Ireland's National Greenhouse Gas Emission Projections 2017

Methodological Approach

Table of Contents

1. Introduction

This report is part of Ireland's submission required under the European Commission Monitoring Mechanism Regulation No 525/2013 to fulfil reporting obligations in 2017. It concerns the methodology underpinning the development of Ireland's greenhouse gas emissions projections for the period up to 2035. The projections and associated data are submitted separately in the reporting template provided by the Commission.

The National Climate Change Strategy (2007)[1] designated the Environmental Protection Agency (EPA) responsible for developing annual national emission projections for greenhouse gases for all key sectors of the economy, in collaboration with relevant State and other bodies. Annual projections serve to inform national policy initiatives and allow Ireland to comply with EU reporting obligations as appropriate. This report outlines the methodology underpinning the development of Ireland's greenhouse gas emission projections, submitted in 2017, for the period up to 2035.

Emission projections are required for the greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). Projections must be reported on a sectoral basis giving priority to those sectors that have the most impact on overall national greenhouse gas emission levels. Table 1 summarises the sectors and gases for which projections are developed and reported to the European Commission in 2017.

In December 2012 the European Commission published Greenhouse Gas Projection guidelines[2], the aim of which was to provide a first step towards a more uniform projection methodology for Member States and the Commission. The projections guidelines do not prescribe specific projection methods to each Member State, but guide the Member States in a tiered methodological approach (called grades) to reflect different approaches and data availability at Member State level. Table 2 outlines the grades used for both activity data and emission factors in the development of national greenhouse gas emission projections in Ireland.

[1] National Climate Change Strategy 2007-2012. Department of Environment, Heritage and Local Government. (2007).
[2] http://ec.europa.eu/clima/policies/g-gas/monitoring/studies_en.htm

Table 1. Source and sink category for emission projections

Source and sink category	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NF_3
1.A.1 Energy Industries							
1.A.1.a Electricity and Heat Production	X	X	X	-	-	-	-
1.A.1.b Petroleum Refining	X	X	X	-	-	-	-
1.A.1.c Solid Fuel Manufacture	X	X	X	-	-	-	-
1.A.2 Manufacturing Industries and Construction	X	X	X	-	-	-	-
1.A.3 Transport							
1.A.3.a Civil Aviation	X	X	X	-	-	-	-
1.A.3.b Road Transportation	X	X	X	-	-	-	-
1.A.3.c Railways	X	X	X	-	-	-	-
1.A.3.d Navigation	X	X	X	-	-	-	-
1.A.3.e Other Transportation	X	X	X	-	-	-	-
1.A.4 Other Sectors							
1.A.4.a Commercial/Institutional	X	X	X	-	-	-	-
1.A.4.b Residential	X	X	X	-	-	-	-
1.A.4.c Agriculture/Forestry/Fishing	X	X	X	-	-	-	-
1.B Fugitive emissions from fuels							
1.B.1 Solid Fuels	-	X	-	-	-	-	-
1.B.2 Oil and Natural Gas	-	X	-	-	-	-	-
2.A Mineral Industry							
2.A.1 Cement Production	X	-	-	-	-	-	-
2.A.2 Lime Production	X	-	-	-	-	-	-
2.A.4 Other Use of Carbonates	X	-	-	-	-	-	-
2.D Non-Energy products from Fuels and Non-Energy Products from Fuels and Solvent Use							
2.D.1 Lubricant Use	X	-	-	-	-	-	-
2.D.2 Paraffin Wax Use	X	-	-	-	-	-	-
2.D.3 Solvent Use	X	-	-	-	-	-	-
2.E Electronics Industry							
2.E.1 Integrated Circuit or Semiconductor	-	-	-	X	X	X	X
2.F Product Uses as Substitutes for Ozone Depleting Substance							
2.F.1 Refrigeration and Air Conditioning	-	-	-	X	-	-	-
2.F.3 Fire Protection	-	-	-	X	-	-	-
2.F.4 Aerosols	-	-	-	X	-	-	-
2.G Other Product Manufacture and Use							
2.G.1 Electrical Equipment	-	-	-	-	-	X	-
2.G.2 SF_6 and PFCs from Other Product Uses	-	-	-	-	X	X	-
2.G.3 N_2O from product Uses	-	-	X	-	-	-	-
3. Agriculture							
3.A Enteric Fermentation	-	X	-	-	-	-	-
3.B Manure Management	-	X	X	-	-	-	-
3.D Agricultural Soils	-	-	X	-	-	-	-
3.G Liming	X	-	-	-	-	-	-
3.H Urea Application	X	-	-	-	-	-	-
4. Land Use, Land Use Change and Forestry							
4.A Forest Land	X	X	X	-	-	-	-
4.B Cropland	X	X	X	-	-	-	-
4.C Grassland	X	X	X	-	-	-	-
4.D Wetlands	X	X	X	-	-	-	-
4.E Settlements	X	X	X	-	-	-	-
4.F Other Land	X	X	X	-	-	-	-
5. Waste							
5.A Solid Waste Disposal	-	X	-	-	-	-	-
5.B Biological treatment of solid waste	-	X	X	-	-	-	-
5.C Incineration and open burning of waste	X	X	X	-	-	-	-
5.D Wastewater treatment and discharge	-	X	X	-	-	-	-
Memo Items							
International Bunkers	X	X	X	-	-	-	-
CO_2 emissions from biomass	X	X	X	-	-	-	-

Table 2. Source and sink category for emission projections – activity data and emission factor grades

Source and sink category	Activity data grade	Emission factor grade
1.A.1 Energy Industries	2/3	1
1.A.2 Manufacturing Industries and Construction	2	1
1.A.3 Transport	2/3	1 (CO_2) & 2 (CH_4/N_2O)
1.A.4 Other Sectors	2/3	1
1.B Fugitive emissions from fuels	2	1/3
2.A Mineral Industry	2	1
2.D Non-Energy products from Fuels and Non-Energy Products from Fuels and Solvent Use	1	1 & 2
2.E Electronics Industry	1	1 & 2
2.F Product Uses as Substitutes for Ozone Depleting Substance	1	1 & 2
2.G Other Product Manufacture and Use	1	1/2
3. Agriculture	1 & 2	1 & 2
4. Land Use, Land Use Change and Forestry	1	1
5. Waste	1 & 2	1
Memo Items	2	1

2. Energy Forecasts and energy related emissions

Sustainable Energy Authority of Ireland (SEAI) publish national energy forecasts[3] showing future energy trends. Energy forecasts, most recently completed in 2017, form the basis for almost all energy-related emission projections discussed.

SEAI compile two energy forecasts scenarios, which are used in national emission projections to 2035, *Baseline* and *NEEAP/NREAP* (adjusted to reflect current progress and the trajectory towards achieving 2020 targets):

- The *Baseline* energy forecast projects forward Ireland's energy demand, incorporating the expected impacts of policies and measures that were in place (e.g. legislatively provided for) by the end of 2015. It represents a hypothetical future scenario in which no further policy actions or measures have been taken. It excludes policies that are committed to but which do not yet have measures in place to deliver them.

- The *NEEAP/NREAP* energy forecast (adjusted for 2017 projections) presents an alternative view of future energy demand that accounts for further implementation of the National Renewable Energy Action Plan[4] (NREAP) and the 3rd National Energy Efficiency Action Plan[5] (NEEAP) based on current progress. Therefore this forecast includes existing *and* further implementation of planned policies and measures based on current progress. For 2017 projections, the latest *NEEAP/NREAP* energy forecast has been adjusted to reflect current progress and the trajectory towards achieving 2020 targets. This includes an expected shortfall in achieving full energy efficiency targets and renewable energy targets for electricity, transport and heat.

[3] http://www.seai.ie/Publications/Statistics_Publications/Energy_Forecasts_for_Ireland/ and http://forecasts.seai.ie/
[4] http://www.dccae.gov.ie/energy/en-ie/Renewable-Energy/Pages/Action-Plan.aspx
[5] http://www.dccae.gov.ie/energy/SiteCollectionDocuments/Energy-Efficiency/NEEAP%203.pdf

The *Baseline* energy forecast underpins the *With Existing Measures* emission projection for the energy sector and the adjusted *NEEAP/NREAP* energy forecast (adjusted based on current progress) underpins the *With Additional Measures* projection for the energy sector.

The *Baseline* energy forecast compiled by SEAI provides future energy demand to 2035 for the following sectors: 1.A.1.a, 1.A.2, 1.A.3.b, 1.A.3.e, 1.A.4.a, 1.A.4.b and 1.A.4.c. The *NEEAP/NREAP* energy forecast (adjusted) provides future energy demand for the above sectors to 2035 whilst accounting for Ireland's targets, and policies and measures presented in Ireland's NEEAP[5] and NREAP[4], to the extent that are expected to be achieved and implemented based on current progress.

Article 4 of Directive 2009/28/EC on renewable energy requires each Member State to adopt a NREAP and submit it to the European Commission. The NREAP[4] sets out the Member State's national targets for the share of energy from renewable sources consumed in transport, electricity and heating and cooling in 2020, demonstrating how the Member State will meet their overall national target established under the Directive.

