

Ireland's Low-Carbon Opportunity

An analysis of the costs and benefits of reducing greenhouse gas emissions



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Analysis carried out by McKinsey & Co

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Section 1

Executive summary

In order to contribute to our understanding of the climate change agenda for Ireland, the Sustainable Energy Authority of Ireland (SEI) commissioned McKinsey & Co to carry out an analysis of opportunities to reduce greenhouse gas (GHG) emissions in Ireland over the period to 2030. The analysis presents marginal cost curves for GHG abatement that illustrate the extent of each opportunity for abatement and the associated societal saving or cost.

The study, co-sponsored by ESB, was conducted in March-May 2009. It involved extensive meetings with over 80 stakeholders and experts, including representatives of seven government departments. SEI would like to record its thanks to all who gave generously of their time and expertise.¹

Cost-curve analysis shows the 'big picture'

The cost-curve analysis is intended to improve our understanding of the opportunities, costs and benefits of GHG abatement. Its main strength is that, by using a coherent framework across all sectors of the Irish economy, it presents a 'big picture' analysis. It therefore emphasises a broad, rather than in-depth, analysis of opportunities within a common structure.

The analysis examines technical opportunities, the extent of their abatement potential (avoidable emissions) and the likely unit cost. It is not intended to be policy-prescriptive, and does not set out the policies or programmes necessary to deliver these opportunities.

For each abatement opportunity, there is a quantitative estimate of the net societal costs or savings per tCO₂e of avoided GHG. This is not the absolute cost of implementing a given technology, but rather the *incremental* cost compared with a more carbon-intensive 'business as usual' alternative. The cost estimate makes a number of assumptions such as project discount rates and fossil-fuel prices. A range of feasible assumptions has been explored for the purpose of sensitivity analysis.

In some cases there are likely to be wider societal benefits that are not captured. The study does not purport to present a comprehensive benefit-cost analysis of any given technology choice. Also, behavioural opportunities are, for the most part, not considered. As an example, the GHG implications of improved efficiency of car engines are examined, but the effect of modal shift on future demand for private car transportation is not.

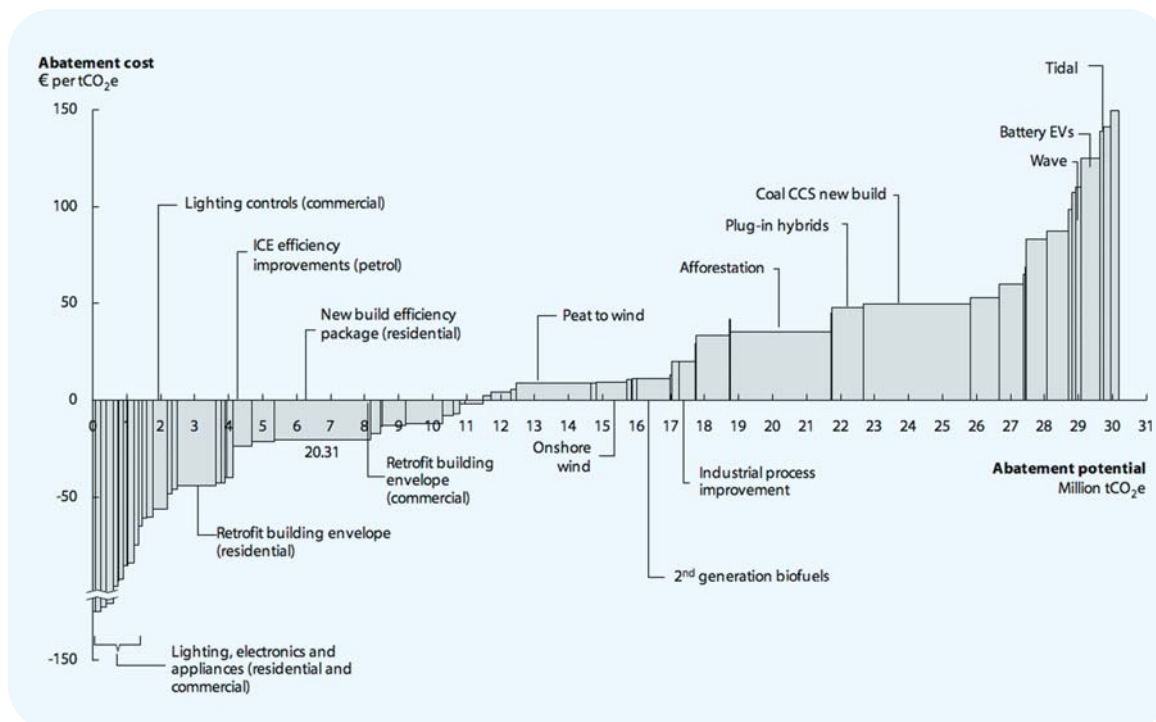
The study should be seen as work-in-progress rather than a finished product. It highlights uncertainties and knowledge gaps, thereby suggesting an agenda for further research in numerous areas of energy, transport and environmental policy.

Cost curves have been constructed for the economy as a whole, as well as for individual sub-sectors, in the years 2020 and 2030. In every case, the curve is composed of rectangular segments, each of which represents the future annual potential for GHG abatement and the associated marginal cost, for a particular technology. These segments are ranked in order of ascending cost, enabling an estimate of the cumulative abatement potential for any given level of marginal cost.

Figure 1.1 shows, for the year 2030, the overall economy cost curve in the main 'reference' abatement scenario which uses a real discount rate of 4% and assumes a crude oil price of \$60 per barrel (bbl). For the most part, a cut-off of €80/tCO₂e is used to confine the analysis to those opportunities most likely to be attractive in 2030.

¹ A full list of contributors and reference materials is provided in the **Technical Appendix** ('Ireland GHG Cost Curve – Outputs and Assumptions'), which is available on SEI's website www.sei.ie

Figure 1.1 Ireland 2030 GHG abatement cost curve – reference scenario



The chart indicates the nature of the opportunities identified – totalling around 30 million tonnes of Carbon Dioxide equivalent (CO₂e) – and the scale of costs that would be incurred in pursuing them. As can be seen, considerable carbon abatement potentials exist across the economy, even before additional behavioural opportunities (not analysed here) are considered.

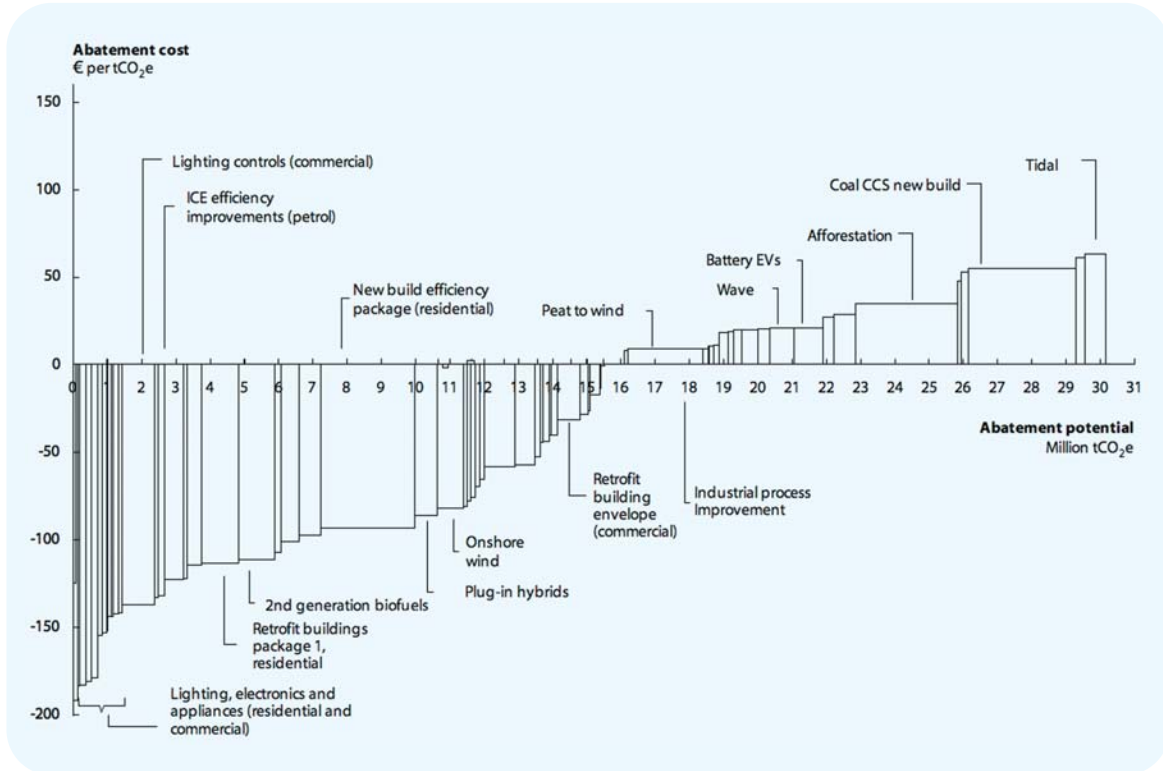
All sectors have a contribution to make, and all present opportunities to adopt new practices and technologies to prepare for the low-carbon future.

It is also noteworthy that about 40% of the abatement potential is estimated to have a negative net societal cost in the reference scenario. In other words, despite the assumption of a relatively low crude oil price, the abatement opportunities save more money over time than they cost². There is also considerable abatement potential available at low positive cost, including a significant contribution from renewable electricity generation.

At a higher oil price assumption (\$120/bbl), many of the abatement costs would be significantly reduced and the ranking order would change slightly. As shown in **Figure 1.2**, the proportion of negative cost opportunities in this alternative scenario would be substantially higher than 40%, although the majority of such opportunities still arise in the commercial and residential building sector.

2 Against the time horizons of 2020 and 2030 analysed here

Figure 1.2 Ireland 2030 GHG abatement cost curve – high oil price scenario



Because the study identified relatively few opportunities above the €80/tCO₂e threshold in the reference scenario, the estimated overall abatement quantity does not increase significantly in the high oil-price scenario. Regardless of the oil price, therefore, there will be a continuing need for complementary behavioural policies, particularly those that could deliver additional negative-cost abatement.

Strong savings potential – if necessary policies implemented

While the analysis demonstrates that significant savings in emissions are possible, it also highlights a number of key challenges in fulfilling this potential. For example, the continued existence of so many negative-cost technical opportunities in the ‘business as usual’ (BAU) case implies that they will not arise automatically, although many recent relevant policies and measures should start to demonstrate deeper impact in the near future.

From a policy point of view, one of the key challenges is that much of the abatement is expected to become feasible between 2020 and 2030, when newer technologies – such as high-penetration renewables or Carbon Capture and Storage – are expected to start making larger contributions.

Another issue for policy is that a relatively high proportion of the expected savings in 2020 and 2030 arise within the EU Emissions Trading sector, primarily electricity generation and large industry. This is significant because, after 2012, the EU Emissions Trading Scheme (EU ETS) abatement targets and the resulting sectoral allocations of EU allowances will be part of an EU-wide regime. Ireland’s national climate targets will be limited to non-EU ETS emissions which are dominated by the residential and commercial sectors as well as transport and agriculture.

In both the \$60/bbl and \$120/bbl oil-price scenarios, improvements to energy efficiency are found to offer the cheapest and most readily available abatement opportunities. This aligns with other analyses, including previous modelling work on Ireland’s energy system. It also tallies with SEI’s programme experience, where work with all energy users continues to reinforce the point that many savings opportunities remain untapped. For example,

recent analysis of the results of SEI programmes that support energy savings in business shows that a typical small to medium-sized enterprise that has not addressed its energy use in the past will typically find it easy to reduce costs by 10-20%.

Experience in Ireland and internationally highlights the same core reasons as to why such significant savings remain untapped. These reasons include:

- a lack of awareness or trusted information;
- constraints on capital investment;
- splits between who controls the energy use and who would benefit from the efficiency gain.

All these issues can be addressed through policies and measures. The Government's recently published National Energy Efficiency Action Plan for 2009-20 sets out over 90 actions currently in place. Energy efficiency will remain a strong focus for policy and action in Ireland.

Study reinforces 'green Ireland' policy

Several of the positive-cost abatement opportunities are of importance to Ireland's stated intent to take a leading global position as a centre of 'green' technology, goods and services. Some of Ireland's priorities in this area, such as ocean energy and electric vehicles, are confirmed by this analysis as being capable of delivering notable contributions to abatement by 2030 in particular.

The study reflects the importance of these newer technologies as important longer-term components of our GHG abatement agenda, as indeed is also shown by similar analyses around the globe. While some may appear relatively costly in terms of GHG emissions abatement, the wider strategic issues embodied in policy decisions are not factored into this quantitative analysis. For both ocean-energy technology and energy systems for electric vehicles, Ireland has taken the strategic decision to position itself with a view to building capacity, attracting investment and winning a global-leader status. It is likely that major business opportunities for Irish companies will arise in these areas, and that a leadership position could bring many positive economic benefits beyond those quantified here.

Challenging target for GHG reductions

As previously indicated, although the main focus of our sector-by-sector analysis is on the year 2030, the study's findings do have implications for Ireland's compliance with its GHG obligations within the European Union, whereby Ireland's non-EU ETS emissions in 2020 are required to be at least 20% below 2005 levels. It is clear that GHG reductions of the magnitude required to meet the 2020 target will be challenging and will require a substantial contribution through both technical and behavioural measures.

Section 2

Introduction

2.1 Background

Climate change is becoming the defining issue of our era. The coming years will be a period of change for everyone as society moves away from energy-intensive, fossil-fuel-based practices and lifestyles. The future will be smarter – less waste, new technologies and the intelligent use of resources. The next phase of growth in new goods and services, will emerge in this area and create many opportunities.

