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Submission to Oireachtas Joint Committee on Environment, Culture and the Gaeltacht Committee on Outline Heads of the Climate Action and Low-Carbon Development Bill

by

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Introduction

The Energy Policy and Modelling Group in UCC's Environmental Research Institute is a group of twelve researchers who carry out energy modelling to increase the evidence base for energy and climate policy. The Group is lead by Dr. Brian Ó Gallachóir and comprises two post-doctoral researchers, six PhD students and three Masters students as shown in Table 1.

Principal Investigator
Brian Ó Gallachóir

Post-Doctoral Researchers
Paul Deane (Energy System and Electricity))
Fionn Rogan (Modelling Future Gas Demand)

PhD Students
Denis Dineen (Residential Sector)
Alessandro Chiodi (2050 Energy and CO_2 Scenarios)
Maurizio Gargiulo (Energy System and Economy)
Emer Dennehy (Energy Efficiency Evaluation)
Declan Doyle (Energy in Industry)
James Glynn (Energy Security)

MEngSc Students
Liam McLaughlin (Energy Efficiency Industry)
Patrick Calnan (Modelling EVs)
Annicka Wänn (Bioenergy Regional Plan)

Table 1 UCC's Energy Policy and Modelling Group

Brian Ó Gallachóir has been involved in energy policy and modelling research for 23 years. He is also a lecturer in Energy Engineering in UCC's School of Engineering and co-ordinator of UCC's taught Masters Programme (MEngSc) in Sustainable Energy. He is the elected Chair of the International Energy Agency Executive Committee for the Energy Technology Systems Analysis Programme (IEA-ETSAP). In addition, he is an elected member of the Royal Irish Academy Climate Change Sciences Committee and and was a member of the Technical Analysis Steering Group on Energy Security and Climate Change. He spent many years as strategic advisor to Sustainable Energy Authority of Ireland and represented Ireland on EU Committees relating to energy statistics and energy modeling. He is currently the highest ranking *Google Scholar* internationally in energy modeling.

Brian has published 99 peer reviewed journal and conference papers (with a further 22 in review), 75 reports and book chapters and delivered 114 invited papers.

The research focus of the Energy Policy and Modelling Group is on i) bottom up techno-economic modelling of sectoral energy demand, ii) electricity dispatch modelling and iii) energy systems optimisation using TIMES.

Our recent research of relevance to the Oireachtas Committee's deliberations on the Outline Heads of the Climate Action and Low-Carbon Development Bill has been to quantify the following:

a. how can Ireland can meet future greenhouse gas (GHG) emissions reduction targets at least cost?
b. what are the implications of different GHG emissions reduction targets for Ireland in terms of technology and cost?
c. what are the marginal abatement costs for different GHG emissions reduction targets in Ireland for the period to 2020, to 2030 and to 2050?
d. to what extent can additional GHG emissions reductions imposed on Ireland's energy system compensate for the low number of mitigation options available in agriculture

Executive Summary

Ireland has faced and continues to face considerable challenges in transitioning towards a low carbon economy. In the period 1990 – 2005, Ireland's greenhouse gas emissions grew by 24% in contrast to the EU, where emissions dropped by 8%. Ireland has particular challenges relating to the role of agriculture, which although largely export based, contributes very significantly to GHG emissions (representing approx 30% of total GHG in Ireland compared with less than 10% for the EU). In a number of key areas Ireland has shown that policy changes can have a significant impact, for example Ireland's wind energy strategy (wind energy increased from 1% of electricity generation in 2000 to 16% in 2011) and changes to private car taxation (the average CO_2 performance of new private cars prior to 2008 was 166 gCO_2/km and this reduced to below 130 gCO_2/km by 2011). However, these successes are in certain areas only and do not extend across the energy system of the whole economy. As a result, Ireland's energy system continues to be dominated by fossil fuels (representing over 90%) with associated high import dependency (88%) raising concerns regarding energy security in addition to the challenges of transitioning to a low carbon economy. and environmental impact. We have developed scenarios for Ireland focussing on the transition to a low carbon economy by 2050. We have quantified the costs and identified the technology change required to achieve this goal. Our results also help to inform Ireland's response to shorter term 2020) pathways and provide an evidence base to develop appropriate national targets for Ireland (and to engage in any EU Directive negotiations for 2030). We make 8 recommendations relating to targets, comprehensiveness of strategy, the need for a robust evidence basis for policies and to build on the useful but limited examples of good policy.

Submission

The most recent Assessment Report from the Inter-governmental Panel on Climate Change (IPCC) [1] concludes that the warming of the climate system is 'unequivocal' and that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gases (GHG) concentrations. Growing worldwide concerns regarding the anthropogenic interference with the climate system, resulted in the Cancun Agreements in 2010 that established global commitment to a maximum temperature rise of 2 degrees Celsius above pre-Industrial levels, requiring deep cuts in greenhouse gas (GHG) emissions levels to achieve this goal [2].

In order to reach that objective an IPCC Assessment Report shows that global GHG emissions must peak by 2020, while by 2050, global GHG emissions should be reduced by at least 50 % below their 1990 levels [3]. The European Union (EU) has proposed that industrialized countries should contribute to this global emissions reduction target by reducing GHG emissions by 30% by the year 2020 and between 80% and 95% by the year 2050, relative to 1990 levels. Even in the absence of wider international agreement on climate policy in order to meet this objective the EU has set ambitious greenhouse gas (GHG) emission reduction targets for 2020 [4, 5] and 2050 [6]. As part of the latter EU Low Carbon Roadmap (see Table 2), the indicative target for 2030 is a 40% reduction in greenhouse gas emissions relative to 1990 levels.

Sectors	2005	2030	2050
Power (CO_2)	-7%	-54 to 68%	-93 to -99%
Industry (CO_2)	-20%	-34 to -40%	-83 to -87%
Transport (incl. CO_2 aviation, excl. maritime)	30%	+20 to -9%	-54 to -67%
Residential and services (CO_2)	-12%	-37 to -53%	-88 to -91%
Agriculture (non-CO_2)	-20%	-36 to -37%	-42 to -49%
Other non-CO_2 emissions	-30%	-72 to -73%	-70 to -78%
Total	-7%	-40 to -44%	-79 to -82%

Table 2 – EU Low Carbon Roadmap GHG reduction compared to 1990 (Source EC)

1 IPCC, 2007. Climate Change 2007 - The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

2 UNFCCC 2011 Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010 Addendum Part Two: Action taken by the Conference of the Parties at its sixteenth session (FCCC/CP/2010/7/Add.1)

3 IPCC, 2007. Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and and New York, NY, USA.

4 EU, 2009 DECISION No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020, in: European Parliament and Council (Ed.). Official Journal of the European Union, p. 13.

5 EU, 2009 DIRECTIVE 2009/29/EC the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community in: European Parliament and Council (Ed.). Official Journal of the European Union, p. 25

6 EC, 2009. Presidency Conclusions. Brussels 29/30 October 2009, in: Council of the European Union (Ed.), Brussels, Belgium.

Within the EU, the short term GHG emissions reduction targets for 2020 have been allocated to Member States (MS) under an effort sharing decision [4,5], but not the longer term target. However, some Member States have already established or are planning long term emissions targets. The United Kingdom has legislated for an 80% GHG emissions reduction target while France is planning to reduce emissions by 75% over the period 1990-2050 [7, 8].

This submission focuses Ireland, and is based on analysis carried [9, 10, 11, 12, 13, 14, 15, 16, 17, 18] out that provide an evidence base to underpin discussions regarding the Outline Heads of the Climate Action and Low-Carbon Development Bill.

Ireland is an interesting case study relative to other Member States for two distinct reasons. Firstly, in contrast to the EU generally, greenhouse gas emissions increased by 24% between 1990 and 2005 as shown in Table 3.

	1990		2005		
	EU-27	*IE*	*EU-27*	*IE*	
Total GHG Emissions	5588.8	55.6	5148.8	69.0	[Mt$_{CO2eq}$]
Variation relative to 1990	-	-	***-7.9%***	***24.1%***	
2050 Target	1117.8	11.1	1117.8	11.1	[Mt$_{CO2eq}$]
Reduction required	*-80%*		*-78%*	*-84%*	

Table 3 – GHG Emissions in EU-27 and Ireland (Data sources: EEA for EU-27, EPA for IE)

Ireland experienced high levels of emissions growth in line with buoyant economic growth, with overall levels of GHG emissions growing from 55.6 to 69.0 Mt. The impact of this is shown in Table , i.e. an 80% emissions reduction target relative to 1990 levels is equivalent in Ireland to an 84%

7 CCC, 2008. Building a low-carbon economy – the UK's contribution to tackling climate change. Published by The Stationery Office, London, United Kingdom, <http://hmccc.s3.amazonaws.com/pdf/TSO-ClimateChange.pdf>.

