Engineers Ireland

Future Climate: Engineering Solutions

Engineers Ireland Climate Plan Report

August 2009

Future Climate
Engineering Solutions

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1 Introduction

Engineers Ireland were invited to participate in the Future Climate: Engineering Solutions project in September of 2008. We participated in the initial conference, setting the Project Objectives and Protocols and have since then been preparing our input from an Irish Context.

The ‘Future Climate’ project is being coordinated by the Danish Society of Engineers (IDA) and comprises of 13 national engineering organisations worldwide who are working together to offer national solutions for the way in which greenhouse gas emissions can be reduced. The common goal of all the national plans in the Future Climate project is to contribute to the reduction of the GHG emissions to a sustainable level. The project’s definition of a “sustainable level” is the IPCC (Inter-governmental Panel on Climate Change) best case scenario whereby the increase in global temperature does not exceed 2° C.

It is the view of Engineers Ireland that this document and the Future Climate: Engineering Solutions project will not just form a snapshot of the engineering and technological solutions to the Climate Change challenge. The project should form a platform on which further and more detailed work can be completed in support of our national policy objectives and the implementation of EU Directives.

The rapid shift in economic climate even within the timescale of the Future Climate Project has proven how quickly global markets can change. The evidence we have now seen of the immediate and direct impact on infrastructural development and investment in research and development activities is significant. As are the potential changes in business and social behaviour (less freight, less commuting, a more frugal lifestyle) that can also have a direct impact on the level of GHG emissions of each country.

It is critical that the Future Climate Project and the constituent inputs of each country recognise a need for flexibility in their climate plans and facilitate adaptation to future economic as well as technological conditions as time progresses.

1.1 Engineers Ireland

Since 1835 Engineers Ireland has been representing the engineering profession across the Island of Ireland. As the Institution of Civil Engineers of Ireland it became one of the first chartered institutions in the then British Isles in 1877. Following a merger between Cumann na n-Innealtóirí (The Engineers Society) and the Institution of Civil Engineers in Ireland into the Institution of Engineers of Ireland there was a widening of its scope to:

- Cater for all engineering disciplines

- Ensure standards in the profession
- Promote engineering as a career
- Encourage Continuing Professional Development for engineers
- Represent the interests of the engineering profession in Ireland and Internationally

Re-branded to Engineers Ireland, the institution now represents 24,000 engineering professionals from every discipline of engineering. We award professional titles to our members according to their qualification including:

- Fellow (CEng FIEI)
- Chartered Engineer (CEng MIEI)
- Associate Engineer (AEng AMIEI)
- Engineering Technician (Eng Tech IEI)

The Energy and Environment Division of Engineers Ireland is one of a range of Divisions and Societies dedicated to providing a central resource for knowledge-sharing in Engineers Ireland. A range of lectures are provided annually by the Division across the following broad areas:

- Energy Infrastructure Development
- Security of Supply
- Conventional Energy use and Strategic Storage
- Novel Energy Technologies

The Future Climate Project will provide an additional and ongoing focus for the division and will facilitate a greater level of engagement between the engineering resource (both professional and technical) in Ireland and the policy-makers defining our path towards a more effective approach to climate change.

1.2 Future Climate Involvement

Engineers Ireland were invited to participate in the Future Climate Project in September 2008. Following participation in the initial conference the Project was discussed by the Energy Environment Division and an article calling for involvement published on the Engineers Ireland Website.

This document forms the Climate Plan of Engineers Ireland prepared in line with the guidelines of the Future Climate Project. It has been prepared with reference to a number of national information resources and, by necessity, will be updated as further information is available to Engineers Ireland.

2 Description of the Work

2.1 General

This Climate Plan is put forward by Engineers Ireland as a platform from which engineering and technological support can be provided to the policy-makers in Ireland who will define our approach to the Climate Change challenge over the coming years.

As technological opportunities and economic conditions change over time it will be necessary to revise this document in order to provide the most cost and carbon effective strategies for Ireland. It is anticipated that, with the delivery of a number of pending reports from other public and academic bodies, in the coming months a ‘Technologies Report’ addendum to this report will be finalised to further clarify and classify the technological solutions available for implementation by the Irish Government. This addendum will be completed in advance of the COP15 negotiations and will support the Irish delegation, in addition to adding to the pool of knowledge created by the Future Climate project.

2.2 Data Sources

A broad range of data sources were used in compiling this report. The primary documents reviewed have included:

- Irish Government White Paper on Energy: Delivering a Sustainable Energy Future for Ireland (2007)
- Ireland’s Energy Balance 2007 (produced by Sustainable Energy Ireland)
- Energy in Ireland: Key Statistics 2008 (produced by Sustainable Energy Ireland and the Energy Policy Statistical Support Unit)
- The Irish National Energy Efficiency Action Plan (2009)
- The Environmental Protection Agency National Inventory Report on Greenhouse Gas Emissions 1990 – 2007 as Reported to the UN Framework Convention on Climate Change (2009)
- The Sustainable Energy Ireland ‘Ireland’s Low Carbon Opportunity’ Report (2009)

3 Description of Sources of GHG's and Irish Energy System – The Present Situation

The Republic of Ireland has a land area of 68,889 sq km, an estimated population of 4.4 million persons in 2008 and a recorded GDP of €160,603m in 2007. Ireland experienced significant economic growth from the mid 1990's to 2007, which was mirrored by a significant increase in GHG emissions. Since early 2007 Ireland has experienced a significant decrease in economic growth and activity compared to previous years, this is likely to result in a small decrease in the projected energy demand trends and GHG emissions trends over time.

3.1 Description of Irish GHG Sources

The following information was drawn directly from the EPA National GHG Emissions Inventory Report 2009. (1 Gigagram Gg CO2 equivalent is equal to 1,000 tonnes CO_2 equivalent.)

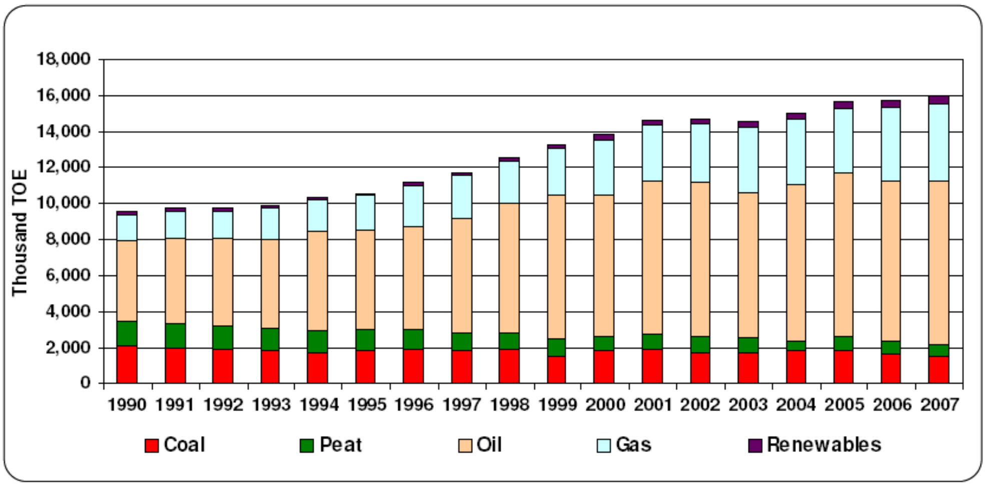
The total emissions of greenhouse gases (excluding the Land Use, Land Use Change and Forestry - LULUCF sector) in 2007, our base year, were 69,205.15 Gigagrams (Gg) CO2 equivalent. The Energy Sector accounted for 66.7 percent of total emissions, Agriculture contributed 25.6 percent while a further 4.7 percent was produced from Industrial Processes and 2.8 percent was due to Waste. Emissions of CO_2 accounted for 67.2 percent of the National total in 2007, with CH_4 and N_2O contributing 18.7 and 11.7 percent respectively. The combined emissions of HFC, PFC and SF6 accounted for 1 percent of total CO_2 equivalent emissions in 2007.