The concept of sustainable energy is not solely focused on climate-change abatement. We must find ways to address the carbon challenge without sacrificing international competitiveness or compromising security of energy supply. Our success in reducing fossil-fuel dependence will be an indicator of our ability to address all of the strategic challenges associated with energy. Less carbon will mean lower costs to business and consumers, reduced dependence on fuel imports, and less exposure to price volatility and risks to supply security.

Many states around the world, in recognition of the economic opportunities that will quickly emerge, have already taken action to develop their business sectors towards sustainable energy and low carbon. All national economic stimulus packages contain a ‘green’ strand, in some cases as the major focus of the plan. Moving early has advantages. We know this change is coming, so we can prepare. The challenge is to know how best to prepare. What technologies and solutions, what sources of energy, what kinds of services are likely to form part of the ultimate solution? Such questions are not easily answered, but we can make intelligent conjectures.

Most of the kinds of technologies and energy sources likely to grow as solutions in the coming 20-30 years already exist, even if only in nascent form. We can estimate their likely impacts and costs, as they grow in importance and scale. Armed with this knowledge, we will be able to consider where low-carbon solutions are likely to come from, what kinds of business opportunities may arise, and what the costs and benefits are likely to be.

SEI commissioned McKinsey & Co to carry out an analysis of GHG emissions abatement opportunities in Ireland, using an established methodology to assess the likely carbon abatement potential of a range of technologies. Our aim is simply to contribute towards a common understanding of the medium-term potential for reducing or offsetting energy-related and agricultural emissions by applying a coherent accounting framework across all sectors of the Irish economy. The analysis, while not exhaustive or definitive, offers a realistic estimate of the overall scale of abatement potential and its aggregate societal cost, while also giving a good sense of ranking for each abatement opportunity.

Although the methodology has been proven in several other countries, the project work was solidly grounded in local research and policy expertise. Over 80 stakeholders and experts were met with, including representatives of seven government departments. (A full list of these is provided in the Technical Appendix³.)

SEI would like to thank the organisations who participated in the project Advisory Panel and the numerous individuals who assisted the project team during the fieldwork phase and during the subsequent peer-review process. We also wish to acknowledge the supportive role of ESB in co-funding the engagement of external consultants.

3 A separate Technical Appendix to this report is available at www.sei.ie giving more details on the methods, data and assumptions of the study.

2.2 Methodological approach

The cost curve for Ireland was constructed in five stages.

First, the model was calibrated for a base year (calendar 2005 or 2006 as appropriate) by reference to historic data for each of six sectors, namely:

- Domestic and Commercial Buildings
- Industry
- Power Generation
- Road Transport
- Agriculture
- Land Use (Carbon Sinks)

Secondly, the GHG emissions for each of these sectors were projected out to 2030 by reference to relevant economic drivers (Gross Domestic Product, population growth, etc), assuming, for the purposes of establishing a baseline, no improvement in technological efficiency.

Thirdly, the projections for 2020 and 2030 were each adjusted downwards to allow for autonomous improvements in efficiency, and for policy measures which are already legislated or under development. This resulted in the Business As Usual (BAU⁴) emissions projections shown in **Figure 2.1**.

Figure 2.1 BAU projection versus corresponding Environmental Protection Agency figures



4 The definition of BAU used in McKinsey's framework is slightly different from UNFCCC guidelines for 'Baseline' scenarios.

Fourthly, all the individual GHG abatement opportunities were calculated up to a specified Marginal Abatement Cost (MAC), namely €80/tCO₂e. (This is considerably higher than the current market price of EU allowances in the EU Emissions Trading Scheme, which in June 2009 has been in the range €12–€15/t.)

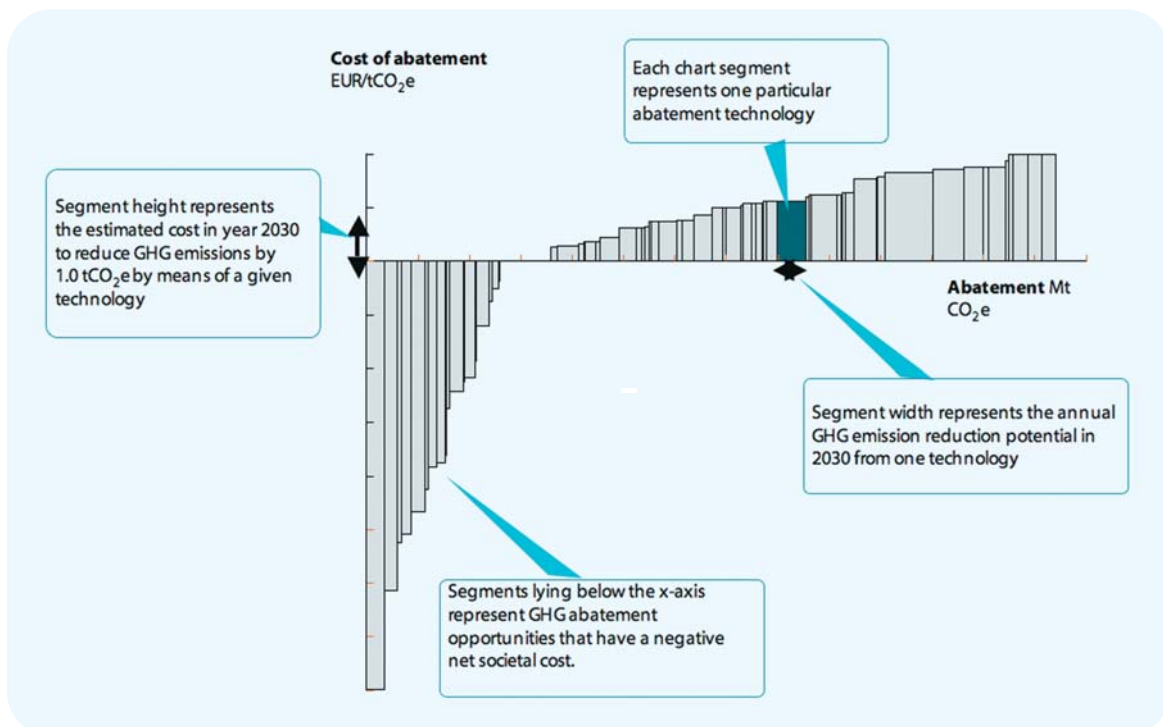
Finally, these opportunities are sorted into ascending order of MAC and are collated as rectangular segments in a histogram chart. As illustrated in **Figure 2.2**, the horizontal axis shows abatement quantity (tCO₂e) and the vertical axis shows the abatement cost per tCO₂e for the chosen year.

The area under the cost curve represents the aggregate societal cost for a specified quantity of potential abatement in the reference year (2020 or 2030) compared with the BAU technologies. The first analysis in each case is referred to as the **reference abatement case**. This is the marginal abatement cost curve using the base-case set of assumptions – principally about oil price and real discount rate. The prices of coal and natural gas are consistent with a crude-oil price of \$60/bbl. Where abatement depends on actions taken over a period of years prior to and/or after the reference year, a real discount rate of 4% is assumed. Wherever an abatement opportunity reduces consumption of a fossil fuel such as petrol, coal or peat, the assumed wholesale prices are consistent with a crude-oil price of \$60 per barrel (bbl) in the reference abatement case. This is in line with recent world oil prices. However, it is also appropriate to consider an alternative case in which oil prices are considerably higher. In the 2030 reference abatement case, the MAC for every abatement technology was calculated by means of the following formula:

$$MAC_{2030} = \frac{(\text{Cost in 2030 of abatement technology} - \text{Avoided cost of BAU technology})}{(\text{2030 Emissions in BAU case} - \text{2030 Emissions in abatement case})}$$

Care has been taken to avoid double-counting of savings from the individual opportunities. For example, measures to improve the efficiency of lighting and other electrical products will reduce the demand for power, thereby reducing the potential for abatement from renewable generation sources. Likewise, the progressive introduction of road transport biofuels will tend to reduce the technical abatement potential from improved engine efficiency.

Figure 2.2 How to interpret the GHG cost curve chart



2.3 Interpretation of results

In the following sections, we discuss the scale and the expected cost of GHG emissions-reduction opportunities for two 'snapshot' years (2020 and 2030), presenting the results in a simple graphical format.

Some of the underlying calculations are necessarily based on assumptions about the future rate of technological progress over the coming decades. For this reason, there are a number of areas (notably in the power-generation sector) where more detailed scientific and/or economic analysis would be worthwhile. SEI therefore regards this document as a work-in-progress. The cost-curve analysis is intended as a contribution to our understanding of opportunities, costs and benefits of GHG abatement. Its strength is in its presentation of a coherent framework to present a 'big picture' analysis. In this respect, the model is unusually broad in sectoral scope, encompassing energy use, industrial process gases, agriculture and land use. The following aspects of the study should, however, be borne in mind.

- It is not policy-prescriptive, but rather an analysis of technical opportunities, their likely extent and their likely cost. It does not set out the policies or programmes necessary to deliver these opportunities.
- It offers estimates of societal costs and savings in carbon terms. It does not offer an analysis of the wider benefits or strategic issues that underpin many policy decisions. Nor does it purport to present a cost-benefit analysis of any given opportunity or technology.
- Behavioural opportunities are, for the most part, not considered. As an example, the carbon implications of improved efficiency of car engines are examined, but the effects of modal shift or demand reduction are not. Further research into these issues is required.
- It focuses only on those emissions-related technologies that are expected to be technically feasible and commercially available within the next 20 years.
- Being 'bottom up', it relies on macroeconomic forecasts of energy service demand and energy market prices but it assumes no change in the future level of service demanded by consumers between the BAU or abatement case.
- Therefore, it does not capture the abatement potential of policies that promote conservation measures such as reduced internal temperatures, or that incentivise behavioural change such as switching from private cars to public transport. Nor does it capture some of the hidden barriers to investment in new abatement technologies, such as transaction costs, restricted access to finance and imperfect markets including principal-agent issues. Consequently, it does not purport to identify an optimal portfolio of policies or of the technologies required to achieve a given emissions target.

Finally, we would again highlight that GHG abatement is not the sole criterion for judging the societal value of investment in novel energy technologies. Factors such as improved security of supply and the development of technological leadership are also relevant.

The use of marginal abatement cost curves in energy-climate policy analysis

Abatement cost estimates are commonly used by policymakers and their advisors to assess the feasibility of achieving national or regional climate policy objectives. For example, in recent years the European Commission and the International Energy Agency have promoted a variety of techno-economic models.

Model	Responsible Organisation	Typical Applications
PRIMES	National Technical University of Athens	EU member state energy projections, marginal abatement costs for energy-related CO ₂ emissions
POLES	Institute for Prospective Technological Studies	Global projections of energy demand, CO ₂ emissions, GHG reduction opportunities
GAINS	International Institute for Applied Systems Analysis	Emissions of transboundary pollutant gases including GHGs
TREMOVE	Transport and Mobility Leuven	Energy demand and air pollutant emissions from the EU transport sector
MARKAL	IEA 'ETSAP' programme	Optimal-cost technology pathways to achieve future delivery of energy service demands, subject to GHG targets and other policy constraints

These software tools generally involve some aspect of dynamic simulation or optimisation, which unavoidably results in a degree of methodological complexity and hence a lack of transparency. For this exercise we deliberately selected a relatively simple model which does not seek to simulate or optimise a given policy package. We consider that the model's intuitive accounting framework is more readily understood by informed lay readers, particularly those in the business community. Originally developed by the McKinsey Global Institute, it has previously been used in published studies of GHG abatement opportunities in EU member states such as Sweden, the Czech Republic, Germany and the UK, as well as several non-EU countries.

Section 3

Discussion of results

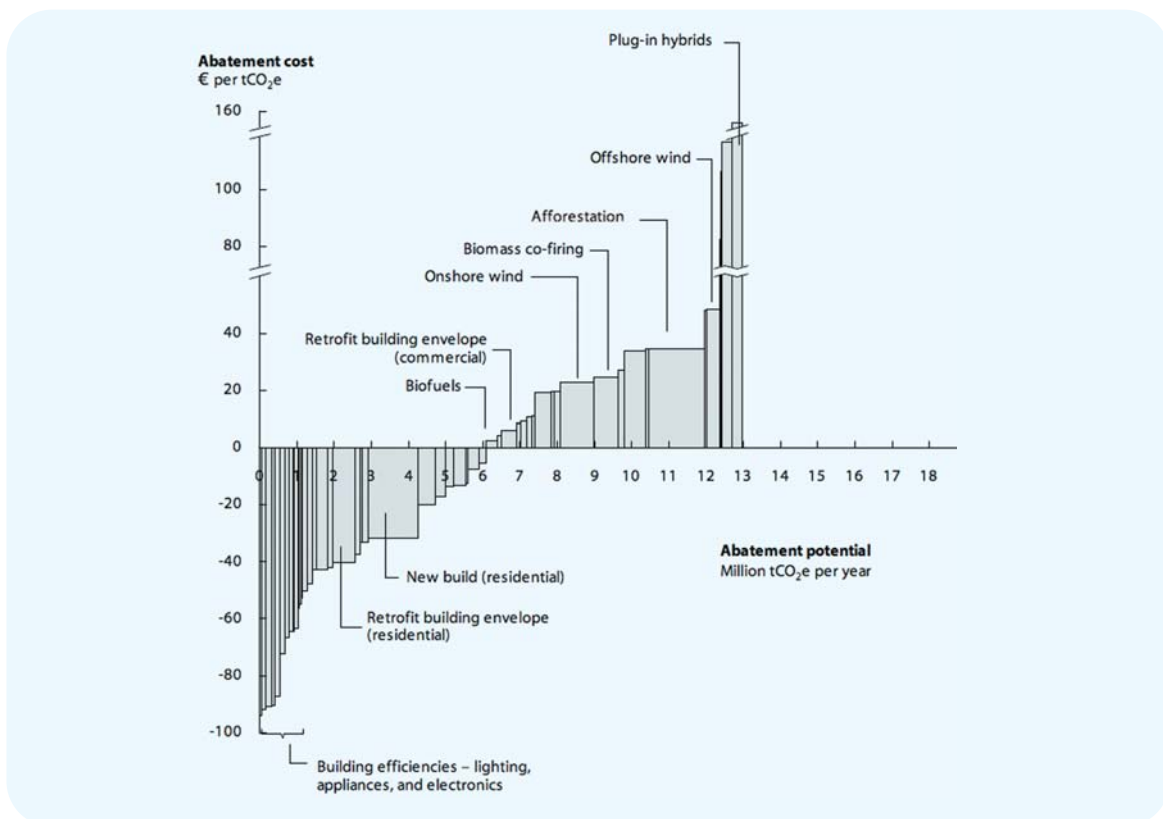
In this section, we present and interpret cost curves for the reference abatement case in 2020 and 2030. While the 2020 picture is relevant to current EU climate policy targets, the 2030 analysis allows for discussion of a wider range of technical measures, some of which will only become commercially viable after 2020. We also present the 2030 abatement cost analysis for a high crude-oil price scenario to show the importance of fossil-fuel price assumptions.

