Analysis of a Personal Cap and Share Scheme

A draft final report for the
Comhar Sustainable Development Council

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1 OVERVIEW

1.1 Introduction

This report presents the final set of modelling results produced by Cambridge Econometrics in the assessment of the impacts of the introduction of a personal cap and share carbon trading scheme in the Republic of Ireland. This quantitative analysis builds on the findings from AEA Energy & Environment (2008), whose report introduces the trading system and outlines many of the more practical aspects of the scheme. These are not described again in detail in this document.

The modelling was carried out using E3ME, a large-scale econometric model of Europe with a detailed sectoral disaggregation and a full treatment of the two-way links between the economy, energy system and environment. The E3ME model is described in Chapter 2.

The following chapters describe the basic methodology and assumptions and how the model was applied to analysing a personal cap and share trading scheme. The results are presented in aggregate and at more detailed levels in Chapter 4 and a list of key conclusions is presented in Chapter 5.

For further information about the E3ME model the reader is referred to the model website, www.e3me.com, and online manual, www.camecon-e3memanual.com/cgi-bin/EPW_CGIU.

Users are requested to report any errors or omissions to the authors.

2 THE E3ME MODEL

2.1 Introduction

Short and long-term effects of E3 policies

E3ME is intended to meet an expressed need of researchers and policy makers for a framework for analysing the long-term implications of Energy-Environment-Economy (E3) policies, especially those concerning R&D and environmental taxation and regulation. The model is also capable of addressing the short-term and medium-term economic effects as well as, more broadly, the long-term effects of such policies, such as those from the supply side of the labour market.

The European contribution

The E3ME model has been built by an international European team under a succession of contracts in the JOULE/THERMIE and EC research programmes. The projects 'Completion and Extension of E3ME'[1] and 'Applications of E3ME'[2], were completed in 1999. The 2001 contract, 'Sectoral Economic Analysis and Forecasts'[3] generated an update of the E3ME industry output, products and investment classifications to bring the model into compliance with the European System of Accounts, ESA 95 (Eurostat, 1995). This led to a significant disaggregation of the service sector. The 2003 contract, Tipmac[4], led to a full development of the E3ME transport module to include detailed country models for several modes of passenger and freight transport and Seamate (2003/2004)[5] resulted in the improvement of the E3ME technology indices. The COMETR[6] (2005-07), Matisse[7] (2005-08) and DROPS[8] (2005-08) projects allowed the expansion of E3ME to cover 29 countries (the EU27 plus Norway and Switzerland) and material inputs. More recently E3ME has been applied in a number of forecasting and Impact Assessment (IA) exercises at the European level. A full list of project references is available on the model website.

E3ME is the latest in a succession of models developed for energy-economy and, later, E3 interactions in Europe, starting with EXPLOR, built in the 1970s, then HERMES in the 1980s. Each model has required substantial resources from international teams and each model has learned from earlier problems and developed new techniques.

The E3ME approach

E3ME combines the features of an annual short- and medium-term sectoral model, estimated by formal econometric methods, with the detail and some of the methods of the Computable General Equilibrium (CGE) models that provide analysis of the movement of the long-term outcomes for key E3 indicators in response to policy changes. It can be used for dynamic policy simulation and for forecasting and projecting over the medium

1 European Commission contract no: JOS3-CT95-0011.
2 European Commission contract no: JOS3-CT97-0019.
3 European Commission contract no: B2000/A7050/001.
4 European Commission contract no: GRD1/2000/25347-SI2.316061.
5 European Commission contract no: IST-2000-31104.
6 European Commission contract no: 501993 (SCS8).
7 European Commission contract no: 004059 (GOCE).
8 European Commission contract no: 022788 (SSPI).

and long terms. As such, it is a valuable tool for E3 policy analysis in Europe and its member countries.

In particular E3ME has the following strengths:

Model disaggregation The detailed nature of the model allows the representation of fairly complex scenarios, especially those that are differentiated according to sector and to country. Similarly, the impact of any policy measure can be represented in a detailed way.

Econometric pedigree The econometric grounding of the model makes it better able to represent and forecast performance in the short to medium run. It therefore provides information that is closer to the time horizon of many policy makers than pure CGE models.

E3 linkages An interaction (two-way feedback) between the economy, energy demand/supply and environmental emissions is an undoubted advantage over other models, which may either ignore the interaction completely or only assume a one-way causation.

2.2 The theoretical background to E3ME

Introduction Economic activity undertaken by persons, households, firms and other groups has effects on other groups after a time lag, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors, and the effects, both beneficial and damaging, accumulate in economic and physical stocks. The effects are transmitted through the environment (with externalities such as greenhouse gas emissions contributing to global warming), through the economy and the price and money system (via the markets for labour and commodities), and through the global transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through incomes leading in turn to further demands for goods and services. These interdependencies suggest that an E3 model should be comprehensive, and include many linkages between different parts of the economic and energy systems.

Key characteristics These economic and energy systems have the following characteristics: economies and diseconomies of scale in both production and consumption; markets with different degrees of competition; the prevalence of institutional behaviour whose aim may be maximisation, but may also be the satisfaction of more restricted objectives; and rapid and uneven changes in technology and consumer preferences, certainly within the time scale of greenhouse gas mitigation policy. Labour markets in particular may be characterised by long-term unemployment. An E3 model capable of representing these features must therefore be flexible, capable of embodying a variety of behaviours and of simulating a dynamic system. This approach can be contrasted with that adopted by general equilibrium models: they typically assume constant returns to scale; perfect competition in all markets; maximisation of social welfare measured by total discounted private consumption; no involuntary unemployment; and exogenous technical progress following a constant time trend (see Barker, 1998, for a more detailed discussion).

2.3 E3ME as an E3 model

The E3ME model comprises:

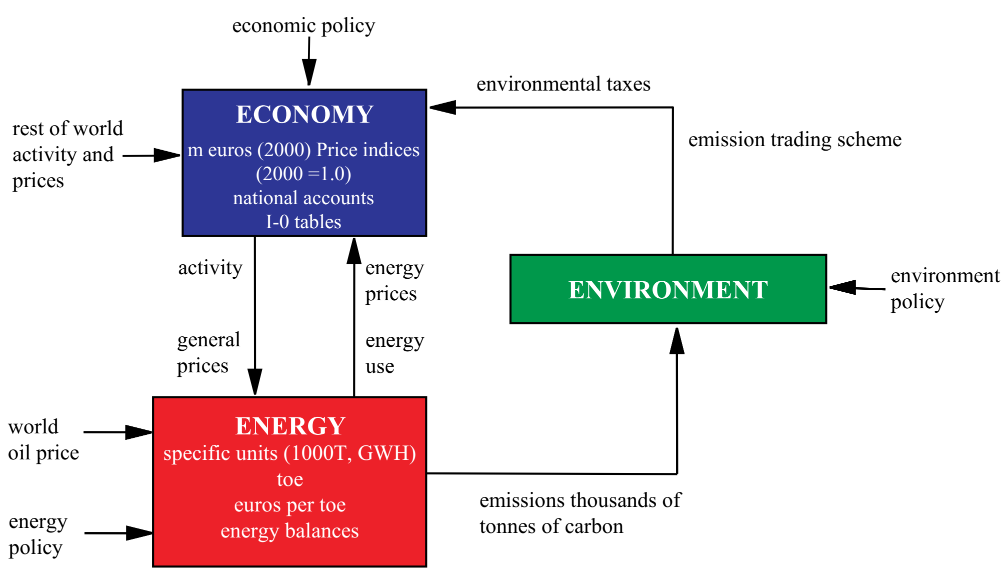
- the accounting balances for commodities from input-output tables, for energy carriers from energy balances and for institutional incomes and expenditures from the national accounts,
- environmental emission flows,
- 29 sets of time-series econometric equations (aggregate energy demands, fuel substitution equations for coal, heavy oil, gas and electricity; intra-EU and extra-EU commodity exports and imports; total consumers' expenditure; disaggregated consumers' expenditure; industrial fixed investment; industrial employment; industrial hours worked; labour participation; industrial prices; export and import prices; industrial wage rates; residual incomes; investment in dwellings, normal output equations and demand for seven material inputs).

Energy supplies and population stocks and flows are treated as exogenous.

The E3 interactions

Figure 2.1 below shows how the three components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box with its own units of account and sources of data. Each data set has been constructed by statistical offices to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For the EU economy, these factors are economic activity and prices in non-EU world areas and economic policy (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the

FIGURE 2.1 E3ME AS AN E3 MODEL



outside factors are the world oil prices and energy policy (including regulation of energy industries). For the environment component, exogenous factors include policies such as reduction in SO2 emissions by means of end-of-pipe filters from large combustion plants. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module. The energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

2.4 Energy-environment links

Top-down and bottom-up methodologies

E3ME is intended to be an integrated top-down, bottom-up model of E3 interaction. In particular, the model includes a detailed engineering-based treatment of the electricity supply industry (ESI). This is based on available technologies and is described in Barker et al (2007). Demand for energy by the other fuel-user groups is top-down (see below), but it is important to be aware of the comparative strengths and weaknesses of the two approaches. Top-down economic analyses and bottom-up engineering analyses of changes in the pattern of energy consumption possess distinct intellectual origins and distinct strengths and weaknesses (see Barker, Ekins and Johnstone, 1995).