8 Environment Round Table, 2009. French Climate Plan. Le Grenelle Environment, 24.

9 Chiodi A., Gargiulo M., Rogan F., Deane J.P., Lavigne D., Rout U.K. and Ó Gallachóir B.P. 2013 *Modelling the impacts of challenging 2050 European climate mitigation targets on Ireland's energy system* **Energy Policy** Vol 53 pages 169 - 189

10 Dineen D. and Ó Gallachóir B. P. 2011 *Modelling the Impacts of Building Regulations and a Property Bubble on Residential Space and Water Heating.* **Energy and Buildings** Volume 43 Issue 1 Pages 166 - 178

11 Smyth B. M., Ó Gallachóir B. P., Korres N. E. and Murphy J. D. 2010 *Can we meet targets for biofuels and renewable energy in transport given the constraints imposed by policy in agriculture and energy?* **Journal of Cleaner Production** Volume 18 Issues 16-17 Pages 1671 - 1685

12 Cahill C. and Ó Gallachóir B.P. 2013 *Assessing the impact of carbon tax on Irish manufacturing costs.* **Energy Policy** (submitted February 2013)

13 Glynn, J., Chiodi A., Gargiulo M., Deane J.P., Bazilian M., Ó Gallachóir B.P. 2013 *Energy Security Analysis: The case of constrained oil supply for Ireland* **Energy Policy** (submitted January 2013)

14 Rogan F., Chiodi A., Gargiulo M., Deane J.P., Bazilian M., Ó Gallachóir B.P. 2013 *Modelling the impacts of carbon capture and storage as a carbon mitigation technology.* **Energy Policy** (submitted December 2012)

15 Chiodi A., Gargiulo M., Lavigne D., Rout U.K. and Ó Gallachóir B.P. 2012 *Modelling the impacts of challenging 2020 non-ETS GHG emissions reduction targets on Ireland's energy system* **Energy** (Submitted July 2012)

16 Rogan F., Ó Gallachóir B.P. 2012 *Building Regulations - how effective are they at delivering energy efficiency?* **Energy Policy** (Submitted May 2012)

17 Dineen D., Rogan F., Ó Gallachóir B.P. 2012 *One energy efficiency programme but a range of possible energy savings.* **Energy** (Submitted June 2012)

18 Daly H.E. and Ó Gallachóir B. P. 2012 *Future Energy and Emissions Policy Scenarios in Ireland for Private Car Transport* **Energy Policy** Vol 51, Pages 172 - 183.

emissions reduction target relative to 2005 levels. This emissions growth in the period 1990 - 2005 that Ireland has experienced is in marked contrast to other industrialised countries between 1990 and 2005, as evident from EU-27 emissions figures that decreased by approximately 8%. These trends have been changing since 2008 by the impacts of the economic recession in Ireland, with emissions reducing from 69.0 Mt CO_2 equivalents in 2005 to 62.3 Mt in 2009.

The second distinguishing characteristic of Ireland is the significant share of GHG emissions arising from agriculture, which according to the EU Low Carbon Roadmap, provides limited scope for deep emissions cuts. Within the EU-27, in 2005 energy accounted for 79% of GHG emissions and agriculture is responsible for approximately 11% (9.3% non-energy). In Ireland, however, as shown in Figure 1, energy accounts only for 66% of emissions (green areas), while agriculture has an important role on the emissions balance contributing to about 28.5% (27.1% non-energy related) of total GHG emissions (EEA, 2010).

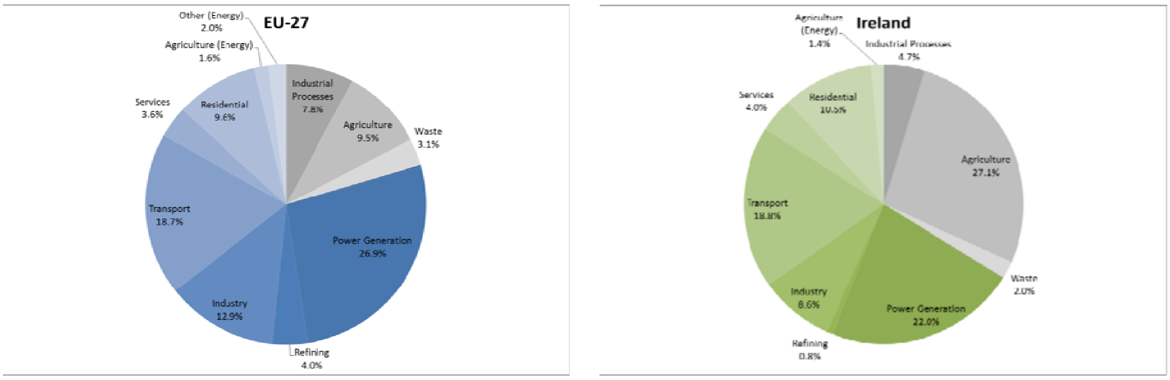

Figure 1 – Comparing 2005 GHG emissions share in EU-27 and Ireland (Data source: EEA)

The combination of these two contextual points (emissions growth to 2005 and the significance of agriculture) results in a considerable challenge for Ireland to meet its emissions reduction targets for 2050 and makes Ireland an interesting case study for analysis.

Mitigation strategies for deep cuts in emissions require significant financial investment and the development of strategies based on poor information and analysis will be expensive and wasteful. Policy makers require comprehensive, robust, knowledge based information to inform their decisions on how to meet these targets in a manner that will most benefit the Irish economy. In particular given Ireland's current economic difficulties, it is vital that modelling capacity is improved as a matter of urgency and that the information base, which feeds into policy decisions, is greatly improved. This submission draws on a number of research projects, in particular the development of the Irish TIMES Energy Systems Model [19], which makes a considerable contribution to Ireland's need to significantly expand its capability in energy modelling.

The Irish TIMES model provides a range of energy system configurations for Ireland that will deliver projected energy service demand requirements optimised to least cost and subject to a range of policy constraints for the period out to 2050. It provides a means of testing energy policy choices

19 Ó Gallachóir B.P., Chiodi A., Gargiulo M., Deane J.P., Lavigne D. and Rout U.K. 2013 *Irish TIMES Energy Systems Model (CCRP 2008 3.1)*. Report published by EPA.

and scenarios, and assessing the implications for a) the Irish economy (technology choices, prices, output, etc.), for b) Ireland's energy mix and energy dependence, and for c) the environment, mainly focussing on greenhouse gas emissions. It is used to both examine baseline projections, and to assess the implications of emerging technologies and mobilising alternative policy choices such as meeting renewable energy targets and carbon mitigation strategies.

This full energy systems approach contrasts with recent policy focus in Ireland, which has tended to be limited to sub-elements within the energy system. We have seen successful policy support for wind energy for example, which resulted in significant increase in the contribution by wind energy to meeting Ireland's electricity needs over the past ten years, as shown in Figure 2. Wind energy accounted for 1% of Ireland's electricity generation in 2001, compared with 16% in 2011.

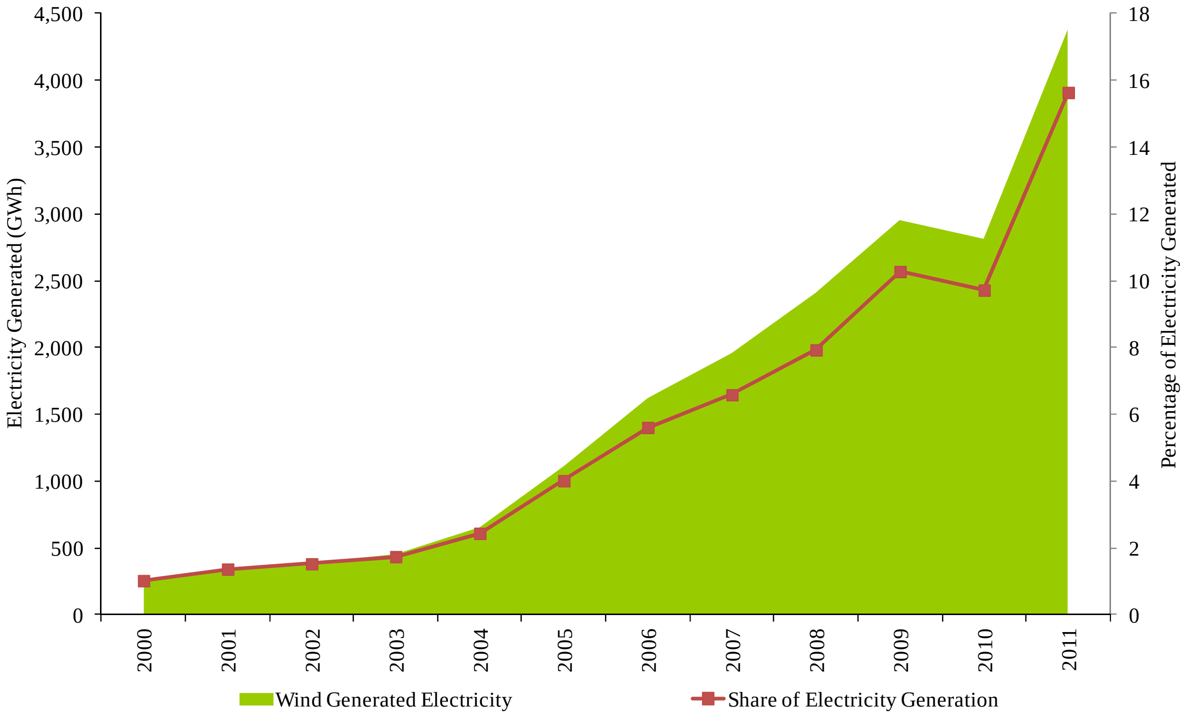

Figure 2 Wind generated electricity in GWH and as a share of total electricity generation - Source SEAI

Another successful policy instrument was the change in car taxation. In December 2007 [20], the Irish government announced that vehicle registration tax (VRT) and annual motor tax (AMT) were to change with effect from 1st July 2008. New cars registered between 1 January 2008 and 30 June 2008 would have their motor tax charged on the basis of engine size but if it was beneficial for these cars to switch to the CO_2 based system, this would be effected on the first renewal of motor tax after 1st July 2008 [21].