In all cases, the abatement quantity and the long-run marginal societal costs/savings are calculated by comparison to a specified BAU case. The relevant BAU assumptions for each scenario are outlined in the following subsections. Further details of the calculation methodology are provided in the Technical Appendix.

3.1 Reference abatement case – 2020

Figure 3.1 shows the overall abatement cost curve for Ireland consistent with an assumed crude-oil price of \$60/bbl. It identifies numerous technical opportunities with a marginal societal abatement cost up to €80/tCO₂e which, in aggregate, could deliver emissions reductions of around 12.4 million tCO₂e in the year 2020.⁵

Figure 3.1 Ireland 2020 abatement cost curve – reference scenario



5 The chart also shows 0.6 million tCO₂e of abatement opportunities in emerging technologies which lie above the €80/tCO₂e threshold but are the subject of specific government policies.

Approximately one-third of this reduction potential relates to installations in the power-generation and industrial sectors that would be covered by the EU ETS. Because EU ETS participants are able to trade EU Allowances in the market, the scheme provides economic incentives for abatement at a marginal cost up to the prevailing (or expected) international market price of Allowances. To date, EU Allowances have been trading at substantially less than €80/tCO₂.

The remaining reduction potential (8 million tCO₂e in 2020) would lie outside the EU ETS and represents approximately 20% of Ireland's current non-Trading Sector emissions. However, any such reduction must be offset against autonomous growth in emissions, linked largely to projected economic growth over the period to 2020. The net reduction would be substantially less than 20%.⁶ Ireland has a binding 20% national reduction target compared to 2005 levels.

This analysis therefore highlights the need for aggressive programme measures, not only to ensure the uptake of technical abatement opportunities but also to encourage behavioural measures that reduce the demand for energy services. Behavioural changes could, for example, include altered practices in heating our homes or a shift away from the use of private motor vehicles. Although our modelling framework does not fully quantify the impacts of such measures, the Technical Appendix does suggest that in the region of 4 million tCO₂e of additional behavioural savings may be achievable.

2020 EU targets

Policy targets for energy and climate change are driven by the EU commitment known as the 20-20-20 Initiative. This initiative aims to reduce greenhouse gas emissions by 20%, to increase the share of renewables in energy use by 20% and to improve energy efficiency by 20% – all to be achieved by 2020.

A Strategic Energy Review, published by the European Commission in December 2008, has placed security of supply as the highest level of priority across the EU. At its core is the Commission's proposal for a five-point EU Energy Security and Solidarity Action Plan, focusing on aspects including infrastructure needs and the diversification of energy supplies, energy efficiency and making the best use of the EU's indigenous energy resources. The Strategic Energy Review also takes the first steps towards the next stage of a European Energy Policy, considering the challenges likely to be faced between 2020 and 2050 and beginning the process of defining an EU response to these longer-term challenges.

One of the significant features of the EU 2020 Climate Change package is the delivery of a new Renewable Energy Directive covering electricity, heat and transport. The new directive on energy from renewable sources seeks to ensure that by 2020 renewable energy makes up at least 20% of the EU's total energy consumption. The directive sets out a target of 16% renewable energy for Ireland for 2020.

⁶ Caution is needed in comparing gaps to target for the non-ETS sector because there is not an exact correspondence between the BAU projections and the EPA's published emissions forecasts.

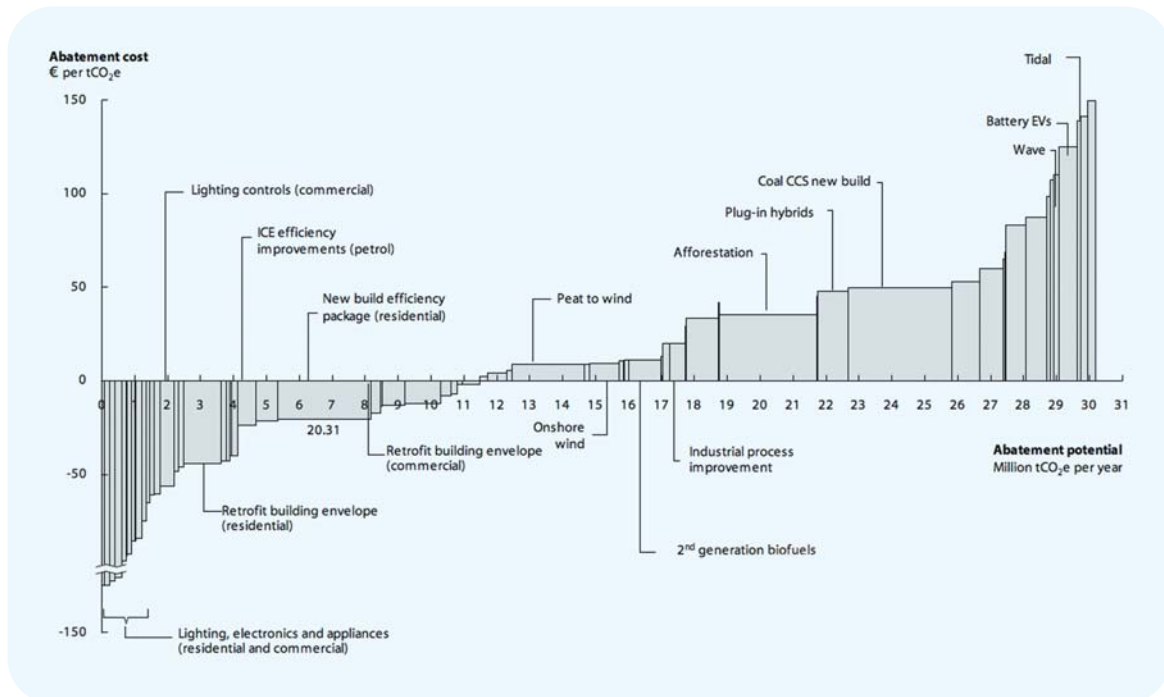
3.2 Reference abatement case – 2030

As outlined in Section 2, our model categorises abatement opportunities into six broad economic sectors, namely: Power Generation; Buildings; Transport; Industry; Agriculture and Land Use/Carbon Sinks. This section will analyse the individual cost curves for each of these sectors in some detail. First, though, we look at the overall picture for 2030.

Figure 3.2 shows the aggregate cost curve for Ireland consistent with an assumed crude-oil price of \$60/bbl. It identifies numerous technical opportunities with a marginal societal abatement cost up to €80/tCO₂e which, in aggregate, could deliver emissions reductions of around 28.7 million tCO₂e during the year 2030.⁷ At the left hand end of the chart are a number of efficiency improvement measures in the Buildings and Industry sectors which mostly have a negative net societal cost. Some of these (for example LED lighting) result in abatement within the Emissions Trading sector while others (such as improved thermal insulation) benefit the non-Emissions Trading sector. The remaining (positive cost) opportunities fall roughly into three groups, namely:

- Conventional technologies to decarbonise electricity generation (e.g. onshore wind)
- Changes in land use that create carbon sinks (afforestation and soil restoration)
- Emerging energy-efficient technologies (e.g. wave power, electric vehicles)

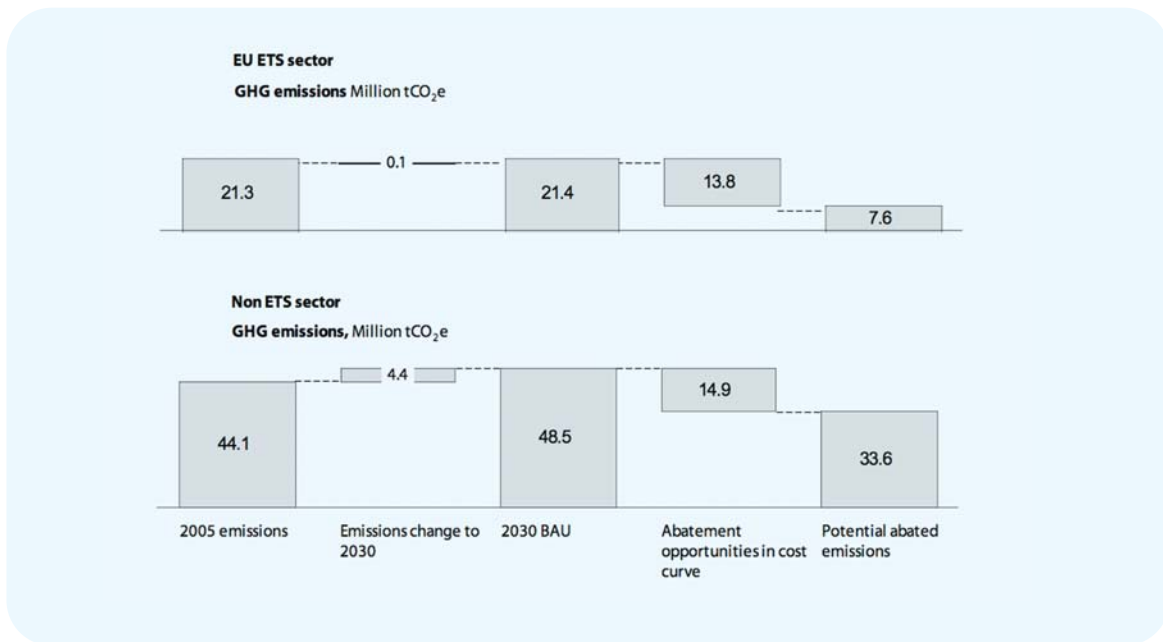
Figure 3.2 Ireland 2030 GHG abatement cost curve – reference scenario



7 The right hand end of the chart also shows 1.3 million tCO₂e of technical opportunities which lie above the €80/tCO₂e abatement cost threshold but are currently the subject of specific government policies.

As shown in **Figure 3.3**, nearly half of the total abatement potential for 2030 is within the scope of EU Emissions Trading. A significant portion of the abatement potential is the result of new or replacement investment in renewable electricity generation and in Carbon Capture & Storage (CCS). Our analysis suggests that the Emissions Trading sector could feasibly achieve a 65% net reduction in emissions (compared to 2005) through technical measures costing less than €80/tCO₂e.

Figure 3.3 Abatement in 2030 – Trading versus non-Trading sector



By contrast, the Irish non-Emissions Trading sector could feasibly achieve a net reduction of just 24% compared to the 2005 emissions levels. This is mainly because there are proportionately fewer abatement opportunities than in the EU ETS sector, but partly also because the BAU projection features proportionately faster growth to 2030.

The remainder of this section presents and interprets the detailed 2030 cost curves for each of the six economic sectors in the model.

