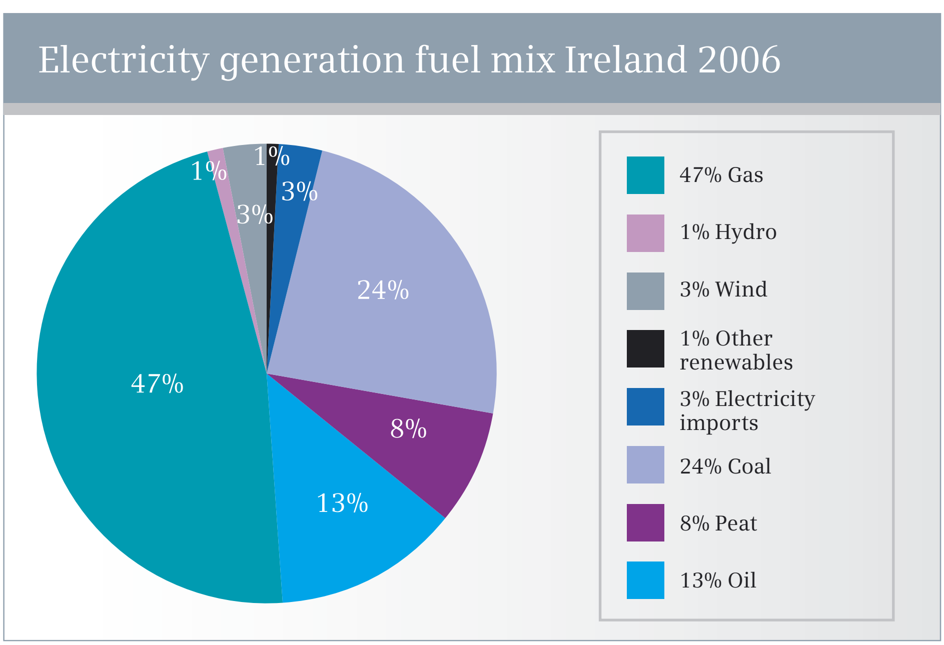

Figure 4.3

by literally switching suppliers at the push of a button. The concept of dynamic peak reduction will become more commonplace, where consumers can programme devices to switch-off at periods of high demand and avoid peak charges.

Smart metering technologies can also open the eyes of the consumer to the precise costs of leaving consumer appliances on standby. The intended effect of smart meter technology is to empower customers, giving them more choice about where they buy their energy from and make them more aware of their consumption patterns.

Enel SpA, the main Italian electrical utility with over 27 million customers, undertook the world's largest deployment programmme of smart metering between 2000 and 2005, when it deployed smart meters to its entire customer base. Enel has estimated the cost of the project at approximately €2.1bn and the savings they are receiving in operation of €500m per year, giving a four-year payback. According to the International Energy Agency (IEA), more than $16 trillion will be spent worldwide between 2003 and 2030, in pursuit of the smart grid vision. Several projects have been announced throughout Europe.

The Irish Government under the Energy Policy Framework 2007-2020 has commenced an extended trial of smart metering to be followed by a full national roll-out to all homes. The trial and further implementation will build on an initial trial in Dundalk being undertaken by SEI, and extend to up to 25,000 homes and possibly to small businesses. The trial involves CER, ESB Networks, SEI and other key stakeholders. All smart meter functions, from display to net metering and active control, will be tested, as will behavioural responses to different types of information [7].

Nuclear power: The issue of nuclear power in Ireland is one which has been surrounded by controversy. Ireland currently has no nuclear power plants, although a nuclear power plant was proposed in 1968. It was to be built during the 1970s in County Wexford, but was dropped in 1981 after strong opposition from environmental groups and because of flattening energy demand. In 1999 under the Electricity Regulation Act, it was made law that nuclear power cannot be used for electricity generation in Ireland.

However, despite opposing nuclear power and nuclear fuel reprocessing at Sellafield, Ireland is due to open an interconnector to the mainland UK to buy electricity in 2012, which is, in some part, the product of nuclear power and depending on the amount imported could have an effect on the carbon intensity of Ireland's electricity.

In April 2006, a government-commissioned report by Forfas pointed to the need to reconsider nuclear power in order "to secure its long-run energy security." In 2007, the ESB also made it known that it would consider a joint venture with a major EU energy company to build nuclear capacity.

However, given that nuclear power generation remains a controversial technology, with significant public and political concerns regarding both its safety and sustainability, it may be the case that it will never be a direct option in Ireland

Carbon Capture and Storage: One possible solution to Ireland's CO_2 emissions problem may be carbon capture and storage (CCS). This involves a relatively new and untested group of technologies for capturing the CO_2 emissions from large emitters such as power plants and industrial sites, compressing the CO_2 and transporting it to suitable permanent storage sites such as deep underground, either onshore or offshore. The main storage sites include geological storage (oil/gas fields), ocean storage and mineral carbonation.

Sustainable Energy Ireland released a report on CCS, which suggested that storing carbon dioxide offshore offers the best solution to the threat of climate change. The ESB's coal-fired power station at Moneypoint, Co. Clare is the single biggest source of greenhouse gas emissions in the State. However, its continued operation is fundamental to maintaining an appropriate level of diversity in the national fuel mix for electricity generation, so as to ensure security of electricity supply. SEI predict that undersea storage in the Celtic sea's depleted gas wells could reduce Ireland's emissions by 6% annually and that Ireland could potentially store all the emissions from electricity generation for the next 250 years under the sea [41].

A study carried out by McKinsey illustrates the capital costs and abatement potential of implementing hypothetical CCS systems in Europe. The study estimates the capital cost of non-CCS coal fired plant built in 2020 at €1.5bn, with the price rising by 50% if a CCS system was to be fitted to the station. Therefore, CCS is an expensive solution to CO_2 emissions in the short term. In the long term, however, the McKinsey study predicts it could offer a competitive answer, with costs for early commercial CCS projects expected to be between €35-50 per tonne of CO_2 [42].

While it appears to be an attractive solution to the CO_2 emissions issue, there is still considerable speculation by experts as to the feasibility of this technical solution. The capture technologies, for example, are based on those that have been applied to refining industries for decades, but the integration of this technology in the power production sector still needs to be demonstrated. There are reservations about the storage potential of deep saline aquifers that need to be resolved. There are also many public concerns regarding the environmental integrity of CCS, such as the issue of CO_2 leakage from the storage facilities. This uncertainty perhaps explains why there are no fully integrated, commercial scale CSS projects in operation currently.

However, the NCCS has set out guidelines on the topic of CCS and states that the potential for the use of carbon capture and storage, whether in new plant or by way of refitting existing plant, will be pursued in the period to 2020, in line with the pace and scale of technological and commercial development, as well as planning frameworks, in relation to these technologies [27].

Co-firing with biomass in power generation: Carbon emissions in the energy sector can be reduced by co-firing with biomass mass in power stations. For example, co-firing biomass with coal, results in less sulphur emissions than burning coal by itself. Biomass can be added to the fuel mix in coal, oil and peat fired systems. Because the majority of Dublin's power in the near future will be based mainly on gas fired power generation, this solution is not directly applicable to Dublin; however, it is a definite option on a national scale.

The Irish Government has already established a target for biomass to contribute up to 30% of energy input at peat stations by 2015, which will contribute to the achievement of the overall renewable electricity target for 2020 [27]. It is estimated that achievement of this target could reduce emissions from peat stations by 0.9 Mt CO_2 nationally per annum by 2015.

Implementation barriers: Potential for carbon abatement in power generation exists at both local and national levels, but so do the impediments. The barriers for decentralised power generation are primarily financial in nature. And in the case of energy supply, the cost tends to fall on Government and key stakeholders rather than the public. Therefore, cities can either be satisfied with the carbon reductions being brought about by other stakeholders, or must engage in creative market interventions to accelerate them.

Tighter building controls, planning requirements and the Energy Performance of Buildings Directive (EPBD), together with a growing awareness and demand for higher energy efficiency among consumers, has led to developers incorporating energy efficient technologies, such as district heating, in their development designs.

City leaders have to remain conscious of the fact that abatement costs associated with power generation are typically higher than those associated with better energy efficiency. Nevertheless, there are a range of interventions that can work at a city level. These include: using subsidies, taxes and regulation to tip the economic balance, such as supportive feed-in tariffs, paying the cost of distribution infrastructure for some solutions, such as a heat grid for CHP, and investing in a large number of local energy generation projects. Although this final point would entail the loss of certain efficiencies in large-scale power generation, introducing local power generation to match local usage patterns could cut waste.

The Government has already set up feed-in tariffs which are guaranteed for up to 15 years, but may not extend beyond 2024. During the first year, 98% of the feed-in tariff support has been allocated to wind farms. The Government intends to expand the feed-in tariff scheme to facilitate delivery of co-firing in peat stations of 30% by 2015 and to encourage waste to energy projects by supporting hybrid projects. The Government has already set up grants for those investing in biomass boilers with support of up 30% of the total investment cost available since 2007 and up until 2010.

On a city level, in accordance with the levers analysed in this chapter, the technology with the greatest potential for the city, is renewable electricity generation. This is followed by CHP, fired by gas or biomass. Implementing the proposed large-scale, low-carbon energy project to feed into the national grid, such as the Dublin District Heating System, would guarantee a significantly positive effect on Dublin's carbon footprint.

Abatement potential: energy sector

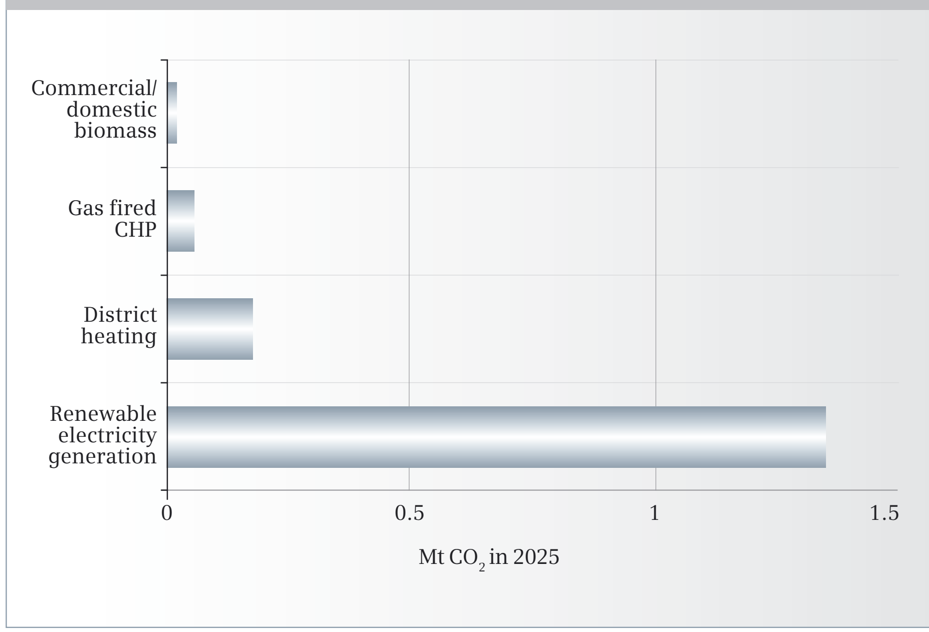

Figure 4.4

Abatement cost: energy sector

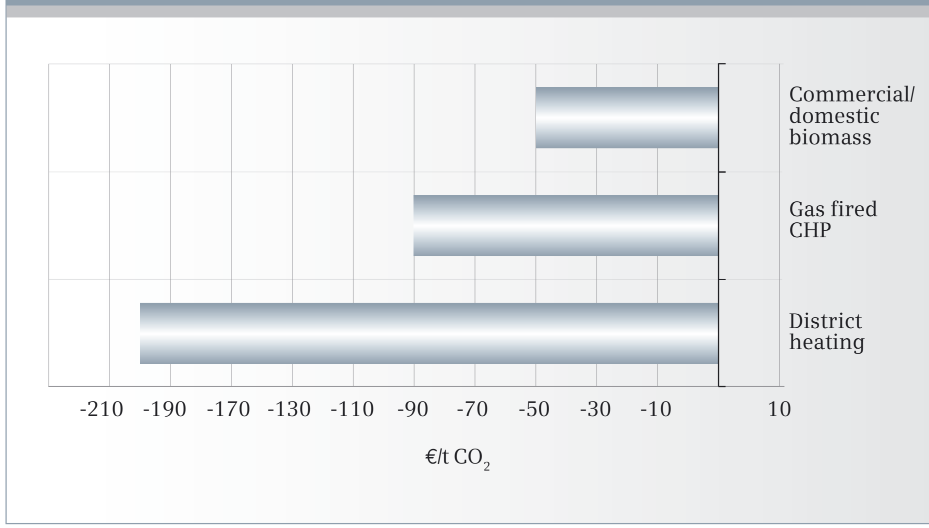

Figure 4.5

CASE STUDIES

Croke Park Green Initiative

Croke Park has been at the heart of Irish sporting life for over a hundred years. A total of 2.2 million people attended Croke Park in 2008, making it the biggest venue in Ireland. The Cúl Green initiative aims to make Croke Park a carbon-neutral stadium, with ambitious targets to reduce its carbon footprint over the next six years. In the immediate term, the new initiative will cut Croke Park's annual 4,500 tonnes carbon emissions output by more than two-thirds. A state of the art environmental-improvement programme covering the stadium's electricity, waste and water management systems is being put in place. Croke Park now contracts all its electricity from a renewable resource.

