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epa Research
Climate - Water - Sustainability
Identifying pressures • Informing policy • Developing solutions

Integrated Modelling Project Ireland

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Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
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ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

Regulation: *We implement effective regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.*

Knowledge: *We provide high quality, targeted and timely environmental data, information and assessment to inform decision making at all levels.*

Advocacy: *We work with others to advocate for a clean, productive and well protected environment and for sustainable environmental behaviour.*

Our Responsibilities

Licensing

We regulate the following activities so that they do not endanger human health or harm the environment:

- waste facilities *(e.g. landfills, incinerators, waste transfer stations)*;
- large scale industrial activities (*e.g. pharmaceutical, cement manufacturing, power plants)*;
- intensive agriculture *(e.g. pigs, poultry)*;
- the contained use and controlled release of Genetically Modified Organisms *(GMOs)*;
- sources of ionising radiation *(e.g. x-ray and radiotherapy equipment, industrial sources)*;
- large petrol storage facilities;
- waste water discharges;
- dumping at sea activities.

National Environmental Enforcement

- Conducting an annual programme of audits and inspections of EPA licensed facilities.
- Overseeing local authorities' environmental protection responsibilities.
- Supervising the supply of drinking water by public water suppliers.
- Working with local authorities and other agencies to tackle environmental crime by co-ordinating a national enforcement network, targeting offenders and overseeing remediation.
- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
- Prosecuting those who flout environmental law and damage the environment.

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- Monitoring and reporting on the quality of rivers, lakes, transitional and coastal waters of Ireland and groundwaters; measuring water levels and river flows.
- National coordination and oversight of the Water Framework Directive.
- Monitoring and reporting on Bathing Water Quality.

Monitoring, Analysing and Reporting on the Environment

- Monitoring air quality and implementing the EU Clean Air for Europe (CAFÉ) Directive.
- Independent reporting to inform decision making by national and local government *(e.g. periodic reporting on the State of Ireland's Environment and Indicator Reports)*.

Regulating Ireland's Greenhouse Gas Emissions

- Preparing Ireland's greenhouse gas inventories and projections.
- Implementing the Emissions Trading Directive, for over 100 of the largest producers of carbon dioxide in Ireland.

Environmental Research and Development

- Funding environmental research to identify pressures, inform policy and provide solutions in the areas of climate, water and sustainability.

Strategic Environmental Assessment

- Assessing the impact of proposed plans and programmes on the Irish environment *(e.g. major development plans)*.

Radiological Protection

- Monitoring radiation levels, assessing exposure of people in Ireland to ionising radiation.
- Assisting in developing national plans for emergencies arising from nuclear accidents.
- Monitoring developments abroad relating to nuclear installations and radiological safety.
- Providing, or overseeing the provision of, specialist radiation protection services.

Guidance, Accessible Information and Education

- Providing advice and guidance to industry and the public on environmental and radiological protection topics.
- Providing timely and easily accessible environmental information to encourage public participation in environmental decision-making *(e.g. My Local Environment, Radon Maps)*.
- Advising Government on matters relating to radiological safety and emergency response.
- Developing a National Hazardous Waste Management Plan to prevent and manage hazardous waste.

Awareness Raising and Behavioural Change

- Generating greater environmental awareness and influencing positive behavioural change by supporting businesses, communities and householders to become more resource efficient.
- Promoting radon testing in homes and workplaces and encouraging remediation where necessary.

Management and structure of the EPA

The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:

- Office of Environmental Sustainability
- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet regularly to discuss issues of concern and provide advice to the Board.

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Integrated Modelling Project Ireland

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EPA Research Report

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Executive Summary

This was a medium scale research project that utilised and advanced national capacities in integrated air and climate modelling and policy analysis to respond to challenges in a number of important research areas for Ireland. The project was completed in December 2016 and was led by EnvEcon with University College Dublin as a partner. This research directly supported Irish engagement on international air and climate policy and offered a broad range of national policy option evaluations and briefs in the context of air and climate targets.

One key deliverable was the provision of robust national evidence generated from a nationally calibrated version of the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model in 2014, 2015 and 2016. This element of the research included a number of direct engagements with the European Commission (EC) and their contractors (International Institute for Applied Systems Analysis) in the development of the next stages of climate and air policy in Europe. Specifically, the research developed GAINS Ireland scenarios that informed the revision process of the Thematic Strategy on Air Pollution (TSAP), and the proposed GHG targets for the Effort Sharing Decision (ESD) out to 2030. This contribution was only possible thanks to the Environmental Protection Agency (EPA) and Department of the Environment, Community and Local Government's (DECLG) foresight and support of this specialised research capacity in Ireland.

In parallel, the research project saw four detailed and topical policy papers through to internationally peer reviewed publication under themes of residential- and transport-related policy options to reduce air and climate emissions in Ireland. These papers deal with solid fuel regulation in Ireland, spatially referenced transport emissions, electrification of residential home heating and transport policy with regards to school commuting. A number of specific policy briefs were also developed and formally released under this project. These included an evaluation of smoky coal regulation across Ireland, and a piece examining a selection of transport policy options in Ireland. The latter was enabled through use of TREMOVE Ireland and a new fleet modelling tool. A number of ad hoc research briefs were also provided directly to government in areas such as target analysis, compliance strategy, and data systems management. The team also participated in numerous climate- and air-policy-related meetings over the course of the project and regularly provided input and research support.

As part of the project, the team also collaborated with other established researchers in Ireland to broaden and strengthen the quality of each other's research outputs. A key initiative in this regard was to soft-link EnvEcon's GAINS Ireland model with University College Cork's IRISH TIMES model so as to explore the synergies and tensions between climate and air policy in Ireland. This work culminated in a policy report that illustrated the outcomes of a particular TIMES climate policy scenario with regard to air pollution and associated impacts.

A further substantial piece of new research under the project was to develop marginal damage cost values for air pollution in Ireland. The first stage of work entailed spatially disaggregating and mapping emissions across Ireland, spatial econometric research, assessment of monitoring station data, and the development of estimates of concentrations of pollutants across Ireland. The second stage assembled the evidence on environmental sensitivity and population to allow for exposure and impact assessments. The final work applied economic and health research methodologies to derive valuations for the marginal damage costs per tonne of air pollution at different levels in Ireland. The work was packaged into an accessible manual and paired with a detailed technical methodology report. The guide has been shared with stakeholders to support the inclusion of air pollution concerns in impact assessment studies for Irish policy and investment decisions. The work will also be formally submitted for consideration in the context of the official Public Spending Code.

All of these deliverables are detailed in this report. They underscore the value of GAINS Ireland and the associated research with regard to more effective national engagement with international policymakers and in supporting the design and deployment of sensible, effective solutions to air and climate policy challenges.

1 Introduction

The Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) Ireland modelling capacity utilised and advanced under this research project was developed to provide effective decision support in relation to complex climate- and air-related questions. As noted previously (Kelly, 2006, 2011, 2013), a major advantage of the GAINS Ireland system is that the model is a pivotal system at European and United Nations Economic Commission for Europe (UNECE) levels. Through these channels, the GAINS model informs and supports the ongoing development and management of climate and air policy across Europe. Pairing the nationally focused analytical capacity of GAINS Ireland with broader economic and environmental policy research has been a central goal of this project. The concept is that the overall research efforts will continue to support national policy and progress by informing critical international engagements and negotiations, by influencing the design of better policy for Ireland and by embedding new knowledge and technical capacity in an accessible manner within the Irish system.

This report is structured as follows. Chapter 2 provides an overview of the context for this work in terms of the role of integrated assessment modelling internationally and the climate and air policy challenges that exist for Ireland and provides a non-technical summary of the GAINS Ireland model. Chapter 3 provides details on the latest technical research for GAINS Ireland, as well as a summary of the current national capacity. Chapter 4 details the national and international engagements undertaken as part of the project, including specific details on selected research support provided to national policymakers and stakeholders. Chapter 5 details each of the main research outputs delivered under this project. Chapter 6 concludes with a concise discussion of the major research outcomes and findings, and from that point it offers recommendations for future research directions based on expected international developments and existing national capacities.

2 Context: Policy and Integrated Modelling

This chapter provides details of the thematic context for this climate and air policy research, followed by a simplified and non-technical summary of the structure, functions and interactions of the GAINS Ireland model. Details of the modelling system simply update a recent summary (Kelly, 2013), as many earlier reports (Kelly, 2006, 2011) and other linked publications and presentations have described the model in far greater detail.

2.1 Climate and Air Policy Context

From an Irish perspective, climate- and air-related regulation stems principally from national policy decisions, European legislation and United Nations (UN)-level agreements. Each of these legislative jurisdictions are intertwined and can influence one another. For example, European legislation can drive changes in national policy, and UN-level agreements and European legislation can, and do, influence one another. On a thematic level, climate change and air pollution are also linked. Climate emissions and air pollution have many common sources (e.g. cars, households and animals) and can influence each other's effect outcomes (e.g. short-lived climate pollutants can impact on both air pollution and climate change). These interconnections justify their assessment and management in an integrated fashion. Integrated policy design sees the interactions of interventions and can thereby be structured to simultaneously respond to challenges from multiple legislative constraints within multiple thematic areas. In this way, integrated analyses help to develop better, more broadly scoped policies that are more acceptable across the full spectrum of interests harboured by policymakers, stakeholders and the general public. Integrated policy design offers synergies in decision-making, and, importantly, it also helps to avoid undesirable and inefficient outcomes that may stem from more narrowly focused analyses. Establishing the capacity for such integrated analysis, and offering sustained research support for integrated policy development and application in Ireland, remains a core objective of the Integrated Modelling Project (IMP) Ireland research. The project delivers research across all sectors of the economy, from agriculture to transport, and addresses thematic concerns including climate, air, health, and environmental and economic outcomes. The main schemes, protocols and directives to which the IMP is of direct relevance are as follows:

- European Union Emissions Trading Scheme (EU ETS);
- European Effort Sharing Decision (ESD) or non-emmisions trading sector (NETS) targets;
- European Thematic Strategy on Air Pollution (TSAP);
- European National Emissions Ceiling Directive (2016/2284/EU) (NECD);
- UNECE Gothenburg Protocol.