A top-down submodel of energy use

The energy submodel in E3ME is constructed, estimated and solved for 19 fuel users (as mentioned above power generation is treated differently), 12 energy carriers, termed fuels for convenience below, and 29 regions. Figure 2.2 shows the inputs from the

FIGURE 2.2: INPUTS TO THE ENERGY SUB-MODEL

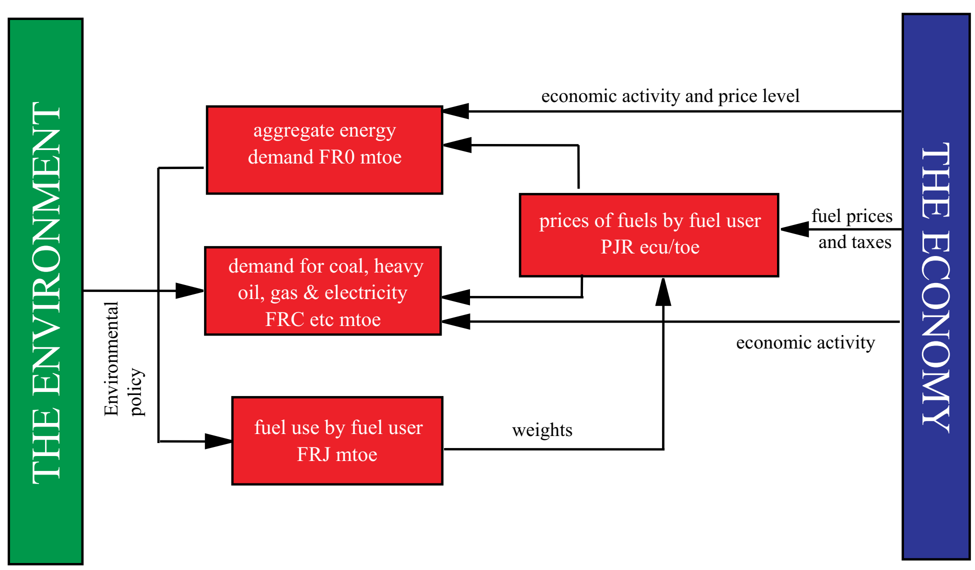
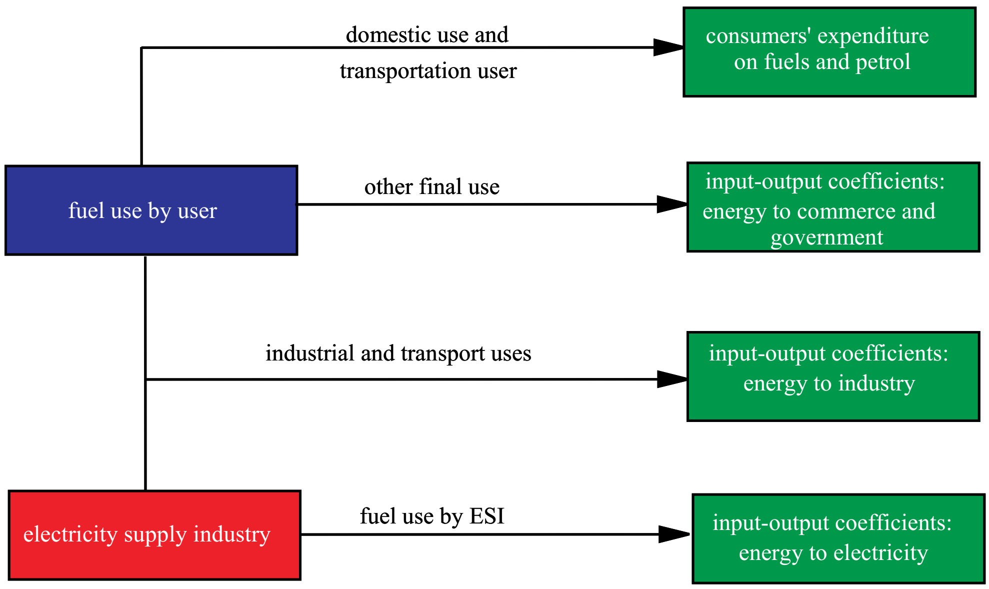


FIGURE 2.3: FEEDBACK FROM THE ENERGY SUB-MODEL



economy and the environment into the components of the submodel and Figure 2.3 shows the feedback from the submodel to the rest of the economy.

Determination of fuel demand

Aggregate energy demand, shown at the top of Figure 2.2, is determined by a set of co-integrating equations[9], whose the main explanatory variables are:

- economic activity in each of the 19 fuel users
- average energy prices by the fuel users relative to the overall price levels
- technological variables, represented by R&D expenditure in key industries producing energy-using equipment and vehicles

Fuel substitution

Fuel use equations are estimated for four fuels - coal, heavy oils, gas and electricity – and the four sets of equations are estimated for the fuel users in each region. These equations are intended to allow substitution between these energy carriers by users on the basis of relative prices, although overall fuel use and the technological variables are allowed to affect the choice. Since the substitution equations cover only four of the twelve fuels, the remaining fuels are determined as fixed ratios to similar fuels or to aggregate energy use. The final set of fuels used must then be scaled to ensure that it adds up to the aggregate energy demand (for each fuel user and each region).

9 Cointegration is an econometric technique that defines a long-run relationship between two variables resulting in a form of 'equilibrium'. For instance, if income and consumption are cointegrated, then any shock (expected or unexpected) affecting temporary these two variables is gradually absorbed since in the long-run they return to their 'equilibrium' levels. Note that a cointegration relationship is much stronger relationship than a simple correlation: two variables can show similar patterns simply because they are driven by some common factors but without necessarily being involved in a long-run relationship.

Emissions submodel

The emissions submodel calculates air pollution generated from end-use of different fuels and from primary use of fuels in the energy industries themselves, particularly electricity generation. Provision is made for emissions to the atmosphere of carbon dioxide (CO2), sulphur dioxide (SO2), nitrogen oxides (NOX), carbon monoxide (CO), methane (CH4), black smoke (PM10), volatile organic compounds (VOC), nuclear emissions to air, lead emissions to air, chlorofluorocarbons (CFCs) and the other four greenhouse gases: nitrous oxide (N2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF6). These four gases together with CO2 and CH4 constitute the six greenhouse gases (GHGs) monitored under the Kyoto protocol. Using estimated (ExternE) damage coefficients, E3ME may also estimate ancillary benefits relating to reduction in associated emissions eg PM10, SO2, NOx (see Barker and Rosendahl, 2000).

CO2 emissions

Emissions data for CO2 are available split by fuel user and fuel (and country). The energy submodel estimates emission coefficients (tonnes of carbon in CO2 emitted per toe) for each case. The coefficients are calculated for each year when data are available, then used at their last historical values to project future emissions. Other emissions data are available at various levels of disaggregation from a number of sources and have been constructed carefully to ensure consistency.

Feedback to the rest of the economy

Figure 2.3 shows the main feedbacks from the energy submodel to the rest of the economy. Changes in consumers' expenditures on fuels and petrol are formed from changes in fuel use estimated in the energy submodel, although the levels are calibrated on historical time-series data. The model software provides an option for choosing either the consumers' expenditure equation solution, or the energy equation solution. Whichever option is chosen, total consumer demand in constant values matches the results of the aggregate consumption function, with any residual held in the unallocated category of consumers' expenditure. The other feedbacks all affect industrial, including electricity, demand via changes in the input-output coefficients.

2.5 Model data sources

European industry-energy analysis

E3ME is a detailed model of 42 product/industrial sectors, mainly defined at the NACE 2-digit level. These are compatible with ESA95 accounting classifications, and include a disaggregation of energy and environment industries for which the energy-environment-economy interactions are central. The model also includes a linked set of 19 fuel-using sectors, covering the energy-intensive sectors in detail (see Appendix A).

Like its predecessors, E3ME is an estimated model (see below). Version 4.6 (E3ME46) is based on international data sources such as Eurostat's[10] national accounts and the

10 http://epp.eurostat.ec.europa.eu/pls/portal/ddis.go_home?p_language=en

OECD Stan[11] database, which provide detailed sectoral disaggregation, and DG Ecfin's AMECO[12] database, which is used for macro-level variables.

The data for the model's energy module come from the IEA's[13]databases, namely the energy balances and price levels.

2.6 Parameter estimation

Econometric specification

The econometric model has a complete specification of the long-term solution in the form of an estimated equation that has long-term restrictions imposed on its parameters. Economic theory, for example the recent theories of endogenous growth, informs the specification of the long-term equations and hence properties of the model; dynamic equations that embody these long-term properties are estimated by econometric methods to allow the model to provide forecasts. The method utilises developments in time-series econometrics, in which dynamic relationships are specified in terms of error correction models (ECM) that allow dynamic convergence to a long-term outcome. The specific functional form of the equations is based on the econometric techniques of cointegration and error-correction, particularly as promoted by Engle and Granger (1987) and Hendry et al (1984).

