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Climate and Air Policy in Ireland: Synergies and Tensions – A GAINS Ireland and Irish TIMES analysis

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EPA RESEARCH PROGRAMME 2014–2020

Climate and Air Policy in Ireland: Synergies and Tensions – A GAINS Ireland and Irish TIMES analysis

(2013-CCRP-MS.14)

by

EnvEcon, University College Cork and University College Dublin

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Executive Summary

The GAINS Ireland and Irish TIMES models have received support from the Environmental Protection Agency in order to develop the analytical infrastructure needed to effectively address climate and air policy challenges for Ireland in both a domestic and an international context. This report is the culmination of a collaborative research initiative between EnvEcon (GAINS Ireland model) and University College Cork (Irish TIMES model). The work draws upon the integrated analytical capacities of the GAINS Ireland model to assess the outcomes of climate and air pollution, the detailed energy system optimisation capacities of the Irish TIMES model, and a health and environmental impact assessment methodology for air pollution, which was developed by EnvEcon. The focus of this report is outlined below.

The Irish TIMES model was utilised to generate an energy system optimisation scenario that delivers a 22% reduction in non-emissions trading sector (NETS) greenhouse gas (GHG) emissions in Ireland by 2030, relative to 2005; this requires a 39% reduction in NETS energy-related emissions to compensate for lower mitigation potential in agriculture. This change is reflective of a potential European target for Ireland to reduce GHG emissions across the non-traded sectors in 2030 by 22%. The Irish TIMES "business as usual" (BAU) scenario offers an outlook for 2030 that is similar in concept to the national "with measures" scenario.[1] For this research, the EnvEcon team adapted the Irish TIMES BAU scenario and the Irish TIMES optimisation scenario, which delivers the 22% reduction in NETS emissions (NETS22), into the GAINS Ireland model as new, individual scenarios. Thereafter, the team assessed the difference in air pollutant emissions and impact outcomes arising between the two scenarios. These assessments were conducted using the GAINS Ireland model and the EnvEcon methodology for health and environmental impact assessment (EnvEcon, 2015), respectively. The objectives of the research were to:

- highlight the potential synergies and/or tensions of climate-focused policy on air pollution outcomes;
- illustrate the importance of broad scope integrated decision support for Irish environmental policy;
- identify a means of soft-linking two powerful analytical models for improved national decision support;
- establish a collaborative platform to assess future directions for such modelling research in Ireland.

The results indicate that, under the Irish TIMES energy scenarios, the 22% reduction in GHG emissions (modelled as a 39% reduction in the energy system) for the non-traded sectors has been achieved with substantial reductions (60%) in SO_2 (sulphur dioxide) emissions and reasonable reductions (27%) in emissions of NO_x (nitrogen oxides). The outcome is less favourable for volatile organic compounds (VOCs), which saw an increase in emissions of 15%. However, the most dramatic difference is for $PM_{2.5}$ (particulate matter with a diameter of less than 2.5 µm), as under the NETS22 scenario, emissions increased by 61% in comparison with the BAU scenario. These changes are driven largely by an increase in biomass use in residential/commercial activities and industrial combustion, with a conservative assumption of emissions control technologies applied over the additional biomass at this point. Overall, however, there is an estimated net benefit in health and environmental impacts of €20 million per annum from 2030, as a result of the move from the BAU to the NETS22 scenario. This net benefit is principally driven by reductions in SO_2 and NO_x, which offset nearly €40 million of additional health costs from the higher $PM_{2.5}$ emissions. However, a comparable analysis between the official "with measures" and "with additional measures" scenarios, delivers a net additional benefit of some €33 million, which is largely due to a more moderate increase in $PM_{2.5}$ emissions. Furthermore, the NETS22 scenario is expected to result in a breach of the anticipated 2030 $PM_{2.5}$ ceiling under the revised National Emission Ceilings Directive

1 It is stressed that the BAU scenario is not directly comparable to the EPA's official national inventory and forecast, nor to the GAINS Ireland forecast scenarios, which do include scenarios that mirror official inventory and forecast values.

(2001/81/EC). Further research is advised with regard to abatement strategies or alternative courses of action, so as to limit, in particular, the potential $PM_{2.5}$ and VOC challenges identified.

The summary recommendation from the analysis is to recognise that a broader focus is important to policy decisions in Ireland if we are to meet the manifold challenges posed by climate, air and other legislative environmental constraints. Dynamic strategic assessment is required to identify and navigate the best available pathways for Ireland in the context of expected legislative, environmental, economic and health-related outcomes. Such decision support can equip policy-makers with the evidence with which to make informed strategic policy decisions in complex areas.

1 Introduction

This work represents a collaborative initiative between two national modelling teams in Ireland: the teams at EnvEcon and University College Cork (UCC) develop, manage and run the GAINS (Greenhouse Gas Air Pollution Interaction and Synergies) Ireland and Irish TIMES (The Integrated MARKAL-EFOM System) models, respectively. These models have been developed for Ireland on foot of research funding initiatives from the Environmental Protection Agency (EPA), and have benefited from a sustained and open engagement with government departments and key agencies such as the EPA and the Sustainable Energy Authority of Ireland (SEAI). While the models are distinct methodologically, they operate in a similar policy arena. The TIMES model focuses principally on energy systems and associated climate emissions, whereas the GAINS model is an integrated assessment model that focuses on both climate and air pollution. A key feature of GAINS, in this case, is its capacity to assess the interactions and synergies of policy across all sectors for these two thematic concerns. The premise of this joint paper was therefore to assess how a purely climate-focused optimisation scenario from TIMES would impact on air pollutants and associated health impacts under the GAINS Ireland methodology. The aim is to understand the synergies and tensions between climate and air policy in Ireland, and to thereafter use the damage impact valuation methodology of EnvEcon to quantify the net outcome of the assessed synergies and tensions.

The report is structured as follows. Chapter 2 presents the methodology for each model, and the method through which they have been linked. Chapter 3 presents the outcomes of the analysis; this includes a description of the changes between the TIMES "business as usual" (BAU) scenario and the NETS22 optimisation. Chapter 3 then discusses the GAINS Ireland estimates of the associated changes in air pollutant emissions, and finally the EnvEcon health and environmental impact analysis arising from the move from BAU to NETS22. Chapter 4 presents the conclusions.

2 Methodology

The first two sections in this chapter present summary details of the GAINS Ireland and Irish TIMES models. These are intended to give a basic understanding of the kind of data that are used to feed the models, how they process and analyse data, and how the models are used both nationally and internationally. The third section outlines the linkage process between the two systems for the purpose of this research report.

2.1 The GAINS Ireland Model

The GAINS model is the predominant integrated assessment model for climate and air policy in a European context (Amann *et al.*, 2011) and is one of the leading regional and global models in this field. The model is deeply embedded in international policy, as evidenced by it being the only model to simultaneously serve in an analytical role for the European Commission, European Parliament, European Council and the United Nations (see, for example, Hoglund-Isaksson *et al.*, 2010; Cofala and Klimont, 2012; Wagner *et al.*, 2013). GAINS has also been adopted as the technical modelling backbone for some major international projects, such as the Climate and Clean Air Coalition (http://www.unep.org/ccac/). The GAINS model regularly runs in a pivotal role with other linked systems (e.g. PRIMES for energy, GLOBIOM for land use) to enable extended analyses. EPA funding has supported the development of national capacity and model infrastructure in this area under the auspices of the Integrated Modelling Project (IMP) Ireland.

The GAINS Ireland model is a national instance of the GAINS model, which has been developed and used by EnvEcon since 2006. This work draws upon multiple national data sources (e.g. EPA, SEAI, Teagasc, industry) as well as a host of international research groups [e.g. the International Institute for Applied Systems Analysis (IIASA), the United Nations Economic Commission for Europe (UNECE) Task Force on Integrated Assessment Modelling]. The outcome of these efforts is a powerful, internationally supported integrated assessment modelling tool, tailored for use in Ireland, which is also understood and accepted in a broader international context.

The GAINS Ireland model is managed under the IMP Ireland project by a small, highly experienced technical team (Dr Kelly and Dr Fu) and is thereafter applied in support of a broad range of national and international policy and modelling needs. The team regularly interacts with national stakeholders, the European Commission and the IIASA, and it is through these well-established channels that the GAINS model and the IMP Ireland project have a direct influence on related international policy development and the national policy response. Specifically, the GAINS Ireland model informs the negotiation and review of international environmental legislation, as well as supporting the strategic decisions and reporting specifications that are subsequently required by Ireland.