Indirectly, the project is also relevant to a number of other air and climate actions, including national initiatives and policies, European ambient air quality standards, the Industrial Emissions Directive (2010/75/EU), fuel standards, vehicle standards and so forth. Details of the national and international engagements undertaken as part of this project, as well as the formal research outputs, are provided in Chapters 4 and 5.

2.2 GAINS Ireland and Integrated Assessment Modelling

The GAINS model is a techno-economic integrated assessment model that combines information on the sources, interactions and impacts of air pollutants and greenhouse gas (GHG) emissions. The model is equipped with parameters to consider a growing list of over one thousand measures for the control or reduction of emissions to air across all sectors of an economy and can be utilised in conjunction with a broad range of both complementary research studies and external analytical systems. The GAINS Ireland model is a mirror instance of the GAINS Europe model, which, inter alia, facilitates independent calibration and modification of the core European system for nationally focused negotiation, research and policy needs. The GAINS Ireland model has been described in detail in a number of earlier research reports by the IMP team and others (see, for example,

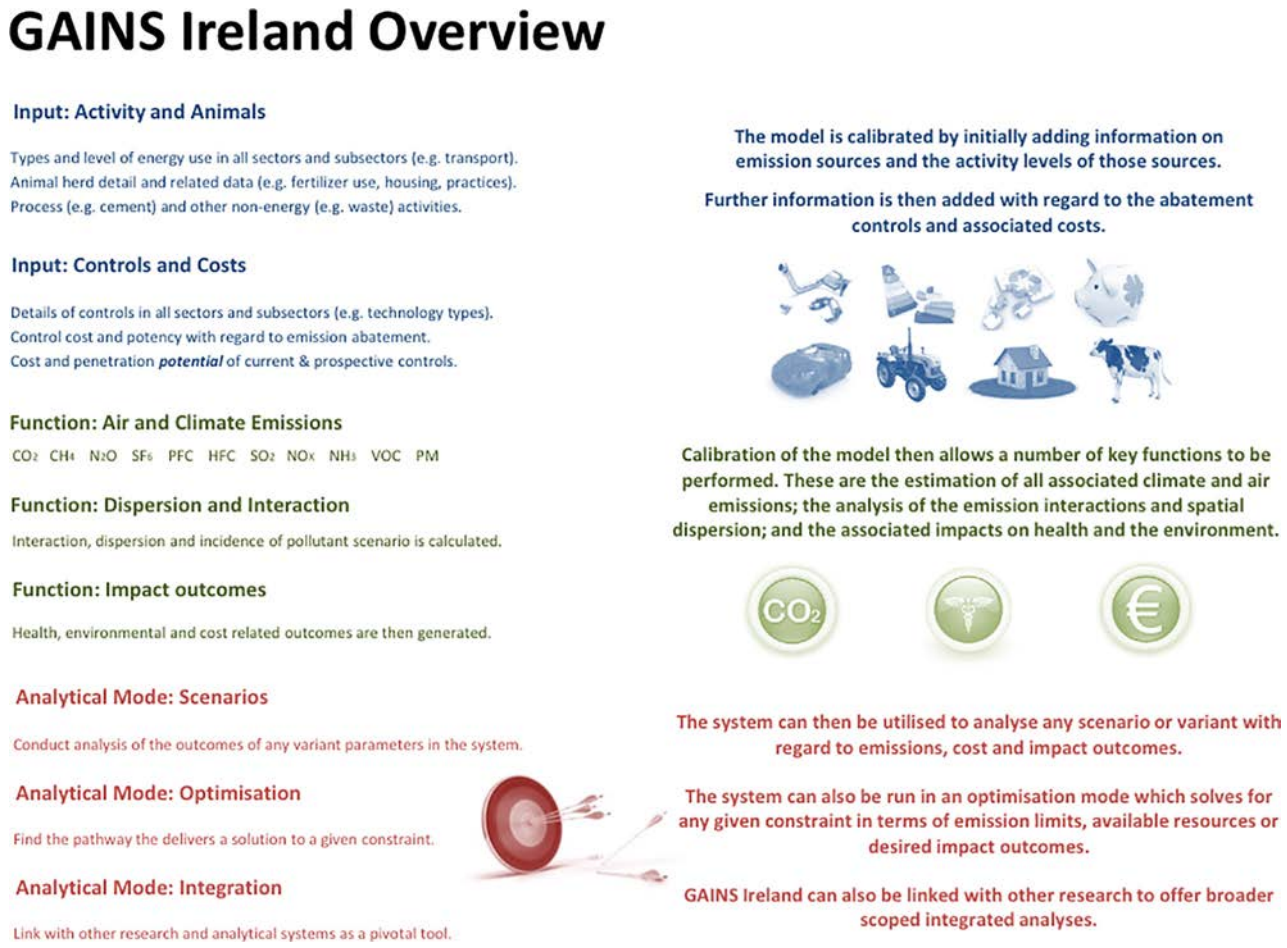

Figure 2.1. Schematic overview of the GAINS model.

Kelly, 2006, 2011, 2013; IMP Team, 2009a, 2010a,b,c; Amann *et al*., 2011a).[1]

In terms of components, the function of the model is based on four main elements. These are activities, controls, costs and effects. Figure 2.1 presents a simplified schematic of these components and how they interact within the modelling system. Once calibrated, the GAINS model can perform a number of functions, which offer an analyst a number of opportunities to evaluate scenario variations, to identify solutions to specified constraints such as an emissions target, or indeed to link this system to part of a broader integrated research effort with a view to offering rigorous broad perspective decision support and analysis.

1 Documentation developed in relation to the model can also be found at the project website www.impireland.ie, at the www.policymeasures.com resource, or through the EPA smart simple and SAFER data systems – see www.epa.ie. Broader literature relating to the GAINS Europe model is available from the International Institute for Applied Systems Analysis at www.iiasa.ac.at

3 Model-related Research and Development

This chapter of the report presents a summary update of the more technically focused research with regard to the GAINS Ireland model calibration, operation and management. Applications of the model are discussed in subsequent chapters of the report.

3.1 Air and Climate Scenarios 2014–2016

A crucial component of the work with the GAINS Ireland model involves research to ensure that the model is appropriately calibrated for Ireland on the basis of the best available national evidence and current scientific understandings at a given point in time. As data and science develop over time, this is a dynamic process requiring a dynamic response. The IMP approach is to ensure, for any given year, that the GAINS model is calibrated on the best available data and scientific knowledge at that time. As part of the project, air and climate scenarios for Ireland were populated, tested and finalised in 2014, 2015 and 2016. The core scenarios incorporate a forecast of national parameters out to 2030 (with scope to extend the time horizon further). In addition to these, a number of variants were developed and produced to inform specific elements of the overall research support. Variations include the standard “with measures” and “with additional measures” scenarios, varied fleet evolution developments, altered residential energy demand, and agricultural scenarios associated with the Food Harvest 2020 and Food Wise 2025 reports. The variants were developed by the team as part of the testing of alternative paths or in response to European Union (EU) scenario results.

The processes involved in scenario building have been described in detail in prior work (see for example IMP Team, 2008a, 2009a, 2010b,c,d) and remain broadly the same, although many specific approaches in this process have been tweaked over time to respond to new national data, revised reporting formats and other changes that can impact on the process. In brief and broad terms, GAINS Ireland scenario building involves the sourcing and processing of activity data from a range of official national sources such as the Environmental Protection Agency (EPA), Central Statistics Office (CSO), Sustainable Energy Authority of Ireland (SEAI) and Teagasc, as well as the review and updating of parameters without an official national data source (e.g. future technology penetration, fleet evolution, residential behaviour) on the basis of other in-house or external research or modelling (e.g. fleet forecasting, policy reviews). Emission factors, cost data and other core parameters of the model are also adjusted where there is adequate national evidence to support the revision. All data are then collated and transformed into an appropriate format and level of aggregation or detail, for integration into the GAINS Ireland model, and from there scenarios are run, tested and revised as necessary – see Figure 3.1. The scenarios developed have fed into the international negotiations on future air and climate targets, as well as ensuring that national analyses with GAINS Ireland can be based on data that are coherent with official national inventory and outlooks.

3.2 Model Management

As a part of the regular research to review the calibration of the GAINS Ireland model and its alignment to official national data, a reconciliation process was undertaken between the GAINS Ireland model and the official national inventory and forecasting data (Figure 3.2). This work went beyond the activity data (e.g. animal numbers and energy use) to consider, in the light of developing national evidence, differences relating to control strategy penetration rates, potential control strategies, aggregation variations, emission source differences (including missing sources) and changes to emission factors. Identifying, understanding and, where possible, addressing these differences ensures that the model is better prepared for incorporating new national activity on a year-to-year basis. Actions were taken within the modelling system as appropriate, and the principal observations and recommendations were then written up in a technical memo. This research also supports the identification of areas within the national inventory and forecasting work, which may be