The results of the latest time-series of estimates shows that total GHG emissions in Ireland increased from 55,383 Gg CO_2 equivalent in 1990 to 70,650 Gg CO_2 equivalent in 2001. Following this long period of sustained increase, the emissions decreased to 68,575 Gg CO_2 Equivalent in 2003, a reduction of approximately three percent since their high in 2001. The emissions increased in both 2004 and 2005 followed by a small reduction in 2007 by 0.7 percent to 68,205 Gg CO_2 equivalent. This represents a level that is 25 percent higher level than it was in 1990.

Trends in Energy and Transportation

Emissions from the Energy Sector increased by 46.8 percent from the 1990 to the 2007 levels. This increase occurred predominantly in the 1990's and was driven in large part by major increases in both energy production (IPCC sub-category 1.A.1. Energy Industries) and transportation (IPCC Subcategory 1.A.3) with emissions being relatively stable in this sector from 2001 – 2007.

Total GHG emissions from energy production increased by 54.9 percent between 1990 and 2001 with a levelling out and reduction to 2007 experienced due to the entry of some new electricity producers, and primary fuels, into the marketplace resulting in the displacement of more carbon intensive primary fuels. Figure 1 below indicates the energy production drivers for CO_2 emissions over the period 1990 – 2007 in thousand tonnes of oil equivalent.



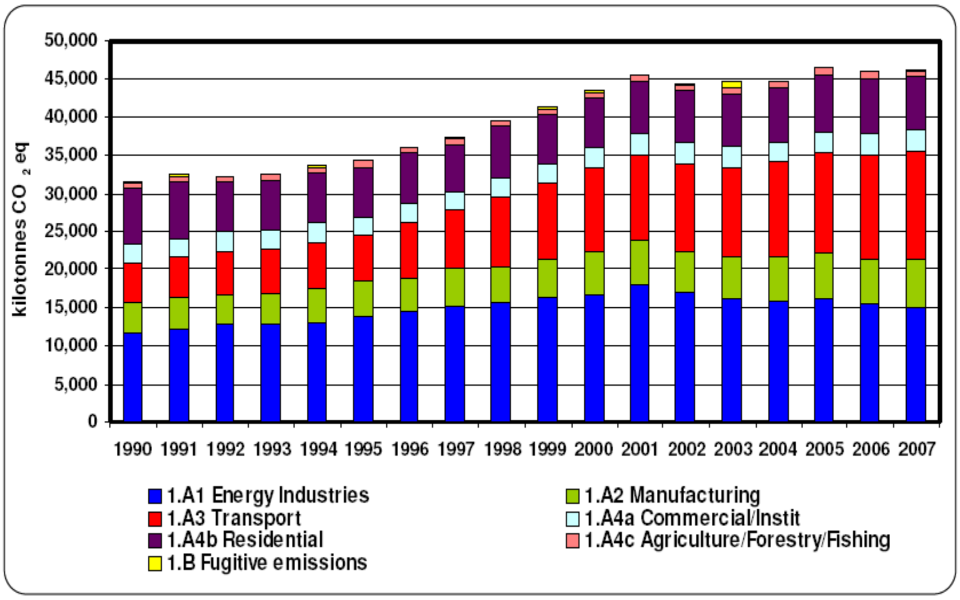
Source: EPA National GHG Inventory Report 2009

Figure 1. GHG Production Drivers in the Energy Sector 1990 – 2007

There are only a small number of energy intensive industries in Ireland (IPCC subcategory 1.A.2). These industries accounted for 7.4 percent and 9.1 percent of total national greenhouse gas emissions in 1990 and 2007, respectively. However, the trend within the sector shows an increase of 53.4 percent over the same period as a result of large increases in the use of petroleum coke and natural gas.

Fuel combustion emissions in the transport sector (IPCC subcategory 1.A.3 increased by 178 percent between 1990 and 2007. This increase is largely accounted for by a 190.8 percent increase in road transport associated emissions over the same period, due to a sustained increase in the use of passenger cars and road freight. It is likely that this figure has been exaggerated by 'fuel tourism' where a certain quantity of road fuels purchased in the Republic of Ireland has been used in vehicles in the UK and other countries. This is estimated to account for 13% of automotive fuels in the Republic of Ireland in 2007.

The Figure 2 below outlines the trends in the major contributing Energy sub-categories between 1990 and 2007.



Source: EPA National GHG Inventory Report 2009

Figure 2. Trends in Major GHG Categories 1990 - 2007

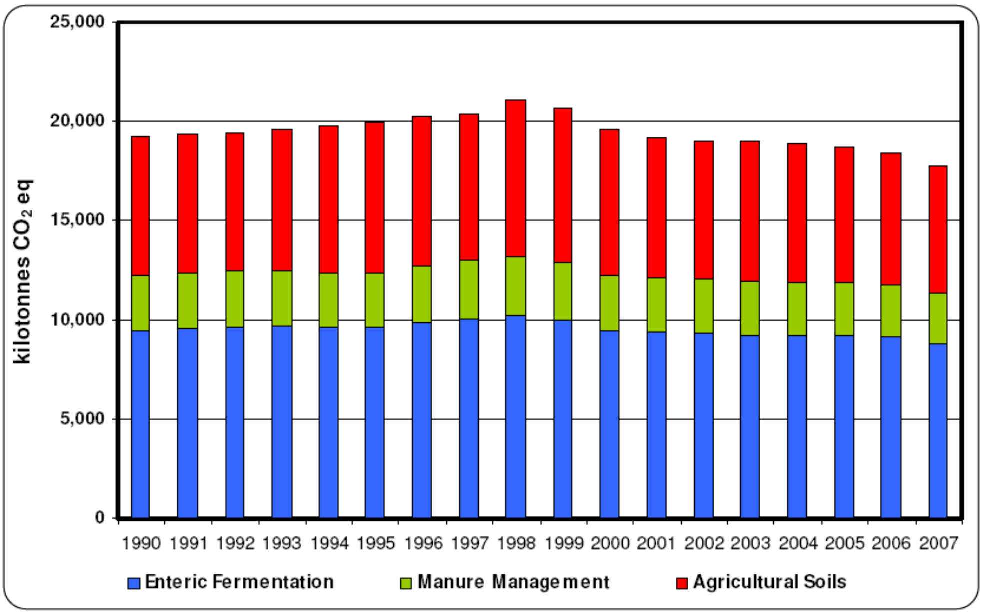
<u>Trends in Industrial Processes and Solvent and Other Product Use</u>

The contribution from Industrial Processes (IPCC Sector 2) is relatively small, accounting for 5.7 percent of total GHG in 1990 and 4.7 percent in 2007. The trend within the sector shows an increase of 3.7 percent but is not necessarily representative of the underlying trends in the sector. For example, in the early 1990's the contribution of the chemical industry to overall sectoral emissions was approximately 64 percent but by 2000, levels had reduced by over 16 percent. The closure of Ireland's ammonia and nitric acid plants in 2003 and 2002 respectively further reduced this contribution of the chemical industry. However, against the backdrop of a boom in the Irish building and infrastructure industry, the level of cement manufacture increased significantly between 1990 and 2007 resulting in a position where in 2007 the cement production industry accounted for over 72 percent of total emissions from Industrial Processes in 2007.