A website was launched to engage with fans, supporters and the general public to encourage them to commit to energy saving activities such as switching off lights and taking public transport to Croke Park. Cúl Green will increase awareness about sustainability and climate change across, not just for the Gaelic Athletic Association (GAA) family, but a far wider supporting public.

Wind Energy: Ireland

Ireland has one of the most promising, untapped energy resources in Europe – wind energy, and it is one of the few sectors where Ireland has the potential to gain a major competitive advantage over other European regions. The total contribution from renewable energy to gross electrical consumption in 2006 was 8.6%. Wind energy in 2006, accounted for 5.6% of Ireland's gross electrical consumption.

As of September 2008, there are 74 wind farms in operation in Ireland with a total capacity of 855 MW. According to Eirgrid, an additional 446.4 MW of wind power is contracted to be connected to the national electricity grid by 2010. Although most countries in Europe have much less favourable wind conditions, they have done more to develop their wind energy resources. Denmark and Germany have greater installed capacity. This is partially due to local authority investment, capital subsidies, mandated electricity purchases, investment subsidies and fiscal benefits, which are used to encourage community investment in wind energy.

Wind Energy: Middelgrunden wind farm Copenhagen

Wind energy is not the energy source that immediately comes to mind when thinking about renewable energy in cities, as few cities have enough space within their area to build large wind farms. However, this did not deter Denmark's capital city Copenhagen, where they constructed a large offshore wind farm, just 2 km from the city's coastline.

The Middelgrunden wind farm consists of 20 wind turbines of 2 MW each, with a rated power capacity of 40 MW. The offshore turbines are connected by cable to a transformer at the Amager power plant 3.5 km away.

The wind resource is limited, but due to the near shore sitting capital, the cost is as low as €1.2m per MW, including grid connection. The cost of electricity is €5.3 per kWh, including operation and maintenance. The total investment in the project was nearly €45m. The wind farm was developed and is owned fifty-fifty by Middelgrunden Wind Turbine Cooperative and the local utility, Copenhagen Energy. The wind farm provides 4% of the electricity for the city's 1.2 million inhabitants and has become a famous landmark of Copenhagen.

The avoided carbon dioxide emissions due to this development are estimated at 86,490 tonnes, with 81,000 tonnes attributed directly to carbon dioxide.

Transport

Transport sector emissions have seen the most notable increase over the past decade. Transport currently accounts for 23% of Dublin's total emissions at 2.9 Mt CO_2. The Dublin emissions data may be primarily attributed to a low population density resulting from a higher degree of urban sprawl. Public transport only accounts for 22% of journeys in Dublin, with 54% of people travelling via car or taxi, and the remainder walking and cycling (as shown in Figure 5.3). 87% of emissions can be attributed directly to private cars and road freight, with public transport accounting for just over 5% of total transport carbon emissions [10].

Key findings:

- The measures outlined in this section could in total abate 1.03 Mt of Dublin's transport emissions in 2025.
- Improving fuel efficiency of petrol cars has the potential to abate 0.16 Mt CO_2 across the transport sector, as well as resulting in financial savings of €350 per tonne of CO_2 abated per year through reductions in fuel consumption.
- Similar fuel efficiency measures applied to diesel cars would lead to reductions in emissions of 0.12 Mt CO_2, as well as resulting in savings of €370 per tonne of CO_2 abated per year through reductions in fuel consumption.
- The introduction of electric vehicles could reduce emissions by a further 0.05 Mt CO_2, if 12% of private cars in the region were electric cars by 2025. Fuel savings of approximately €300 per year per car would also be gained. (This study assumes that cars are charged at night when electricity demand is lowest. It also assumes that the electricity used for charging is generated from both fossil fuels (50%) and renewable sources (50%)).
- Public transport is more carbon efficient than private transport. However, any major change in commuting patterns would have to be superseded by a complete overhaul of the current infrastructure, in order to give commuters an incentive to switch from private to public transport. The implementation of Transport 21 should be the change needed to induce a modal shift in transport. It is projected that once the strategy is complete, 0.51 Mt CO_2 will be avoided in 2025. The total national investment for Transport

Comparison of abatement cost variation (2025) based on crude oil prices

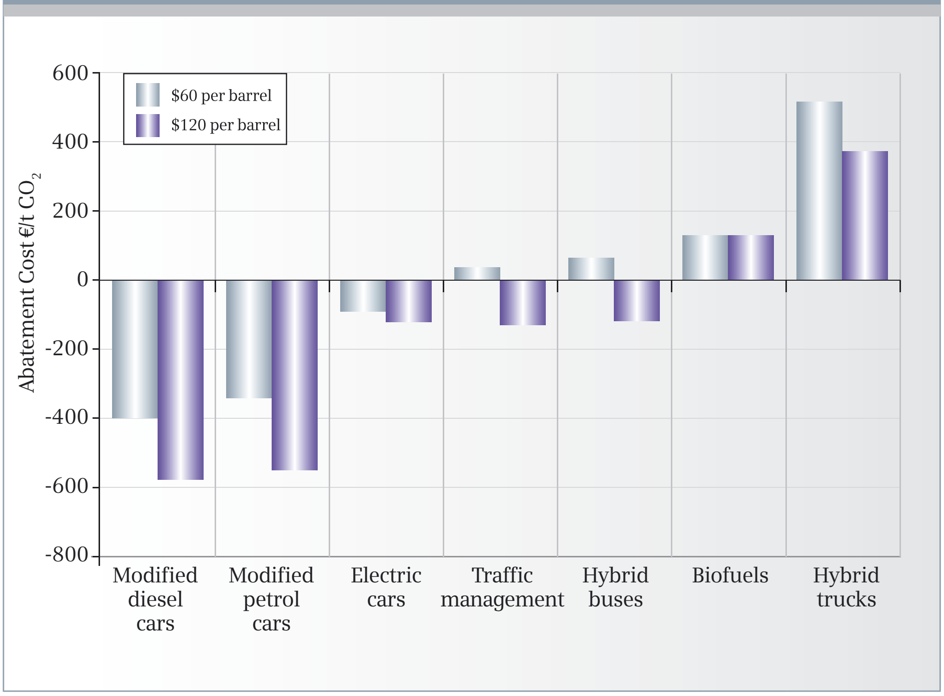

Figure 5.1

21 is estimated to be €34 billion. An abatement cost was not calculated due to the significant and complex nature of the strategy.

- For all calculations involving fuel, an oil price of $60 per barrel is assumed between 2005 and 2025, based on a forecast by the International Energy Agency [18]. Higher energy prices (such as those experienced in 2008 when oil reached $120 per barrel) would lead to a dramatic decrease in the abatement costs of each technology. For example, at $120 per barrel the abatement costs associated with the implementation of a traffic management system or hybrid buses would be -€120, and -€110 respectively (see Figure 5.1).
- According to the City of Dublin Energy Management Agency (CODEMA), behavioural changes, such as switching from private to public transport, could result in a further reductions of 0.06 Mt CO_2 in the 12 year period 2008-2020 or on average 0.005 Mt CO_2 per annum [10]. (This figure is not included in the final abatement total, as it is a projected figure based on available knowledge at the time. As it depends purely on human behaviour, the actual figure may be very different compared with the figures for technology which are not likely to change as radically).

As stated Dublin's annual carbon emissions resulting from transport are approximately

Summary of transport technological levers		Abatement Potential	Abatement Costs	Required Investment
Lever Name	**Brief Description**	Mt CO_2 in 2025	€/t CO_2	€m
TRANSPORT				
Transport 21	Implementation of integrated transport system in Dublin – including Metro North/West, LUAS upgrade, bus services improvement, interconnector/DART electrification	0.51	Not calculated	34,000
Modified petrol cars	Engine efficiency measures for private petrol cars	0.16	-350	270
Modified diesel Cars	Engine efficiency measures for private diesel cars	0.13	-370	75
Vehicular biofuels	Increasing the share of biofuels in the fuel mix to 10% by 2020 in accordance with EU Directives on Biofuels	0.12	120	N/A
Electric cars	12% penetration of electric cars by 2025	0.05	-60	Not calculated
Hybrid trucks	Full hybrid engines for heavy commercial vehicles	0.02	520	24
Traffic management	Optimisation of traffic flow leading to reduced congestion based on existing infrastructure	0.02	20	10
Hybrid buses	Full hybrid engines for Dublin Bus fleet	0.02	40	70

Figure 5.2

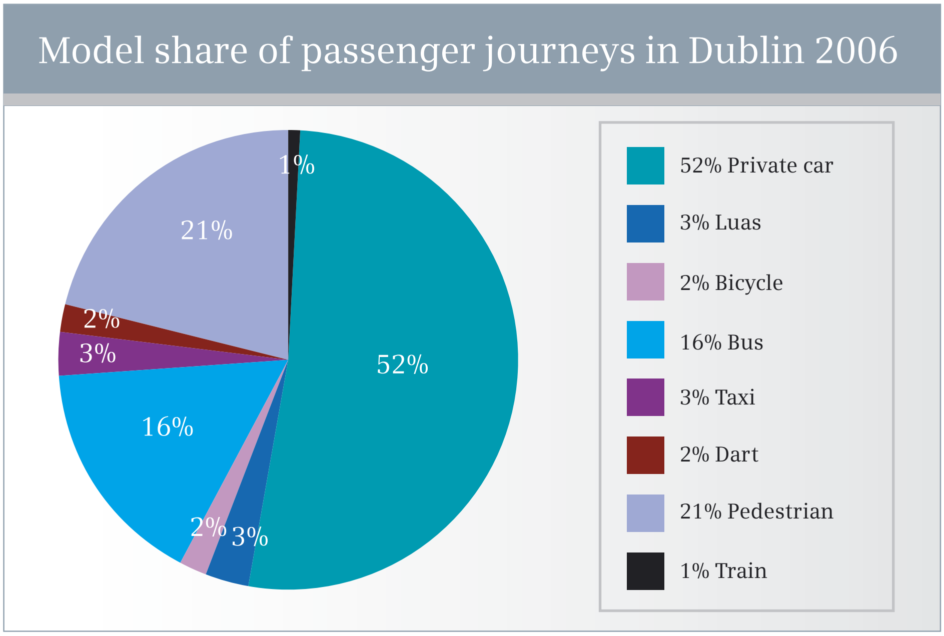

Figure 5.3

2.9 Mt CO_2 [10]. This amounts to 2.4 tonnes CO_2 emissions per person. These figures compare poorly to other urban areas, such as New York (1.8 tonnes per person) and London (1.6 tonnes per person).