The new system is based on specific CO_2 emissions rather than engine size. This type of policy is one of the three main pillars of policy that can focus on reducing energy related emissions, the other two being the labelling guidelines and consumer information campaigns and the voluntary

20 http://www.budget.gov.ie/2008/financialstatement.html#_Toc184577380
21 DEHLG, 2010. Motor Tax – General Information.

commitments of the European, Japanese and Korean associations of auto manufacturers [22]. The impact of the new VRT and AMT policy in Ireland has attracted international interest from the EU ODYSSEE network [23] and the International Energy Agency [24].

Figure 3 shows the change in the weighted average CO_2 performance of new private cars entering the fleet in Ireland over the period 2000 – 2012. The impact of the car taxation change is clearly evident. The average CO_2 performance of new private cars prior to 2008 was 166 gCO_2/km and this reduced to below 130 gCO_2/km by 2011.

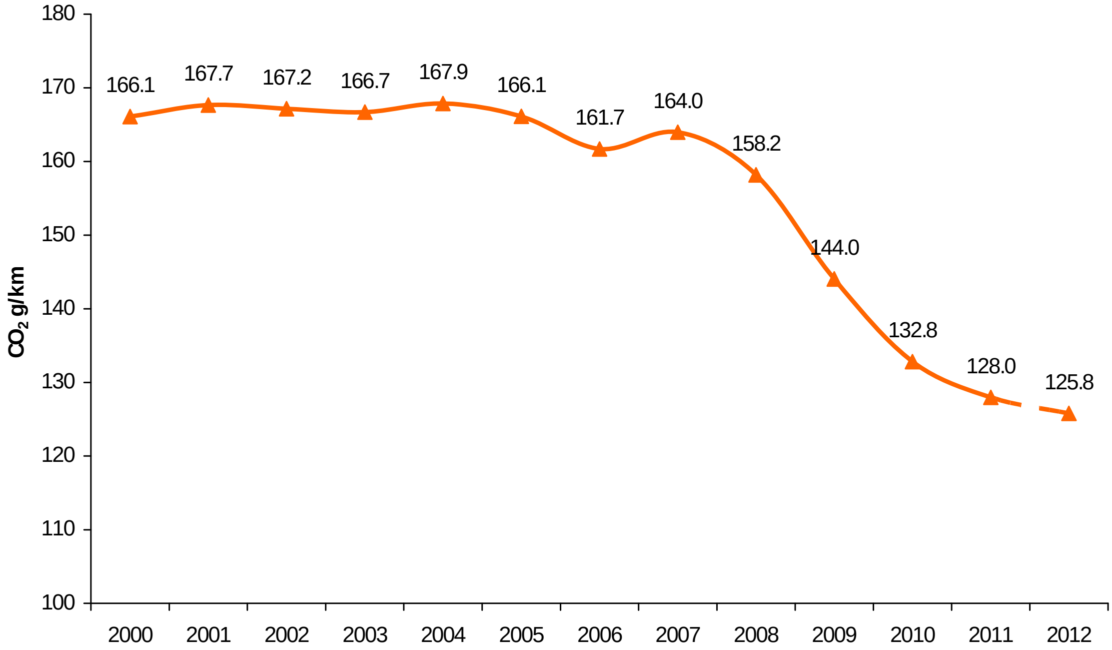

Figure 3 Weighted average CO_2 performance of new private cars in Ireland - Source SEAI

While acknowledging the success of these individual policies (other examples also exist but in some cases their effect is not yet evident, including changes in building regulations to improve he energy performance of new homes), what is clearly needed is a full energy systems plan and this is the approach adopted here.

There are clear limitations that need to be borne in mind when interpreting the results from the energy systems modelling, most notably these results are not attempts to forecast the future. The scenarios are based on different policy assumptions and the results from one scenario are best interpreted through comparison with the results from other scenarios, rather than as absolute results. Regarding the absolute results, they clearly depend on robustness of future projections of economic

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22 Frondel, M., Schmidt, C.M., Vance, C. (2010) A regression on climate policy: The European Commission's legislation to reduce CO2 emissions from automobiles. *TRANSPORTATION RESEARCH PART A*, 1-9.

23 Howley, M., Ó Gallachóir, B.P., Dennehy, E. 2009 The greening of the vehicle registration tax (VRT) and the annual motor system in Ireland. . Proc ODYSSEE Workshop May 18- 19 2009, Paris, France.

24 Howley, M., Ó Gallachóir, B.P. 2009 Data Gaps and Barriers - Experience from Ireland. . Proceedings of IEA Workshop on Data, Analysis and Policy: the Three Faces of Energy Efficiency Indicators, Paris.

growth and fuel prices that drive the model. In addition, as the focus of this model is on technology choice, the representation of behavioural effects is only represented in a limited manner.

Despite the limitations, the real value of the Irish TIMES model is in the new insights if gives us into some of the key challenges and decisions facing Ireland in energy and climate policy. The two key new perspectives this research project provides us with is a full energy systems modelling approach and a focus that can examine the medium term (to 2050) as well as the short term (to 2020).

GHG emissions reduction targets for 2020

This section focuses on scenario results that address the following questions

- What are the implications of Ireland's target for greenhouse gas (GHG) emissions reductions (particularly in non emissions trading (non-ETS) sectors as stipulated in EU Decision 406/2009) for Ireland's energy system?
- If agriculture-related GHG emissions to 2020 are in line with the Food Harvest 2020 policy, can Ireland's energy system achieve deeper emissions reductions to compensate for growth in agriculture, and at what cost?

Two scenarios are built in Irish TIMES to inform decisions regarding Ireland's target to reduce non-ETS GHG emissions by 20% below 2005 levels by 2020 as stipulated in EU Decision 406/2009. The *NETS-CO2* scenario imposes a 20% constraint on the energy system only. This implicitly assumes that the other non-ETS sectors of the economy (notably agriculture) can also deliver a 20% GHG emissions reduction target by 2020. The *NETS-GHG* scenario assumes that agriculture-related GHG emissions follow a trend aligned to the Food Harvest 2020 policy. In this case, the non-ETS emissions reduction target for the energy system is increased to 31.5% to compensate for a lower than 20% reduction achieved by agriculture. The purpose of these scenarios is to inform decisions regarding the different sectoral contributions to meeting Ireland's overall non-ETS sector target. Further details are available in Chiodi *et al*, *2012b* [see footnote 15]

Figure 4 shows Ireland's energy-related non-ETS emissions from 2005 to 2020, comparing the *REF* scenario results with the *NETS-CO2*. In particular Figure 4 indicates which sectors contribute most to non-ETS emissions reduction. It is important to note that the *REF* scenario represents a least cost energy system pathway and hence already includes cost effective energy efficiency improvements and renewable energy deployment. The *REF* scenario also incorporates the effects of the 2008 and 2011 Building Regulations, which has the effect in the model that new buildings have a significantly improved energy performance compared with existing buildings. In this NETS-CO2 scenario, the results suggest that significant non-ETS emissions reductions may be achieved within the residential (accounting for 42.1% of the emissions reduction compared with REF), transport (accounting for 31.3% of the emissions reduction) and the services sector (24.4% of the emissions reduction).

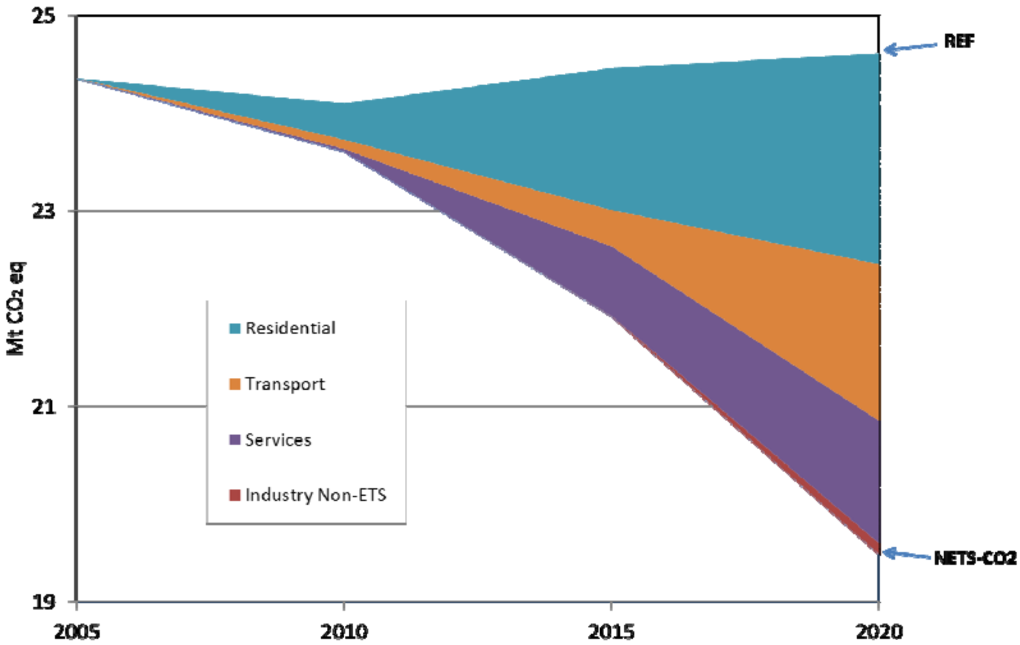

Figure 4 - Comparing Non-ETS CO_2 emissions in *REF* and *NETS-CO2* (Mt)

The emissions reductions in the *NETS-CO2* scenario are achieved through increased energy efficiency and as a result of two key fuel switching pathways, namely significantly increasing the amount biofuels used in transport and the electrification of heating in buildings. In the case of the latter, electrification of heating shifts CO_2 emissions from the non-ETS sectors (heating in the residential and services sectors) to the ETS sectors (namely electricity generation). Electrification of transport (i.e. introducing electric vehicles) delivers a similar result but this technology does not feature significantly in the results due to the cost of EVs (in particular the battery costs).

