Ireland's National Greenhouse Gas Emissions Projections 2010

Methodological Approach

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1. Introduction

This report describes the methodology underpinning the development of Ireland's greenhouse gas emissions projections for the period up to 2020.

The National Climate Change Strategy (2007)[1] designated the 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, published in 2010, for the period up to 2020.

Emission projections are required for the greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). 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 were developed.

Table 1. Source and sink category for emission projections

Source and sink category	CO_2	CH_4	N_2O	HFC	PFC	SF_6
Agriculture						
Enteric Fermentation	-	x	-	-	-	-
Manure Management	-	x	x	-	-	-
Soils	-	-	x	-	-	-
Indirect Emissions	-	-	x	-	-	-
Agricultural Fuel Use	x	x	x	-	-	-
Energy						
Power Generation	x	x	x	-	-	-
Oil Refining	x	x	x	-	-	-
Peat Briquetting	x	x	x	-	-	-
Fugitive Emissions	-	x	-	-	-	-
Transport						
Road Transport	x	x	x	-	-	-
Domestic Aviation	x	x	x	-	-	-
Rail Transport	x	x	x	-	-	-
Navigation	x	x	x	-	-	-
Industry						
Industrial Energy Use	x	x	x	-	-	-
Process Emissions	x	-	-	-	-	-
F-gases	-	-	-	x	x	x
Solvent Emissions	x	-	-	-	-	-
Residential	x	x	x	-	-	-
Commercial/Institutional	x	x	x	-	-	-
Waste Management						
Solid Waste Disposal in Landfill	-	x	-	-	-	-
Waste Incineration	**x**	**x**	**x**	-	-	-
Sewage Sludge	-	x	-	-	-	-
Human Sewage	-	-	x	-	-	-
Forestry sinks	x	-	-	-	-	-

[1] National Climate Change Strategy 2007-2012. Department of Environment, Heritage and Local Government. (2007).

2. Energy Forecasts

Sustainable Energy Ireland (SEI) publish annual national energy forecasts showing energy trends up to 2020. These energy forecasts, most recently published in 2009[2], form the basis for almost all energy-related emission projections reported here.

Sustainable Energy Ireland published three energy forecasts, two of which are used in national emission projections: *Baseline* and *White Paper Plus*.

- The *Baseline* energy forecast projects forward Ireland's energy demand, incorporating the expected impacts of policies and measures that were in place (legislatively provided for) by the end of 2008. It excludes policies that are committed to but which do not yet have measures in place to deliver them.
- The *White Paper Plus* energy forecast presents an alternative view of future energy demand that may occur, if the key targets and measures contained in the Energy White Paper[3], the National Energy Efficiency Action Plan (NEAAP)[4] and the Programme for Government are met. Therefore this forecast includes existing *and* planned policies and measures.

The *Baseline* energy forecast underpins the *With Measures* emission projection and the *White Paper Plus* energy forecast underpins the *With Additional Measures* projection.

The *Baseline* energy forecast is produced by the Economic and Social Research Institute (ESRI) for SEI using an energy demand model which is linked to the ESRI's macroeconomic model, HERMES. The energy forecast is generated at an aggregated top-down sectoral level and the key variables relate to parameters such as price, economic growth, population, household growth and occupancy. To produce the finalised *Baseline* energy forecast, SEI amends the output of the HERMES energy demand model to take account of the expected impact of energy efficiency measures put in place before the end of 2008 but which are considered too recent to be detectable in any time-series analysis. The *White Paper Plus* energy forecast builds on the *Baseline* forecast with adjustments made to account for additional policies and measures outlined in the Energy White Paper[3], the National Energy Efficiency Action Plan (NEAAP)[4] and the Programme for Government. A detailed description of the methodology behind the development of the energy forecasts is given in the 2009 SEI energy forecasts report[2] and a detailed description of the HERMES model and associated energy demand model is provided in an ESRI Working Paper[5].

The energy forecasts that underpin the energy-related emissions projections are based on the ESRI's *World Recovery* scenario[6] in which Ireland experiences a sharp economic decline during 2009, an assumed further small decline during 2010 and modest growth in 2011-2020. Table 2 shows the key parameters underlying the *World Recovery* scenario and therefore the *With Measures* and *With Additional Measures* emissions projections. The forecasts are based on oil price assumptions consistent with the price assumptions underpinning EU DG-TREN's most recent

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[2] Energy Forecasts for Ireland to 2020. Sustainable Energy Ireland. (2009).
[3] Delivering a Sustainable Energy Future for Ireland 2007-2020. Department of Communications, Marine and Natural Resources. (2007).
[4] Maximising Ireland's Energy Efficiency. The National Energy Efficiency Action Plan 2009-2020. Department of Communications, Energy and Natural Resources (2009)..
[5] A complete description of the energy model is available in ESRI Working Paper 146.
[6] Economic and Social Research Institute Research Series 007 'Recovery Scenarios for Ireland' (2009)

forecast for EU-27 based on the PRIMES model. For the period 2009-12, CO_2 prices are based on the EU Allowance futures market prices prevailing in Q4 2009. For the period 2013 onwards, they are based on shadow carbon prices in current Department of Finance guidelines.

Table 2. Key assumptions underpinning the energy forecasts[1]

	Growth Rate (% per annum)			Average Annual Growth Rates	
	2008	**2009**	**2010**	**2010-2015**	**2015-2020**
GDP	-3.0	-7.8	-2.3	5.2%	3.3%
GNP	-2.7	-9.0	-1.9	5.5%	3.3%
Personal Consumption	-1.0	-6.9	-2.9	2.8%	4.0%
	2008	**2009**	**2010**	**2015**	**2020**
No. of households ('000)	1,560	1,585	1,606	1,756	1,931
No. of persons per household	2.8	2.8	2.8	2.6	2.5
Fuel Prices and CO_2 price assumptions					
	2008	**2009**	**2010**	**2015**	**2020**
CO_2 €/tonne	23.84	13.83	14.54	20.74	30.74
Coal (€/tonne)	49.50		55.68	67.28	78.89
Oil (€/barrel)	65.3		33.9	56.0	68.2
Gas (€/MWh)	25.8		17.7	21.3	26.2

2.1. Energy related emissions

The energy forecasts published in 2009[2], which are based on the 2008 energy balance[7], form the basis for the majority of energy-related emissions projections namely:

- Power generation
- Road transport
- Industrial combustion
- Residential
- Commercial services and
- Fuel use in the agricultural sector.