From private to public transport: Technological levers, in the transportation sector, outlined in this study, if adopted would result in a reduction of 1.03 Mt CO_2 by 2025. Public transport is much less carbon intensive than private cars due to greater passenger numbers. Private cars produce approximately 115g of CO_2 per passenger per kilometre while public transport has lower emissions per passenger kilometre of 24g of CO_2 for the LUAS and 47g of CO_2 for buses [10].

While car emissions have decreased over the past decade, in part due to a voluntary agreement signed in 1999 between all manufacturers selling vehicles in Europe and the Commission, where the manufacturers undertook to reduce CO_2 emissions from cars by 25% between 1995 and 2008, the reductions have not been as much as expected. The Commission recently stated that "the strategy has brought only limited progress towards achieving the target of 120g CO_2/km by 2012." Therefore, a new proposal has been put forward for EU legislation to reduce CO_2 emissions from new cars and vans, which would require average emissions from new cars sold in the EU-27 to reach the 120g CO_2/km target by 2012. From this, it is expected that in general the energy efficiency of passenger cars sold in Ireland will continue to improve. However, without sufficient information and pricing incentives, people may not be aware of the least environmentally damaging vehicles on the market and choose vehicles with negative characteristics such as more weight, engine power and size. Therefore, while it appears that we can rely on regulations from the EU Commission to reduce the CO_2 emissions per vehicle, it is national legislation which may determine which vehicles are actually driven on Irish roads.

Significant improvements can be achieved through implementing energy efficient technologies to further improve public transport. Beyond technological levers, an obvious means of cutting carbon emissions would be to encourage people to move away from private cars. Reducing the number of kilometres driven by individuals and commercial vehicles in many ways is more difficult than finding a technological solution to emissions reduction on a per vehicle basis; however, it is the issue that we have most control over at national level. While European legislation can set the efficiency of the vehicles sold, Irish policy will determine how much people actually use their vehicles. A temporary solution may be sought in the form of a carbon levy or fuel taxes which, although not designed to address congestion, reduce the incentive to drive more miles. Carbon levies have the advantage over fuel taxes in promoting sustainable transport in that they target fuels with higher carbon content over alternative fuels and technologies.

Transport 21: The single most influential lever in the transport sector is the Transport 21 strategy. Transport 21 involves a significant investment in the Irish transport network and is due to be completed by 2015. During this time period, it is estimated that €34 billion will be invested in improving transportation both nationally and within the Dublin region. These measures aim to upgrade the national road network, rail services, bus services and regional airports [43]. Measures that will directly affect Dublin include:

- The development of Metro North and Metro West. Metro North will consist of a 17km line from Swords and Dublin Airport, to the city centre with projected passenger figures of 34 million passengers per year once fully operational in 2013.
- The construction the suburban rail interconnector which will provide an underground link between Heuston Station and the Docklands, via St. Stephen's Green and linking with the Northern line.
- The extension of the LUAS network to the Docklands, Citywest, Bray and construction of a new line from St Stephen's Green to Liffey Junction (joining the two existing LUAS lines), and a separate line from Lucan to the city centre.
- The improvement of the bus network to take into account all of the rail developments described above; including doubling of the Quality Bus Corridors to 200km, and a 60% increase in capacity on Dublin buses.
- Upgrading the DART service. This will include increased electrification of the system.
- Completion of the M50 upgrade.

The combined projects planned for Transport 21, if fully implemented, would abate 0.51 Mt CO_2 per year [44]. As most of the measures outlined in the strategy are part of Dublin's transportation system, the city will benefit the most from these emission reductions. If the strategy also succeeds in causing a modal shift of passengers from private to public transport, then it is likely, given the costs of running a private car that consumer savings will be made in conjunction with CO_2 reductions.

Whether these reductions predictions become a reality or not depends on the progress made in the next few years. The following summarises the main advances that have been made in the Transport 21 plan [45]:

- First Major Inter Urban (MIU) route opened (M1 Dublin – Border)
- 86% of planned MIUs open or under construction - remainder through statutory approvals process
- 67 new rail carriages on Dublin-Cork line, hourly services on route
- Over 100 of 183 railcars for other Intercity routes delivered, in service on Dublin-Sligo, Dublin-Westport and Dublin-Limerick lines
- Dublin Docklands station opened
- Additional buses for Dublin Bus and Bus Éireann
- Construction underway on Midleton line, western rail corridor and Kildare line
- Construction well advanced on Luas extensions to Cherrywood and Docklands
- Railway order approval for first phase of Navan line
- Planning well advanced for Metro North
- Planning progressing for Luas Lucan line and Metro West, phase 2 of Navan line and DART interconnector

Petrol/diesel cars: Straightforward fuel efficiency measures for petrol cars offer the second largest carbon abatement potential of the technological levers examined in the transport sector. Implementing a number of fuel efficiency levers for petrol cars that are economically viable would reduce emissions by 0.16 Mt CO_2 by 2025. These fuel efficiency measures include improved engines, start stop technology, improved aerodynamics, thermal engine management, lower rolling resistance tyres and manufacture of parts with lighter materials.

Similar fuel efficiency measures for diesel cars would reduce emissions by 0.12 Mt CO_2 by 2025. The measures applied to diesel cars are similar to those listed for petrol cars with the inclusion of torque oriented boost. The number of diesel cars has increased in recent years from 13% in 2000 [46] to an 18% share of the current Irish market [47]. Currently 50% of all new car sales in the EU are diesel cars [48]. Conventionally, the decision to implement these fuel efficiency measures for diesel cars lies with car manufacturers, but in certain cases, government or consumer demand can influence this.

The average carbon emission from cars in Ireland was 161g CO_2/km in 2006 [46]. The European Commission has set new targets for car manufacturers to reduce average emissions from petrol and diesel engines to 120g CO_2/km by 2012 [49]. A premium of €20 per gCO_2/km emissions per year will be imposed on all new vehicles for each gCO_2/km in excess the target limits for each car class. It is expected that these premiums will continue to rise significantly each year after 2012, increasing to €95 per gCO_2/km in 2015 [49].

Vehicular biofuels: Various EU directives on biofuels have set targets of 10% penetration in the Irish transport sector by 2020 [30, 50]. The adoption of biofuels in transportation in Dublin has an abatement potential of 0.1 Mt CO_2 by 2025. In 2007, at a local level Dublin Bus and at a national level, Bus Eireann moved all of their fleet to a 5% biofuels blend, while all buses manufactured from 2008 are capable of using a 30% biofuel blend [7]. There is a high cost of €120 per tonne of emissions abated associated with implementing a 12% biofuel mix. This may be attributed to higher costs associated with the crops needed to produce biofuels compared to the price of oil assumed in this study. As the price of oil increases, the use of biofuels will become more economically attractive. The subject of biofuels has proven to be controversial, as only those derived from sustainable farming of certain crops, such as sugar cane, have a real abatement potential. Moreover, deforestation of land for the growth of crops mitigates against the carbon abatement potential of biofuels. It is assumed that only plants with a beneficial carbon balance will be used in all biofuels for Dublin vehicles. Finally, the effect of biofuel agriculture on the food versus fuel debate, is another topical issue associated with increasing utilisation of these fuels.

Electric cars: The Irish Government has signalled that 10% of all vehicles will be electric by 2020 [51]. This is an ambitious target, however, other countries such as Israel, are hoping to have 40% penetration of electric vehicles in the same time period, while also installing a comprehensive recharging network. The advantages of electric vehicles include lower carbon emissions and financial savings through significantly reduced running costs. Replacing 12% of cars with electric vehicles by 2025 will result in an abatement of 0.05 Mt CO_2 annually with (annual) fuel savings of over €300 per vehicle. The average range for a standard electric car is 165km, with a maximum speed of 112km/hr [52]. Electric vehicles have the greatest potential in urban areas such as Dublin, where the average distance travelled to work is 12.8km [46]. As most vehicles will be charged during off peak hours, they will not increase electricity demand. At present, electric vehicles in Ireland are exempt from vehicle registration tax and fall into the lowest motor tax category.

Hybrid heavy commercials: Hybrid vehicles can greatly reduce carbon emissions, as they consume less fuel by combining conventional engines with an electric battery. The battery recharges itself during breaking, prolonging the battery life and reducing the consumption of fuel. Hybrid vehicles are an attractive option due to their high abatement potential. The installation of heavy commercial vehicles (unladen weight greater than 7.5 tonnes) with hybrid technology was examined for this lever. The large fuel consumption of these heavy commercial vehicles (36 l/100km) and their driving habits - heavy traffic volumes, and the start-stop nature of the traffic within the M50 ring in Dublin makes them a suitable choice for hybrid technology [23]. However, as high upfront investment costs are involved with them, they are a more expensive way of reducing emissions compared to other levers. Hybrid trucks would have an abatement potential of 0.02 Mt CO_2 by 2025 and would reduce fuel consumption by 30%, but with a high

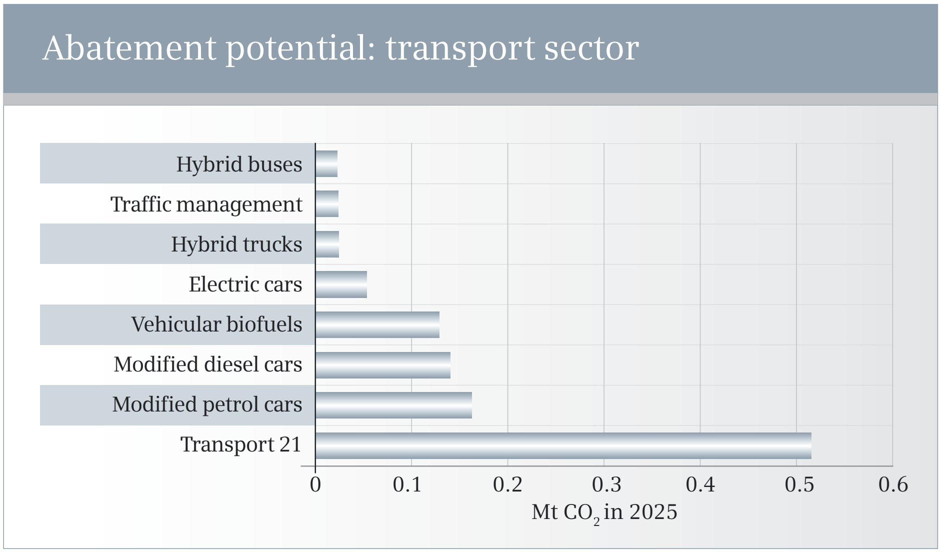

Figure 5.4

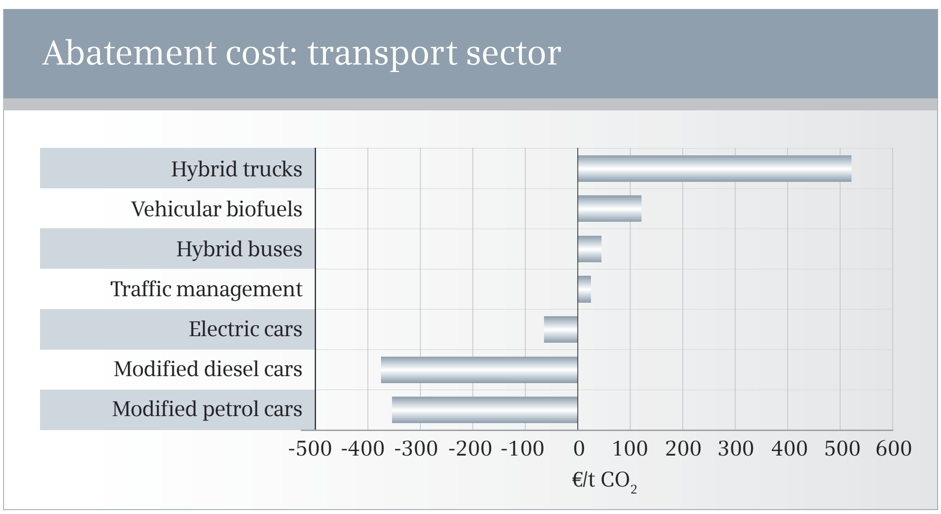

Figure 5.5

abatement cost (€520 per tonne of carbon emitted). Two thirds of containerised trade to and from Ireland is handled by Dublin Port, while between 40% and 50% of imports are delivered within the M50 ring surrounding Dublin. This figure increases to 75% when a radius of 80km is considered [53].