Ireland submitted its NREAP to the European Commission in July 2010. Three progress reports have subsequently been submitted, one in January 2012, the second in February 2014 and the third in April 2016.

The NEEAP[5] sets a clear vision for each of the sectors covered by the Action Plan, around which public and private sector actors can mobilise. Ireland's first NEEAP was published in May 2009, which built on the Energy Efficiency Action Plan submitted to the Commission in 2007 and was required as part of Ireland's obligations under the Energy Services Directive[6]. Subsequently two further iterations have been published, Ireland's NEEAP II in 2012 and NEEAP 3 in 2014.

For the *Baseline* energy forecast, the Economic and Social Research Institute (ESRI) use macro-economic projections which are produced using the COSMO model[7]. The baseline projections and underlying assumptions are described here in Chapter 1 of "Ireland's Economic Outlook: Perspectives and Policy Challenges", which was published on 5 December 2016[8]. Projections on the global economic environment, including oil prices, as based in simulations using the NiGEM model (National Institute Global Econometric Model[9]) maintained by the National Institute of Economic and Social Research[10]. Projections from the COSMO model were used to produce projections of the energy demand equation time series variables (i.e. demand equations by fuel and sector). The integration of energy demand into the COSMO model is work that is due to be undertaken in 2017.

Annual electricity demand, which is an output of the electricity demand equations/COSMO was transferred, as well as fuel prices, as an input into an electricity dispatch model to determine fuels used at an hourly level to service aggregate electricity demand. This process provides a high level of accuracy on the fuels used in the electricity sector. The software used for the energy forecasts to model the Irish Electricity Market is PLEXOS 7.4 R01. PLEXOS is a power systems modelling tool used for electricity market modelling and planning.

[6] Directive 2006/32/EC on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC
[7] https://www.esri.ie/projects/modelling-the-irish-economy/
[8] http://www.esri.ie/pubs/EO1.pdf
[9] https://nimodel.niesr.ac.uk/
[10] http://www.niesr.ac.uk/

The energy forecast includes sectoral output figures and other relevant key variables such as price, economic growth, population and housing stock. To produce the finalised *Baseline* energy forecast, SEAI amends the output of the energy demand produced by ESRI (described above) to take account of the expected impact of energy efficiency measures put in place before the end of 2015 but which are considered too recent to be detectable in any time-series analysis. The *NEEAP/NREAP* energy forecast (adjusted) builds on the *Baseline* forecast with adjustments made to account for further implementation of additional policies and measures outlined in the NEEAP[5] and NREAP[4]. For 2017 projections, the *NEEAP/NREAP* energy forecast has been adjusted to reflect current progress and the trajectory towards achieving 2020 targets. This includes an expected shortfall in achieving energy efficiency and renewable energy targets.

Details regarding energy related policies and measures are available in a number of SEAI reports[3].

The energy forecasts that underpin the energy-related emissions projections are based on macroeconomic projections as described above. Table 3 shows the key parameters underlying the macroeconomic outlook and therefore the *With Existing Measures* and *With Additional Measures* emission projections scenarios. The forecasts are based on international fuel import oil prices. Coal and gas prices were published by the United Kingdom's Department of Energy and Climate Change. The carbon prices are those circulated by the European Commission in June 2016. Carbon dioxide price assumptions in the non-ETS sectors are based in the medium term on the Finance Bill 2010[11] which saw the introduction of a carbon tax of €15 per tonne CO_2. In the longer term the carbon tax is assumed to follow the EU ETS carbon price.

Table 3. Key assumptions underpinning the energy forecasts

	2016 – 2020	2021-2025	2026-2030	2031-2035
Average Annual % Growth Rate				
GDP	+3.74%	+3.24%	+2.59%	+2.59%
GNP	+3.42%	+3.32%	+1.97%	+1.97%
Personal Consumption	+2.97%	+2.57%	+1.11%	+1.11%
	2016	**2020**	**2025**	**2030**
Housing Stock ('000)	1,967	2,018	2,112	2,206
Population ('000)	4,674	4,834	5,027	5,209
EUETS: Carbon €$_{2013}$/tCO$_2$	9	15	22.5	33.5
Carbon tax €$_{2013}$/tCO$_2$	18.3	15	22.5	33.5
Coal $\$_{2013}$/boe	9.8	9.9	11.6	10.6
Oil $\$_{2013}$/boe	40.5	56.8	62.8	69.4
Gas $\$_{2013}$/boe	27.0	20.4	24.6	27.3
Peat €/MWh	25	25	25	25

Further details on the models used are included in the submission made under Article 14 of the Monitoring Mechanism Regulation (Regulation 525/2013).

[11] Finance Bill 2010. http://www.finance.gov.ie/ga/news-centre/press-releases/finance-bill-2010

The energy forecasts completed in 2017, which follow the 2015 national energy balance[12], form the basis for the majority of Fuel combustion activities (1.A) emissions projections namely:

- Energy Industries (1.A.1.a)
- Manufacturing Industries and Construction (1.A.2)
- Road transportation (1.A.3.b)
- Other transport (1.A.3.e)
- Commercial /Institutional (1.A.4.a)
- Residential (1.A.4.b)
- Agriculture/Forestry/Fishing (1.A.4.c).

Emissions from these sectors accounted for approximately 99 per cent of fuel combustion activities related emissions in 2015. Emission projections for the remaining fuel combustion activities (i.e. oil refining (1.A.1.b), peat briquetting (1.A.1.c), rail transport (1.A.3.c), domestic aviation (1.A.3.a), and navigation (1.A.3.d)) are calculated separately and are based on data provided to the EPA and from EPA databases. Emissions from 1.A.5 (Non-Specified) combustion is reported as "IE" (Included elsewhere) as emissions from combustion are accounted for in the other sectors as listed above.

3. Non-energy related emissions and removals

Non-energy related emissions cover the following sectors:

- Agriculture (3.A, 3.B, 3.D, 3.G and 3.H)
- Waste (5.A, 5.B, 5.C & 5.D)
- Industrial processes (2.A.)
- 2D Non-Energy Products from Fuels and Non-Energy Products from Fuels and Solvent Use
- Fluorinated gases (2.E, 2.F and 2.G) and
- Land Use, Land Use Change and Forestry (4.A – 4.D)

The methodologies employed to develop emission projections for each of these sectors is discussed in the relevant sections of this report.

4. Emission Factors

In general, CO_2, CH_4 and N_2O emission factors are those used in historical emission inventories (1990-2015). These are either plant specific, country specific or default emission factors from IPCC guidelines. Carbon dioxide emissions from the combustion of biogenic carbon are not included in the calculation of projected emissions (in accordance with IPCC Guidelines[13] for compiling greenhouse gas inventories).

Further information on emission factors and methodologies used in in compiling the 1990-2015 National Inventory Report can be found at the following link:

https://cdr.eionet.europa.eu/ie/eu/mmr/art07_inventory/ghg_inventory/envwmlbzw/

In calculating emissions from natural gas combustion, it is known that imported gas meets 97.1 per cent of gas demand in 2015 (imported gas is more carbon intensive than domestic

[12] http://www.seai.ie/Publications/Statistics_Publications/Energy_Balance/
[13] e.g. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy. Chapters 2 & 3.

sources). For the projections, from 2016 a new domestic source of natural gas is included which has the potential to provide 36 per cent of domestic demand in 2020.

5. Policies and Measures

Emissions projections are developed under two scenarios; *With Existing Measures* and *With Additional Measures*. As stated, the *With Existing Measures* emission projection is based on the *Baseline* energy forecast and includes existing policies and measures that were in place prior to the end of 2015.

The *With Additional Measures* includes existing measures *and* planned policies and measures and is based on the *NEEAP/NREAP* energy forecast (compared to previous years this has been adjusted to reflect current progress towards achieving 2020 targets).

SEAI include planned policies and measures from both the NREAP[4] and the NEEAP[5] by subtracting the necessary energy savings from the *Baseline* energy forecasts to give the *NEEAP/NREAP* energy forecast (adjusted for 2017 projections as described above). These measures and associated fuel and emission savings, as calculated by SEAI and EPA, are reported in the relevant sections of this document.

Emission savings associated with policies and measures are described in each of the following sections for each of the economic sectors. Further details on policies and measures are reported under Article 13 of the Monitoring Mechanism Regulation (525 of 2013).

6. Emissions Trading Scheme

The impact of the EU Emissions Trading Scheme (EU-ETS)[14] in the power generation sector was included in the energy forecasts underlying the emissions projections by including a price for carbon in the SEAI Plexos_Ireland model (see Table 3 for carbon price assumptions) which is used to model the power generation (1.A.1.a) sector.

The main source of emissions from the emissions trading sector in the industrial processes sector (2.A.1) is modelled using projected GDP growth.

7. Energy Industries (IPCC sector 1.A.1)

The energy industries sector is sub-divided into (i) power generation (1.A.1.a) (ii) oil refining (1.A.1.b) (iii) solid fuel manufacture (1.A.1.c). Emissions projections were developed for each sub-sector, covering all combustion sources of CO_2, CH_4 and N_2O.