Emissions from these sectors accounted for 98.9% of energy-related emissions in 2008. Emission projections for the remaining energy sectors (i.e. oil refining, peat briquetting, fugitive emissions, rail transport, domestic aviation and navigation) are calculated separately and are based on data provided by operators and from EPA databases.

2.2. Non-energy related emissions

Non-energy related emissions cover the following sectors:

- Agriculture
- Waste
- Industrial processes
- F-gases and
- Non-methane volatile organic compounds (NMVOCs)

[7] Energy in Ireland 1990-2008 (2009 Report). Sustainable Energy Ireland (2009)

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

2.3. Emission Factors

In general, CO_2, CH_4 and N_2O emission factors are derived based on historical emission inventories (1990-2008). These are either plant specific, country specific or default emission factors.

Carbon dioxide emissions from the combustion of biogenic carbon are not included in the calculation of projected emissions (in accordance with IPCC Guidelines[8] for compiling greenhouse gas inventories). Methane and N_2O emissions are estimated and included in the emission projections using IPCC default emission factors.

In calculating emissions from natural gas, it is assumed that imported gas meets 96% of gas demand in 2010 (imported gas is more carbon intensive than domestic sources). In 2015 and onwards, it is assumed that 50% of gas demand is met by domestic sources and 50% is imported.

2.4. Policies and Measures

Emissions projections are developed under two scenarios; *With Measures* and *With Additional Measures*. As stated, the *With 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 2008. The *Baseline* in the 2009 energy forecasts differs from that produced in 2008 in that the forecasts are calibrated to a further year's historical data, and new energy efficiency measures introduced in 2008 have led to energy savings, notably, the 2008 Building Regulations, private car taxation changing to an emissions-based system and the Home Energy Savings Scheme. These measures amongst others are incorporated into the *Baseline* forecast and associated emission savings are reported in the relevant sections of this document.

The *With Additional Measures* includes existing measures *and* planned policies and measures and is based on the *White Paper Plus* energy forecast. Sustainable Energy Ireland included planned policies and measures from the Energy White Paper[3], the National Energy Efficiency Action Plan[4] and Programme for Government by subtracting the necessary energy savings from the *Baseline* energy forecasts to give the *White Paper Plus* energy forecast. These measures and associated emission savings, as calculated by SEI, are reported in the relevant sections of this document.

2.5. Emissions Trading

The impact of emissions trading in the power generation sector was included in the energy forecasts underlying the emissions projections by including a price for carbon in the ESRI's electricity dispatch model[9] (see Table 3 for carbon price assumptions).

Under both *With Measures* and *With Additional Measures* emissions projections, combined emissions from all ETS sectors are projected to be below the annual allocation of allowances that installations received under the second National Allocation Plan. This is as a result of the projected slow-down in economic growth over the short-term. In addition, the *White Paper Plus* energy forecast (and therefore

[8] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy. Chapters 2 & 3.
[9] http://www.esri.ie/research/research_areas/energy/idem/

With Additional Measures scenario) assumes the achievement of ambitious renewable targets.

3. Energy

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

3.1. Power Generation

Power generation covers all electricity generation including electricity generated from renewable sources. The ESRI's electricity dispatch model[9] was used to determine the fuel mix for electricity generation and forms the basis for projecting emissions from this sector.

In the *Baseline* energy forecast (and therefore the *With Measures* emissions scenario) the renewable energy contribution to Ireland's gross electricity consumption increases from 11.4% in 2008 to 20.3% in 2010 and 26.7% in 2020. Wind generation is projected to grow strongly between 2008 and 2012, at 8.3%, reflecting increased capacity, but slows to 4.2% following this period in line with the conclusion of Gate 2[10] . Wind is projected to deliver 85% of renewable energy in 2020. Hydro and biomass generation remain relatively static over the period, with close to zero annual growth rates. Hydro is projected to deliver 12% of renewable electricity in 2020 and biomass is projected to deliver 3%. In relation to peat, the Public Service Obligation (PSO) supports for the peat-burning power stations at Edenderry runs out in 2015 and in 2019 for the ESB plants which impacts on their dispatch merit and results in a lighter running duty. This results, in particular, in a significant reduction (94%) in peat consumption in 2020 which subsequently impacts on emissions in that year. Plant commissioning and decommissioning is assumed according to previously announced timetables. In addition, from 2012 onwards, the impact of a new 500MW interconnector linking Wales to the Republic of Ireland is included.

In the *White Paper Plus* energy forecast (and therefore the *With Additional Measures* emissions scenario) it is assumed that 21% Ireland's gross electricity consumption comes from renewable energy by 2010 increasing to 41% by 2020. This is consistent with the amended Energy White Paper targets on the achievement of renewables penetration (including biomass co-firing) and power generation fuel diversity targets. In this scenario, wind is assumed to deliver 65% of renewable electricity in 2020, followed by biomass (17%), ocean energy (11%) and hydro (8%). In relation to peat, consumption is projected to be significantly higher in 2020 in comparison with the *With Measures* scenario which reflects the impact of co-firing of peat with biomass. As biomass co-firing targets are assumed to be met under the *With Additional Measures* scenario, the consumption of peat and therefore emissions increases in 2020 relative to the *With Measures* scenario. Emissions attributable solely to combustion of peat in 2020 are 1.6 Mtonnes of CO_2e higher under the *With Additional Measures* scenario. This is a significant policy finding whereby it appears that increasing renewables consumption in terms of biomass co-firing with peat may actually result in higher emissions through increased peat consumption and cancel out savings from the increased penetration of other renewables on the system. In addition, in this scenario, it is assumed that there will be a 20% improvement in

[10] Since December 2004 renewable generators wishing to connect to the transmission or distribution systems have been subject to group processing of connection applications through a series of successive "Gates". There have been two Gates to date. Gate 1 was finalised in December 2004 and processed applications equating to 373 MW of renewable capacity. The principles and criteria for Gate 2 were finalised in June 2006. Gate 2 could potentially see a further 1300 MW of renewable generation capacity connected to the system.

energy efficiency by 2020, as outlined in the Energy White Paper[3], which will reduce demand for electricity from all sectors.