Hybrid buses: Hybrid buses use 30% less fuel than standard diesel buses. The nature of urban traffic, combined with frequent stops and starts for collecting passengers, make buses suitable for hybrid technology. Due to higher mileage and greater fuel consumption of buses than heavy commercial vehicles, hybrid technology becomes a more attractive option due to the smaller costs associated. This lever focuses on replacing the Dublin Bus fleet of over 1,000 vehicles with hybrid vehicles, assuming 100% of buses will be hybrids by 2025. Implementing hybrid buses across all routes would lead to a potential abatement of 0.02 Mt CO_2 by 2025, with an abatement cost of €40 per tonne of CO_2. This technology is currently available, with the first hybrid bus coming into service as part of the Dublin Bus fleet in late 2008, as a pilot scheme [54].

Traffic management: Implementing a traffic management system has proved successful in cities such as Athens, Budapest and a number of German cities of varying size and population. A typical system gathers and evaluates traffic information from a large range of sources including public transport and makes it available to various users to optimally guide traffic through the city. Implementing this system across 25% of Dublin would lead to a carbon emission abatement of 0.02 Mt CO_2 at a cost of €20 per tonne of CO_2 abated, based on an initial investment of €10 million. The abatement potential increases with the percentage of the city the lever is be applied to - for 50% penetration the abatement potential is 0.04 Mt CO_2 while with a 75% penetration 0.09 Mt CO_2 can be abated. The abatement costs also decrease further with increased penetration. As traffic flow improves, people might start switching back to their cars, making more traffic measures necessary. However, optimising rail traffic, LUAS, DART and bus services, could improve journey times and optimise capacity on these networks, further reducing carbon emissions and increasing energy savings.

Implementation barriers: The largest barrier facing the transport sector in Dublin is the fact that the city lacks a truly integrated, efficient system. Implementing a high quality traffic management system for example, can only lead to a certain amount of improvement, which is ultimately determined by the state of the existing infrastructure.

Dublin is currently adopting some of the levers outlined in the study. For example, Dublin Bus is already using a 5% blend of biofuels and since 2007 all new buses are capable of running on a 30% blend.

The levers concerning private cars and trucks, which account for a much higher proportion of emissions, are mainly under the control of consumers and manufacturers. However, the government directly influences consumer/manufacturer choices through imposing taxes or other measures. A revision of the vehicle registration tax (VRT) system came into effect in July 2008 based on carbon emissions rather than just engine size. The tax system was redistributed to provide incentives for motorists to buy cleaner more fuel efficient cars, while higher taxes were imposed on carbon intensive vehicles [55]. The number of lower emission diesel cars on the road is expected to increase as a result of these measures. Other initiatives introduced include the Tax Saver ticket, which acts as an incentive to use public transport by giving commuters tax saving benefits when they avail of an annual ticket for public rail or bus services. Proven measures to reduce carbon emissions have been introduced by other urban areas. These include the congestion charge in London, which has been broadly deemed to be a success. From February 2003, any vehicles entering the city had to pay a fee of £5. Since then the area has been expanded and the fee per day increased to £8. The number of car trips in the city per day has decreased by 16% as a direct result of these charges.

TRANSPORT CASE STUDIES

Project Better Place - Israel

Project Better Place is an initiative between Renault-Nissan and the Israeli government, which will see the development of a national recharging grid by 2011 and a target of 100,000 electric vehicles throughout Israel. Electric cars typically have a range of 100km in traffic and up to 150km when travelling on motorways.

Israeli President, Shimon Peres has called the project, "a pilot project, before it's applied to other, bigger industrialised nations." Israel is considered to be a practical choice for this project for a number of reasons. These include its size, the high price of oil in Israel ($1.70 per litre) and the fact that 90% of drivers in Israel travel less than 70km per day and that Israel's major cities are less than 150 km apart.

In order to meet the targets set out in the initiative, 500,000 electric charging points will be installed throughout Israel and 200 battery swapping stations. Better Place will own the batteries, rather than individual drivers, enabling drivers to swap batteries with greater ease. The government also reduced its automobile tax to only 10% for electric vehicles as a further incentive to consumers.

Dublin Bus Pilot Scheme: Hybrid Electric Bus

On the 15th December, 2008 Dublin city welcomed the arrival of Dublin Bus's newest vehicle – a diesel-electric hybrid double deck bus. According to the Minister for Transport, Noel Dempsey and Dublin Bus, the new bus can deliver fuel savings of up to 30% on normal diesel powered buses. A 30% saving on fuel for Dublin Bus across all its buses would equate to some 10.8 million litres of diesel. It is 50% quieter and emits 30% less CO_2 than a standard bus. It is ideally suited to city driving because it allows regenerated energy from braking to power the electric battery.

The new hybrid vehicle has been introduced as a demonstration project into regular service on one of Dublin Bus' cross city routes. Based on Wright's Gemini bodywork, with a normal double deck passenger layout, the new bus is powered by a 2.4 litre Ford Transit Euro 4 diesel engine and a Siemens hybrid electric drive system, supported by lithium ion batteries and regenerative braking.

Other cities such as London, Dresden, and New York, have all successfully added hybrid buses to their fleets. These cities also have advanced metro/underground systems and provide a range of transport options for their commuters.

LUAS

The LUAS, Dublin's light rail transit system first came into service in 2004. The total cost of the construction of both lines was €770 million. At present 90,000 passengers travel on it daily along its two routes. Nearly 29 million passengers travelled on the LUAS service in 2007, which was an increase of nearly 3 million passengers from 2006 and 7 million passengers since 2005.

Minister for Transport, Noel Dempsey TD commenting on the increases in passenger figures said, "These figures for LUAS are very encouraging. It is further proof that if you make reliable, top quality public transport available to the public, then it will be used. Freeing up our city centres from severe congestion is vital for economic growth and for improved quality of life. Reliable public transport will play a central role in addressing this issue."

The Red line runs from the city centre to the west of the city, and the Green line serves the city centre and south county Dublin. As part of the Transport 21 strategy, a significant expansion of the Luas network is underway. The Red line is currently being extended by 1.7 km to Dublin Docklands, and the Green line is being extended southwards by 7.2 km to Cherrywood. Other proposed expansions of the LUAS network include further extensions to both the Red and Green lines, a connecting line between both lines, and two new lines servicing the city centre.

Buildings & Lighting

Summary of buildings and lighting technological levers		Abatement potential	Abatement costs	Required investment
Lever name	**Brief description**	Mt CO_2 in 2025	€/t CO_2	€m
BUILDINGS AND LIGHTING				
Domestic appliances	Increased penetration of more efficient white goods i.e., washing machines, dryers, dish washers, fridges and freezers	0.12	-200	55
Residential lighting	Increased penetration of compact fluorescent lighting in residential buildings	0.09	-400	10
Cavity wall insulation	Cavity wall insulation in residential buildings	0.02	-280	10
Solid wall insulation	Solid wall insulation in residential buildings	0.29	-170	545
Attic insulation	Attic insulation in residential buildings	0.13	-270	70
Hot water insulation	Hot water tank/piping insulation in residential buildings	0.02	-300	2
Draught proofing	Draught proofing in residential buildings	0.01	-50	30
Condensing boilers	Replacement of boilers in existing residential housing stock with condensing boilers	0.16	-260	65
Improved heating controls	Improved heating controls in residential buildings	0.01	-210	10
Floor insulation	Floor insulation in residential buildings	0.09	-140	145
Commercial building heat recovery	Replacement of inefficient ventilation systems with heat recovery systems in commercial buildings	0.04	-130	25
Commercial/industrial lighting	Switch from less to more efficient fluorescent lamps in commercial and industrial buildings	0.09	-180	100
Improved lighting controls	Improved lighting controls in commercial buildings	0.01	-180	5
LED street lights	Replacement of sodium street lamps with LED lights	0.02	-470	75
Windows	Replacement of single glazed windows with low emissivity double glazing in residential buildings	0.04	-170	250

Figure 6.1

This section summarises the abatement potential of implementing certain technological levers in both residential and commercial buildings. For residential buildings, the focus is on construction standards and energy technology. The remainder of the findings focus on energy savings that can be made through the replacement of lighting systems, for example, by the replacement of sodium street lamps with LED alternatives.

Key findings:

- The measures outlined in this section could together abate 1.14 Mt of CO_2 emissions in Dublin in 2025.
- The application of a range of straight-forward retrofitting measures, such as cavity wall insulation, coupled with the installation of more efficient lighting and electrical appliances, could lead to the abatement of 0.98 CO_2 emissions in residential buildings.
- Improved lighting efficiency and control in commercial and industrial buildings could lead to the abatement of 0.1 Mt of CO_2, as well as resulting in significant savings both financially and in energy consumption.
- According to CODEMA, behavioural changes in both the commercial and residential sectors could lead to a reduction in CO_2 emissions of 0.3 Mt per annum in the 12 year period 2008-2020 [9]. (As mentioned in the mobility section this figure is not included in the overall abatement figure).
- Further reductions in emission and energy costs could also be achieved by implementing more efficient heating/air-conditioning systems.

The per capita emissions associated with buildings in Dublin city are on average, high compared with those of many other cities. At 5.36 tonnes per year, they are significantly higher than those of London residents (3.5 tonnes per capita per year) and almost double those of Tokyo (2.9 tonnes per capita per year) and Stockholm (2.6 tonnes per capita per year) [10]. The housing stock in some areas of the Dublin region is relatively new, with approximately 155,000 units (37%) of a total stock of 420,429, constructed since 1994 [23]. However, there are still many houses in the region which were built before 1950 and are poorly insulated. It is estimated that over 60% of homes built before 1940 have no wall insulation and 40% have no roof insulation [10].

In recent years, in order to reduce emissions from the sector, measures aimed at increasing energy efficiency have been introduced. For residential buildings, the focus is on construction standards and energy technology [54]. On a broader scale, an emphasis has been placed on sustainable residential development, including the energy efficient layout of housing developments and sustainable urban and rural settlement patterns that can aid the minimisation of transport–related energy consumption.

While the current per capita emissions associated with buildings is relatively high, emissions from the average dwelling have actually fallen by approximately 30% since 1990, primarily as a result of strengthened energy efficiency standards for new buildings and the shift from solid fuels to natural gas for heating [25]. The increased energy efficiency standards are a result of the introduction of the Building Regulations, which first came into force in 1992. The regulations enhanced the thermal performance standards of both new and refurbished buildings. SEI estimates that the nominal heating demand of a dwelling constructed to 2002 building regulation standards, is 76% less than that of an equivalent home constructed in the 1970s. However, higher internal temperature expectations, attributable to increased living standards, are likely to eradicate a substantial quantity of these improvements. It has been estimated that the 2005 building standards will save in the region of 0.07 Mt of CO_2 in Dublin in the period of 2008-2012. The new 2008 Building Regulations expand the scope of the thermal performance requirements of a new dwelling to include high efficiency boilers, energy efficient lighting, renewable energy systems, as well as tighter insulation and air infiltration requirements [25]. These revised standards are expected to provide an energy efficiency improvement of up to 40% over 2005 standards and an additional CO_2 abatement of 0.024 Mt per annum in the period of 2008-2012.