3.2.1 Power generation

Key assumptions in BAU projection and reference abatement case

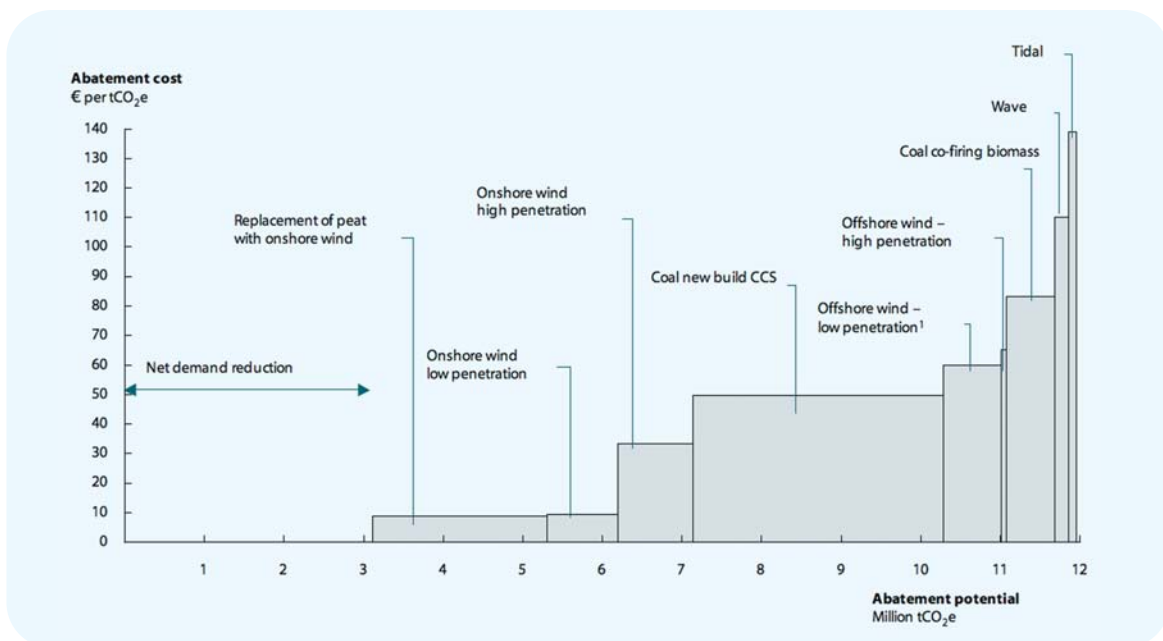
The BAU projection for 2030 assumes no co-firing with biomass in any fossil-fuelled stations, and no early retirement of capacity. The level of investment in renewable generation is frozen at current commitment levels. Any existing oil-fired or gas-fired power stations that reach the end of their economic life are assumed to be replaced by Combined Cycle Gas Turbine (CCGT) plants. Any growth in electricity demand is also met by investment in CCGT. The existing coal-fired (3 x 300MW) station at Moneypoint is taken to be replaced by new coal-fired capacity. The three existing peat-fired stations continue to operate to 2030 with little or no co-firing of biomass. An ongoing programme of investment in electricity transmission infrastructure is assumed to take place in accordance with Eirgrid's 'Grid 25' strategy. It should be stressed that these assumptions are purely for cost-comparison purposes and do not necessarily depict the evolution of a sustainable or operationally efficient portfolio of generation plant.

The reference abatement case assumes the same schedule of retirements for oil and gas-fired stations as in the BAU case. However, they are replaced by a portfolio of renewable generation technologies rather than by CCGT plants. The peat-fired stations are also closed and are replaced by renewable generation. Furthermore, any growth in electricity demand to 2030 is also met by investment in renewables. Moneypoint coal-fired station is assumed to be replaced by a new 1000MW station that co-fires coal with biomass but also features Carbon Capture & Storage (post-2020).

Technical potential in the reference abatement case

The power sector reference abatement scenario, as shown in Figure 3.4, places considerable emphasis on proven technologies such as onshore and offshore wind generation.

Figure 3.4 Power sector 2030 abatement cost curve



At the left hand side of the chart is a segment labelled 'Net demand reduction'. The avoidable emissions (3.1 million tCO₂e) in this category actually relate to the use of energy-efficient lighting, motors and other appliances by end users in the Buildings and Industry sectors. Most of these technologies have a negative societal cost, and they are accounted for separately in the relevant end-use sectors. However, because they reduce demand for electrical power, they also reduce the technical potential for replacing fossil plant with renewable generation. Our model takes care not to double-count such emissions reductions.

The second chart segment, labelled 'Replacement of Peat with Onshore Wind', shows that 2.2 million tCO₂e of emissions in 2030 will be avoided if, at the end of their economic lives, the three existing peat-fired stations are replaced on the system by on-shore wind. The levelised abatement cost (just under €9/tCO₂e) is calculated by comparing the total average unit cost of peat-fired generation against that of onshore wind generation at prime sites (consistent with 32% load factor).

The third and fourth segments, with a combined abatement potential of 1.9 million tCO₂e, relate to onshore wind generation which either replaces existing oil/gas-fired plant or is needed to meet the growth in electricity demand. The capital costs are the same in each case but the project economics are quite different. Specifically, 'Low Penetration' (costing just over €9/tCO₂e) corresponds to prime sites for wind-farms, whereas 'High Penetration' (around €33/tCO₂e) corresponds to less favourable onshore locations with a lower assumed load factor of 28%.

The fifth segment ('Coal – new build CCS') assumes the replacement of 900MW of conventional coal generation with a 1000MW coal/biomass/CCS facility. The potential abatement from CCS is around 3.2 million tCO₂e. The associated abatement cost (€50/tCO₂e) is estimated by comparing the total average generation cost for each type of plant, assuming 70% load factor in each case. The CCS plant is assumed to have a higher capital cost and lower thermal efficiency than the conventional plant, but 80% of its emissions are captured and sequestered. For the purpose of pipeline costing, the CCS plant is assumed to be located in Co. Clare, and the storage is assumed to take place at the Kinsale gasfield. However, numerous other permutations of capture/storage sites would be possible.

The sixth and seventh segments, with a combined abatement potential of 0.8 million tCO₂e, relate to offshore wind generation. The levelised abatement cost (€60-€65/tCO₂e) is substantially higher than that for onshore because of higher construction and operating costs. The distinction between 'low' and 'high' penetration refers in this instance to the incremental cost of bringing power cables ashore from more remote marine locations. The same generation load factor (40%) is assumed to apply in all cases.

The eighth segment (coal co-firing biomass) also refers to the 1000MW coal/CCS plant, for which around 15% of the generation fuel is assumed to be a variety of biomass fuels. The abatement cost lies slightly above the previously-discussed €80 threshold in the low oil-price scenario.⁸

Finally, the ninth and tenth segments, with a combined abatement potential of 0.3 million tCO₂e refer to 113MW of tidal generation and 154MW of wave generation. The relatively high unit abatement costs associated with these emerging technologies should be regarded as merely indicative, since they are contingent on the technological progress of ongoing RD&D work. It should also be noted that the assumed rate of deployment for these technologies reflects the assumption of no early retirement of existing fossil plant, and that it does not imply any technical constraints on the achievement of government targets. Indeed, the recent *All Island Grid Study* indicates that renewables could readily supply more than 40% of delivered energy with only a small impact on societal cost of electricity. However, this analysis does highlight the importance of assumptions about early retirement of fossil-fuelled power stations, and the need for a better understanding of the likely impact of high-penetration renewables on wholesale markets.

Although the possibility of including a nuclear power plant in the generation portfolio is not considered in the reference abatement case, the Technical Appendix does briefly analyse an alternative scenario in which a 600MW nuclear plant is constructed to replace Moneypoint coal-fired station in 2025. Compared to coal-biomass firing with CCS, the technology appears to be a relatively inexpensive abatement option. However, this may underestimate the full societal cost, since the analysis does not include a detailed consideration of network system requirements such as spinning reserve. Nor does it include any set-up costs for security enforcement, safety inspection, or the storage and disposal of spent reactor fuel.

Key opportunities in the power sector

Compared to other EU Member States, Ireland relies heavily on imported oil and gas. This has raised concerns for energy cost competitiveness and security of supply. However, the country is also relatively rich in wind, wave and tidal energy resources. As the relevant technologies mature, an opportunity exists to exploit these indigenous resources to displace fossil energy imports while creating 'green' employment in the process. This could include marketable expertise in the development and deployment of novel offshore technologies, or in the management of transmission networks with high levels of intermittent renewable sources in the generation portfolio. Moreover, given adequate investment in electrical interconnection between Ireland and the rest of Western Europe, it may also be commercially feasible for Ireland to become a major net exporter of clean energy.

There is also a significant medium-term opportunity to introduce at least one Carbon Capture & Storage project, given the desirability of retaining some coal-fired generation in the mix for security of supply reasons. As identified in previous SEI studies, there are numerous potential storage sites in the form of aquifers, exhausted offshore gas fields and underground salt deposits. The optimal arrangement will partly be determined by the

⁸ It should be noted, though, that the abatement cost associated with such fuels may be lower in other applications such as small-scale Combined Heat and Power schemes.

cost of proving the geological suitability of individual sites and partly by the logistics cost of transporting CO₂ from the preferred site of capture. It is possible that EU funding may be available for demonstration projects.

A definitive assessment of the potential for CCS in Ireland was published by SEI in a consultancy report, titled *An Assessment of the Potential for Geological Storage of CO₂ for the Island of Ireland*. The cost-curve study uses a similar methodology for assessing the likely project costs associated with a capture at a new coal-fired power station, although it should be noted that the assumed storage site (Kinsale) is only one of several potential sites that were identified. The estimated abatement costs are broadly similar in the two studies, despite differences in the assumed market price of coal.

Outstanding issues for the power sector

Although the ramp-up of renewable generation in Ireland could be of considerable societal benefit, a number of structural or institutional barriers could threaten its progress. For example, there may be commercial risks from the developer's perspective, reflecting a degree of uncertainty over the long-term structure of the wholesale electricity market on the island of Ireland. Such uncertainty might well be amplified by the impact of increased interconnection with Britain or mainland Europe. Consequently, it may be necessary to provide alternative arrangements or supports for an extended period.

The potential consequences of high renewable penetration wind may also be a cause for concern to investors considering investment in CCS or other fossil-fuelled plants in Ireland. The recent All-Island Grid Study suggests that an arrangement in which more than 40% of delivered energy is derived from intermittent base-load generators is technically feasible. It also suggests that such an arrangement could be implemented at a relatively low societal cost, although the financial returns on certain types of conventional generation plant may be altered as a consequence. A certain amount of coal- and gas-fuelled capacity is likely to be required to provide system balancing and supply security. To ensure that the necessary private-sector investments are viable, it would therefore be helpful to have a better understanding of the commercial implications for fossil-fuel generators operating in a wholesale power market with interconnection.

3.2.2 Residential and commercial buildings

Key assumptions in BAU projection and reference abatement case

The main source of CO₂ emissions from domestic dwellings is from the direct combustion of fossil fuels in boilers to generate space and water heating, and also cooking. The BAU case is assumed to be driven mainly by population growth, household size and income. The commercial property sector is a relatively intense consumer of electricity for a variety of purposes such as office lighting, office equipment and air-conditioning. The relevant activity levels and their associated CO₂ emissions are assumed to correlate with GDP. In both sectors, the BAU case assumes a frozen technology, with little or no implementation of the 2008 Building Regulations in new construction, and virtually no retrofit of existing buildings for the purpose of improved energy efficiency.

Strictly speaking, since the 2008 regulations have taken legal effect, they should be included in the BAU case. The reason for not doing this was to facilitate a comparison with Ireland's recently published National Energy Efficiency Action Plan (NEEAP) for 2009-20 which includes quantitative estimates of avoided CO₂ emissions through refitting of existing buildings and enforcement of new building regulations. The cost-curve analysis and the NEEAP use common assumptions about future building rates, but they employ quite different methods for the adoption of new building standards in Ireland. Whereas the NEEAP analysis examines a sequence of progressively more stringent building regulations, this study models this as a phased uptake of a single thermal efficiency standard.

Technical potential in the reference abatement case

Figure 3.5 shows the combined cost curve for domestic and commercial buildings in 2030. There are numerous abatement opportunities with a negative societal cost in the reference abatement case. As itemised in Table 3.1, these relate mainly to energy-efficient electricity use, boilers and insulation in new and existing buildings.

The overall abatement quantities for 2020 from the buildings sector are broadly consistent with the corresponding NEEAP projections for 2020, the NEEAP figures being slightly higher in commercial buildings (2.1 million tCO₂e versus 1.6 million tCO₂e) but slightly lower in domestic dwellings (2.9 million tCO₂e versus 3.8 million tCO₂e).

Figure 3.5 Buildings sector 2030 cost curve

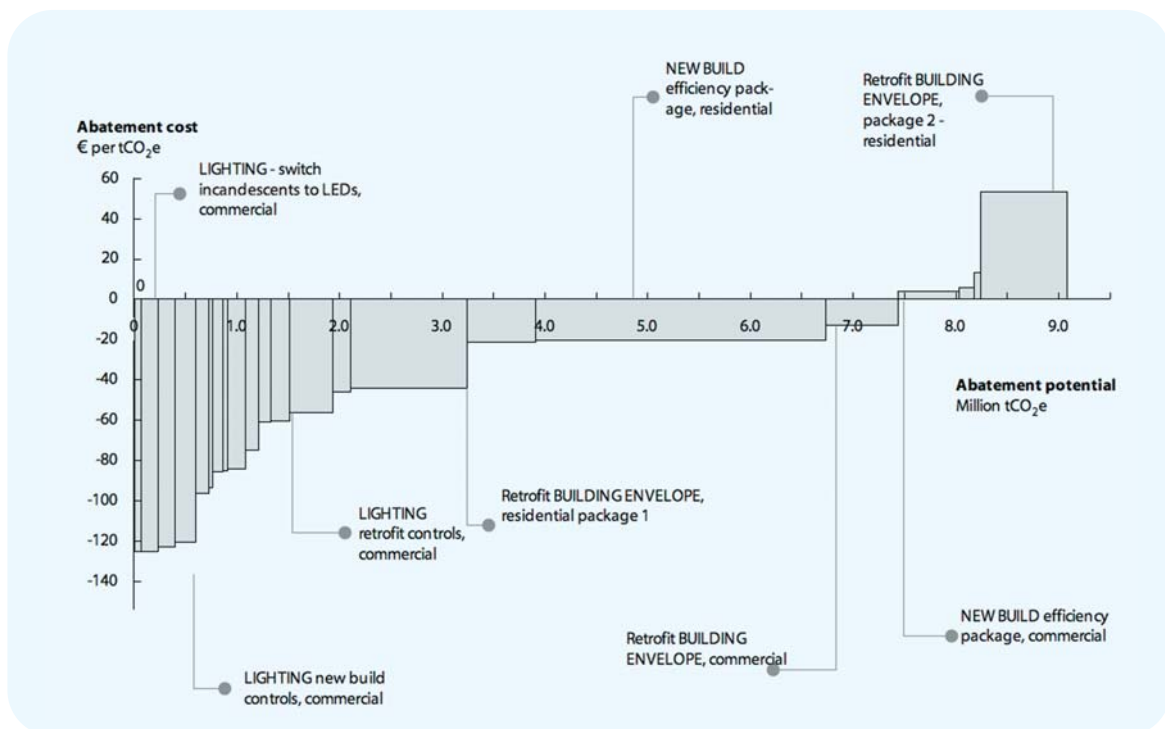


Table 3.1 Buildings sector – negative cost abatement opportunities

Description	Abatement potential in 2030 MtCO ₂ e	Marginal societal cost per tCO ₂ e avoided
<i>Residential</i>		
Efficient consumer electronics	0.07	-€125
Lighting – switch from incandescent to LED	0.16	-€123
Efficient appliances	0.14	-€96
Lighting – switch from CFL to LED	0.04	-€93
Retrofit HVAC	0.17	-€84
Maintenance of HVAC systems	0.18	-€60
Retrofit thermal insulation ('package 1' ⁹)	1.14	-€44
Retrofit heating systems	0.66	-€21
Improved thermal insulation – new build	2.83	-€20
<i>Commercial</i>		
Lighting – switch from incandescent to LED	0.17	-€125
Lighting controls – new build	0.20	-€120
Efficient electronics	0.10	-€85
Efficient appliances	0.04	-€85
Lighting – switch from CFL to LED	0.12	-€75
Retrofit HVAC controls	0.12	-€61
Lighting – retrofit controls	0.43	-€56
Retrofit HVAC	0.17	-€46
Retrofit thermal insulation	0.70	-€13

The remaining (positive cost) opportunities relate to very high energy-efficiency standards in new buildings (i.e. considerably beyond 2008 regulations) and to the retrofit of comparatively expensive energy-saving measures in existing houses.