GHG emissions from Solvents and Other Product Use (IPCC Sector 3) do not affect the overall trend in Greenhouse Gas Emissions in Ireland. The CO_2 emissions from this source were estimated to be just 79.43 Gg CO_2 in 1990 and 83.19 Gg CO_2 in 2007.

Trends in Agriculture

The trend in the Agriculture Sector (IPCC Sector 4) is represented in Figure 3 below. These emissions decreased by a total of 7.7 percent between 1990 and 2007. Emissions increased by 9.5 percent between 1990 to a peak in 1998, reflecting an increase in animal numbers and the use of synthetic nitrogen on farms. Following this peak in emission levels, the annual emissions from the sector decreased by 15.7 percent to those in 2007 as a result of a reduction in animal numbers and also a reduction in synthetic nitrogen use due to reforms of the Common Agricultural Policy.



Source: EPA National GHG Inventory Report 2009

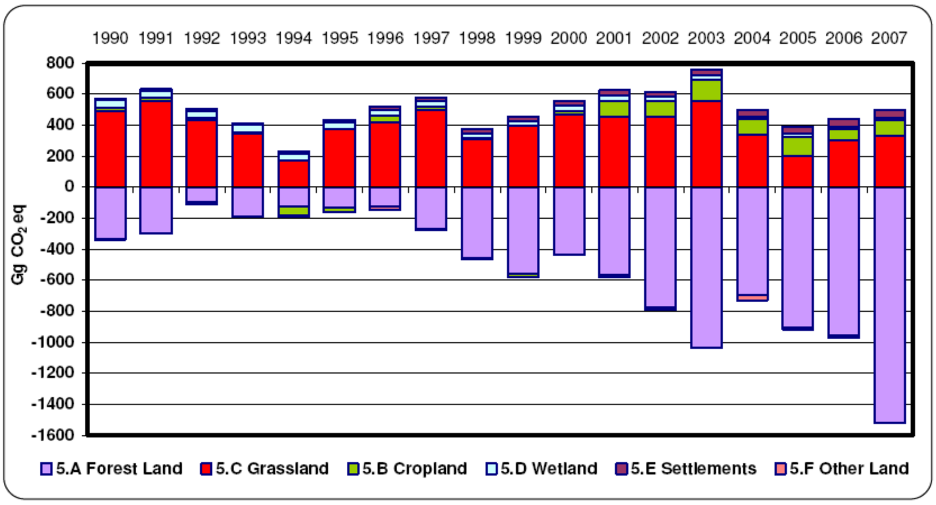
Figure 3. GHG Production Drivers in the Agricultural Sector 1990 – 2007

Methane emissions from Enteric Fermentation and Manure Management are dependent on both the number and type of livestock present on farms, in Ireland these quantities are largely determined by the cattle population. Cattle account for almost 90 percent of annual methane emissions in Irish Agriculture.

The emissions of N_2O from the agriculture sector generally follow the same trends to those of CH_4 because cattle numbers largely determine the amount of nitrogen inputs to agricultural soils from synthetic fertilizer and animal manures (which produces the bulk of N_2O emissions).

Trends in Land Use, Land Use Change and Forestry

This sector can be a net source of emissions in certain years and a net sink for emissions in other years. This is largely determined by the balance between forest land (a major carbon sink) and grassland, where soil disturbance and liming of agricultural lands generate relatively large emissions of CO_2. The complex dynamics of land-use change from year to year between categories and relative contributions from biomass and soils lead to highly fluctuating estimates of sectoral GHG emissions and removals over the period between 1990 and 2007. Figure 4 below demonstrates the rapidly changing balance between these categories over the period.

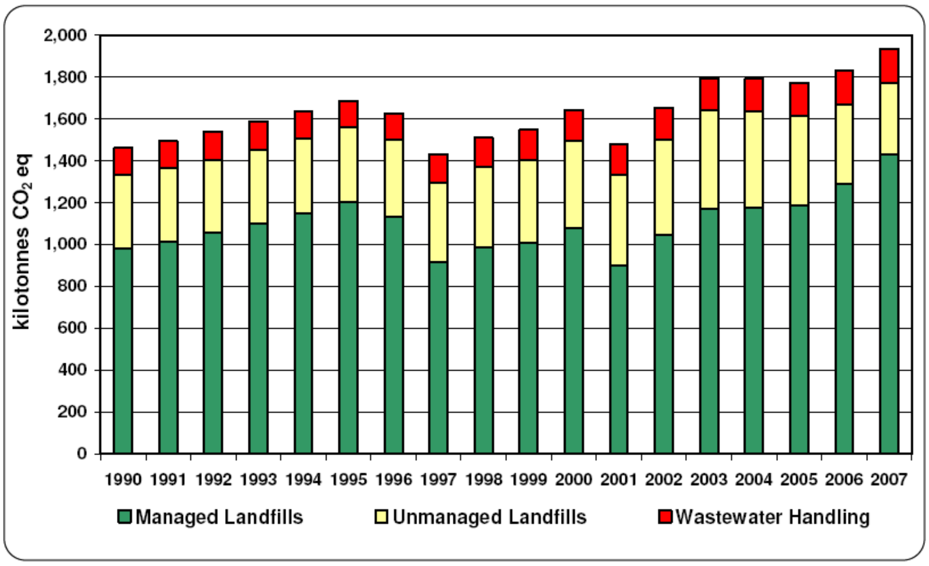


Source: EPA National GHG Inventory Report 2009

Figure 4. GHG Emissions and Sinks in the LULUCF Sector 1990 – 2007

Trends in Waste

The waste sector is an important source of methane emissions, the contribution of which is increasing steadily due to the continued dominance of Landfill as a means of solid waste disposal in Ireland. Emissions increased by 32.5 percent between 1990 to 2007. This increase in emissions takes into account the recovery of landfill gas for energy production and flaring at landfill sites, without which emissions in this sector would be considerably higher. Figure 5 overleaf outlines the trend in emissions from this sector over the period 1990 – 2007.



Source: EPA National GHG Inventory Report 2009

Figure 5. GHG Production Drivers in the Waste Sector 1990 – 2007

In accordance with the Future Climate sectoral classification of Greenhouse Gas emissions sectors, the following split (shown in Figure 6 below) has been estimated for the Ireland 2007 base case.

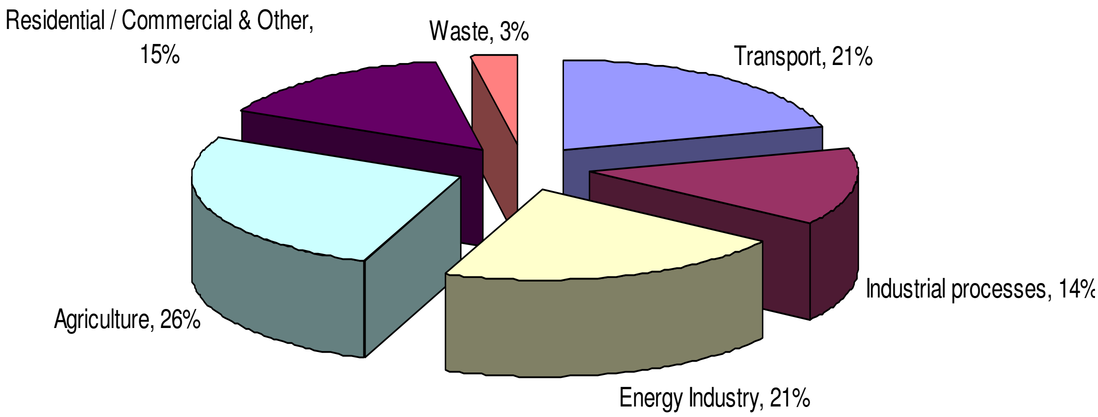


Figure 6. GHG Emissions from Future Climate Sectors Baseline Year 2007

3.2 Irish Energy System

3.2.1 Primary Energy Supply and Energy Use

Currently, nearly 90 percent of Irish Energy demand is supplied by imported primary fuels and electricity. While security of supply is a global challenge, Ireland's position as one of the most import dependent energy economies in the EU places us in a highly vulnerable position. Our energy import dependency has increased from a level of 68 percent in 1990 to a level of 89 percent in 2007.