As a multi-effect and multi-pollutant integrated model covering all sectors of the economy, the calibration and development research associated with the GAINS platform also offers many opportunities to support, benefit and otherwise collaborate with other researchers and institutions at national and international scales. Such interactions have historically included close working relationships with the EPA Inventory and Forecasting teams and the team at IIASA, as well as strong participation in the UNECE Task Force on Integrated Assessment Modelling and direct support and engagement with relevant government departments and agencies. The broad scope of the GAINS model affords the opportunity to incorporate knowledge from a diverse range of research and industry sources, all with a view to developing and maintaining a dynamic and increasingly appropriate modelled reflection of Ireland, over time and into the future, so as to support better, broader decision making.

2.1.1 Review: the GAINS model methodology

The GAINS model is a rich and complex system that distils large volumes of complex data and scientific knowledge into a structured and meaningful set of processed outcomes. These outcomes are principally in the form of emissions (e.g. CO_2, $PM_{2.5}$) and the associated effects (e.g. health impacts, acidification) and costs (e.g. abatement technology investments).

The model can run at global, regional, national and even sectoral scales, depending on the context of the analysis. For example, independent national scenarios can be run to identify costs or abatement potentials for a defined pathway, whereas to assess transboundary pollution impacts, broader regional scenario analyses are required. Detailed, yet accessible, descriptions of the individual methodological components of the model have been compiled by the IMP team and can be readily sourced online (http://www.policymeasures.com/resources/), and full technical details and reports can be found on IIASA's website (http://tinyurl.com/iiasaapd).

Figures 2.1, 2.2 and 2.3 offer a summary overview of the GAINS modelling system. Figure 2.1 summarises the scope of the model, with a listing of the principal pollutants modelled, the sectors covered and the forms of outputs and analysis generated. Figure 2.2 offers a simplified function of the main components at work within the GAINS model. These are the levels of "activity" of a given emission source (e.g. cars or cows), the abatement controls either in place or potentially in place, the emission outcomes, and thereafter the health, environmental and cost outcomes of the overall scenario. Figure 2.3 identifies the two principal modes that can be used when running the model, namely scenario and optimisation mode.

2.2 The Irish TIMES Model

The Irish TIMES model is an energy system model for Ireland developed by UCC under the Climate Change Research Programme 2007–2013. It was developed to build a range of medium- (until 2020) to long-term (until 2050) energy and emissions policy scenarios in order to inform policy decisions. The Irish TIMES model was originally extracted from the Pan European TIMES (PET) model, a 36-region (EU-27, Iceland, Norway, Switzerland, and six Balkan countries) model of Europe (Gargiulo and Ó Gallachóir, 2013), and was then updated and expanded using local and more detailed data and assumptions (Ó Gallachóir *et al.*, 2012). The model represents the Irish energy system and its

Figure 2.1. GAINS model scope.

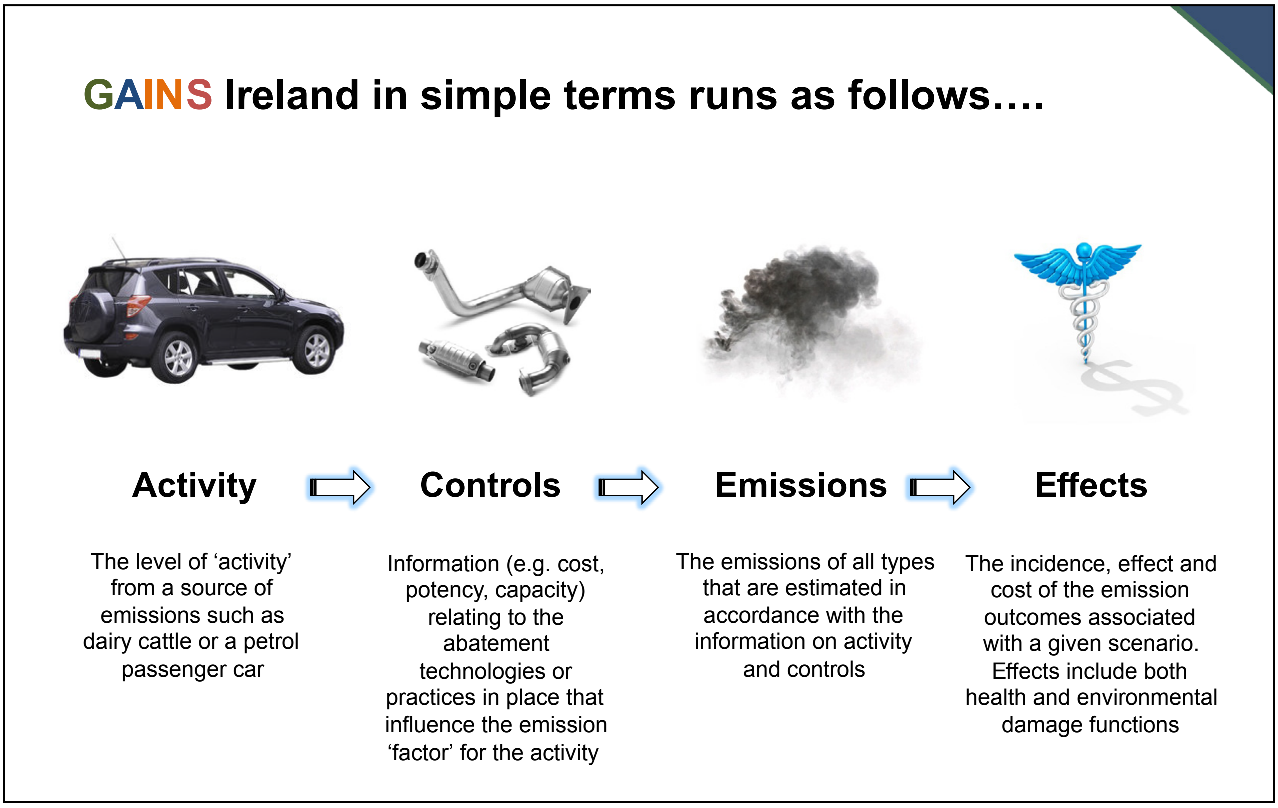

Figure 2.2. GAINS model simplified function.