7.1. Power Generation (IPCC sector 1.A.1.a)

Power generation covers all electricity generation including electricity generated from renewable sources. The Plexos_Ireland model was used to model electricity generation for each year to 2035. As an electrical systems model, the core input data comprises technical details of generators, transmission lines and loads as well as fuel costs, operational costs and emission reduction rates and costs.

In the *Baseline* energy forecast the renewable energy generated shows Ireland reaching 22.7 per cent of electricity consumption from renewable energy by 2020. Renewable electricity generation capacity is dominated by wind but also includes, for example, the operation of a

[14] http://ec.europa.eu/clima/policies/ets/index_en.htm

second waste to energy incinerator and the continued development of landfill gas electricity generation. It is also assumed that electricity trading occurs through the 500 MW East-West interconnector. In 2030 it is estimated that renewable energy generation increases to 25 per cent of electricity consumption and returns to 22 per cent in 2035.

In the *NEEAP/NREAP* energy forecast (adjusted) (and therefore the *With Additional Measures* emissions scenario) it is assumed that for 2020 there is a 37.3 per cent share of renewable energy in electricity generation as a result of additional expansion in wind energy, biomass electricity generating capacity in addition to solar photo voltaics and the continued development of landfill gas electricity generation. The largest contribution is from wind which at 896 ktoe in 2020 is 62 per cent above that included in the *Baseline* and therefore the *With Existing Measures Scenario*. This falls short of the full target of 40 per cent share of renewable energy in electricity generation in 2020. In 2030 it is estimated that renewable energy generation reduces to 29 per cent of electricity consumption and 26 per cent by 2035.

The impact of existing and planned policies and measures that will impact the power generation sector are listed in Table 4 with the anticipated emissions savings estimated.

Table 4. Emissions savings due to policies and measures included in the *With Existing Measures* and *With Additional Measures* scenarios for the power generation sector

Policy and measure	CO_2e (Gg)			
	2020	**2025**	**2030**	**2035**
With Existing Measures				
Increased efficiency in power generation	827.1	862.5	862.4	862.4
Reduced transmission and distribution losses	39.1	38.3	39.3	41.1
22.7% renewables by 2020	1,381.7	1,370.1	1,364.4	1,358.8
Reduced electricity demand from energy efficiency measures	605.6	591.9	608.7	636.2
Domestic Lighting (Eco-Design Directive) – *included in reduced electricity demand from energy efficiency measures above*	42.1	41.2	42.4	44.3
Total	**2,853.5**	**2,862.8**	**2,874.8**	**2,898.5**
With Additional Measures				
Reduced electricity demand from additional energy efficiency measures in industry, services and residential	2.15	1.98	2.02	2.06
Increased electricity demand from electric vehicles roll-out	-6.29	-5.96	-6.23	-6.55
Replacement of coal fired generation with natural gas	-	587.06	920.36	1512.73
37.3% renewable by 2020	1,535.9	1,440.9	1,440.9	1,440.8
Total	**1,531.7**	**2,023.9**	**2,357.0**	**2,969.64**

7.2. Oil refining and solid fuel manufacture (IPCC sectors 1.A.1.b & 1.A.1.c)

Projections for oil refining and solid fuel manufacture are based on data provided by the relevant operators as energy demand from these sectors is not covered in SEAI's energy forecasts. The oil refining sector (1.A.1.b) in Ireland consists of a single installation. Carbon dioxide emission projections, provided by the operator, are based on assumptions about future product specifications, crude oil qualities and market demand.

With respect to solid fuel manufacture (1.A.1.c), one large operator produces a range of peat based fuels for domestic and industrial customers including the electricity generation sector. Carbon dioxide emission projections for solid fuel manufacture are provided to the EPA by the operator.

7.3. Projected greenhouse gas emissions in the Energy Industries sector (IPCC sector 1.A.1)

The main source of emissions from the energy industries sector (1.A.1) is power generation, accounting for 96.3 per cent of emissions from this sector in 2015. Projected emissions from solid fuel manufacture and oil refining remain static with emissions projected to be 335 and 100 kt CO_2eq from 2020 onwards respectively.

Under the *With Existing Measures*, emissions from power generation are projected to decrease by 13.6 per cent between 2015 and 2020 while fuel used in electricity generation is projected to increase by approximately 3 per cent over the same period. Over the period 2015 to 2035, emissions from the sector are projected to increase by 24.7 per cent to 14.1 Mt CO_2 eq.

Under the *With Additional Measures*, emissions from power generation are projected to decrease by 27.2 per cent between 2015 and 2020 while fuel used in electricity generation is projected to increase by approximately 3 per cent over the same period. This reflects more renewables such as wind and biomass being used for electricity generation in the *With Additional Measures* Scenario compared to the *With Existing Measures* scenario. The forecasts assume a replacement of coal fired electricity generation in 2025 with natural gas. Emissions from the sector are projected to decrease by 1.3 per cent between 2015 and 2035.

8. Manufacturing Industries and Construction (IPCC sector 1.A.2)

The *Baseline* energy forecast underpins the *With Existing Measures* emission projection for the industrial sector. The *NEEAP/NREAP* (adjusted) energy forecast underpins the *With Additional Measures* emission projection.

Existing and planned policies and measures are listed, with the anticipated emissions savings estimated, in Table 5. These measures were included in the *Baseline* and *NEEAP/NREAP* (adjusted) energy forecasts and therefore the *With Existing Measures* and *With Additional Measures* emission projections.

Table 5. Emissions savings due to policies and measures included in the *With Existing Measures and With Additional Measures* scenarios for the industrial sector

Policy and measure	CO_2e (Gg)			
With Existing Measures				
	2020	**2025**	**2030**	**2035**
SEAI Large Industry Programme	356.73	356.73	356.73	356.73
CHP deployment	106.13	106.13	106.13	106.13
Accelerated Capital Allowance (ACA)	4.2	4.2	4.2	4.2
Renewable Heat	71.51	71.51	71.51	71.51
Carbon tax	132.26	132.26	132.26	132.26
Better Energy Workplaces	17.8	17.8	17.8	17.8
Total	**688.63**	**688.63**	**688.63**	**688.63**
With Additional Measures				
RES-H*	129.44	136.99	141.57	152.87
Buildings remainder	28.41	28.41	28.41	28.41
Total	**157.8**	**165.4**	**169.9**	**181.2**

*The projected rate of thermal energy sourced from renewable sources is 9 per cent (across the residential, commercial services and industrial sectors) by 2020 based on current forecasts. This is referred to as RES-H.

8.1. Projected greenhouse gas emissions in the Manufacturing Industries and Construction sector (IPCC sector 1.A.2)

Under the *With Existing Measures* emission projection, emissions from industrial combustion in this sector are projected to increase by 16.8 per cent between 2015 and 2020 while final energy demand is projected to increase by 19 per cent over the same period. Emissions in 2035 are projected to be 16.8 per cent higher than in 2020 with approximately 22 per cent increase in final energy demand in the sector over the same period.

Under the *With Additional Measures* emission projection, emissions from industrial combustion are projected to increase by 13.3 per cent whilst final energy demand increases by 19.5 per cent by 2020. The level of projected emissions under the *With Additional Measures* scenario is lower compared with the *With Existing Measures* scenario as a result of the additional policies and measures outlined in Table 5. In 2035 emissions from industrial combustion are projected to be 16.9 per cent higher than in 2020. Final energy demand increases by approximately 22 per cent over the same period.

9. Transport (1.A.3)

Transport emissions cover (i) Road Transportation (ii) Rail (iii) Domestic and International Aviation (iv) Navigation and (v) Other transportation (Pipeline Compressors). The *With Existing Measures* and *With Additional Measures* emissions projections for road transportation and gas transmission are based on the *Baseline* and *NEEAP/NREAP* energy forecasts (adjusted), respectively, published by SEAI. Energy forecasts for the aviation sector were developed separately in consultation with the relevant bodies i.e. individual Airport Authorities.

9.1. Domestic aviation (IPCC sector 1.A.3.a)

Forecasted data, where available, related to aircraft movements were provided to the EPA by the management authorities of Ireland's main airports (Dublin, Cork and Shannon). In terms of domestic aircraft movements from other minor airports in Ireland, they are assumed to remain static at 2015 levels for each year to 2035.

9.2. Road transportation (IPCC sector 1.A.3.b)

The Biofuels Obligation Scheme[15] places an obligation on suppliers of mineral oil to ensure that 6 per cent of the motor fuels (generally Gasoline and Motor Diesel) they place on the market in Ireland is produced from renewable sources, e.g. Ethanol and Biodiesel. The obligation was increased from the 1st January, 2013. It was previously 4 per cent. In the energy forecast underpinning the *With Existing Measures* emission projection for road transport, it is forecasted that renewables (biofuels) account for 5.5 per cent of road transport fuel in 2020 thus increasing from the 2015 level of renewables penetration (5.1 per cent).