Our primary energy requirement by fuel is best summarised in Table 1 and Figure 7 overleaf, drawn directly from the SEI/EPSSU Energy in Ireland: Key Statistics 2008 document.

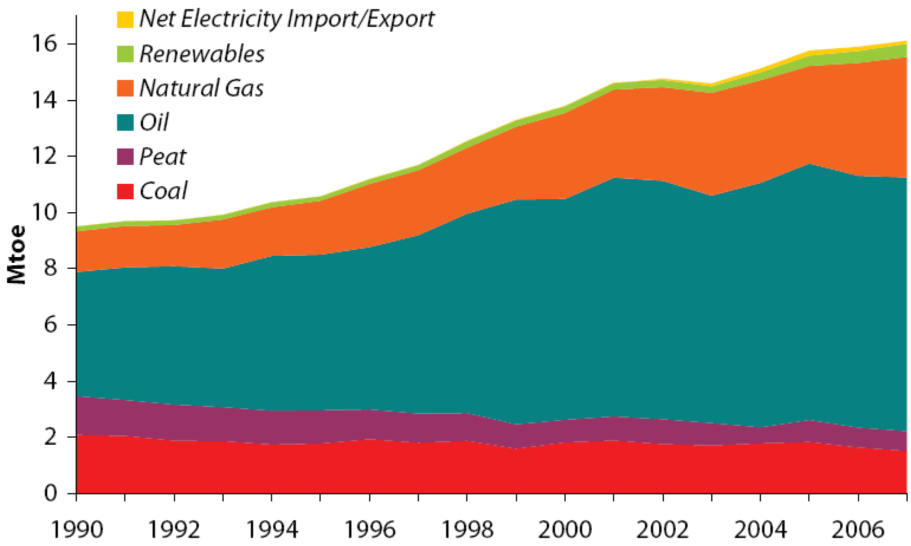
Ireland has limited indigenous resources to address our primary fuel needs, with no major commercial oil deposits and current limited access to commercial Irish gas resources. The level of renewable energy penetration into our primary energy demand is limited by the size and nature of our land-use to date and also by constraints associated with our energy supply infrastructure and limited interconnectivity / isolated grid.

	Total Primary Energy Requirement (ktoe)						Shares %	
	1990	1995	2000	2005	2006	2007	1990	2007
Coal	2,085	1,777	1,815	1,832	1,631	1,508	21.9	9.3
Peat	1,377	1,184	803	776	707	701	14.5	4.3
Oil	4,427	5,547	7,877	9,146	8,978	9,047	46.6	56.1
Natural Gas	1,446	1,916	3,059	3,477	4,019	4,293	15.2	26.6
Renewables	168	155	235	367	422	468	1.8	2.9
Elect. Imports	0	-1	8	176	153	114	0.0	0.8
Total	9,503	10,577	13,797	15,774	15,910	16,132		

- Total primary energy requirement increased by 70% between 1990 and 2007 with natural gas showing the largest relative increase, 197% (6.6% per annum on average).

Source: SEI/EPSSU Energy in Ireland : Key Statistics 2008

Table 1. Total Primary Energy Requirement 1990 – 2007



Source: SEI/EPSSU Energy in Ireland : Key Statistics 2008

Figure 7. Total Primary Energy Requirement 1990 – 2007

3.2.2 Energy Infrastructure

Ireland is an Island nation with limited energy interconnectivity to Europe.

Ireland's Natural Gas network currently comprises approximately 2,300km of transmission pipelines and approximately 10,500km of distribution pipelines. Over 140 population centres across 18 counties are now supplied with natural gas in Ireland. In 1999, Bord Gáis Éireann in conjunction with the Department of Communications Marine and Natural Resources commissioned the Gas 2025 Feasibility Report to recommend future national network infrastructure & configuration. A Second Gas Interconnector from Scotland was recommended to be built immediately together with the Gas Pipeline to the West on security of supply grounds but also to open up the Midlands and West to the benefits of Natural Gas. Today the network includes a high pressure ring main connecting Cork, Limerick, Dublin, and Galway (Cork Dublin Pipeline and Gas Pipeline to the West). High pressure pipelines also extend from Dublin to Belfast (South North Pipeline), Belfast to Derry and to the North East Region (including towns such as Kingscourt, Virginia, Navan, Drogheda and Dundalk). A number of towns in Co. Mayo are now supplied by natural gas from the Mayo-Galway Pipeline which connects the ring main at Craughwell to the Shell E&P Ireland gas processing terminal at Bellanaboy. Three gas inter-connectors link the Irish gas transmission network to the UK gas network at Scotland. One of these supplies Belfast, while the other two inter-connectors make landfall at Loughshinny and Gormanston Co. Meath.

The Kinsale Gas Field (which came on stream in the late 1970's) is now virtually depleted. Over 90% of natural gas consumed in Ireland (North and South) is now imported via the interconnector pipelines. Consequently it has become increasingly important that new sources of gas and additional storage capacity be developed to meet forecasted demands. It is expected that the Corrib Field Development off the Mayo coast may come on stream during 2010 / 2011. This will provide up to 60% of peak demand over a period of 15 years. In 2008, Shannon LNG applied for planning permission to construct a LNG storage facility at Foynes. This would add significantly to Ireland's storage capacity and reduce our dependence on supplies direct from the UK via Europe. Other options for gas storage in Ireland include the development of a salt cavity in Northern Ireland by Bord Gáis Éireann.

In 2008 the electricity Transmission Grid Operator in Ireland, Eirgrid, published a report on Irish electricity infrastructure, Grid25, which provided it's strategy for development in the future. The following general description of the grid is taken from this document.

The transmission grid in Ireland is made up of circuits and equipment at three voltage levels 400kV, 220 kV and 110kV, with the 400kV and more extensive 220kV circuits providing the main means of transporting bulk power around the country. The 220kV network was first introduced in the early 1960's and the 400kV network was built in the early 1980's. Since the mid 1980's this bulk power network has not changed significantly, while demand in the same period has grown by over 150%. This has left little capacity for future growth in demand. Projected bulk power flow on the systems indicates that the capacity of the system will need to double by 2025.