The impact of existing and planned policies and measures that will impact the power generation sector are listed in Table 3 with the anticipated emissions savings.

Table 3. Emissions savings due to policies and measures included in the *With Measures* and *With Additional Measures* scenarios for the power generation sector

Policy and measure	CO_2e (ktonnes)		
	2010	**2015**	**2020**
With Measures			
Transmission and distribution efficiencies improvement	65	68	72
CHP	65	92	114
Winter Peak Demand Reduction Scheme	13	13	13
Renewables Penetration in line with Gate 2	1345	1714	2041
Total	**1488**	**1887**	**2240**
With Additional Measures			
40% renewables by 2020	7	373	971
Reduced electricity demand from energy efficiency measures	202	941	-994
Total	**209**	**1314**	**-23**

In quantifying the impact of renewable energy penetration in terms of CO_2e emissions avoided, it is assumed that renewable energy displaces gas-fired electricity generation.

3.2. Oil refining and solid fuel manufacture

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 SEI's energy forecasts.

The oil refining sector in Ireland consists of a single installation at Whitegate in Cork. Carbon dioxide emission projections, provided by the operator Conocco Phillips, are based on assumptions about future product specifications, crude oil qualities and market demand.

Bord na Móna Fuels Limited produce a range of peat based fuels for domestic and industrial customers. Carbon dioxide emissions projections for these operations were provided by Bord na Móna to the EPA.

3.3. Fugitive Sources

Fugitive emissions of greenhouse gases cover those associated with natural gas distribution and production. In relation to natural gas distribution, Bord Gas 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 zero 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 4% of gas demand in 2010 comes from domestic sources. This is assumed to increase to 50% in 2015. Emissions associated with this level of gas production are calculated.

3.4. Energy Industries Sector Emissions

The main source of emissions from the energy industries sector is power generation, accounting for 96.3% of emissions from this sector in 2008.

Under the *With Measures* emission projection, emissions from power generation are projected to decrease by 33.5% between 2008 and 2020 while demand for electricity is projected to increase by 10.7% over the same period. The decline in emissions is attributable to new and increasingly efficient power plants coming on-line, the increased deployment of renewable energy in electricity generation in line with Gate 2 and the decline of oil-based electricity generation. In addition, electricity imports are assumed to contribute approximately 4.0% of our energy supply by 2020.

Under the *With Additional Measures* emission projection, emissions from power generation are projected to decrease by 33.2% between 2008 and 2020 while electricity demand is projected to increase by 6.3% over the same period. Increased combustion of peat, as a result of co-firing, in 2020 is offsetting the emissions savings outlined in Table 3.

4. Transport

Transport emissions cover (i) road transportation (ii) rail (iii) aviation (iv) navigation and (v) gas transmission. The *With Measures* and *With Additional Measures* emissions projections for road transportation and gas transmission are based on the *Baseline* and *White Paper Plus* energy forecasts, respectively, recently published by SEI[2]. Energy forecasts for the rail and aviation sectors were developed separately in consultation with the relevant bodies i.e. Irish Rail and Dublin Airport Authority.

4.1. Road transportation

In the energy forecast underpinning the *With Measures* emission projection for road transport, it is assumed that renewables will account for 3.0% of road transport fuel by 2010 (with biofuels making the largest contribution and the use of renewable electricity in electric vehicles a smaller contribution). Biofuels penetration is assumed to be delivered through the Mineral Oil Tax Excise Relief Scheme (MOTR). Biofuels in transport increased from 1.1 ktoe in 2005 (0.02%) to 55.5 ktoe in 2008 (1.2%) and is forecast to be 134.6 ktoe in 2010 (3.0%). This represents an increase of 142% in demand for biofuels between 2008 and 2010 which shows the extent of the challenge required to meet targets on biofuel penetration,

In the energy forecast underpinning the *With Additional Measures* emission projection for road transport, it is assumed that renewables will account for 10% of road transport fuel by 2020 (which includes 10% electric vehicle penetration) in line with the EU renewables target in Directive 2009/28/EC[11]. This is called the RES-T target in the Energy White Paper[3]. In addition, the impact of transport measures from the National Energy Efficiency Action Plan (NEEAP)[4] are included in the *Baseline* and *White Paper Plus* energy forecast and therefore the *With Measures* and *With Additional Measures* emission projection as appropriate. These existing and planned measures are listed with the anticipated emissions savings, as estimated by SEI, in Table 4.

Table 4. Policies and measures included in *With Measures* and *With Additional Measures* emission projections for the road transport sector

Policy and measure	CO_2e (ktonnes)		
	2010	**2015**	**2020**
With Measures			
VRT and Motor Tax Changes linked to CO_2	9	31	53
Improved fuel economy	68	237	407
Total	**77**	**268**	**459**
With Additional Measures			
Efficient Driving Campaign	29	102	172
Mobility Management and Travel Plans	48	169	287
More Sustainable Public Transport Fleets	4	14	24
E-working+	7	23	39
Electric vehicle deployment	42	148	251
RES-T*	0	413	861
Additional Measures	0	52	184
Total	**130**	**921**	**1,818**

* Renewables (biofuels and 10% electric vehicle deployment) will account for 10% of road transport fuel by 2020

[11] DIRECTIVE 2009/28/EC. The promotion of the use of energy from renewable sources

4.2. Rail

Projected fuel usage in the rail sector was provided by Irish Rail to the EPA. They estimated that fuel use in the rail sector will decrease between 2008 and 2009 and remain constant thereafter. The decrease is due to the introduction of new intercity railcars during 2008 which have smaller more fuel efficient engines.