11 http://www.oecd.org/document/15/0,3343,en_2649_201185_1895503_1_1_1_1,00.html
12 http://ec.europa.eu/economy_finance/indicators/annual_macro_economic_database/ameco_en.htm
13 http://data.iea.org/ieastore/statslisting.asp

3 DETAILED METHODOLOGY

3.1 Introduction

The study was carried out using version 4.6 of the E3ME model. The results therefore reflect the structure of the model and the system of National Accounts (see Eurostat, 1995), the cross-section and time-series data collected, and the equation parameters estimated from these data. This chapter describes the assumptions that are most relevant to the model results; for an in-depth technical description the reader is referred to the model manual (Cambridge Econometrics, 2007).

Geographical coverage

In the scenarios E3ME was run for Ireland and the UK. As the policies are domestic to Ireland, with the rest of Europe being affected only in terms of international trade, the other countries in the model were fixed as exogenous. In addition, as Ireland is a small country in Europe, it was assumed that there were no impacts on the allowance price in the European Emission Trading Scheme (ETS).

The policy options were defined in terms of model variables in a series of scenarios, which are described in Section 3.3. These were compared to a baseline solution, which is described in Section 3.2. The analysis covers the period up to 2020, with the policy options in place from 2010 onwards.

3.2 Baseline forecast

The role of the baseline forecast is to provide a context for which forward-looking (ex-ante) quantitative analysis may be carried out. All the scenarios outlined in Section 3.2 represent carefully defined differences from this baseline case.

Impacts on results

The baseline does not normally have a direct impact on the scenario results, which are typically reported as percentage differences from base; however, the indirect effects should not be dismissed. In the field of energy policy, the two most common cases where the baseline has a significant impact on results are:

- when an emissions target is set relative to historical values (eg a reduction in CO2 emissions compared to 2005 levels)
- when assessing the impacts of tax rates defined in euros per unit of energy, where the baseline energy prices determine the resulting relative increase in fuel prices

Both of these are highly relevant to the results presented in this report. Alternative energy prices were tested through sensitivity analysis in the high oil-price scenarios.

Overall objective

The baseline should therefore provide a set of projections that is regarded as a neutral viewpoint of future developments (ie not something that is seen as being obviously too high or too low which will bias the results). It need not represent the views of the modelling team and should not necessarily be regarded as a most likely outcome.

To aid interpretation of results, the baseline includes only policies that already exist or are certain to come into existence (ie the legislation is in place). This allows a direct comparison of the policies defined in the scenarios with the current situation. The most important policy change in place over the forecast period in the baseline is the inclusion of aviation in the ETS. This means air transport is not included in the cap and share schemes or carbon taxes that are modelled in the scenarios. However, other sectors which have been proposed for inclusion in the ETS (mainly non-ferrous metals and chemicals) are not included in the ETS and are therefore subject to the cap and share and carbon tax schemes.

The PRIMES baseline

The current preferred method is that a baseline is usually formed on the basis of expert specialist views to form an overall context and large-scale computer models to fill out the details. It is important to note that the modelling results are used to inform rather than replace the human aspect of the development process.

Available software

In Europe the E3M-Lab at the National Technical University of Athens produces a combined energy-environment-economy (E3) forecast, using its PRIMES model (E3M-LAB, 2005). PRIMES is a large-scale Computable-General-Equilibrium (CGE) model with a very detailed specialist treatment of Europe's energy systems.

The economic part of the forecast is derived from a solution of the GEM-E3 model (KU Leuven, 2005), a commonly used Computable-General-Equilibrium (CGE) model that may be used for long-term economic forecasting. Other inputs to the energy modelling include global energy prices from the POLES model (Criqui, 2001) and transport activity from the SCENES model. The RAINS model (Amann et al, 2004) may also be attached to provide more detailed emissions projections.

The key point is that the projections provide a consistent picture of economic development and energy demands. It is thus a suitable forecast to calibrate an integrated E3 model such as E3ME to.

Forecast version

The version of the forecast that is used in the current version of the E3ME model was published in spring 2008 (see European Commission, 2008). It includes indicators of demographic developments, economic activity disaggregated across energy-intensive sectors, detailed energy demands, and CO2 emissions disaggregated by broad sector. The forecast is based on five-year snapshots covering the period up to 2030, of which the period up to 2020 has been used in the scenarios.

Further processing

The figures presented in the published forecast were converted into classifications consistent with those used in E3ME and expanded to form annual time series. This mainly involved a system of linear interpolation and disaggregation of economic projections for the service sectors. This work was carried out using custom software developed with the Ox programming language (see Doornik, 2007).

To account for slight discrepancies in historical data (for example in cases where there were missing data points) and to prevent discontinuities in time series, growth rates were applied to E3ME's historical data sets.

Other economic variables, such as fixed investment and international trade, were estimated using simple assumptions based on the structure of the National Accounts. The baseline forecast for employment was taken from recent projections using E3ME carried out for CEDEFOP (see Wilson et al, 2007).

Summary of the baseline

Table 3.1 presents a quantitative summary of the baseline forecast for Ireland and other key indicators. The oil price does not take into account recent increases, but are expected to rise by 1% pa plus inflation over 2010-20. Results from an alternative set of scenarios based on higher oil prices are presented in Section 4.3. The main ETS carbon price, which is fixed in all of the scenarios, is also set to rise by 1% pa plus inflation over 2010-20.

Alternative baselines for Ireland

It should be noted that there are alternative views of future developments in Ireland, for example produced by ESRI. The choice of forecast was the subject of some discussion at the start of the project. We do not suggest that one forecast is any better or worse than the alternatives available. The PRIMES forecast was chosen as the baseline because E3ME is set up to use this for its European analysis; recalibrating the model solution to an alternative baseline forecast would have required some considerable use of resources.

3.2 Formal definition of scenarios

Other than the baseline, the scenarios fall into three groups:

- cap and share schemes
- carbon tax scenarios
- a combination of these (or "hybrid schemes")

Each of these schemes was run for a set of emission-reduction targets (30%, 20% and 10%) in 2020 with baseline oil prices and higher oil prices. The targets were defined as reduction in energy-related CO2 emissions from the non-ETS sectors compared to 2005. It should be noted that, in the baseline, CO2 emissions from the non-ETS sectors were

TABLE 3.1: BASELINE SUMMARY

	2005	2010	2020	2010-20 % pa
GDP (€2000bn)	134.7	171.9	241.3	3.4
Employment ('000)	1962	2222.6	2528.9	1.3
Energy demand (th toe)	18078.2	19940.3	21823.9	0.9
C02 emissions (th tC) - ETS	5974.2	6498.2	6811.7	0.5
C02 emissions (th tC)-non-ETS	6864.5	7176.4	7566.6	0.5
Oil price ($05/boe)	54.5	54.5	61.1	1.1
ETS price €05/tCO2	18	20	22	1

Source(s) : European Commission, E3ME.

10% higher in 2020 than in 2005 so a larger reduction in CO_2 emissions in 2020 compared to base is required to meet the 30% target.

Cap and share schemes

The cap and share scheme places a fixed ceiling on the level of emissions from a group of sectors, in this case the non-ETS sectors. Every time a company or individual releases one unit of CO_2, they must purchase an allowance. The price of the allowance is set on an open market and adjusts to a level that means the groups included in the scheme release the target level of emissions. In the personal cap and share scheme, at the start of each year the allowances are distributed equally to households who then sell these through a financial intermediary to the companies (and households) that emit CO_2. Thus there is a transfer of wealth from these groups to (non-polluting) households.

The cap and share scheme is modelled using E3ME's emission trading scheme routines (with the main European ETS price treated as exogenous). The assumptions in the modelling therefore reflect the ones used in these routines, mainly:

- a single carbon price is calculated each year
- the carbon price is added on to the cost of energy and is treated the same way as an increase in energy costs for any other reason
- all installations (including households) that are included in E3ME's non-ETS sectors are included in the scheme; all installations that are included in E3ME's ETS sectors are excluded from the scheme
- there are no signalling or awareness effects
- there is no equivalent action in other countries
- all allowances are used, and the market for allowances is assumed to clear
- there are no transaction costs other than those mentioned below

E3ME calculates the allowance price based on the supply of allowances (fixed to meet a specified target) and demand (determined by emissions of CO_2, which in turn is determined by the level of energy use and economic activity). The allowance price automatically adjusts (causing demand to adjust in response to higher energy prices) until demand and supply are equal. The supply of allowances declines evenly each year until the target is met in 2020. This approximately equates to a 3% reduction each year.

Only direct emissions are counted in the calculation, so there is no increase in the price of electricity.

It is assumed that government plays a role in the scheme by collecting the revenues and then redistributing them to households through the transfer of allowances.

Use of revenues

The revenues that are received by government from the auction of allowances are returned to households (in the shape of personal allowances) after a correction to ensure revenue neutrality (see below). This completes the cap and share scheme. Households receive equal amounts from government, regardless of income or socio-economic status; the policy is thus highly equitable. This lump-sum payment represents a transfer of wealth from government to households.

Transaction costs

Usually in E3ME's emission trading routines transaction costs are assumed to be zero. However, in this case data on transaction costs were provided from the first part of the study by AEA Energy and Environment (2008) and this was incorporated into the modelling. The assumption was that households had to pay a small fee to banks to sell their allowances. This is factored into the results but it should be noted that even when the fees from all Irish households are added together the impact is very small (around €4m pa).