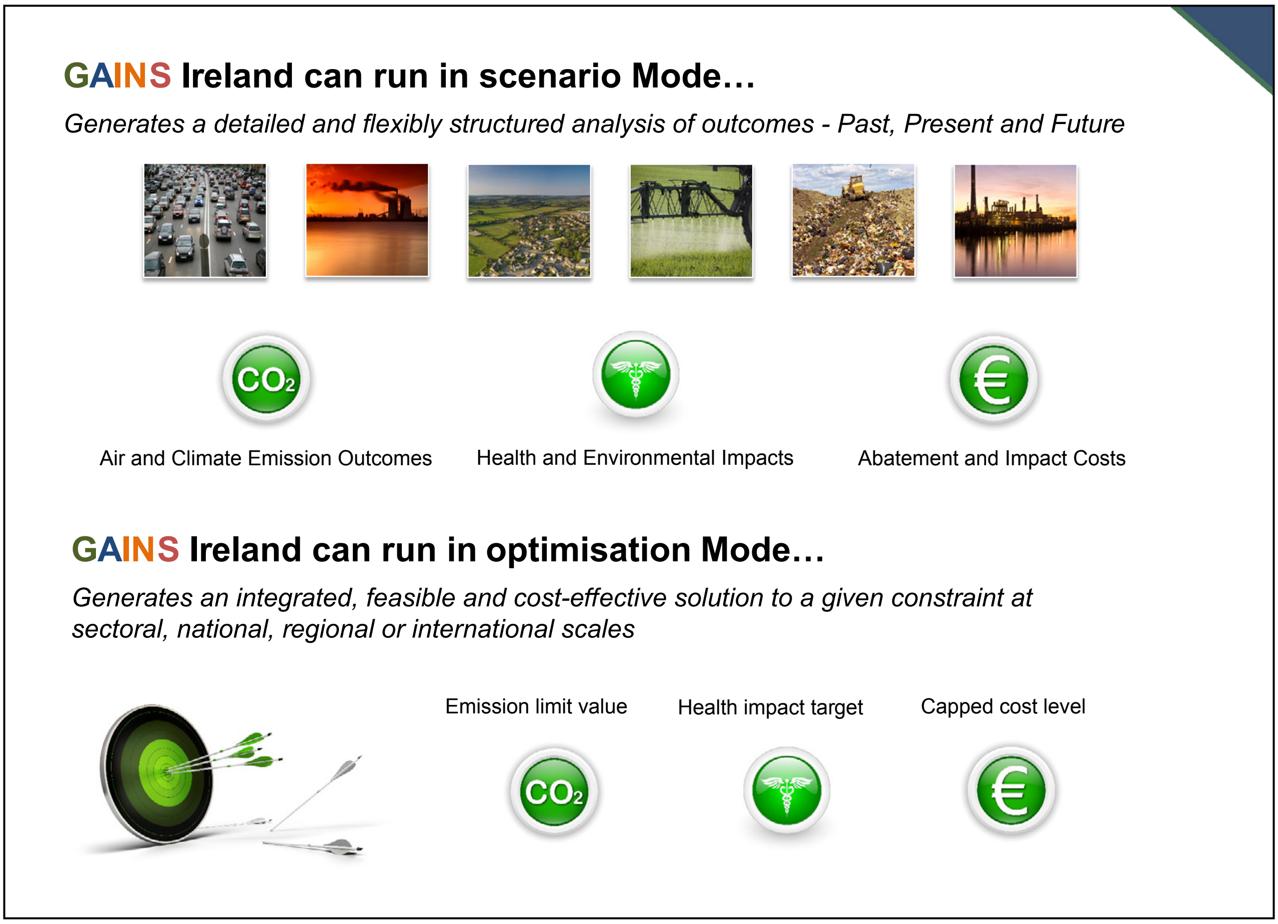

Figure 2.3. GAINS model analysis.

possible long-term evolution through a network of processes that transform, transport, distribute and convert energy from its supply sector (fuel mining, primary and secondary production, exogenous import and export), to its power generation sector (which also includes the combined heat and power description), and to its demand sectors (residential, commercial and public services, agricultural, transport and industry). Figure 2.4 summarises the structure of the model, with a representation of the sectors covered and its interactions with other sectors, and the principal group of processes and commodities modelled.

The model is designed to determine the optimal energy system that will meet the energy service demands over the entire period of time at the least possible cost, by indicating the optimal mix of technologies and fuels at each period, the associated emissions, mining and import activities and the equilibrium level of the demand. The model outputs are energy commodity prices, energy flows, quantities of greenhouse gas (GHG) and transboundary emissions (Irish TIMES currently focuses on GHG emissions), capacities of technologies (e.g. installed megawatts of wind power) and energy costs (comprising capital costs, operation and maintenance costs, fuel costs, etc.). Running the model in the absence of a policy constraint generates a set of results associated with a "reference scenario". This will not normally completely align with national energy forecasts that are generated by simulating the anticipated future energy use, mainly because TIMES optimises the energy systems providing a least-cost solution. When a (single of many) policy constraint is then imposed on the model (e.g. minimum share of renewable energy or level of energy security, or maximum amount of GHG emissions), it generates a different least-cost energy system. When the results are compared with those from the reference scenario, the different technology choices that deliver the policy constraint at least cost can be identified.

The widest current applications of TIMES are related to the analysis of policies designed to reduce GHGs from energy and materials consumption. As the framework depicts individual technologies, it is particularly useful for evaluating policies that promote the use of technologies of greater efficiency in energy or materials or the development and use of new technologies. It provides a means of quantifying the economic cost associated with a range of climate mitigation strategies

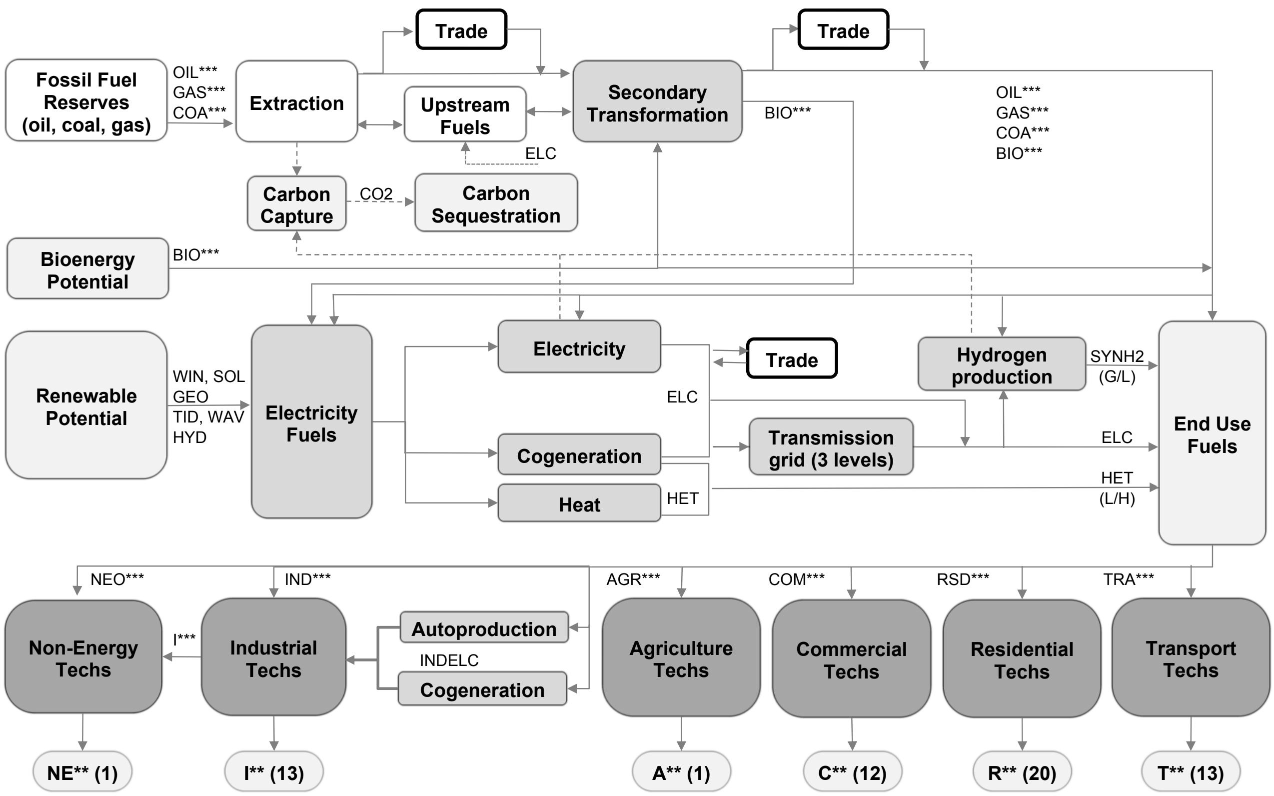

Figure 2.4. Irish TIMES Model reference energy system. Reproduced from Chiodi *et al*. (2013a), with permission from Elsevier.

and the impacts of climate change policies on economic growth. Irish TIMES has been used to build a range of energy and emissions policy scenarios to explore the dynamics behind the transition to low-carbon energy systems (Chiodi *et al*., 2013a,b), to analyse energy security (Glynn *et al*., 2014), to assess impacts of limited bioenergy resources (Chiodi *et al*., 2015a) and to explore new modelling approaches (Deane *et al*., 2012; Chiodi *et al*., 2015b). Moreover, since June 2013, the Irish TIMES model has been used extensively to inform some key policy developments, such the development of (1) national legislation on climate change and (2) Ireland's negotiation position regarding the proposed EU 2030 Carbon and Energy Policy Framework.