⁹ Refers to measures such as attic and wall insulation, and air tightness, as opposed to 'package 2' measures to bring a building to passive house standards

Key opportunities in the buildings sector

Major opportunities for abating CO₂ emissions in the buildings sector in 2030 will arise from updating and enforcing mandatory regulations, particularly as they relate to the thermal insulation of walls, floors windows, doors; ventilation systems and draft-proofing; boiler thermal efficiency; and lighting, motors and electrical appliances. Non-regulatory measures, such as information campaigns, market-building and financial supports, will also be appropriate.

For example, for the residential sector the model assumes a gradual move towards 'passive' building standards, corresponding to an overall annual thermal energy demand of 40kWh per square metre of floor area. This is substantially better than the 2005 building standards (150kWh) and the 2008 building standards (96kWh). It is worth noting, though, that current government policy envisages going beyond the passive standard to 'zero carbon' from 2013. Achieving this objective will require deployment of additional technologies (such as micro-generation) that are not currently included in the model.

There will also be significant opportunities to meet higher thermal efficiency standards through the retrofit of the existing stock of residential and commercial property. This cannot readily be enforced through mandatory standards, but can be encouraged through a variety of educational programmes and financial incentives such as SEI's Greener Homes Scheme and Home Energy Saving Scheme.¹⁰

Outstanding issues in the buildings sector

Arguably, the key issue for improving energy efficiency and hence reducing CO₂ emissions in new buildings is the timely enforcement of mandatory regulations by Building Control Officers within each local authority. For existing buildings, there appear to be a number of barriers to making investments which would seem to have a negative net societal cost. For example, householders may lack the necessary information about the benefit-cost trade-off, or they may consider the payback time on efficiency investments to be too long. This is particularly a concern for rented properties, where landlords may be unwilling to invest in energy-saving measures where the financial benefits accrue to their tenants.

3.2.3 Road transport

Key assumptions in BAU projection and reference abatement case

The projected transport sector energy service demand (expressed in annual vehicle-kilometres for each category of vehicle) is derived in the BAU case by reference to population and GDP growth. It was calibrated using vehicle mileage data from the National Car Test (NCT) database. Exactly the same levels of vehicle ownership and annual mileage are assumed in the reference abatement case, implying no switch in consumer preferences towards car sharing or alternative forms of transport. Moreover, the abatement case also assumes no change in preference towards smaller passenger vehicles.

In the case of improved engine efficiency, the relevant investment by automotive manufacturers is assumed to be driven by US, Asian or European emissions standards or air-quality regulations, regardless of the policy framework in Ireland. The same consideration also applies to the marginal abatement cost of cellulose-derived transport biofuels; whether these are from domestic production or from imports, they are assumed to be at world prices.

Similar considerations apply for vehicle electrification. The incremental vehicle cost will depend on how quickly the production cost of batteries and power-trains can be brought down due to international learning effects and economies of scale. The net societal cost per tonne of avoided CO₂ may also depend on whether the manufacturers' efficiency savings and/or product development costs are fully passed on to customers; our model assumes full pass-through. Nevertheless, the abatement *quantity* achievable from such technologies within Ireland may be significantly influenced by financial incentives to encourage the purchase of motor vehicles with

¹⁰ A recent cost benefit analysis of the Home Energy Saving scheme undertaken by SEI indicates that, based on assumed programme spend of €100m, the net present value of the savings to participants up to 2020 will be over €215m. Thus, the levelised societal benefit to 2020 (counting energy savings against Exchequer and participants' investment) will be over €125m, even allowing for some of the potential savings being offset by increased thermal comfort in the home.

the lowest CO₂ emissions per km for any given engine performance. In both the BAU and reference case, a wholesale price of gasoline is calculated, consistent with the \$60/bbl crude price. Being a societal fuel cost, it does not include fuel excise duty.

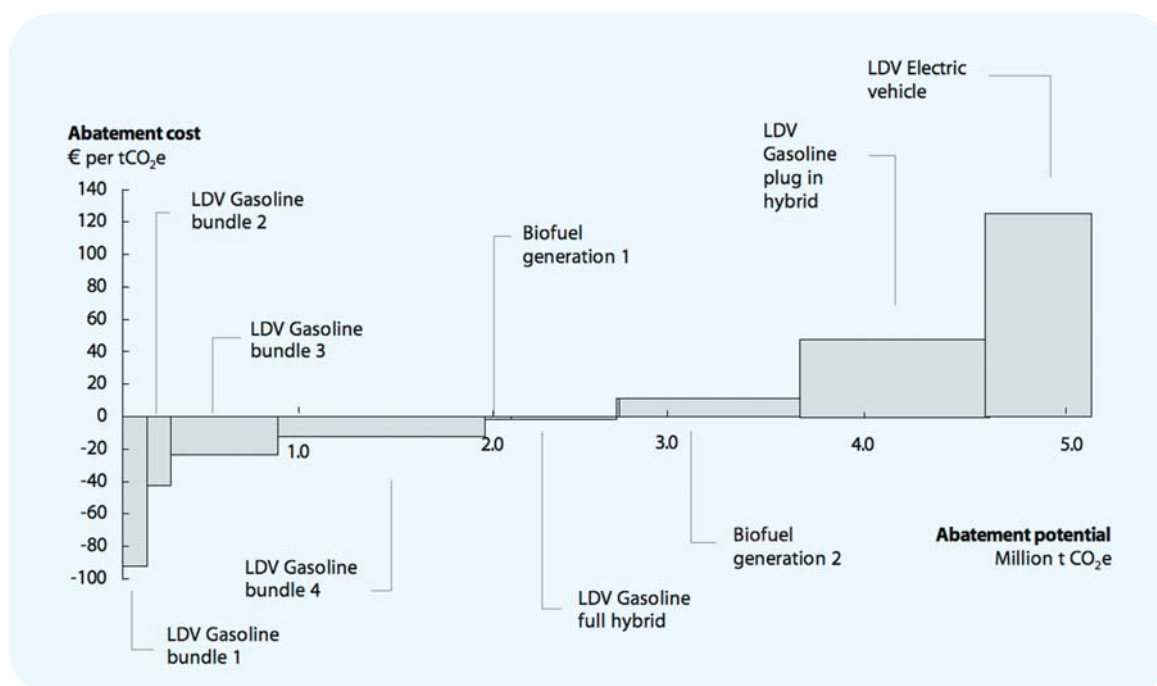
Technical potential in the reference abatement case

Figure 3.6 shows the abatement cost curve for light-duty vehicles (LDV), a category consisting of private cars and small commercial vans. The first four, with an aggregate abatement potential of 1.9 million tCO₂e, relate to a series of ‘bundles’ of potential improvements to vehicle design, including reduced rolling resistance and improved aerodynamics. There is also an abatement potential of nearly 0.6 million tCO₂e at a cost of -€2/tCO₂e from petrol hybrids.

Two further opportunities (first- and second-generation bio-ethanol) relate to fuel switching and have an aggregate abatement potential of 1.1 Million tCO₂ at a marginal cost up to €11/tCO₂e. The second-generation fuels are expected to be more widely used, despite them remaining somewhat more expensive. This is because, being cellulose-derived, they are less likely to compete with food crops for farm resources.

Finally, there are two opportunities relating to electric vehicles. Both are based on our best projections of battery and power-train production costs as well as societal electricity-generation costs. In this regard, it is important to note that the cost analysis assumes a significant portion of night-time charging. Petrol plug-in hybrids are estimated to have an abatement potential of 0.9 million tCO₂e at a marginal cost of €48/tCO₂e, while battery-electric vehicles are estimated to have a potential of nearly 0.6 million tCO₂e at a marginal cost of €125/tCO₂e. The latter are more expensive, primarily because of the need for larger batteries, although considerable work is underway to bring costs down.

Figure 3.6 Transport sector 2030 cost curve



Key opportunities in the road transport sector

Arguably, the biggest opportunities to reduce emissions in transport are through behavioural shifts, such as smaller cars and fewer car journeys, which lie outside the scope of our analysis. The relevant policy framework will entail the promotion of car-sharing schemes or providing financial incentives to use public transport. These issues are addressed in the NEEAP, based on analysis and policies set out in the Department of Transport's recent policy document *Smarter travel: a sustainable transport future*. This latter document sets out in full detail current policy towards sustainability in the transport sector, covering dimensions much wider than those analysed here.

Outstanding issues in the transport sector

Our analysis does not include the impact of investment in public-transport infrastructure, or of better spatial planning to reduce car commuting distances. Although the issue of fuel tourism is acknowledged, it is not explicitly modelled. Rather, the primary focus is on Irish-registered private vehicles and on passenger transport in particular. As such, the analysis potentially misses several significant opportunities for emissions abatement. Conversely, it may overstate slightly the abatement opportunity from switching to electric vehicles. For example, encouraging an increased uptake of such vehicles may impact disproportionately on sales of relatively energy-efficient vehicles such as full hybrids. Moreover, such vehicles may have lower annual mileage than the national average.

It is worth noting that the 'on-road' vehicle emissions (gCO_2/km) which have been used to calculate the abatement cost for various vehicle-related abatement opportunities are roughly 40% higher than the published standard vehicle test-emissions data. The discrepancy suggests a considerable abatement potential from promoting behavioural measures such as eco-driving, and also from the relief of traffic congestion.

3.2.4 Industry

Key assumptions in BAU projection and reference abatement case

Due to its large emissions contribution, cement manufacture is highlighted among industrial sectors. Industry is effectively analysed in two parts - cement manufacture and the rest of industry.

For the cement sector, BAU demand to 2030 is assumed to follow the level of activity in the construction sector. Roughly two-thirds of cement-sector CO_2 emissions are assumed to arise from the chemical decomposition of limestone in the clinker production process, with the remainder coming from kiln fuel combustion. The average chemical composition of cement products is assumed to remain unchanged at just under 90% clinker content, and the composition of kiln fuels (mainly coal and petroleum coke plus a small amount of biomass) also remain unchanged. In the reference abatement case, market demand for cement remains undiminished but the percentage clinker content is reduced substantially without any loss of performance. There is also a substantially increased amount of biomass kiln fuel used as a substitute for coal.

For other industrial sectors, the BAU level of energy use is assumed to track GDP as per recent ESRI projections. The reference scenario assumes no fundamental change in manufacturing processes, but does assume that progressive improvements can be made to energy efficiency through improved process design and the use of more efficient electric pumps and motors.