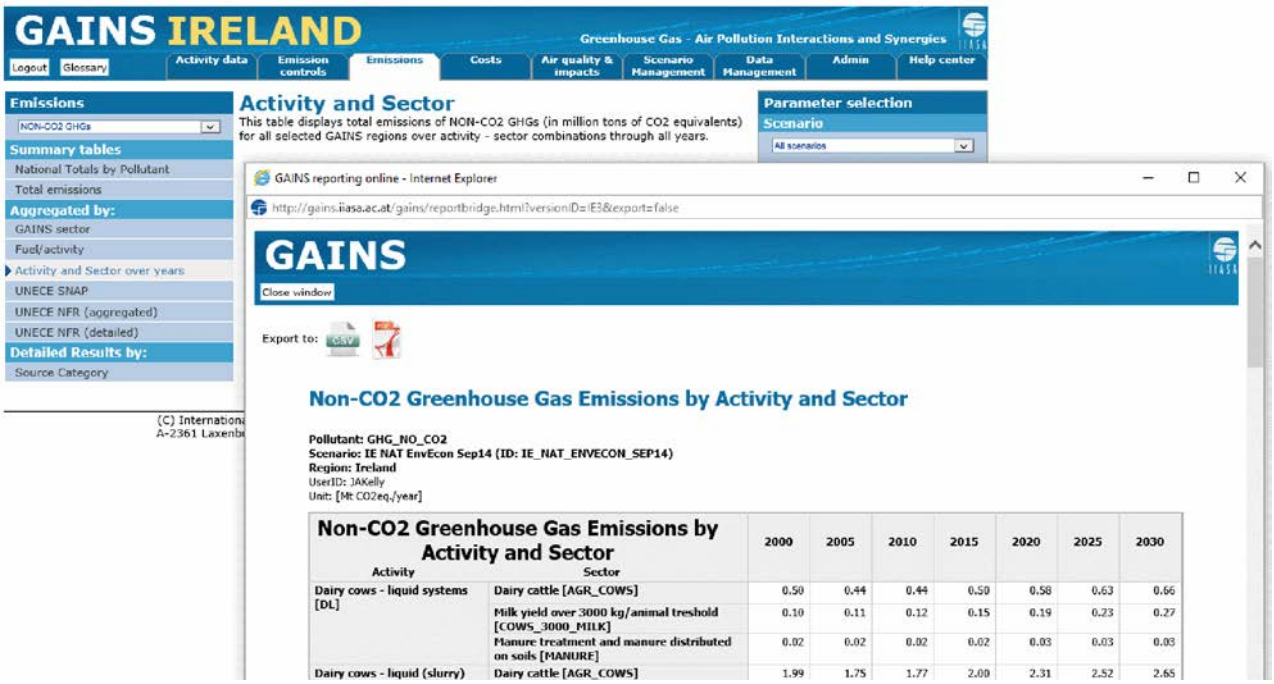

Figure 3.1. Screenshot of GAINS Ireland's website.

revised in the future. Selected summary points from this model management work included the following:

1. SO_2 is now very well aligned with the national data. A more rapid penetration of relevant technologies and fuel controls have now also been recognised out to 2030 in the model.
2. Nitrogen oxides (NO_X) emissions are generally well aligned with the national data, although some variations persist. In particular, in the transport sector, diesel consumption by heavy-duty and light-duty trucks differs from the national estimates. The reason for this is the consideration of gross vehicle weight (GAINS/COPERT/TREMOVE) in the model versus the use of unladen weight in national statistics when allocating fuels by vehicle class in GAINS. A brief was previously drafted on this topic.
3. With regard to the NO_X outlook, the vehicle fleet evolution has been updated in GAINS. The fleet outlook is informed by recent historical data, modelled trends using the TREMOVE Ireland model and research outputs from the new fleet model developed and applied under the project. These fleet changes, and some other minor adjustments, contribute to GAINS NO_X values (while using official national energy projections),

Figure 3.2. Cover of inventory/forecast reconciliation report.

being slightly higher than national estimates for historical years (~2 kt) and slightly lower in future years (~1 kt).

4. NH_3 emissions are well aligned historically; however, recent changes in the extension to 2030 and the recognition of Food Wise 2025 did lead to forecast differences. Leaving aside the difference in emissions from the increased activity data, analysis suggested an issue with reconciling national estimates of Food Wise 2025 emissions with GAINS Ireland "Food Wise 2025" emissions. These were found to relate to nitrogen excretion rates, which were remaining static into the future. The lesson was that the weighted average for these rates must be evaluated and applied to new scenarios and then recoded back into the GAINS emission vector. This requirement has been noted for future scenarios.
5. Volatile organic compound (VOC) emissions differ somewhat in GAINS and this is due to a number of source variations and gaps restricting a closer match. It is recommended that future national research focuses on developing a better understanding of national VOC emissions from the food and drink sector, as well as offering greater detail with regard to VOC from transport (road and non-road) sources to allow reconciliation.
6. Particulate matter with a diameter of 2.5 µm or less ($PM_{2.5}$) matches reasonably closely on aggregate now, but detail is still lacking in available national data to revise sources and emissions factors on a fine scale. Variations are strongly influenced by the residential sector, where increased focus is recommended with regard to residential combustion.

3.3 IMP Ireland Research – Capacity Overview as of 2016

The IMP Ireland research is now operated by a compact team of two. The team offers strong analytical expertise in economic and policy analysis, as well as operational expertise with a range of international models (e.g. GAINS, TREMOVE, COPERT and other systems) and methods (e.g. geographic information system spatial analysis, econometric techniques, cost–benefit, programming, policy research and analysis). The technical capacity to calibrate, operate and interrogate these models and to conduct tailored policy-relevant research is complemented by strong established relationships with the key data providers and policy actors in Ireland, as well as with the international modelling community and relevant key officials in the European Commission. This package affords Ireland a valuable resource that is capable of anticipating policy challenges, robustly responding to the international negotiation and compliance assessment processes, and providing timely and relevant research-led decision support to inform the national response to these dynamic challenges over time.

As part of the current project, the team has significantly advanced its capacities in relation to transport fleet modelling, spatial analysis of emissions and impact valuation. Each of these areas contribute to the availability of a research resource that can provide practical decision support across all sectors and multiple thematic concerns. The team has placed a strong focus on residential, transport and agricultural research, and it plans to divert increased resources to further applied policy research under these headings in the future.

4 National and International Engagements

The IMP team recognises the need for research to be communicated clearly in a targeted fashion so as to enhance the impact and awareness of the research within national and international circles. Over the duration of the project, the team engaged in a number of important international bilaterals, communicated the project research within international fora, collaborated with nationally based colleagues and provided research support across multiple government departments and technical groups. These activities are extremely important in terms of ensuring that the value of the research is realised by the science and policy communities. A summary of the main engagements is described under individual headings below.

4.1 European Commission and IIASA

The European Commission contracts the International Institute for Applied Systems Analysis (IIASA) to support its decision-making with regard to European air and climate policy development. IIASA utilises the GAINS Europe model to conduct the EU-wide modelling and analysis that underpins many of the proposals and decisions in this context. The intricate and iterative process of proposing, revising and agreeing major European legislation with regard to climate and air policy ran in parallel to the IMP research. Specifically, the Commission had been seeking to formally agree the NECD revisions to a time horizon of 2030, as well as the climate targets across Europe on that same timeline. The process has involved discussions across European institutions, as well as bilateral meetings with individual Member States. In the latter case, there is considerable effort to understand abatement potentials, abatement costs, future outlooks and impacts, and the GAINS model plays a central role in this process. In an Irish context, the IMP team provided research support to the European Commission bilateral meetings between Ireland and the EU with regard to the revision of the TSAP and the associated NECD, as well as with regard to the climate-focused proposals with regard to the NETS covered under the ESD. This work involved reviewing European scenarios and proposals, supporting national understanding of the model and outputs, developing alternative “national” scenarios and perspectives, and directly engaging in the bilaterals, as well as *ex ante* preparations and *ex post* responses.

4.2 UNECE Task Force on Integrated Assessment Modelling

Transboundary air pollution does not end at European borders. As such, there remains an important role for the UNECE in terms of co-ordinating collaborative research and wider international community agreements. One key group in this work is the UNECE Task Force on Integrated Assessment Modelling (TFIAM). The IMP team is heavily involved in the activities of this group, which generates and integrates research into the GAINS modelling system and the general UNECE-level policy discussions, so as to drive further improvements in international transboundary air quality. This work has underpinned the revision to the UNECE Gothenburg Protocol and thereby also continues to strongly inform (as a result of the overlapping personnel and purpose) European air pollution policy. The TFIAM group also considers the climate outcomes (in particular synergies/trade-offs) of air pollution policy, so as to promote the delivery of better and broader legislative decisions and policy responses. During the project, the team has participated in and presented at all of the TFIAM meetings (Helsinki, Edinburgh, Lisbon), as well as at other meetings of this international modelling community, to ensure regular exchange of national and international research in this arena.

4.3 National Partnerships and Collaborations

Over the course of the project, the team has continued its working relationship with many of the key data providers and researchers in the field of climate and air research within Ireland. This included engagements for the sharing of data, the review of indicators, commenting on research and the dissemination of the IMP research findings. The main groups involved in these working relationships were the EPA, CSO,

National Economic and Social Council (NESC), Teagasc, SEAI, Commission for Energy Regulation (CER), Single Electricity Market Operator (SEMO), Economic and Social Research Institute (ESRI), University College Dublin (UCD) and University College Cork (UCC). With regard to the last group, a joint research report was also completed with UCC, whereby a soft link was established between the Irish TIMES energy model and the GAINS Ireland system. This report is described in more detail in section 5.9.

The team also sought to engage more with industry and the business community, and to this end participated in and presented at Ibec-run events relating to environmental policy, and engaged with the Irish-led International Sustainability and Investment Centre and its series of events. The team also connected with Glen Dimplex as part of this research project to develop a policy paper focused on electrification of residential heating in Ireland. Glen Dimplex provided technical data and input to facilitate the development of the now published paper described in section 5.3.

With regard to sustained and passive outreach, the team implemented a strong dissemination strategy consisting of a professional website, internationally peer-reviewed papers published as open source, the design and release of a project infographic, the design and distribution (physical and electronic) of the marginal damage valuation guidebook, and multiple presentations to a variety of groups and events.

4.3.1 National climate policy – TRAM and the CCAC

As part of a concerted national response to climate change-related challenges, the government has established an interdepartmental technical group known as the Technical Research and Modelling Group (TRAM). This body covers a number of specialised strands of work and engages many government departments, agencies and a select number of national experts and modelling teams. The IMP is one such team and has engaged with the TRAM since its inception through regular participation in its meetings and the provision of technical modelling support and relevant policy and compliance research and commentary. The government has also established the Climate Change Advisory Council (CCAC) to offer guidance nationally in respect of climate policy and climate challenges. The IMP team has presented to and engaged and collaborated with members of the CCAC as part of the IMP research. Examples of research-based support to these groups include briefings on the compliance mechanisms and potential penalties of failure with regard to European air and climate legislation, assessments regarding the inclusion or otherwise of transport in the EU ETS, input with regard to the negotiation strategy in the light of the Food Wise 2025 outlook, and meetings and discussions on future policy research priorities and opportunities.