The Grid25 Strategy document identifies the key factors causing power to flow, driving future grid investment. These are:

- Higher demand levels
- Significantly higher renewable generation capacity levels
- Location of new conventional generators and output levels
- Connection points of future interconnectors and transfer levels

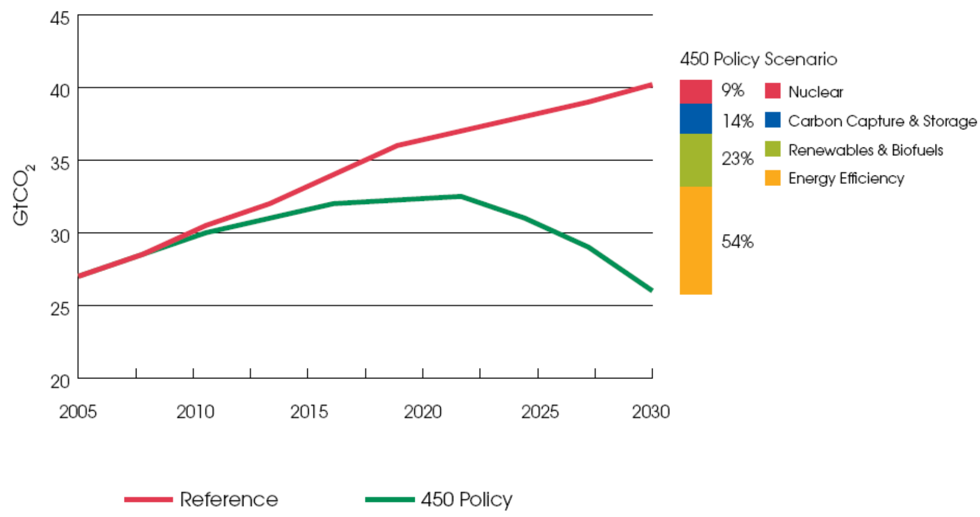
The nature of our existing transmission grid significantly inhibits the penetration of Renewable Energy into our electrical generation portfolio, this has been widely recognised by industry, government, grid operator and our energy regulator.

4 Description of Most Important Technologies and Solutions Proposed

This aspect of the Engineers Ireland Climate Plan will ultimately be supported by an explicit Technologies Report incorporated into an addendum to this document. A significant body of work has been conducted by Sustainable Energy Ireland in producing a Renewable Energy Research Inventory for 2007 and 2008. On publication of this report, the supplementary Technology Reports will be finalised for critical technology areas.

4.1 Demand Side

Energy and Carbon Efficiency is internationally recognised as the most cost effective way of reducing carbon emissions and dependence on fossil fuel. With a 96% dependency on carbon-producing fossil fuels and an 89% dependency on imported energy in 2007, it is critical that we reduce this overall demand, and develop alternatives. The International Energy Agency has also outlined that to achieve their 450 Policy Scenario (targeting a stabilisation of GHG emissions at 450ppm CO_2-eq for energy production) that 54% of the required savings will be achieved through Energy Efficiency, see Figure 8 below.



Source: National Energy Efficiency Action Plan 2009-2020 (IEA World Energy Outlook 2008)

Figure 8. IEA CO_2 Reduction Breakdown

This has been recognised by Irish policy makers, and reflected in their recent publication of a National Energy Efficiency Action Plan 2009 – 2020 for Ireland, outlining the pathways by which we can achieve maximum energy efficiency across a range of sectors. The economic case for a drive towards energy efficiency as a GHG reduction lever is further evidenced in the Sustainable Energy Ireland 'Ireland's Low-Carbon Opportunity' report which analyses the costs and benefits of reducing GHG emissions. This presents a range of carbon abatement methodologies and scenarios in a cost curve format outlining the level of carbon abatement which can be achieved by various abatement methods against the cost per tonne CO_2 equivalent of implementing the abatement method. Critically, it identifies that in a 2030 scenario, approximately 40 percent of abatement potential is estimated to have a negative net societal cost (assuming a crude oil price of $60 per barrel). The majority of this 40 percent is associated with improvements to demand side performance in the form of energy and process efficiency.

Modelling of future cost curves by its nature must involve assumptions and risks associated with same. These are outlined in detail in the report and sensitivity analyses were conducted to ensure the validity of assumptions. The report serves as a robust and informative appraisal of the potential future cost for carbon abatement in Ireland into the future. It will serve as a platform upon which further revisions and iterations can be made as technology and cost certainty improves over time.

4.1.1 Transportation

A reduction in the production of GHG emissions from transport will require a combined engineering approach from both a planning, infrastructural and technological standpoint. The following solutions will all need to be addressed by the engineering profession for there to be a significant impact on transport related GHG emissions:

Transport and Traffic Planning: Traffic and transport planning as a discipline is increasingly becoming more critical for both new development and for the ongoing prosperity of existing business and residential communities. The incorporation of Energy / Carbon evaluation into Transport and Traffic planning will be a critical step to ensuring that the engineering solutions provided within a traffic and transport plan facilitate and enforce a mode-shift from more carbon intensive and/or individual transport options to less carbon intensive and/or more communal modes of transport. Innovation in Traffic and Transport Planning and a recognition of Energy/Carbon efficiency as a critical evaluation tool will be essential.

Internal Combustion Engine – Conventional Fuel: It is likely that improvements in efficiency in the Internal Combustion Engine will lead to a reduction in the GHG emissions associated with both private and commercial transport. This will be essential to meet short to medium term GHG emission targets, prior to the delivery of medium to long term solutions. The engineering knowledge associated with the design of Internal Combustion Engines is now also being used to define efficient driving methods which can be and are being applied across our transport fleet.

Internal Combustion Engine - Biofuel: For certain elements of the Irish Transport Fleet, electrification is not likely to be an option even in the medium to long term. It is likely that this will be the case for freight / heavy goods vehicles. Biofuel technologies has the potential to fill this void, however, this technology can only be integrated into the Irish freight fleet in the context of our own biofuel production potential and the socio-economic impacts of intensive biofuel crop production in place of more conventional food crops.

Electrical Vehicles: Electrification of transport to some extent seems inevitable. This will require both a shift in the provision of vehicle technologies and a shift in the provision of 're-fuel / re-charge' services. In addition, it will be critical that the additional load electrical demand being placed on the system will be supplied by indigenous, low carbon generation. Hybrid cars are currently available in the marketplace and have enjoyed some success. The two electrical vehicle technologies that will have the greatest impact will be Plug-in Hybrids and Battery Electric Vehicles. These technologies are recognised as being mature, however, further improvements in vehicle range and efficiency are likely to be required for a large uptake.

The supporting infrastructure that will need to be put in place (apart from increased indigenous low-carbon electricity production) is significant. This could include a network of recharging points at home, at work and potentially at the kerbside for users. This may include slow-charge points and quick recharge points. An alternative could be to provide battery exchange points. To fully realise the load-balancing potential of plug-in vehicles it is also likely that a separate metering / control system may be required to control overnight recharging.

All of these options will require engineering input. Firstly to evaluate and identify the most cost and carbon effective model for delivery of a large-scale penetration of electric vehicles into the Irish fleet. Following that, the delivery of the electrical infrastructure required to deliver and support the fleet will be required.

The current Irish Energy Efficiency Action Plan has put in place an ambitious target in place to have a minimum of 10% (over 240,000 vehicles) of the passenger car and light commercial fleet electrically powered by 2020.

4.1.2 Residential and Commercial Sector

Significant improvements in residential and commercial sector energy efficiency and GHG emissions reduction have been achieved to date in Ireland. This trend is set to continue. This is largely through the delivery of mechanisms which support the integration of mature, existing technologies and solutions into business and domestic life. Many of these support mechanisms have been delivered by the Government and administered by Sustainable Energy Ireland.

There is still a significant opportunity for GHG abatement in this sector. Some of the support mechanisms may be required to stay in place in order to realise the full abatement potential in the sector. The most important technologies/solutions to this sector will be:

- Building envelope improvements (insulation, glazing, air-tightness)
- Heat source (on-site renewables / District Heating)
- Heat delivery method and control
- Electricity source (on-site renewables / District Power)
- Lighting type and control
- Building Energy Management Systems

While the implementation of these methods and associated innovation will be required to achieve a high level of GHG abatement in the sector, the cumulative benefit of the technologies must be examined. The engineering profession will be required to define the best ‘whole-building’ solution, where the building as a system is considered, as opposed to the isolated implementation of individual technologies and solutions. A number of building technologies and methodologies can be incompatible where not considered cumulatively. It is critical that the engineering profession define best-practice solutions for the building sector to achieve an optimised refurbishment of existing building stock and the definition of improved performance levels for new building stock.