Carbon taxes

The carbon taxes are imposed at a rate that meets the CO2 emissions reductions specified in the scenarios. The exact rate is determined by a software algorithm recently developed at Cambridge Econometrics which effectively runs the model repeatedly until the desired result is obtained. As is the case with the cap and share scheme, the tax is gradually increased over time so that the emission reductions occur evenly over the forecast period. In practical terms the carbon tax is levied on fuels according to their carbon content. The emission factors used for this calculation were provided by the steering group and allocated to the fuel-types as defined in E3ME. These are presented in Table 3.2.

Electricity was not taxed in the carbon tax scenarios.

Revenue recycling

Revenues from the carbon tax were returned to households in the form of reduced income taxes and higher social benefits (after a correction to ensure revenue neutrality, see below). The main effect of this was to increase real household incomes. This is subtly different from the transfer received from the cap and share scheme, which is an increase in wealth. Typically a much larger share of wealth is saved with OECD (2004) showing saving rates of 90-100% of increases in wealth in large European countries. A good comparison is with the recent one-off rebates in the United States which also transferred wealth to households in the face of a slowing economy and higher energy prices; it was reported that 90% of this was saved. The US Federal Reserve assumes saving rates of 96.25% for increases in both housing and financial wealth in its model.

TABLE 3.2: EMISSION FACTORS USED IN CARBON TAX

Fuel	tCO2/toe
Hard coal	3.96
Other coal	4.14
Crude Oil	2.67
Heavy fuel oil	3.18
Middle Distillates	3.01
Other gas	2.38
Natural gas	2.38
Electricity	0

Source(s) : Project Steering Group.

There are additional incentive effects from the revenue recycling through income taxes and benefits but these largely cancel out (lower income taxes encourage people to work but higher social benefits encourage people not to work).

Hybrid scenarios

As an additional step, two hybrid scenarios including a combination of cap and share schemes and carbon taxes were set up. The targets were 30% and 20% reductions in CO2 emissions in the non-ETS sectors in 2020 compared to 2005. The cap and share is applied to domestic use, and the carbon taxes to industrial use. The revenue recycling methods are also different in that revenues from the carbon taxes are used to reduce employers' social security contributions, keeping a balance between payments and receipts by households and businesses. Road transport is assumed to be 50% domestic and 50% for business purposes in these scenarios.

Revenue neutrality

It is assumed that all the scenarios are revenue neutral. The modelling results therefore represent the impacts of a shift in taxation rather than a change in the overall level of taxation. It should be noted that this is not the same as saying that the cap and share or carbon tax schemes are revenue neutral as policies because one of the main impacts of these policies was to substantially reduce demand for motor fuels which are subject to excise duties. Other tax receipts (for example VAT) are also changed but to a lesser degree. The distinction is important in terms of not introducing bias to the results, the underlying principle is that the government deficit as a share of GDP remains constant in all the scenarios.

3.3 Additional assumptions

Sectoral allocation

The cap and share schemes and carbon taxes are applied to CO2 emissions from fossil fuels that are not included in the European ETS. In E3ME these are defined by sector. The sectoral allocation is shown in Table 3.3. Aviation is assumed to be covered by the ETS and so is not included in the cap and share schemes. However, emissions from the non-ferrous metals and chemicals sectors, which may also be covered by the ETS in the forecast period, are not included in it in the modelling. As the cap and share schemes and carbon taxes focus on energy emissions, non-energy emissions are not included in the schemes.

Fuel switching options for road transport

E3ME includes twelve energy carriers (termed "fuels" for convenience) of which four are explicitly modelled: hard coal, heavy fuel oil, natural gas and electricity. The other eight fuels are modelled as fixed ratios to aggregate energy demand or similar fuels. Road transport is modelled on the basis that a single fuel, middle distillates, is consumed.

Historically this has been an accurate description of fuel consumption by motor vehicles. However, more recently, and to a greater extent over the forecast period, alternative fuels will become available for motorists. In the case of biofuels, the share is held constant at 10% of total consumption in 2020 in line with the proposed EU directive. The assumption is that any further expansion of biofuels would be prevented by capacity constraints on supply.

TABLE 3.3: E3ME FUEL USER CLASSIFICATION

Sector	Included in cap and share?	Included in ETS?
Power own use & transformation	No	Yes
Other energy own use & transformation	No	Yes
Iron & steel	No	Yes
Non-ferrous metals	Yes	No
Chemicals	Yes	No
Non-metallic mineral products	No	Yes
Ore-extraction (non-energy)	Yes	No
Food, drink & tobacco	Yes	No
Textiles, clothing and footwear	Yes	No
Paper & pulp	No	Yes
Engineering etc	Yes	No
Other industry	No	Yes
Rail transport	Yes	No
Road transport	Yes	No
Air transport	Yes	No
Other transport services	Yes	No
Households	Yes	No
Other final use	Yes	No
Non-energy use	No	No

The case of electric vehicles is more difficult to address. It is likely that electric vehicles will become available over the forecast period but there are no historical data available with which to estimate their take-up rates. Furthermore, the cap and share and carbon tax schemes are likely to increase the rate of take-up. After discussion with the project steering group it was decided that any fuel-switching in the road transport sector would be by assumption and the results are easiest to interpret if the assumption is zero. Therefore no fuel switching is allowed in this sector in the period up to 2020.

This does not have an effect on the type of impacts seen in the economic results but it does affect the magnitude of these results. This is because the allowance price in the cap and share schemes is pushed higher, and possibly quite a lot higher, because the reductions in fuel demand must come from greater (liquid) fuel efficiency in petrol and diesel-driven cars (including hybrids) and fewer journeys being made by car or truck, rather than by fuel switching. This in turn means that there are more revenues available for the positive impacts, ie households can sell their allowances for a larger sum.

Given that, in terms of CO2 emissions, road transport is the largest of the sectors included in the scheme this is a key assumption.

Fixed input-output coefficients

The sectors in the E3ME model interact through the input-output relationships defined in the most recent OECD publication (Yamano and Nadim, 2006). Where equations exist (for energy sectors, water supply and producers of minerals or biomass), these input-output relationships are allowed to vary according to equation results, for example, if demand for coal by the iron and steel sector doubles in the energy equations, the economic purchases of that sector from the coal industry also double. However, for other sectors, there are no time-series data to estimate equations, so input-output coefficients remain fixed in the scenarios.

This is important in the results for land transport, which is largely made up of road haulage companies. Most of the demand for this sector comes from other companies and is therefore calculated using fixed input-output coefficients. This means that if prices in this industry increase, as happens in the scenarios, its demand does not decrease (all other things being equal). In fact as retail output increases in the scenarios, this sector is forced to spend more on transportation and distribution to fill the shelves. One way of looking at it is that there is no alternative (rail transport is also included in land transport) so users of haulage firms have to accept the higher costs and possibly pass them on to customers.

The result is that, despite a fairly large increase in prices, economic activity in the land transport sector does not decrease. To properly assess these impacts a fully-integrated transport model would be required.

Price elasticities

Long-run price elasticities are the only parameters in E3ME that are taken from the economic literature rather being estimated empirically. The reason for this is that when these elasticities are estimated from time-series data they tend to be biased downwards because, in the past, changes in energy demand have been viewed as temporary and therefore not induced behavioural change. E3ME's elasticities are taken from cross-sectional studies using data across members of the OECD by Franzen and Sterner (1995) and Johansson and Schipper (1997) and in the US by Roy et al (2006). These are shown in Table 3.4. Power generation uses a separate technology-driven submodel (see Barker et al, 2007) and so is not estimated.

The key price elasticity for the scenarios is the one for road transport, which is -0.7. This was found in Franzen and Sterner (1995) for the OECD countries. Although the size of the elasticity is often regarded as high, in internal studies at Cambridge Econometrics the same value has been estimated using a similar technique for the EU member states with more recent data.

Use in the scenarios

These elasticities, and indeed most of E3ME's other model parameters, do not change in the scenarios. For example this means that an increase in petrol prices from €1/litre to €1.10/litre will cause the same percentage reduction in demand (10% price increase × 0.7 = 7% in the long run) as an increase in prices from €2/litre to €2.20/litre. This ignores the possible existence of "tipping points" that are often described in more qualitative analysis.

It is not always clear whether this is an appropriate assumption to make, as the basis for the elasticities was a period of low fuel prices while the ambitious scenarios form a period of very high energy prices. However, if the analysis is to be based on equations that are estimated empirically, using standard estimation techniques it is necessary to impose such an assumption. This assumption does not directly affect the economic results but does impact on the allowance price and carbon tax rates (although the direction is not clear), and therefore indirectly impacts the scale of the economic effects.

TABLE 3.4: LONG-RUN PRICE ELASTICITIES FOR AGGREGATE ENERGY DEMAND

Sector	Long-run Elasticity
Power own use & transformation	N/A
Other energy own use	-0.25
Iron & steel	-0.25
Non-ferrous metals	-0.25
Chemicals	-0.20
Non-metallics nes	-0.20
Ore-extraction(non-energy)	-0.20
Food, drink & tobacco	-0.20
Textiles, clothing	-0.20
Paper & pulp	-0.20
Engineering etc	-0.20
Other industry	-0.20
Rail transport	-0.20
Road transport	-0.70
Air transport	-0.40
Other transport services	-0.20
Households	-0.20
Other final use	-0.20
Non-energy use	N/A

Note(s) : Figures show long-run price elasticities imposed on equations for aggregated energy demand in E3ME.
Source(s) : Cambridge Econometrics.