In the energy forecast underpinning the *With Additional Measures* emission projection for road transport, it is assumed that renewables will account for 8 per cent of road transport fuel by 2020 (which includes the penetration of electric vehicles into the national car fleet) in line with the EU renewables target in Directive 2009/28/EC[16]. In addition, the impact of transport measures from the NEEAP[4] and NREAP[3] are included in NEEAP/NREAP energy forecast (risk adjusted) and therefore the *With Additional Measures* emission projection as appropriate. It is projected that the 8 per cent renewables in 2020 is largely maintained out to 2035. This falls short of the full NREAP 10 per cent target. Existing and planned measures to 2020 are listed with the anticipated emissions savings, as estimated by SEAI and the EPA in Table 6.

9.3 Rail (IPCC sector 1.A.3.c)

It is assumed that fuel use in the sector will remain constant at 2015 levels for each year out to 2035.

9.4. Navigation (IPCC sector 1.A.3.d)

Emissions from navigation have remained relatively static over the last number of years. Projected fuel combustion from navigation is assumed to be equal that combusted in the sector in 2015 for each projected year to 2035.

[15] http://www.dccae.gov.ie/energy/en-ie/Renewable-Energy/Pages/Biofuels.aspx
[16] DIRECTIVE 2009/28/EC. The promotion of the use of energy from renewable sources

Table 6. Emissions savings due to policies and measures included in *With Existing Measures* and *With Additional Measures* scenarios for the transport sector

Policy and measure	CO_2e (Gg)			
	2020	**2025**	**2030**	**2035**
With Existing Measures				
VRT and Motor Tax changes	172.1	172.2	172.2	172.2
Improved fuel economy of private cars	226.9	227.1	227.0	227.0
Public transport efficiency improvements	41.5	41.5	41.5	41.5
Aviation efficiency	66.4	66.5	66.5	66.5
Carbon tax	23.9	23.9	23.9	23.9
Renewables	430.6	490.1	484.5	477.6
Total	**961.4**	**1,021.3**	**1,015.6**	**1,008.7**
With Additional Measures				
Electric vehicle deployment	5.41	5.41	5.41	5.41
Natural gas transport savings between scenarios	7.59	8.69	9.33	10.83
RES-T*	193.83	218.71	216.7	214.17
Total	**206.83**	**232.81**	**231.44**	**230.41**

* Renewables (biofuels and electric vehicle deployment) will account for 8 per cent of road transport fuel by 2020

9.5. Other transport (IPCC sector 1.A.3.e)

Emissions in this sub-sector refers to the use of natural gas in pipeline compressor stations. Future gas demand for "own use and transformation" is inferred based on forecast gas demand in the residential, commercial and industrial sectors in both the *Baseline* and *NEEAP/NREAP* energy forecasts (adjusted). Subtracting the amount of gas estimated to be lost from the distribution network (reported in fugitive emissions section 12) allows "own use" gas demand and associated emissions to be estimated for the *With Existing Measures* and *With Additional Measures* scenarios.

9.6 Projected greenhouse gas emissions from the Transport sector (IPCC sector 1.A.3)

The main source of emissions from the transport sector is road transportation, accounting for 95.7 per cent of emissions in 2015. Under the *With Existing Measures* emission projection, emissions from transport are projected to increase by 12.2 per cent between 2015 and 2020. Emissions are projected to increase by 11.3 per cent between 2020 and 2035, the main driver being a projected increase of 11.4 per cent in diesel. Petrol consumption remains relatively stable in the period to 2020.

Under the *With Additional Measures* emission projection, emissions from transport are projected to increase by 10.5 per cent between 2015 and 2020. The lower level of increase in emissions relative to the *With Existing Measures* emission projections is primarily attributable to increased biofuel penetration and more efficient traffic movements projected to deliver additional savings. With respect to 2035, emissions are projected to increase by 11.3 per cent between 2020 and 2035. The RES-T share of 8 per cent for 2020 is largely maintained to 2035.

10. Commercial/Institutional/Services sector (IPCC sector 1.A.4.a)

The *Baseline* energy forecast underpins the *With Existing Measures* emission projection for the commercial services sector. The *NEEAP/NREAP* energy forecast (adjusted) underpins the *With Additional Measures* emission projection. Existing and planned policies and measures are listed, with the anticipated emissions savings, in Table 7. These measures were included in the *Baseline* and *NEEAP/NREAP* energy forecasts (adjusted) and therefore the *With Existing Measures* and *With Additional Measures* emission projections.

Table 7. Emissions savings due to policies and measures included in the *With Existing Measures* and *With Additional Measures* scenarios for the commercial services sector

Policy and measure	CO_2e (Gg)			
With Existing Measures				
	2020	**2025**	**2030**	**2035**
Public Sector Programme	285.3	285.3	285.3	285.3
2005 Building Regulations	313.5	313.5	313.5	313.5
SEAI Small Business Support	46.2	46.2	46.2	46.2
SEEEP and EERF	37.4	37.4	37.4	37.4
Accelerated Capital Allowance (ACA)	7.61	7.61	7.61	7.61
Public Sector Building Demonstration Programme	19.7	19.7	19.7	19.7
CHP deployment	44.2	44.2	44.2	44.2
Renewable Heat	29.7	29.7	29.7	29.7
Carbon tax	69.1	69.1	69.1	69.1
Better Energy Workplaces	47.7	47.7	47.7	47.7
Energy Supplier Obligation Scheme (non-residential)	243.4	243.4	243.4	243.4
Better Energy Communities	45.0	45.0	45.0	45.0
Total	**1188**	**1188**	**1188**	**1188**
With Additional Measures				
Buildings remainder	25.6	25.6	25.6	25.6
RES-H**	312.4	360.9	390.1	461.7
Total	**338**	**386.5**	**415.7**	**487.3**

* Supports for Exemplar Energy Efficient Projects (SEEEP) and Energy Efficiency Retrofit Fund (EERF)

** The projected rate of thermal energy sourced from renewable sources is 9 per cent (across the residential, commercial services and industrial sectors) by 2020 based on current forecasts. This is referred to as RES-H.

10.1. Projected greenhouse gas emissions from the Commercial Services Sector

Under the *With Existing Measures* emission projection, emissions from the commercial services are projected to increase by 10.9 per cent between 2015 and 2020 while final energy demand is projected to increase by 34.6 per cent over the same period. It is projected that emissions from the commercial service sector will increase by 24 per cent between 2020 and 2035 and energy demand will increase by 42.5 per cent over the same period.

Under the *With Additional Measures* emission projection, commercial services sector emissions are projected to decrease by 8.5 per cent as a result of the policies and measures outlined in Table 7. Between 2020 and 2035 emissions are projected to increase by 19.7 per cent.

11. Residential sector (IPCC sector 1.A.4.b)

The *Baseline* energy forecast underpins the *With Existing Measures* emission projection for the residential sector. The *NEEAP/NREAP* energy forecast (adjusted) underpins the *With Additional Measures* emission projection. Existing and planned policies and measures are listed, with the anticipated emissions savings in Table 8. These measures were included in the *Baseline* and *NEEAP/NREAP* energy forecasts (adjusted) and therefore the *With Existing Measures* and *With Additional Measures* emission projection.

Table 8. Emissions savings due to policies and measures included in the *With Existing Measures* and *With Additional Measures* scenarios for the residential sector

Policy and measure	CO_2e (Gg)			
With Existing Measures				
	2020	**2025**	**2030**	**2035**
2002 Building Regulations	443.0	443.0	443.0	443.0
2008 Building Regulations	160.3	160.3	160.3	160.3
2011 Building Regulations	50.9	50.9	50.9	50.9
Efficient Boiler Standard	142.6	142.6	142.6	142.6
Greener Homes Scheme	24.9	24.9	24.9	24.9
Warmer Homes Scheme	80.4	80.4	80.3	80.1
Better Energy Homes	285.1	285.0	284.9	284.4
Energy Supplier Obligation Scheme (residential)	177.7	177.6	177.2	175.5
Better Energy Communities	48.4	48.4	48.3	48.3
Carbon Tax	83.0	83.0	82.8	82.2
Total	**1496.3**	**1496.1**	**1495.2**	**1492.2**
With Additional Measures				
Buildings remainder	27.4	27.4	27.4	27.3
RES-H*	46.4	128.1	244.2	343.9
Total	**73.8**	**155.5**	**271.6**	**371.2**

* The projected rate of thermal energy sourced from renewable sources is 9 per cent (across the residential, commercial services and industrial sectors) by 2020 based on current forecasts. This is referred to as RES-H.

11.1. Projected greenhouse gas emissions from the Residential sector (IPCC sector 1.A.4.b)

Under the *With Existing Measures* emission projection, residential sector emissions are projected to increase by 1.5 per cent between 2015 and 2020 while final energy demand is projected to increase by approximately 8 per cent over the same period. Final energy demand in 2035 is projected to be 22.3 per cent above that in 2020, with an associated increase in emissions over the period by 5 per cent.

Under the *With Additional Measures* emission projection, in 2020 residential sector emissions are projected to be at approximately the same level as emissions in 2015 with a 10 per cent projected increase in energy demand in the same period. Savings are anticipated to be delivered through further energy efficiency measures and increased rate of thermal energy sourced from renewable sources. In 2035, residential sector emissions are projected to be at the same level as projected emission levels in 2020 with a 22 per cent projected increase in energy demand in the same period. Deeper penetration of renewable sources of energy in the sector facilitates the relatively stable level of projected emissions in this period.