Integration of smart metering at the customer interface is also likely to provide increases in overall energy efficiency. The additional information provided to consumers and incentives offered through time-of-use charges is likely to provide benefit to both customer and grid operator. Pilot studies are currently underway in Ireland to establish the potential benefit of the roll-out of smart-metering technology. The appropriate level of penetration of this technology should follow the results of these pilot trials.

4.1.3 Agriculture

The production of GHG emissions in the agricultural sector is predominantly from enteric fermentation and soils. With regard to 'demand-side' management on farms there are however a number of technologies that can impact directly on the quantity of energy demand at these sites, in addition, changes in farming practices and the type of farming (food crop, biofuel crop, sheep, dairy and beef) could impact directly on emissions in the transportation sector. A shift to greater crop production (given favourable land conditions) as opposed to livestock may cut down on the significant enteric and manure management GHG contributions. However, the knock-on effects regarding soil-related emissions should be considered, as should the broader and potentially significant socio-economic impact on the farming community of this type of shift.

On-farm energy efficiency will need to be improved, as will wastes management. Anaerobic digestion is a mature technology that can be implemented in certain cases on an on-farm basis and could also have potential as a centralised plant option. Other technologies are also examining the on-farm utilisation of certain agricultural residues such as straw, poultry litter and spent mushroom compost. Innovation in this sector, potentially cutting down both direct and indirect agricultural emissions will be critical to Ireland's contribution to climate change targets.

4.1.4 Industry

As cement production is such a large contributor to this sector in Ireland (over 72%), improvements in efficiency and GHG emissions in this sector should have the greatest focus. Due to the relatively recent upturn in cement demand and production during the mid to late 1990's, the current portfolio of cement production plants is relatively efficient, providing only a small potential for direct efficiency improvements in this sector.

There is currently a trend in both the building sector and the cement production industry to use less carbon intensive substitute raw materials (crushed limestone and ground blastfurnace slag in place of clinker) in the production of cementitious products. The substitution of indigenous and renewable fuels for conventional fuels in cement kilns is also currently being examined by many cement producers. However, the definition of fuels and wastes locally and at a European level, with associated licensing constraints can be a limiting factor in the implementation of this as a widespread solution.

4.2 Supply Side

The supply of indigenous renewable energy to Ireland in the future is critical to our achievement of Climate Change targets alongside an immediate need to increase the security of supply of our primary energy needs. Many of the technologies on the demand side will only achieve their full GHG abatement potential where the primary energy they are using comes from renewable resources, electric vehicles for example. This is most acutely felt in the North-west region where a study is currently being completed by Eirgrid to future-proof electrical infrastructure in the area.

Ireland's position as a country with limited electrical interconnection currently limits our ability to meet renewable energy generation targets, particularly where these targets are largely based on our ability to allow wind energy into the generation mix. This difficulty is exacerbated by an internal national grid that, if left static, will have difficulty responding to increased levels of demand and significantly increased levels of renewable energy (predominantly wind) generation.

4.2.1 Transmission, Distribution and Storage Infrastructure

The Eirgrid 'Grid25' study was produced to define a pathway to accommodate increased demand and also to accommodate increased levels of renewable energy onto the grid. To facilitate this, its general proposals are that:

- Approximately 1,150km of new circuits will be required. This represents an increase of about 20% on the total length of the existing network. Of this, 800km will need to be at 220kV or higher with the additional 350km at 110kV.

- 2,300km of the existing transmission network will need to be upgraded to provide greater capacity. This includes 1,100km of the existing 220kV network and 1,200km of the 110kV network.

- Additional interconnections to new and upgraded generators at high voltage will also be necessary.

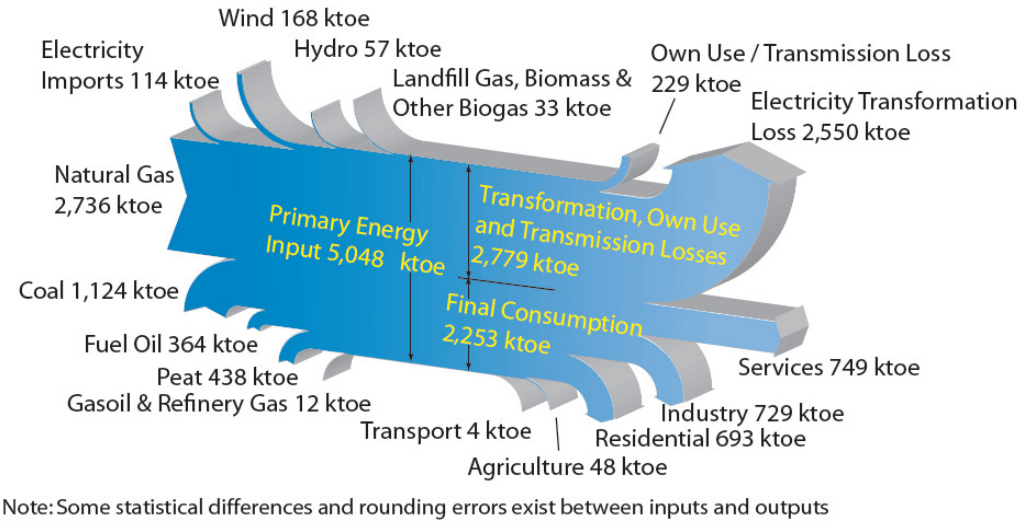
An element of these grid enhancement proposals is to provide greater interconnection between Ireland and a larger energy grid, and energy market. An East-West HVDC interconnector is now proposed between Ireland and Wales together with a new North-South interconnector between Dublin and Northern Ireland. It is anticipated that this would facilitate a greater penetration of renewable energy into the Irish generation portfolio where our internal grid infrastructure allowed this.

To achieve the levels of GHG emissions reduction and energy security required by European and National Policy it is likely that Interconnection will form a part of the suite of solutions required, however it is also likely that a more innovative solution may be required for Ireland. This is particularly the case if the penetration of residential and commercial on-site embedded generation continues to grow and is not necessarily subjected to the same controls as larger generators.

It is likely that energy storage will form a key part of Ireland's energy infrastructure into the future. The technologies that may ultimately provide this service are wide ranging and include *inter alia* distributed Hydrogen / Fuel-cell technologies, pumped hydro storage solutions and compressed air energy storage, and flow battery storage. The greater penetration of electric vehicles could also provide a positive balancing/storage effect where controlled appropriately. These technologies are at varying stages of maturity and commercial readiness and could provide significant challenges in their implementation.

4.2.2 Conventional Fuelled Power Stations

Ireland has an electricity generation portfolio dominated by fossil fuels. The 2007 breakdown in primary fuel consumption for electricity generation is provided in Figure 9 below, taken from the 'Energy in Ireland: Key Statistics 2008' report produced by Sustainable Energy Ireland / Energy Policy Statistical Support Unit.



Source: SEI/EPSSU Energy in Ireland : Key Statistics 2008

Figure 9. Breakdown of Primary Fuel Consumption 2007

It is likely that conventional fossil-fired generation will remain the major part of our generation portfolio for some time to come. The replacement of more carbon intensive fossil fuels (coal, oil, peat) with less carbon intensive primary fuels (natural gas) will need to be achieved, alongside an examination of security of primary energy supply.