These results point to the need to reassess Ireland's renewable energy policies in light of the non-ETS emissions reduction target. The results point to a focus on renewable heat, renewable transport and electrification of heat, in contrast to the current dominant focus on wind generated electricity. In order to meet Ireland's targets for renewable heat and to achieve further emissions reductions it will be necessary to develop effective policy measures for fuel switching. Two previous schemes have encouraged fuel switching to renewable for heating, namely Greener Homes in the residential sector and ReHeat in the commercial, industrial, services and public sectors. These schemes finished in 2011. The scenario results also suggest that the current policy focus will likely result in failure to meet the non-ETS target while ETS companies may have significant amount of emissions allowances to sell and trade with other companies across the EU.

Figure 5 also graphs Ireland's energy-related non-ETS emissions from 2005 to 2020, but in this case comparing the *NETS-CO2* with the *NETS-GHG* results. It captures the effect of the additional burden placed on the energy system to compensate for agriculture.

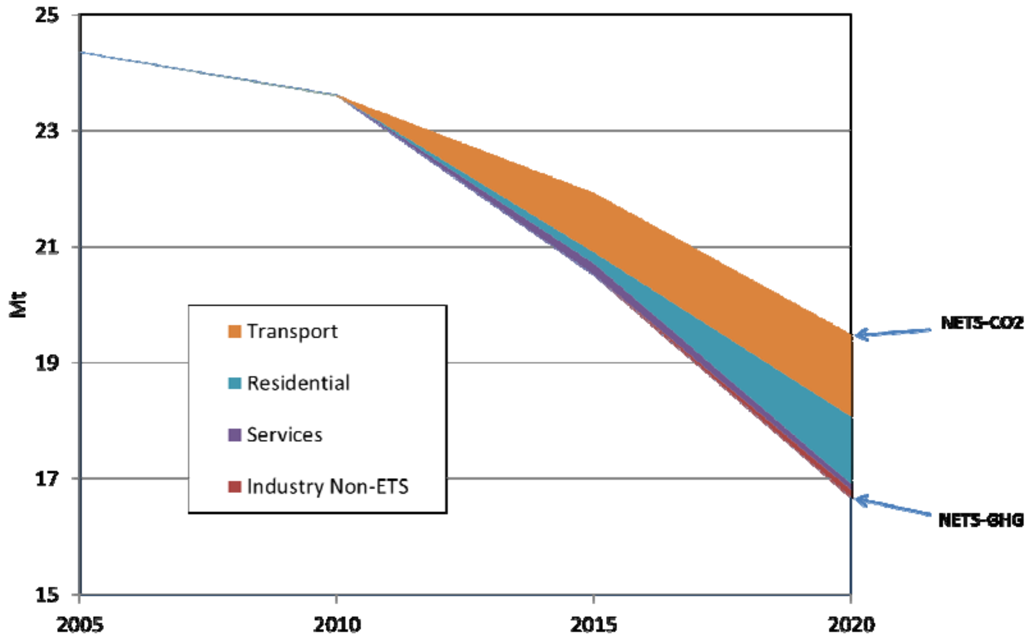

Figure 5 - Comparing Non-ETS CO_2 emissions in *NETS-CO2* and *NETS-GHG* (Mt)

The *NETS-GHG* scenario points to further use of biofuels for transport, compared with *NETS-CO2* (resulting in 21% RES-T) and further electrification of heat in buildings. Figure 6 provides an interesting comparison between the renewable energy pathway envisaged in Ireland's NREAP with that arising from the *NETS-GHG* scenario.

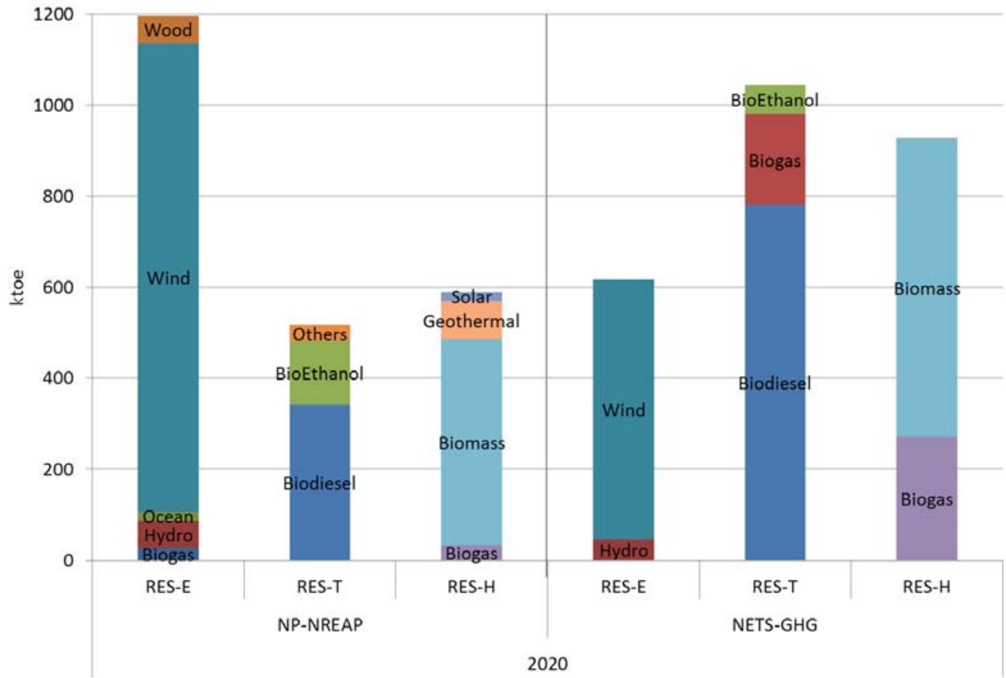

Figure 6 - Comparing Renewable Energy in the NREAP and *NETS-GHG* (ktoe)

It is important to note that the NREAP is designed to meet Ireland's target under the EU Renewable Energy Directive (Directive 2009/28/EC) rather than Ireland's target for non-ETS emissions (EU Effort Sharing Decision 406/2009). The renewable energy arising from the *NETS-GHG* scenario accounts for 18.5% of overall energy use, hence exceeding the EU Renewable Energy Directive target for Ireland of 16%.

The more interesting facets of Figure 6 relate to the different technology choices. The *NETS-GHG* scenario understandably points to greater contributions from renewable heat and renewable transport technologies as these are the non-ETS sectors. The contribution from renewable electricity in the NREAP is double that shown in the *NETS-GHG* scenario. Given the fact that wind generated electricity does not contribute directly to the non-ETS target, this again is understandable. As mentioned earlier, the key message from these results is not that we arrest the momentum in wind energy deployment but that we increase our resolve in increasing renewable transport and renewable heat energy, if we intend meeting the non-ETS target. It is also worth recalling that in the *NETS-GHG* scenario, the energy system emissions reduction is 31.5% compared with 2005 levels, compensating for agriculture emissions growing in line with Food Harvest 2020 policy.

Figure 7 captures the explicit impact of this in terms of renewable energy, by comparing the renewable energy results for *NETS-CO2* and *NETS-GHG*. In *NETS-CO2*, the amount of biofuels required is similar to the NREAP (comparing with the left hand side of Figure 6), although the mix is quite different due to the penetration of biogas as a transport fuel in *NETS-CO2*. Moving from *NETS-CO2* to *NETS-GHG* requires almost a doubling of biofuels, and this additional biofuels is necessary to compensate for agriculture not meeting a 20% emissions reduction target.