The Building Energy Rating (BER) certificate is an energy rating requirement for newly constructed dwellings that was introduced in January 2007 [54]. The BER was also introduced for new non-domestic buildings from July 2008 and for existing buildings when being let or sold from January 2009. A BER certificate provides an objective scale for comparison of a building's energy performance and CO_2 emissions. The rating assigned to the property is indicated on a scale from the most efficient (A1 rating) to the least efficient (G Rating). It can be used by tenants and buyers to quantify the energy performance of a building and factor energy costs into a purchase or renting decision. In order to aid building owners and landlords in

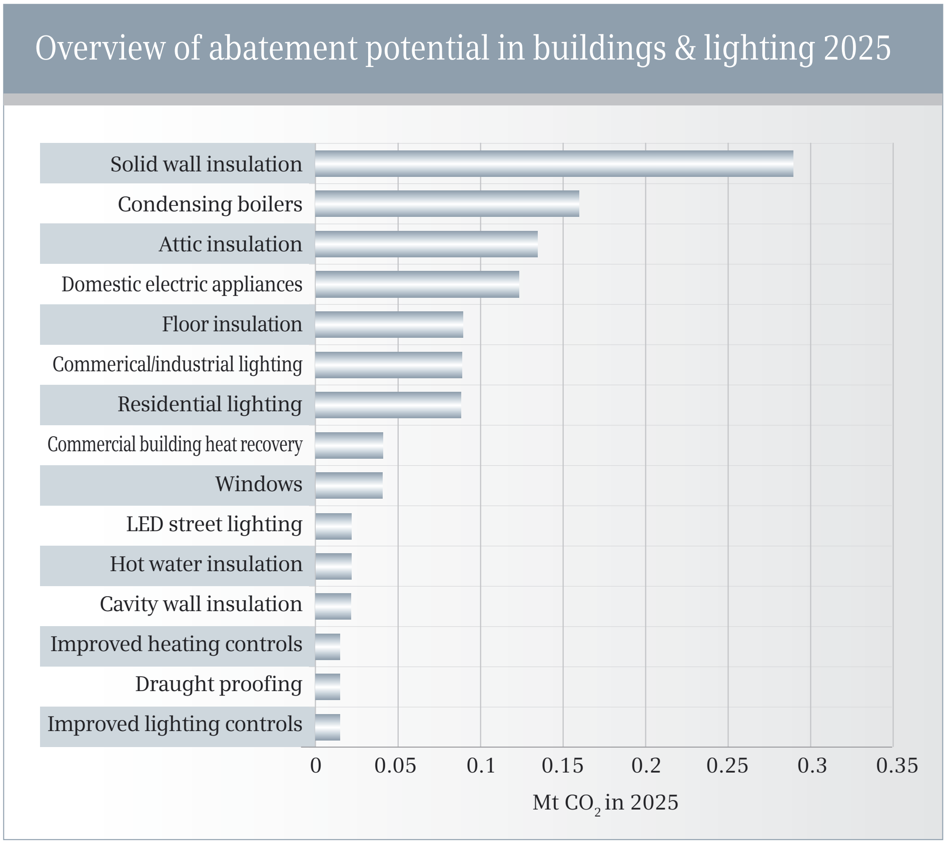

Figure 6.2

planning future upgrade works, an advisory report accompanies the BER certificate, which details cost-effective procedures that will enhance building efficiency. The estimated BER of a typical Dublin house is currently E1 [10].

The Greener Homes Scheme is another strategy aimed at reducing building emissions, which was launched in 2006 and is administered by Sustainable Energy Ireland [25]. Between 2006 and 2011 the scheme provides €47 million in grant assistance for homeowners who want to install a renewable energy heating system in either new or existing homes. The scheme is predicted to save in the region of 0.01 Mt of CO_2 emissions in the Dublin region by 2011.

Ireland is set to switch from highly inefficient incandescent light bulbs to their more efficient compact fluorescent lamps (CFL) counterparts. Modern CFL bulbs can last up to 15 times longer than incandescent bulbs, whilst consuming 80% less energy. The Irish Government has unveiled plans that will see a phased ban on incandescent light bulbs from 2009. After that date, bayonet and screw top incandescent bulbs of 75W and over will no longer be sold, with retailers permitted three months in which to clear

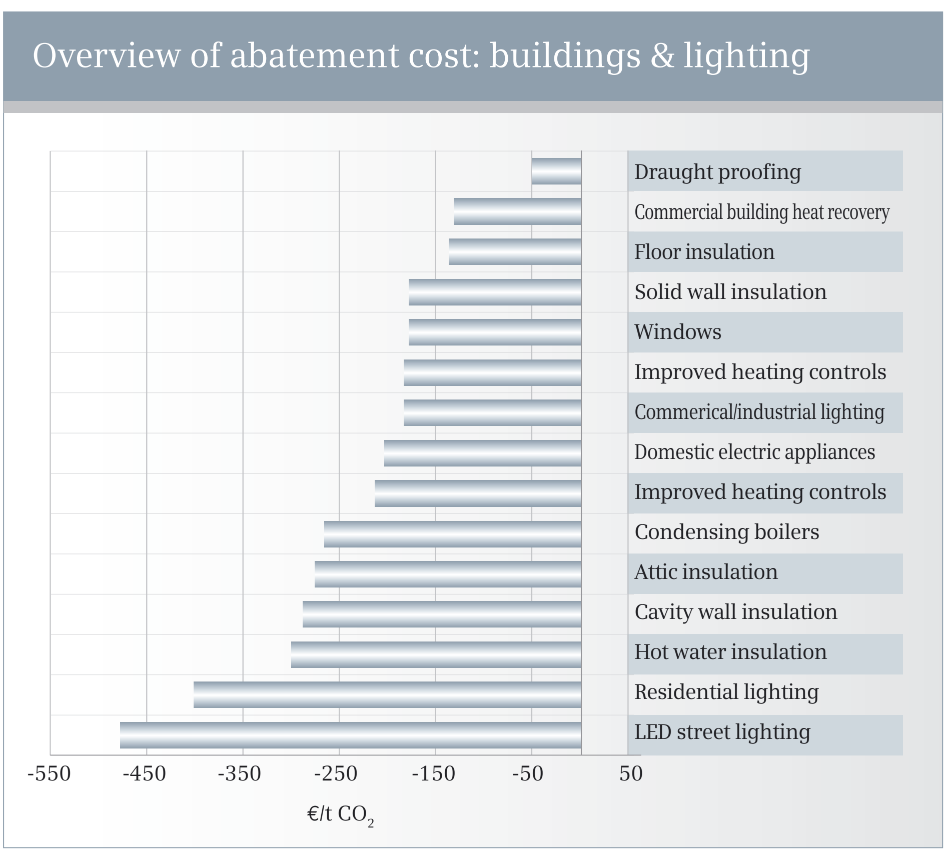

Figure 6.3

their stock. The scope of the transition will be widened in 2010 and following years, until all energy incandescent fittings are removed from the market.

Identified Reduction Potential: The building-related technological levers identified in this study could provide a reduction in emissions of 1.14 Mt CO_2 per annum in 2025. The technological levers applicable to residential buildings provide a total abatement potential of 0.98 Mt of CO_2, while the levers outlined for commercial and industrial buildings could provide an additional abatement potential of 0.16 Mt of CO_2. Furthermore, as a consequence of the associated energy savings, the initial investment cost required for the adoption of most of the technological levers is more than recouped. Insulation in residential buildings in particular, in all its various forms, could abate 0.78 Mt of CO_2 per year by 2025. Almost every type of insulation pays back the required investment, barring double-glazed windows, which would come at an additional cost. The uptake of more efficient electrical appliances, encompassing refrigerators, dryers, washing machines, freezers and dishwashers, could lead to the abatement of a further 0.12 Mt of CO_2 in

2025. The compulsory switch from inefficient incandescent light bulbs to more efficient CFL bulbs is predicted to lead to the annual abatement of 0.09 Mt of CO_2 in 2025.

Commercial, public sector and industrial buildings have self-funding technological levers available. These mainly relate to more energy efficient lighting and appliances, as well as building automation systems that control ventilation, cooling and lighting. In these sectors, the adoption of more energy efficient lighting provides an abatement potential of 0.09 Mt, while the incorporation of lighting control in commercial buildings could reduce CO_2 emissions by a further 0.01 Mt. Furthermore, the adoption of a heat recovery system for ventilation in commercial buildings provides a CO_2 abatement potential of 0.04 Mt of CO_2 in 2025.

LED Street Lamps

Dublin currently has in the region of 123,000 street lights, which are a combination of both high and low pressure sodium lamps. LED street lamps not only have a lifespan of up to eight times that of an equivalent sodium lamp, but also provide a better lighting performance at smaller power consumptions. The replacement of sodium street lamps with their corresponding LED alternatives provides an abatement potential of 0.02 Mt of CO_2 at a saving of €470 per tonne of CO_2

Implementation barriers: For both individuals and businesses, the adoption of most of these technological levers should be a relatively simple and straightforward decision. However, this is generally not the case as numerous obstacles hinder their uptake. Some of the barriers to the fitting of these energy saving measures are financial. Large initial investment costs can act as a disincentive to governments, businesses and consumers alike, particularly if they erroneously believe that the investment might not pay off as intended. Additionally, the monetary cost of these measures is not inclusive of the inconvenience associated with their installation. For example, an extremely effective and relatively inexpensive energy loss reduction method, such as cavity wall insulation, can be retrofitted relatively easily. However, it can involve considerable domestic disruption which can lead to delay or postponement.

Another issue is identification of the beneficiary of such retrofit measures. Within the Dublin region, approximately 22% of dwellings are known to be privately rented [55]. For these properties, landlords are generally responsible for expenditure on structural improvements, such as insulation, but the immediate benefit is experienced by the tenants, who are usually responsible for utility bills. In such scenarios, lack of obvious payback acts as a disincentive to landlords, whereas the transient nature of properly letting, means that tenants may have little influence in the matter. However, when it comes to selling a home, features such as better insulation and efficient heating systems can help bolster a sale, especially since the introduction of the BER certificate. Nevertheless, the full value of the investment is likely not to be as great for a landlord as it is for a homeowner.

The effort required to install any type of energy saving measure is another simple barrier. For many individuals the time and motivation required to take on the job, even when the associated benefits are quite apparent, often proves to be too cumbersome. This problem is often exacerbated by a lack of clear information about energy efficiency and possible solutions. Consumers that are unsure about the best approach and the potential rewards available, will be unwilling to take any action. For businesses in particular, information comes at a cost in terms of time and money. For many companies, even though energy prices have increased considerably, this still only represents a small part of their overall costs.

In order to overcome these barriers, cities need to provide leadership. In Dublin, in order to heighten consumer awareness and encourage the use of energy efficient practises, energy awareness initiatives are provided by Sustainable Energy Ireland campaigns and the national Power of One awareness campaign. These initiatives coupled with the impending prohibition of inefficient light bulbs, the Greener Homes Scheme, the BER certificate as well as the new building regulations, are contributing to the creation of a sustainable Dublin.

Financial barriers to local governments also must be tackled. Irrespective of the payback from improved energy efficiency, local governments face restrictions on borrowing levels and consequently may lack the funds necessary for any upfront investment. A solution to this problem, is to treat the potential savings as a saleable asset, as instigated by the City of Berlin in 1996. Here, the city outsourced its energy management to private partners in what was known as the 'Energy Saving Partnership Berlin'. The city received an assured 25% saving on its annual energy costs, while the financing and expertise provided by the partners improved the energy efficiency of the cities' buildings. More than 6% of these savings are delivered directly to the city budget, while the remainder is utilised in the financing of the modernisation and optimisation of buildings within the city. In return, the partners receive any savings above those guaranteed to the city, while the city retains ownership rights to the newly installed equipment.