12. Fugitive emissions from Fuels (IPCC sector 1.B.2)

Fugitive emissions of greenhouse gases cover those associated with natural gas distribution and production (1.B.2) and historical coal mining (1.B.1). In relation to natural gas distribution, ERVIA (formerly Bord Gais Éireann (BGE)), Ireland's gas company, assessed methane losses in the pipeline network in the context of the needs of annual greenhouse gas inventory reporting. A long-term programme to replace cast-iron mains with polyethylene pipe in all urban areas served by natural gas is underway. Projections made by BGE for five-year intervals from 2000 show losses decreasing to negligible amounts by 2020 on completion of the pipe replacement programme. Methane emissions from natural gas production relate largely to gas extraction.

In determining future emissions from domestic gas production, it is assumed that 3 per cent of gas demand in 2015 comes from domestic sources rising to 36 per cent in 2020 as a new gas field on the west coast of Ireland is exploited. Emissions associated with this level of gas production are calculated. Coal mining ceased in Ireland in 1995, however emissions can still occur. Emissions from this sector are estimated using the default methodology as presented in the 2006 IPCC Guidelines and follows the approach undertaken in the national greenhouse gas emission inventory.

13. Industrial Processes and Product Use (IPCC Sector 2)

Industrial Processes and Product use includes cement and lime production, other product use of carbonates, non-energy products from fuels and the use of fluorinated gases. Major industrial processes within the chemical sector and metal production are no longer undertaken in Ireland.

13.1. Mineral Industries (IPCC sector 2.A)

Process emission projections were developed for the cement and lime industries (2.A.1 and 2.A.2) and other process use of carbonates (2.A.4) only. Only one projected scenario was developed for these sectors. The other industrial process emission source glass production (2.A.3) is no longer undertaken in Ireland therefore projected emissions are not estimated. Projected emissions from the cement industries are estimated using projected GDP data which is one of the macroeconomic inputs to the SEAI energy forecasts. Projected emissions from lime production are assumed to remain at 2015 levels.

Process emissions from mineral industries are projected to increase by 18.2 per cent from 1.8 Mt of CO_2eq in 2015 to 2.1 Mt of CO_2e in 2020 under both the *With Existing Measures* scenario, and *With Additional Measures* scenarios. Emissions are projected to grow by 47.2 per cent between 2020 and 2035 to 3.1 Mt CO_2 eq.

13.2. Non-Energy Products from Fuels and Non-Energy Products from Fuels and Solvent Use (IPCC sector 2.D)

Emissions projections of CO_2eq from solvent use for the following activities were developed:

- Paraffin wax use (candles and other uses)
- Lubricant use
- Solvent use

Projected emissions from Paraffin wax use (candles and other uses) and Lubricant use are assumed to remain at 2015 levels.

Only one scenario was developed for solvent use which uses the rate of population growth in determining projected emissions. Emissions of CO_2eq from solvent use is projected to increase by 4.3 per cent between 2015 and 2020 to 83.69 Gg CO_2 eq and increases to 93.45 Gg CO_2 eq in 2035.

13.3. Fluorinated-gases (IPCC sector 2.E, 2.F, 2.G) and N_2O from Product Uses

Only one Fluorinated-gas emission projection outlook is developed and used in the two scenarios: *With Existing Measures* and *With Additional Measures*. Fluorinated gases accounted for 1.9 per cent of Ireland's total national greenhouse gas emissions in 2015. The relevant source of fluorinated gas emissions in Ireland is production, use and disposal of equipment containing these fluids (e.g. refrigerators, mobile air conditioning systems, metered dose inhalers and electrical switch-gear).

Projections were developed for four fluorinated gases: HFC, PFC, SF_6 and NF_3. In 2015, HFCs accounted for 94.2 per cent of total fluorinated gas emissions with 84.4 per cent of HFC emissions estimated to come from stationary refrigeration and air conditioning systems in vehicles. Perfluorinated compounds, used in semi-conductor manufacturing, accounted for 1.7 per cent of total fluorinated gas emissions in 2015 while SF_6 accounted for 3.8 and NF_3 accounted for less than 0.1 per cent.

Projections were developed for all four fluorinated gases and for all the sources reported in the national greenhouse gas inventory. Table 9 summarises the basis for developing projections for each F-gas from the relevant sector.

In the *With Existing Measures* and *With Additional Measures* emission projection, the impact of Directive 2006/40/EC[17] relating to emissions from air-conditioning systems in motor vehicles is estimated as a result of SI No. 127 of 2009[18] which came into effect in April 2009. The savings associated with the impact of Directive 2006/40/EC are included in the *With Existing Measures* and *With Additional Measures* scenario and are presented in Table 10. Under the *With Existing Measures* and *With Additional Measures* emission projections, fluorinated-gas emissions are projected to decrease by 19.8 per cent to 915.69 Gg CO_2eq between 2015 and 2020 and are estimated to reduce by 24.4 per cent between 2020 and 2035.

[17] Directive 2006/40/EC. Relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/15/EEC

[18] Statutory Instruments. S.I. No 127. European Communities (Motor Vehicles Type Approval) Regulations 2009

Table 9. Key assumptions underlying the F-gas projections

Sector	F-gases	Basis for projection
Refrigeration and air conditioning	HFC	Table 34 page 126 Emission Projections Guidelines
Mobile Air Conditioning (MAC)	HFC	Projected new car registrations and introduction of low (< 150) GWP fluids
Fire-extinguishers	HFC	Current disposal factor maintained with no net growth in the number of units installed as older units are replaced
Aerosols	HFC	Pro-rata basis using UK emission projections and UK and Irish population projections
Metered dose inhalers	HFC	Population projections and prevalence of asthma in the Irish population
Semi-conductor manufacture	HFC, PFC, SF_6 and NF_3	GDP
Electrical equipment	SF_6	Projected use and stock of SF_6 used in switchgear in the electricity transmission network provided by electricity distribution operator
Window sound-proofing	SF_6	Projections are based on the known current stock of SF_6 in installed windows, annual leakage and disposal factors
Medical Applications	SF_6	The use of SF_6 in Irish hospitals is assumed to remain constant at 2015 levels

Table 10. Emissions savings due to policies and measures included in the *With Existing Measures* and *With Additional Measures* scenarios for F-gases

Policy and measure	CO_2e Emission Saving (Gg CO_2e)			
	2020	2025	2030	2035
With Existing Measures* and *With Additional Measures				
Directive 2006/40/EC	65.8	123.1	206.6	229.3

14. Agriculture (IPCC sector 3)

Emissions projections for CH_4 and N_2O were developed for the agricultural sector. The agricultural activities of importance in Ireland are:

(i) enteric fermentation
(ii) manure management and
(iii) agricultural soils

The key sources of CH_4 emissions in the agricultural sector are enteric fermentation and manure management. The key sources of N_2O emissions are manure management and agricultural soils. Estimates of historical N_2O emissions from these sources are determined using a Tier 1 or default approach in the inventory. The same methodology is used in developing emission projections.

Two scenarios were developed for agricultural emission projections, a *With Existing Measures* scenario and a *With Additional Measures* scenario. Projected activity data (animal numbers, crop areas and fertiliser use) are provided by Teagasc (The Irish Agriculture and Food Development Authority) to the EPA in order to prepare agricultural emission projections. The emission projections discussed here are based on the activity supplied to the EPA in advance of emissions projections that were prepared in 2016. This includes the

proposed national herd, crop areas and fertilizer use to meet the overarching objectives of Food Wise 2025.

The FAPRI-Ireland model was used for preparing agricultural forecast data to underpin the emissions projections. This model is linked to the FAPRI world modelling system and so takes account of and contributes to, the projections for prices obtained and quantities traded on the world markets. The activity data assumes that there is an expansion in the value of Irish agriculture over the period to 2025 to meet the targets set out in "Food Wise 2025"[19] published by the Department of Agriculture, Food and the Marine in 2015. The main growth projections set out in this document are as follows:

- Increasing the value of agri-food exports by 85 per cent to €19 billion.
- Increasing the value added in the agri-food, fisheries and wood products sector by 70 per cent to in excess of €13 billion.
- Increasing the value of Primary Production by 65 per cent to almost €10 billion.

The *With Additional Measures* scenario includes an estimate of the savings associated with the introduction of nitrification and urease inhibitors in synthetic nitrogen fertilizer to meet nutrient efficiency gains in the Ireland's Rural Development Programme 2014-2020[20]. It is envisaged that under this measure that there will be reduction in the requirement for nitrogen fertilizer by 10,000 tons nitrogen in 2018, increasing linearly to 30,000 tonnes reduction in 2020 and which is maintained at that level thereafter to 2035.

14.1. Enteric Fermentation (IPCC sector 3.A)

The FAPRI-Ireland model provides projected livestock population data for dairy cows and 'other cattle' (i.e. dairy heifers, other heifers, cattle < 1 years, cattle 1-2 years, cattle > 2 years, bulls and beef cows).