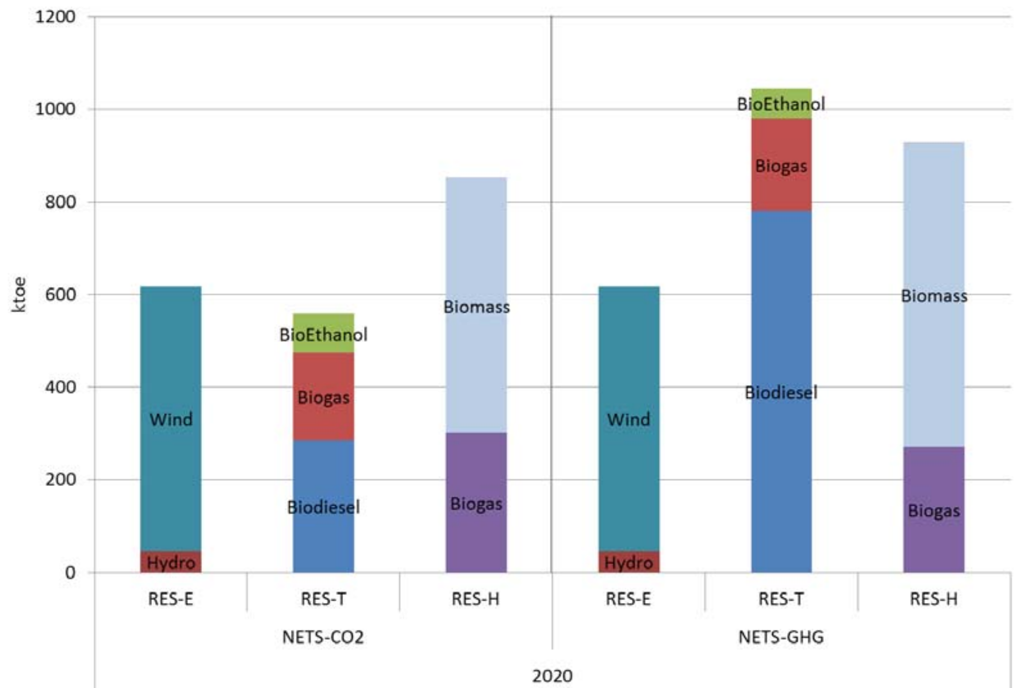

Figure 7 – Renewables consumption by mode in NETS-CO2 and NETS-GHG (ktoe)

This raises a further interesting policy issue – if we use more biofuels to enable the agriculture sector to generate GHG emissions in line with Food Harvest 2020, separate to the issue of costs, to what extent will this result in land-use competition issues that may in turn impact on Food Harvest 2020?

There is a significant challenge in quantifying the costs of climate mitigation policies, in determining how these costs should be allocated and in developing an effective mechanism to ensure that the costs are then allocated as they should be. To date, the Irish TIMES project has focussed on shedding light on two aspects that do not purport to meet this challenge but do provide some useful inputs to discussions and analysis. The CO_2 marginal abatement costs can readily be extracted from the model results, i.e. the cost of delivering the last (marginal) tonne of abatement in a particular scenario. The second metric developed is a crude measure of the cost of mitigation as a proportion of GDP in a particular time period. This is estimated by calculating the difference in total energy system costs between a mitigation scenario and the *REF* scenario in each time period and by then dividing this by the cumulative GDP generated in that period.

Table 1 shows the marginal cost of CO_2 abatement in 2015 and in 2020 for three scenarios. Focussing on the 2020 results, the marginal cost of meeting non-ETS target increases from $€_{2000}158/tCO_2$ to $€_{2000}213/tCO_2$ moving from a 20% non-ETS CO_2 emissions reduction to a 20% non-ETS GHG emissions reduction. This increase quantifies the effect of the energy system facing a 20% target compared with a 31.5% target (compensating for lower emissions reduction in agriculture). One way to interpret what these numbers mean is to consider no policy measures other than a carbon tax being applied. In this scenario, the marginal cost is equivalent to the level of tax that would need to be applied to meet the scenario target. For comparison in terms of the scale these costs represent, current level of carbon tax in Ireland is €20/tCO_2. This suggests it will be very expensive to meet the non-ETS mitigation target for 2020.

[$€_{2000}$/ton CO_2]	Scenario	2015	2020
Non-ETS Emissions	*CO2-20*	0	46
	NETS-CO2	89	158
	NETS-GHG	97	213

Table 1 –CO_2 shadow prices in *CO2-20, NETS-CO2* and *NETS-GHG*

A third scenario is also shown in Table 1, the *CO2-20* scenario. This scenario imposes an overall reduction target of 20.5% on energy-related CO_2 emissions by 2020 relative to 2005 levels rather than a separate 21% ETS target and 20% non-ETS target. It is worth nothing that *CO2-20* scenario is not aligned with National or European legislation, but has been presented here to quantify the impact of not having a separate ETS or Non-ETS targets. The *CO2-20* emulates the approach adopted by the European Commission at EU level to determine the EU ETS and non-ETS targets [25]. Firstly, the

25 EC, 2008. Commission Staff Working Document. Impact Assessment. Document accompanying the Package of Implementation measures for the EU's objectives on climate change and renewable energy for 2020. SEC(2008) 85/3. available from <http://ec.europa.eu/energy/climate_actions/doc/2008_res_ia_en.pdf>.

least cost pathway for meeting the overall EU 2020 20% GHG emissions reduction targets (relative to 1990 levels) was established, pointing to a 21% emissions reduction target for ETS sectors and a 10% reduction target for non-ETS sectors (in both cases relative to 2005 levels). Initial individual Member State non-ETS emissions reductions targets were then determined using a least cost optimisation approach. In the results of this 'cost efficient policy case' Ireland's Non-ETS GHG emissions reduction were 17% below 2005 levels (Table 4 of SEC(2008) 85 Vol II). The EU analysis indicated that the *cost efficient policy case* can be achieved at a marginal abatement cost of €40 - €50/tCO_2. The ability of individual Member States to invest in mitigation was then taken into account to ensure an equitable distribution of effort. Ireland had a relatively high level of GDP per capita in 2005 and was thus allocated a target to achieve a 20% reduction relative to 2005.

The Irish TIMES results in Table 1 raise a number of questions regarding the analysis that underpinned Ireland's obligations under the Effort Sharing Decision 2009/406/EC. One significant finding is that imposing a 20% target on Non-ETS energy-related CO_2 emissions target results in a high marginal abatement cost ($€_{2000}$158/tCO_2) which suggests the target set for Ireland is far from a cost optimal target. This is before incorporating the fact that agriculture represents nearly half of Non-ETS emissions in Ireland, with few mitigation options. When this is taken into account (by imposing a larger target emissions reduction on the energy system), the marginal abatement cost increases further to $€_{2000}$213/tCO_2. This challenges the marginal abatement cost of €40 - €50/tCO_2 marginal abatement costs in the analysis for EU using. The *CO2-20* scenario however points to a marginal abatement cost of $€_{2000}$46/t CO_2, which does align much more closely with the EU analysis figures. Comparing the difference in the cumulative energy system costs over the period 2005 – 2020, this points to the cost of this misinformed target and is quantified to amount to $€_{2005}$3.6 billion.

Figure 8 illustrates the implications of this in terms of Ireland's non-ETS emissions reduction target. The energy-related CO_2 emission trajectories for the *NETS-CO2* scenario and the *CO2-20* scenarios to 2020 are compared Figure 8 (along with the *REF* scenario results). Focussing on the non-ETS emissions reduction only, Figure 8 suggests that a return to 2005 levels by 2020 in non-ETS emissions would have been significantly more cost optimal than the 20% emissions reduction target allocated to Ireland. It is worth noting here that these scenarios focus on the energy system only and hence implicitly assume that agriculture can meet an equivalent emissions reduction target. A 0.3% reduction in emissions relative to 2005 levels by 2020 for agriculture is however consistent with the analysis underpinning the emissions associated with the Food Harvest 2020 policy.

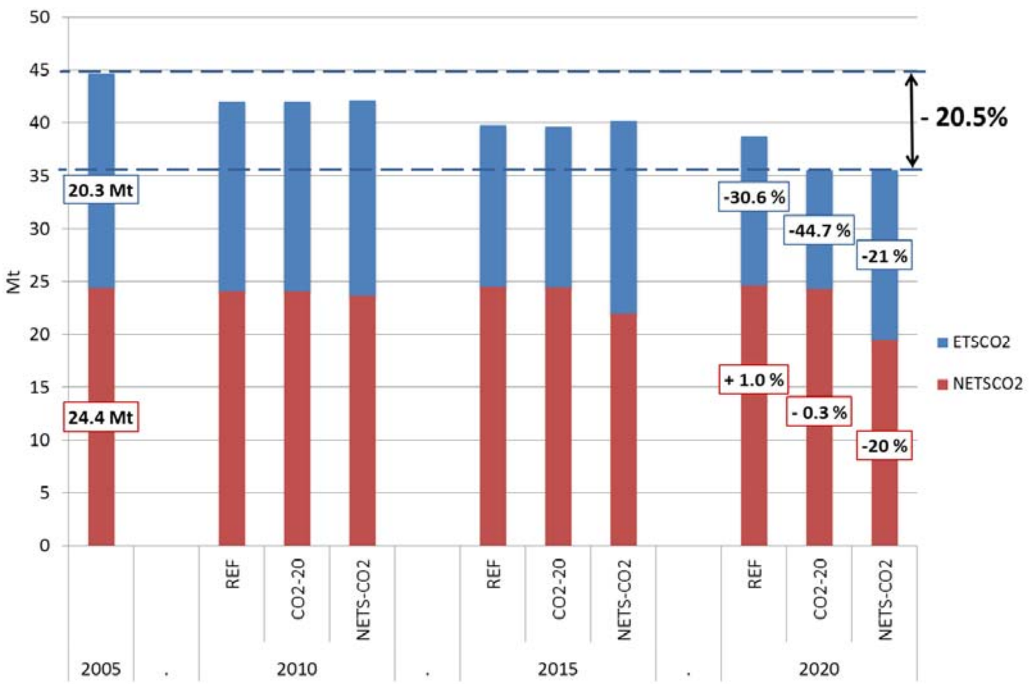

Figure 8 – ETS and Non-ETS CO_2 emissions trajectories in REF, CO2-20 and NETS-CO2 (Mt)

GHG Emissions reduction targets for 2050

This section focuses on scenario results that address the following questions

- Can Ireland's energy system deliver our energy service demands to 2050 and also achieve an 80% reduction in energy-related GHG emissions relative to 1990 levels, and if so at what cost?
- If the agriculture sector does not achieve an 80% GHG emissions reduction by 2050 what are the implications for the energy system, i.e. can it achieve emissions reductions beyond 80% and if so at what cost?