LED Street Lighting, Tralee, Co. Kerry

Tralee, Co. Kerry has become the first town or city in Ireland to pilot low energy street lighting. The Tralee Town Council replaced the existing inefficient incandescent lights in The Square and Abbey Court area with LED (light emitting diode) light fittings in October 2008. The increased efficiency of the LED lights is expected to yield a reduction of up to 40% in energy costs, creating a payback period in the region of three to four years. Furthermore, the LED lights have a lifespan of over 50,000 hours and provide a greater lighting output than their incandescent counterparts. It is hoped that LED lights will eventually replace all of the approximate 2,000 incandescent public lights in the town.

The Canadian town of Banff, conducted a similar pilot project in November 2007 to convert its street lighting to LEDs. Compared to conventional street lights, it was expected that the LEDs replacements would lead to a 36% saving in power consumption, and a 93% reduction in maintenance costs. Since they have been implemented, no maintenance has yet been required on any of the LED streetlights and from tests in November 2008, the light level has not deteriorated.

Redevelopment of York Street

The redevelopment of the York Street apartments in Dublin city is a very important and high profile housing project for Dublin City Council, as it addresses issues of environmental sustainability in building design. A target of a 51% reduction in energy and carbon dioxide and a 70% reduction in running costs was set at the outset of design. The redevelopment comprises 66 new council apartments arranged in five blocks with communal spaces on the ground floor. A group heating system is present in each block and provides space heating and domestic hot water. Hot water is piped to each apartment where usage is measured by a heat meter, upon which residents are charged. The system is powered primarily by solar thermal panels, with highly efficient (>90%) condensing gas boilers providing back-up at peak loads. High levels of thermal efficiency are achieved through the use of highly insulated building fabrics, in addition to southerly facing glazed balconies, which maximise solar gains.

The Building Energy Ratings (BER) of the York Street apartments range from A3 to B2, with an average of B1, which corresponds to an annual energy usage of 92 kWh/m2/yr. These are excellent ratings and can be mainly attributed to the high level of thermal insulation and the community heating system powered by solar thermal panels and high efficiency condensing gas boilers.

Water

This chapter identifies methods of reducing water consumption in the Dublin region. The major catalyst in the water sector in Dublin would be the introduction of water metering and charging.

Key findings:

- If water metering and charging was introduced in residential buildings in the Dublin region, it would lead to a reduction in water consumption of 4.3 billion litres in 2025.
- The implementation of water saving devices, such as aerated taps and dual flush toilets would lead to a combined saving of 2.65 billion litres in 2025.
- Currently, water to households is ‘free’ at the point of use, however, if charging for water based on consumption was introduced (at a marginal cost of 0.0015 €/l) and the associated levers implemented, then households would save €1.20 per m^3 water saved. In this scenario, these levers would pay back their investment within a few years and would reduce the water bill of houses with meters.
- Improved water pump efficiency would decrease the energy consumption of water stations, which would lead to reductions in CO_2 emissions associated with water production.
- Dublin city loses 20% of its water due to leakages and in response the city council has put in place a Leak Reduction Programme [20]. While this goes some way to addressing the city’s water issue, Dublin still faces future potential water shortages and should consider options for reduction on the demand side. Although businesses are charged water rates, Dublin is one of the few European cities where householders do not pay for water. Charging for water creates an incentive for people to consume less.

This section summarises technological levers which would lead to a reduction in water consumption in the Dublin region. It is estimated that unless action is taken, the Greater Dublin Area will face

Summary of water technological levers		Reduction potential	Reduction costs	Required investment
Lever name	**Brief description**	Million m^3 of water in 2025	€/m^3 reduction	€m
WATER				
Water meter penetration	Implementation of water metering with 100% penetration in households by 2015	4.3	1.00	54
Dual flush toilets	Implementation of dual flush toilets in up to 50% of households by 2015	0.87	-1.20	6
Aerated taps	Implementation of aerated taps in households	1.78	-1.00	8

Figure 7.1

water shortages in less than 10 years. Current policy focuses mainly on one option – piping water 105 kilometres from Lough Ree on the river Shannon to Dublin. Water consumption in the region, therefore, should to be reduced in order to accommodate future shortages, but there is another issue which must be addressed even before this – leakage rates. Water consumption in Dublin is currently approximately 145 litres per person per day, which compares moderately with other European cities, although Dubliners consume more than residents in major cities such as Paris and Berlin [1, 56].

Water production per person in Dublin, however, is very high, due to the high leakage rates in Dublin's water infrastructure (distribution leakage of 20 % of water production in 2008) [20]. This is due, in part, to the age of the network – about 50% of the network dates back to pre 1940s [57]. It is estimated that there is, on average, water customer leakage of 50 to 60 litres per property per day [56].

The overall impact of this is that the entire water production for each Dublin resident reaches approximately 66 cubic metres per year, which is almost double that of Berlin (45), and much higher than Paris (56). This is despite the latter's significantly greater consumption [1].

Because this study focuses on Dublin, it does not address a number of other water-related issues, such as access for the population, water quality, and the efficiency and quality of the sewage system. Although they are not pressing issues in Dublin, they are certainly relevant in other cities, in particular those in less developed countries.

Identified reduction potential: To accammadate potential water shortages in the near future, it has been proposed that water from Lough Ree should be piped to Dublin. There is, however, another option: reduce demand through charges. Currently, water to households is 'free' at the point of use, although it, in fact, costs about €1.2 billion annually to deliver [56]. Metering of households and charging for water is a way of meeting Dublin's water needs for the medium term.

Metering of water supplied by utilities to residential, commercial and industrial users is common in most developed countries, except for the United Kingdom, where only about 30% of users are metered and in Ireland, where metering has only penetrated non domestic entities [1].

The implementation of water meters alone in 100% of domestic homes by 2015 would lead to a reduction of 6 billion litres consumed. This is equivalent to the amount of water consumed by over 113,000 Dubliners in one year. This assumes that the implementation of water meters induces water conscious behaviour that results in savings beyond the installation of the devices already mentioned. This is a reasonable assumption given the average 12% drop in water use their installation brings today, when such appliances are not widespread. This does not come for free, however, but would involve some cost for installing the meter. This study assumes that this cost has to be borne by the consumer.

The technology levers outlined in this study, apart from leading to savings in money, could reduce total consumption by the city by 7.07 billion litres by 2025 or 11 % reduction compared to consumption in 2005, despite a growing population - and for most of these technologies the savings would outweigh the costs.

The introduction of aerated taps in conjunction with water metering, would lead to a further decrease in water consumption of 1.7 billion litres per year in 2025, while saving the consumer €0.99 per m^3 water. With aerated taps, additional air is mixed into water tanks, increasing the volume whilst decreasing the actual quantity of water used. They can reduce flow rates by up to 50% and provide the same ability of the stream to wash. They also reduce splashing.

Dual flush toilets lead to further

reductions in consumption of almost one billion litres in the year 2025, while once again saving the customer money - €1.16 per m^3 water. Dual flush toilets significantly decrease the amount of water used in the home. They can save an additional 25% over a 6-litre ultra low flow toilet and up to 80% less than a 20 litre toilet.

Interestingly, both aerated taps and dual flush toilets effectively pay for themselves through reduced water use. It has been reported, however, that measures such as aerated showerheads do not pay for themselves, primarily because the flow of water through a showerhead tends not to be as much as through household taps, thereby reducing the scope for savings. The above figures have been calculated based on the assumption that all the measures are implemented. It is reasonable to assume that if metering is made mandatory (which is a probable scenario), then most people will invest in technologies such as dual flush toilets, in order to avoid wasting water, particularly if water charges are introduced in conjunction with metering.

Although levers for Dublin's water supply were not evaluated, further work should include continued network upgrading and pipe replacement, in order to reduce the amount of water lost through leakage.

This is in fact taking place on some level already. The Dublin Region Water Conservation Project led by Dublin City Council and along with Wicklow, Dun Laoghaire/Rathdown, South Dublin, Fingal and Kildare County Councils, put in place a network of water meters and telemetry to track the distribution of water throughout the Dublin region. The project, which cost in the region of €47 million, reduced leakage from 42.5% to 28%. The second phase of this project is underway as the Dublin Region Water Main Rehabilitation Project, which started in 2006. This is a strategy put in place to identify the areas of the network where leakage was worst and to rehabilitate the mains in those areas. The capital budget that has been allocated for this project by Government (€118m) and the Local Authorities will be sufficient to carry out water main rehabilitation on approximately 250km of the water main network in the greater Dublin region [57].

The analysis in this study has shown that the introduction of water charges and metering would act as a major catalyst in the water consumption patterns in Dublin. However the city's leakage problem must first be addressed before any other measures can be introduced.

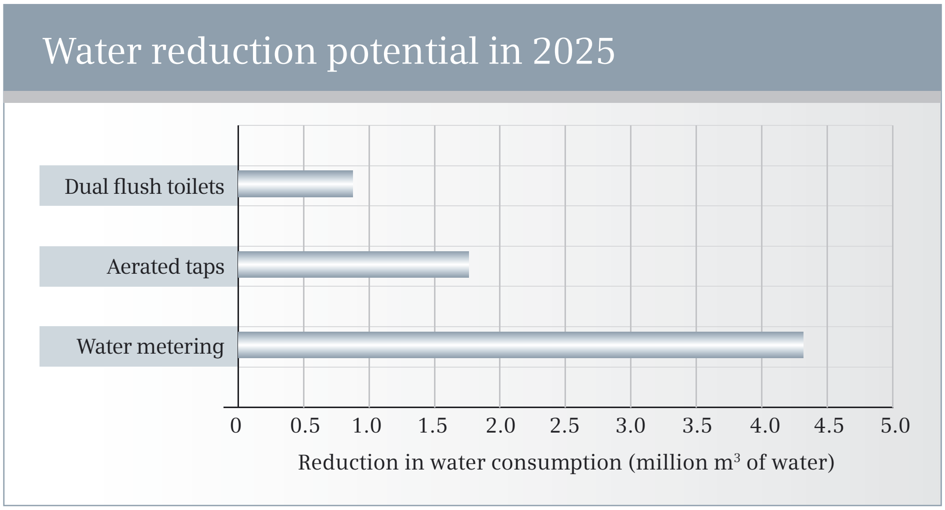

Figure 7.2

Implementation barriers: The key barrier to implementing water meters and water saving measures is that water used in domestic residences is deployed free of charge, so consumers have no financial incentive to reduce demand. This also means that most residents, therefore, have no idea how much water they are using. Only commercial buildings in Dublin are currently metered.

Another implementation barrier is the gap between those making the investment and those benefiting from the investment. Any improvements to domestic water systems that reduce usage – such as the installation of a dual flush mechanism in a toilet – would be an economic cost to the consumer, but the benefit would accrue solely to the water company.

However, national experience has shown that it is only by measuring and paying for a service that we establish a responsible attitude towards consumption of that service. Domestic refuse charges have proven very successful and significantly reduced waste volumes - down 30% in one local authority alone - while encouraging enhanced recycling rates. It is likely that similar success would be achieved, if water charges became mandatory in Dublin.

Water reduction costs in 2025

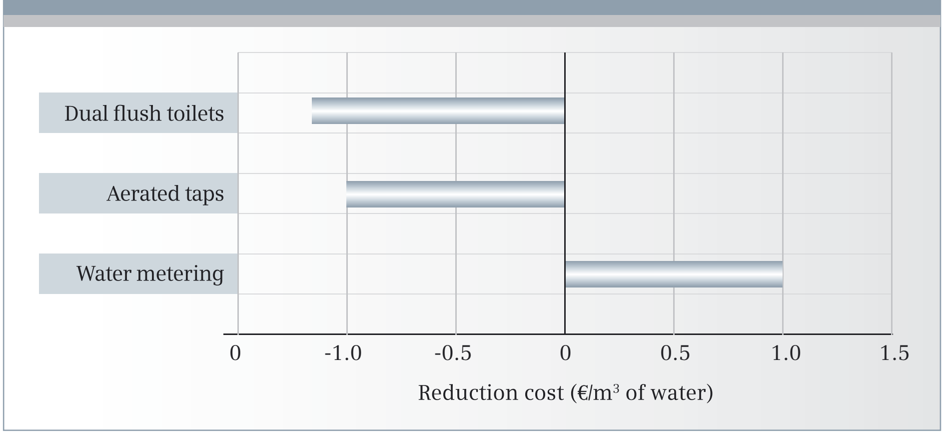

Figure 7.3

WATER CASE STUDY

Water Metering - Munich

The city of Munich, Germany introduced metering in the 1980s, first as a pilot study and from the results, opted for the introduction of water meters in the entire city. The approach taken by Munich officials in implementing metering could serve as a useful template for the Dublin region.