The identification of new, accessible and commercial natural gas fields will be critical to Ireland achieving greater carbon efficiency while improving its security of supply in the short to medium term. Beyond 2020 it is possible that carbon capture and sequestration as a technology could form a large part of Ireland's GHG emission reduction methodology.

Considering the significant level of solid fuel generating capacity in Ireland for the short to medium term it is also possible that advances in clean coal technologies could also represent a potential technology options for GHG abatement.

4.2.3 Wind Energy

Both onshore and offshore wind have a large role to play in Ireland's future energy mix. Ireland has a significant absolute wind resource when compared to its absolute energy demand. The limiting factors for wind energy in Ireland currently relate to our position as a constrained and isolated grid. A combination of improved grid infrastructure, improved interconnection and energy storage options would be needed for Ireland to realise it's full wind resource (and become a country at the beginning of a long pipeline/transmission cable as opposed to a country at the end of one).

4.2.4 Hydro Energy

Ireland currently supplies approximately 0.35% of its total primary energy requirement utilising Hydro Energy. This is through a combination of Large-scale hydro generation plant, smaller scale conventional pumped storage facilities and a limited number of run of the river generators. There are arguably few opportunities left for large-scale hydro-power generation projects in Ireland. However, it is likely that as an element of a broader electricity storage/balancing strategy that additional pumped storage facilities may prove attractive as a technological solution.

4.2.5 Ocean Energy

Significant research is being conducted into Ocean Energy in Ireland, both with regard to Tidal power and Wave power systems. Current indications in the market are that the tidal power technologies are closer to commercial development than wave power technologies but both are showing significant promise. While Ireland is targeting becoming a leading authority on Ocean Energy - reflected in the current market position of a number of companies and research centres – it is likely that the technology itself will not contribute significantly to our abatement of GHG emissions in the short to medium term. Ireland has a relatively small tidal resource and while our wave resource is arguably higher, this technology remains further along the development pipeline. Long-term, however, it is likely that both technologies will form part of our generation mix to some extent.

4.2.6 Biomass and Liquid Biofuels

Biomass and liquid biofuel production and use are likely to form an element of our primary energy mix both in the short to medium term and in the long term. There is currently a demand for biomass primarily in the residential and commercial heat market and also an increasing demand for biofuels in certain parts of the transport sector (both general fuel substitution and captive fleets).

In 2007 Ireland supplied over 90% of its biomass demand from indigenous resources but only 54% of its liquid biofuel demand. The development of a robust biomass and biofuel market (both supply and demand) will be a requirement if Ireland is to achieve their GHG abatement and energy security targets. However the scale of this market is limited and must be delivered in the context of broader socio-economic activities.

4.2.7 Waste to Energy

Large-scale, centralised waste-to-energy facilities form a part of many power generation portfolios world-wide, utilising an indigenous feedstock to produce base-load electricity and heat. The integration of this technology into the Irish generation portfolio will increase our security of supply and contribute significantly to carbon abatement, displacing fossil-fuels and also reducing the carbon emission associated with the landfilling of waste or waste by-products from other treatment methods. Currently, many of Ireland's regional waste management plans have a waste to energy component e.g. Poolbeg in Dublin.

4.2.8 Solar Thermal and Photovoltaic

Solar thermal technology will contribute significantly to built environment energy demand reduction, particularly at the residential and small-scale commercial level. Solar photovoltaic technologies are improving continuously in their ability to provide efficient and commercial levels of electricity in areas of low direct sunshine. It is possible that by the 2050 horizon that solar PV will form an element of our energy generation mix, although predominantly on the user / demand side.

4.2.9 Nuclear

The current government in Ireland has retained a legal ban on the development of nuclear generation capacity in Ireland. It is likely that through either a change in legislation allowing either generation here in Ireland or through imported electricity, that nuclear power will support the Irish Energy mix into the future.

From a technological stand-point, nuclear power would facilitate a significant step-change in the abatement Ireland's power-related carbon emissions, albeit not reducing significantly our dependency on imported primary fuels. Challenges with regard to the scale of nuclear plant constructed and the supporting grid infrastructure would also present themselves from an engineering standpoint were a facility to be considered.

5 Description of Climate Plan

The following section outlines the activities that will need to be carried out by the engineering sector in order to enable the delivery of key technologies and infrastructure for Ireland to meet its carbon abatement and energy security targets. These activities comprise the current technological and engineering Climate Plan proposed by Engineers Ireland to support our policy makers.

5.1 Demand Side:

Transportation:

- Engineers, as traffic planners, must continue to encourage the switch from more carbon intensive modes of transport to less carbon intensive modes. Layout, routing and control of thoroughfares must also begin recognising the carbon impact of traffic planning decisions.

- Engineers must continue to innovate in relation to fuel consumption and overall efficiency of the internal combustion engine. This must be in the context of increased use of biofuels in the transport fleet.

- The development of Hydrogen fuel cells for transportation should be reviewed periodically.

- A technical review determining the most cost and carbon-effective use of the realistic Irish liquid biofuel resource should be conducted. These should examine all options such as 100% fuel substitution in a captive fleet, fuel mix in a captive fleet, fuel mix for general/public distribution. It is likely that Public Sector fleets will form an essential element of any liquid biofuel use programme. It should also consider the full range of first, second and subsequent generation biofuels from both virgin resources (sugarbeet, rapeseed, grasses, seaweed/algae) and waste materials (plastics, waste oils) etc.

- A technical and economic analysis of the most appropriate 'electric vehicle solution' must be completed. This must include an analysis of all vehicle technologies and supporting infrastructure required to provide substantial penetration of this technology into the marketplace. The primary source of supply and profile of electrical demand by these vehicles will also need to be considered. Particularly against the background of Ireland's current and future energy mix and the supply vs. demand trade-offs faced by our isolated electricity grid.

<u>Residential and Commercial Sector:</u>

- Significant objective (no technological / solution bias) engineering and technical support needs to be provided to those delivering and availing of support mechanisms for improvement in the residential and commercial built environment. This applies to both new-build and retro-fit scenarios.

- The definition of 'whole-building' or 'building as a system' solutions should be considered. With case studies of typical 'best practice solutions' being identified for varying building typologies. The cumulative benefits of solutions often do not meet predicted targets, due to being considered in isolation from previous, subsequent or parallel technologies and solutions being implemented.

- The completion of the Smart-metering pilot studies should be followed and accompanied by carefully prepared 'full-scale rollout' cost and benefit analyses with regard to both energy/carbon and capital investment.

<u>Agricultural Sector:</u>

- On-farm and Agricultural Energy Efficiency measures need to be promoted. This should involve direct communication between the engineering and agricultural sectors.

- Process innovation and innovation in agricultural machinery should be promoted (utilisation of GPS in crop application, fertiliser distribution etc.)

- Research and Development of on-farm waste reduction and energy production technologies should be increased. This needs to be completed with both centralised and distributed solutions in mind.

<u>Industry Sector:</u>

- Efficiency in new-build and refurbishment of industry needs to become prioritised. This can be difficult where private capital investment constraints the 'value-engineering' window within which internal rates of return and simple payback are considered.

- Further innovation in the Cement industry needs to be considered, both in the use of substitute raw materials and the utilisation of replacement, less carbon intensive fuels. This will require multi-disciplinary engineering input.

- A technical discussion on the utilisation of less carbon intensive cementitious products needs to be completed within the engineering industry. Less carbon intensive products have been proven to meet and surpass performance levels of conventional cementitious products for certain applications.