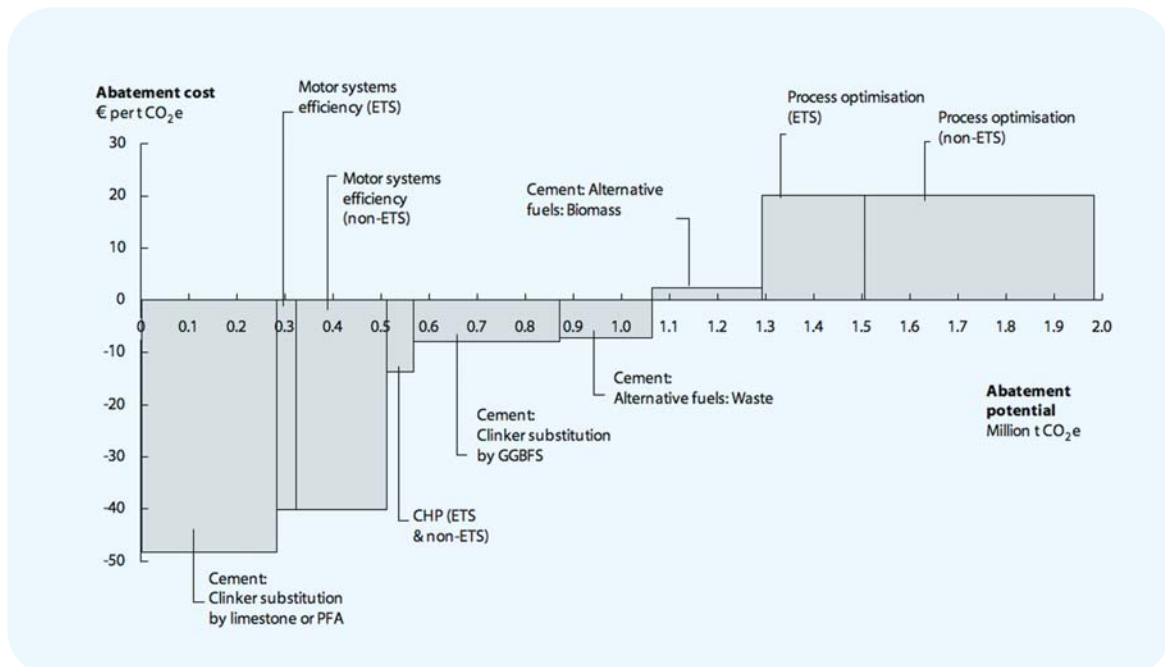
Technical potential in the reference abatement case

Figure 3.7 shows the cost curve for industry, excluding commercial buildings. Around 0.3 million tCO_2e of emissions could be avoided at a marginal abatement cost of $-\text{€}48/\text{tCO}_2\text{e}$ by the increased use of Pulverised Fly Ash and/or ground limestone as substitutes for clinker in blended cement. A further 0.3 million tCO_2e of abatement potentially arises from the use of Ground Granulated Blast Furnace Slag (GGBFS) at an abatement cost of $-\text{€}8/\text{tCO}_2\text{e}$. In each case, the cost saving arises from the avoided long-run marginal cost of clinker

production, albeit partly offset by the purchase cost of substitute materials. In this regard, GGBFS commands a substantially higher price than the other substitute materials. This is partly because its supplies within Europe are limited but also because it enables high-performance cements to be produced with substantially lower clinker content.

Other negative cost opportunities relate mainly to the use of more efficient motors in manufacturing industries such as food and chemicals. All of the resulting electricity savings (including the use of CHP) have the potential to reduce emissions in the power-generation sector. There are also two positive-cost chart segments, both labelled as process optimisation. These refer to a wide range of industrial processes where investment in better control systems or process redesign can result in fuel or electricity savings. The distinction between EU ETS and non-ETS installations has implications for 2020 EU targets. In both cases, however, the projected savings are highly specific to the individual end-user, and further research would be required to verify the estimates. Our estimates involve making extrapolations from previous UK studies of comparable industries.

Figure 3.7 Industry sector 2030 cost curve – reference abatement scenario



Key opportunities in the industry sector

There are a wide range of energy-intensive process technologies that are industry-specific. SEI continues to work closely with firms to achieve progressive improvements in process design and energy management. Initiatives include the Large Industry Energy Network (LIEN), the IS 393 Energy-Management Systems programme, and the promotion of energy-efficient design.

Outstanding issues in the industrial sector

The production of cement is a highly specialised capital-intensive process and is subject to stringent environmental regulations. The product itself is also subject to internationally agreed quality standards, and product choices are strongly influenced by technical experts. Accordingly, the opportunity to reduce emissions by fuel substitution or by amending the chemical composition of blended cement can be a complex issue. Such operational decisions are therefore best made by the manufacturers themselves, in the context of other commercial considerations, including the expected long-term availability of kiln capacity and of substitute fuels or raw materials.

Across all industries, there are a number of well-documented organisational barriers to reducing CO₂ emissions through improved energy management. These are the subject of ongoing attention through policies such as the Accelerated Capital Allowance scheme, and a number of support and advice programmes.

3.2.5 Agriculture

Key assumptions in BAU projection and reference abatement case

The BAU assumptions in respect of agricultural GHG emissions include a number of policy drivers, notably:

- Reform of the EU's Common Agricultural Policy, particularly as it relates to livestock numbers in the beef and dairy industry
- EU directives on the use of chemical fertiliser in sensitive areas
- Changes in land-use, for example to promote the domestic production of biofuels

The reference abatement case assumes no change in livestock numbers, trends in agricultural land use or on-farm energy consumption, but it does take account of the potential for better farming practices which could reduce non-CO₂ emissions for a given level of output.

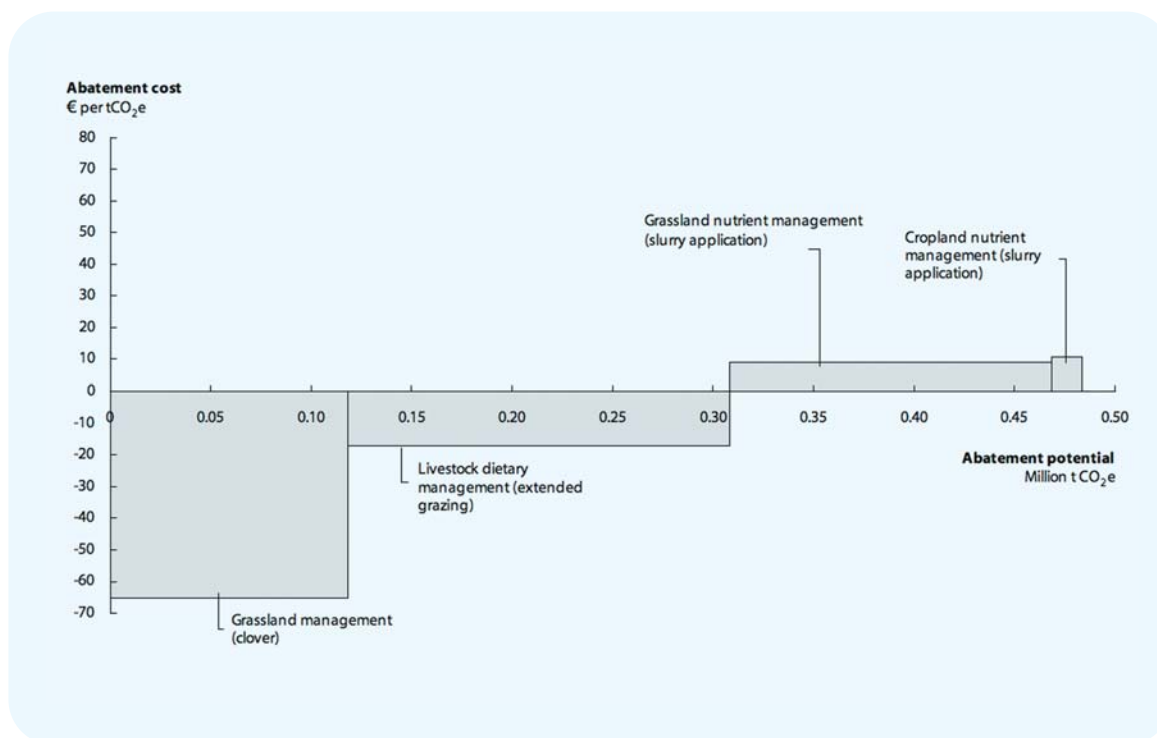
Technical potential in the reference abatement case

Figure 3.8, which shows the agricultural cost curve, reflects the importance of Ireland's beef and dairy farming sector. The three largest opportunities all relate to improved management of grassland:

- Just over 0.1 million tCO₂e at a cost of -€65/tCO₂e relates to growing clover on pastureland, thereby reducing the need for nitrogenous fertiliser with associated emissions of the potent greenhouse gas nitrous oxide.
- Nearly 0.2 million tCO₂e at a cost of -€17/tCO₂e relates to extending the cattle grazing season, thereby reducing the use of feed supplements and, in doing so, reducing the quantity of enteric methane emissions.
- Nearly 0.2 million tCO₂e at a cost of +€9/tCO₂e relates to the optimal timing of slurry application on pastureland (and to a lesser extent on cropland), thereby reducing the need for nitrogenous fertiliser.

Although a number of additional novel technologies (such as anti-methanogenic vaccines and soil de-nitrification inhibitors) were identified, none is sufficiently advanced to be included on the cost curve.

Figure 3.8 Agriculture sector 2030 cost curve



Key opportunities in the agriculture sector

Assuming no change to the structure of Ireland's agriculture sector, the technical opportunities for reducing GHG emissions are small in comparison to current emissions levels and also compared to the potential identified in other sectors of the economy. Although some recent international research (particularly in New Zealand) shows considerable promise, there is as yet no 'silver bullet' that would inhibit cattle from emitting methane. Likewise, although there has been some international research into chemical additives to prevent the decomposition of nitrogenous fertiliser, these appear to be a long way from being commercially viable. The potential savings identified mostly appear to relate to farming practice, presumably best encouraged through educational programmes.

Outstanding issues in the agriculture sector

The methane emissions associated with milk and beef production in Ireland are difficult to measure empirically, and are in any case spread across thousands of farms. Accordingly, the emissions reported annually by the Environmental Protection Agency (EPA) to the European Commission are based on default international emissions factors. Therefore, even if it were possible for individual farmers to reduce the level of emissions from cattle through dietary changes, improved grazing practice or vaccinations, the benefit would not necessarily be recorded without changes to the inventory system. Moreover, the underlying environmental problem would not be addressed if Irish farmers converted their grazing land to other types of agricultural use. The international demand for beef and milk would remain unchanged and would simply be met by farmers in other countries.

3.2.6 Land use and carbon sinks

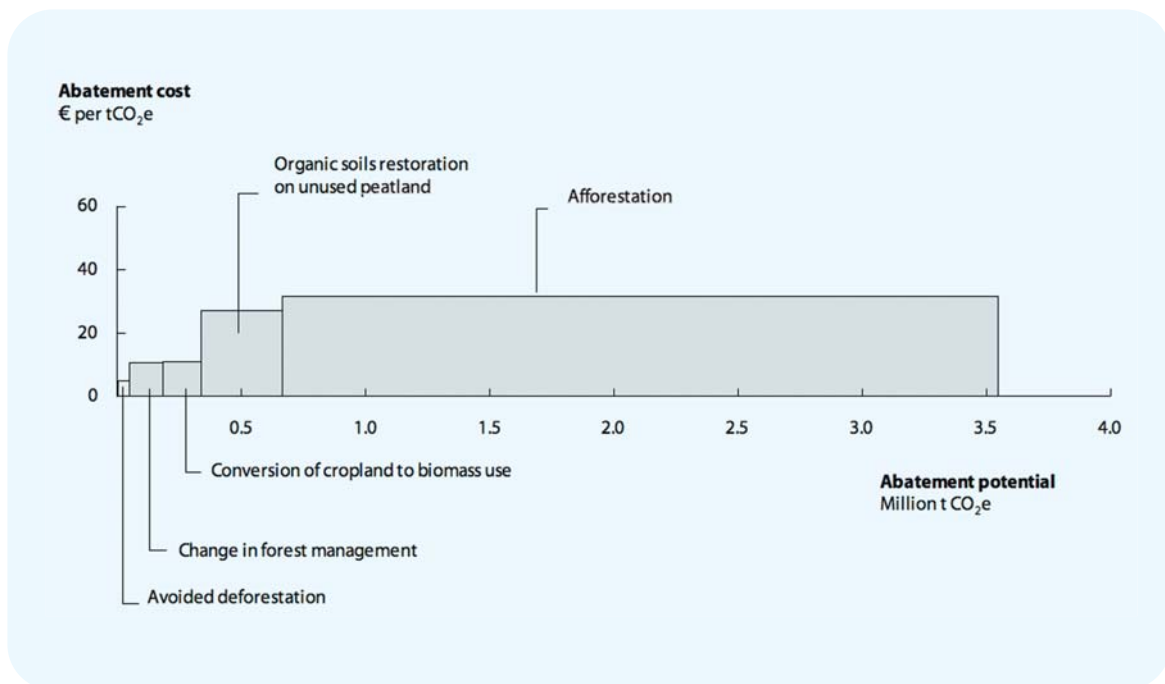
Key assumptions in BAU projection and reference abatement case

The key BAU assumption is that 8,000 hectares of Irish agricultural land is afforested annually up to 2030 in line with current trends. In the reference abatement case, however, this figure increases to 20,000 ha per annum. This is in line with previously-stated government policy, but may require additional supports. The rental value of farmland converted to forestry is indirectly estimated by reference to annual premiums paid to foresters. The offsetting value of harvested wood is derived from estimates by COFORD, the National Council for Forest Research and Development.

Technical potential in the reference abatement case

Figure 3.9 shows Ireland's carbon sink potential in 2030, over and above BAU levels. The single largest opportunity (3.0 million tCO₂e at a cost of €30/tCO₂e) relates to additional afforestation. A further 0.3 million tCO₂e at a cost of €11/tCO₂e relates to forestry management, including biofuels crops. A further 0.3 million tCO₂e at a cost of €27/tCO₂e relates to restoration of disturbed peatlands that have no other economic use.