4.3. Domestic aviation

The forecast number of annual domestic landing and takeoff (LTO) cycles up to 2020 were provided in 2009 to EPA by Dublin Airport Authority (DAA). These show LTO cycles decreasing by 11% in 2009, a further 1.5% in 2010, 0.5% in 2011 and 0.3% in 2012. Growth is assumed to return post 2012 as the economy recovers with an average growth rate of 3.7% per annum between 2013 and 2020. It is assumed that LTO cycles for Shannon and Cork airports follow the same trend as those of Dublin airport.

4.4. Navigation

Emissions from navigation have remained relatively static between 2003 and 2008. Energy use, and subsequently greenhouse gas emissions, are projected forward assuming that they remain at 2008 levels for each year out to 2020.

4.5. Gas Transmission

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 *White Paper Plus* energy forecasts. Subtracting the amount of gas estimated to be lost from the distribution network (reported in fugitive emissions above) allows “own use” gas demand and associated emissions to be estimated.

4.6. Transport Sector Emissions

The main source of emissions from the transport sector is road transportation, accounting for 97.0% of emissions in 2008.

Under the *With Measures* emission projection, emissions from road transport are projected to increase by 25.7% between 2008 and 2020 which implies an annual average growth rate of 2.0%. This compares to an annual average growth rate of 5.8% between 1990 and 2008. The growth in emissions from road transport is projected to slow significantly as a result of a projected slow-down in the economy. In addition, the penetration of biofuels is assumed to reach 3% by 2010.

Under the *With Additional Measures* emission projection, emissions from road transport are projected to increase by 12.6% between 2008 and 2020 which implies an annual average growth rate of 1.0%. The decline in emissions relative to the *With Measures* emission projections is primarily attributable to increased biofuel penetration with the roll out of electric vehicles and mobile management and travel plans also projected to deliver significant savings.

5. Residential

The *Baseline* energy forecast underpins the *With Measures* emission projection for the residential sector. The *White Paper Plus* energy forecast underpins the *With Additional Measures* emission projection.

Existing and planned policies and measures are listed, with the anticipated emissions savings in Table 5. These measures were included in the *Baseline* and *White Paper Plus* energy forecasts and therefore the *With Measures* and *With Additional Measures* emission projection.

Table 5. Policies and measures included in the *With Measures* and *With Additional Measures* emission projections for the residential sector

Policy and measure	CO_2e (ktonnes)		
	2010	**2015**	**2020**
With Measures			
2008 Building Regulations	31	287	591
Home Energy Saving Scheme	112	142	148
Efficient Boiler Standard	96	332	570
Total	**239**	**760**	**1,309**
With Additional Measures			
2010 Building Regulations	0	113	261
Low Carbon Homes 2013	0	26	94
RES-H*	28	79	153
Further potential measures**	0	204	734
Total	**28**	**422**	**1,242**

* The Energy White Paper target for thermal energy sourced from renewable sources is 12% (across the residential, commercial services and industrial sectors) by 2020. This is referred to as RES-H.
** SEI report that these are further measures that are required, but which have not yet been identified, to bring energy savings in line with the 20% energy efficiency target.

5.1. Residential Sector Emissions

Under the *With Measures* emission projection, residential sector emissions are projected to decrease by 3.9% between 2008 and 2020 while final energy demand is projected to increase by 1.8% over the same period.

Under the *With Additional Measures* emission projection, residential sector emissions are projected to decrease by 20.3% as a result of the policies and measures outlined in Table 5. The largest savings in the additional measures are anticipated to be delivered through as yet unidentified policies and measures. The 2010 Building Regulations which require minimum building energy performance standards for new residential developments are also projected to deliver significant savings.

6. Commercial Services

The *Baseline* energy forecast underpins the *With Measures* emission projection for the commercial services sector. The *White Paper Plus* energy forecast underpins the *With Additional Measures* emission projection.

Existing and planned policies and measures are listed, with the anticipated emissions savings, in Table 6. These measures were included in the *Baseline* and *White Paper Plus* energy forecasts and therefore the *With Measures* and *With Additional Measures* emission projections.

Table 6. Policies and measures included in the *With Measures* and *With Additional Measures* emission projection for the commercial services sector

Policy and measure	CO_2e (ktonnes)		
	2010	**2015**	**2020**
With Measures			
SEI Small Business Support	20	40	72
Accelerated Capital Allowance (ACA)	1	3	6
Total	**21**	**43**	**78**
With Additional Measures			
2010 Building Regulations	0	128	331
CHP	21	29	36
RES-H*	51	179	306
Further potential measures**	0	249	549
Total	**72**	**585**	**1,222**

* The Energy White Paper target for thermal energy sourced from renewable sources is 12% (across the residential, commercial services and industrial sectors) by 2020. This is referred to as RES-H.
** SEI report that these are further measures that are required, but which have not yet been identified, to bring energy savings in line with the 20% energy efficiency target.

6.1. Commercial Services Sector Emissions

Under the *With Measures* emission projection, emissions from the commercial services are projected to decrease by 24.6% between 2008 and 2020 while final energy demand is projected to increase by 0.7% over the same period. The decrease in emissions is driven by an increasing share of electricity in final energy demand from this sector (45.5% in 2008 and 57.1% in 2020). In addition, demand for fossil fuels is projected to move from carbon intensive fuels such as coal and oil to less carbon intensive fuels such as gas and renewables.