During this project, UCC developed the first detailed energy and energy-related CO_2 emissions scenarios for Ireland, based on new macro-economic projections for Ireland to 2050 that were generated by the ESRI.

The EU has committed to achieving emissions reduction in the range of 80% - 95% below 1990 levels by 2050. The scenarios here were developed in order to inform the discussions regarding Ireland moving towards a low carbon economy by 2050 and are illustrated in Figure 9. In the *CO2-80* scenario, an 80% emissions reduction target is applied to the energy system only. Further scenarios were developed to compensate for agriculture not meeting an 80% emissions reduction target. In the absence of agriculture emissions projections for Ireland beyond 2020, initially a projection was developed based on assuming agriculture GHG emission levels in 2050 were the same as 2020 levels. Based on this assumption, the energy system would be required to meet a 127% CO_2 emissions reduction by 2050 relative to 1990 levels. This is the *CO2-127* scenario shown in Figure 9. The energy system would be required to generate -8 Mt CO_2 emissions in 2050. Biomass

CCS is a technology that does deliver negative emissions but this is not yet available in Irish TIMES. An alternative approach was adopted, whereby Ireland's energy system is required to deliver a 95% emissions reduction by 2050 and this was adopted here as the *CO2-95* emissions scenario. The emissions reduction is applied to total CO_2 emissions.

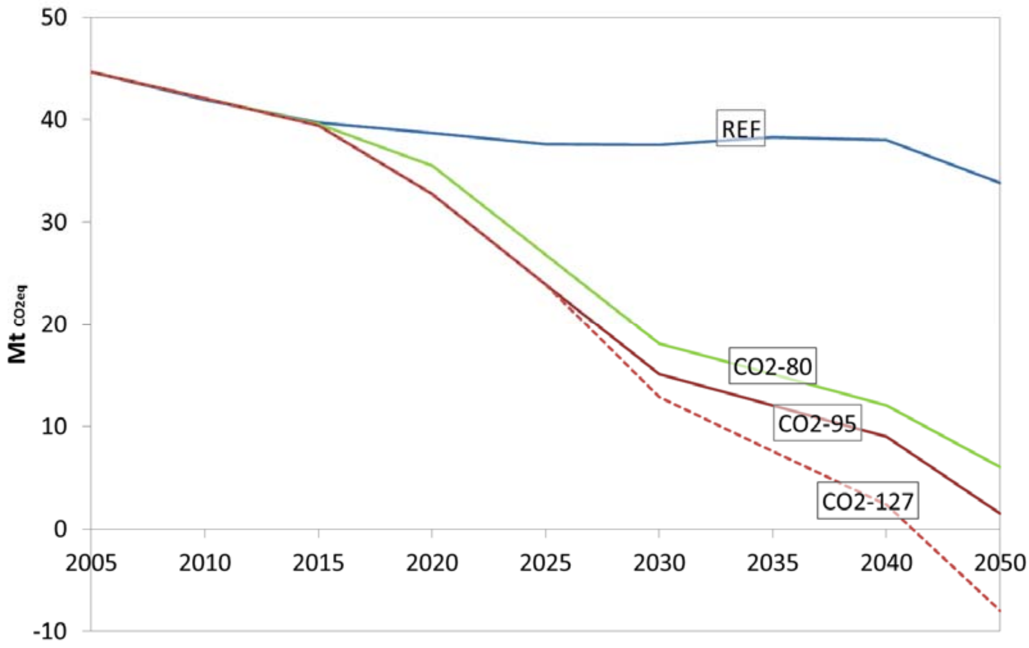

Figure 9 – Mitigation Scenario Pathways to 2050 (Mt)

Figure 9 underlines the scale of the long term challenge facing Ireland. If agriculture can achieve a 50% reduction in GHG emissions by 2050, the energy system must achieve a 95% reduction in CO_2 to deliver an overall GHG emissions reduction of 80%. This means the maximum energy-related CO_2 that the energy system can produce in 2050 is 1.5Mt. This is equivalent (in terms of today's energy system) to less than 10% of current emissions from electricity generation, noting that electricity accounts for just 18% of Ireland's energy use. Given the lack of mitigation options facing agriculture, this effectively mean a significant reduction in agriculture economic activity and output.

The model results from the 2050 scenarios indicate that these deep emissions cuts are technically possible, while also meeting our future energy service demands by incorporating radical changes in energy demand side and supply side technologies. The results point to which energy efficiency and renewable energy technologies will have a determining role to deliver the target at least cost. Figure 10 shows the CO_2 emissions results from these long term scenarios, comparing the *REF* scenario with *CO2-80* and *CO2-95*. The results show the contribution of individual sectors to CO_2 emissions reduction. Reductions are important in the whole energy system, but mainly in transport, electricity generation and industry.

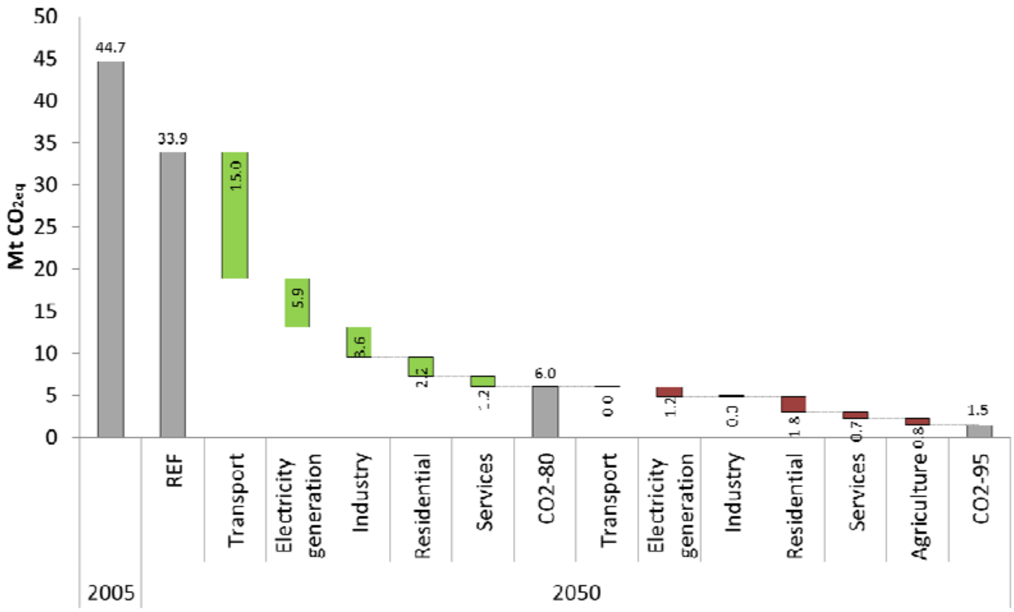

Figure 10 – Decomposition of 2050 CO_2 emissions between REF, CO2-80 and CO2-95 (Mt)

Figure 11 compares the final energy use in the *REF*, *CO2-80* and *CO2-95* scenarios. The results in the period 2030 – 2050 illustrate the improvement in end use energy efficiency moving to an increasingly low carbon energy system. It is worth noting that the *REF* scenario also already includes cost effective efficiency improvements delivered over the time horizon. Comparing the results in 2050, final energy use in the *CO2-80* and *CO2-95* scenarios is 20.5% and 23.1% less than *REF*.

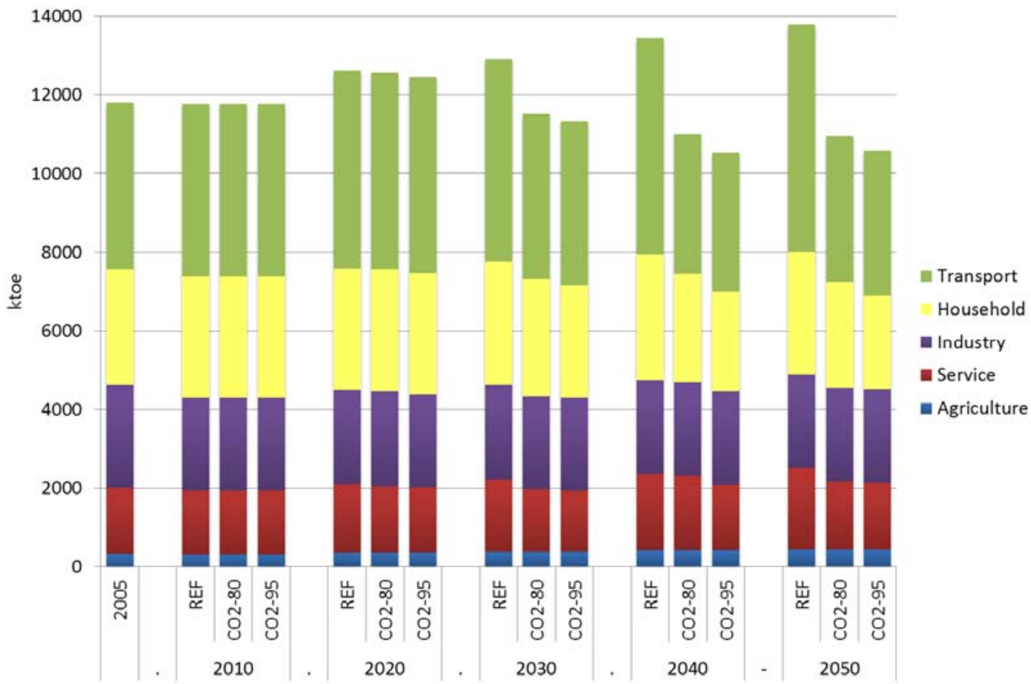

Figure 11 – Final energy demand by sector in REF, CO2-80 and CO2-95 (ktoe)