Non-energy emissions

The scenarios did not target non-energy emissions (which in any case are not modelled in E3ME) and so these were not included in the target reductions. In particular the agricultural sector was forced to pay for allowances for its use of carbon-based fuels, but not for emissions resulting from livestock.

Manufactured fuels

The analysis makes the incorrect assumption that the economic output of the manufactured fuels sector is zero. This is not by design but because the team were unable to find data for this sector:

- Eurostat does not go down to this level of detail
- OECD data implicitly set this sector to zero

The most likely reason for this is that there are a small number of companies in this sector (ie refineries) so data have been withheld under disclosure rules. Limited data are available from the Irish CSO but were not immediately comparable. This suggested that values for the manufactured fuels industry may have been included elsewhere in the E3ME databases and adding them again risked double counting, so the numbers were not used. Overall, however, the figures suggest that although this treatment leads to a small upward bias in the economic results, this is a very small sector (for example, counting for less than 0.5% of total value added in 2002) and so the impact on the aggregate results would have been small.

4 MODEL RESULTS

4.1 Aggregate results

The carbon price required to meet the target is high

One of the main outcomes of the scenarios is that there is a substantial fall in energy demand and emissions from the non-ETS sectors. This is part of the design of the scenarios but in most cases a high carbon price is required to achieve the reductions (see Table 4.1). When there is a 30% target, the required carbon price in 2020 is over 300€/tCO2 (in 2008 prices), compared to an average EU ETS price around 24€/tCO2 in the first half of 2008. It should also be noted that there are substantial differences in the required allowance prices for the different targets, with the price in 2020 roughly halving for a 20% target and again for a 10% target.

The patterns with the carbon taxes are similar. In the scenarios with carbon taxes the rates of the tax are set to achieve the same emissions reductions. Although the carbon taxes are converted to energy units according to the carbon content of each fuel type, the 30% target requires a tax double that required to meet the 20% target.

The differences between the carbon tax and cap and share scenarios are mainly in the economic results.

Explaining the high carbon prices

The high carbon prices may be surprising but there are several underlying reasons:

- the 30% emissions reduction target (compared to 2005) for the non-ETS sectors is highly ambitious, with the baseline predicting a 10% rise in emissions
- the eleven-year period in which to achieve this goal is relatively short
- one of the largest-affected sectors, road transport, does not have options in the modelling for switching to alternative fuels or vehicles

TABLE 4.1: ENERGY/ENVIRONMENT RESULTS, 2020

Scheme	Cap & share			CO2 tax		Hybrid	
Target Reduction	30%	20%	10%	30%	20%	30%	20%
Energy Demand	-14.9	-11.2	-7.5	-14.4	-10.9	-15.2	-11.5
CO2 Emissions	-18.8	-14.2	-9.6	-18.0	-13.6	-18.8	-14.1
Allowance price (€08/tCO2)	308.8	167.2	83.9	0.0	0.0	325.9	221.9
Carbon tax (€08/tC02)	0.0	0.0	0.0	329.0	182.0	328.8	163.9

Note(s) : Figures show change in energy demand and CO2 emissions in Ireland, relative to baseline, and the carbon prices required to achieve this.

Source(s) : E3ME.

Road transport is a key sector in the results, as it is the largest sector included in the schemes. In the long run it is also a sector that has options for reducing fuel demands through efficiency gains. However, replacing the national fleet of vehicles requires time and does not fit well into the eleven-year period (remembering that the allowance price increases over time, so motor-fuel prices do not increase by much in the early years of the scheme). In addition, the modelling does not allow for the adoption of electric vehicles, as there are no historical data on which to base their rate of uptake; in reality, however, much higher fuel prices may speed up the introduction of these fuels. The share of biofuels in petrol is assumed to remain unchanged due to capacity constraints. This share is consistent with the proposed EU directive.

Emissions from power generation increase slightly

Overall energy demand falls by a lower percentage than the fall in CO2 emissions. This is because the cap and share schemes and the carbon taxes affect the most carbon-intensive fuels (ie coal rather than oil and oil rather than gas). In particular, electricity is not covered by either of the schemes so demand for electricity does not fall and, in sectors where there is the possibility of switching between gas and electricity, there may be an increase in demand. This results in a small increase in required generation capacity, and emissions from the power generation sector increase by 2-3%. In the refining sector, which is also part of the ETS, the opposite is true as reduced demand for transport fuels means that less refining capacity is required.

In the other sectors included in the European ETS there is no direct impact on energy demand or emissions, although changes in relative prices or economic activity may mean that there are small changes in fuel demands.

Overall CO2 emissions in Ireland fall by around 19% in the 30% target cap and share scenario, compared to the baseline.

The cap and share scheme has little impact on GDP and employment

The macroeconomic results present a balance of positive and negative impacts. The main negative impact is the increase in energy prices, which increases the overall price level (ie has an inflationary impact) and reduces real incomes and household consumption. In the 30% cap and share scenario, the price level is 3-4% higher in 2020 than in the baseline, mainly due to higher prices of road fuel and gas for heating, but also partly due to higher costs being passed on in the prices of manufactured goods. The effects of this are partly compensated by the lump-sum payments that households receive from selling allowances but total consumption still falls by ¾% in 2020 compared to the baseline. However, excluding reductions in spending on energy products, consumption increases by ¼%.

In the final GDP figures this is compensated by an improvement in the trade balance and, in particular, a reduction in imports. This may seem surprising but simply represents the fact that much less oil is being imported, meaning that the cap and trade scheme effectively becomes a tax on imports. Somewhat surprisingly there was little impact on export volumes, mainly because Irish firms were found not found to increase prices in response to higher unit costs and instead absorbed the increases (possibly as Ireland is a

TABLE 4.2: ECONOMIC RESULTS, % DIFFERENCE FROM BASE, 2020

Scheme	Cap & share			CO2 tax		Hybrid	
Target Reduction	30%	20%	10%	30%	20%	30%	20%
GDP	0.0	-0.0	-0.0	0.9	0.5	-0.1	-0.1
Household spending	-0.8	-0.6	-0.3	1.7	1.0	-1.0	-0.7
Investment	0.0	-0.1	-0.1	0.5	0.3	-0.1	-0.1
Imports	-0.5	-0.4	-0.2	-0.1	-0.1	-0.5	-0.3
Exports	-0.0	-0.0	-0.0	0.0	0.0	-0.0	-0.0
Employment	-0.0	-0.0	-0.0	0.0	0.0	-0.0	-0.0
Price level	3.1	1.9	1.1	2.4	1.5	3.5	2.5

Note(s) : Table shows percentage change in main economic indicators, compared to baseline.
Source(s) : E3ME.

small country firms are price takers). This did have some negative impact on profitability in exporting sectors[1] (see Section 4.2).

Overall in the cap and share scheme, lower household spending was balanced by lower imports so there was no impact on GDP.

Employment was not directly affected by the scheme and did not really change at the aggregate level, although there are changes in some sectors.

The carbon taxes have net positive benefits

The increase in energy prices in the carbon tax scenarios is roughly the same as in the cap and share scenarios. However, the revenues raised from the tax are used to reduce income taxes and increase benefit rates rather than being spread evenly between households. This has some impacts on incentives, but the two effects (lower taxes increasing incentives to work but higher benefits reducing incentives to work) largely cancel each other out; the main difference is subtle but important: lump sums in the cap and share scheme are treated as a transfer of wealth while altering the taxation system changes disposable income. The difference is wealth is allowed to accumulate over time, but in the long run all income is spent. As a result household consumption increases by 1¾% in 2020 in the highest tax scenario. Some of this is met by imports, but aggregate GDP increases by almost 1%.