Under the *With Additional Measures* emission projection, commercial services sector emissions are projected to decrease by 68.6% as a result of the policies and measures outlined in Table 6. Significant savings are projected to be delivered through the 2010 Building Regulations, which require minimum building energy performance standards in new non-residential developments, increased renewable penetration in thermal heat demand with a further 0.5 Mtonnes of savings projected to be delivered through as yet unidentified measures.

7. Industry

7.1. Industrial Combustion

The *Baseline* energy forecast underpins the *With Measures* emission projection for the industrial sector. The *White Paper Plus* 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 7. These measures were included in the *Baseline* and *White Paper Plus* energy forecasts and therefore the *With Measures* and *With Additional Measures* emission projections.

Table 7. Policies and measures included in the *With Additional Measures* emission projection for the industrial sector

Policy and measure	CO_2e (ktonnes)		
	2010	2015	2020
With Measures			
SEI Energy Agreements	114	196	279
Large Industry Network	34	43	143
Accelerated Capital Allowance (ACA)	0	2	4
Total	**148**	**241**	**426**
With Additional Measures			
CHP	43	61	76
RES-H*	73	333	621
Further potential measures**	0	19	69
Total	**116**	**413**	**766**

* The Energy White Paper target for thermal energy sourced from renewable sources is 12% (across the residential, commercial services and industrial sectors) by 2020. This is referred to as RES-H.
** SEI report that these are further measures that are required, but which have not yet been identified, to bring energy savings in line with the 20% energy efficiency target.

7.1.1. Industrial Combustion Emissions

Under the *With Measures* emission projection, emissions from industrial combustion are projected to increase by 15.4% between 2008 and 2020 while final energy demand is projected to increase by 14.3% over the same period.

Under the *With Additional Measures* emission projection, emissions from industrial combustion are projected to only increase by 1.6% and final energy demand by 9.3%. The level of projected emissions under the *With Additional Measures* scenario is lower compared with the *With Measures* scenario as a result of the additional policies and measures outlined in Table 7. The largest savings are anticipated to be delivered through thermal energy sourced from renewable sources.

7.2. Process Emissions

Process gas emission projections were developed for the cement and lime industries. For the cement industry, it was assumed that clinker output decreases to 2011, in line with a projected decrease in volume output in the construction sector[12].

[12] http://www.environ.ie/en/Publications/StatisticsandRegularPublications/ConstructionIndustryStatistics/FileDownLoad,21120,en.pdf

Thereafter, clinker production is assumed to grow back to 2000 levels over five years (up to 2016), followed by an annual increase of 2% thereafter. Carbon dioxide emissions are derived from clinker output, using the average implied emission factor averaged over the last five years (2004-2008).

The three lime production sites are treated separately. For Clogrennane Lime Ltd in Carlow an increase in lime production of 1.9% per annum is assumed from 2008. This is the annual average increase between 1991 and 1998. The CO_2 emission factor used is an average of the 2001-2008 emission factors. For Clogrennane Lime Ltd in Clare, CO_2 emissions are assumed to reach the level assigned to that facility under the National Allocation Plan in 2012, and to be constant thereafter. For Premier Periclase Ltd, CO_2 emissions are assumed to reach the level assigned to that facility under the National Allocation Plan in 2012, and to be constant thereafter.

Process gas emissions are projected to decrease by 9% between 2008 and 2020.

7.3. Solvents

Emissions projections of CO_2e from solvent use for the following activities were developed:

- Paint Application
- Degreasing and Dry Cleaning
- Chemical Products and
- Other Solvent Uses.

Clear trends in per capita emissions from each sub-sector are evident from the historical data.

In estimating future emissions from this diverse sector into the future, it is assumed that per capita emissions will remain reasonably constant for (i) Paint Application and (ii) Degreasing and Dry Cleaning and, therefore, solvent usage will be driven by population growth. For (iii) Chemical Products per capita emissions have been declining since 1990 and this trend is assumed going forward. For (iv) Other Solvent Uses per capita emissions have been declining and then stabilising, and are assumed constant.

Only one scenario was developed for this emission source. Emissions of CO_2e from solvent use is projected to increase by 5.2% between 2008 and 2020.

7.4. F-gases

F-gas emission projections were developed under two scenarios; *With Measures* and *With Additional Measures*. Fluorinated gases accounted for 1% of Ireland's total national greenhouse gas emissions in 2008. The only relevant source of F-gas emissions in Ireland is production, use and disposal of equipment containing these fluids (e.g. refrigerators, mobile air conditioning systems and electrical switch-gear).

Projections were developed for three fluorinated gases : HFC, PFC and SF_6. In 2008, HFCs accounted for 75.7% of total F-gas emissions with the majority of these emissions estimated to come from stationary refrigeration and air conditioning and air conditioning systems in vehicles. PFCs, from semi-conductor manufacturing, accounted for 15.4% of total F-gas emissions in 2008 while SF_6 accounted for 8.8% with the majority of emissions coming from semi-conductor manufacturing and electrical equipment.

Projections were developed for all three F-gases and for all the sources reported in the national greenhouse gas inventory. Table 8 summarises the basis for developing projections for each F-gas from the relevant sector.

Table 8. Key assumptions underlying the F-gas projections

Sector	F-gases	Basis for projection
Refrigeration and air conditioning	HFC	GDP
Mobile Air Conditioning (MAC)	HFC	Projected new car registrations.
Foams	HFC	GDP
Fire-extinguishers	HFC	The use of HFCs in fire-extinguishers is assumed to grow at 12.5% per annum in line with assumptions in the annual inventory
Aerosols	HFC	Pro-rata basis using UK emission projections and UK and Irish population projections
Metered dose inhalers	HFC	Process emissions based on GDP. In-life emissions are based on population projections
Semi-conductor manufacture	HFC, PFC and SF_6	GDP
Electrical equipment	SF_6	Estimate from ESB based on continued and increasing utilisation of SF_6 switchgear in the network
Window sound-proofing	SF_6	SF_6 is no longer used in window insulation. Projections are based on the known current stock of SF_6. Assumptions on loss rate of in-life emissions is in line with the greenhouse gas inventory
Medical Applications	SF_6	The use of SF_6 in Irish hospitals is assumed to remain constant at 2007 levels
Sport goods	SF_6	SF_6 emissions from disposal of sports equipments is inferred based on the projected disposal of sporting goods containing SF_6

In the *With Additional Measures* emission projection, the impact of the F-gas Regulations[13] and Directive 2006/40/EC[14] relating to emissions from air-conditioning systems in motor vehicles are included. The savings associated with these measures are reported in Table 9.