The extensive introduction of water meters in Munich started in 1990. By 1992 domestic water consumption for metered apartments (112 litres/capita/day) was 18% lower than for unmetered apartments (137 litres/capita/day). Meter penetration all over Germany is now 100% in single-family households. Simply looking at the consumption per capita in Germany, which is now just 126 litres per day, one can see the effects and results that are possible from implementing metering.

Waste

Irish people on average produce the largest amount of municipal waste in the EU at 824kg per capita compared to London, where people produce approximately 600kg of waste per capita [1, 58]. In 2007, residents of the Dublin region produced approximately half a million tonnes of household waste [20].

At present in Ireland any waste not recycled is sent to landfill. This current system of waste disposal is unsustainable. The Dublin Regional Waste Management Plan (DRWMP) is an initiative set up by the local authorities to meet EU waste targets [59]. The EU Directive on Landfill aims to reduce the dependence on landfill for municipal waste, in favour of more environmentally friendly alternatives [29]. The DRWMP also encourages consumers to "Reduce, reuse and recycle" through a number of initiatives in workplaces and schools [59].

Identified reduction potential: No technological levers were examined in this report for the treatment of waste, as reducing waste volumes is largely a behavioural issue. This report focused on what to do with the waste being produced in the Dublin region. The four Dublin Local Authorities are responsible for the collection, segregation, recycling and disposal services for household waste. They have adopted a 'polluter pays' principle, where the polluter who generates waste, also pays for its removal and disposal. Each of the four local authorities has introduced separate charges reflecting this strategy.

Landfill: Landfill is the main disposal route for municipal solid waste in Ireland and the main source of greenhouse gas emissions in the waste sector. The reduction of landfill is the current focus for the Irish Government. EU directives on landfill have set targets to reduce the amount of national waste being sent to landfill from 1,300,000 tonnes of waste in 1990 to 450,000 tonnes in 2016 (representing a 65% reduction) [29]. Taxes are the main incentive to reduce the amount of waste to landfill. The landfill tax imposed by the Irish Government is €19 per tonne of waste in 2007; this is much lower than other European countries, for example Austria charges €87 per tonne, Denmark €50.70 per tonne and the UK €47 per tonne [60]. As landfill taxes increase, alternatives to landfill have to be sourced. A certain portion of waste will still need to go to landfill, however, there are no other alternatives, but to reduce the amount of waste being sent to landfill.

Recycling: If the production of waste can not be avoided, the most sustainable option for disposal of waste is recycling. Currently 40% of Dublin's municipal waste is recycled; corresponding to over half a million tonnes of waste from the household, commercial and industrial sectors [61]. The Dublin region has also proposed biological treatment facilities for treating organic waste. Two out of the four local authorities have already implemented 'brown bin collections' for the collection of organic waste, which will divert a further 30% of waste from landfill. The two remaining authorities have plans to implement similar measures to reduce the amount of waste to landfill. At present, there are no charges for the collection of green and brown household recycling bins in Dublin. However, it is important to note that a high proportion of Ireland's recycled waste is shipped abroad, which in turn, results in emissions.

Incineration: An incinerator has been proposed for Poolbeg in Dublin, consisting of two incineration lines with a design capacity of 35 tonnes per hour, which equates to 600,000 tonnes per year for the whole plant. Incineration involves combusting waste at a high temperature, which can then be used to provide heating as well as generating electricity. The electrical output of the proposed incinerator will be approximately 60MW, and it is planned that it will contribute to the Dublin district heating system [22]. Waste-to-energy schemes have proved successful in many other European countries. The first incineration

plant with energy recovery for power and heating was commissioned in Denmark in 1903. The targets for waste management in Denmark are similar to those for Ireland with 66% recycling, 26% incineration and the remaining 8% going to landfill. Local authorities in Denmark are responsible for waste segregation, with recycling collected in separate bins from households with the remainder incinerated with energy recovery. There has been opposition to incineration in Ireland on environmental and health grounds.

Other methods of waste treatment: Another alternative includes the use of microorganisms which break down biodegradable waste in the absence of oxygen, greatly reducing the volume and mass of the original materials. They also reduce the amount of landfill gases emitted.

- Anaerobic digestion is a controlled biological waste treatment process that leaves approximately 10% of the original volume to be disposed of in landfill. Advantages of this process are that the remaining nutrient rich solids may also be used as fertilisers, while the gases produced can be used in biofuels to reduce the dependence on fossil fuels.
- In-vessel composting is similar to anaerobic digestion, but it breaks down the organic waste directly into compost. It is carried out in an enclosed container or vessel making it much more suitable for large scale or industrial processes.
- Another variation includes anaerobic digestion coupled with the production of refuse-derived fuel that compresses waste into pellets that can be used to fuel electricity plants. Paper and plastic is generally added to the waste, in order to improve the calorific value of the pellets. Another issue is that some toxic substances may be emitted during the process, which may raise public concerns.

Some of these methods could become economically viable if the fertilisers and compost produced could be sold, and if the cost of landfill continues to increase.

WASTE CASE STUDY

Plastic Bag Levy

Ireland was the first country to introduce an environmental levy on all plastic shopping bags in 2002. The levy, which was first introduced at 15c per bag, and raised to 22c in 2007, has led to a 90% reduction in the use of plastic bags. The aim of the levy was to promote the use of reusable bags and to help change attitudes towards litter and pollution in Ireland. Revenue generated from the levy goes to an Environmental Fund to promote recycling, waste management and other environmental campaigns. €78 million was generated in the first five years, since the levy was introduced.

Conclusion

Sustainable development is a global issue, but its impact will be greatest in urban areas. People continue to gravitate towards cities and it is where environmental stresses are most keenly felt. While cities and urban residents are part of the problem of climate change, they can also offer opportunities for sustainable living.

This study has highlighted some of the environmental challenges facing Ireland and in particular, the Dublin region. Ireland will struggle to meet its Kyoto and EU targets, even with the 'additional measures' planned by the government to combat climate change. Putting the challenge in perspective for Dublin, based on its population size and current rate of emissions, Dublin would need to reduce its emissions by 2.6 Mt to contribute its share for Ireland to meet its EU 20-20-20 target. As it stands, Dublin's emissions per capita are higher in relative terms than comparable European cities, such as Munich and Edinburgh.

Therefore Ireland has two options: spend money on carbon credits, which will be mandatory in the future if carbon emissions are exceeded, or invest in technologies that will enhance the region's infrastructure, reduce emissions and allow targets to be achieved.

This study has identified 22 technological levers that could reduce Dublin's emissions by 28% or by 3.7 Mt CO_2 in 2025, which is equivalent to the amount of CO_2 released by over 384,000 Dublin city residents last year. While some would require a significant initial capital investment, 75% of the solutions identified would pay back their capital costs within 10-15 years and deliver savings by 2025 through more efficient energy usage.

Reducing the carbon intensity of the national grid by increasing the contribution of renewables would have the greatest abatement potential in the Dublin region, closely followed by retrofitting of buildings and Transport 21. However smaller scale measures such as switching to more energy efficient lighting would prove very effective in reducing emissions as well as delivering substantial savings for consumers.

While a whole range of readily available technology solutions covering buildings, energy generation and transport were identified, it was found that the more fashionable solutions such as PV systems and hybrid cars proved to be a more expensive means of reducing CO_2 emissions.

This study also investigated the environmental challenges Dublin and Ireland face in the areas of waste and water. Irish people on average produce the largest amount of waste in the EU, with the

majority of Ireland's waste sent to landfill. Waste to energy technologies offer an alternative and ecological means for treating waste while reducing CO_2 emissions. As Dublin faces future water shortages, simple technological solutions that reduce water consumption were also analysed.

Encouraging businesses and consumers to invest in such technologies would seem straightforward because most of the levers that cut carbon emissions pay back their investment and deliver savings through reduced energy consumption. In reality, urban life is much more complex, with many stakeholders involved in making sustainability-related decisions. Without the necessary information, incentives and regulation, the simple availability of the technology alone is insufficient stimulus for people to implement them, regardless of their economic and ecological merits. Local authorities and national governments should drive the adoption of these technologies by putting in place the supporting policy framework. It is important that any new strategies/policies address the gaps between those who invest in the sustainable solutions and those that receive the financial benefits.

For sustainable strategies to succeed, it is vital that conurbations like Dublin pursue an integrated and lateral approach to solving the challenges they face. The advantage of cities is they offer the opportunity to take a holistic approach.

Climate change is happening now and will pose catastrophic consequences for all of us if we do not act decisively today. In recent months, the financial crisis and economic downturn have overshadowed environmental concerns. And yet economic growth and fighting climate change need not be mutually exclusive. With the right technological levers, policy makers and the public can achieve their goals and make a difference to sustainability, all at a manageable cost.

By investing in innovative technologies that are available today and pay for themselves through energy savings, not only can Dublin and Ireland avoid the financial penalties for exceeding emissions targets, we can improve the region's competitiveness and quality of life and in the process create green collar jobs.

The bottom line is that technology is the key to reducing greenhouse gas emissions, and it is also the engine that drives modern knowledge-based economies. By reconciling the need for a more sustainable urban infrastructure with job creation and economic competitiveness, there is a real opportunity to put Dublin at the vanguard of sustainable development.

Lever Summary

		Abatement potential	Abatement costs	Required investment
Lever name	**Brief description**	Mt CO_2 in 2025	€/t CO_2	€m
ENERGY				
Renewable electricity generation	Increasing the share of renewables that supply the Irish grid to 40% by 2020	1.34	-110	9,450
City district heating scheme	Implementation of district heating system of thermal capacity 535MW	0.15	-200	780
Gas fired CHP	Implementation of a number of gas fired CHP plants each with capacities of between 0.5-10MW Total capacity 100MW	0.03	-90	27
Commercial/domestic biomass	Incorporation of biomass boilers district heating system with installed capacity 26MW	0.01	-50	4
TRANSPORT				
Transport 21	Implementation of integrated transport system in Dublin – including Metro North/West, LUAS upgrade, bus services improvement, interconnector/DART electrification	0.51	Not calculated	34,000
Modified petrol cars	Engine efficiency measures for private petrol cars	0.16	-350	270
Modified diesel Cars	Engine efficiency measures for private diesel cars	0.13	-370	75
Vehicular biofuels	Increasing the share of biofuels in the fuel mix to 10% by 2020 in accordance with EU Directives on Biofuels	0.12	120	N/A
Electric cars	12% penetration of electric cars by 2025	0.05	-60	Not calculated
Hybrid trucks	Full hybrid engines for heavy commercial vehicles	0.02	520	24
Traffic management	Optimisation of traffic flow leading to reduced congestion based on existing infrastructure	0.02	20	10
Hybrid buses	Full hybrid engines for Dublin Bus fleet	0.02	40	70