4.3.2 National air policy – TSAP and the NECD

Air pollution is a significant contributor to environmental damage and human health impacts across the globe. Within Ireland, estimates indicate that more than 700 premature deaths per annum are attributable to ambient air pollution (EnvEcon, 2015; WHO, 2015), as well as environmental damage and the associated challenges that air pollutant emissions bring with regard to compliance with international legislation [e.g. NECD and the ambient air quality directive (2008/50/EC)]. These considerations should see air pollution policy recognised as a high-ranking public policy issue. As part of the IMP research, the team sought to contribute to national air policy in four primary ways. First, the team provided support to the departments [principally the Department of the Environment, Community and Local Government (DECLG) and the Department of Agriculture, Food and the Marine (DAFM)] with regard to NECD/TSAP negotiations, which are underpinned by GAINS model analysis. As noted, this research involved tasks such as analysing EU scenarios, building Irish scenarios and assessing the impact of changes in the national inventory or forecasts. Second, the team generated research briefs and guidance documents to build awareness and understanding of the challenges associated with air pollution in Ireland. This included accessible and concise pieces such as policy snapshot briefs for each pollutant, which outlined the gap to target, and principal abatement measures, as well as a broader interdepartmental guide to help stakeholders understand the EU clean air package and associated developments. Third, the team developed research and capacities in Ireland to support a better policy response in the future. This research included work

such as the spatial analysis of emissions and sources in Ireland, the development of the marginal damage value guidebook for air pollutants (section 5.7) and the analysis of various scenarios relating to the proposed smoky coal ban in Ireland. Fourth, the team developed and released policy-relevant research that developed the knowledge base in Ireland regarding interventions that can support progress. Formal research outputs are detailed in Chapter 5.

5 Research Outputs

Under the project, four policy papers have been followed through to successful publication in *Energy Policy, Journal of Transport Geography* (two papers) and *Applied Geography*. A further two technical policy briefs have also been developed and released. The first of these deals with transport fleet evolution in Ireland, and the second offers an analysis with regard to smoky coal legislation in Ireland. In addition to these, a marginal damage cost guidebook has been produced based on a major research undertaking. This guidebook has been paired with a detailed technical report also developed under the research project, and both have been widely distributed to support analysts seeking to incorporate air pollution considerations into their decision-making process so as to develop better and more broadly scoped policies and investments. Many other additional ad hoc research memos and briefs were also generated under the project, and these are also briefly detailed below.

5.1 Paper Summary: Residential Solid Fuel Use

This paper was revised, finalised and published under the project. It offers a comprehensive analysis of the factors determining solid fuel use in the residential sector across Ireland (Figure 5.1). The paper identified the relevance of home heating fuels to both climate change and air pollution and marshalled multiple national datasets via an innovative spatial econometric approach as part of the analysis. The developed methodology has since been modified for application to other research questions requiring a blend of spatial and econometric analysis. The results of the paper included spatially referenced maps that identified the factors that influence solid fuel use in all the regions of Ireland. Important factors included the proximity to a natural resource (e.g. peat bogs), legislative restrictions (e.g. smoky coal ban areas) and proximity to relevant infrastructure (e.g. gas network). Further information regarding deprivation and building energy ratings was also incorporated into the analysis to assess fuel poverty risk. Together, this integrated spatial analysis offered results that gave a more in-depth understanding of the drivers of solid fuel use in Ireland, and it enabled the team to develop spatial assessments of the expected resistance to behavioural change across the country. These "resistance to change" maps were designed to identify areas where policy may require specific tailoring to the local circumstances and challenges. The overall objective was to inform the recommendation of area-appropriate interventions that could ultimately curtail residential solid fuel combustion, while limiting the risk of fuel poverty, and thereby to deliver on the potential health and environmental impacts that may be derived from shifting away from solid fuel use for residential heating in Ireland.

5.2 Paper Summary: School Transport

This paper was updated, finalised and published under the project. This research piece considered the relevance of primary school transport (Figure 5.2) to traffic congestion and associated emissions, and sought to understand the factors that contribute to such high levels of "private car drop-offs" (PCDOs) for primary school children. The paper then sought to identify case-specific policy interventions that could support desirable changes in behaviour. The data analysis identified 2 km as the "splitting line" above which students will rarely walk to school. The research then took a Dublin area with a very high level of PCDOs as a case study and explicitly identified the catchment and school combinations where specific interventions (e.g. walking school bus, actual school bus) could offer the greatest chance of success. The methodology developed was applied to the case study area in Dublin, but can be replicated to provide community guidance in other areas for planning school transport policy interventions that target reductions in PCDOs. In this manner, the research was geared towards developing methods by which the research community can support increasingly tailored, case-specific policy action.

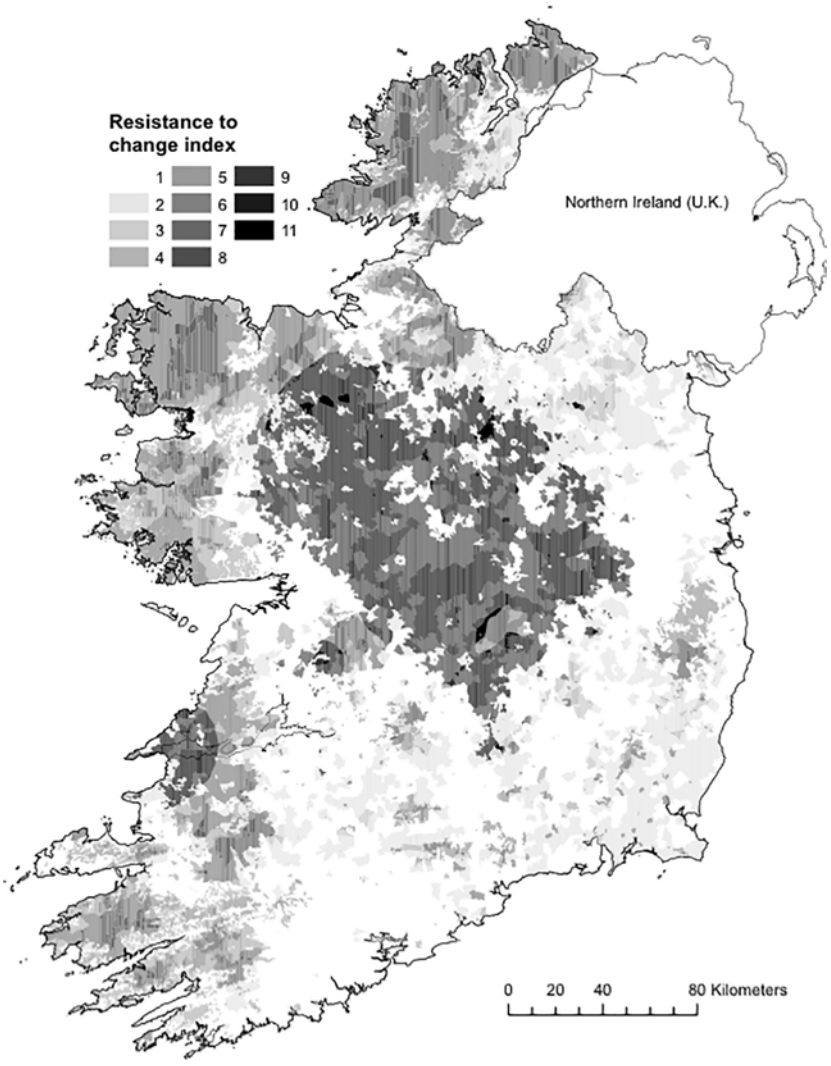

Figure 5.1. Resistance to change from solid fuel index.

5.3 Extended Paper Summary: Residential Heating Electrification

This policy paper was conceived, developed and published as open source in *Energy Policy* under the project. The concept for the work was to consider, specifically in the Irish market, the potential for air source heat pump (ASHP) technology to displace oil and solid fuel use for residential home heating. The residential sector in Ireland accounts for approximately 25% of primary energy demand with the 2011 census indicating that approximately 45% of primary home heating was fuelled by oil and 11% by solid fuels. Displacing oil and solid fuel usage with ASHP technology could offer household cost savings, reductions in emissions and reduced health impacts. The team collaborated with Glen Dimplex at the outset of this work in order to identify the current leading edge of performance for this technology, as well as to gather information regarding capital cost and feasibility in specific dwellings. It then turned its attention to an evaluation of the residential heating market in Ireland. Drawing on regional weather data and the extended Building Energy Rating (BER) dataset of the SEAI, the team estimated the energy demand and energy performance of buildings across Ireland. The analysis excluded apartments and homes that already had heat pump technologies, with the final sample exceeding 400,000 homes. The analysis was then scaled to the total stock of houses in Ireland using data from other sources (e.g. census data) in order to assess the full national potential for ASHP technology in Ireland. The outcomes include findings in relation to the economic costs, potential policy supports, anticipated air and climate emission changes and associated health and environmental impacts.