F-gas emissions are projected to increase by 26.4% between 2008 and 2020 under the *With Measures* emission projection. Under the *With Additional Measures* emission projections, F-gas emissions are projected to increase by 4.2% between 2008 and 2020.

[13] Regulation (EC) No 842/2006. On certain Fluorinated Greenhouse Gas.
[14] Directive 2006/40/EC. Relaing to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/15/EEC

Table 9. Policies and measures included in the *With Additional Measures* emission projection for F-gases

Policy and measure	CO_2e Emission Saving (ktonnes)		
	2010	**2015**	**2020**
F-gas Regulations (No. 824/2006)	30	30	30
HFC emissions from air conditioning in motor vehicles (Dir 2006/40/EC)	8	65	123
Total	**38**	**95**	**153**

8. Agriculture

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

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

In addition, emissions from combustion sources in the agricultural sector were estimated based on energy forecasts recently published by SEI[2]. Energy-related emissions hold a small share of total emissions from the agricultural sector accounting for 4.6% of total emissions from the sector in 2008.

The methodology used to develop emissions projections for both CH_4 and N_2O are consistent with those employed in compiling the national greenhouse gas inventory.

The key sources of CH_4 emissions in the agricultural sector are enteric fermentation and manure management. Detailed country specific methodologies (referred to as Tier 2 methodologies) are used in calculating CH_4 emissions from the Irish cattle population in the annual greenhouse gas inventory. In estimating projected emissions the same methodology is used. Methane emissions from other livestock are calculated using a simpler methodology (referred to as Tier 1 or default).

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.

Only one scenario was developed for agricultural emission projections. The projected activity data for agricultural emission projections were produced by the FAPRI-Ireland partnership[15] and provided to the EPA. The FAPRI-Ireland 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 assumptions included in the model are :

- Developments in agricultural markets (e.g. cereal (and animal feed) prices, fertiliser prices and dairy prices) as reflected in recent input and output price levels.
- The gradual abolition of milk quota by 2015 and associated increases in the national quota until abolition.

8.1. Enteric Fermentation

The FAPRI-Ireland model provided projected livestock numbers 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 greenhouse gas

[15] The research partners are Teagasc – The Irish Agriculture and Food Development Authority, and five Irish Universities, namely, NUI Cork, NUI Dublin, NUI Galway, NUI Maynooth and Trinity College Dublin. The main activity of the FAPRI-Ireland Partnership is based in the Teagasc Rural Economy Research Centre, Dublin.

inventory[16]. For dairy cows, CH_4 emission factors have been increasing by an average of 0.4% 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 annum reflecting projected continuing growth in milk yields. For other cattle categories, where there is a clear trend in emission factors over time, this is applied going forward. In the absence of a trend, emission factors are held constant at an average of 2003 – 2008 levels.

FAPRI-Ireland also provided projected animal numbers 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 for animal weights (following the approach of the inventory).

8.2. Manure Management

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 farm facilities surveys[17], and the work on emission factors for enteric fermentation in cattle, mentioned above, are the basis for revised CH_4 emission factors for manure management[18] used in the greenhouse gas inventory. Changes in CH_4 emission factors over the projection period are assumed to follow the trends observed in recent years. 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. slurry storage, solid storage and pasture) were determined using information on the allocation of animal manures to different animal waste management systems (taken from farm facilities survey and the national greenhouse gas inventory), nitrogen excretion rates (from the Department of Agriculture Food and Forestry) and projected animal numbers. The 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).

8.3. N_2O Emissions from Agricultural Soils

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

[16] "Development of Emission Factors for Enteric Fermentation from the Irish Cattle Herd". LS 5.1.1. Frank O'Mara. Environmental Protection Agency. (2006).
[17] Farm Facilities Survey – Ireland 2003. Report prepared for the Department of Agriculture by Teagasc, Johnstown Castle.
[18] See Ireland National Inventory Report 2010 (EPA) for more information on this work.

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 FAPRI-Ireland.

- Amount of animal manure nitrogen and organic nitrogen in sewage sludges applied directly to soils, adjusted for the amount that volatilises as NH_3 and NO_x. Projected sludge production and the proportion applied on agricultural lands is taken from waste sector data.

- Amount of nitrogen fixed by nitrogen-fixing crops. Projected annual production of pulses was provided by FAPRI-Ireland.

- Amount of nitrogen fixed in crop residues that is returned to the soils. FAPRI-Ireland 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 that volatilises.

- Emissions of N_2O from nitrogen leaching. This is assumed to be 10% of available nitrogen in 2008 and assumed to remain constant over the projection period.

8.4. Combustion Sources

The *Baseline* energy forecast underpins the *With Measures* and *With Additional Measures* emission projection for combustion related emissions from the agricultural sector.

8.5 Agriculture Emissions

Total emissions from the agricultural sector are projected to decrease by 5% between 2008 and 2020. This is predominantly driven by a projected decline in animal numbers; total cattle numbers are projected to decrease by 5% over the projection period. Similarly sheep and pig numbers are projected to decrease by 16% and 27% respectively. Nitrogen fertiliser use in 2020 is projected to be similar to the total quantity used in 2008 (approximately 309,000 tonnes).

9. Waste

Emission projections for the waste sector are developed for CO_2, CH_4 and N_2O.