5.2 Supply Side

Transmission, Distribution and Storage Infrastructure:

- Detailed technical and economic analyses need to be performed on the proposed large-scale grid refurbishment. This needs to acknowledge the future technological requirements of a more diversified energy portfolio in the first instance with policy drivers considered in parallel.

- Analysis of geological and alternative gas storage options needs to be continued.

- An in-depth technical analysis of Interconnection and Storage options is needed to assess Ireland's technological and infrastructural compatibility with current renewable energy targets. It is likely that a combination of interconnection and storage methods will be required to meet Ireland's Carbon and Security of supply targets.

- All storage and interconnection options need to be examined from a technology neutral (with no bias towards or away from any technology) standpoint in the first instance to judge their technical potential and technical appropriateness. Policy, Environmental and Land-use Planning constraints should be considered following the identification of a technology-neutral suite of options.

Conventional Fuelled Power Stations:

- The development of Carbon Capture and Storage/Sequestration technologies needs to be followed. The technical and economic capacity for Ireland to implement these technologies with our existing and future generation portfolio (and to adapt our portfolio to same) needs to be updated on a periodic basis as this technology becomes more mature and commercial.

- Advances in natural gas exploration and recovery need to be pursued to ensure short to medium term achievement of carbon targets alongside an improvement in security of supply.

- Development and adoption of clean coal technologies, against the backdrop of Ireland's generation portfolio needs to be conducted periodically.

Hydro Power:

- The potential for pumped storage facilities needs to be examined on a technical and economic basis, in conjunction with the examination of other potential load balancing options (interconnection, electric vehicles, compressed air storage) *inter alia*.

Ocean Energy:

- Technology development and technology transfer to commercial markets needs to continue in this area. Ireland has an opportunity to position itself as a centre of excellence for ocean energy devices. The engineering sector is critical to achieving this.

- The resource potential of Ocean Energy delivered to the Irish grid should be reviewed periodically as these technologies come closer to the market.

Biomass and Liquid Biofuels:

- Biomass and liquid biofuel production technologies will continue to perform a role in the Irish energy portfolio. The supply chain and ultimate use of these products needs to be examined from a technical and economic standpoint in order to achieve the most carbon and cost effective utilisation of these resources.

Waste to Energy:

- The integration of this indigenous energy resource as base-load energy generation needs to be considered and developed. Waste to Energy is a mature technology which has a place in Ireland, the penetration of which will be limited by the waste resource potential.

Solar Thermal and Photovoltaic:

- Increased utilisation of these technologies could provide a significant level of GHG abatement in the residential and commercial sector. Treatment of these as part of a 'whole building solution' is required to optimise their effectiveness. Engineering input will be required to achieve this.

<u>Nuclear:</u>

- An objective technical and economic study on the merits of integrating nuclear power into the Irish generation mix needs to be conducted.

5.3 Innovation and Education

Innovation, research and demonstration need to be promoted by, and within, the engineering profession in the academic, public and private sectors.

The success achieved in the biomedical, pharmaceutical and ICT sectors through academic and private industry linkages is demonstrated in the level of successful spin-off businesses and incubation centres based around centres of excellence within the country. It is also reflected in the high esteem with which Irish research in these sectors is held. The level of manufacturing in Ireland has shown a decreasing trend in recent years. This needs to be replaced by a research and technology development employment profile. Initiatives promoting engineering and technological education and careers are critical to the achievement of this.

The link between innovation, energy and employment policy is critical in this regard. Engineering input on relevant energy technologies (and technology sectors) in the development pipeline needs to be provided to policy-makers in order to ensure that education, funding and employment incentives are directed correctly to achieve the required result.

Methods to increase the quality and level of technical education available to students from an early age should be increased. The methods currently utilised to promote technical education need to be further supported and expanded by both the engineering profession and policy-makers.

5.4 Cross-sectoral Activities

The engineering profession needs to take a leadership role in the drive toward a more carbon-effective economy. This needs to be delivered via greater interaction between the engineering profession and policy-makers and the provision of objective, technology-based, support which can then be delivered against the backdrop of policy, environmental and land-use planning objectives.

The importance of delivering engineering knowledge to a broader audience will be critical to achieving the ambitious energy efficiency targets established by the government in their National Energy Efficiency Action Plan. The engineering profession must become more central to the delivery of this message and to the achievement of behavioural change in addition to their traditional role in the delivery of technical and technological change. The profession needs to communicate its expertise more effectively.

The engineering profession is critical to environmental protection, climate change prevention and adaptation. It is essential that a broader technical forum is created for debate on energy infrastructure, use and carbon related challenges. This will critically require the involvement of major stakeholders in the environmental and land-use planning areas. A transparent understanding and consensus must be achieved with regard to:

- recognition of the climate change challenges we face;
- the range of technical solutions to these challenges;
- the constraints faced by Ireland in implementing these challenges; and
- the means by which these solutions can be facilitated.

Engineers should provide the lead in this cross-sectoral forum. Participants should also include land-use planners, environmental scientists, geographers and geologists among others. The major points of agreement and conflict of this forum should then be aired in the public arena to ensure that more informed national debate can be progressed on these issues.

6 Measures Required to Facilitate Climate Plan

The following section outlines the general measure that will be required to facilitate the delivery of both the Climate Plan and the delivery on the ground of the infrastructure, technologies and methodologies identified as forming an element of the carbon abatement solution for Ireland. Many of these measures are outside the general remit of engineers and will require implementation by other governmental and non-engineering sectors of the economy.

- The provision of support for energy efficiency programmes has had a significant positive impact on both energy efficiency and energy and broader carbon awareness in Ireland, this needs to be continued and expanded for Ireland to reach its GHG and energy security targets.

- The approach toward energy and carbon solutions needs to become increasingly more technology-neutral, relying initially on technical and economic review in the first instance to provide a suite of options that can then be considered in a policy framework. The provision of initial targets for energy security, renewables penetration, carbon abatement etc. will in the first instance need to be a combined effort and is likely to be iterative on review of the technological capacity and possibility of achieving those targets.

- Environmental and Land-use Planning stakeholders need to engage with engineers regarding the possible options available to achieve policy requirements with regard to security of supply, renewable energy penetration and carbon abatement. This debate needs to take into account broader socio-economic factors in addition to environmental, planning and technical.

- Private sector industries, in tandem with the government, must provide leadership in the development of new market sectors and in the penetration of new technologies into the marketplace e.g. electric vehicles.

- Investment Fund Managers and Lending Institutions need to incorporate a greater level of Engineering and Technological analysis and input into their investment methodologies.

7 Economic Impact, Business and Job Creation

The engineering sector in Ireland is currently experiencing a downturn in employment. This applies in nearly every sector of engineering including consultancy, manufacturing and construction. In the R&D and energy sectors specifically, activity remains generally high. However, a decrease in infrastructural lending and capital investment has resulted in at least a temporary slowdown in growth.

It is important for Ireland that the solutions provided to our security of supply and climate change challenges incorporate a learning curve in the energy and climate business sectors. This could occur in four or five major segments of the industry:

- Research and Development
- Design and Project Management/Delivery Consultancy
- Construction
- Manufacturing
- Project Finance and Business Analysis

It is highly unlikely that a similar level of growth will occur in each of the business sectors above, and it should be recognised that in some cases, the growth in these sectors will only be temporary. An analysis of the technical solutions on offer to Ireland should be accompanied by a long-term employment review / projection by organisations such as Enterprise Ireland and the IDA, in an attempt to identify the best area to focus Irish efforts and the areas which should be targeted for indigenous business and academic growth for long-term security of supply of both energy and employment.

Appendix A – Data Sheet From Climate Plans