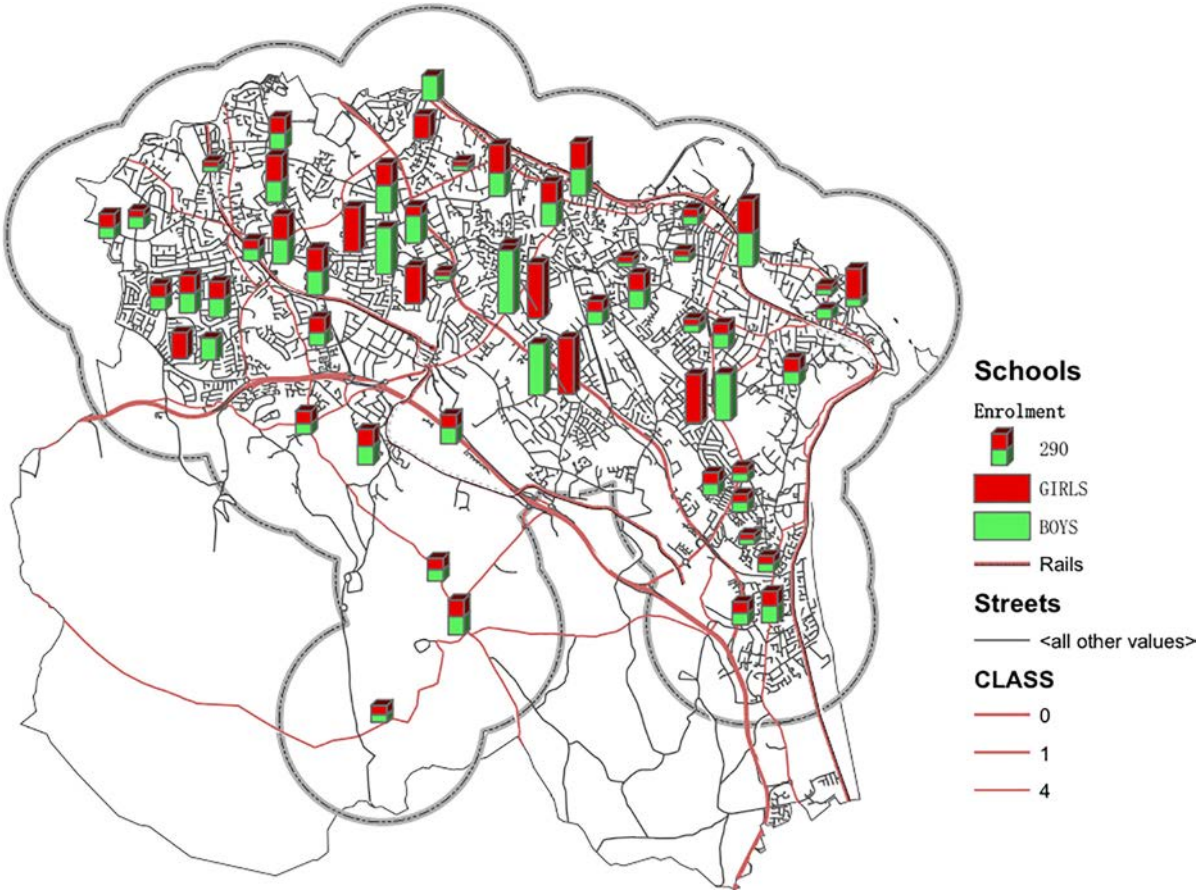

Figure 5.2. Distribution of primary schools.

Specifically, the results of this research indicate that for a large proportion of Irish households, representing almost all types of heating systems, there is an economic justification for moving to ASHP technology when considering the annualised capital and running costs of their existing home heating system. Indeed, the analysis suggests that for some 60% of the oil-fired heating system users in Ireland who invest in ASHP technology could reap substantial savings in the region of €600 per annum. A number of alternative scenarios were also evaluated to assess the influence of capital grants and a higher oil price on the potential market for ASHPs in Ireland. The results suggest that a lump sum capital grant of €2400 could increase the potential uptake of heat pumps by oil users by 17 percentage points, whereas a higher oil price, similar to oil prices in 2013, could increase the potential of switching by heating oil and LPG users by a further 24 percentage points. It is therefore clear that the oil-fired heating users represent a substantial and viable market that could be targeted by policymakers. However, although promoting ASHPs at a time of higher oil prices (or price expectations) and offering capital grants may stimulate a greater market response, the research findings note that there is already considerable potential for this market that has not yet been realised. Two of the other presumed major barriers are, first, an absence of clear information for households by which they can assess the potential merits of the change and, second, the provision of innovative financial products to support access to the initial capital necessary for the investment. This EPA-funded research has sought to support the resolution of the latter issues by enhancing the national evidence base.

From a public policy perspective, there are also important benefits to be captured from a growth in ASHP technology in Ireland. The evaluated scenarios show that up to 8 kt of $PM_{2.5}$ and 3.7 kt of NO_x could be abated if ASHP technology replaced all solid fuel and oil heating systems in the country, as well as reductions in CO_2 emissions of approximately 4.3 million tonnes per annum. The health and environmental benefits associated with this level of reductions in air pollutants alone are estimated to be in the region of €80 million and €125 million per annum

for the evaluated scenarios, and the contribution to national climate targets under the European ESD are significant. These estimated outcomes would push the internal rate of return of such investments to well in excess of the 5% test discount rate.

The paper also flags the importance of a targeted approach to grant aid. It is not advised to offer the grant to all users of a specific home heating system. Instead, we suggest targeting the grant system at homes where adequate savings are estimated (accounting for home size, location, building energy performance). This study allows such a determination to be readily made by policymakers.

In terms of future work, greater detail on residential insulation and actual energy consumption behaviour of the households would allow further refinement of this work. Similarly, detailed information about household fuel use and technologies would enable refinement of the air pollutant emission factors beyond the Tier 1 values utilised in this work. Future studies may combine this analysis with a residential insulation policy programme and householder behavioural analysis to refine the targeting of policy actions (e.g. deep retrofit) to those that would deliver improved returns in terms of saving households money and reducing the environmental and health impacts associated with the residential sector. Ultimately, the analysis clearly shows that ASHPs can play an important role in managing residential emissions and reducing household energy costs now and in the future in Ireland.

The full article is published with open access online: http://dx.doi.org/10.1016/j.enpol.2016.09.016

5.4 Extended Paper Summary: Estimating Annual Daily Traffic and Transport Emissions

This paper was conceived, developed and published under the project. The motivation for the paper was a recognition of the continued and growing significance of the transport sector in the context of environmental policy in Ireland and the added value that developing new capacity for spatially refined independent estimates of traffic data throughout the country would offer. Although Ireland does possess traffic count data on a number of major routes, this does not extend to every road in the network. The researchers understood that regular and robust collection of traffic data for the entire road network, in any given country, currently would require a high-cost investment in traffic surveys and automated traffic counters. This research developed a solution that provides an alternative and low-cost approach for estimating annual average daily traffic values (AADTs) and the associated spatially referenced transport emissions for all road segments, using Ireland as the case study (Figures 5.3 and 5.4). The methodology involved parsing and processing commonly available data and information from many existing resources. These included geographical data, census data, traffic count data and vehicle fleet data. All of these were then combined in a complex spatial analysis. All other things being equal, testing of the results confirmed that this new approach to annual average daily traffic estimation performs better than neural network and traditional regression models. The system can also be further refined to support the development of independent bottom-up transport-specific demand forecasting. This would be an extremely valuable addition to national analytical capacities in this context, as official transport activity forecasting for the official national energy forecast is at present handled via top-down macroeconomic modelling that delivers sectoral energy outcomes. Transport policy research and planning ideally requires sectoral-specific research that takes into account constraints and parameters that are often not well captured within such macroeconomic modelling.

This work can be further developed to provide independent road transport activity forecasting, high-resolution pollution concentration analysis, localised impact assessments, and transport-specific simulation modelling and analysis.

5.5 Policy Brief: Transport Fleet Modelling Ireland

Transport is a particularly important sector in the context of air, climate and general national policy. Within that frame, it was recognised that research and analysis to consider how the transport fleet may evolve over time, or in response to specific policy or behavioural changes, would be important as both stand-alone work and, indeed, as an advanced capacity to complement related research nationally. The team has an extensive background in transport research, in particular as part of the TREMOVE Ireland