2.2.1 The Irish TIMES model methodology

Irish TIMES is a full energy system model of Ireland developed in TIMES. TIMES is a widely applied techno-economic model generator for local, national and multi-regional energy systems, developed and supported by the ETSAP (Energy Technology Systems Analysis Programme) community, an implementing agreement of the International Energy Agency (IEA-ETSAP, 2011).[2] TIMES combines all the advanced features of MARKAL (Market Allocation) models (Fishbone and Abilock, 1981) and to a lesser extent EFOM (Energy Flow Optimisation Model) models (Van der Voort, 1984). It uses linear programming optimisation to provide a technology-rich basis for estimating energy dynamics over a long-term, multi-period time horizon. The objective function is to maximise the overall surplus. This is equivalent to minimising the total discounted energy system cost while respecting environmental and many technical constraints. This cost includes the costs of investment, operation and maintenance, plus the costs of imported fuels, minus the incomes of exported fuels and the residual value of technologies at the end of the horizon. The full technical documentation of the TIMES model is available in Loulou *et al*. (2005). The usefulness and strengths of TIMES can be surmised from its popularity. It is currently in use in 177 institutions across 69 countries, and it therefore has the significant advantage that the results can be compared with those of other countries. A selection of applications and case studies covering the period 2005–2015 are summarised in IEA-ETSAP (2008, 2011) and Giannakidis *et al*. (2015).

2 See http://www.iea-etsap.org/web/index.asp for more details.

The Irish TIMES model version used in this analysis calibrated the years 2005–2012 to the national energy balances (Howley *et al*., 2006, 2012), which consists of a time horizon of 65 years (to 2070) and a time resolution of four seasons with day–night time resolution, the latter comprising day, night and peak time slices. Energy demands are driven by a macroeconomic scenario covering the period to 2050, which is based on the ESRI HERMES macroeconomic model of the Irish economy. HERMES is used for medium-term forecasting and scenario analysis of the Irish economy. Most recently the model was used to generate the scenarios underpinning the 2013 edition of the ESRI's *Medium-Term Review* (FitzGerald *et al*., 2013). On the supply side, fossil fuel prices are based on IEA's current policy scenario in its *World Energy Outlook 2012* report (IEA, 2012).

Extensive description and details of the modelling structure and approach can be found in Chiodi *et al*. (2013a,b) and Ó Gallachóir *et al*. (2012). Additional information regarding the model features, key assumptions and their use in Irish TIMES may be found online (http://www.ucc.ie/en/energypolicy/irishtimes/).

2.3 Linkage of GAINS Ireland and Irish TIMES

GAINS Ireland and Irish TIMES are fundamentally different models. The models are both complex systems that address emissions and can run optimisations, but there are differences in scope, method, data structure and focus. Indeed, both models operate on an international scale and there is broad recognition in the relevant international research communities that the models are not designed to operate in a formally integrated fashion. However, as both models are used to provide decision support and have both been developed for Ireland, there is potential value in examining how the models may be used to complement and augment one another. For the purpose of this study, the Irish TIMES team at UCC delivered a climate optimisation scenario focused on energy, which finds a pathway from an Irish TIMES BAU scenario to a scenario that offers an emission pathway in line with the proposed targets for Ireland in the Climate and Energy Policy Framework for 2030 (EC, 2014). The following assumptions have been used in the two alternative scenarios:

1. A BAU scenario that does not impose emissions targets and efficiency improvements and is used as

a counterfactual base case against which to compare a low-emissions policy scenario.

2. A NETS22 scenario in which NETS (non-emission trading sector) GHG emissions are constrained across the entire time horizon to be no greater than 20% and 22% below 2005 levels in 2020 and 2030, respectively, while ETS emissions are assumed to reduce by 2.2% per year as a proxy for the EU-wide target as specified in Directive 2009/29/EC (EU, 2009). Given the low mitigation potential in agriculture, this scenario is modelled as a 39% constraint on the energy system NETS emissions.

Non-energy-related emissions from agriculture and waste, which are not included in this analysis, are supposed to be in line with the most recent national emissions projections (EPA, 2014). Assuming that these emissions will reduce by 0.3% by 2030, relative to 2005 levels, a 38.6% emissions reduction target (16.6 Mt $CO_{2,eq}$) for 2030, relative to 2005 levels, is hence imposed in the NETS22 scenario on NETS energy-related CO_2 emissions.

The outputs from the Irish TIMES BAU scenario and NETS22 optimisation were presented to the EnvEcon team in the form of energy values for specific sectors and technologies. A sample for the intercity bus sector is shown in Table 2.1.

While both TIMES and GAINS cover the same general sectors in relation to energy and activities, there are substantial differences in relation to subsectoral categorisation and indeed technology details that are relevant to the GAINS Ireland analysis of climate and air pollution emission outcomes. Given the scope and detail of both TIMES and GAINS, as well as the different structures, there was no reliable way to automatically parse and map TIMES data into the GAINS Ireland format. As a result, the methodological approach involved a more research-intensive approach of manually mapping TIMES data into the most appropriate corresponding categories within two GAINS Ireland scenario structures. This process involved hundreds of cases in which the varied focus of the models required Irish TIMES data to be either aggregated or disaggregated in order for it to be adapted successfully into the GAINS Ireland model, and there were a number of rounds of queries between the UCC and EnvEcon teams to complete the process.

In broad terms the allocation of the energy data was reasonably straightforward, but it required care and thought to ensure that the appropriate subsectors and fuel types were used in GAINS for the TIMES values. The greater challenge related to the control strategy aspects relevant to air pollutants, which are not included in the TIMES scenarios. The approach taken was to adapt a recently developed EnvEcon control strategy for the official national 2030 forecast to be used for the BAU; this control strategy was then adjusted appropriately for the NETS22 optimisation on the basis of the description of changes provided by the UCC team. For some sectors, such as the transport sector, subsectors are more aggregate in TIMES. For example, cars (without subclasses) from TIMES had to be mapped to the control strategies in GAINS; this required them to be divided into more detailed emission control technologies, e.g. NSC_TRA and EUI~EUVI. In other sectors, however, TIMES provides more detail for control technology information and fuel shares, e.g. for power stations of new or existing types, and the information

Table 2.1. Sample (for Intercity bus sector) of the data provided by Irish TIMES to GAINS (ktoe)

Sector	Technology code	Description	Fuel	NETS22 Scenario				
				2010	2015	2020	2025	2030
Intercity Bus	TBISDST100	Base-year Diesel/ Biodiesel Intercity bus	Diesel	35.6	18.7	–	–	–
			Biodiesel	1.9	–	–	–	–
	TBISGSL100	Base-year Gasoline/ Ethanol Intercity Bus	Gasoline	0.1	0.1	–	–	–
			Ethanol	0.0	–	–	–	–
	TBISDST101	Diesel Intercity Bus	Diesel	22.9	24.1	20.7	21.9	42.2
			Biodiesel	1.2	–	1.1	–	–
	TBISBDL101	Biodiesel Intercity Bus	Biodiesel	–	–	–	–	0.5
	TBISETH101	Ethanol Intercity Bus	Ethanol	–	–	24.9	24.9	24.9
	TBISGSL101	Gasoline Intercity Bus	Gasoline	–	19.4	18.4	18.4	–
			Ethanol	–	–	1.0	1.0	–

in these cases was more readily adapted into GAINS. Overall, the GAINS–TIMES linking approach drew upon useful parameters from both TIMES and GAINS. As this specific research report is a valuation of the changes of pollution and damage values of the BAU and NETS22 scenarios of TIMES, we prioritised the use of TIMES' input and used the GAINS inputs and parameters as complements only where TIMES data presented a gap or simply lacked an adequate level of detail.

With the BAU and NETS22 scenarios built for GAINS Ireland, the remaining task was to run the model and compile and analyse the emission outcome variations between those two scenarios. Thereafter, those results were fed into the EnvEcon impact analysis process for damage valuation. The next chapter presents a description of the Irish TIMES scenarios from the UCC team, followed in sections 3.2 and 3.3. by EnvEcon's assessment of the corresponding air pollutant and impact outcomes from the two scenarios.

3 Outcomes of the Analysis

3.1 Irish TIMES BAU to NETS22

This chapter presents some key results from an energy systems modelling perspective of the two alternative scenario storylines. It first presents the resultant GHG emissions trends from 1990 to 2030, as envisaged by Irish TIMES. These GHG results are followed by details of energy usage in 2030 by sector and fuel under these scenarios, and finally some details on the change dynamics and time horizons involved, as well as system-wide and individual sector results.