Country specific CH_4 emission factors for Irish cattle were developed as part of an in-depth analysis of cattle production systems and associated animal feed and energy required to improve the reporting of CH_4 emissions in the national greenhouse gas inventory[21]. For dairy cows, CH_4 emission factors have been increasing by an average of 0.4 per cent per annum since 1990 which is primarily due to increasing milk yields. In developing the projections, it is assumed that the CH_4 emission factor for dairy cows continues to grow at 0.4 per cent per annum reflecting projected continuing growth in milk yields. For other cattle categories, emission factors are held constant at 2015 levels.

FAPRI-Ireland also provide projected animal population for sheep, swine, horses, mules and goats which allowed projected CH_4 emissions from these livestock categories to be calculated. The type of information used to derive Tier 2 CH_4 emission factors for cattle is not available for sheep, swine, horses, mules and goats. Therefore, IPCC default CH_4 emission factors are used, adjusted were necessary to reflect national circumstances (following the approach of the national inventory).

[19] Food Wise 2025. A 10-year vision for Irish agri-industry. Department of Agriculture, Food and the Marine, 2015. https://www.agriculture.gov.ie/foodwise2025/
[20] http://agriculture.gov.ie/ruralenvironment/ruraldevelopmentprogrammerdp2014-2020/
[21] "Development of Emission Factors for Enteric Fermentation from the Irish Cattle Herd". LS 5.1.1. Frank O'Mara. Environmental Protection Agency. (2006).

14.2. Manure Management (IPCC sector 3.B)

CH_4 Emissions

The decomposition of organic material in animal manures can be a source of CH_4 emissions if anaerobic conditions prevail in the animal waste management systems being used. The estimation of such emissions requires information on the quantity of manure produced from the animal groups concerned, the type of waste management systems employed and the CH_4 production potential of the wastes. Information obtained from a farm facilities survey[22], and the development of country specific emission factors for enteric fermentation in cattle, mentioned above, are the basis for CH_4 emission factors for manure management used in the greenhouse gas inventory. Emission factors over the projection period are assumed to follow 2015 levels. The calculation of CH_4 emissions from manure management of sheep, swine, horse and poultry were determined using projected animal numbers and IPCC default emission factors (as used in the inventory).

N_2O Emissions

Nitrous oxide emission projections from manure management (i.e. liquid systems, solid storage and dry lot, pit storage, deep bedding and pasture) were determined using information on the allocation of animal manures to different animal waste management systems (taken from the farm facilities survey and the national greenhouse gas inventory), nitrogen excretion rates (from the Department of Agriculture Food and the Marine and the national greenhouse gas emission inventory) and projected animal numbers. Projected N excretion rates follow last year's projections methodology, which are estimated for dairy cows based on projected feed intake and milk output contained in a dairy production roadmap for 2020 developed by Teagasc. Post 2020 nitrogen excretion from dairy cows is assumed to increase at 0.6 per cent per year. IPCC default emission factors were used to determine the amount of nitrogen that is lost as N_2O (following the approach of the national inventory).

14.3. N_2O Emissions from Agricultural Soils (IPCC sector 3.D)

Nitrous oxide is produced naturally in soils through the processes of nitrification and denitrification. It is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic nitrogen in the soil. Estimates of N_2O release from soils in the future is, therefore, based on human-induced net nitrogen additions to soils (e.g. synthetic or organic fertilisers, deposited manure, crop residues, sewage sludge).

Direct N_2O soil emissions are therefore calculated as the sum of

- Amount of fertiliser nitrogen applied to soils, adjusted for the amount that volatilises as NH_3 and NO_x. Projected synthetic nitrogen use was provided by Teagasc. Projected sludge production and the proportion applied on agricultural lands is taken from projected assumption in the treatment of wastewater (IPCC sectors 5.D.1 and 5.D.2).

[22] Farm Facilities Survey – Ireland 2003. Report prepared for the Department of Agriculture by Teagasc, Johnstown Castle.

- Amount of nitrogen fixed by nitrogen-fixing crops. Projected annual production of pulses was provided by Teagasc.
- Amount of nitrogen fixed in crop residues that is returned to the soils. Teagasc provided projected annual production of pulse, potatoes, barley, oats and wheat.

Indirect emissions of N_2O from agricultural soils also occurs through two routes. The first of these pathways is the volatilisation of nitrogen, as NH_3 and oxides of nitrogen (NO_x), following the application of synthetic and organic nitrogen fertilisers and/or manure deposition from grazing animals. These gases and their products are deposited onto soils and the surface of lakes and other waters. The second pathway is the leaching and runoff from land of nitrogen from, for example, synthetic and organic fertiliser additions and manure deposition from grazing animals. Where nitrate is present in the soil in excess of biological demand, e.g. under cattle urine patches, the excess leaches through the soil profile and can be transformed to N_2O.

Indirect N_2O emissions are therefore calculated as the sum of

- Emissions of N_2O from atmospheric nitrogen deposition and fraction of animal manure nitrogen and sewage sludge applied to agricultural land that volatilises.
- Emissions of N_2O from nitrogen leaching. This is assumed to be 10 per cent of available nitrogen and assumed to remain constant over the projection period.

14.4. Liming and Urea Application to agricultural soils (IPCC sectors 3.G and 3.H)

Liming (3.G) accounted for approximately 0.4 Mt CO_2 in 2015 as a result of the application of approximately 892 kilo tonnes of lime to agricultural soils in 2015. This level of application is 23 per cent lower than the peak amount applied in 2013. For each projected year it is forecasted that the application of lime to agricultural soils will be at least equal to the average application rate historically and result in emissions of 0.35 Mt CO_2 in 2020 and 2035 respectively.

Projected fertilizer use for agricultural soils is provided by Teagasc. However, no information is currently available in relation to the forecasted breakdown of fertilizer application by product type (i.e. calcium ammonium nitrate, urea etc.). It is thus assumed that the proportion of urea fertilizer in the latest inventory year (2015) is maintained for each projected year to 2035.

14.5. Projected greenhouse gas emissions from the Agriculture sector (IPCC sector 3)

In the *With Existing Measures* scenario total emissions from the agricultural sector are projected to increase by 4.9 per cent between 2015 and 2020 as a result of proposed national herd, crop areas and fertiliser use to meet overarching objectives of Food Wise 2025. Dairy cow numbers are projected to increase by over 7 per cent between 2015 and 2020. Fertilizer nitrogen use is projected to increase by 21 per cent between 2015 and 2020. By 2035 it is estimated that dairy cow numbers will have increased to 1.46 million head (15 per cent above 2015) and that fertilizer nitrogen use will be approximately 395,000 tonnes in 2035. There is projected to be a contraction in animal numbers in the less profitable other cattle sector between 2015 and 2020 and more significantly out to 2035. Projected emissions in 2035 are projected to be 19.5 Mt CO_2 eq in 2035 (1.5 per cent higher than 2015).

Under the *With Additional Measures* scenario projected total emissions will increase by 4.1 per cent between 2015 and 2020 (20.01 Mt CO_2 eq in 2020) and 0.7 per cent between 2015 and 2035 (19.36 Mt CO_2 eq in 2035).

Table 11. Emissions savings due to policies and measures included in the *With Additional Measures* scenario for the agriculture sector

Policy and measure	CO_2e Emission Saving (Gg CO_2e)			
	2020	2025	2030	2035
With Additional Measures				
Nitrogen use efficiency	156.7	156.7	156.7	156.7

15. Land Use, Land Use Change and Forestry (IPCC sector 4)

The Land Use, Land Use Change and Forestry sector includes greenhouse gas emissions and removals due to land use and land use change. It consists of six subcategories: Forest Land (4.A), Cropland (4.B), Grassland (4.C), Wetlands (4.D), Settlements (4.E) and Other Land (4.F). The 2015 submission under the MMR, was the first time that Ireland reported projections for the LULUCF sector. The approach taken in estimating greenhouse gas emission and removals from the sector utilises the approach used for the national greenhouse gas inventory in conjunction with a projected land use and land use change matrix developed with external consultants in 2014.

Emissions and removals from the sector follow a hierarchical approach in line with the GHG Projections Guidelines[2] (page 182 Grade 1 emission factors projections, Alternative 1 approach (emission factors for future years is based on the average of previous ten years). In Ireland, projected forest land areas are the most developed, followed by wetland areas and areas under settlement. Projected cropland and grassland areas are supplied by Teagasc in conjunction with the activity data supplied for the agriculture sector. The remaining land areas are assumed to remain constant for the projected time series.

15.1 Forest Land (IPCC sector 4.A)

Projected emission and removal estimates are undertaken for the following activities Forest Land remaining Forest Land (4.A.1) and Land converted to Forest Land (4.A.2), as well as for activities Forest Land converted to Grassland (4.C.2.1), Forest Land converted to Wetlands (4.D.2.1), Forest Land converted to Settlements (4.E.2.1) and Forest Land converted to Other Land (4.F.2.1), Information on projected afforestation and deforestation is provided by the Department of Agriculture, Food and the Marine[23].