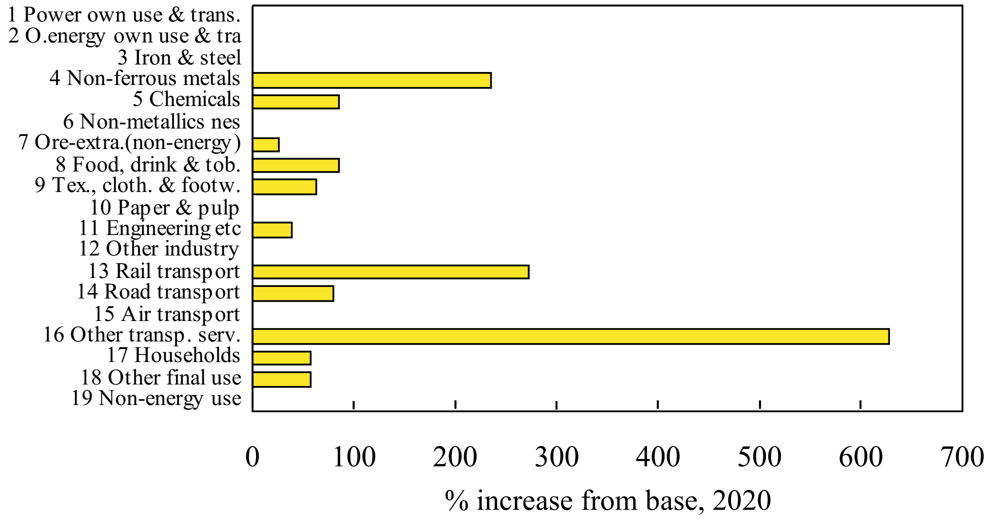
4.2 Sectoral results

Changes in energy price and demand

Figure 4.1 presents the relative increase in energy prices for each of E3ME's fuel user groups under the cap and share scheme in the 30% reduction scenario. This illustrates one of the main issues with the cap and share scheme adding a nominal amount on to the price of fuels; to meet the target there must be a large increase in the price of motor fuels, however these are already highly taxed so the relative impacts on other sectors are much higher. Most obviously if the same charge could be added to the price of fuels used for

1 As national accounts data do not tend to include profits this is something that is difficult to measure.

FIGURE 4.1: INCREASE IN ENERGY PRICES, BY SECTOR



Note(s) : Chart shows increase in average energy prices in the 30% target cap and share scenario.
Source(s) : E3ME.

shipping, it would increase the price more than seven times. It should also be noted that electricity prices do not increase in the scheme so sectors that use more electricity (for example households) are affected less.

These differences are reflected in reductions in sectoral energy demand (see Table 4.3). Road transport has a high price elasticity of demand for fuel but smaller relative price increases. Households and some other sectors are able to switch to electricity, meaning that their emissions fall but energy demand less so and emissions in another sector, power generation, may increase as a result. The main trends in these results also hold for the carbon tax scenarios.

Output increases in most sectors under the cap and share scheme

Three sectors stand out for having gains in output under the cap and share schemes, each for their own reason:

- Retailing: Despite a reduction in total household spending the retail sector benefits from the way that spending is redirected away from energy goods, which are either supplied directly (eg gas) or at low margins (petrol), to other consumer products, including cars (see below).
- Motor vehicles: In response to the higher fuel prices, motorists are more likely to upgrade to newer, more efficient vehicles. Other transport also benefits, although to a lesser extent.
- Electricity: The cap and share scheme encourages households and other user groups to switch from gas to electricity as gas prices increase, while electricity prices do not.

The sector that loses out the most by far is Gas distribution, where output falls by up to 20%. It should be noted that if data were available for Manufactured fuels we would also

TABLE 4.3: FUEL DEMAND BY FUEL USER, % DIFFERENCE FROM BASE, 2020

Scheme			**Cap & share**
Target Reduction	30%	20%	10%
1 Power own use & trans.	2.1	1.4	0.9
2 O.energy own use & tra	-0.6	-0.3	-0.1
3 Iron & steel	0.9	0.6	0.4
4 Non-ferrous metals	-58.2	-49.1	-36.0
5 Chemicals	-6.9	-4.5	-2.6
6 Non-metallics nes	0.2	0.1	0.1
7 Ore-extra.(non-energy)	-3.8	-2.3	-1.3
8 Food, drink & tob.	-17.7	-12.3	-7.7
9 Tex., cloth. & footw.	-8.5	-5.6	-3.3
10 Paper & pulp	0.8	0.6	0.4
11 Engineering etc	-5.4	-3.3	-1.8
12 Other industry	0.3	0.2	0.1
13 Rail transport	-67.6	-56.1	-41.6
14 Road transport	-28.0	-18.1	-10.4
15 Air transport	2.0	0.8	0.2
16 Other transp. serv.	-78.6	-67.8	-53.2
17 Households	-5.1	-3.2	-1.8
18 Other final use	-47.5	-40.5	-30.2
19 Non-energy use	0.0	0.0	0.0

Source(s) : E3ME.

expect to see a large fall in output from this sector. The other sector where there is a fall in output (of nearly 1% in 2020) is Construction; this is mainly a result of new capacity in gas supply not being required, hence lower demand for building work.

In the other sectors the effects of the cap and share scheme on output are limited. Some sectors gain, others lose out slightly, but overall there is little net change.

Sectoral exports are largely unaffected by the scheme

One of the arguments frequently put against environmental taxation is the effects of competitiveness in affected industries. There are many ways of measuring competitiveness (see Andersen, 2005 for a discussion in the context of environmental tax reform); here we focus on the impact on exports. Ireland's exports are dominated by a small number of sectors (see Table 4.4). Of these, only food and drink is negatively affected by the cap and share scheme. In the other sectors, either energy makes up a very small share of unit costs, export prices are not increased (most sectors) or export volumes are not affected by higher prices (less common). The result that export prices do not increase in response to higher unit costs is consistent with Ireland being a price taker in the global market. This means that it is company profits rather than export volumes that are adversely affected by the higher costs (this could have further impacts on business investment but due to a lack of data this cannot be modelled).

TABLE 4.4: DETAILED EXPORTS RESULTS

	Export share in Ireland's total, 2006 (%)	Energy consumed as share of output, 2000 (%)	Export price increase, 2020 (%)	Change in exports, 2020 (%)
Electronics	31.8	0.1	0.0	-0.0
Chemicals nes	24.3	3.7	0.1	-0.0
Food	8.6	2.3	0.4	-0.2
Pharmaceuticals	8.4	0.3	0.0	0.0
Elec. Eng. & Instrum.	7.2	1.7	0.0	-0.0
Printing & Publishing	4.8	0.3	0.0	0.0
Mech. Engineering	1.7	1.2	0.0	-0.0

Note(s) : Table shows relative importance of export industries and of energy to these industries, plus change in export prices and volumes in the 30% cap and share scenario.

Source(s) : E3ME.

Impacts on profitability

It is not possible to quantify the effects of the scenarios on company profits as data for profits tend not to be published in national accounts data sets and profits are usually of interest at a firm, rather than sectoral, level. However, it is possible to make a qualitative analysis, defining profits as the difference between output and input costs, including wages. Not all sectors will lose out as a result of the policies but the following sectors could be expected to be adversely affected:

- land transport, which does not increase prices in line with costs
- sectors that are major exporters and do not increase prices (eg Electronics, Chemicals, Food and drink)
- sectors that use land transport services but do not increase prices (eg Distribution)

Output increases in most sectors under the carbon tax

The impacts on the energy sectors are broadly the same under the carbon tax and cap and share scheme. The main sectoral differences, which lead to an overall increase in output, are due to the extra income being spent by households. Sectors where demand comes from household expenditure benefit the most; notably retail and other service sectors, but also in motor vehicles.

Aggregate employment is unchanged, but there are variations between sectors

Overall employment does not change in the cap and share scenario but there is a marked difference in the results between sectors. The main sectors where employment increases are the higher-skilled engineering sectors, including machinery and transport equipment. There are two reasons for this: demand for these industries' products may increase due to investment patterns, and these sectors are subject to the cap and share and so may substitute labour for energy inputs. In contrast, employment falls in the more basic manufacturing sectors (and pharmaceuticals) that are covered by the cap and share scheme. In the service sectors there is not much change in employment levels.

With the CO2 tax the same patterns are evident but the magnitude of the impacts is larger. Overall there is no change in employment levels.

4.3 Impacts on the fuel mix

The cap and share and carbon tax scenarios both target the most carbon-intensive fuels. However, the most carbon-intensive fuel of all, coal, is not widely used in the sectors where the schemes are applied. Consequently, use of coal does not decrease and across the economy as a whole actually increases due to demand from the power generation sector (see below).

Heavy fuel oil is the next most polluting of the main fuel groups. Its use falls by almost 40% in the most ambitious scenarios, mainly due to a reduction in demand by non-ferrous metals. Fuel oil accounts for almost 15% of energy CO2 emissions in the baseline in 2020 so this is a sizable contribution to meeting the target.

Demand for middle distillates falls by around a quarter in the 30% target scenarios, almost completely from the road transport sector, which is by far the largest user of this fuel. Demand for gas falls by 17-18% due to reductions in demand from households and from commerce.

As electricity prices are not affected at all by either the cap and share scheme or the carbon taxes there is no downward pressure on its consumption. There is, however, upward pressure on demand due to fuel-switching from gas. This is mainly for heating in houses and in offices, but to a lesser extent other sectors can also switch. Overall demand for electricity therefore increases by up to 7-8%. This means that in turn the power generation sector must increase capacity and its emissions rise, by 2-3%.

The impacts on the fuel mix are shown in Table 4.5.