		Abatement potential	Abatement costs	Required investment
Lever name	**Brief description**	Mt CO_2 in 2025	€/t CO_2	€m
BUILDINGS AND LIGHTING				
Domestic appliances	Increased penetration of more efficient white goods i.e., washing machines, dryers, dish washers, fridges and freezers	0.12	-200	55
Residential lighting	Increased penetration of compact fluorescent lighting in residential buildings	0.09	-400	10
Cavity wall insulation	Cavity wall insulation in residential buildings	0.02	-280	10
Solid wall insulation	Solid wall insulation in residential buildings	0.29	-170	545
Attic insulation	Attic insulation in residential buildings	0.13	-270	70
Hot water insulation	Hot water tank/piping insulation in residential buildings	0.02	-300	2
Draught proofing	Draught proofing in residential buildings	0.01	-50	30
Condensing boilers	Replacement of boilers in existing residential housing stock with condensing boilers	0.16	-260	65
Improved heating controls	Improved heating controls in residential buildings	0.01	-210	10
Floor insulation	Floor insulation in residential buildings	0.09	-140	145
Commercial building heat recovery	Replacement of inefficient ventilation systems with heat recovery systems in commercial buildings	0.04	-130	25
Commercial/industrial lighting	Switch from less to more efficient fluorescent lamps in commercial and industrial buildings	0.09	-180	100
Improved lighting controls	Improved lighting controls in commercial buildings	0.01	-180	5
LED street lights	Replacement of sodium street lamps with LED lights	0.02	-470	75
Windows	Replacement of single glazed windows with low emissivity double glazing in residential buildings	0.04	-170	250

		Reduction potential	Reduction costs	Required investment
Lever name	**Brief description**	Million m^3 of water in 2025	€/m^3 reduction	€m
WATER				
Water meter penetration	Implementation of water metering with 100% penetration in households by 2015	4.3	1.00	54
Dual flush toilets	Implementation of dual flush toilets in up to 50% of households by 2015	0.87	-1.20	6
Aerated taps	Implementation of aerated taps in households	1.78	-1.00	8

References

[1] Siemens/McKinsey, '*Sustainable Urban Infrastructure London Edition – A view to 2025.*' (2008)

[2] Environmental Protection Agency, *'Ireland's National Greenhouse Gas Emissions Projections to 2020.'* (2008)

[3] House of Lords European Union Committee 27th Report of Session 2007–08, *'The EU's Target for Renewable Energy: 20% by 2020. Volume I: Report.'* (2008)

[4] Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. A European Strategic Energy Technology Plan, *'Towards a low carbon future.'* (2007)

[5] Environmental Protection Agency, *'Ireland's Greenhouse Gas Emissions in 2007.'* (2007)

[6] Environmental Protection Agency *'Ireland's National Allocation Plan for Emission Trading 2008 – 2012.'* (2008)

[7] Department of Communications Marine and Natural Resources Government White Paper 2007, '*Delivering a Sustainable Energy Future for Ireland. The Energy Policy Framework 2007 – 2020.'* (2007)

[8] Department of Communications, Energy and Natural Resources, *'National Energy Efficiency Action Plan for Ireland 2007-2020.'* (2007)

[9] Environmental Protection Agency, *'Ireland's Greenhouse Gas Emissions Projections 2008 - 2020.'* (2009)

[10] City of Dublin Energy Management Agency, *Personal Communication* (2008)

[11] Jørgen Lund Madsen, Environmental Protection Agency, '*Initiatives against Climate Change and need for future actions in Copenhagen.'* Fourth Municipal Leaders Summit on Climate Change (2005)

[12] Referat für Gesundheit und Umwelt (City Council Munich). Bekanntgabe CO2-Monitoring 1990 – 2006.' (2006)

[13] The City of Edinburgh Council, *'Human Pressures: Environmental Footprints.'* (2005).

[14] Point Carbon. www.pointcarbon.com

[15] Sustainable Energy Ireland, 'Renewable Energy in Ireland. 2007 Update.' (2008)

[16] Department of Communications, Energy and Natural Resources, *'All Ireland Island Grid Study Overview.'* (2008)

[17] Department of Transport, '*2020 Vision – Sustainable Travel and Transport: Public Consultation Document.'* (2008)

[18] International Energy Association, '*World Energy Outlook.*' (2007)

[19] Frank J. Convery, Chairperson, Comhar Sustainable Development Council, '*The Elephant in the Room; Meeting Dublin's Water Needs –the Shannon or Pricing?*' (2008)

[20] Forfás, '*Assessment of Water and Waste Water Services for Enterprise*.' (2008)

[21] Environmental Protection Agency, *'National Waste Report 2006.'* (2006)

[22] Dublin Waste to Energy, www.dublinwastetoenergy.ie

[23] Central Statistics Office, www.cso.com

[24] Eurostat www.eurostat.com

[25] Nicholas Stern, '*Review on the Economics of Climate Change.*' (2006)

[26] World Commission on Environment and Development, '*Our Common Future*.' (1987)

[27] Department of the Environment, Heritage and Local Government, '*National Climate Change Strategy 2007-2012.'* (2007)

[28] National Development Plan 2007-2013, '*Transforming Ireland – A Better Quality of Life for All.'* (2007)

[29] Environment and Engineering Strategic Policy Committee in association with CODEMA, '*Climate Change Strategy for Dublin City 2008-2012*.' (2008)

[30] European Union Directive on Biofuels, '*Directive 2003/30/EC of the European Parliament and Council*.' (2003)

[31] European Union Landfill Directive, '*Directive 99/31/EC of the European Parliament and Council.'* (1999)

[32] Sustainable Energy Ireland, *'Energy in Ireland Key Statistics*.' (2008)

[33] Sustainable Energy Ireland *"Energy in Ireland 1990-2007.*" (2008)

[34] Keynote Address by Amory Lovins. '*The Negawatt Revolution Solving the CO_2 Problem,'* Green Energy Conference, Montreal. (1989)

[35] Electricity Supply Board, Personal Communication. (2008)

[36] Sustainable Energy Ireland '*CHP in Ireland, Options for a National Policy to 2010*.' (2006)

[37] Sustainable Energy Ireland, Personal Communication. (2008)

[38] Olivier Gaillot, John Walsh, Poul Weiss, Niels Otto Clausen, '*Dublin District Heating Project 2007 Feasibility Study*.' (2008)

[39] Dr Robin Cotton, Managing Director of Wood Energy Ltd., '*Biomass -The Natural Solution,'* Building Services & Environmental Engineer. (2008)

[40] Rolf Adam and Walter Wintersteller, '*What's So Smart about the Smart Grid?'* Strategy and Business, (2008).

[41] Sustainable Energy Ireland and Environmental Protection Agency Ireland, '*Assessment of the Potential for Geological Storage of CO_2 for the Island of Ireland.'* (2008)

[42] McKinsey& Company '*Carbon Capture and Storage: Assessing the Economics.'* (2008)

[43] Transport 21, www.transport.ie

[44] Department of Transport, '*2020 Vision – Sustainable Travel and Transport:* Public Consultation Document.' (2008)

[45] Maurice Treacy, Department of Transport, '*Transport 21 Progress in Motion Presentation.'* (2008)

[46] Sustainable Energy Ireland, *'Energy in Transport*.' (2007)

[47] AA Roadwatch, www.aaroadwatch.ie

[48] Verband Der Automobilindustrie, www.vda.de

[49] European Commission Communication COM (2007) 856, '*Commission proposal to limit the CO_2 emissions from cars to help fight climate change, reduce fuel costs and increase European competitiveness*.' (2007)

[50] Department of Communications, Energy and Natural Resources, '*Biofuels Obligation Scheme*.' (2008)

[51] Department of Environment, Heritage and Local Community Communication COM 26/11/08 '*Transforming transport will help economy to recover - 250,000 electric vehicles on the road by 2020*.' (2008)

[52] Green Aer Mobility, www.greenaer.ie

[53] Dublin Port, www.dublinport.ie

[54] Dublin Bus, www.dublinbus.ie

[55] Department of Finance, *Irish Budget 2007*. (2007)

[56] Department of the Environment, Heritage and Local Government, *'Building Regulations 2008*.' (2008)

[57] Private Residential Tenancies Board, Personal Communication. (2008)

[58] Dublin City Council, Personal Communication. (2008)

[59] ENFO, The Environmental Information Service '*Thermal Treatment and Landfill*.' (2007)

[60] Dublin Region Waste Management Programme, www.dublinwaste.ie

[61] Confederation of European Waste to Energy Plants. www.cewep.eu (2007)

[62] Prepared jointly by the Dublin Local Authorities, Dublin City Council, Dun Laoghaire-Rathdown County Council, Fingal County Council and South Dublin County Council. *'Waste Management Plan for the Dublin Region 2005-2010. Annual Progress Report 2007.'* (2007)

Glossary

Abatement cost (€/t CO_2): This is the cost or net saving per unit of improvement (given as € per tonne of CO_2 abated). This is calculated as a comparison to the reference technology in the baseline. All calculations take into account both the investment and running costs of a particular lever and its reference technology.

Abatement potential: The amount of annual improvement (reduction in CO_2 emissions) that could come from the adoption of each technological lever by 2025.

Additional measures: Principal measures outlined in the National Climate Change Strategy 2007-2013, over and above those already in place when the review of the first National Climate Change Strategy was published in 2006. The strategy draws together the Government's collective effort across all sectors to tackle climate change. Some of these measures are also included in recent policy statements, such as the Energy White Paper and Budget 2007.

Anaerobic decomposition /digestion: the breakdown of organic materials in the absence of oxygen. CH_4 is a by-product, either vented to the atmosphere or used as an energy source.

Biomass: as a renewable energy source, refers to living and recently dead biological material that can be used as fuel or for industrial production.

'Business as usual' scenario: A business as usual scenario is a policy neutral reference case of future emissions, i.e. projections of future emission levels in the absence of changes in current policies, economics and technology.

Carbon intensity (kg CO_2/kWh): This is the amount of carbon dioxide that will be released per kWh of energy of a given fuel. For most fossil fuels the value of this is almost constant, however in the case of electricity it will depend on the fuel mix used to generate the electricity and also on the efficiency of the technology employed. Renewable sources of electricity generation, such as hydro and wind, have zero carbon intensity.

CO_2/Carbon dioxide: The main greenhouse gas arising from human activities, and also naturally occurring. Atmospheric concentrations have risen from about 280ppm prior to the industrial revolution to about 380ppm currently.

DART: Dublin Area Rapid Transit. Surface rail line which runs along the coast of Dublin, from Howth/Malahide to Greystones, Co Wicklow.

Fossil fuel: Peat, coal, fuels derived from crude oil (e.g. petrol and diesel) and natural gas are called fossil fuels because they have been formed over long periods of time from ancient organic matter. All contain varying amounts of carbon, and in the recovery of energy from the fuel through combustion in the presence of air, the carbon combines with the oxygen to form CO_2, which is vented to the atmosphere.

Gross domestic product (GDP): The gross domestic product represents the total output of the economy over a period.

Light emitting diode (LED): Semiconductor device which converts electricity into light.

LUAS: Light rail transportation system in Dublin.

Retrofitting: Refers to the addition of new technology or features to older systems. For the purposes of this study, the term refers to the retrofitting of buildings specifically. The measures included in this specific case include solid wall insulation, draught proofing, and improved heating controls.

Technological lever: This report outlines a number of measures, largely technology driven, also referred to as technological levers, that have the potential to abate carbon emissions associated with urban areas.

Transport 21: Transport 21 is a capital investment framework under the National Development Plan through which the transport system in Ireland will be developed, over the period 2006 to 2015.

VRT: Vehicle registration tax.

Units:
1 Mt = 1,000 kilotonnes = 1,000,000 tonnes
1 MW (megawatt) = 1,000 kilowatts = 1,000,000 watts

Publisher: Siemens Limited
Fitzwilliam Court
Leeson Close
Dublin 2
Ireland
Tel. +353 1 216 2000
Internet: www.siemens.ie

Siemens gratefully acknowledges the contributions of the following people in the preparation of this research report:
Professor Dr.- Ing. Dr. h.c. Gerry Byrne FAIE FREng.,
Professor of Mechanical Engineering, University College Dublin
Dr. Donal Finn B.E., M. Eng.Sc., Ph.D., C.Eng.,
Senior Lecturer Mechanical Engineering, University College Dublin
Ms. Ruth Hanly B.E., MSc.
Ms. Maria Geraghty B.E.
Mr. Brian Whelan B.A., B.AI

Printed in Ireland on recycled paper.

www.siemens.com/sustainablecities