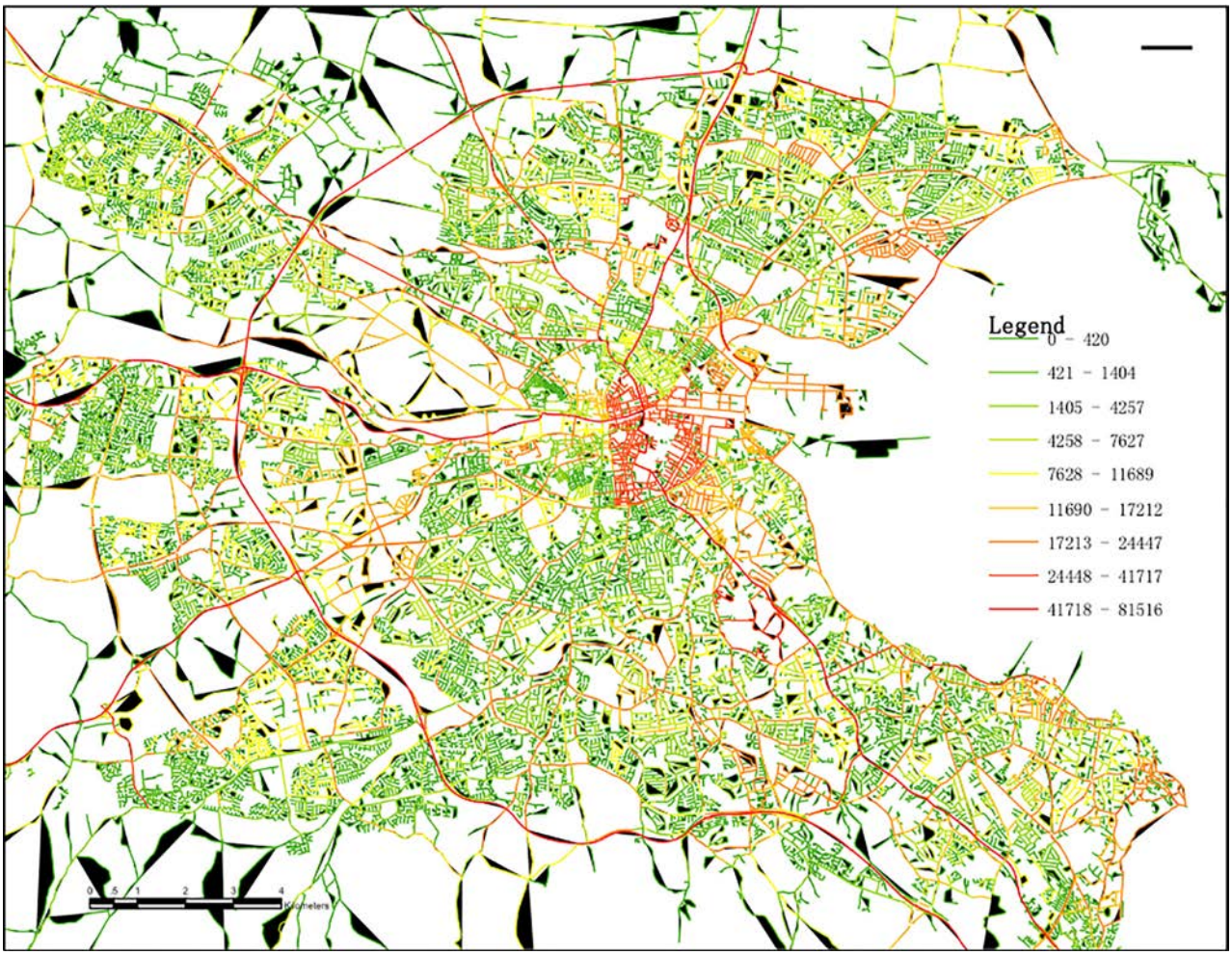

Figure 5.3. Estimated AADTs of roads in Dublin.

research, but in this case a new approach was taken to advance national capacities in this area. The approach combined modelling elements from TREMOVE, COPERT and a new fleet modelling system. The work draws from the latest fuel consumption and emission factors from the COPERT system, the transport demand forecasting capacities of TREMOVE Ireland, fleet analytics from the new modelling system and various associated baseline parameters (e.g. mileage, new technologies) and national data (e.g. car sales, fuel sales). Desk research by the team then provided insights on the potential impact of price or taxation changes on transport sector outcomes. As part of the IMP project, the objective was to strengthen analytical capacities in this regard and to then showcase the capacities within a transport policy brief developed for the TRAM group. A particular objective was to highlight the counterfactual assessment that is possible with regard to implemented policies. Summary outcomes of this research are described below.

5.5.1 Revision of all 120 km/h speed limits to 100 km/h nationally

A cumulative reduction of approximately 3.9 Mt of CO_2 between 2017 and 2030 was estimated. The impact on NO_X emissions was not significant. Alternative speed limits and spatially refined adjustments would reduce the potential emission savings, but would also be expected to offer a more viable tailored policy option.

5.5.2 Counterfactual study of the influence of current vehicle registration tax and motor taxes on diesel car purchases

Analysis suggests that these taxes will increase the demand for diesel cars (7.1%) and reduce the demand for petrol cars (9.6%) in 2030. Overall, the combination of the current tax incentives and the evolution and price of diesel cars is estimated to generate a proportion of 36.7% petrol cars to 63.3% diesel cars in 2030.

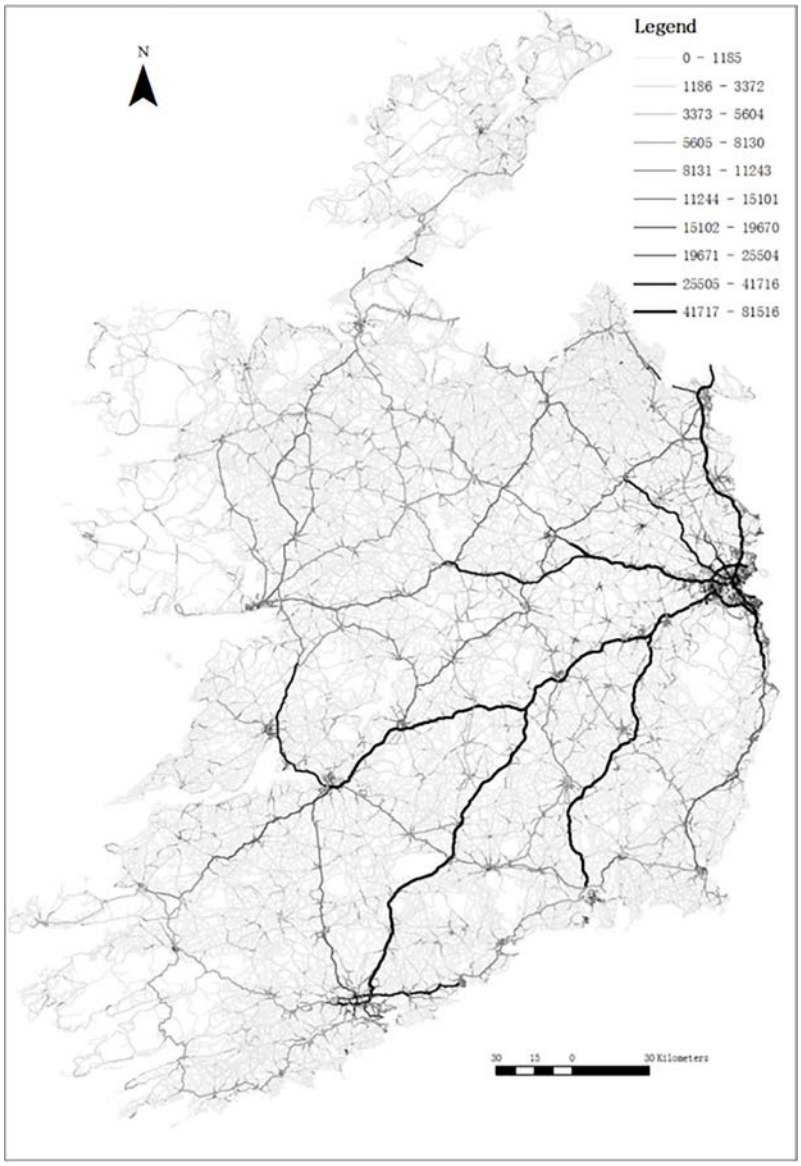

Figure 5.4. Estimates AADTS of roads in Ireland.

5.5.3 Counterfactual study of current vehicle regisration tax and motor taxes with regard to CO_2 and NO_X emissions

These taxes are estimated to reduce a total 0.8 Mt of CO_2 between 2017 and 2030, while delivering a slight increase in NO_X emissions. Advancing technologies and a lack of impact on vehicle use are the main reasons why the counterfactual study shows small savings. There are synergies when the vehicle registration tax (VRT) and motor tax changes are combined with a carbon tax.

5.5.4 Counterfactual study of the influence of the current carbon tax on CO_2 and NO_X emissions

The current carbon tax is estimated to account for 3.2 Mt of CO_2 emissions avoided in the period from 2017 to 2030. Although the higher fuel costs and reduced travel account for some production loss for firms and utility loss for households, the beneficial outcomes from the reduction in other externalities (e.g. air pollution, noise) render the policy narrowly positive from a total societal welfare perspective.

5.5.5 *Counterfactual study of the impact of tax changes for goods vehicles introduced in 2016*

The change to a more extensive tax band system for goods vehicles from the current system is anticipated to incentivise the purchase of larger, heavier trucks. On balance, it is expected that the change may result in a moderate increase in CO_2 emissions. However, the sensitivity to load factor assumptions is noted as being of relevance – specifically the challenge to ensure that trucks operate at high loads for both legs of all trips.

5.5.6 *Difference between real-world and type-approval emission outcomes*

This analysis sought to highlight the potential scale of variation between type-approval CO_2 emission factors for vehicles and more plausible "real-world" driving condition emission factors. The analysis suggests that "real-world" emissions can be in the region of 15% higher for cars and over 30% higher for light-duty trucks.

5.5.7 *Impact of electric and hybrid vehicle penetration shares on emissions in the Irish market*

This assessment quantified the potential impact of electrified vehicles (principally hybrids) growing their share to 31% of the fleet in 2050. Although the gap between conventional internal combustion engine (ICE) vehicles and electrified vehicles is expected to narrow in the future, fleet electrification can deliver notable reductions in the emissions of air pollutants and GHGs. On the time horizon to 2030, the projected CO_2 reductions are 1.1 Mt for what constitutes a reasonably moderate set of expectations for fleet electrification in Ireland. More ambitious goals structured around appropriate and well-designed policy supports and incentives are recommended for future-focused research.

5.6 Policy Brief: Nationwide Smoky Coal Ban

As part of the project, research support was provided to model the costs and benefits of "clean air" policy scenarios for residential heating in Ireland. Analyses were conducted in 2015/2016 and initial findings were presented at an EPA meeting where the Minister for the Environment, Community and Local Government, Alan Kelly, announced a planned nationwide ban on smoky coal for Ireland. Analysis was conducted to provide a concise assessment of the outcomes of a pair of clean air policy scenarios with respect to energy and emission changes. The piece also offered a number of policy points to support the implementation and management of this strand of clean air policy in the future in Ireland. Key findings and policy notes were as follows:

- $PM_{2.5}$ and SO_2 are the key pollutants with respect to residential emissions.
- Reducing these accounts for 90% of the benefit from tackling air pollution from this source.
- Between health and ecosystem damage, again, over 90% is health damage.
- Medium-scale towns (> 15,000 persons) return the greatest benefit as an initial target of the policy.
- Climate benefits arise from reductions in coal use and strengthen the case for action in all situations.
- Smaller towns are expected to present greater implementation and management issues.

This work utilised research developed with regard to the residential home heating paper (section 5.3) and the marginal damage value (MDV) guidebook (section 5.7), and offers a good example of how research and capacities can be adapted and linked to develop better policy strategy and policy evaluations. One aspect of the work was also to identify areas of national data that should be prioritised for improvement. Specifically, the work noted the absence of adequate detail nationwide on household combustion technologies and fuel use data.