Figure 12 shows the changes in the fuel mix for electricity generation for the period 2005 – 2050 comparing the three scenarios. The *REF* scenario points to significant decarbonisation and the mitigation scenarios deepen this further. The *CO2-80* scenario is dominated by renewable energy with natural gas CCS and natural gas CCGT power plants also contributing. Renewable generated electricity in 2050 accounts for 71.9% of overall electricity use in *CO2-80*, compared with 100% renewable electricity generation (in addition to imports of 2.3% of GEC) in *CO2-95*. The remaining electricity in *CO2-80* is provided by gas CCS (accounting for 18%of GEC). The additional efforts required to move from *CO2-80* to *CO2-95* (i.e. delivering further reductions of 4.5 Mt) are mainly concentrated in the power sector (gas CCS displaced by biomass) and increased electrification of heating in the residential and services sector.

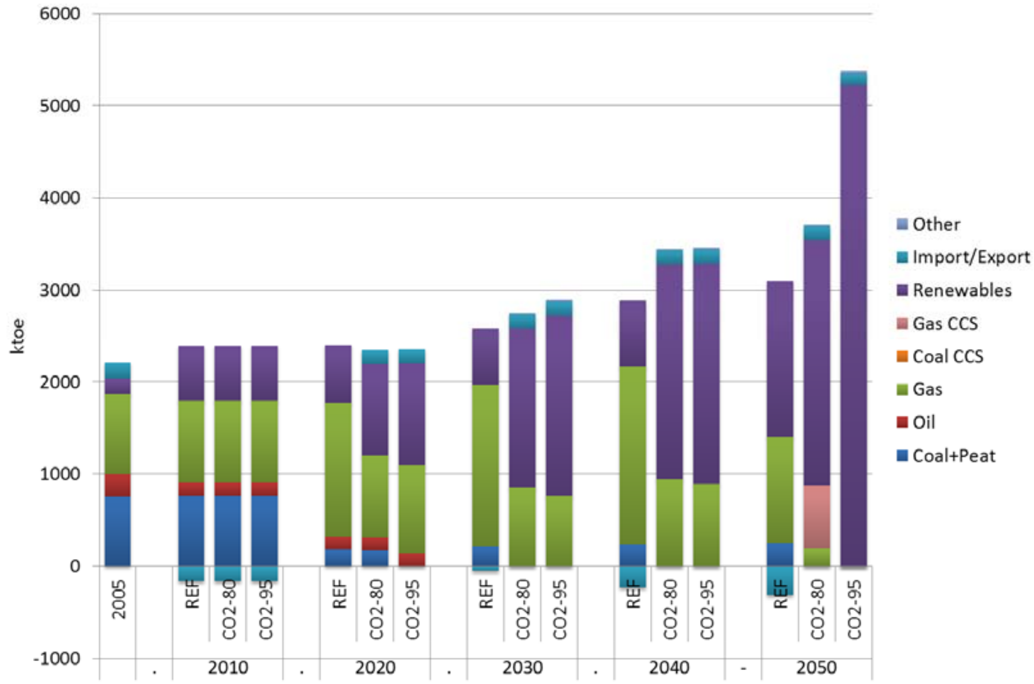

Figure 12 – Electricity generation by fuel in *REF*, *CO2-80* and *CO2-95* (ktoe)

In the *CO2-95* scenario, we see a complete decarbonisation of our electricity system in 2050 (67% wind, 28% biomass, including biogas, a small contribution from hydro power and the remainder from electricity imports). Also evident in Figure 12 is the increase in electrification of heating across the scenarios causing the differences in total electricity generation. This is more clearly visible in Figure 13.

Moving from *REF* to *CO2-80* electrification of transport starts to take place in 2030, as does electrification of residential heating. In *CO2-95* more significant electrification of residential heating occurs and the impact of this is that electricity demand more than doubles between 2005 and 2050.

Electrification of heat in particular but also of transport results in the share of energy use delivered by electricity increasing from 18.8% in REF (similar to current levels) to 31.0% in CO2-80 and 46.7% in CO2-95. It is worth noting however that this also means that over 50% of Ireland's energy needs are delivered of non-electric direct transport and thermal energy usage.

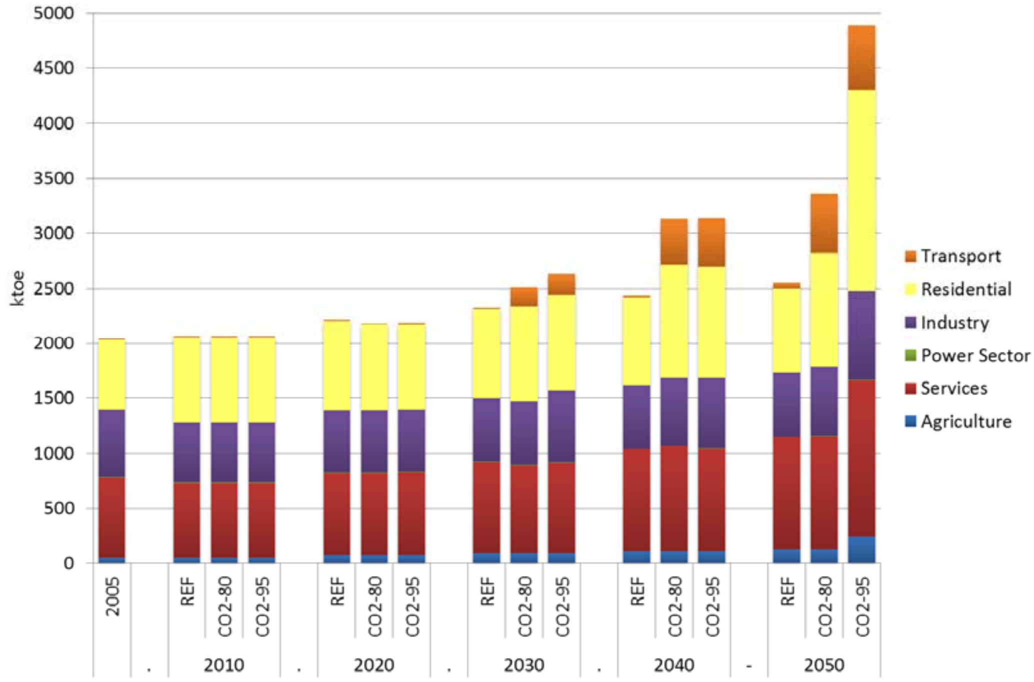

Figure 13 – Electricity consumption by sector in REF, CO2-80 and CO2-95 (ktoe)

Regarding transport energy use, Figure 14 compares the different scenario results in 2050, distinguishing between private transport, freight and public transport. Most of transport energy is also decarbonised with private cars diverting to EVs, freight and public transport to biofuels (comprising biodiesel and biogas).

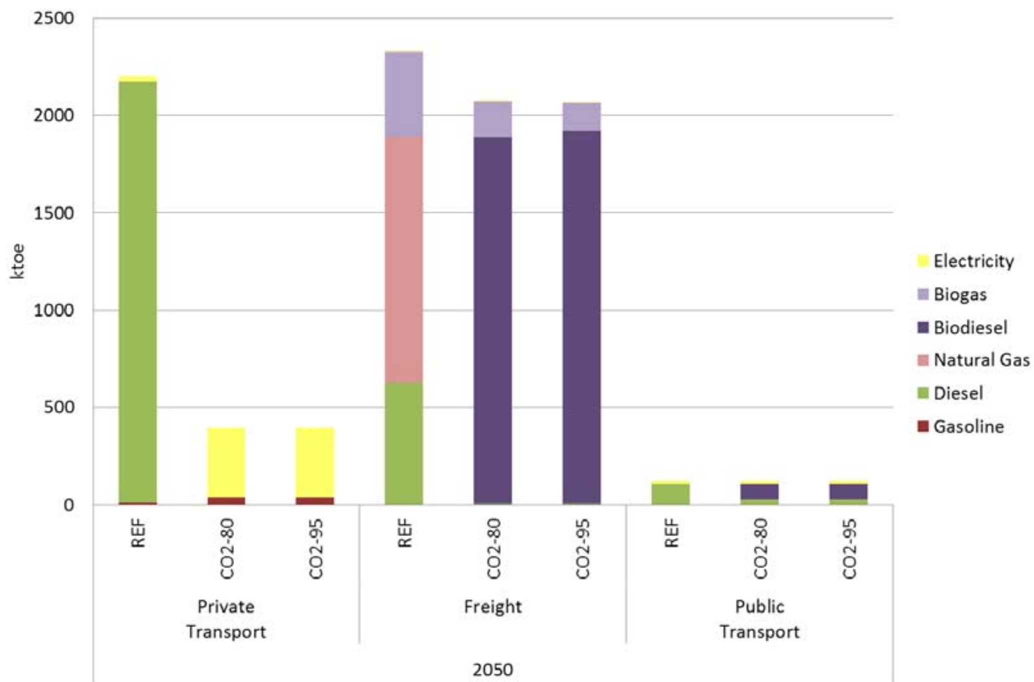

Figure 14 – 2050 transport energy by end-use in REF, CO2-80 and CO2-95 (ktoe)

Renewable energy in 2050 accounts for 25.3% of gross final energy consumption in the *REF* scenario, increasing to 71.7% in *CO2-80* and 90.1% in *CO2-95*. The main renewable energy resources used are biomass (biodiesel and biogas for transport and biomass for heat) and wind. Figure 15 compares the *CO2-80* and *CO2-95* results in terms of renewable energy usage in 2050 by mode.