Solid waste disposal to landfill 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, whilst N_2O emissions also arise from the production of human sewage. In addition, CO_2, CH_4 and N_2O emissions arise from the incineration of municipal solid waste which will become a method for the disposal of waste in Ireland over the next decade.

In these emission projections it is assumed that Ireland meets its Landfill Directive targets progressively in 2010, 2013 and 2016. In addition it is assumed that the two municipal solid waste incinerators under construction in Carranstown and Poolbeg become operational in 2011 and 2015, respectively.

9.1. Solid waste disposal in landfill sites

Only one scenario is used in the projection of CH_4 emissions from landfills. It is assumed that Ireland meets the requirements of the Landfill Directive targets (Directive 1999/31/EC) in 2010, 2013 and 2016. 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. It is assumed that the Landfill Directive targets (Directive 1999/31/EC) will be reached in 2010, 2013 and 2016 for which progressive targets have been set out in the Landfill Directive[19] to reduce the proportion of BMW going to landfill. Ireland's revised targets for diverting BMW from landfill are set out in the National Waste Database 2008[20], published by the EPA in 2009 and are summarised in Table 10 below. The quantity of biodegradable municipal waste disposed of to landfill decreased by 23% to 1,196,044 tonnes from 1,475,078 tonnes between 2007 and 2008, leaving Ireland within 280,000 tonnes of the first Landfill Directive target of 916,000 tonnes of biodegradable municipal waste to be landfilled in 2010.

[19] Council Directive 1999/31/EC on the landfill of waste.
[20] National Waste Report 2008. Environmental Protection Agency 2009.

Table 10. Ireland's revised targets under the Landfill Directive

1995	(Baseline BSW Generation)	1,220,840*
Year	**Target**	**BMW tonnes allowed in landfill**
2010	75%	916,000
2013	50%	610,000
2016	35%	427,000

*Data derived from EPA National Waste Database Report 1995 and recalculated through additional information and reconsideration of biodegradability factors by the Agency since publication of 1995 NWD.

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[19] and the allowable future intake of BMW at landfills proposed by the EPA technical guidance document on Muncipal Solid Waste – Pre-treatment and Residuals Management[21].

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 dissolved organic carbon (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. Methane correction factors are used to account for the effect of landfill type and level of management on CH_4 generation. The model is applied for the five largest landfills in Ireland individually and to all other landfills by assigning them to seven groups according to annual waste intake and life cycle. Two additional model runs are used to account for sewage sludge and street cleanings. The model incorporates varying lag periods (dependent on the individual landfill or group of landfills) before CH_4 generation commences, followed by active CH_4 production over a period of decades. The calculations include the allocation of wastes between well-managed landfill sites i.e. those landfills that are licensed (where the full CH_4 potential is realised) and unmanaged landfills (for which between 40% and 70% of the potential CH_4 potential is realised, which is of importance as these landfills currently and for future years contribute to emission totals). 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 2008 63% of methane produced in landfill sites was treated in this manner. In projecting emissions, it is conservatively assumed that the amount of landfill gas flared and utilised for energy production increases to 65% by 2010 and to 75% by 2020.

[21] Municipal Solid Waste – Pre-treatment & Residuals Management. An EPA Technical Guidance Document. Environmental Protection Agency, 2009.

9.2. Waste incineration

Waste incineration is defined as the combustion of waste in controlled incineration facilities. Modern waste incinerators use specifically designed combustion chambers, which provide high combustion temperatures, long residence times, and efficient waste agitation while introducing air for more complete combustion. Currently there is no municipal waste incinerator in operation in Ireland, however construction has begun on two such plants. The first plant in Carranstown Co. Meath is currently being built and is due to begin operation in 2011 and cater for 200,000 tonnes per year when fully operational. The second plant is in Ringsend in Dublin and will cater for 600,000 tonnes per year. Whilst the Ringsend plant has just started construction and there are still a lot of issues both legal and otherwise with its operation it is assumed that the project will go ahead, opening in 2015 and fully operational in 2017. Both plants will use moving grate (stoker) type technology. Incineration of municipal waste is a source of CO_2, CH_4 and N_2O. The methodological approach to emission estimation is that of the 2006 IPCC GL. Please note that only CO_2 resulting from the oxidation during incineration of carbon in waste of fossil origin is considered a net emission. Carbon dioxide emissions from the combustion of biomass are biogenic and therefore are not included in national totals. It is projected that by 2020 waste incineration will account for 0.32 M tonnes CO_2e.

9.3. CH_4 Emissions from Wastewater and Sludge

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 water 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[22] indicate that 3% 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.

9.4. N_2O Emissions from Human Sewage

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.

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

9.5. Waste Sector Emissions

As only one projected outlook is undertaken for the waste sector, both *With Measures* scenario and the *With Additional Measures* are the same. Emissions are projected to decrease by 6% between 2008 and 2020. Emissions from solid waste disposal at landfill are projected to decrease by 42% over the same period based on the assumption that Ireland meets its targets for the diversion of BMW from landfill under Directive 1999/31/EC. This large reduction in emissions is however offset to a large extent by incineration which in 2020 is projected to account for 31% of emissions from the waste sector.

10. Forestry

COFORD, the National Council for Forest Research and Development, provided estimates to the EPA on the extent to which new forests could sequester CO_2 over the projection period.

The sequestration potential of forest sinks in Ireland has been substantially enhanced by the establishment of more than 25,000 hectares of forest since 1990 following the introduction of afforestation grant schemes. Estimation of the extent to which forests sequester carbon in the mid to long-term is however hindered by a high degree of uncertainty due to spatial heterogeneity and temporal variability.

The Irish carbon reporting system (CARBWARE)[23] was initially implemented to meet reporting requirements to the UNFCCC on national forest sources and sinks. Since then, CARBWARE has evolved from a tier 2 to tier 3 system (using nationally derived emission factors), based on forest inventory data, yield models and national research information[24,25,26,27,28,29]. Carbon dioxide removal as a function of forest growth is simulated using models parameterised for a variety of species with similar growth characteristics. It also includes emission factors such as those associated with thinning and cultivation.