3.1.1 GHG emissions results

In the absence of mitigation and efficiency improvements, associated GHG emissions grow unabated, and in 2030 the BAU scenario shows Ireland's emissions at approximately 70 megatonnes, which is up 16% from 61 megatonnes in 2010. Energy-related CO_2 emissions deliver almost three-quarters of these emissions (51 Mt). The emission reduction scenario shows a pathway that delivers approximately half of the energy-related BAU CO_2 emissions (28 Mt), underpinning a GHG reduction of 22%, relative to 2005.[3] The greatest reduction in emissions relative to 2010 is in the built environment sectors (i.e. residential and services) with reductions from 10.1 megatonnes to 3.5 megatonnes, followed by electricity generation (from 12.9 Mt to 6.4 Mt) and industry (from 6.5 Mt to 5.3 Mt in 2030). Transport emissions will increase slightly (+3%). Figure 3.1 compares the trend in the reduction in NETS22 with that of BAU.

3.1.2 Energy system in 2030

Energy trends for different primary fuels and within different sectors of the energy system are presented in the following Sankey diagrams for the target year 2030.[4] Figure 3.2 shows the BAU scenario, which is very similar to the current energy system and which

3 It is worth noting that in both scenarios, non-energy related emissions from agriculture and waste, which are not included in this modelling analysis, are supposed to be in line with the most recent national emissions projections (EPA, 2014), assuming that these emissions will reduce by 0.3% by 2030, relative to 2005 levels.

4 Please note that bar sizes between the Sankeys are not to scale (refer to the numbers indicated in the text).

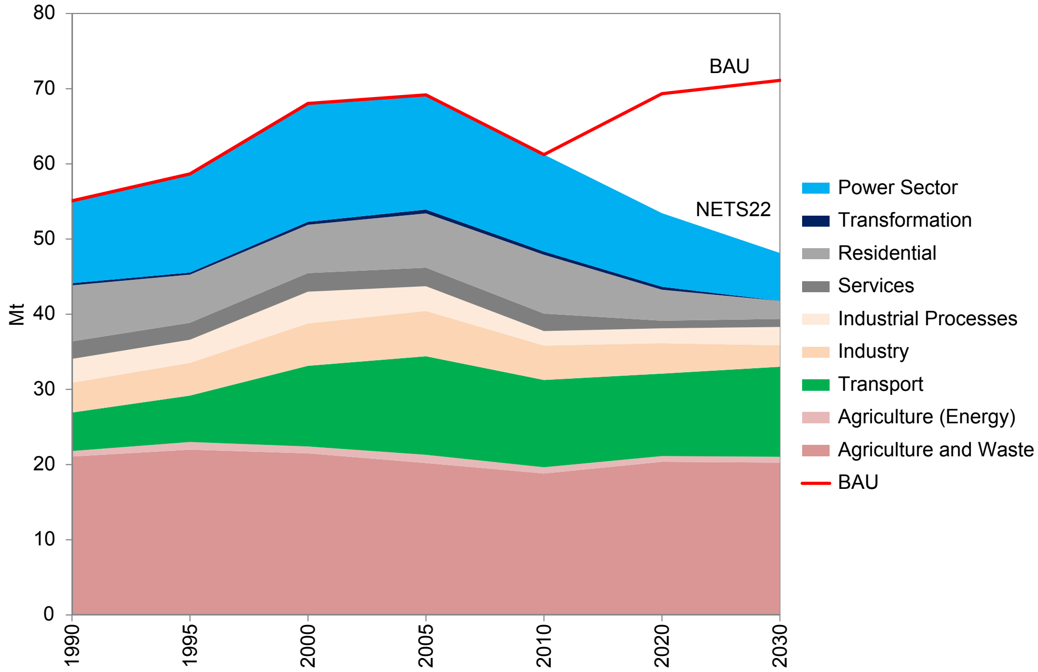

Figure 3.1. GHG emissions 1990–2030 for BAU and NETS22.

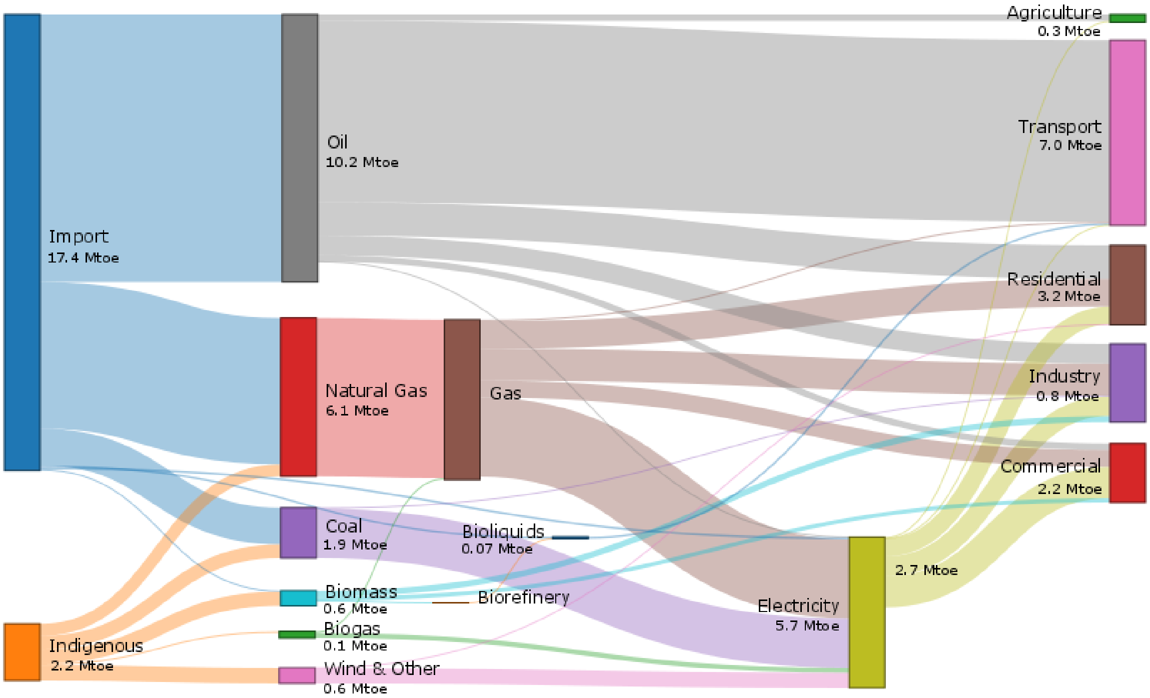

Figure 3.2. Sankey diagram 2030 for energy system under BAU scenario.

substantially relies on oil and gas with a small share of renewables. The NETS22 scenario is represented in Figure 3.3, which shows a drop in reliance on oil (–39% compared with BAU), whereas bioenergy expands (from 711 ktoe to 1602 ktoe). Liquid biofuels are mostly used in transport, and biomass in industry. There is a significant expansion in wind energy (almost 5 GW installed), which replaces coal. The residential sector shows a marked increase in electrification of heating systems, i.e. heat pumps.

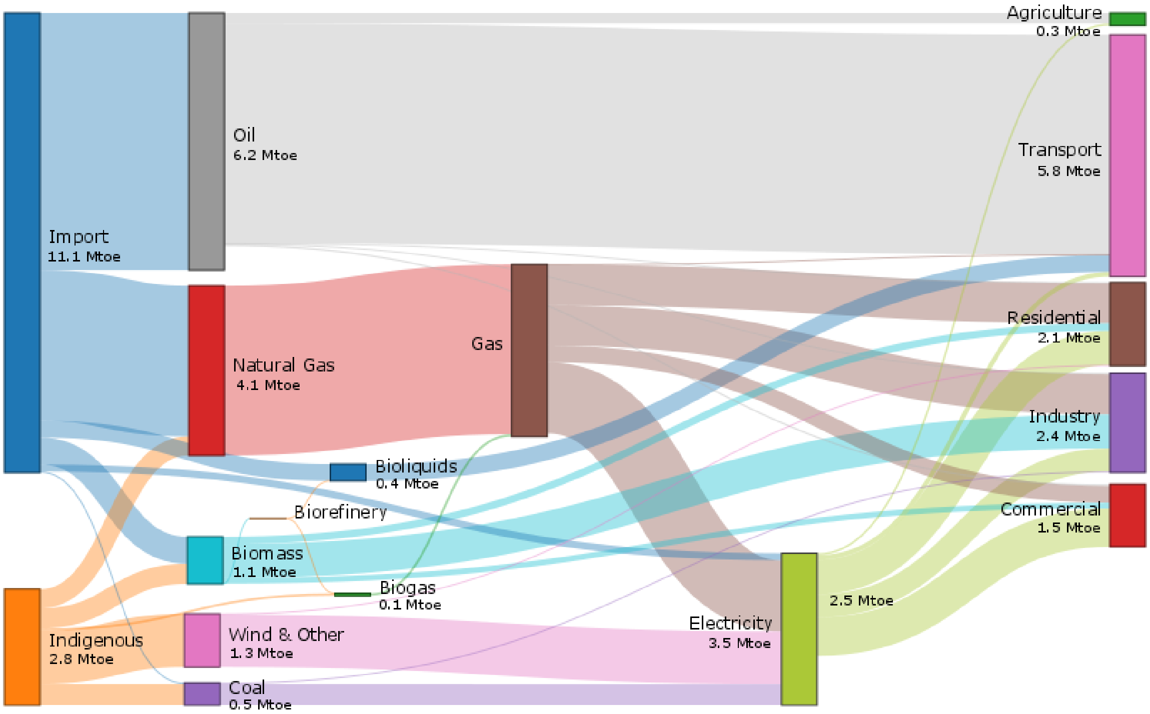

Figure 3.3. Sankey diagram 2030 for energy system under NETS22 reduction scenario.