15.2 Cropland and Grassland (IPCC sectors 4.B and 4.C)

This section covers both Cropland (CL) and Grassland (GL) land uses as these land uses are closely linked. Projected emission and removal estimates are undertaken for the following activities: Cropland remaining Cropland (4.B.1), Land converted to Cropland (4.B.2), Cropland remaining Grassland (4.C.1) and Land converted to Grassland (4.C.2). In addition, information in relation to Cropland converted to Forest Land (4.A.2.1), Cropland converted to Grassland (4.C.2.2), Cropland converted to Settlements (4.E.2.2), Grassland converted to Forest Land (4.A.2.2), Grassland converted to Cropland (4.B.2.2) and Grassland converted to Settlements (4.E.2.3) is also used.

[23] http://www.coford.ie/

15.3 Wetlands (IPCC sector 4.D)

Projected emission and removal estimates are undertaken for the following activities 4.D.1 (Wetland remaining Wetland) and 4.D.2 (Land converted to Wetland), as well as for activities 4.A.2.3 (Wetlands converted to Forest Land), 4.C.2.3 (Wetlands converted to Grassland) and 4.E.2.3 (Wetlands converted to Other). In addition it is expected that Bord na Mona[24],will exhaust their current peat reserves prior to 2030, therefore leading to land use change within this sector. The draft National Peatlands Strategy[25] details proposed future uses of peatlands and where relevant these proposed future land uses have been taken into account.

15.4 Settlements (IPCC sector 4.E)

As an initial approach the total area of Settlements (both remaining and in transition) has been estimated based on the GDP projections. Projected emission and removal estimates have been undertaken for the following 4.E.1 (Settlements remaining Settlements) and 4.E.2 (Land converted to Settlements). In addition it is assumed that as there is no land use change from Settlements to other lands in the historic national inventory estimates, that it will not occur into the future. The area under activity 4.E.1 is considered fixed, as in the historical series. Therefore, the increase in areas are disaggregated between the different land uses in 4.E.2 (Land converted to Settlements). Information in relation to deforestation of Forest Lands that convert to Settlements is already included in forest projections. The disaggregation between the remaining activities (4.E.2.2, 4.E.2.3 and 4.E.2.5) has been performed by applying the historical mix.

15.5 Other Land (IPCC sector 4.F)

Projected emission and removal estimates are undertaken for the following activities 4.F.1 (Other Lands remaining Other Lands) and 4.D.2 (Land converted to Other Lands), as well as for activities 4.A.2.5 (Other Lands converted to Forest Land) and 4.E.2.5 (Other Lands converted to Settlements). The only source of new Other Lands in the historical series is Forest Land. Deforestation of Forest Lands that convert to Other Lands are provided in forestry projections. In order to estimate the projection of the activity 4.F.1 (Other Land remaining Other Land), it is necessary to estimate the conversions from Other Lands to other land uses. Conversions to Settlements are already estimated and explained in the previous section on Settlements.

16. Waste (IPCC sector 5)

Emission projections for the waste sector are developed for CO_2, CH_4 and N_2O. Solid waste disposal to landfill (IPCC sector 5.A) is currently the main source of emissions from the waste sector. Methane emissions arise from (i) solid waste disposal in landfill sites and (ii) wastewater and sludge treatment (IPCC sector 5.D), whilst N_2O emissions also arise from the production of human sewage. In addition, CO_2, CH_4 and N_2O emissions arising from the incineration of hazardous wastes (solvents) in the pharmaceutical industry (IPCC sector 5.C) and the mechanical and biological treatment of waste (IPCC sector 5.B) are also estimated. The emissions associated with the incineration of municipal solid waste for electricity generation (WtE) are included in emissions estimates for electricity generation (IPCC sector 1.A.1.a). Only one scenario was developed for the waste sector.

[24] http://www.bordnamona.ie/
[25] https://www.npws.ie/sites/default/files/general/Final%20National%20Peatlands%20Strategy.pdf

16.1. Solid waste disposal in landfill sites (IPCC sector 5.A)

Methane is the important emission from solid waste disposal to landfill. This gas is emitted through the anaerobic decomposition of biodegradable municipal waste (BMW) which is disposed in solid waste disposal sites. Biodegradable municipal waste is produced largely by households and business. The principal biodegradable components of municipal waste are organic matter, including street cleansings, paper, textiles and wood.

The starting point for the estimation of emissions from BMW in landfill is to gain an understanding of the level of this 'active' waste that will go to landfill in the future and the composition of this waste. Progressive targets have been set out in the Landfill Directive[26] to reduce the proportion of BMW going to landfill. Ireland has met all Landfill Directive targets for diversion of biodegradable municipal waste from landfill to date.

The CH_4 production potential of biodegradable solid wastes is determined by the amount of degradable organic carbon (DOC) in the wastes, which in turn depends on the amount and composition of the waste material. The composition of BMW going to landfill in the future is estimated based on current fill rates, remaining void space at individual landfills and the allowable future intake of BMW at landfills.

The approach to determine CH_4 emissions from decomposing BMW is the 2006 IPCC Guidelines model and is the same as that used in compiling the annual greenhouse gas emission inventory. The relationship between CH_4 production and contributing waste deposited is based on a first-order decay model for landfill gas production which captures the diminishing rate of CH_4 production over a period of decades. The model is applied on a multi-phase basis, where data on waste composition are used directly to quantify the amount of the various constituents that produce DOC. The model contains ranges of default values for DOC content and CH_4 generation rate constant of the waste constituents from which values appropriate to national circumstances are selected. The one model is applied using activity data related to the total municipal solid waste that has historically been landfilled in addition to the total amount that is projected to be landfilled in remaining operating landfills out to 2035. It is assumed that the use of unmanaged sites for the receipt of waste stopped with the advent of waste licences for landfills circa 1998 and that all waste sent to landfill after this time and thus also for projected years is to managed sites. Emissions of CH_4 from landfill are minimised through landfill gas flaring and utilization for energy production. It is estimated that in 2015 there was 63 per cent methane recovery from solid waste disposal. It is assumed that the amount of landfill gas flared and utilised for energy production reaches 75 per cent by 2020 and is maintained at this level for each year to 2035. Policies and measures in the waste sector are listed, with the anticipated emissions savings estimated, in Table 12.

Table 12. Emission savings due to policies and measures included in the *With Existing Measures* and *With Additional Measures* scenarios for solid waste disposal at landfills (IPCC sector 5.A).

Policy and measure	CO_2e (Gg)			
	2020	2025	2030	2035
With Existing Measures* and *With Additional Measures				
Landfill Directive	80.5	313.4	420.8	491.9

[26] Council Directive 1999/31/EC on the landfill of waste.

16.2. CH4 Emissions from Wastewater and Sludge (IPCC sector 5.D)

Wastewaters can be a source of CH_4 when treated anaerobically. In compiling the annual greenhouse gas inventory, it is assumed that all domestic and commercial wastewaters (sent to municipal wastewater treatment plants, wastewater treated in septic tanks, and commercial wastewater either treated in municipal wastewater treatment plants or on site) are treated aerobically and therefore result in negligible CH_4 production. Therefore emissions projections were not developed for this sub-sector.

National studies[27] indicate the level of sludge produced in both industrial wastewater, domestic and commercial wastewater handling, including septic tanks, is treated anaerobically and therefore has the potential to produce CH_4. The projected amount of industrial organic sludge, domestic and commercial organic sludge produced in urban wastewater treatment plants is determined based on population projections. CH_4 emissions are calculated using IPCC default emission factors. Some of this sludge is sent to landfill and is accounted for in the estimate of degradable organic carbon that generates CH_4 in landfills. A portion of the sludge is also spread on agriculture lands where it contributes to N_2O emissions from soils described in the agricultural sector.

16.3. N2O Emissions from Human Sewage (IPCC sector 5.D)

Projections of N_2O emissions from human sewage were calculated based on population forecasts, typical protein intake, IPCC default proportion of the nitrogen content in protein and applying the default emission factors to obtain the quantity of nitrogen in sewage ultimately entering the atmosphere as N_2O.

16.4. Hazardous Waste incineration and open burning of waste (IPCC sector 5.C)

There are currently only a small number of facilities based in the pharmaceutical and chemical sectors that operate incinerators or thermal oxidisers for the treatment of hazardous waste, mainly for solvent or liquid/vapour destruction. The facilities that operate these units report emissions to the atmosphere to the EPA as part of licensing requirements. Estimates of the quantity of hazardous waste incinerated at the relevant facilities are determined from returns to the National Waste Database. It is assumed the quantities of hazardous waste incinerated remains constant at that reported for 2015 for each future year.

16.5. Mechanical and Biological Treatment of Waste (IPCC sector 5.B)

The mechanical treatment of waste aims to reduce the volume of waste disposed of by separating waste material into fractions that will undergo further treatment e.g. composting for organic waste, recycling for plastics etc. Mechanical treatment may also involve shredding and crushing of material.

Biological treatment of organic waste is a source of CH_4 and N_2O. Estimates are undertaken using the emission factors provided in the 2006 IPCC Guidelines and projected quantities of organic waste available for composting.