Carbon dioxide sequestration depends on the annual afforestation rate and, in addition, species planted, harvest management and soil type.

It is assumed that current afforestation levels are c. 7,000 hectares per annum rising to 10,000 hectares in 2012 for both the *With Measures* and *With Additional Measures* emission projection.

The forestry sector is projected to sequester on average 2.7 Mtonnes of CO_2 per annum over the Kyoto period (2008-2012), increasing 4.8 Mtonnes of CO_2 emissions in 2020.

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[23] Gallagher, G., Hendrick, E., Byrne K. 2004. Preliminary estimates of biomass stock changes in managed forests in the Republic of Ireland over the period 1900-2000. Irish Forestry: 61: 16-35.

[24] Black, K. and Farrell E.P. eds. 2006. Carbon Sequestration in Irish Forest Ecosystems. Council for Forest Research and Development (COFORD), Dublin p 76. ISBN 1 902696 48 4.

[25] Black, K., Tobin, B., Saiz, G., Byrne, K. and Osborne, B. 2004. Improved estimates of biomass expansion factors for Sitka spruce. Irish Forestry 61: 50 –65.

[26] Black, K., Bolger, T., Davis, P., Nieuwenhuis, M., Reidy, B., Saiz, G., Tobin, B. and Osborne, B. 2007. Inventory and Eddy Covariance Based Estimates of Annual Carbon Sequestration in a Sitka spruce (Picea sitchensis (Bong.) Carr.) Forest Ecosystem. Forest Ecosystem. Journal of European Forest Research 126: 167-178 doi 10.0007/sl0342-005-0092-4.

[27] Black, K. (2008) Ireland's forest carbon reporting system. In: Proceeding from COFORD conference on: Forestry, Carbon and Climate Change - local and international perspectives, Eds Hendrick and Black, COFORD, pp 14-20.

[28] Black K, O'Brien P, Redmond J, Barrett F and Twomey M (2009a) The extent of peatland afforestation in Ireland. Irish Forestry, 65, 61-71.

[29] Black K, Byrne K, Mencuccini M, Tobin B, Nieuwenhuis M, Reidy B, Bolger T, Saiz G, Green G, Farrell T and Osborne B (2009b). Carbon stock and stock changes across a Sitka spruce chronosequence on surface water gley soils. Forestry, 85(3), 225-271.

11. Sensitivity Analysis

EPA commissioned ESRI to carry out a sensitivity analysis on SEI's *Baseline* energy forecast (which underpins the *With Measures* emission projection) to gain a better understanding of the key sensitivities in HERMES and associated models. The ESRI looked at three scenarios: (i) High Oil Price (ii) High Carbon Price and (iii) Prolonged Recession.

Under the *High Oil Price* scenario it is assumed that the price of oil reaches $150 a barrel in 2020 which increases from $55 a barrel in 2010. Under SEI's *Baseline* energy forecast[2] the price of oil increases from $52 a barrel in 2011 to $87 a barrel in 2020.

Under the *High Carbon Price* scenario it is assumed that the price of carbon in the EU Emissions Trading Scheme increases to €50 per tonne in 2020 from €14.50 per tonne in 2010. Under SEI's *Baseline* energy forecast the price of carbon increases from €14.50 per tonne in 2010 to €30.70 per tonne tonne in 2020.

Under the *Prolonged Recession* scenario, the effects of lower macro-economic growth are considered. This is done by simulating the effects of the *Prolonged Recession* scenario from the ESRI 2009 report[6] which assumes that the world economy recovers from the recession in 2012 rather than 2011.

The results of the sensitivity analysis relative to the *With Measures* scenario are shown in Table 6.

Table 6. Comparison of sensitivity analysis scenarios with the *With Measures* emission projection

2008-2012	
With Measures	-
High Oil Price	-0.4%
High Carbon Price	-0.1%
Prolonged Recession	-0.5%
2020	
With Measures	-
High Oil Price	+3%
High Carbon Price	-1%
Prolonged Recession	-2%

There is very little effect in the 2008-2012 period when comparing the sensitivity analysis with the *With Measures* emission projection. In terms of the *High Oil Price* and *High Carbon Price* scenarios, the sensitivity analyses are run so that the difference in each key parameter (i.e. oil and carbon) happens from 2011 onwards therefore the overall impact of the 2008-2012 is unsurprisingly small.

Under the *High Oil Price* scenario, in 2020, emissions are projected to be 3% higher compared with the *With Measures* scenario. The most significant impact of an assumed higher oil price is in the power generation sector where emissions are projected to be 50% higher in 2020 compared with the *With Measures* scenario. In the *Baseline* energy forecast which underpins the *With Measures* emission projection, coal does not run as baseload throughout the year. However, once the oil price increases, coal improves its position in the merit order and is always dispatched before natural gas generation. Increased emissions in the power generation sector are off-set by lower projected emissions in transport, industrial combustion, residential and commercial services in 2020 as a result of reduced demand. The overall impact is 3% higher emissions in 2020 relative to the *With Measures* scenario.

Under the *High Carbon Price* scenario, in 2020, emissions are projected to be 1% lower compared with the *With Measures* scenario. The most significant impact is in the power generation sector where emissions are projected to be 8% lower in 2020 compared with the *With Measures* scenario. The results show that as the assumed price of carbon increases, demand for more carbon intensive fuels in power generation decreases which results in lower emissions from this sector. The overall impact is 1% lower emissions in 2020 relative to the *With Measures* scenario.

Under the *Prolonged Recession* scenario, in 2020, emissions are projected to be 2% lower compared with the *With Measures* scenario. Lower emissions, in the range of 2-4% lower, are projected across all sectors compared with the *With Measures* scenario. For industrial combustion the impact is more significant with 8% reduction in emissions in 2020 compared with the *With Measures* scenario. The overall impact is 2% lower emissions in 2020 relative to the *With Measures* scenario.