3.1.3 Renewable energy

This section details the sectoral results for renewable energy from the analysis of the optimal energy system cost for the BAU scenario and the NETS22 reduction scenario. The results in Figure 3.4 show a strong correlation between renewables development and the emissions reduction targets. The projected BAU scenario suggests a growth in renewable energy in line with current trends, delivering approximately 8% of gross final consumption of energy (GFC) in 2030. The NETS22 scenario shows a renewable energy expansion, which will triple by 2030. There is a significant expansion of wind energy which displaces coal and some natural gas in the generation mix. Liquid biofuels (mostly ethanol) increase 4.5 times compared with 2010, with significant growth of biomass in industry [from 7% to 35% of total final consumption (TFC)] and in buildings (from 1.4% to 10%).

3.1.4 Energy efficiency

Energy savings are quantified in the model as a reduction in final energy consumption compared with the BAU scenario (Figure 3.5). The BAU scenario does not assume any technology improvements over the time horizon to 2030 and it is therefore a counterfactual against which the other scenarios can be compared. The BAU scenario in 2030 shows that the total final consumption of energy is 14,168 ktoe. This is an increase of approximately 28% on 2010 levels. In the NETS22 scenario, total final energy consumption drops to 10,623 ktoe. The sector with the greatest reduction in energy consumption (compared with the BAU scenario) in absolute terms is the built environment (residential and services) sector with a reduction of 34% in the residential sector and 32% in the services sector, followed by the transport sector, which shows a reduction of 22%.[5]

The energy intensity for residential buildings in NETS22 scenario is forecast to reduce dramatically from 21.6 MWh/year per dwelling in 2010 to 11.8 MWh/year per dwelling in 2030. This is largely driven by investments in heating systems, which replace oil- and coal-fuelled systems with high-efficiency heat pumps and biomass boilers, and by retrofit measures on buildings. In the transport sector, energy intensity also reduces; however, this reduction is mostly driven by the introduction of more efficient vehicles in the market, instead of fuel switching. Specific energy consumption of cars is forecast to reduce by almost 30% in the period 2010–2030, while trucks will reduce their energy intensity by about 15%. Electric vehicles are forecast to have

5 Note that figures quoted for final consumption do not include international aviation.

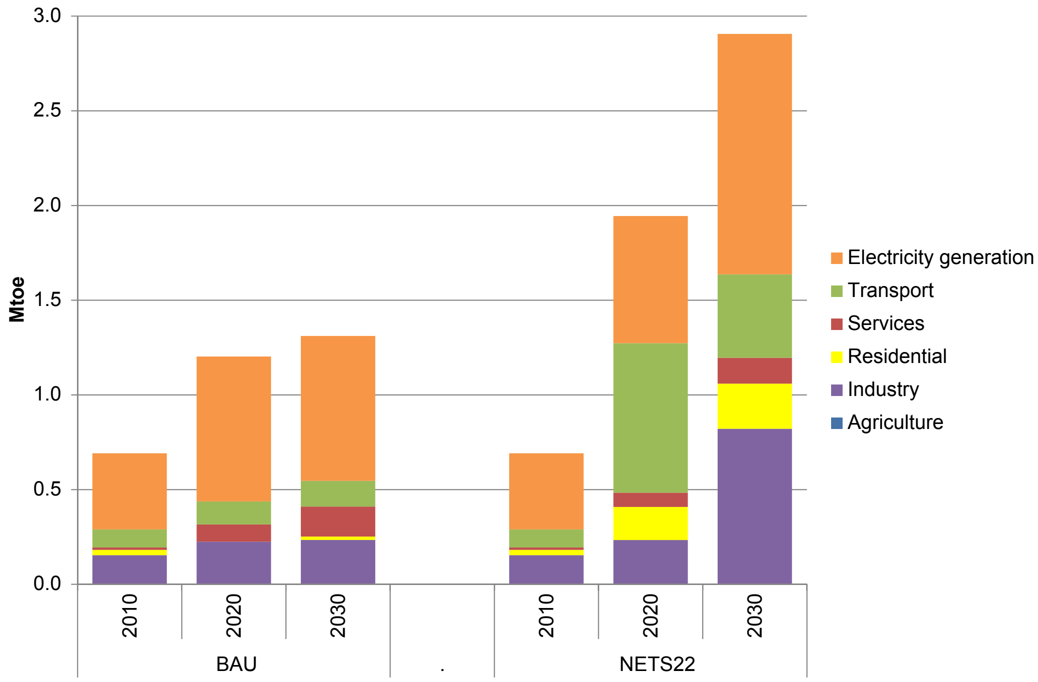

Figure 3.4. Renewable energy by sector for BAU and NETS22 scenario (Mtoe).

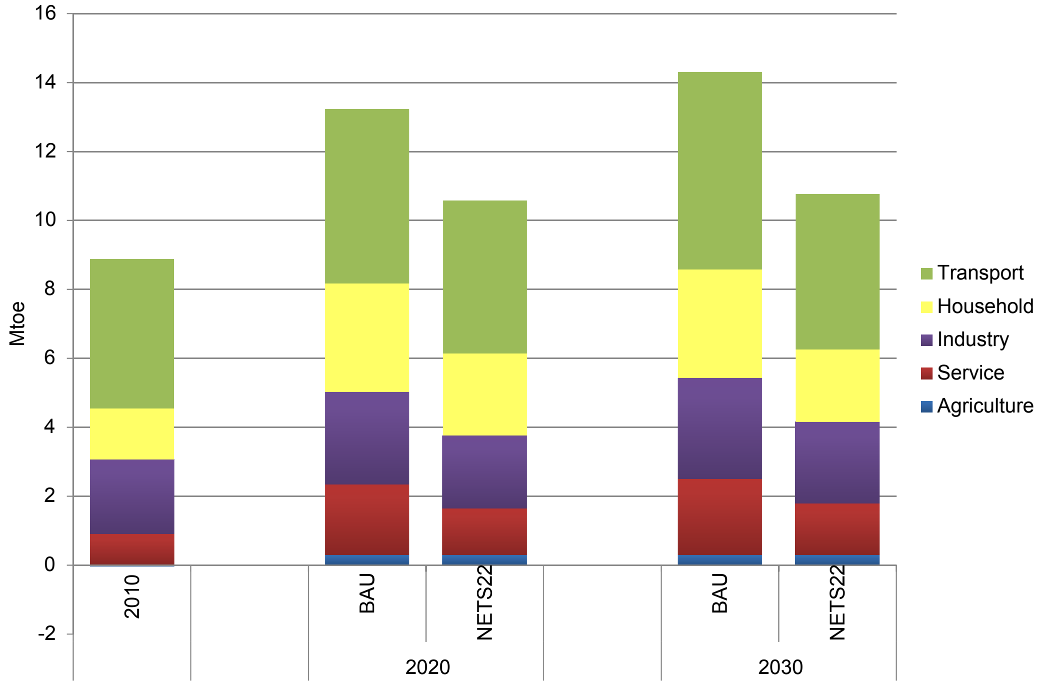

Figure 3.5. Final energy consumption by sector for BAU and NETS22 scenario (Mtoe).

a limited role in delivering the NETS22 targets, accounting for only 5% of the private transport consumption in 2030.