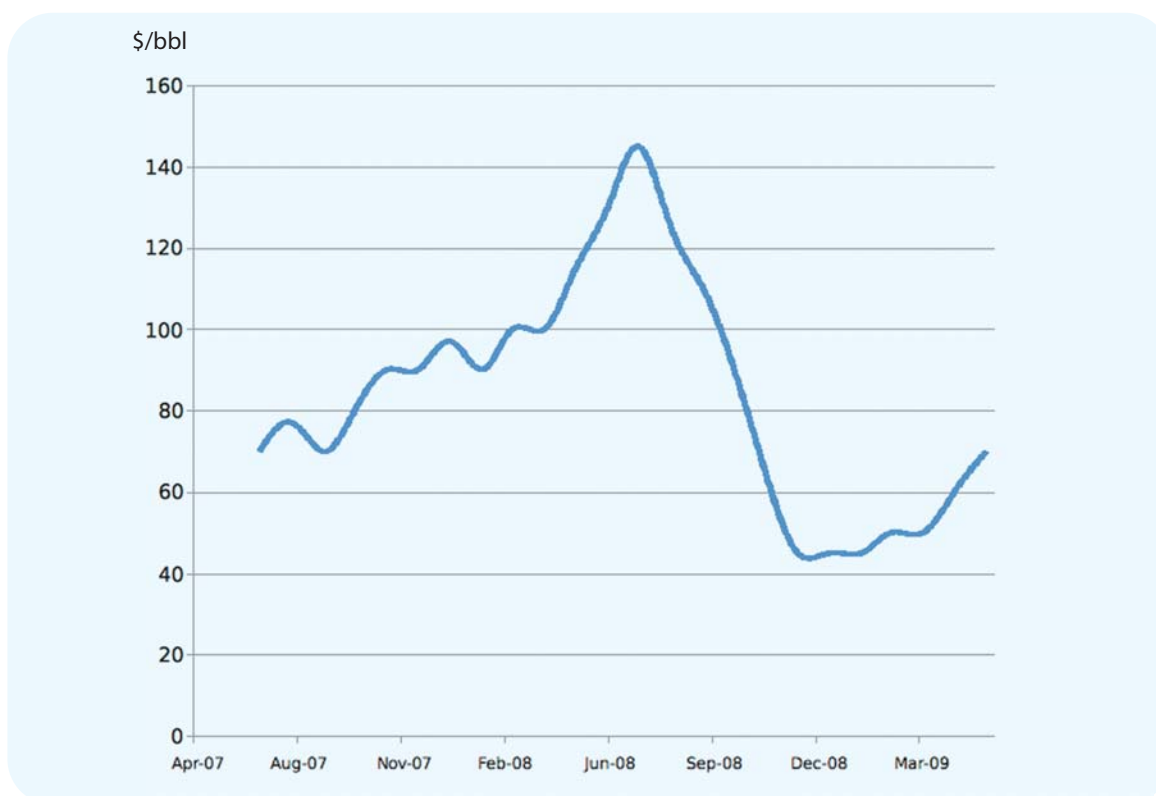
Figure 3.9 Land use and carbon sinks 2030 cost curve – reference abatement scenario



3.3 High oil price scenario

All the preceding cost analysis assumes a crude oil price of \$60/bbl, which was chosen for consistency with forecasts in the IEA World Energy Outlook. Coincidentally, it was also close to the prevailing price for Brent crude during May 2009. However, crude prices have recently been rising despite the global recession, and some commentators are forecasting a gradual return to the very high levels observed during late 2007 and early 2008 (Figure 3.10). This is a very important question, as the abatement costs calculated in our model are very sensitive to the assumed oil price.

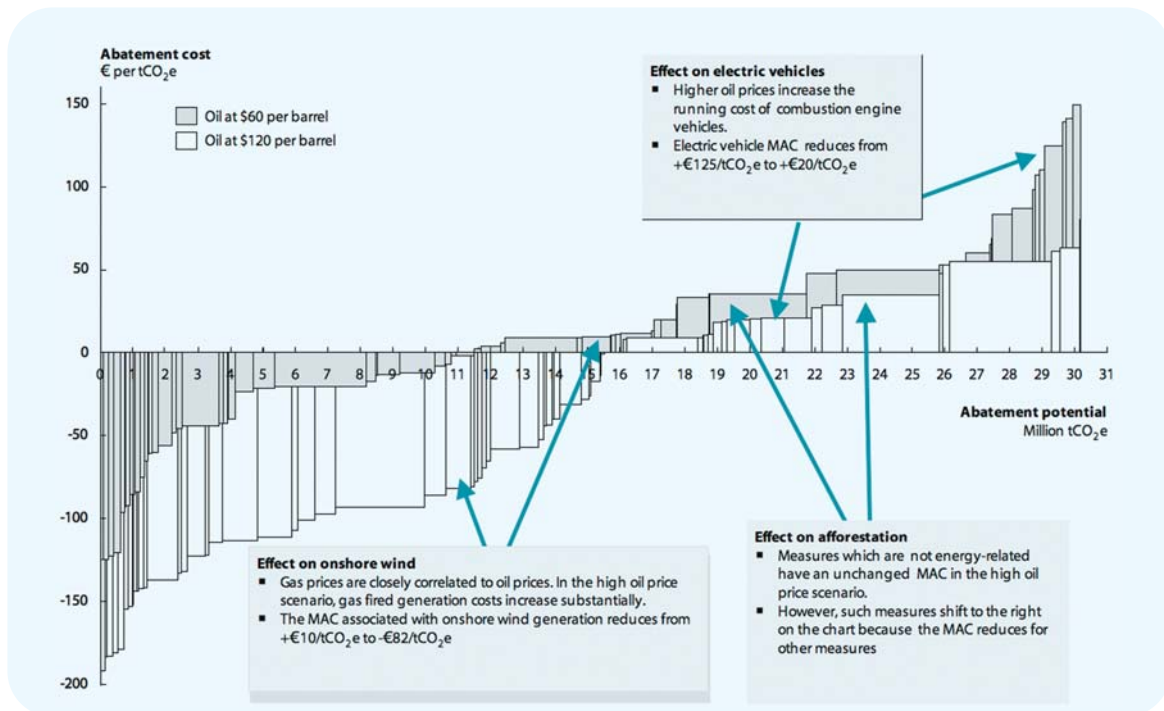
Figure 3.10 Historic Brent crude-oil prices



In this context, a variant scenario in which crude oil is priced at \$120/bbl appears quite feasible. This scenario is analysed here, with the cost of all fossil fuels (including petrol, natural gas and coal) assumed to be substantially higher. We ignore the potential macro-economic impacts of higher oil prices, and therefore assume no change in the demand for energy services compared to the \$60/bbl BAU. As illustrated in Figure 3.11, this has a material impact on the marginal economics of energy-related emissions abatement, although not for agricultural or land-use abatement. Annex 1 compares the abatement cost under each oil price scenario for all the individual technologies.

Because the assumed costs of avoided fossil-fuel technologies are higher, the abatement costs associated with renewable generation and energy-efficiency measures are significantly reduced. However, caution is needed in interpreting these results, which are contingent on economic factors that the model does not capture. For example, the impact of higher global oil prices on GDP growth over the period to 2030 is not considered. Likewise, the short-run impact of domestic fuel prices on energy service demand is not considered.

Figure 3.11 Marginal abatement cost curves under different oil-price assumptions



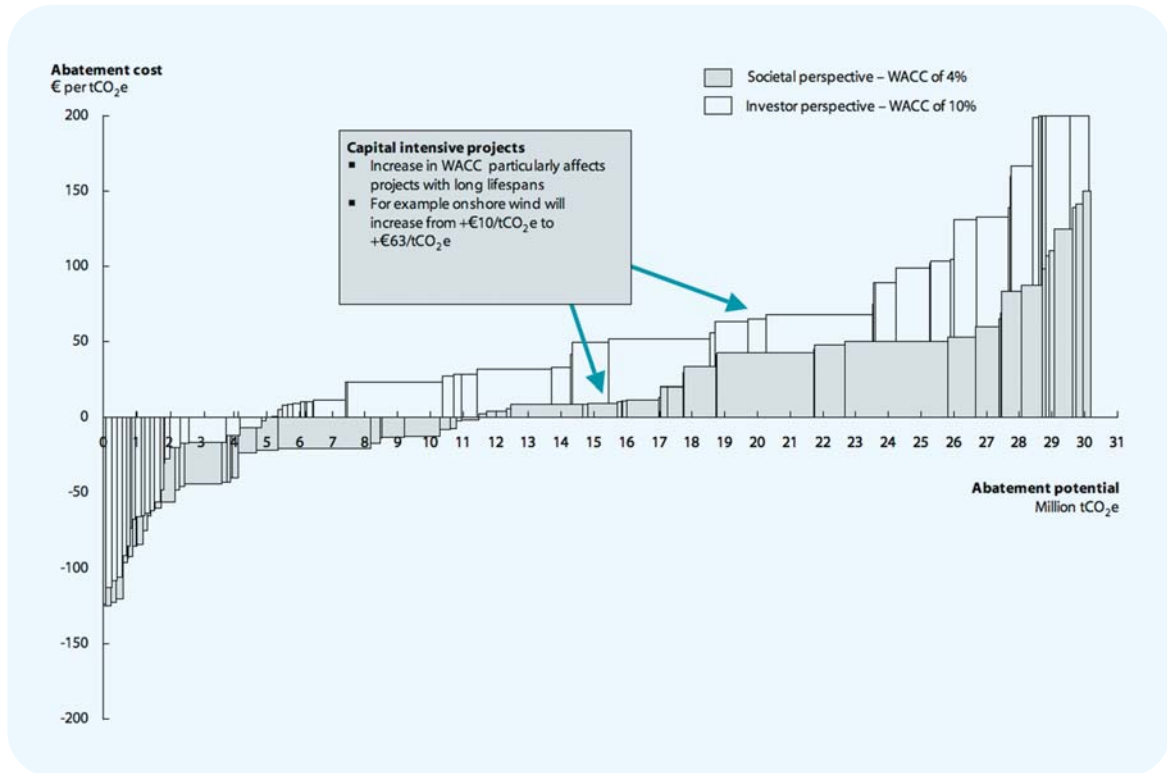
3.4 Discount rates and investor perspective – alternative scenario

For both the \$60/bbl and \$120/bbl oil-price scenarios, the preceding analysis is an estimate of the societal cost of technical abatement options under the assumption of a 4% real discount rate. This is in line with Department of Finance guidelines for evaluating public-sector projects. In practice, however, the investment decisions of private firms and individuals are based, either explicitly or implicitly, on substantially higher rates, typically in the range 10%-20%. Accordingly, there will be some investments that clearly have a net societal benefit in terms of GHG abatement but would not automatically occur in the BAU case. In such cases it may prove necessary for policymakers to provide financial incentives, or to impose regulatory requirements. The same applies to investment in certain types of biomass and renewable generation.

Figure 3.12 illustrates the general principle by redrawing the 2030 cost curve (\$60/bbl oil price) with the assumption of a 10% real discount rate. It should be noted, though, that what appear to be even higher revealed discount rates for some energy-efficiency investments may also reflect hidden costs or market imperfections. Such barriers are extensively documented in the literature¹¹ but they lie outside the scope of the current study.

11 See, for example, *The Economics of Energy Efficiency: Barriers to Cost-Effective Investment* by S Sorrell, E O'Malley, J Schleich and S Scott (2004). Edward Elgar, Cheltenham, UK.

Figure 3.12 Impact of assumed discount rate on 2030 cost curve



Section 4

Key issues for energy and climate policy

While the findings of this study provide insights and raise issues for all sectors of the economy, discussion here is confined to some of the key issues that pertain to the interests and mandate of SEI. In this chapter we select some of the issues that we see as most important and discuss some of the issues raised by the findings of this study.

4.1 Unlocking the ‘no regrets’ abatement opportunities

Existing measures

Analysis in the preceding sections indicates that significant negative or low-cost opportunities exist across all sectors. Most notably, these include a range of efficiency measures such as lighting replacement and building upgrades, where the initial costs of investment are more than paid for over the lifetime of the investment, and so result in net societal savings. While the analysis does not include transaction or hidden costs associated with investment, the magnitude of the identified savings clearly indicates that they are not illusory. Moreover, the negative cost opportunities identified in this study align well with SEI’s previous experience – that substantial energy efficiency gains are accessible across all sectors.

Why do these many negative cost opportunities remain untapped? The explanation lies in a variety of market barriers that prevent the uptake of such opportunities. The following are the most commonly cited when implementing energy-efficient and DSM (demand side management) measures.

- **Financial barriers** prevent many energy-efficiency measures that are fully cost-effective from being undertaken. Such barriers include:
 - *Lack of access to capital and high costs of capital.* Many individuals and business will not make investments in energy efficiency because they lack capital to buy new energy-efficient equipment or make the required insulation retrofit.
 - *Feedback delay.* The financial benefits of energy-efficient measures often involve a feedback delay in informing customers how much energy and money they are saving. For example, loft insulation improvements carried out in the summertime will not reveal noticeable savings until the winter utility bill is issued. For businesses, although savings may be available they may take too long in accruing to justify the initial capital outlay.
- **Split incentives** refer to the potential difficulties that arise when two parties engaged in a contract have different goals and different levels of information. A common example is ‘the landlord-tenant problem’. This occurs when the landlord is responsible for the building fabric (such as insulation properties of the building), but the tenant is responsible for heating the building and paying the commensurate bills. In this situation, there is little incentive for the landlord to choose the most energy-efficient building material.
- **Lack of information** about the true costs and benefits of energy-efficiency measures – this is because the financial savings from energy-efficient appliances and equipment are often embedded in utility bills, which are typically issued on a bi-monthly basis. Also, decision makers may not know what options are available to them or where to go for advice they can trust.
- **Other nascent-market-type barriers**, where new solutions find it hard to gain traction when they are relatively unknown or not widely demonstrated.

These market failures and barriers have been well documented over many years¹² and, in SEI's view, provide an adequate explanation as to why many of the economically feasible energy-efficient measures (negative cost opportunities) are not always adopted. Such obstacles can be mitigated through the provision of information to encourage change in consumer behaviour and through policy and programme intervention to effect change in the way energy companies and consumers make their investment decisions.

Clearly defined energy-efficiency standards, performance ratings and labelling therefore need to be in place to inform consumers and make sure that energy efficiency is properly reflected in their purchasing decisions. Many such measures are already in place, including regulation, taxation, financial assistance (grants, accelerated capital allowances, etc) and information and awareness programmes.