5.7 Guidebook Summary: MDV Guidebook for Air Pollution

This guidebook was conceived, developed and completed under the project. The purpose of the MDV guidebook was to offer Irish stakeholders, agencies and other analysts a clear and accessible reference manual with regard to incorporating the value of the marginal damage caused by air pollution in Ireland into their own assessments and evaluations. The concept is that the values would be incorporated into cost–benefit style analyses to offer a weighting in the decision-making process for air pollution-related

outcomes. This would broaden the scope of policy decisions by embedding consideration of multiple factors.

The guidebook proved to be a major research undertaking given the underlying data requirements and the complexity of the integrated methodology. This research required spatial distribution of national emission sources and emissions, spatial dispersion modelling of emissions, estimation of concentrations from emissions including evaluation of monitoring data, mapping of impact receptors in Ireland, and estimating and valuing health and environmental impacts. Although a significant undertaking, the research process, and the expected outputs, were identified early on as being highly complementary to many other aspects of the project research (e.g. the MDV guidebook results were incorporated into other project outputs including the smoky coal work, the residential electrification paper, the air and climate synergies report and other ad hoc pieces). The final output was a popular, accessible and concise guidebook that has been widely distributed in Ireland in physical and electronic form. The piece was also shared with international colleagues and presented internationally.

A detailed methodological report was also compiled to accompany the guidebook (see section 5.8). The purpose of this was to afford analysts clarity and confidence with regard to the rigour of this initial approach and the plans for further enhancement into the future. It is hoped that this methodological report can support the ultimate consideration of the MDV guidebook for formal adoption in the Public Spending Code developed by the Department of Public Expenditure and Reform. An infographic and a simplified table of MDVs were key components of the guidebook and these are presented in Table 5.1 and Figure 5.5.

5.8 Report Summary: Methodological Report on MDV Guidebook

The detailed methodological report on the MDV guidebook was developed and completed to support the consideration of the MDV values for inclusion in the Public Spending Code of the Department of Public Expenditure and Reform. The underlying methodology for the guidebook spanned multiple areas of research and all sectors of the economy. To include this detail within the guidebook itself would have made that piece less accessible and less appealing to policy analysts and end users. However, it was recognised that, for certain official bodies to consider formally applying the values presented within the guidebook, there would need to be a more detailed and transparent methodological document available to facilitate further scrutiny. The requisite detail was included in this report. The piece was structured under the following five headings.

1. Estimating the baseline of spatially allocated air pollutant emissions and concentrations in Ireland.
2. Identifying the presence and sensitivity of receptors (e.g. environment/people) affected by air pollution in Ireland.

Table 5.1. MDV guidebook summary values for national, urban and rural areas

Aggregate national estimate of marginal damage value per tonne of pollutant (€2010 per tonne per annum)					
	NO_x	NH_3	SO_2	NMVOC	$PM_{2.5}$
	Incl. secondary PM	Incl. secondary PM	Incl. secondary PM	Incl. secondary PM and O_3	Primary PM only
Ireland All	1000	825	4825	875	7500
Ireland Rural	925	650	4825	850	6600
Urban Large (Dublin)	9350	13,175	10,300	2675	67,650
Urban Medium (Pop ≥ 15,000)	1550	3300	4750	1550	22,825
Urban Small (Pop. 10,000–15,000)	1375	1500	5275	1350	14,800
Small Towns (Pop. < 10,000)	1150	1050	4725	1025	9650

PM, particulate matter.

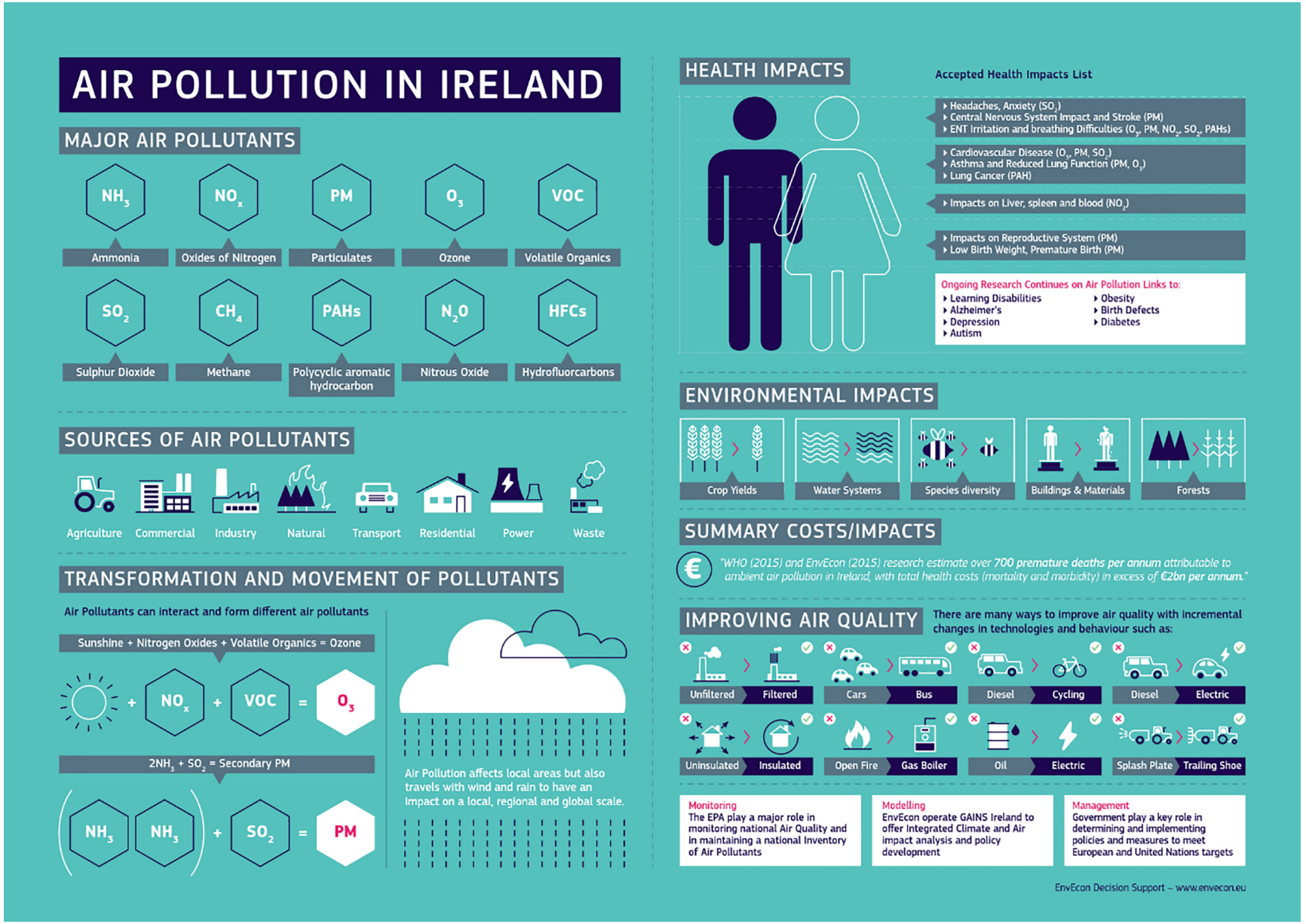

Figure 5.5. Air pollution in Ireland infographic.

3. Determining the damage associated with air pollution exposure and then estimating the corresponding value of that damage.
4. Establishing relationship functions for the association between emission changes and pollutant concentrations across Ireland.
5. Calculating the marginal change in damage and the level of damage values associated with changes in pollution concentrations.

5.9 Report Summary: Air and Climate Synergies Report

The GAINS Ireland and Irish TIMES models have been supported by the EPA in order to develop the national analytical infrastructure and support that are necessary to effectively address climate and air policy challenges for Ireland in both a domestic and an international context. This report was the culmination of a collaborative research initiative between EnvEcon (GAINS Ireland model) and UCC (Irish TIMES model). The work drew on the integrated analytical capacities of the GAINS Ireland model to assess climate and air pollution outcomes, the energy system optimisation capacities of the Irish TIMES model, and a health and environmental impact assessment methodology for air pollution developed by EnvEcon.

The specific focus of the report was as follows. Initially, the Irish TIMES model was utilised to generate an energy system optimisation scenario that would deliver a 22% reduction in NETS GHG emissions in Ireland by 2030, relative to 2005. This change was reflective of a potential European target for Ireland to reduce GHG emissions across the non-traded sectors in 2030 by that amount. The Irish TIMES model also had a business as usual (BAU) scenario available that offers an outlook for 2030 that is similar in concept to the national "with measures" scenario.[2] For this research, the EnvEcon team adapted the Irish TIMES BAU and the Irish TIMES optimisation that delivers the 22% reduction in NETS emissions (NETS22) into the GAINS Ireland model as two new individual scenarios. Thereafter, the team assessed the differences in air pollutant emissions and impact outcomes arising between those two scenarios. These assessments were conducted using the GAINS Ireland model and the EnvEcon methodology for health and environmental impact assessment (EnvEcon, 2015; see section 5.7), 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 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 for the non-traded sectors is achieved with substantial reductions (60%) in SO_2 emissions and reasonable reductions (27%) for NO_X. For VOC, the outcome is less favourable, with an increase in emissions of 15%. However, the most dramatic difference is for $PM_{2.5}$. Under the NETS22 scenario, $PM_{2.5}$ emissions increase by 61% compared with the BAU scenario. These changes are driven largely by increased biomass use in residential/commercial activities and industrial combustion, with a conservative assumption of emissions control technologies applied over the additional biomass combustion at this point. Overall, however, there is an estimated net benefit in health and environmental impacts of €20 m per annum from 2030 delivered by the move from the BAU to the NETS 22 scenario. This net benefit is principally driven by the SO_2 and NO_x reductions, which offset almost €40 million of additional health costs from the higher $PM_{2.5}$ emissions. However, it is noted that a comparable analysis of the official "with measures" and "with additional measures" scenarios delivers a net additional benefit of some €33 million largely due to a more moderate increase in $PM_{2.5}$ emissions. The NETS22 scenario is also expected to result in a breach of the anticipated 2030 $PM_{2.5}$ ceiling under the revised NECD (2001/81/EC). Therefore, further research is advised with regard to the particular issues that give rise to the substantial increases in $PM_{2.5}$ and VOC emissions in the future.