3.1.5 *Fossil fuels*

The projected primary energy consumption in the BAU scenario suggests future trends very similar to the current situation, i.e. fossil fuels in 2030 will constitute about 93% of total primary energy consumption (TPER), in line with the current 91.4% (Howley *et al*., 2014). Oil will constitute 52% of TPER (47% in 2013), while natural gas will grow to about 31% (29% in 2013). As CO_2 constraints are applied to the energy system, fossil fuels will still have an important role; their share in terms of TPER, however, will reduce to 79%. In 2030, oil will still be the predominant fuel in the energy system (45% of TPER by 2030), particularly in the transport sector, where it represents 88% of domestic transport consumption. Coal and peat face a decline in their usage for heating and electricity production, while natural gas will still play an important role across a number of sectors' energy systems, showing stable consumption levels on the whole horizon. A summary of the key TPER patterns is shown in Table 3.1.

3.2 GAINS Ireland Estimates of Air Pollutant Emission Changes

The Irish TIMES BAU scenario is not designed to match official national inventories and forecasts, and, as such, the focus in this analysis is on the proportional differences that result from moving from the BAU scenario in 2030 to the NETS22 scenario in 2030. The Irish TIMES data for both the BAU 2030 and NETS22 2030 scenarios were adapted into the GAINS Ireland model, and

Table 3.1. Total primary energy consumption shares by fuel for BAU and NETS22 scenarios

Fuel	2010	2020		2030	
		BAU	NETS22	BAU	NETS22
Fossil fuels/TPER	95.5%	93.5%	86.7%	93.3%	79.0%
% Coal	13.4%	12.2%	9.2%	9.8%	3.9%
% Gas	31.0%	29.6%	31.3%	31.1%	29.8%
% Oil	51.0%	51.7%	46.3%	52.4%	45.2%
Renewables/TPER	4.5%	6.5%	13.3%	6.7%	21.0%

an analysis was conducted to examine the outcomes of that climate optimisation in terms of proportional changes in air pollutants. It is therefore important to remember that the baseline BAU scenario from Irish TIMES does not correspond directly to the official national inventory and forecast; consequently, direct comparisons should not be made with the outcomes of a strategy to meet the NETS22 reduction target of 22% in 2030 based on the official national "with measures" forecast for 2030. Table 3.2 presents the GAINS Ireland results for the proportional changes between BAU and NETS22 emissions in 2030.

The results show favourable outcomes for emissions of NO_x (nitrogen oxides) and SO_2 (sulphur dioxide), with decreases of 27% and 60% achieved. These are a result of the adjustments envisaged by Irish TIMES, which are described in section 3.1. The results of volatile organic compound (VOC) emissions show a less favourable outcome, with a 15% increase in emissions identified as the result of the move from BAU to NETS22. However, $PM_{2.5}$ emissions resulted in the most significant outcome, with an increase of 61% between the BAU scenario and the NETS22 optimisation of Irish TIMES.

To offer further details on these changes, the adjustments in emissions have been divided into sectors in Figure 3.6. In this figure, the bar for a given pollutant represents the total change in emissions, as detailed in Table 3.2 (e.g. for NO_x this is a 27% reduction) and the coloured sections indicate how much of a share of

Table 3.2. Proportional changes in air pollutant emissions from BAU to NETS22

Proportional changes in air pollutant emissions – BAU to NETS22	
NO_x	27% decrease
SO_2	60% decrease
VOC	15% increase
$PM_{2.5}$	61% increase

the total change can be attributed to each sector. Upon examinaton of Figure 3.6, it becomes clear that for NO_x, power and heating plants, road transport, domestic, non-road mobile and industrial combustion (ranked from large to small) all contribute comparably to the reduction of NO_x. Such a uniform contribution to emission changes is not the case for the other pollutants. In the case of $PM_{2.5}$, industrial combustion is responsible for the bulk of the increase in emissions, whereas the domestic sector contributes to the balance and the other sectors offer modest reductions. Examining the underlying data more closely shows that the driver of the $PM_{2.5}$ changes is the significant increase in biomass in the industrial (from 192.2 ktoe to 782.4 ktoe) and residential sectors (from 0 ktoe to 221.7 ktoe), as envisaged in the TIMES NETS22 scenario. Moving on to SO_2, an examination of the underlying data indicates that these changes for industrial combustion also explain 58.5% of the reduction in SO_2. Specifically the main adjustment sees heavy fuel oil use being largely displaced

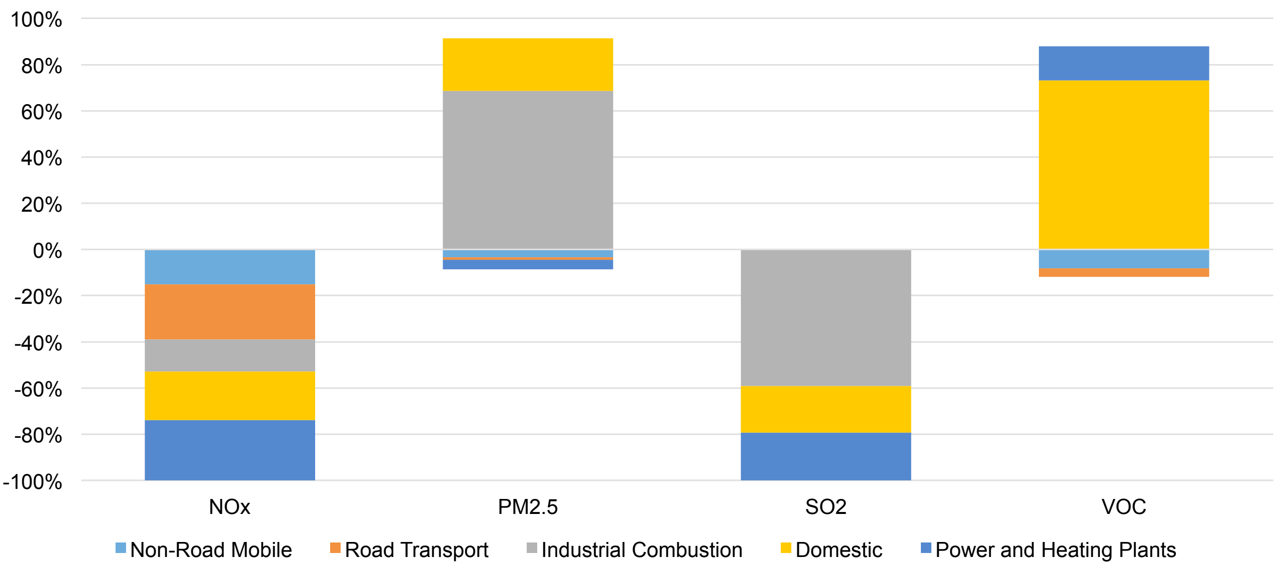

Figure 3.6. Sectoral attribution of the air pollutant emission changes between BAU and NETS22 scenarios.

in Ireland, with increased biomass combustion coming in as one of the major changes across the industrial sector. The power and domestic sectors each account for 20% of the shares of the overall SO_2 reduction. In the case of power, this is largely due to a reduction in gas use in the sector, and the elimination of hard coal, with a doubling of energy from on-shore wind. Finally, with regard to VOCs, the bulk of the increase is attributable to the domestic sector, where there are some large reductions in oil use and more moderate changes in gas use in favour of electricity and biomass.

3.3 EnvEcon Analysis of Marginal Damage Impacts of Air Pollutants

In order to estimate the marginal damage value of the changes in the air pollutant emissions that occur between the Irish TIMES BAU and Irish TIMES NETS22 scenarios, the EnvEcon team has utilised its recently completed research on marginal damage value estimations for Ireland (EnvEcon, 2015). The underlying methodology for the development of these estimations broadly includes:

- estimating a baseline level of spatially allocated air pollutant emissions and concentrations across Ireland;
- determining the presence and sensitivity of receptors (e.g. environment/people) affected by air pollution;
- estimating the health and environmental damage associated with air pollution exposure;
- calculating the corresponding value of this health and environmental damage;
- estimating the association between emission changes and pollutant concentrations across Ireland;
- calculating the marginal changes in damage and values associated with changes in pollution concentrations.

Extended details on the methodology and results are available in EnvEcon, 2015.