4.4 Household distributional results

Introduction

E3ME includes a basic model of distributional impacts based on the most recent household spending survey data published by Eurostat in Spring 2008. This splits households into 13 groups, including five income groups, six socio-economic groups and a split between urban and rural households. Nominal incomes are estimated for each group according to increases in wages, benefits and other income (eg dividends) and the

TABLE 4.5: FUEL DEMAND BY FUEL TYPE, % DIFFERENCE FROM BASE, 2020

Scheme	**Cap & share**			**CO2 tax**		**Hybrid**	
Target Reduction	30%	20%	10%	30%	20%	30%	20%
Coal	0.5	0.2	0.0	1.6	0.9	0.4	0.3
Heavy fuel oil	-39.5	-31.9	-22.4	-37.6	-29.7	-37.0	-28.1
Electricity	7.7	5.5	3.3	8.2	5.8	7.3	5.1
Gas	-16.7	-14.3	-10.7	-16.1	-14.1	-17.2	-14.3
Middle distillates	-24.8	-17.2	-10.7	-24.7	-17.4	-25.7	-18.5

Source(s) : E3ME.

importance of these in the incomes of each group. Real incomes are calculated by dividing this by an aggregate price deflator, which is calculated by taking a weighted average of the prices of each consumer good, with the weights being the share of expenditure by each group. The results are then scaled to match the main model aggregates, which take into account changes in the shares.

The main distributional impacts come from:

- different sources of income
- differences in spending patterns

The spending patterns are summarised in Table 4.6. The main patterns are that the lower-income groups are much more reliant on social benefits for their incomes and, as incomes in the lowest group are half the mean, the lump sum payments have a much larger relative effect. In the spending patterns there is not much difference between the groups in spending on heating fuels but there are large differences in consumption of motor spirit, with the higher income groups spending a larger share of earnings on motor fuel. Rural population groups also spend a larger share of income on transport.

TABLE 4.6: SHARE OF SPENDING ON ENERGY, 2005

	Heating fuels	Transport fuels	Total (All households=1)
All households	3.40	4.70	1
First quintile	7.40	3.80	0.50
Second quintile	5.10	4.80	0.70
Third quintile	3.80	4.90	1
Fourth quintile	2.90	5.30	1.30
Fifth quintile	2.20	4.30	1.50
Manual workers	2.80	4.20	1.10
Non-manual workers	2.80	4.20	1.30
Self-employed	3.40	5.30	1.10
Unemployed	4.10	5.00	0.70
Retired	4.90	4.70	0.70
Inactive	4.80	4.50	0.70
Densely populated	3.00	3.60	
Sparsely populated	4.20	6.70	

Note(s) : Eurostat data scaled to official national statistics values.
Source(s) : Eurostat and the Central National Statistics Office Ireland.

The cap and share scheme benefits low income households

The scenarios could therefore all be considered equitable, in that the burden of higher energy prices falls more on high-earning households. The carbon tax scenarios also help out low-income groups through increasing social benefit rates. However, the largest impact is the receipt of the lump-sum payment on low-income households. The size of the increase is determined by the value of the allowances compared to average incomes in each group. In the lowest income group, incomes are around half the mean for Ireland as a whole and in the scenarios the lump-sum payment can increase incomes in the lowest income groups by more than 5%.

The other key trend is that households in urban (defined as densely-populated) areas are likely to gain more from the schemes. The reason for this is that spending on transport fuels makes up a larger share of total spending by rural households and therefore they are more affected by the price increases for petrol and diesel.

The impacts of the cap and share and carbon tax scenarios on the different household groups are presented in Table 4.7.

4.5 Results in the context of higher oil prices

Most of the scenarios (and the baseline) were also run in the context of higher global oil prices. This serves two purposes: to test the robustness of the model results to a key input assumption, and to run the scenarios under an oil price that is closer to actual prices in mid 2008. The two sets of oil prices are shown in Table 4.8. Under these high oil

TABLE 4.7: INCOME DISTRIBUTION, % DIFFERENCE FROM BASE, 2020

Scheme	**Cap & share**			**CO2 tax**		**Hybrid**	
Target Reduction	30%	20%	10%	30%	20%	30%	20%
All households	1.8	1.1	0.6	2.1	1.3	1.6	1.0
First quintile	5.6	3.5	2.0	4.2	2.7	5.2	3.4
Second quintile	3.2	2.0	1.1	2.0	1.2	2.9	1.9
Third quintile	1.5	0.9	0.5	1.9	1.1	1.3	0.8
Fourth quintile	0.8	0.5	0.3	2.0	1.2	0.7	0.4
Fifth quintile	0.6	0.3	0.2	2.6	1.5	0.5	0.3
Manual workers	1.2	0.7	0.4	1.7	1.0	1.0	0.6
Non-manual workers	1.1	0.6	0.3	2.4	1.4	0.9	0.6
Self-employed	1.1	0.7	0.4	1.7	1.1	1.0	0.6
Unemployed	3.4	2.1	1.2	2.3	1.4	3.2	2.1
Retired	3.3	2.0	1.2	4.6	2.8	3.0	1.9
Inactive	3.4	2.1	1.2	2.0	1.3	3.1	2.0
Densely populated	2.4	1.4	0.8	2.9	1.7	2.3	1.5
Sparsely populated	1.1	0.7	0.4	0.8	0.5	0.8	0.5

Source(s) : E3ME.

TABLE 4.8: OIL PRICES

		2010	2015	2020
Baseline	\$2005/boe	54.50	57.90	61.10
	nom \$ /boe	60.01	70.78	83.41
High oil scenario	\$2005/boe	56.50	69.45	84.86
	nom \$ /boe	67.13	91.60	125

Note(s) : Figure shows price of oil in barrels of oil equivalent in real and nominal terms.

price scenarios the oil price is roughly 50% higher in 2020. The ETS prices were not assumed to change.

The higher oil prices have two main impacts on the scenarios. First, the emissions targets are easier to achieve because baseline emissions are lower due to higher energy prices. Second the relative impact of the policies on fuel prices is less (eg to raise prices by 10% a much higher allowance price is required.

The study is not intended to examine the effects of higher global oil prices (which would have impacts on Ireland's trading partners in the rest of Europe as well, but other than the UK, these were not modelled) but for reference, GDP is up to 1% lower in 2020 under the higher oil prices, mainly due to falls in real income and household spending. Exports and import volumes are also lower by up to 1%.

The impacts of the scenarios are similar (see Table 4.9) but generally smaller in magnitude, because the targets become less ambitious. For example, the allowance price in the 30% target cap and share scenario is €221 rather than €309, a fall of nearly 30%.

TABLE 4.9: ENERGY RESULTS, % DIFFERENCE FROM RESPECTIVE BASE, 2020

Scheme				**Cap & share**
Target Reduction	30%	30% high oil	20%	20% high oil
Energy	-14.9	-8.7	-11.2	-4.9
CO2	-18.8	-11.6	-14.2	-6.5
Allowance price (€08/tCO2)	308.8	221.3	167.2	85.1
Carbon tax (€08/tCO2)	0	0	0	0
Scheme				**CO2 tax**
Target Reduction	30%	30% high oil	20%	20% high oil
Energy	-14.4	-8.4	-10.9	-4.8
CO2	-18	-11	-13.6	-6.2
Allowance price (€08/tCO2)	0	0	0	0
Carbon tax (€08/tCO2)	329	239.6	182	92.4

Note(s) : Figures show change in energy demand and CO2 emissions in Ireland, relative to baseline, and the carbon/energy prices required to achieve this.
Source(s) : E3ME.

This means that there is 30% less revenues to redistribute to households, so the economic impacts are smaller. This does not make much difference at the aggregate level, where impacts were small anyway but does have some effect at the more detailed level, including for low-income households, where incomes including the value of the allowance increase by 3.6% rather than 5.6% when the oil price is lower.

Matching the ETS price

For comparison, a scenario was set up that set a carbon tax for the non-ETS sectors that was equal to the main European ETS price in €/tCO2, meaning that all sectors pay the same for releasing one tonne of CO2. This scenario was run in the context of high oil prices (although baseline ETS prices were assumed unchanged). Overall, this tax did not have a very big impact on CO2 emissions, reducing overall CO2 emissions in the non-ETS sectors by around 1% in 2020. This compares with the 24% reduction required to match the 30% target with the higher oil price.

TABLE 4.10: ECONOMIC RESULTS, % DIFFERNCE FROM RESPECTIVE BASE, 2020

Scheme				**Cap & share**
Target Reduction	30%	30% high oil	20%	20% high oil
Scenario oil price (nom $/boe)	83.4	125.0	83.4	125.0
GDP	0.0	0.1	-0.0	0.0
Household spending	-0.8	-0.5	-0.6	-0.3
Investment	0.0	-0.0	-0.1	-0.1
Imports	-0.5	-0.4	-0.4	-0.2
Exports	-0.0	-0.0	-0.0	-0.0
Employment	-0.0	-0.0	-0.0	-0.0
Price level	3.1	1.7	1.9	0.8

Scheme				**CO2 tax**
Target Reduction	30%	30% high oil	20%	20% high oil
Scenario oil price (nom $/boe)	83.4	125.0	83.4	125.0
GDP	0.9	0.6	0.5	0.2
Household spending	1.7	1.1	1.0	0.3
Investment	0.5	0.3	0.3	0.0
Imports	-0.1	-0.1	-0.1	-0.1
Exports	0.0	0.1	0.0	0.0
Employment	0.0	0.0	0.0	0.0
Price level	2.4	1.1	1.5	0.6

Note(s) : Table shows percentage change in main economic indicators, compared to baseline.
Source(s) : E3ME.