2 It is stressed that the BAU scenario is not directly comparable with the EPA's official national inventory and forecast, or with the GAINS Ireland forecast scenarios, which do include scenarios that mirror official inventory and forecast values.

The overall summary recommendation from the analysis is to recognise that a broader focus is important for policy decisions in Ireland if we are to meet the manifold challenges posed by climate, air and other legislative environmental constraints. Dynamic and strategic integrated 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 policymakers with the evidence on which to make better informed strategic policy decisions in these complex areas.

5.10 Other Reports and Ad Hoc Research Briefs

Over the course of the project, a number of other research briefs and reports were created and submitted in response to specific challenges that arose where the ongoing project research and capacities allowed the team to provide research support on issues requiring a more immediate response. This work included pieces such as:

- a research assessment of national environmental compliance cost charges with respect to climate and air legislation;
- an assessment of compliance strategy for the NETS targets;
- a submission on the national mitigation plan;
- a summary brief on the IMP work for the climate change advisory council;
- a submission on the smoky coal ban proposals; a submission on the national ambient air quality monitoring programme;
- a submission on the North South solid fuel policy report;
- an assessment of the implications of Irish inventory revisions on the TSAP 2030 proposals;
- explanatory notes for colleagues in respect of the GAINS model and associated international processes;
- a departmental briefing note on the EU clean air policy package;
- analysis of residential heating shares;
- analysis of the costs and benefits of clean air policies for residential heating in Ireland;
- input into European Commission surveys on national research and modelling capacities;
- the development of a measures and database template for the national mitigation plan;
- a review of the draft sectoral national mitigation plans;
- an updated assessment of the gaps to target and compliance strategy for NETS 2030;
- the preparation of facts and figures from the model and related processes in support of discussions and negotiations related to national climate and air policy developments as necessary.

6 Summary Conclusions of the Research

The summary conclusions of this research project are described in this section. First, one major recommendation is to further co-ordinate and combine nationally developed analytical capacities in support of sustained progress on national climate and air obligations. The existing challenges, and those now being set in place for 2030 and beyond, will require a range of carefully designed and dynamically managed policy interventions and initiatives to be achieved. However, these actions must not be narrow in their ambition and considerations. Instead, the actions must balance between progress on targets, political and public acceptability, technological constraints and economic and social rationales. This requires a considered evidence-based approach. The developed capacity of the IMP research has been geared to offer decision support to national decision-makers in this context and is now primed to do so in the future. Second, it is recommended that the MDV guidebook is formally adopted into the Public Spending Code so that national decision-making processes give an appropriate weighting to air pollution considerations. This will thereby ensure that policies are broadened in scope to incorporate air-related concerns, in the same manner that other priorities such as climate, competitiveness and so on may be considered when developing better, broader policy. Third, a number of policy research pieces have been developed and reviewed internationally. It is recommended that these are promoted and considered with a view to informing Irish policy actions in the future. Finally, the project offers selected recommendations with regard to future research areas on the basis of anticipated challenges and identified gaps.

6.1 National Capacity and Air and Climate Research Support

National capacity in integrated air and climate research support has been strengthened under this project. There is increasing co-ordination at a national level that should now leverage this capacity in support of evidence-based responses to developments in international environmental legislation and, crucially, in managing a dynamic policy response in Ireland to the many challenges that now exist. The legislative landscape is now settling out to 2030, and it is clear that a path to compliance will be extremely difficult to navigate. A failure to respect our legally binding commitments will be costly, but there are also opportunities presenting themselves in this context. Adequate, consistent and experienced specialised analytical capacity is necessary to guide national decision-making in this regard. The TRAM, the CCAC, all of the affiliated agencies and departments, and indeed the principal policy modelling teams in this area now offer a coherent framework for progress, and include many of the capacities necessary to deliver progress across multiple thematic concerns. The IMP team has sought to anticipate the key research areas and needs for future policy interventions, and the developed capacities of the research and team are ready to support national efforts to meet our manifold obligations in an efficient and cost-effective manner.

6.2 Marginal Damage Values

Developing the MDV guidebook was an important element of the project. In brief, the piece supported the development of the IMP team by pushing it to develop new methods and an understanding relating to all facets of the air pollution problem. However, the developed guidebook is also important from a practical policy perspective as it affords decision-makers and analysts the means of giving a weighting to air pollution in their decision-making process using nationally specific research. The importance of this development is that it can ensure that policy takes a broader perspective during the design process (i.e. air pollution concerns and associated impacts) and thereby supports more rounded policy consideration and a better outcome on the implementation of policy.

6.3 Policy Research

The IMP project has sought to prioritise its research agenda to deliver policy-focused analysis and capacities that respond to topical needs in the Irish system. During this project, a particular focus was placed on the transport, residential and agricultural

sectors, as these are the key sectors to manage with regard to the national response to international climate and air challenges. This is because power and heavy industry are increasingly less significant in an air pollution context for Ireland, and they are covered by the EU ETS from a climate perspective. With regard to agriculture, the main support provided from this project was related to the European Commission/ IIASA bilaterals and associated negotiations of air and climate targets. However, for transport and the residential sector there were a number of formal policy papers produced, as detailed in Chapter 5. These papers developed knowledge on the following topics and can each support associated policy development in Ireland:

- understanding what factors influence solid fuel use behaviour in Ireland;
- understanding the potential impacts of a national smoky coal ban policy;
- enhancing spatial analysis of emissions in key sectors of the economy, e.g. transport;
- evaluating the economic and environmental potential of residential electrification of home heating;
- assessing local policy action opportunities with regard to transport and school commuting;
- identifying and evaluating policy options related to transport taxes and other transport policy change.

6.4 Future Research Directions

With regard to climate and air policy, it is recommended that research increases the focus on the residential, transport and agricultural sectors. These are the key sectors where national policy initiatives and more localised actions are required, particularly given the existence of broader prevailing legislation dealing with large point sources in heavy industry and the power sector (e.g. ETS, Industrial Emissions Directive, etc.).

Specific selected recommendations for future research in Ireland include the following:

- gathering detailed and contemporary data with regard to residential fuel use in Ireland;
- further assessments of the impacts of climate-focused policies (e.g. biomass promotion) in relation to air quality and associated human health impacts;
- assessments of land use opportunity costs for the farming community;
- a detailed study of VOC emissions from the food and drink sectors;
- detailed analyses of $PM_{2.5}$ emissions from residential sources (monitored and estimated);
- detailed spatial analyses of transport fleet policies and fleet evolution in Ireland;
- independent forecasting of sector-specific activities, e.g. transport evolution, residential, agriculture;
- spatially referenced policy instrument design to influence residential air and climate emissions;
- potential impacts of dietary changes, market price or other demand changes on Irish agriculture;
- developing a template for a “back-on-track” report for ESD non-compliance reporting;
- regular review of environmental compliance/credit markets, strategies and penalty risks;
- development, extension and regular revision of a national mitigation options database.

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Abbreviations

AADT	Annual average daily traffic value
ASHP	Air source heat pump
BAU	Business as usual
CCAC	Climate Change Advisory Council
CSO	Central Statistics Office
EPA	Environmental Protection Agency
ESD	Effort Sharing Decision
EU	European Union
EU ETS	European Union Emissions Trading Scheme
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GHG	Greenhouse gas
IIASA	International Institute for Applied Systems Analysis
IMP	Integrated Modelling Project
MDV	Marginal damage value
NECD	National Emissions Ceiling Directive
NETS	Non-emmsions trading sector
NO_x	Nitrogen oxides
PCDO	Private car drop-off
$PM_{2.5}$	Particulate matter with a diameter of 2.5 µm or less
SEAI	Sustainable Energy Authority of Ireland
TFIAM	Task Force on Integrated Assessment Modelling
TRAM	Technical Research and Modelling (Group)
TSAP	Thematic Strategy on Air Pollution
UCC	University College Cork
UN	United Nations
UNECE	United Nations Economic Commission for Europe
VOC	Volatile organic compound
VRT	Vehicle registration tax

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
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- 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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Integrated Modelling Project Ireland

Author: J. Andrew Kelly

National capacities in integrated air and climate modelling were utilised and advanced, along with policy analysis, to respond to pressing challenges regarding climate and air pollution. The research employed a broad array of models and methodologies to critically evaluate the issues, and thereafter to rigorously develop and deliver valuable insight and practical decision support.

Identifying Pressures

Integrated modelling tools were applied to identify environmental pressures across multiple sectors under the thematic headings of climate and air pollution. The team developed and ran numerous climate and air scenarios in the GAINS Ireland model to explore the evolving national challenges in relation to climate and air targets in Ireland. This research also supported national engagements in relation to the determination of national climate and air targets under European legislation.

Informing Policy

In addition to modelled scenarios, it is recognised that actionable policy support requires bespoke analysis of the broader issues, challenges and considerations that policymakers face. As part of the decision support proposed by this research, relevant policy analysis has been offered for topics including residential solid fuel use, electrification of residential heating, school transport strategies, air and climate policy synergies, transport policy intervention assessments and many other topics.

Developing Solutions

The project advanced and maintained critical analytical infrastructure such as GAINS Ireland, providing research support in European policy development, and delivering concise policy briefs, papers and recommendations. In addition, the project delivered a guidebook for policy analysts. This involved the development of supporting research for spatial distribution of emissions and the application of that research to a developed methodology for estimating the marginal damage values of a tonne of a given air pollutant in Ireland. A formal guidebook was then developed, designed and released to support the weighting of air pollution into public policy evaluations. A detailed methodological report was also released to support the potential adoption of this work into formal Irish evaluation processes.

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