The significant difference between the scenarios is the full move to renewable generated electricity in *CO2-95*. Some of the biomass that was used for thermal energy in *CO2-80* is used for electricity generation in *CO2-95.*

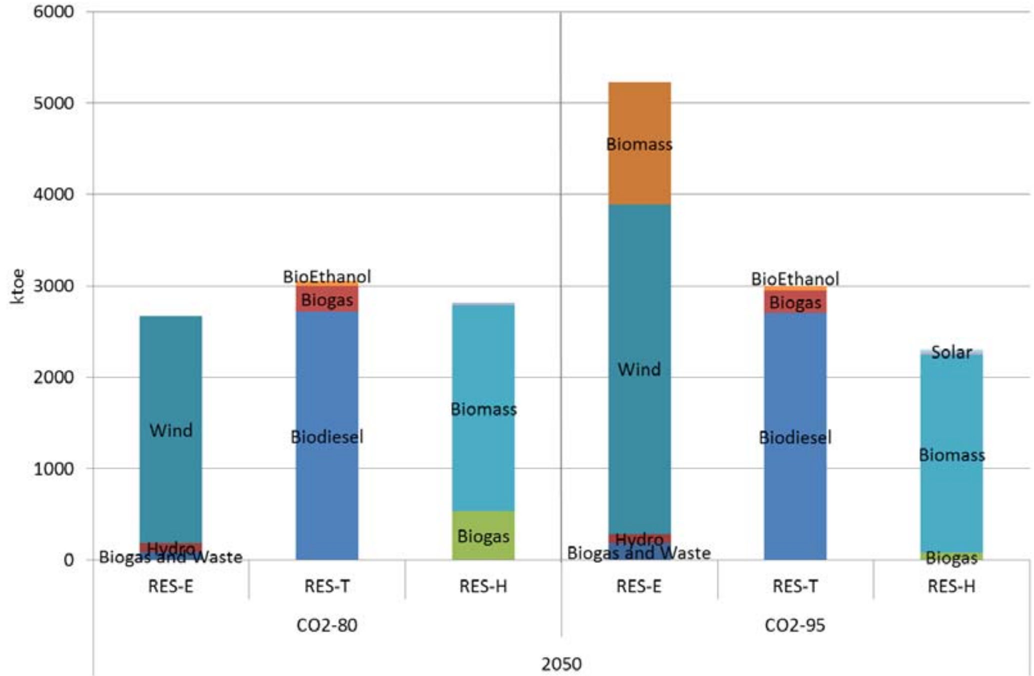

Figure 15 – Renewables consumption by mode in CO2-80 and CO2-95 (ktoe)

The economic impacts of these scenarios use the same metrics used for the 2020 GHG emissions reduction scenarios, namely marginal cost of CO_2 abatement and the ratio between energy systems costs and GDP. Table summarises the marginal abatement costs for the *CO2-80* and *CO2-95* scenarios relative to *REF*. The results suggest a significant increase in marginal abatement costs by 2050 from €$_{2000}$273 to €$_{2000}$1308 in the *CO2-80* and *CO2-95* scenarios respectively. Two additional intermediate scenarios with different emissions reduction target (-85% and -90%) are also included for comparison. This indicates the challenge in moving beyond an 80% CO_2 emissions reduction scenario.

Scenario	2020	2030	2040	2050	
CO2-80	33	136	99	273	*€$_{2000}$/tonne CO_2*
CO2-85	*33*	*131*	*158*	*523*	*€$_{2000}$/tonne CO_2*
CO2-90	*33*	*127*	*158*	*694*	*€$_{2000}$/tonne CO_2*
CO2-95	65	185	173	1308	*€$_{2000}$/tonne CO_2*

Table 4 – CO_2 shadow prices [26]

Table 5 summarises the scenarios considers and adds a further two to reflect the desire to continue to increase agricultural output and assess the consequences for Ireland's GHG emissions reduction target. A zero growth in agricultural GHG emissions suggest and increase in economic activity coupled with significant mitigation. Recalling the marginal abatement costs associated with the different CO_2 emissions reduction scenarios (Table 4) suggests a 50% GHG emissions reduction target for Ireland (comprising an 80% reduction in emissions in the energy system by 2050 relative to 1990 levels coupled with a return to 1990 levels for agriculture) is a reasonable target for Ireland.

Percentage emissions change relative to 1990			
Scenario	Energy	Agriculture	GHG
CO2-80	-80	-80	**-80**
CO2-95	-95	-50	**-80**
Alt 1	-95	0	**-57**
Alt 2	**-80**	**0**	**-49**

Table 5–Long term GHG emissions reduction scenarios for Ireland.

Recommendations

1. Ireland needs a comprehensive strategy to enable a transition to a low carbon economy. We have good experience with successful policies but they are limited to sub-elements within the economy.
2. Regarding renewable energy for example, the policy focus in Ireland is dominated by achieving 40% of renewable electricity, while renewable transport receives a much lower focus and there are no current policy mechanisms in place to promote renewable heat. Given that electricity represents just 17% of Ireland's energy use, this is clearly insufficient.
3. Targets are useful in providing an overarching goal. Our success of wind energy is very unlikely to have been realised without having the renewable electricity target to aim for. A reasonable target for Ireland is to achieve a 50% reduction in GHG emissions by 2050 relative to 1990 levels.
4. The EU Low Carbon Roadmap suggests that by 2030 that across the EU, we should have reach GHG levels that are 40% below 1990 levels. This is equivalent a <u>35% reduction relative to 2005</u>. Since Ireland's GHG emissions grew while the EU emissions reduced over the period 1990 – 2005, a <u>36% GHG reduction relative to 2005</u> in Ireland is equivalent to 20% reduction

26 Equivalent European studies such WETO-H2 [9] and SECURE [10] indicate for similar policy assumptions (Johannesburg Agreement scenario and Carbon constraint case) CO_2 marginal prices for EU27 and EU27+ (Europe including Balkans and Turkey) of 312 €$_{2000}$/ton (392 €$_{2005}$/ton) and 159 €$_{2000}$/ton (200 €$_{2005}$/ton) for the year 2050

relative to 1990. Hence, a 40% GHG 2030 reduction target for EU is consistent with a 20% GHG 2030 reduction target for Ireland.

5. According to the Research Prioritisation Steering Group *Research plays an important role in helping Government to achieve its policy objectives ... facilitates us in meeting our objectives at minimum cost.... Research programmes designed to inform the policy process play a vital role in agenda setting and increase the likelihood of translating important findings in relation to ...., environment and other research domains into feasible and implementable services and systems. In a number of areas, policy is negotiated with the European Union, out of which emerge obligations, regulations and income transfers. The quality of our negotiating effort is directly shaped by the quality of the evidence-based research that we bring to the negotiating table. High quality research, informing both our negotiating position and then the implementation of decisions, is required if we are to succeed.* The results underlying basis for Ireland's obligations under the Effort Sharing Decision 2009/406/EC to reduce non-ETS GHG emissions by 20% below 2005 levels are evidence of this (the cost of the misinformed target quantified as close to €3.6 billion). Our negotiating effort at the time was diminished because of the absence of a modelling tool such as Irish TIMES. As we enter negotiations regarding Ireland's contribution to 2030 and 2050 EU targets for energy efficiency, renewable energy and climate mitigation, this modelling tool provides the capacity to improve both our negotiating position and then the implementation of decisions.
6. The results for renewable heat point highlight the importance of developing reliable production chains to allow this potential to be achieved. Furthermore the Irish TIMES model indicates negligible contributions of ocean energy in the electricity sector by 2020 due to their high costs, while EVs will have a marginal role in the transport sector, which instead relies on increasing shares of biofuels. The results also point to half of biofuels in transport coming from biogas, while the NREAP points to biodiesel and bioethanol, suggesting that this focus should be re-examined.
7. The results from the 2020 non-ETS scenarios suggest that significant non-ETS emissions reductions may be achieved within the residential, transport and services sector through two key pathways, namely electrification of heating in buildings (i.e. shifting CO_2 emissions from the non-ETS sectors to the ETS sectors (namely electricity generation) and significantly increasing the amount biofuels used in transport. This points to the need to reassess Ireland's renewable energy policies in light of the non-ETS emissions reduction target. The results point to a focus on renewable heat, renewable transport and electrification of heat, in contrast to the current dominant focus on wind generated electricity.
8. Further work is required in a number of areas to improve the results and to extend the scope of the analysis, namely extending the analysis to fully incorporate agriculture, quantifying feedbacks between the energy scenarios and economic growth, using other complementary modelling tools to further shed light on a number of results, in particular renewable contribution to electricity, land use implications of bioenergy, electrification and gasification of heating, to name but a few.