5 CONCLUSIONS

5.1 Introduction

The E3ME model was set up to assess the energy, environmental and economic impacts of the introduction of a personal cap and share emission trading scheme in Ireland. The scheme was applied to all economic sectors that are not included in the EU's Emission Trading Scheme and covered all energy-related CO2 emissions. E3ME determined the carbon prices in the scheme such that the targets, described below, were met. The economic impacts resulting from this increase in energy costs were evaluated according to the structure of the national accounts, as embodied in the E3ME model, and the model's two-way linkages between the environment, energy systems and economy.

As a comparison, scenarios with an equivalent carbon tax and revenue recycling were also modelled, and two hybrid options that split the burden between business and households.

The cap and share schemes included a set of ambitious emission-reduction targets in the sectors that were covered by the scheme. The largest reduction was 30% in 2020 compared to 2005 levels, compared to a projected 10% increase under business as usual conditions. This roughly represents a 3% reduction in CO2 emissions in each year up to 2020.

Each scenario was compared to an agreed baseline solution and an alternative base case, with higher oil prices, was used to test the sensitivity of the modelling results to this key input assumption.

5.1 Economic impacts

The overall impact of the cap and share scheme on aggregate GDP and employment levels is almost zero. However, looking at the more detailed results, the following trends are clear in the modelling results:

- higher energy prices has an inflationary impact
- this reduces real incomes and household spending (although excluding energy, household expenditure increases)
- sales of allocated allowances boost household wealth, but most of this is saved
- a reduction in energy imports boosts Ireland's Balance of Payments, as exports are largely unchanged

Sectoral impacts

At the sectoral level there are some sectors that are able to increase output, while others lose out. The sectors that lose out are concentrated in the energy branch, in particular gas distribution and manufactured fuels (although this could not be modelled due to missing data). The construction industry was also found to lose out due to lower investment in gas infrastructure. The gains were more widely spread, including recipients of consumer spending (eg retail) but also sectors that manufacture energy-efficient products, in particular motor vehicles and mechanical engineering. These highly-skilled sectors were found to increase employment, while employment decreased in more basic manufacturing sectors. Output from the electricity industry also increased in response to higher demand.

In terms of profitability, and also possibly investment, firms in some sectors are likely to be particularly affected, mainly those that are unable to pass on cost increases to domestic markets and, in particular, exporting firms that are unable to increase prices in international markets.

The impacts on haulage firms are difficult to measure; undoubtedly the sector faces higher costs but it is not clear how much of this can be passed on to customers and how this would affect output and profitability in the sector. To fully assess these impacts, a transport model with an equation to describe demand for road freight is required.

Distributional impacts

The cap and share scheme was found to be highly equitable, partly because the product that had the largest price increase (motor fuels) makes up a larger share of spending in higher-earning households, but mainly because the relative value of the allowance was much higher for low-income households.

The other notable distributional impact is that households in urban areas gain more from the scheme as they spend a smaller share of income on transport fuels.

5.2 Energy and environment impacts

A high carbon price is required

The reduction in CO2 emissions is part of the definition of the scenarios. The modelling results suggest a very high carbon price would be required to achieve these targets by 2020. This partly reflects the ambitious nature of the targets and the sectors that are included in the scheme, and partly reflects modelling assumptions. In particular, the modelling does not allow the provision of electric vehicles, meaning that emission reductions had to be met through efficiency improvements in liquid fuels or a reduction in the number of journeys made.

Furthermore, while the highest carbon price is large enough to increase the price of motor fuels by 80%, adding this on to the fuels used by some other sectors increases their average energy prices by much more. The reason for this is that motor fuels are already taxed heavily through excise duties, so a larger allowance price is required to change behavioural patterns.

Other sectors

As electricity, which does not directly produce CO2 emissions, does not increase in price, households and some other sectors covered by the cap and share scheme are able to switch from use of gas to use of electricity. Overall consumption of electricity increases. This has a secondary impact that additional capacity is required in the power generation sector. Consequently, emissions from this sector increase slightly and overall use of coal in Ireland is also slightly higher.

5.3 Comparing cap and share with carbon taxes

The effects of the cap and share schemes and the carbon taxes on energy prices, fuel demand and emissions are almost identical; the extra cost is added on to the price of the fuels and this reduces demand according to the price elasticities. The main difference comes from the revenue recycling methods and their economic and distributional impacts.

The main difference between the two policies is that under the personal cap and share scheme, households receive an increase in financial wealth through the allowances that they receive. Much of this is saved (in Ireland 8% is spent, in line with the European average and similar to figures quoted in other studies). Under the carbon taxes, the revenue recycling feeds directly into income, through lower income taxes and higher social benefits. While some of this is also saved, a larger share is used for immediate consumption and in the long-run (which could be after 2020) all the extra income is spent. The multiplier effects of higher immediate spending boost output in the period up to 2020.

At a distributional level the carbon taxes with revenue recycling are less beneficial for low income households, although due to the increases in social benefits their incomes do increase. However, the reduction in income taxes is of more benefit to the higher-earning groups.

6 REFERENCES

AEA Energy and Environment (2008) ‘Cap and Share: Phase 1; policy options for reducing greenhouse gas emissions’, report produced for Comhar Sustainable Development Council.

Amann, Markus, Janusz Cofala, Chris Heyes, Zbigniew Klimont, Reinhard Mechler, Max Posch and Wolfgang Schöpp (2004) ‘RAINS Review 2004’. International Institute for Applied Systems Analysis, K(255,51,0,0)http://www.iiasa.ac.at/Admin/PUB/Documents/IR-06-029.

Andersen, Mikael Skou (2005) ‘ETR and Competitiveness - Conceptual Issues’, COMETR, European Commission project No 501993 (SCS8).

Barker, Terry, Ole Løfsnaes and Hector Pollitt (2007) ‘The ETM in E3ME43’, Cambridge Econometrics, K(255,51,0,0)http://www.camecon.com/suite_economic_models/e3me/pdf%20files/ETM.pdf.

Barker, T S (1998), ‘Use of energy-environment-economy models to Inform greenhouse gas mitigation policy’, Impact Assessment and Project Appraisal, vol. 16, no. 2, pp. 123-131.

Barker, T S, Ekins, P and N Johnstone (1995), Global Warming and Energy Demand, Routledge, London.

Cambridge Econometrics (2007), ‘E3ME Manual’, K(255,51,0,0)http://www.camecon-e3memanual.com/cgi-bin/EPW_CGIU.

Criqui, P (2001) ‘POLES Prospective Outlook on Long-term Energy Systems’, INSTITUT D’ECONOMIE ET DE POLITIQUE DE L’ENERGIE, K(255,51,0,0)http://web.upmf-grenoble.fr/iepe/textes/POLES8p_01.pdf.

Doornik, Jurgen A. (2007). ‘Ox: An Object-Oriented Matrix Language’, Version 5, London: Timberlake Consultants Press.

E3M-LAB (2005) ‘The PRIMES Energy System Model: Reference Manualô’, Institute of Communication and Computer Systems, National Technical University of Athens, K(255,51,0,0)http://www.e3mlab.ntua.gr/manuals/PRIMsd.pdf.

Engle, R F and C W J Granger (1987), ‘Cointegration and error correction: representation, estimation and testing’, EconometricaEM, 55, 251-76.

European Commission (2008), ‘Energy and Transport: Trends to 2030 (Update 2007)’, Directorate General for Transport and Energy, European Commission, K(255,51,0,0)http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/index_en.htm.

Eurostat (1995), ‘European System of Accounts (ESA95)’, Eurostat, European Commission.

Franzen, M and T Sterner (1995) ‘Long-run Demand Elasticities for Gasoline’ in Barker, T, N Johnstone and P Ekins (eds), *Global Warming and Energy ElasticitiesI, Routledge.*

Hendry, D F, Pagan, A and J D Sargan (1984), Dynamic specification, in Handbook of EconometricsEM, Vol II, Griliches, Z and M D Intriligator (eds), Amsterdam, North Holland.

Johansson, Olof and Lee Schipper (1997) ‘Measuring the long-run fuel demand of cars’, *Journal of Transport Economics and PolicyI, Volume XXXI, No 3, pp 277-292.*

KU Leuven (2005) ‘GEM-E3 Computable General Equilibrium Model for studying Economy-Energy-Environment Interactions for Europe and the world’, see K(255,51,0,0) http://www.gem-e3.net/download/GEMmodel.pdf.

OECD (2004) ‘Housing Markets, Wealth and the Business Cycle’, OECD Economic Outlook (2004), Chapter IV, see K(255,51,0,0) http://www.oecd.org/dataoecd/4/60/31920338.pdf.

Roy, Joyashree, Alan Sanstad, Jayant Sathaye and Raman Khaddaria (2006) ‘Substitution and price elasticities using inter-country pooled data in a translog cost model’, Formal Report, LBNL-5306, 2006.

Wilson, Rob, Frank Cörvers, Ben Gardiner, Ben Kriechel, Hector Pollitt, Ilias Livanos and Unnada Chewpreecha (2007) ‘Medium-term forecasts of occupational skill needs in Europe’, Report for CEDEFOP, European Commission project No 2006/S 125-132790.

Yamano, Norihiko and Nadim Ahmad (2006) 'THE OECD INPUT-OUTPUT DATABASE: 2006 EDITION', STI working paper 2006/8, Statistical Analysis of Science, Technology and Industry, OECD.