These programmes have demonstrated that intervening to remove the market barriers and failures results in net benefit, as the costs can be considerably less than the benefits that flow from the uptake of the efficiency opportunities. For example, SEI's programmes to support energy efficiency in business deliver societal gains (energy and carbon cost reductions) of more than ten times the programme costs.

Planned measures

Although the many government policies and initiatives continue to deliver substantial energy savings, the analysis suggests that many negative cost opportunities remain untapped. The analysis also indicates that, in the non-ETS sector, efficiency in buildings and (to a lesser extent) in transport seems to offer most abatement potential at lowest cost. This finding aligns well with our previous understanding of abatement opportunities and with the recently launched National Energy Efficiency Action Plan (NEEAP), which expects to deliver 23,730GWh of energy savings by 2020, commensurate savings in CO₂ emissions of approximately 5.7 million tonnes and €1.6 billion in avoided energy costs for the economy in the year 2020.¹³ Almost half of these savings are expected to come from the residential sector, where significant improvements in building regulations and the recently launched SEI Home Energy Saving scheme are expected to deliver considerable savings.

There are however, further opportunities to expand and intensify the various existing and planned measures identified in NEEAP, to overcome the market barriers and deliver greater efficiency uptake, particularly in the commercial buildings sector. Examples of suggested initiatives can be taken from the SEI 2008 report *Demand Side Management in Ireland: Evaluating the Energy Efficiency Opportunities*. Areas that may merit further attention include commercial sector buildings, and upgrade of lighting and appliances, where this new analysis reinforces the potential savings available.

4.2 The rationale for promoting higher-cost abatement opportunities

The right hand side of the reference scenario abatement cost curve depicts numerous abatement opportunities for which operating costs are increased or for which the investment costs will not be fully returned over the project life in the absence of an avoided carbon cost (no market price of carbon is included in the calculation of the potential cost of the opportunities). The same is also true, albeit to a lesser degree, in the high oil-price abatement scenario. Importantly, though, no opportunity, technology or policy action is ever designed, or evaluated, in terms of carbon alone.

As noted earlier, however, the metric of ranking in this study is a simple one of levelised cost per tonne of carbon-dioxide-equivalent abated; it is acknowledged that a range of important potential societal benefits are not included in the quantification. For energy-related opportunities, these include very significant considerations of energy security and import dependence, as well as competitiveness and energy-cost dimensions. In this context, it is worth discussing some of the wider benefits of and reasons for pursuing some of the technologies and measures that, in simple terms, cost more for the carbon savings they deliver than the prevailing market price of EU Allowances. This discussion will focus on the important agenda of transforming Irish enterprise in preparation for a new future that is characterised by low-carbon goods and services.

¹² For a range of discussion over time, see, for example, Energy Strategy: The Road Not Taken?, Foreign Affairs, Amory B Lovins, October 1976, and the EU Action Plan for Energy Efficiency, COM(2006)545.

The challenges of our 2020 carbon-reduction targets are clear enough from the figures in this analysis, but the agenda to 2050 will be one of much deeper cuts in emissions. A debate on this is already well underway in countries such as the UK. Business is already responding – many businesses are looking to energy efficiency to reduce their costs and prepare for the future. Many are also investing in sustainable supply such as biomass heat or wind turbines.

The next phase is the new businesses that are starting to emerge to exploit the new opportunities arising from concern about climate change and energy costs. As this study shows clearly, in a few short years all our lives will have changed – from the types of cars we drive to how we build our houses. A huge technological shift is coming as we prepare for the transition to low carbon. The challenge is to identify and exploit those areas where Ireland has the natural and human resources that will enable it to become a technology leader rather than a technology importer.

4.3 Exploiting Ireland's competitive advantage

There are a number of areas where Ireland has a competitive advantage in resources, such as wind and ocean energy. For example, with just 1% of the EU population, it has over 13% of the coastal resource. Thus Ireland has the potential to be a centre of activity in ocean energy, but the key question is whether we will simply be renting out turbine sites to international companies, or whether we nurture a thriving indigenous ocean-energy technology industry, eventually exporting expertise, technologies and services around the globe.

Ocean energy in Ireland

Energy contained in waves and tidal currents have the potential to provide renewable energy in Ireland. The first devices to exploit this resource are currently under development. The Irish Government put in place a number of targets to support its policy to accelerate the development of ocean energy in Ireland, particularly a target for the connection of 500MW of ocean power by 2020, and the creation of a centre of excellence in Ocean Energy technology and the stimulation of a world-class industry cluster.

The growing level of activity and commitment of significant developers and utilities reflects a growing confidence that the 500MW target is technically achievable, and that production capacities could grow further in subsequent years in line with the development of the necessary grid capacity. These levels of activity could result in large numbers of jobs and significant levels of CO₂ reduction for the Irish economy.

Ireland also has competitive advantage in certain areas of expertise and skills that are at the heart of the low-carbon agenda. Around the world, smart economies based on low carbon and high efficiency will rely on information and communications technologies, on innovative services models, and, more than anything, on knowledge. Ireland has already attracted inward investment because of local expertise in control systems, remote sensors and software. The global focus on a clean technology-centred recovery represents an opportunity for us to use such skills to create new business opportunities.

Sustainable energy and clean technology can create jobs. Meeting the EU's ambition of energy efficiency gains of 20% by 2020 could create one million jobs, according to a European Commission report published in 2005. In Ireland, a recent study estimated that meeting our current target of 40% renewable electricity by 2020 will create more than 10,000 jobs.¹⁴ This is just from the activity associated with Ireland's domestic renewables target. The export opportunities associated with the skills, services and technologies could be far greater. And these jobs are in areas where Ireland has the right skills.

¹³ Based on average 2008 energy prices.

¹⁴ *Jobs and Investment in Irish Wind Energy*, Irish Wind Energy Association, June 2009.

Similarly, in construction, Ireland has a well-skilled workforce. This industry is currently under considerable pressure and is looking at ways to restore activity and employment. Movement is already underway. The Government's home energy retrofit programme will, in 2009 alone, support over 3,000 jobs. This could become a significant growth sector over the coming years, progressing from a domestic service into a potentially lucrative export opportunity.

The Government is already acting to create the conditions for Irish businesses to capture these emerging opportunities. Government must take a visible position of leadership, sending a strong signal of intent. This is important to build confidence, and must be backed by appropriate action in regulation, policy development and fiscal supports. Certain technologies that are not yet fully commercial may require financial support to allow their markets to grow and mature. In other areas, new solutions challenge conventional systems of standards, permissions and regulations, so some flexibility and adaptation may be necessary. It will also be important to prepare the skill and knowledge bases required. This encompasses everything from R&D capacity to re-orientation of technical training towards the new technologies. As a small, knowledge-oriented economy, Ireland can become an excellent 'test-bed' for new technologies and also the ideal place to develop standards of quality and performance.

Ireland has already started the transition towards an enterprise sector ready to capture new opportunities emerging from low-carbon and sustainable-energy imperatives. There is already strong entrepreneurial activity, and state bodies such as the IDA and Enterprise Ireland are actively pursuing opportunities and supporting businesses in this area. These are the foundations of a process of change and business growth that could emerge to be the most significant ever experienced in the State.

Building Ireland's Smart Economy

In 2008 the Irish Government published *Building Ireland's Smart Economy: A Framework for Sustainable Economic Renewal*.

Building Ireland's Smart Economy provides a framework for addressing the current economic challenges and reorganising the economy to build and stimulate the Smart Economy over the next five years. The focus is on developing a thriving enterprise sector, alongside high-quality employment, secure energy supplies, an attractive environment, and first-class infrastructure.

The paper identifies the energy and environmental areas as key to the agenda, with the following stated objectives:

- To make Ireland's economy and environment mutually reinforcing
- To put the energy/climate change agenda at the heart of Ireland's economic renewal
- To deliver a sustainable, competitive and secure energy future
- To move the economy onto a low-carbon pathway
- To radically enhance energy efficiency across all sectors of the economy
- To ensure energy security and reduce dependence on fossil fuels
- To maximise the business opportunities presented by the clean energy/green economy
- To mobilise the public sector as energy efficiency exemplar and as a driver of green innovation
- To advance the integration of the environment in measures of economic progress

Section 5

Reflections and conclusions

Climate change pressures are likely to drive a process of technological change at a scale and pace that are unprecedented. It is imperative we understand the implications of this for all sectors of Irish society. This study adds to our understanding of the GHG abatement challenge for Ireland. It shows that while considerable abatement opportunities exist, some will require significant effort to capture. It also shows that if pressing abatement policy targets are to be met, all sectors will have to be engaged and all opportunities pursued, including many important behavioural opportunities that were outside the scope of this study.

Much abatement is linked to innovation and will not be delivered without an aggressive programme of technological development. This highlights the role of research, development and demonstration, and also the importance of entrepreneurship. Thus the social dimension is also vital, not only in the additional opportunities related specifically to behaviour change, but also in delivery of many of the technical opportunities that require societal engagement, change or investment. People across society will need to be actively engaged, whether it is in changing their own behaviour, in adopting new technologies, or in accepting the infrastructural development required to support our low-carbon future.

Even before a price is put on carbon itself, and without pricing any of the wider benefits such as supply security and import reduction, close to half the opportunities identified in this study pay for themselves, typically through energy cost reductions. However, most of these require pump-priming investment, even in cases where the outlay is amply returned over time. This creates a challenge in how best to finance these actions. For those that the State should lead, current pressures on public spending exacerbate the challenge. Novel approaches to financing technological change will be required, with a longer term view and better ways to both share risk and value the wider benefits.

While some of the climate change agenda implies cost, it also clearly implies opportunity. Most importantly, the agenda aligns with the imperative of preparing Irish society and enterprise for a new environment focused on clean, low-carbon technologies and behaviour. SEI intends to work with all concerned to examine these issues further. The goal is to support the national agenda of a realignment towards a new, clean, low-carbon economy that can deliver domestic needs as well as exploiting new global opportunities.

Annex 1

Abatement potentials and marginal costs

Technology	\$60 scenario Euro/tCO ₂ e	\$120 scenario Euro/tCO ₂ e	2030 Abatement Potential MtCO ₂ e
LDV Petrol ICE Bundle 1	-92	-192	0.13
Lighting - switch incandescents to LEDs, commercial	-125	-183	0.17
Lighting - switch incandescents to LEDs, residential	-123	-181	0.16
Lighting new build controls, commercial	-120	-179	0.20
Appliances - residential	-96	-155	0.14
Biofuel Generation 1	-2	-153	0.14
Lighting- switch CFLs to LEDs, residential	-93	-152	0.04
Electronics - office, commercial	-85	-144	0.10
Appliances - refrigerators, commercial	-85	-144	0.04
Retrofit HVAC - electric resistance heating to electric heat pump, residential	-84	-142	0.17
LDV Petrol ICE Bundle 2	-43	-142	0.12
Biofuel Generation 2	11	-137	0.96
Lighting - switch CFLs to LEDs, commercial	-75	-133	0.12
Retrofit HVAC maintenance - residential	-60	-132	0.18
LDV Petrol ICE Bundle 3	-24	-123	0.56
Retrofit HVAC controls, commercial	-61	-122	0.12
Lighting retrofit controls, commercial	-56	-114	0.43
Retrofit Building Envelope, residential	-44	-113	1.14
LDV Petrol ICE Bundle 4	-12	-112	1.09
Retrofit HVAC, commercial	-46	-107	0.17
LDV Full hybrids	-2	-101	0.55
Retrofit HVAC - gas/oil heating, residential	-21	-97	0.66
New Build efficiency package, residential	-20	-93	2.83
LDV Petrol Plug in hybrids	48	-86	0.93
Onshore wind	10	-82	0.89
Clinker substitution by Fly Ash	-43	-75	0.14
Clinker substitution by Limestone	-48	-69	0.14
Grassland management (Clover)	-65	-65	0.12
Onshore wind high penetration	33	-58	0.98
Aggregated New Build efficiency package, commercial	4	-57	0.60

Technology	\$60 scenario Euro/tCO ₂ e	\$120 scenario Euro/tCO ₂ e	2030 Abatement Potential MtCO ₂ e
Water Heating - replacement of electric, commercial	6	-53	0.15
Lighting - T12 to T8/T5, commercial	13	-44	0.06
Alternative kiln fuels - Waste	-7	-43	0.19
EU ETS sector Motor Systems	-40	-40	0.04
Non ETS Motor Systems	-40	-40	0.19
Retrofit Building Envelope, commercial	-13	-33	0.70
Offshore wind	60	-31	0.73
Alternative kiln fuels - Biomass	2	-28	0.23
Offshore wind high penetration	65	-26	0.06
Livestock dietary management (grazing period)	-17	-17	0.19
EU ETS sector CHP	-14	-14	0.02
Non-ETS CHP	-14	-14	0.04
Peat to wind	9	9	2.19
Grassland nutrient management (slurry)	9	9	0.16
Cropland nutrient management	11	11	0.02
Forest Management	11	11	0.13
Conversion of cropland to biomass use	11	11	0.15
Clinker substitution by Blast Furnace Slag	-8	18	0.30
Wave power	110	19	0.18
EU ETS sector process optimisation	20	20	0.21
Non ETS process optimisation	20	20	0.48
LDV Battery Electric Vehicles	125	20	0.56
Retrofit Building Envelope, package 2 - residential	53	21	0.84
Organic soils restoration on non-farmland	27	27	0.33
Water Heating - replacement of electric, residential	87	29	0.64
Pastureland Afforestation	30	30	2.99
Tidal	139	48	0.10
Coal CCS new build	50	55	3.15
Biomass co-firing with coal	83	63	0.61



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