[27] O' Leary G., Carty G. (1998). Urban Waste Water Discharges in Ireland - *A report for the Years 1996 and 1997.*

16.6. Projected greenhouse gas emissions from the Waste Sector

Emissions are projected to decrease by 36.1 per cent between 2015 and 2020. Emissions in 2035 are projected to be 26.1 per cent lower than in 2020 at 0.45 Mt CO_2 eq. Emissions from solid waste disposal at landfill are projected to decrease by 47.8 per cent between 2015 and 2020 and 49.8 per cent between 2020 and 2035.

17. Sensitivity analysis

The SEAI and ESRI undertook a sensitivity analysis of the *Baseline* energy forecast (which underpin the *With Existing Measures* emissions projection). Details of the assumptions used in the sensitivity analysis are presented in Table 12. Underlying fuel prices are based on the EU Reference Scenario 2016 values as circulated by the Commission in 2016 (recommended harmonised values for key supra-nationally determined parameters). The ETS EU Carbon Price is the same as what was used in the emissions projections.

For the agriculture sector the sensitivity analysis undertaken assumes a reduction in the national herd (dairy and other cattle) in the *With Existing Measures* scenario by 10 per cent.

The 2012 national waste statistics report[28], provides details of municipal waste that is exported for recovery in incinerators abroad. In the sensitivity analysis it is assumed that a quantity of extra waste material is disposed of in solid waste disposal sites in Ireland as opposed to being exported for recovery in incinerators abroad. For the sensitivity scenario it is assumed that an additional 350,000 tonne of municipal waste requires management in landfills for each future year. This represents an almost 80 per cent increase in the quantity of municipal waste landfilled in 2020.

Table 13. Key assumptions underpinning the energy forecasts sensitivity analysis

	2016-2020	2021 – 2025	2026-2030	2031-2035
	Average Annual % Growth			
GDP	3.0%	2.1%	1.9%	1.9%
GNP	2.6%	2.1%	1.3%	1.3%
Personal Consumption	2.7%	1.4%	0.4%	0.4%
	2016	**2020**	**2025**	**2030**
Housing Stock ('000)	1,967	2,016	2,068	2,104
Population ('000)	4,674	4,834	5,027	5,209
EUETS: Carbon $€_{2013}/tCO_2$	9	15	22.5	33.5
Carbon tax $€_{2013}/tCO_2$	18.3	15	22.5	33.5
Coal $\$_{2013}$/boe	13.4	16.6	21.4	26.0
Oil $\$_{2013}$/boe	59.7	87.2	106.3	118.9
Gas $\$_{2013}$/boe	45.4	56.2	65.2	72.0
Peat €/MWh	25	25	25	25

Sectoral and overall results of the sensitivity analysis split on emissions covered by Decision 406/2009/EC and total emissions included in the scope of the Union's emissions trading scheme established by Directive 2003/87/EC are provided in Tables 14 and 15. In comparison with Table 3, there are marked differences in fuel prices in Table 13, in particular oil prices, with oil prices in the sensitivity analysis substantially higher than those used in the emission projections (e.g. $106.3/boe in 2025 in the sensitivity analysis

[28] http://www.epa.ie/pubs/reports/waste/stats/EPA_NWR12_Complete_to_web_5Aug14.pdf

compared to €62.8/boe in the emissions projections) which inter alia will lead a decrease in emission levels in some sectors (e.g. Transport). Coal and gas prices are also significantly higher in the Sensitivity scenario. Lower economic growth is assumed in the sensitivity with a per annum increase in GDP of 3 per cent compared to 3.7 per cent in Table 3 in the period 2016-2020. Reduced economic growth is also evident in annual average growth in personal consumption in the sensitivity analysis.

In terms of ETS emissions, overall total emission levels are higher in the sensitivity scenario which is mainly driven the energy industries sector (e.g. power generation) for the years 2020, 2025 and 2030 as shown in Table 13. All other ETS sector emissions are lower in the sensitivity scenario.

In line with lower economic growth the resultant emission levels as presented in Table 14 show that total Non-ETS emissions under the *Sensitivity* scenario are approximately 8 per cent, 12 per cent, 13 per cent and 14 per cent lower in 2020, 2025, 2035 and 2035, respectively than emissions in the *With Existing Measures* scenario. Reductions in emissions are particularly notable in the Manufacturing Industries and Construction, Transport Commercial/Institutional sectors. In addition reductions in emissions in the agricultural sector amount to approximately 7.5 per cent lower in the years shown. For the waste sector the management of an additional 350,000 tonnes of municipal waste per annum in solid waste disposal sites leads to a 7 per cent, 13.6 per cent, 18.9 per cent and 23.4 per cent increase in emissions from the waste sector in 2020, 2025, 2030 and 2035 respectively.

Table 14. Results of sensitivity analysis –ETS emissions (Gg CO_2 eq)

	***With Existing Measures* ETS**			
	2020	**2025**	**2030**	**2035**
Energy Industries	9766.6	11085.2	12336.3	14054.0
Manufacturing Industries and Construction	3942.4	4007.3	4135.4	4605.9
Transport	14.1	16.0	17.1	19.8
Commercial/Institutional	28.3	31.2	32.9	35.1
Industrial Processes and Product Use	2163.0	2506.2	2823.9	3184.8
Total	**15914.4**	**17645.9**	**19345.5**	**21899.7**
	***With Existing Measures* Sensitivity ETS**			
	2020	**2025**	**2030**	**2035**
Energy Industries	12479.6	13650.8	14587.9	15663.9
Manufacturing Industries and Construction	2759.1	2827.7	2905.1	2993.5
Transport	9.7	10.6	11.7	12.3
Commercial/Institutional	23.4	25.1	25.8	27.2
Industrial Processes and Product Use	2093.5	2303.4	2523.2	2765.9
Total	**17365.4**	**18817.6**	**20053.7**	**21462.8**
	% Difference			
	2020	**2025**	**2030**	**2035**
Energy Industries	27.8%	23.1%	18.3%	11.5%
Manufacturing Industries and Construction	-30.0%	-29.4%	-29.8%	-35.0%
Transport	-31.2%	-33.4%	-31.9%	-37.8%
Commercial/Institutional	-17.2%	-19.7%	-21.4%	-22.5%
Industrial Processes and Product Use	-3.2%	-8.1%	-10.6%	-13.2%
Total	**9.1%**	**6.6%**	**3.7%**	**-2.0%**

Table 15. Results of sensitivity analysis Non-ETS emissions (Gg CO_2 eq)

	***With Existing Measures* Non ETS**			
	2020	**2025**	**2030**	**2035**
Energy Industries	448.4	477.5	490.7	507.5
Manufacturing Industries and Construction	1369.2	1391.8	1436.3	1599.7
Transport	13254.3	15045.5	14905.6	14750.9
Commercial/Institutional	1901.8	2099.1	2207.1	2357.6
Residential	6134.6	6344.2	6368.5	6444.3
Agriculture/Forestry/Fishing	633.2	674.4	709.5	775.2
Fugitive Emissions from Fuels	24.1	22.4	20.9	19.4
Industrial Processes and Product Use	1080.4	1006.0	895.8	870.7
Agriculture	20167.0	20128.9	19603.4	19519.9
Waste	622.6	546.7	499.7	459.9
Total	**45635.6**	**47736.3**	**47137.5**	**47305.0**
	***With Existing Measures* Sensitivity Non ETS**			
	2020	**2025**	**2030**	**2035**
Energy Industries	446.3	464.4	479.0	496.2
Manufacturing Industries and Construction	958.3	982.1	1009.0	1039.7
Transport	11657.9	12038.5	11591.8	11408.2
Commercial/Institutional	1574.9	1686.6	1735.2	1828.2
Residential	6327.2	6177.8	6044.4	5804.0
Agriculture/Forestry/Fishing	525.3	556.4	579.8	647.9
Fugitive Emissions from Fuels	24.0	22.3	20.8	19.3
Industrial Processes and Product Use	1076.8	998.7	887.5	859.1
Agriculture	18640.7	18601.4	18123.2	18046.4
Waste	666.1	620.8	593.9	567.6
Total	**41897.4**	**42149.1**	**41064.6**	**40716.4**
	% Difference			
	2020	**2025**	**2030**	**2035**
Energy Industries	-0.5%	-2.7%	-2.4%	-2.2%
Manufacturing Industries and Construction	-30.0%	-29.4%	-29.8%	-35.0%
Transport	-12.0%	-20.0%	-22.2%	-22.7%
Commercial/Institutional	-17.2%	-19.7%	-21.4%	-22.5%
Residential	3.1%	-2.6%	-5.1%	-9.9%
Agriculture/Forestry/Fishing	-17.0%	-17.5%	-18.3%	-16.4%
Fugitive Emissions from Fuels	-0.4%	-0.5%	-0.6%	-0.7%
Industrial Processes and Product Use	-0.3%	-0.7%	-0.9%	-1.3%
Agriculture	-7.6%	-7.6%	-7.6%	-7.5%
Waste	7.0%	13.6%	18.9%	23.4%
Total	**-8.2%**	**-11.7%**	**-12.9%**	**-13.9%**