An important thing to note in relation to the values presented in this policy report is that the marginal damage value estimation work in this study utilised the national scale approach for changes in air pollutant emissions. In other words, the emission changes were not analysed as specific localised changes within specific towns and localities across Ireland. This is simply because the scenario outputs from Irish TIMES focus on the national energy system, as opposed to being spatially resolved to individual locations. It is noted, however, that, with additional research to allocate detailed changes spatially, the changes in air pollutant emission concentrations and impacts could be refined. It is expected that such detailed analysis would deliver higher impact values given that the major changes that occur are for key pollutants such as $PM_{2.5}$, and apply within important sectors for health impacts such as residential/commercial and transport. Changes in this pollutant and within these sectors will generally result in larger adjustments in human health impacts, given the major role played by PM in that context, and the more common proximity of transport and residential/commercial activities to areas of higher population.

The results in Table 3.3 indicate that there is an overall additional benefit of €20 million arising from reduced health and environmental impacts generated in 2030 under NETS22, compared with the BAU scenario. While this is encouraging, the dramatic increase in $PM_{2.5}$ emissions is a cause for concern on two fronts. First, a substantial negative cost is associated with this particular emission change, and the damage that would be caused comprises almost entirely negative health outcomes for Irish citizens. Second, while the net position of the NETS22 optimisation would result in a benefit, the increase in $PM_{2.5}$ emissions, as envisaged under the NETS22 optimisation, would also be expected to result in a breach of the anticipated national emissions ceiling for $PM_{2.5}$ in 2030, bringing the risk of substantial financial penalties from the European Court of Justice (Kelly, 2014). This may also have corresponding negative impacts in relation to ambient air quality limits in specific locations across Ireland.

Furthermore, while the BAU to NETS22 optimisation delivers a net additional benefit of approximately €20

Table 3.3. Difference in air pollutant health and environmental costs from BAU to NETS22

Changes in health and environmental costs – BAU to NETS22	
NO_x	€15 m benefit per annum in 2030
SO_2	€50 m benefit per annum in 2030
VOC	€6 m cost per annum in 2030
$PM_{2.5}$	€39 m cost per annum in 2030
Total	€20 m net benefit per annum in 2030

million per annum from 2030 in air pollutant impacts, a similar analysis by EnvEcon between the official national “with measures” scenario and the “with additional measures” scenario delivers a net additional benefit of some €33 million per annum due to a more balanced approach across climate and air considerations, which would not result in such a significant increase in particulate emissions. It should also be remembered that even this most recent “with additional measures” scenario is not expected to meet the NETS reduction target for Ireland in 2030.

The results confirm that policymaking in Ireland must maintain a broad perspective when analysing and addressing policy challenges. The results show that a climate and air pollution policy can present both significant synergies and trade-offs. Good policy must therefore consider a path that can simultaneously navigate a successful course on both tracks. National modelling capacities, such as Irish TIMES and GAINS Ireland, can help to meet this challenge and can further evolve to incorporate even broader thematic and societal concerns to provide better, broader decision support.

4 Conclusions

Both technical and policy outcomes have resulted from this collaborative research piece. On a technical level, this work has demonstrated how two of the major national modelling capacities in Ireland can engage to enhance the overall depth and scope of decision support for Irish policymakers. While there is no easy automated solution for linking the Irish TIMES model with GAINS Ireland, the teams have shown that a soft-link is possible. This allows the energy-focused optimisations of Irish TIMES to be analysed under the climate- and air-focused methodology of the GAINS model. This enables assessments of what such climate optimisations imply for legally binding air pollutant targets for Ireland, and it further allows the estimation of air pollutant-related impact costs by EnvEcon using their marginal damage valuation methodology (EnvEcon, 2015).

It is also useful, for the future, to have experience of reconciling the energy pathway recommendations from the Irish TIMES model with the GAINS Ireland modelling system. This technique will allow those pathways to be assessed in the familiar GAINS format by the European Commission or other international policymaking bodies during the negotiation and review processes for international climate and air policy.

In terms of policy outcomes, the scenario analysis is particularly useful, as it highlights some of the wider policy inter-linkages and "real world" policy and legislative constraints that may not have been emphasised by more narrowly focused assessments. The research has shown that the aggressive changes in the NETS22 optimisation deliver GHG reductions and can also result in substantial reductions (60%) in SO_2 emissions, with lesser reductions (27%) for NO_x. However, the welcome progress in those areas must be weighed against the undesirable outcomes with regard to $PM_{2.5}$ and VOC emissions. VOC emissions increase somewhat (15%), but the major challenge, as anticipated, relates to particulate emissions. The increase in $PM_{2.5}$ emissions, as a result of the move from the BAU scenario to the NETS22 optimisation, is 61%. This increase is driven largely by changes (principally increased biomass use) in the areas of residential and commercial/industrial combustion.

European legislation is now expected to require Ireland to reduce emissions of $PM_{2.5}$ and VOC by 41% and 32%, respectively, in 2030, relative to 2005 levels. Thus, the NETS22 optimisation is not compatible with these goals as currently formulated. That said, the authors acknowledge that the study has taken a conservative approach to the application of abatement control technologies over the additional biomass use at this point, and indeed the authors also recognise that there are higher cost options to limit the emission changes through the use of specific technologies, good practice enforcement and so forth. Therefore, a clear recommendation from this work is to undertake further research to specifically assess the practicality of any increased biomass use in these sectors in Ireland, consistent with appropriate policies and technologies, in order to avoid a breach of our legal obligations with regards to air pollutant emissions under the National Emission Ceilings Directive. Related to this, research should formally assess the directly corresponding health and environmental impacts that could otherwise occur due to associated increases in the levels of air pollutants across the country.

This analysis has identified some specific areas that would merit greater attention as policy options are reviewed in the light of national climate and air emission obligations to 2030 and beyond. The results highlight the importance of integrated policy analysis, or, in other words, taking a broader perspective with national decision-making that considers a policy change from multiple angles such as air, climate, economy, health and so forth. Adopting a narrow focus when "solving" one problem may well create other challenges in terms of costs and compliance, as has been demonstrated in this research. In GAINS and TIMES, Ireland possesses a modelling infrastructure that can usefully inform the negotiation and direction of national policy. Supplementing this modelling with tailored policy research will help to identify practical means of delivering better policy decisions for Ireland in the future.

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Abbreviations

BAU	Business as usual
EFOM	Energy Flow Optimisation Model
EPA	Environmental Protection Agency
ETSAP	Energy Technology Systems Analysis Programme
GAINS	Greenhouse Gas Air Pollution Interaction and Synergies
GFC	Gross final consumption of energy
GHG	Greenhouse gas
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IMP	Integrated Modelling Project Ireland
Ktoe	Kilotonne of oil equivalent
MARKAL	Market Allocation
Mtoe	Million tonne of oil equivalent
NETS	Non-emissions trading sector
NO_x	Nitrogen oxides
PET	Pan European TIMES
PM	Particulate matter
SEAI	Sustainable Energy Authority of Ireland
SO_2	Sulphur dioxide
TFC	Total final consumption
TIMES	The Integrated MARKAL-EFOM System
TPER	Total primary energy consumption
UCC	University College Cork
VOC	Volatile organic compound

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- An Oifig um Cosaint Raideolaíoch
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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Climate and Air Policy in Ireland: Synergies and Tensions – A GAINS Ireland and Irish TIMES analysis

Authors: Andrew Kelly, Alessandro Chiodi, Miao Fu, Paul Deane and Brian P. Ó Gallachóir

epaResearch
Climate - Water - Sustainability
Identifying pressures • Informing policy • Developing solutions

Identifying Pressures

Many measures to combat climate change may also have knock-on impacts on air quality. This collaborative research broadens the horizons of national climate and energy research to consider links to air quality and the associated health and environmental impacts.

Informing Policy

The broadened perspective on pressures and outcomes can inform the design of better, coherent policy. The research quantifies outcomes that would otherwise not be captured if the focus was exclusively on greenhouse gas emissions. This allows decision makers to consider multiple challenges simultaneously and to set a strategic path that simultaneously addresses climate and air quality concerns.

Developing Solutions

The research highlights specific issues in respect of increasing share of diesel vehicles in the national fleet, and the growth of biomass combustion in the residential and industrial sectors. Identification of these issues will inform the design of policy and regulation, and investment in alternative or additional technologies, to avoid or reduce negative impacts.

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